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Guidebook on the development of projects for uranium mining and ore processing

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FOREWORD

The successful development of a project for a uranium mining and ore processing operation requires a sequence of integrated steps. The purpose of this Guidebook is to present an overview of all major steps in the development process. The Guidebook is directed toward both management and technical personnel involved in planning and implementing a project. It is part of a reports series on uranium mining and ore processing being developed by the IAEA's Division of Nuclear Fuel Cycle and Waste Management (NENF). These reports are referenced throughout the Guidebook.

The Agency wishes to thank the Consultants who took part in the preparations of this report for their valuable contributions: Messrs. G. Erdi-Krausz (MECSEK Ore Company, Hungary), W. Floter (Uranerzbergbau GesmbH, Germany), C.A. Freitag (KILBORN Engineering & Construction Co., Canada), and P. Gasós (Junta de Energía Nuclear, Spain). Thanks are also due to the Consultants' Member States and organizations for their generous support in providing experts for the preparation of this Guidebook. Mr. E. Mueller-Kahle (NENF) assisted in the preparation of several chapters, and Mr. S. Ajuria and Mr. D.C. Seidel (NENF) were the Agency's Responsible Officers.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

The production of uranium is a major industrial undertaking. The construction of a production facility requires a significant commitment of resources. It is important that the owner keep foremost in his mind that any such achievement can be considered successful if it can yield a net positive benefit. The indication that such a net positive benefit can be achieved is a common theme in this guidebook, repeatedly stressed as project feasibility. *The end product of a uranium development project* is a saleable uranium concentrate. Saleability is determined by the acceptance of the market to buy the product at a price which provides a net positive benefit.

Bringing a uranium operation into production involves a sequence of interrelated steps. These are outlined in the simplified diagram of Fig. 1. The challenge is to determine how the various steps of the development sequence should function and whether the costs are sufficiently low to return a positive benefit to the owner.

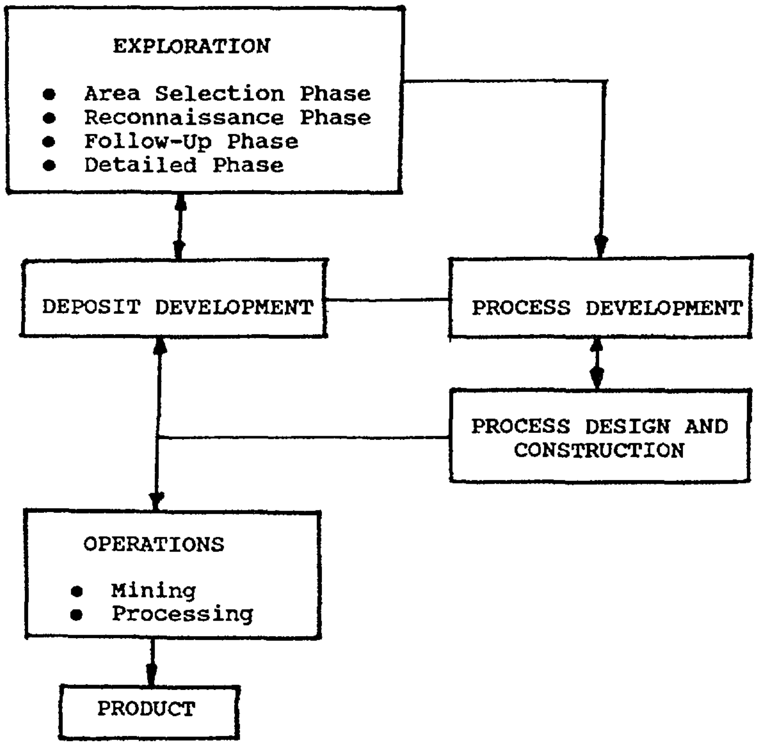

FIG. 1. Project development sequence.

This Guidebook has been prepared to aid in the planning, development and implementation of feasible uranium projects. It is one in a series of publications by the IAEA. This guidebook is essentially the executive summary of the other publications. It is an overview of the systematic approach to project development. It might be viewed as the "road map" of a project. A list of other publications in this series is provided in the Bibliography.

Each chapter of the Guidebook addresses a critical aspect of project development. Chapters follow a general sequence, but none should be considered in isolation. Each Chapter presents an overview of the requirements for reaching decisions necessary to advance a project. References are provided to more definitive information and to documents which will be required by technical personnel on a project. Such detailed publications include IAEA books such as "An Instruction Manual on Methods for Estimation of Uranium Ore Reserves", and the "Significance of Mineralogy in the Development of Flow Sheets for Processing Uranium Ores".

This Guidebook does not detail how to do project development but rather what must be done to insure that all critical elements of a project are considered.

The development of a project follows a sequence such as that illustrated in Fig. 2. This bar diagram indicates the general groups of activities and their timing as the project progresses. There are no simple shortcuts in this process. Each phase must be addressed and carefully considered. The time and resources required for each step cannot be easily predicted. Figure 1 offers an example, but each project has its own specific needs. However, all projects require these basic phases for successful completion. It should also be noted that positive answers are not guaranteed. The owner should be prepared to reconsider very carefully projects which show poor feasibility at any phase. The essential purpose of this project development process is to avoid unnecessary expenditures if a project is not feasible.

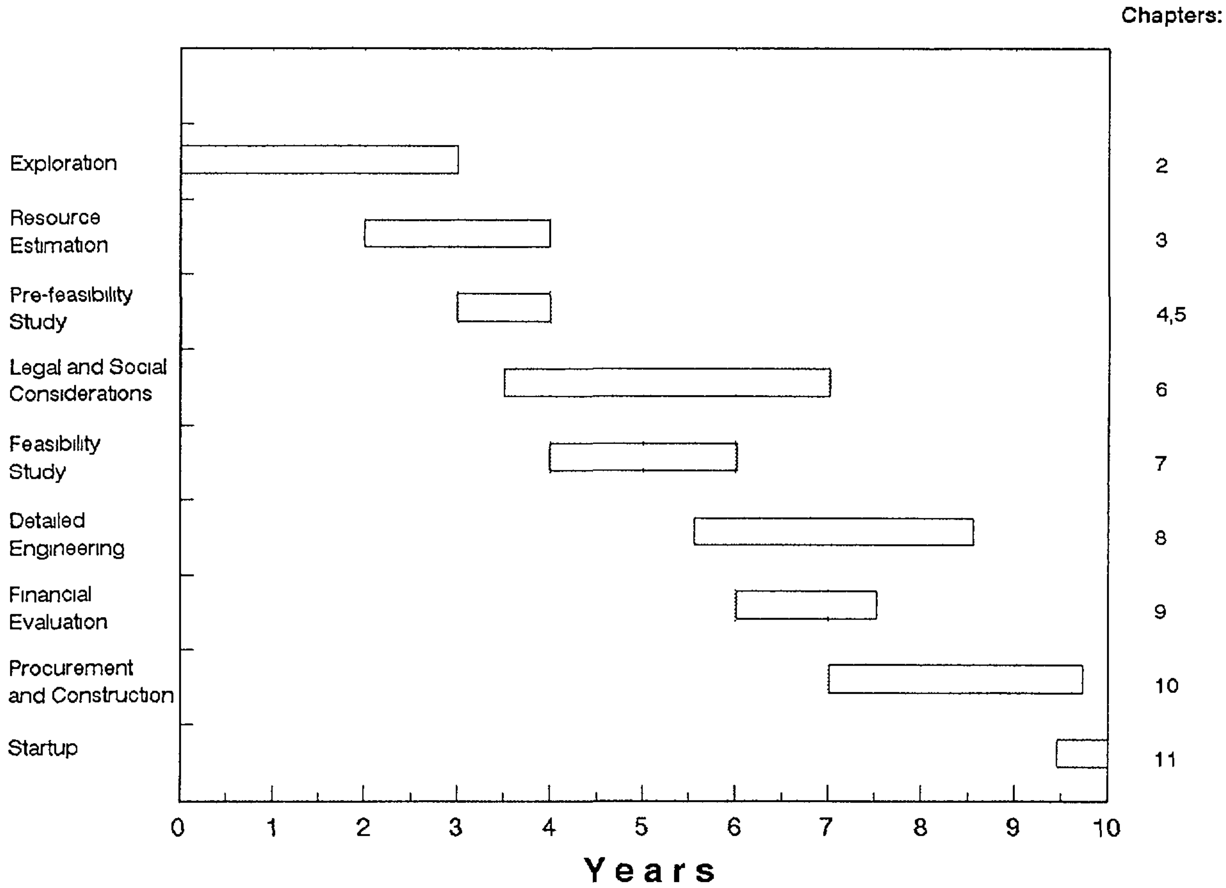

FIG. 2. Phases of project development: an example.

It is perhaps useful to appreciate from the very beginning of a project, the magnitude of the commitment that is required to achieve complete success. Uranium plants of various sizes and production outputs have been built but few are smaller than 100 tonnes of uranium per year and the largest can produce about 5000 tonnes per year. The total cost of projects varies depending on the size and complexity. However, overall costs are rarely less than US $50 million and have been as high as US $500 million.

As a project progresses the cost commitment increases. Fig. 3 provides an illustration of the magnitude of financial requirements over the life of a project. Costs are accumulated at varying rates up until operations commence. Thereafter, revenues from operations repay the investment. At some point the revenues returned should exceed the commitment (the break-even point). Thereafter the project yields a positive net benefit. It should be noted that the two major costs are exploration and construction. Exploration costs can vary widely and cannot be easily predicted. Construction costs can be predicted with considerable accuracy and much of the feasibility study is designed to achieve that accuracy. A further significant cost can be start-up. At the point of start-up the bulk of the expenditures have been made. Start-up bears all of these capital expenditures but is generating little, if any, revenue. Start-up time and costs can be minimized if all of the project development work has been performed thoroughly. As can be seen in Fig. 2, the rate of expenditure and the total financial commitment in the early stages of development are small. High quality work in these early phases can prevent major problems and delays at the final pre-operational stage.

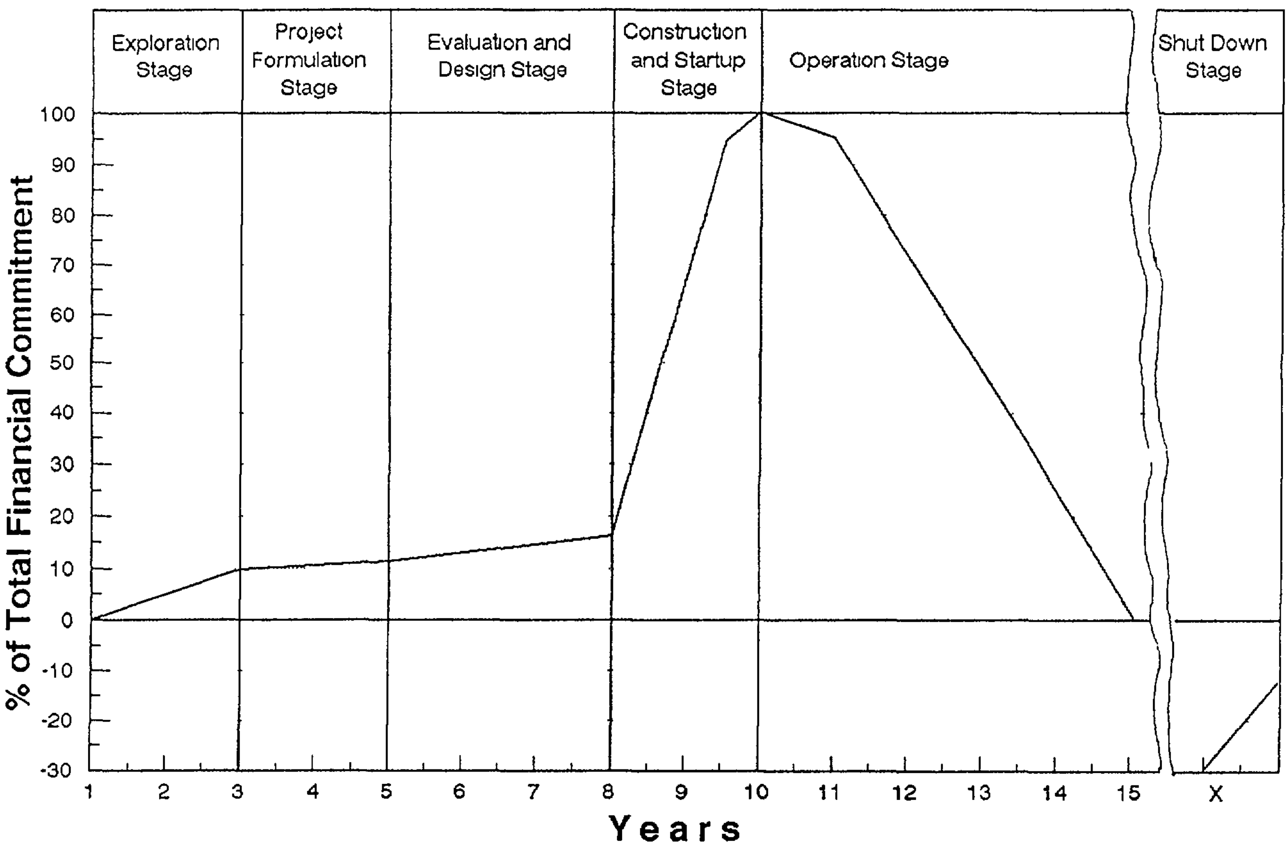

FIG. 3. Project development expenditures.

In the development of a project there are two fundamental activities: information gathering and decision making. Information can be gathered from a wide variety of sources such as consultants, experts, literature and advisors. Decision making however rests with the owner.

The owner must give careful consideration to the people making decisions. While consultants and experts provide necessary inputs, the owner should have people who are specifically employed to keep the owner's interests in mind. Ultimately the owner must operate the plant and should be in control of decisions which affect the project from the outset. It is therefore strongly recommended that the owner assign his own staff personnel to the project from the beginning. Such a person should have some background in the technologies involved so as to understand the overall process and project requirements. As the project progresses additional personnel with specialitiesin mining, process engineering, finance and operations may be added. These staff personnel do not replace the need for consultants and experts, but are key in monitoring the project on the course set by the owner. In this manner, the owner retains control of the resources he is committing. As this Guidebook is followed, the requirements expertise and technical know-how become apparent. In addition, the need for decision making is clear. The stop-wise approach provides opportunities for deciding whether the project should proceed or not. The Guidebook is intended to aid good decision making.

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2. EXPLORATION

2.1. INTRODUCTION

The process of exploration for uranium deposits follows a number of steps or phases with the overall objective of greatly increasing the chances of discovering an economic deposit at the least possible cost. Each phase has its clearly defined and understood objective; each has particular requirements as to methods to be used and their cost benefit; each phase terminates with a decision to continue to the next phase at increasing cost or to terminate the project.

The phases of a modern exploration programme are; (1) **area selection**; (2) **reconnaissance**; (3) **follow-up**, and; (4) **detailed**. During each phase a process of selection and elimination is carried out with the aim of eliminating from further consideration those areas with little or no potential while focusing attention on those areas with greatly increased potential. The areas selected during each phase become the areas of study during the succeeding phase. At the completion of the detailed phase the prospects found become the subject of a completely different process, that of deposit development. The various exploration phases are discussed briefly below.

2.2. AREA SELECTION

The phase of area selection is the begining of any phased exploration programme. Starting with a region of perhaps 100 000 km^2, mainly office studies are made in an attempt to define those parts of the region with the greatest uranium favourability. These studies are carried out by a senior, experienced uranium geologist. They entail the compilation of all available geological favourability information, photogeological studies, and rapid field visits to examine geology, radioactivity and general regional uranium distribution by means of uranium geochemical analyses of samples collected. During these visits the geologist will have examined the terrain and surficial environment in order to select the exploration methods most suitable for the programme. Regional data are normally compiled on maps of 1:250 000 or 1:500 000 scale.

Depending on the size of the region studied, area selection may take one or two years, at a cost of perhaps US \$ 1-2/km^2. In the course of such studies perhaps 70 - 80% of the region will be eliminated from further consideration, leaving one or more areas totalling perhaps 20 000 to 30 000 km^2 to be examined in the next or reconnaissance phase. National organizations carrying out the early phases of exploration may decide that the geological environment of the region is favourable for commodities other than uranium and select a larger proportion of the region for multicommodity resource evaluation studies.

2.3. RECONNAISSANCE PHASE

The objective of the reconnaissance phase is to "locate areas of interest" in the areas previously selected for exploration. Several exploration methods may be considered for use during the reconnaissance phase either used singly or in combination. Airborne radiometric surveys are frequently used in this phase with line spacing up to 5 km. In suitable environments geochemical surveys may offer advantages in terms of simplicity and increased amounts of data returned. In these cases sample densities of 1 sample by 1 or 2 km^2 are common. Determination of radon in surface or subsurface waters or radon in soil-air has been used effectively on occasion. In reconnaissance surveys, however, radon methods would not be used alone but in combination with other geochemical and radiometric methods. Data from reconnaissance surveys are usually plotted at scales of 1:100 000 to 1:250 000.

It is normally the case that the reconnaissance programme will eliminate more than 80% of the area surveyed. Costs for reconnaissance level surveys are usually in the order of US $ 15 to 50 per km^2, depending on the difficulty of the terraine and the methods employed. The "areas of interest" or reconnaissance anomalies outlined during the reconnaissance programme are the targets for study in the succeeding, follow-up phase.

2.4. FOLLOW-UP PHASE

The objective of the follow-up phase is "to locate exactly on the ground the extent of anomalies in the areas of interest". This objective is achieved by resampling the areas of interest at greatly increased sample density. Densities of 10 to 20 samples per km^2 are normally used. It is customary to sample the same material as that used in the reconnaissance phase. However, where stream sediment or water was used, bank soils may be sampled in addition. Radioactivity measurements made at the same time add valuable information at little extra cost. Radon measurements of waters or soil air are frequently valuable, and if a sufficient number of springs can be found radon content of ground waters should be measured. The occasion may be taken to improve the geological mapping, but this should be done as much as possible without delaying the progress of the sampling. The very high cost of good geological mapping in most cases precludes its extensive use at this stage. The results of the follow-up programme are reported at scales of 1:25 000 or 1:10 000.

The follow-up programme may eliminate as much as 90% of an area of interest, outlining anomalies of a few to perhaps 10 km^2 in extent. These may frequently show strong directional trends, pointing to possible lithological or structural controls. Costs for follow-up surveys may be in the order of US $75 to 200 per km^2. The follow-up anomalies outlined in this phase are the subjects of study during the succeeding, detailed phase.

2.5. DETAILED PHASE

The objective of the detailed phase is "**to distinguish between anomalies** due to potentially economic mineralization and those due to uneconomic mineralization or other causes". It is in this phase that direct indications of a mineral deposit are located and tested. In this a wide selection of exploration methods will be used: radiometric prospecting; detailed geochemical surveys; detailed geological mapping; trenching; core and/or rotary drilling with radiometric logging, etc. Radon measurement of soil air, along with soil sampling for uranium and/or radium determination are frequently used. Bed-rock sampling, including sampling and analysis of core or cuttings for uranium analysis should be considered as well.

It is clear that a high density of sampling and measurement will be required in the detailed phase, perhaps as much as 2500 per km^2. For this reason it is difficult to put a cost figure on this phase. Several methods will be employed in order to better define and characterize the prospect.

Each method has its own cost and benefit. The data developed during the detailed phase are normally compilled on maps at scales of 1:500 or 1:1000.

The detailed phase, and the exploration programme in general, may be said to terminate with the achievement of ore grade intersections in surface trenches and/or in the sub-surface drilling programme.

2.6. DEPOSIT DEVELOPMENT

The proving of the deposit is properly the work of the development programme, and requires methods of mineralogy, structural geology, sampling, ore test work, and ore reserve estimation that are different from, and much more costly than, those of the exploration programme. Extensive sampling will be done of surface trenches, drill core and /or cuttings, underground openings and water sources. Many of the samples will be large bulk samples which must be collected and prepared with care. Attention will have to be paid to correct procedures of sampling and subsampling for the results obtained to have correct economic significance.

Throughout the development programme economic considerations play a large role. At any point in the programme the results obtained may indicate that the deposit cannot be exploited economically. Upon the quality off the work done will depend the validity of these conclusions. It must never be forgotten that a deposit is only an ore deposit when the development programme has proved the existence of a concentration of ore that can be mined, processed and sold at a profit. Errors made during the development programme can lead to financial disaster.

2.7. ANALYTICAL REQUIREMENTS FOR URANIUM EXPLORATION

During the course of uranium exploration several, rather different, analytical requirements are in evidence. These needs change as the programme progresses through the various phases outlined above. The laboratory called upon to support the analytical needs of an exploration programme should be aware of the particular requirements of each, of the number and type of samples to be expected and the element requirements. These matters require full discussion with the exploration geologist responsible for the execution of the project.

Most analyses carried throughout the exploration programme, up to the later stages of the detailed phase, are geochemical analyses. A geochemical analysis is a rapid analysis using a method capable of large throughput at low unit cost. In addition, geochemical methods must be capable of dealing with a wide range of element concentrations in a wide range of natural sample materials with varrying and complex matrices, including soils, stream sediments, rocks, waters, and biological materials. Most geochemical methods make use of partial rather than total sample attack because of the important geochemical information contained in the way an element is bound in a sample. Uranium, for example, is frequently determined after extraction of the sample with hot 4N HNO_3 because a total dissolution of the sample will liberate uranium held in resistate phases that has no bearing on ore forming processes and may obscure evidence of the presence of those processes. Because of the use of partial dissolution of the sample, the concept of accuracy is seldom of relevance in geochemical analytical methods. Precision, on the other hand, is of great importance when samples will be analysed only once.

3. RESOURCE ESTIMATION

This term refers to the activities used to estimate the quantity and quality of mineral resources that are or may be present in a certain area (nation, province, mining property) and categorizing them into categories according to the resources' levels of confidence of existence and separating them further into categories based on the estimated cost of production.

In the following, the different steps of the resource estimation and the methodologies will be described [1,2]. In addition an overview on the NEA/IAEA uranium resource classification system and resources types is presented.

3.1. DATA GATHERING

In general, data gathering involves the generation of those parameters required to calculate the volume of the mineralized body, its tonnage, grade and metal content. This is one of the main steps in resource estimation, as the basic data determines the precision and reliability of the reource estimate.

The material used to generate these parameters are samples, taken from the mineralized rocks formation and its surroundings. To obtain results that resemble the mineralized body as closely as possible, representative samples have to be used especially in the advanced stages of resource estimation.

The sampling methods depend on the accessibility of the material to be tested. Exposures on the surface or underground in mine workings are commonly sampled by chip or channel samples normal to the strike of the mineralization. Broken material (scree, muck) can be sampled by grab, muck or even mine car sampling. In the case of radioactive rocks, the sampled material can be tested radiometrically and correlation between chemical and radiometric grade be established. Sites not accessible as in the subsurface have to be sampled by drilling using techniques such as core drilling using, non-core rotary drilling, percussion or churn drilling. The sample material recovered consists of cores, cuttings or even dust and can be lithologically, radiometrically and chemically examined, while the holes are usually radiometrically and electrically (Spontaneous Potential (SP), and Resistivity) probed.

The density of sampling including the drill hole patterns and their spacing influences heavily the precision of the final resource estimates, but is dependent on presence of outcrops, topography and access to locate drill sites, and the type of deposit looked for.

The sample material recovered from the sampling is used for various examinations aimed basically at determination of those parameters needed to carry out the volume, tonnage, grade and uranium content calculations. These parameters include thickness and areal extent of the mineralized body, its density, and average uranium grade at a given cut-off. In addition, a number of geological, mineralogical and radiometric studies can be carried out.

3.2. TREATMENT OF ASSAY RESULTS

This step refers to the averaging and combining of grade and thickness of the mineralized rock from a series of samples. Average grades and thickness must be known for the calculation of the metal content of the ore body.

For the calculation of the average grade from a number of samples of the same location the following formula applies:

$$\text{average grade} = \frac{\text{total GT}}{\text{total T}}$$

whereby G = grade (%)
T = thickness

In the case of samples taken from different locations, e.g. from along a vein, an additional parameter, the length of influence, must be taken into account. For this case, the following formulas for the determination of the average grade and thickness are valid:

$$\text{average grade} = \frac{\text{total GTL}}{\text{total TL}}$$

and

$$\text{average thickness} = \frac{\text{total TL}}{\text{L}}$$

wherein

L = length of influence.

3.3. CUT-OFF GRADE AND THICKNESS

Prior to the estimation of the ore reserves it must be decided, under which minimum grade and thickness conditions the assumed ore body can be mined to recover the direct costs. This grade and thickness is referred to as "cut-off grade" and "cut-off thickness".

The cut-off grade is defined as the grade at which the value of the extracted ore equals the direct operating cost per tonne or ore. The costs used in this definition are determined in feasibility studies or by analogy with costs of mines working similar deposits in a similar environment and location.

For the determination of the cut-off grade a number of similar equations have been developed in different countries (Canada, France, South Africa, USA). They are similar in their approach. Widely used is the following formula developed by the former US-Atomic Energy Commission:

$$g = \frac{\text{costs of mining, milling, haulage, royalties per ton of ore}}{\text{price per lb } U_3O_8 \text{ x recovery rate x 20}}$$

where g is the cut-off grade in % U_3O_8.

A change in the cut-off grade has significant effects on the reserves and the economics. In general, an increase of the cut-off grade, increases the average grade, but lowers the reserves and the metal content, and a decrease lowers the average grade, but increases the tonnage and the metal content. Usually, resources are estimated using different cut-off grades, and this resource number is selected which optimizes the economic return of the operation.

The selection of the cut-off thickness is governed by economical and practical considerations: it is therefore defined as the minimum ore thickness that can be mined economically and practically using an assumed mining method. For underground methods this is approximately 1.50 - 2.00 m, for open pit methods somewhat less.

3.4. CALCULATION OF VOLUME, TONNAGE, AVERAGE GRADE AND URANIUM CONTENT OF ORE BLOCKS

The parameters such as thickness, grade, and and density as determined above, together with the measured area covered by mineralized work, are used to calculate the volume, tonnage, average grade and uranium content of a deposit.

The volume calculation entails a simple multiplication of average thickness times area; its result multiplied with the rock density yields the tonnage and its multiplication with the average grade results in the uranium content of a block of mineralized material.

Tonnage and uranium content of a number of blocks can simply be added. Their average grade, however, can be obtained by dividing the total aggregate uranium content by the tonnage.

3.5. CONVENTIONAL RESOURCE APPRAISAL METHODS

There are many methods to appraise resources of higher confidence level, which include Reasonably Assured Resources (RAR) and Estimated Additional Resources (EAR-I) as defined further below. Each of these methods has its particular strengths and weaknesses and is therefore particularly suitable for specific deposit types. In the following, a distinction will be made between methods applicable to flat-lying uranium deposits, such as sandstone and quartz pebble conglomerate types, and those applicable for steeply dipping deposits (vein and certain unconformity related deposits). In addition, one method is described separately, as it seems suitable for both flat-lying and steeply dipping deposit types.

The estimation methods for flat-lying deposits including the following ones have been described in detail in the Manual on the Estimation of Uranium Ore Reserves [1]:

- Uniform area of influence method, using circular or rectangular areas;
- Variable area of influence method;
- Polygonal method;
- Triangular method;
- Cross-section method;
- Isopapach method;
- General outline method.

In addition, the same manual refers to one method suitable for the estimation of reserves in steeply dipping deposits.

The method referred to above as being suitable for both flat-lying and steeply dipping deposit types is the inverse distance method. In contrary to the methods listed above, which are purely geometrical methods assigning a geometric area of influence for each sample, the inverse distance method uses also samples outside the area for which the reserves are being estimated, but weighs them differently according to their distance. The method is considered a very useful one and is related in its approach to the geostatistical methods.

3.6. STATISTICAL AND GEOSTATISTICAL METHODS

As a mineral occurrences or an ore deposits is a distribution of mineralized material of various grades it can be considered a statistical population. Using this feature, statistical and later geostatistical resource estimation methods were developed.

One statistical method that has been applied is based on the fact that many deposits have a lognormal type of grade distribution. This means that the logarithms of the grade values form the normal statistical distribution. If the data of a particular deposit confirms that the grade distribution is lognormal type, the data can be used to determine the parameters of a fitted lognormal distribution, such as mean and variance.

Geostatistics, based on the theory of regionalized variables for geological applications, considerations, considers the position at which a variable is measured, information on the surrounding area as well as the numerical value of the variable. The two steps for a geostatistical resource estimation include the construction of variograms showing the variations and the estimation itself, referred to "bringing" after D.G. Krige. This step determines an unbiased statistical estimator of the average block value by seeking the optimum combination of weighing values for all sample values in the vicinity. Using the information from the variogram and from Kriging, the weighing factors are calculated which minimize the estimation variance of the blocks and the variance of the estimator.

The basic difference between the geostatistical method and the conventional approaches, is that the geostatistics provide a measure of the reliability of the resource estimates.

3.7. RECOVERY FACTORS

For the final resource estimation a determination of the losses in the processes of mining and milling are needed. These losses include mining losses, dilution and milling losses. In general, in situ resources minus mining losses and dilution are referred to as mineable resources, and mineable resources minus milling losses are recoverable resources.

Mining losses refer to those parts of a mineral deposit, which cannot be extracted, and depend mainly on the value of the ore, the shape of the ore body, the host rock characteristics, mine planning, mining methods, skill, and the location of shafts, haulage ways and important surface installations in relation to the ore body. Mining losses are expressed as percentage of the ore body and may reach 25 - 30%, but are commonly less.

Dilution of the in situ resources occurs, when some waste material will be mixed with the ore in the mining process. This lowers the average grade but increases the ore tonnage. The dilution depends mainly on the thickness of the ore, the mining process and the grade control used.

The effect of the dilution on the tonnage and grade in a portion of a deposit is determined as follows:

$$\text{tonnage (diluted)} = \frac{(T + b)}{T} \times \text{tonnage (undiluted)}$$

$$G \text{ (diluted)} = \frac{\text{tonnage (undiluted)}}{\text{tonnage (diluted)}} \times G \text{ (undiluted)}$$

where: T= average ore thickness
b= thickness of barren material

If a global dilution factor is established for an entire ore deposit, the diluted ore tonnage and grade are calculated using the following formulas:

$$\text{tonnage (diluted)} = (\text{dilution factor} + 1) \times \text{tonnage (undiluted)}$$

$$G \text{ (diluted)} = \frac{U - \text{content}}{\text{tonnage (diluted)}}$$

In addition to the mining losses and dilution, there are milling losses as not all uranium can be extracted from the ore. They are expressed as a percentage of the extracted ore, i.e. adjusted for the mining losses and the dilution. Milling losses depend mainly on the mineralogical composition of the ore, the grain size distribution of ore minerals, the ore grade and the metallurgical process used. They range between 5 and 30%. The calculation of recoverable resources is simply a subtraction of the metallurgical losses from the diluted mineable resources.

3.8. URANIUM RESOURCE CATEGORIES

There a number of resource classification systems used by national organizations and the IAEA. Their approximate correlation is shown in Fig. 1. The criterion for these systems are the reliance in the existence of these resources.

The classification used by the Nuclear Energy Agency (NEA) of OECD and the IAEA in their periodic reports "Uranium Resources, Production and Demand [2] and other publications contain the following resource categories, in the order of decreasing confidence in the estimate:

Reasonably Assured Resources (RAR) refers to uranium that occurs in known mineral deposits of such size, grade and configuration that it could be extracted with currently proven mining and processing technology. RAR have a high assurance of existence.

Estimated Additional Resources (EAR) are divided in two categories: Category I and II.

Estimated Additional Resources - Category I (EAR-I) includes uranium that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well explored deposits, less reliance than on RAR can be placed on EAR-I.

Estimated Additional Resources - Category II (EAR-II) refers to uranium that is expected to occur in deposits believed to exist in geological trends or areas with known uranium deposits. EAR-II therefore refers to undiscovered resources and less reliance can be placed on the estimates in this category than on those for EAR-I.

<table>
<tr><th></th><th colspan="8">KNOWN RESOURCES</th><th colspan="2">UNDISCOVERED RESOURCES</th></tr>
<tr><td>NEA/IAEA</td><td colspan="6">Reasonably Assured</td><td colspan="2">Estimated Additional I</td><td>Estimated Additional II</td><td>Speculative</td></tr>
<tr><td>Australia</td><td colspan="6">Reasonably Assured</td><td colspan="2">Estimated Additional I</td><td colspan="2">Undiscovered</td></tr>
<tr><td>Energy, Mines and Resources Canada</td><td colspan="4">Measured</td><td colspan="2">Indicated</td><td colspan="2">Inferred</td><td>Prognosticated</td><td>Speculative</td></tr>
<tr><td>France</td><td colspan="3">Reserves I</td><td colspan="3">Reserves II</td><td>Perspectives I</td><td>Perspectives II</td><td colspan="2"></td></tr>
<tr><td>Fed. Rep. of Germany</td><td colspan="2">Proven</td><td colspan="3">Probable</td><td colspan="3">Possible</td><td>Prognosticated</td><td>Speculative</td></tr>
<tr><td>South Africa</td><td colspan="6">Reasonably Assured</td><td colspan="2">Estimated Additional I</td><td>Estimated Additional II</td><td>Speculative</td></tr>
<tr><td>United States DOE</td><td colspan="6">Reasonably Assured</td><td colspan="3">Estimated Additional I + II</td><td>Speculative</td></tr>
<tr><td rowspan="3">USBM USGS</td><td colspan="8">Identified</td><td colspan="2">Undiscovered</td></tr>
<tr><td colspan="6">Demonstrated</td><td colspan="2" rowspan="2">Inferred</td><td rowspan="2">Hypothetical</td><td rowspan="2">Speculative</td></tr>
<tr><td colspan="4">Measured</td><td colspan="2">Indicated</td></tr>
<tr><td>Some non-WOCA countries</td><td>A1</td><td colspan="3">A2</td><td>B</td><td>C1</td><td colspan="2">C2</td><td>P1
D</td><td>P2</td></tr>
</table>

The terms illustrated are not strictly comparable as the criteria used in the various systems are not identical. "Grey zones" in correlation are therefore unavoidable, particularly as the resources become less assured. Nonetheless, the chart presents a reasonable approximation of the comparability of terms.

FIG. 1. Approximate correlations of terms used in major resource classification systems.

Speculative Resources (SR) refers to undiscovered resources believed to exist mostly on the basis of indirect evidence and geological extrapolations. The location of SR could only be specified as being somewhere within a given region. As the term SR implies, the existence and size of these resources are highly speculative.

The NEA and the IAEA, for the purpose of a further separation of these resources described above (RAR, EAR-I, EAR-II and SR), have introduced "forward cost of production categories" or in brief, cost categories. For the estimation of these cost categories, expressed in USUS $/kg U the following cost items are to be included:

- The direct costs of mining, transporting and processing the uranium ore;

- The costs of associated environmental and waste management;

- The costs of maintaining non-operating units where applicable;

- In the case of ongoing projects, those capital costs which remain unamortized;

- The capital cost of providing new production units where applicalbe including the cost of financing;

- Indirect costs such as office overheads, taxes and royalties where applicable;

- Future exploration and development costs wherever required for further ore delineation to the stage where it is ready to be mined.

Sunk costs should not normally be taken into consideration.

Fig. 2 illustrates the inter-relationship between the different NEA/IAEA resource categories. The horizontal axis expresses the level of assurance about the actual existence of given tonnages based on varying degrees of geological knowledge while the vertical axis expresses the economic feasibility of exploitation by the division into cost categories.

The dashed lines between RAR, EAR-I, EAR-II and SR in the highest cost category indicate that the distinctions of level of confidence are not always clear. The shaded area indicates that because of the degree of confidence in their existence, RAR and EAR-I recoverable at up to US $130/kg U are distinctly important: for the purpose of the report they are referred to as "known resources".

Because resources in EAR-II and SR categories are essentially undiscovered, the information on them is such that it has not always been possible to divide them into different cost categories and this is indicated by the horizontal dashed lines between the different cost categories.

As regards the consideration of mining losses, dilution and metallurgical losses in the resource estimates, RAR and EAR-I are expressed as recoverable tonnes uranium, which EAR-I and SR refer to uranium contained in situ.

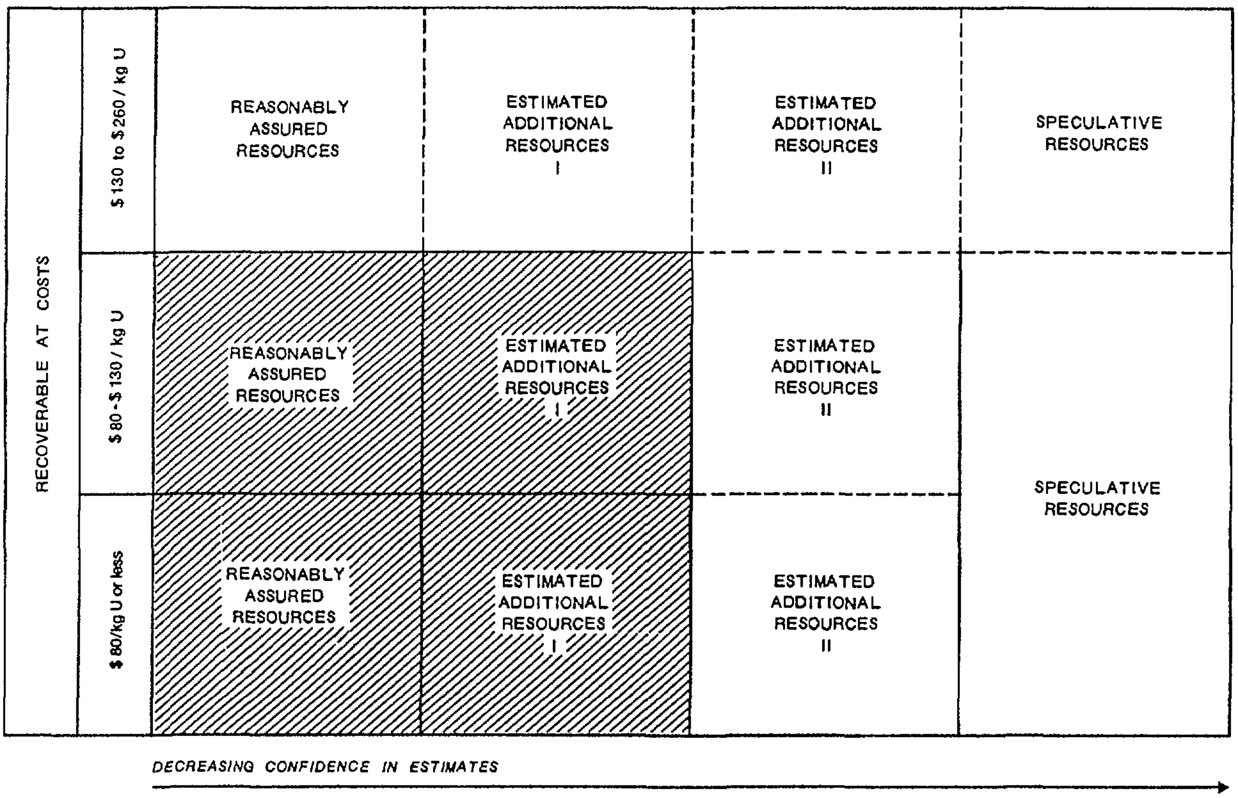

FIG. 2. NEA/IAEA classification scheme for uranium resources.

3.9. TYPES OF RESOURCES

To obtain a better understanding of uranium resources and their hosts, reference is made to different geological types of deposits. In addition, a distinction is drawn between conventional and unconventional resources.

On the basis of their geological setting, the uranium resources have been assigned to the following seven types of uranium deposits:

1. Quartz-pebble conglomerate deposits;

2. Unconformity-related deposits;

3. Disseminated magmatic, pegmatitic and contact deposits in igneous and metamorphic rocks;

4. Vein deposits;

5. Sandstone deposits;

6. Surficial deposits;

7. Other deposit types.

The main geological features of these deposits are described in more detail in [2].

The terms conventional and unconventional resources are defined as follows: conventional resources have an established history of production, where uranium is either a primary product, co-product or significant by-product as in the case of gold production in South Africa. The first six geological types of uranium deposits listed above, including selected types from "other deposit types" are considered to contain conventional resources. Unconventional resources are very low grade deposits, which at present are uneconomic or from which uranium is only recoverable as a minor by-product (e.g. phosphates, monazite, coal, lignite, black shales, etc.).

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4. PRE-FEASIBILITY STUDY

At some time during many exploration projects, a potential orebody is outlined by preliminary drilling. This is usually the beginning of the first conceptual feasibility consideration in a simple manner. This assists the planning of on-going drilling and the preparation of a Pre-feasibility Study.

All types of feasibility studies are joint efforts of all knowledge of the area. Pre-feasibility studies have a large input from the Owners, not only in the geological data but also the area and site knowledge they have gained from probably some years of working on the site.

The single most important requirement for a feasibility study is the experience of the participants in projects of a similar nature. The successful economic completion of the study draws very heavily on data available from similar projects worldwide.

4.1. OBJECTIVES

- Collect, review and evaluate existing technical and economic data.
- Establish the overall project concept for the mine and surface plant facilities, services and infrastructure.
- Develop sufficient process and engineering design to form the basis of the preliminary cost estimates.
- Prepare capital and operating costs on all aspects of the project.
- Define all of the detailed data requirements for a Feasibility Study and the methods of obtaining this information.
- Prepare a detailed schedule of activities from definition of detailed data requirements to completion of the Feasibility Study.
- Develop conceptual mine layouts.
- Identify mine service requirements.

4.2. BASIC TECHNICAL STUDIES

These studies can generally be considered under three headings, mining, processing and infrastructure.

4.2.1. Mining

The geology of the area is usually kept up to date during the exploration and drilling programme, with plans and sections showing the drill holes and geological features. Geological ore reserves can then be readily calculated.

A mining method must be selected based on the geological data and experience. This may be open pit, underground or a combination of both. At this time the following should be done:

- Prepare preliminary lists of major mine equipment
- Prepare preliminary production and manpower schedules

A mineable ore reserve must now be calculated taking into consideration a pre-selected cut off grade, ground stability, percent extraction and percent dilution. This will result in a tonnage and grade which will be a major factor in selecting the production rate.

It is extremely important to categorize this ore into the generally accepted categories of "proven", "probable" and "inferred" as only those reserves in the proven category may be acknowledged by outside financial institutions.

At the completion of these technical studies there should be requirements for additional detailed work necessary for incorporation into a Feasibility Study. This may include such items as:

- Further drilling to increase the reserves in the "proven" category.
- Additional geotechnical work to define pit slopes, underground working dimensions, wall rock stability and dilutions, water inflows and disposal requirements, rock temperatures and ventilation requirements, pilot holes for shafts or declines, etc.

On open pit mines consideration should be given to heap leaching "sub-ore" which is removed as part of the stripping operation.

4.2.2. Processing

After all of the basic testwork has been completed as outlined in Section 4.1, the various unit process options should be listed and compared for their applicability to this ore and site and their cost effectiveness. Some of these process options are as follows:

- Three stage crushing following by rod milling;
- One stage crushing followed by autogeneous or semi-autogeneous milling;
- Ball milling vs. pebble milling;
- Conventional thickeners vs. high capacity thickeners;
- Acid vs. basic leaching (in some cases);
- Leaching in pachucas, downflow draft pachucas or conventional agitators;
- Number of leaching stages;
- Type and supply of oxidant;
- Elevated temperature leaching;
- Autoclave leaching with auto-oxidation of sulphides to sulphuric acid;
- CCD liquid solid separation with conventional or high capacity thickeners;
- Filtration with drum or belt filters;
- Resin-in-pulp;
- Solvent extractions on solutions;
- Ion exchange or solution followed by solvent extraction;
- Ammonia or magnesia precipitaton;
- Drying to yellowcake or oxides.

Laboratory tests will usually be carried out at the same time as the ore body is being explored. At the early stages, samples of the orebody are used to define the general outlines of the most desirable process. As the knowledge of the orebody improves and more representative samples become available, it is then possible to classify the ore body according to its uranium minerals and host rock. These characteristics can affect every component of the uranium recovery process.

Laboratory testing has the following primary objectives:

- To determine if the uranium in the ore can be recovered by conventional treatments such as those used in industrial uranium plants.
- To define the most desirable flowsheet for the ore and to select suitable equipment for the various unit operations.
- To determine the physical and chemical variability of the orebody.
- To establish design and operational parameters for the future full-scale plant. These parameters together with the chosen flowsheet and equipment become the basis for subsequent prefeasibilitiy studies.

4.2.2.1. Sampling

The ore body samples used for laboratory testing will be taken in accordance with a sampling plan, which may be revised as more complete information orebody becomes available.

The sampling plan requires close collaboration between the geologists, mining engineers, and metallurgists to assure that laboratory tests are carried out on representative samples of the orebody.

Approximately 20 kg of ore will be needed for the preliminary studies, which include chemical analyses, mineralogical examinations, and leaching tests.

As the project progresses, the exploration programme produces more definitive information of the morphology, degree of homogeneity, and size of the ore body. At this point, the mean ore grade and ore reserves can be calculated. Also, the ore body can be classified into zones that have similar projected processing characteristics.

Representative samples obtained from the drilling and experimental mining operations will be used for the process development investigations. Approximately 100 kg of ore will be needed to study all of the unit operations in a projected flowsheet.

Chemical and mineralogical analyses together with comminution tests, leaching studies, and solid-liquid separation tests will be conducted on each ore body sample. A detailed experimental plan should be developed to determine the amount of sample and the appropriate particle size for each kind of test.

4.2.2.2. Chemical and mineralogical analyses

Developing information on both the chemical and mineralogical characteristics of an ore is a particularly important component of the process development investigation. The uranium grade, the ore mineralization, and the composition of the host rock determine the processing requirements. For example, mineralogical characterization of both a leach feed and the leach tailings can help identify reasons for relatively low leach extractions.

4.2.2.3. Comminution

The run-of-mine ore must be crushed and ground to the particle size required for effective leaching of the uranium. The optimum particle size is determined by a series of leaching tests on ore samples ground to various particle sizes.

The crushing and grinding flowsheets most widely used in uranium plants include the following alternatives:

(a) One or more stages of crushing followed by grinding in rod and/or ball mills.

(b) Primary crushing followed by autogenous or semi autogenous grinding in large diameter mills.

If the type (a) flowsheet is chosen, laboratory tests are carried out to define crushing and grinding parameters. These tests include:

Type of Test	Test Result
Impact Crushing	Bond Work Index [1]
Rod Mill Grindability	Bond Work Index [2]
Ball Mill Grindability	Bond Work Index [2]
Abrasion Testing	Abrasion Index [3]

From these indexes, the equipment sizes and power requirements can be calculated as a function of feed and product sizes. For type (b) flowsheets pilot plant tests are often required to develop reliable mill sizing data.

4.2.2.4. Leaching

This unit operation must be carefully studied during the laboratory testing studies. Leaching is the primary determinant factor of uranium recovery and can also affect subsequent solid-liquid separations. The solid-liquid separation operations are often the most capital intensive sections of a uranium plant.

Most uranium plants have used either acid or alkaline leaching. Nearly all acid leaching operations have used sulfuric acid. The leaching agent in alkaline leaching operations is a mixture of sodium carbonate and bicarbonate. Selection of the leaching agent depends on the mineralogical composition of the ore. Sulfuric acid leaching is normally the most desirable system unless the grade of the carbonates or other acid consuming componets is too high.

The leaching tests must investigate all critical leaching variables. Laboratory leaching experiments are designed to study the effect of variables such as the following:

- Type and amount of leaching agent
- Leaching temperature
- Leaching time
- Type and amount of oxidant
- Ore particle size
- Pulp density
- Degree of agitation

Preliminary tests, which are carried out on the first available samples, define the range of the most important variables. It is advisable to use partial factorial experiments for the preliminary tests; this technique allows the study of many variables with a minimum number of tests.

To develop the data required for prefeasibility studies, the leaching experiments should be designed to determine uranium recovery as a function of the different variables and the interactions among the variables. The most important variables to consider for the prefeasibility study are those with major influence on investment and operating costs. These variable include reagent requirements, required grind size, process temperatures, residence times, etc. Complete factorial experiments at two levels are advisable at this point; these experiments should be based on results from the preliminary experiments. Test results will define the effects of both the critical variables and their interactions. It is not usually possible to determine exact levels for the variables because of the relatively small scale (100-500 g of ore) of these experiments. The results will, however, establish the most significant variables, their effects in the optimum range, and the interactions among the variables. If more precise information is required, pilot scale testing may be needed.

4.2.2.5. Solid-liquid separation

Solid-liquid separation follows leaching in conventional flowsheets for uranium recovery. This unit operation is performed, in most plants, with thickeners or filters (drum or belt). Pregnant solution coming from the solid-liquid separation operations must normally be clarified before subsequent solvent extraction or ion exchange operations.

Laboratory tests are also used to determine unit settling or filtration rates, and the solids content of thickener underflow or filter cake. A theory of sedimentation developed by Kynch [4] was used by Talmadge and Ficht [5] to develop a laboratory test that measures unit settling area and predicts underflow pulp densities. The procedure also provides data that can be used to calculate the height of the thickening zone [6]. The data are developed through simple tests using 1.0 - 1.5 L of pulp in a graduated cylinder. The technique can also evaluate the effect of flocculants. The data are applicable for sizing thickeners and the overall design of an entire countercurrent washing system.

Laboratory filtration tests normally use a 0.1 ft^2 (93 cm^2) leaf for drum filters and a Buchner type filter of similar dimensions for belt filters. Filtration and washing unit areas are determined as a function of several different variables, such as, kind of filter cloth, type and amount of flocculant added, and cake thickness.

For high-rate thickeners and clarification systems it may be necessary to do pilot plant tests or to send samples to equipment suppliers for special tests.

4.2.2.6. Extraction and precipitation

Pregnant solution coming from solid-liquid separation systems has a low uranium concentration and a relatively high impurities content. The uranium is concentrated and purified by solvent extraction or ion exchange.

Laboratory-scale solvent extraction tests will be used to choose the type of extraction reagent, diluent, and modifier from among those used in similar processes. Extraction isotherms will be determined using pregnant leach liquors. These isotherms will be used to calculate the required number of extraction stages. Kinetic tests will also be conducted to define mixer retention time. In a similar way stripping of the organic phase will be studied using the most appropriate stripping agents.

Results from these experiments are used to size the mixer-settlers, which are the type of equipment used in most uranium processing operations. Several important questions such as the effects of recycling and organic losses cannot usually be answered by batch-test experiments. Laboratory scale continuous solvent extraction systems or even pilot-scale testing may be required. Pilot scale tests are also usually necessary if pulse-type extraction columns are being considered.

The majority of resin ion exchange operations have used fixed-bed columns. Batch tests in small columns can be used for resin selection and also for developing the break through curves used for designing full-scale columns.

Bench-scale batch tests are also used to study the uranium concentrate precipitation operation. The tests investigate variables, such as, reagent type, reagent consumption, temperature, pH conditions, retention time, etc. Setting and thickening characteristics must also be determined.

4.2.2.7. Time and cost

The preliminary investigation will develop cumulative information about the most desirable process for the particular ore being tested. This study normally requires 2-6 months and costs will be in the order of US $20 000 - US $50 000, depending on the difficulty of the ore.

The more detailed systematic studies will investigate all unit operations of the chosen flowsheet. They usually can be carried out over a period of 6-18 months at a cost of about US $50 000 to US $200 000.

The time and costs can be appreciably greater if a very complex or difficult ore is to be treated.

The resulting flowsheet and unit process selection will probably have recommendations for further testwork to more closely define the design parameters for the Feasibility Study.

4.2.3. Infrastructure

A large portion of the capital and operating costs are spent on the infrastructure and support facilities for the mining and processing functions. Factors such as those listed below must be as carefully addressed:

- Soils - Available soil data must be carefully reviewed and after preparation of a proposed site plan will require site specific testing for structures and tailings in order to prepare a Feasibility Study.

- Climate - All existing meteorological data should be reviewed not only for temperature constraints on design but also for evaporation -

precipitation calculations. A net evaporative area is dramatically different in water and tailings criteria and costs compared to a net precipitation area.

- Water - Site water balances must be done for potable, fresh process and reclaim water quantities. Assumptions can then be made with the existing data for this study. Additional field work may be required for feasibility study or permitting purposes.

- Tailings - All potential tailings sites should be examined with one being selected for this study. A tailings disposal and management scheme can then be costed. Additional soils and topographical site information will probably be required for a feasibility study. Testwork may also be required to improve discharge water qualities for environmental acceptance.

- Shops and Warehouse - The on-site warehousing and maintenance facilities required to support the operation must be assessed and costed. The availability and accessibility of such commercial services in the region should also be carefully considered with the objectives of minimizing this at site.

- Labour - A review of current labour supply and costs is necessary for the study. This may require a more detailed assessment for the Feasibility Study particularly for trades and skills and training programmes with their resulting costs.

- This labour force must be housed during the construction and operating phases and therefore a full manning requirement is part of this study. Remote areas may have fly-in, fly-out considerations for this labour supply. Adequate change rooms and other personnel facilities are also necessary as part of this operation.

- Fuels - A preliminary assessment of all fuel requirements for vehicles, buildings and process is required. The availability storage, costs and alternates may require further definition.

- Power - The study should include an estimate of connected, peak and average power loads plus the largest motors noted. The power supply may not require careful consideration where hydroelectric power is available in the immediate area but even then it will require further definition of supply plus capital and operating costs.

- In remote areas a power plant is part of the project capital and operating costs. The costs plus associated fuel supply and storage become significant. Large motors may impose technical limitations and require further evaluation.

- Administration - All administration costs should be included for construction and operation. Some of these may require further clarification as to their location. These costs may include general mobile equipment such as ambulance, fire truck, cars and trucks.

- Construction - Allowances must be made for all construction indirect costs. These can be large in remote areas. These should also include all engineering and management functions.

- Further Studies - Allowance must be made for additional studies, test work, and data collection as defined in the preceding and as required for the Feasibility Study.

These will probably include a major allowance for all environmental and socio-economical studies plus discussions and submissions to various pertinent authorities.

- Other - Costs are associated with the project for the owner's ongoing involvement, and allowances may be required for financing charges, warehouse inventory, working capital, startup allowances, interest and financial charges, contingency and escalation.

  A cash flow(s) may be prepared showing return on investment, payback period or other property financial data. This frequently enhances financial areas which may require governmental or public participation in order to be a viable project.

4.3. ENGINEERING

The engineering component of the Prefeasibility Study should include the components listed below:

- Prepare general arrangement drawings and preliminary sketches of major process and support facilities;
- Prepare overall site plan at 1:10 000 and a general plant layout showing approximate locations of all facilities, contours interpreted from published mapping;
- Define types of structures and building requirements; factor quantities of structural steel from data for buildings of similar type and volume;
- Define preliminary foundation concepts for equipment and buildings; concrete quantities based on adopted concepts;
- Select type of principal cladding materials and other principal architectural features;
- identify building services and estimate costs as a factor of the size If each facility;
- Estimate process piping from historical data;
- Prepare preliminary sketches of material handling systems and estimate costs from historical data;
- Estimate electrical requirements from historical data and assumed power source;
- Factor instrumentation requirements from historical data;
- Factor plant site utilities considering type and extent of services required;
- Factor tailings system based on preliminary estimate of storage requirements and local topography; when significant, preliminary quantities of material are developed;
- Identify environmental requirements based on governing regulations of control agencies and specifics of site.

4.4. SCHEDULING

A prefeasibility study should contain a realistic schedule of all data requirements, studies, site work and decisions, commencing at a decision date through to the completion of the Feasibility Study.

It should define the main activities which may include additional drilling, sample acquisition, pilot planting, engineering, estimating and report preparation. Milestones should be included as variances from them may affect the schedule and costs. Review and progress meetings may also be included.

A typical detailed feasibility study schedule is included (Fig. 1).

4.5. REPORT PRESENTATION

A prefeasibility study does not require the volumes of detail that are required for a final study. It should contain sufficient data to give a clear understanding of the project and its costs.

Adequate drawings are required to define all site facilities and their relation to each other, mining methods and preproduction requirements, ore reserves, test summaries, equipment lists and sizing for all mining, processing and ancillaries, arrangement drawings for all structures on site, all criteria and assumptions, allowances for all non-defined items, a Feasibility Study schedule, reagent and supply calculations, manpower tables, all capital and operating costs, project financial analysis, flowsheets, etc.

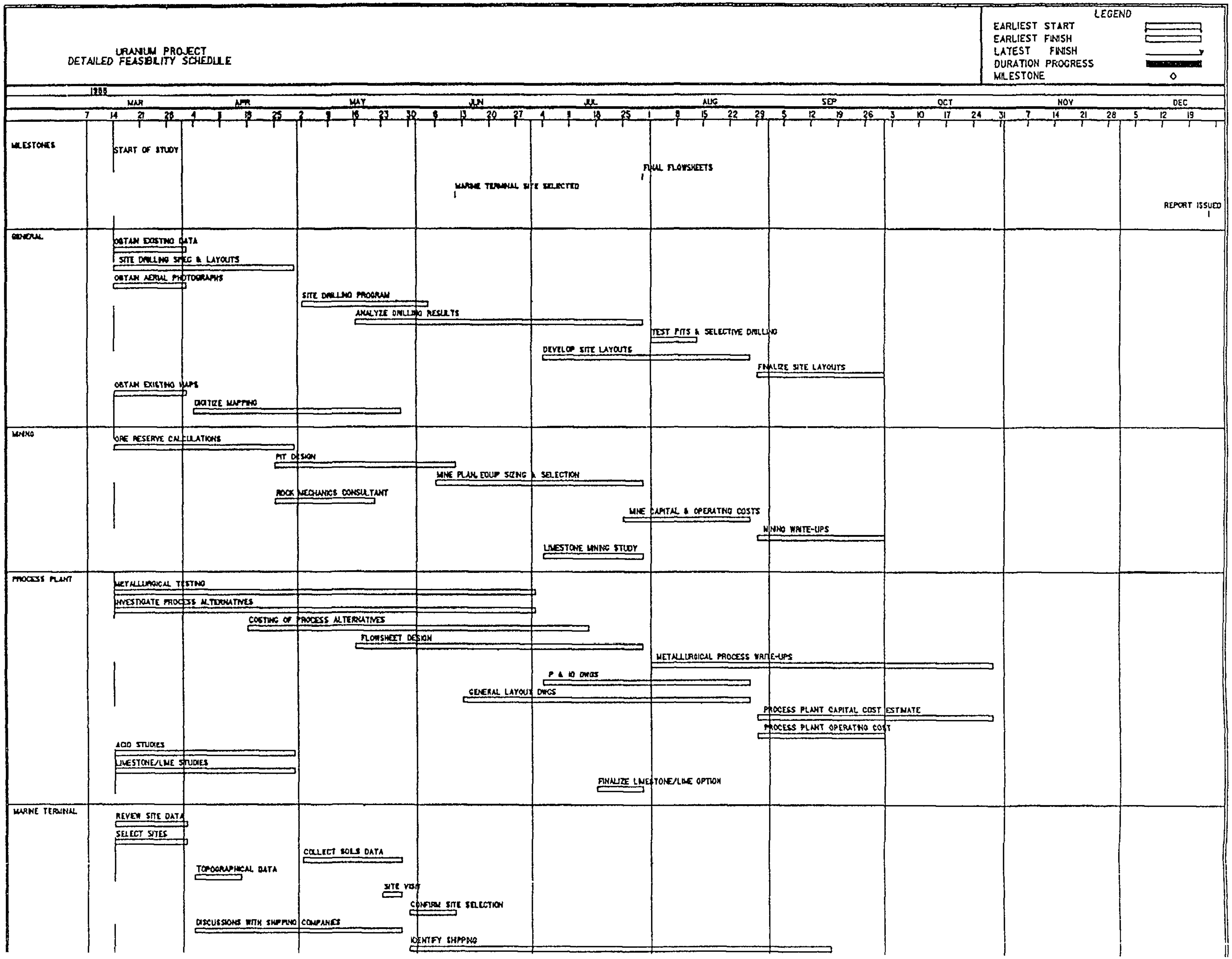
A typical prefeasibility study table of contents is included (Table 1).

Based on this document a Feasibility Study may be committed at a cost of 10 to 20 times the cost of a Prefeasibility Study.

4.6. DEVELOPMENT PROGRAMME

A typical four phase development programme is included, to illustrate the level of work required in each phase of a project (Table 2 [a-d]).

North American practice is to group Phase III (preliminary engineering) and Phase IV (detailed) together and to "fast-track" the project once approval to proceed has been given.


URANIUM PROJECT
DETAILED FEASIBILITY SCHEDULE
LEGEND
EARLIEST START
EARLIEST FINISH
LATEST FINISH
DURATION PROGRESS
MILESTONE
1988
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MILESTONES
START OF STUDY
FINAL FLOWSHEETS
MARINE TERMINAL SITE SELECTED
REPORT ISSUED
GENERAL
OBTAIN EXISTING DATA
SITE DRILLING SPEC & LAYOUTS
OBTAIN AERIAL PHOTOGRAPHS
SITE DRILLING PROGRAM
ANALYZE DRILLING RESULTS
TEST PITS & SELECTIVE DRILLING
DEVELOP SITE LAYOUTS
FINALIZE SITE LAYOUTS
OBTAIN EXISTING MAPS
DIGITIZE MAPPING
MINING
ORE RESERVE CALCULATIONS
PIT DESIGN
MINE PLAN, EQUIP SIZING & SELECTION
ROCK MECHANICS CONSULTANT
MINE CAPITAL & OPERATING COSTS
MINING WRITE-UPS
LIMESTONE MINING STUDY
PROCESS PLANT
METALLURGICAL TESTING
INVESTIGATE PROCESS ALTERNATIVES
COSTING OF PROCESS ALTERNATIVES
FLOWSHEET DESIGN
METALLURGICAL PROCESS WRITE-UPS
P & ID DWGS
GENERAL LAYOUT DWGS
PROCESS PLANT CAPITAL COST ESTIMATE
PROCESS PLANT OPERATING COST
ACID STUDIES
LIMESTONE/LIME STUDIES
FINALIZE LIMESTONE/LIME OPTION
MARINE TERMINAL
REVIEW SITE DATA
SELECT SITES
COLLECT SOILS DATA
TOPOGRAPHICAL DATA
SITE VISIT
CONFIRM SITE SELECTION
DISCUSSIONS WITH SHIPPING COMPANIES
IDENTIFY SHIPPING

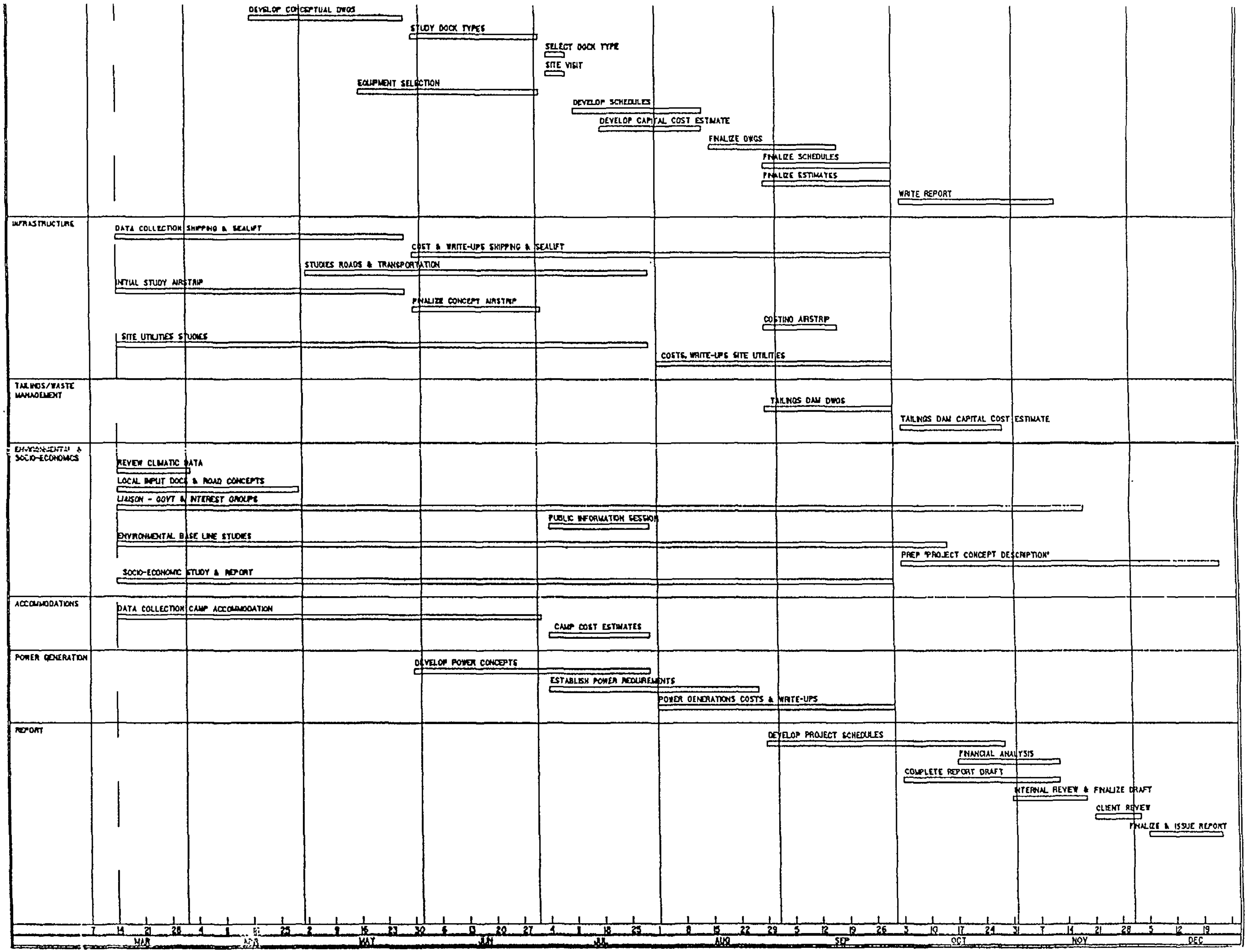


FIG. 1. Example of detailed feasibility study schedule.

TABLE 1. PREFEASIBILITY STUDY TYPICAL TABLE OF CONTENTS

1. INTRODUCTION

   Location and Site Description
   Historical Data
   Purpose and Scope of Study

2. CONCLUSIONS AND RECOMMENDATIONS

   Conclusions
   Recommendations
   Summary of Factors Affecting Cost

3. SUMMARY OF STUDY

   Conceptual Design
   Capital Costs
   Financial Analysis

4. PRODUCTION CRITERIA

   Mining
   Process Plant

5. METALLURGY

   Review of Metallurgical Data
   Recommended Testing Program
   Conceptual Flowsheet

6. SURFACE PLANT

   General Design Criteria
   Mine Surface Facilities
   Process Equipment List
   Plant Layout
   Process Control Concept
   Tailings Disposal Concept
   Support Services and Facilities
   Off Site Facilities
   Environmental Engineering Standards

7. ENGINEERING MANAGEMENT

   Project Execution Approach
   Preliminary Project Development Schedule
   Engineering Estimate

8. CONSTRUCTION

   Construction Execution Approach
   Construction Wage Rates

TABLE 1. (cont.)

9. CAPITAL COST DETAILS

Summary
Mining
Process Plant
Support Facilities
Allowances
Working Capital
Total Capital Costs
Estimate Definitions
Project Cost Escalations

10. DRAWINGS

(The following list of drawings is representative of the requirements for a study of the scope and complexity proposed for the project. Final requirements may vary to suit the particular characteristics of the proposed study. The drawings are listed by engineering disciplines for each of the project areas as defined in the Scope of Work).

Site Plan, Mine and Plant

Mine Conceptual Layout

Production Hoisting
- General Arrangement

General Site
- Building Location Plant

Preliminary Flowsheets

Primary Crusher Station (surface)
- General Arrangement

Coarse Ore Storage
- General Arrangement

Crushing and Screening
- General Arrangement

Fine Ore Storage and Grinding
- General Arrangement

Concentrator
- General Arrangement

Drying Storage, Loadout
- General Arrangement

Shops, Changerooms, Warehouse
- General Arrangement

Office & Laboratory
- General Arrangement

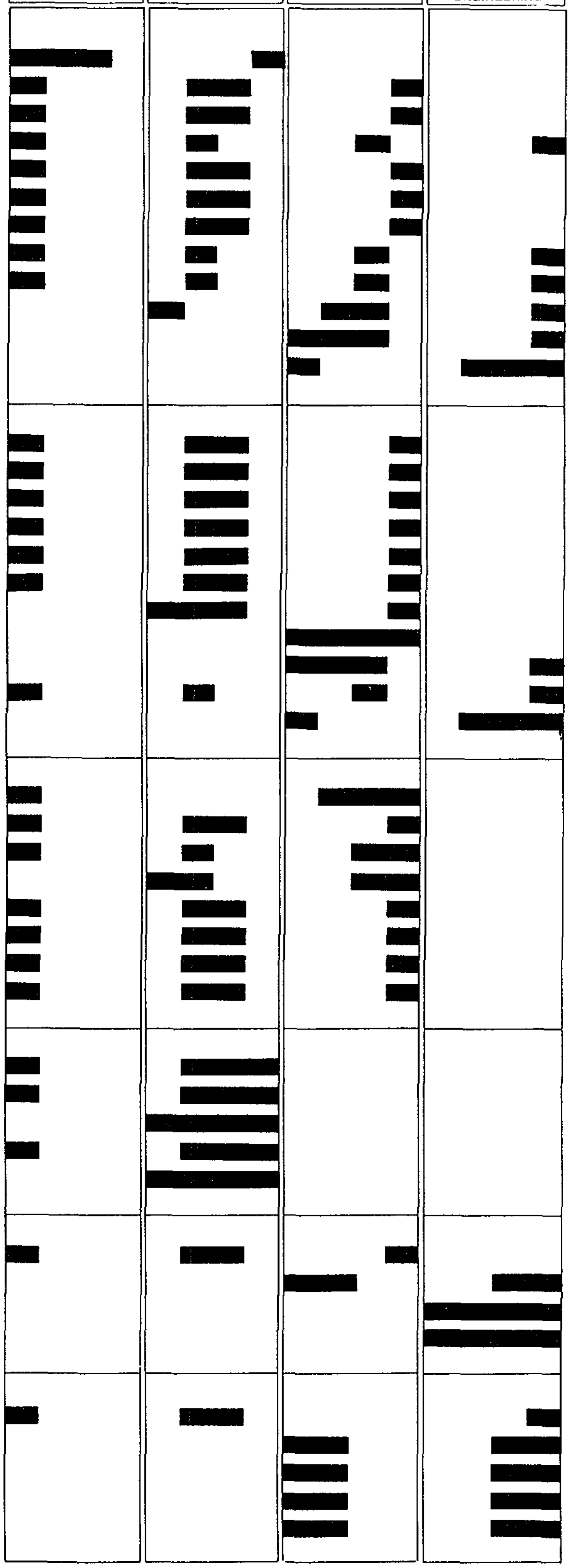
TABLE 2a

METALLURGICAL PROJECT PHASED DEVELOPMENT PROGRAM

PERCENT OF WORK IN EACH PHASE

0 25 50 75 100

PHASE I PRELIMINARY FEASIBILITY STUDY	PHASE II DETAILED FEASIBILITY STUDY	PHASE III PRELIMINARY ENGINEERING	PHASE IV DETAILED ENGINEERING



MINING
Geological Review
Ore Reserve & Grade Studies
Rock Mechanics & Ground Water Studies
Mine Layout
Waste Dump Studies
Annual Mining Schedule
Mining Methods & Equipment Studies
Mine Ventilation
Mine Services and Ancillaries
Equipment Specifications
Equipment Quotation Analysis
Vendors Drawings Review

METALLURGICAL ENGINEERING
Crushing & Grinding Tests
Minerals Separation & Concentration Tests
Flowsheet Design
Ore and Water Balance
Metallurgical Balance
Equipment Sizing
Equipment List
Equipment Specifications
Equipment Quotation Analysis
Plant Layout Review
Vendors Drawings Review

SPECIAL STUDIES
Soils Investigation
Water Supply Study
Tailings Disposal Study
Sources of Construction Materials Study
Electrical Supply Study
Housing & Accomodation Study
Transportation Study
Communications Study

FINANCIAL ANALYSIS
Capital Cost Estimate
Operating Cost Estimate
Sales Revenue
Cash Flow
Cash Flow Sensitivities & Risk Analysis

ESTIMATING/COST CONTROL
Project Budget Estimate
Definitive Project Estimate
Construction Contract Estimates
Trend Forecasting & Cost Monitoring

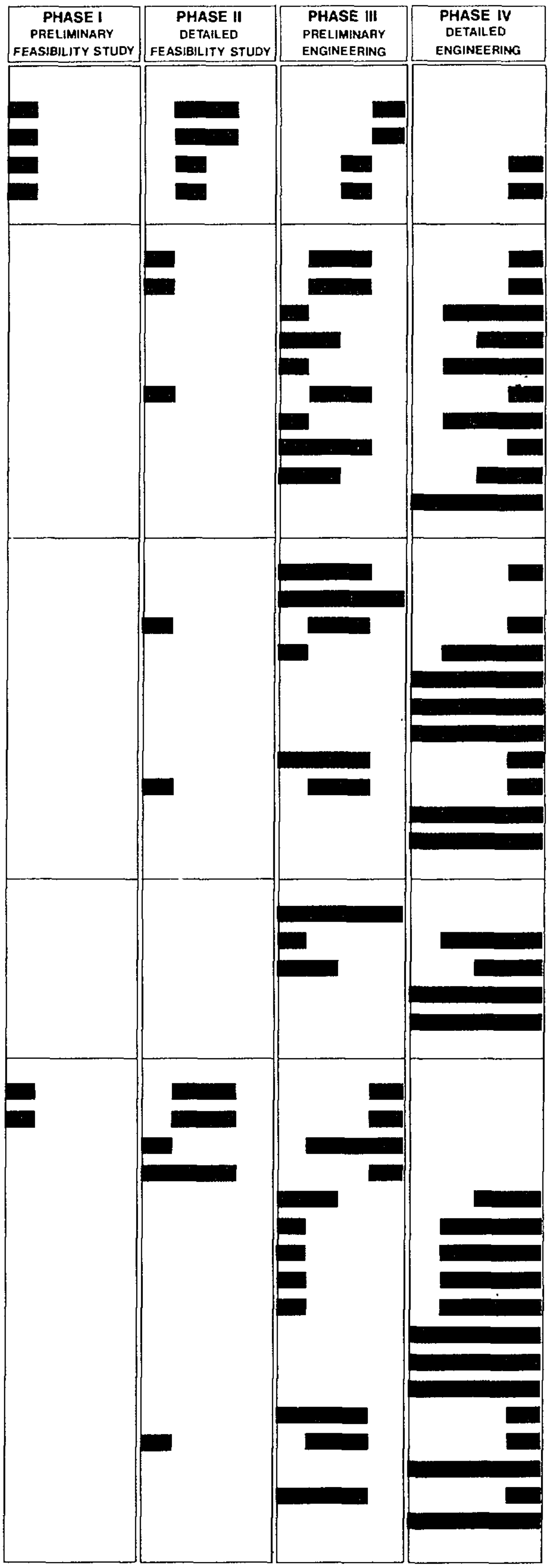
PLANNING & SCHEDULING
Objectives Schedule
Master Project Schedule
Manpower Schedules
Contract & Procurement Schedule
Summary Project Schedule

TABLE 2b

METALLURGICAL PROJECT PHASED DEVELOPMENT PROGRAM

PERCENT OF WORK IN EACH PHASE

0 25 50 75 100



GENERAL LAYOUT
Flowsheets
Site Plans
Process Plant Layouts - Plans & Elevations
Service Buildings Layouts - Plans & Elevations

MATERIAL HANDLING
Material Handling Equipment Design
Material Handling Equipment Layouts
Material Handling Equipment Drawings
Tanks, Pump Boxes, Launders Design
Tanks, Pump Boxes, Launders Drawings
Dust Collection Design
Dust Collection Drawings
Equipment Specifications
Equipment Quotation Analysis
Vendors Drawings Review

PROCESS PIPING
Process Piping Flow Diagram
Piping Specifications
Hydraulics Analysis & Line Sizing
Plan & Elevation Drawings
Isometric Drawings (Special Piping)
Stress Analysis
Pipe Supports
Pump Data Sheets
Estimate Quantities
Material Takeoffs & Requisitions
Vendors Drawings Review

INSTRUMENTATION
Instrumentation Flowsheet
Instrumentation Control Schematics
Instrumentation Specifications
Instrumentation Quotation Analysis
Vendors Drawings Review

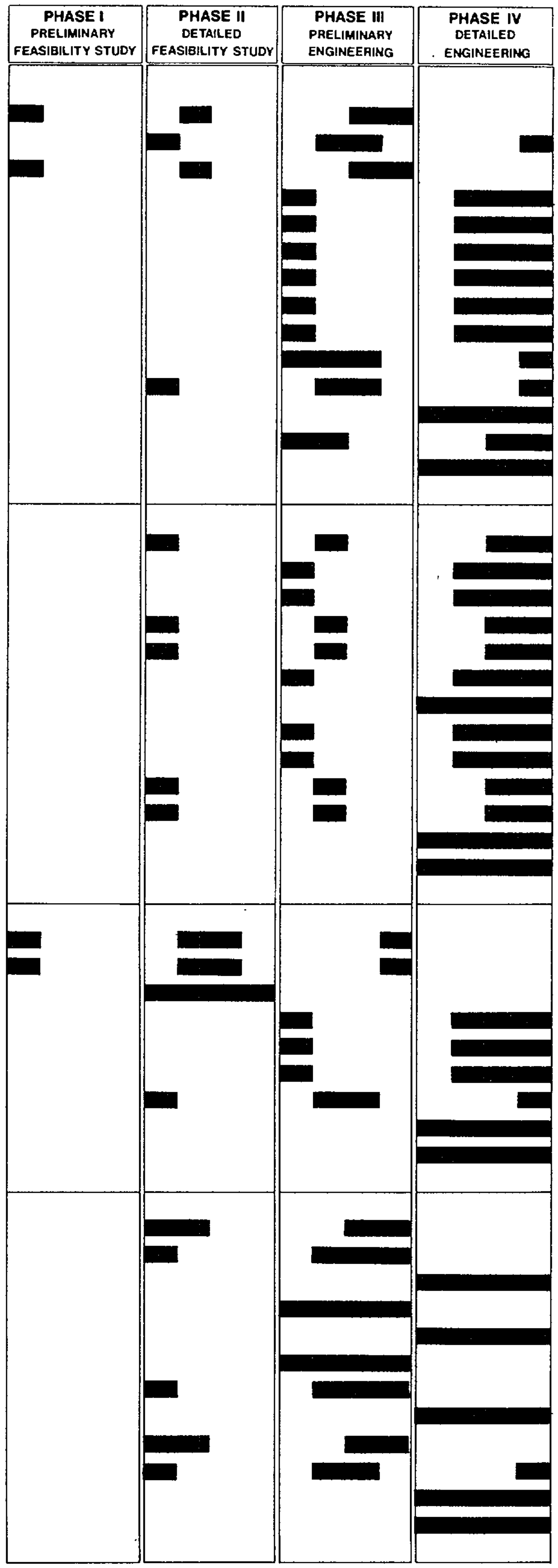
ELECTRICAL
Design Criteria
Power Distribution Scheme
Electrical Control & Interlocking Scheme
Single Line Diagrams
Schematic Diagrams
Electrical Equipment Arrangement Drawings
Cable Tray Layout Drawings
Grounding Systems Drawings
Lighting Systems Drawings
Annunciator Systems Drawings
Communication Systems Drawings
Fire Protection Electrical System Drawings
Equipment Specifications
Estimate Quantities
Material Takeoffs & Requisitions
Equipment Quotation Analysis
Vendors Drawings Review

TABLE 2c

METALLURGICAL PROJECT PHASED DEVELOPMENT PROGRAM

PERCENT OF WORK IN EACH PHASE

0 25 50 75 100



SERVICES
Design Criteria
Design Calculations
Boiler Room Layout Drawings
Process Steam System Drawings
Cooling Water System Drawings
Potable Water System Drawings
Fire Protection System Drawings
Heating & Ventilation Drawings
Plumbing & Drainage Drawings
Equipment Specifications
Estimate Quantities
Material Takeoffs & Requisitions
Equipment Quotation Analysis
Vendors Drawings Review

CIVIL/SITE SERVICES
Site Access Road Layout
Rough & Finished Site Grading Plans
Plant Roads Layout Drawings
Water Supply Systems Drawings
Tailings Disposal Drawings
Dykes and Earthwork Structures
Yard Fencing Plan
Yard Fire Protection Drawings
Yard Piping Drawings
Sewerage Systems Drawings
Estimate Quantities
Material Takeoffs & Requisitions
Vendors Drawings Review

ARCHITECTURAL
Design Criteria
Architectural Design
Architectural Perspective Drawing
Plan and Elevation Drawings
Floor and Roof Plans
Detail Drawings
Estimate Quantities
Material Takeoffs & Requisitions
Vendors Drawings Review

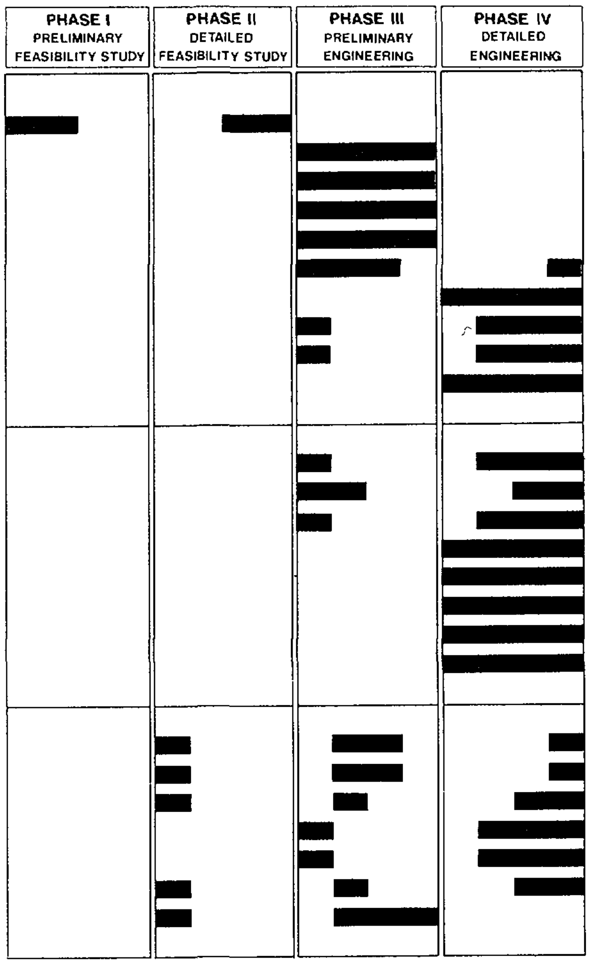
STRUCTURAL
Design Criteria
Design Calculations
Structural Concrete Drawings
Concrete Specification
Structural Steel Drawings
Structural Steel Specification
Bin Design
Bin Detail Drawings
Estimate Quantities of Structural Steel
Estimate Quantities of Concrete & Rebar
Material Takeoffs & Requisitions
Vendors Drawings Review

TABLE 2d

METALLURGICAL PROJECT
PHASED DEVELOPMENT PROGRAM

PERCENT OF WORK IN EACH PHASE

0 25 50 75 100



PROCUREMENT
Preliminary Price & Delivery Data
List of Vendors
Quotation Instructions
Shipping, Routing & Packing Instructions
Drawings & Technical Data Requirements
Major Equipment & Critical Material Inquiries
Minor Equipment & Bulk Material Inquiries
Quotation Analysis
Purchase Orders
Expediting & Shop Inspection

CONSTRUCTION CONTRACTS
Define Contract Packages
Project Master Tender/Contract Documents
Prequalify Tenderers
Construction Specifications
Contract Tender Documents
Tendering
Evaluation of Tenders
Contract Awards

CONSTRUCTION MANAGEMENT
Construction Planning
Logistic Studies
Access Road Study
Equipment Requirements
Temporary Facilities
Manpower Studies
Construction Camp Requirements

SUPPORT FACILITIES

TOWNSITE

POWER SUPPLY

TRANSPORTATION

PORT FACILITIES

SUPPORT FACILITIES TO BE PROVIDED TO SUIT THE PROJECT WITH SEPARATE CHECKLISTS OF ACTIVITIES APPROPRIATE TO EACH.

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[4] KYNCH, G.J., "A Theory of Sedimentation" Trans. Farady Soc. 48 166-176 (1952).

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[6] ROBERTS, E.J., "Thickening-Art or Science?" Trans. AIME, 184 61-64 (1949).

5. LICENSING

5.1. ENVIRONMENTAL CONSIDERATIONS

5.1.1. Introduction

Processes of mining and milling of ores will have an environmental impact that must be considered in any project development. Furthermore, the nuclear industry is faced with particular public scrutiny which makes it imperative that uranium mines and mills understand and implement practices for the protection of the environment. Uranium mines and mills produce several types of waste that can have a negative impact if discharged directly into the open environment. Such wastes are not unique to uranium mining. These are :

Liquid effluents

Solid tailings such as:

- Waste rock from mining
- Dusts
- Solid wastes

5.1.2. Environmental impact statement

The Environmental Impact Statement comprises all project related items that may impact the physical, natural, social, cultural and historical environment of the defined area for the planned mine/mill project.

The major topics of the Environmental Impact Statement are :

- Development schedule;
- Resource base data and size of the project;
- Project description with technical data for mine and mill, water regime, radiation protection, waste management;
- Environmental baseline with meteorology, soils, hydrology, flora and fauna;
- Archaeology;
- Socio-economic background;
- Impact prediction and mitigating measures;
- Monitoring programs;
- Decommissioning and rehabilitation of the project area.

The topics above are described in detail in the following:

<u>Development Schedule</u> means a time plan comprising the sequence of the major activities during the development phase of the project. Those major activities usually are road connection to the planned project area, detailed mine and mill design, mine and mill construction, waste management system, start-up of the mine/mill facility.

<u>Resource Base Data</u> and size of the project comprise the geological structure of the ore deposit to be mined, the dimensions of the orebody, the ore reserves and range of ore grade, mineralogy of the ore, petrology of the host rock and the intergrowth of ore minerals and gangue matrix. Included are

the relation of tons of waste material to tons of ore to be mined as well as the quality and amount of overburden - if any - to be stripped in advance to mining.

Project Description comprises the detailed description of the technical facilities for the mine and mill complex and the design criteria for the architectural structure and for the equipment to be installed in the mine and mill areas. The water regime for the planned operation, i.e. the handling of the surface water, ground water and waste water, as well as safety measures to be applied, radiation protection are also included. Special consideration will be given to the type of waste management, i.e. neutralization of tailings, tails pond design, control of supernatant, radium removal, discharge of treated and softened waste water into the environment.

Environmental Baseline comprises the meteorology and climate in the project area prior to operating the planned facility and the description of the quality of the undisturbed soils, as well as of the rock and ore bearing formations outcropping the area. The quality and amount of surface and ground water available in the area will be covered in the hydrological chapter. A guideline may be established to regulate the consumption of fresh water for the mine/mill facility. A study on the existing specimen in the flora and the living fauna may be conducted as well as the description of the wildlife allowed for hunting and trapping and the fish specimen which can be caught.

Archaeology Research comprises the combination of cultural information available on prehistoric and on the traditional past of the project area. Included are identification of early settlements and architectural cultural remainings as well as sacred sites. Of special interest is the information on archeological specimen in the area to be registered and saved prior to or simultaneously with the operation planned. The co-operation of archaeologists assigned by the governmental authority and the operator will be regulated by the guideline, too.

Socio-Economic Background describes the status of the professional activities of the inhabitants of the project area prior to the planned operation as well as the professional background and number of employees needed in future. In order to use as many people as possible originally living in the project area, usually an employment policy plan will be given to the public. This employment plan will offer job opportunities or - if necessary - training possibilities to acquire for the jobs offered. The employment plan will also inform on the constructural conditions of the jobs whether unionized or not and on the organization of the transportation of employees, i.e. commuting to the work site or living of the employees in a new company owned camp or town site close to the project site. In connection with the latter the arrangements for regulating the cost sharing between the employees and the company will be defined in an agreement between both.

Impact Prediction and Mitigating Measures - The possible impact to the air quality can be predicted using existing climatological dispersion models. This is done to control and minimize this impact which can be caused by process emissions. As significant emissions to the atmosphere are discharged through a stack, this point of emission can exactly be controlled and monitored. The same is valid for fugitive dust emissions and for radon emissions from the mill, where polluted exhaust air is ventilated through stacks. If necessary, washing devices can be added to the intake of the stacks.

The responsible agency will regulate the limits for the allowable emissions of the plant facility and will incorporate the plant specific limits into the license to operate the mine/mill complex.

The principal mitigating measures to be adopted usually involves the restoration of the exposed areas and environment to the original status as much as reasonably achievable.

Monitoring Programs means programs to collect and evaluate data to define source, kind and importance of impact, if any.

Monitoring comprises air quality, soils chemistry of surface water and ground water, waste table, biological status of the waters regarding microlife and fish population, radiochemical dispersion in waters, wildlife and vegetation.

The operator of the project or its consultant will present the results of the monitoring program to the government on a routine basis.

Decommissioning and Rehabilitation of the Project Area means restoration of the project are after ceasing of mining and processing operations. Decommissioning activities will be carried out with respect to all relevant areas, including pits, waste rock storage areas, process plant and auxiliary facilities, camp or town site, tailings pond, site roads, yards and parking areas, sewage treatment facilities.

The decommissioning activities will be carried out in observance of the applicable government regulations. Usually decommissioning will take place over approximately a two year period.

5.2. LEGAL AND SOCIAL ASPECTS

5.2.1. Mining

a) Right of access by the operating company to the ore body

It is of vital importance for a mining company which is contemplating to invest substantial amounts of money in exploration activities that in case of successful exploration its access to the discovered ore body is guaranteed. This can be achieved through a variety of means, e.g. through a direct contractual arrangement between the land owner and the mining company, or, where the exploration activities are conducted on public lands, through applicable provisions of the respective mining legislation, or, especially in countries, where the minerals belong to the state, through a direct arrangement with this state respectively the entities which are entrusted by the state to regulate mining activities.

b) Mining law and regulations for radiation protection

Mining law is the method used by governments to regulate mining activities proper. Traditionally the main function of mining laws focused on the relationship between mining and land ownership and on state regulation of mining activities. The mining law governed the issue, the administration and the cancellation of mining titles; it organized government agencies and their supervisory powers; and it covered settlement of disputes between competing claims. Especially developing countries have enacted mining legislation as a replacement for pre-independence legislation. Furthermore, the emphasis on environmental and social protection provided for in mining laws has been growing rapidly.

As regards radiation protection legislation one has to realize that long before the first nuclear installations were built after the Second World War national rules and regulations were issued to protect the persons who were engaged professionally with X-rays and radioactive substances in medicine and science. One of the very first official radiation protection provisions is the Danish X-ray Act (Law No. 147) of April 15, 1930, which is still in force without any modifications in the meantime. Today this area is to a very high degree influenced by the existence and work of international organisations. This influence is very important in the creation and development of radiation protection legislation from the beginning until now. In principle one has to differ between the so-called International Non-Governmental Organisations, e.g. The International Commission on Radiological Protection or the International Commission on Radiation Units and Measurements, founded on a private basis and without an international legal personality, and the International Governmental Organisations, founded by the states or other entities of international public law on a basis of international agreement and usually possessing legal personality, e.g. IAEA, WHO, OECD/NEA, Euratom.

However, it must be recognized that the enactment of legislation is the prerogative of sovereign states. Unification of legislation, as desirable as it may be, is therefore only possible if the sovereign states involved agree to enact that unified legislation. The fields in which unification has been achieved are rather small. Unification, or a very close approach, has notably been achieved in:

- Safe transport of radioactive materials;
- Consumer products containing radioactive materials;
- Dose limits for radiological workers and individual members of the public respectively;
- De-minimize levels where radiation protection measures must be applied, but differences in de-minimize levels for certain materials are already emerging.

c) Mining license

The mining license should be the document, which contains all those specific terms and conditions in respect of a specific project, which are not dealt with in a general nature in the applicable mining laws and regulations. This mining license is the legal document which permits the mining company in whose favor the document is issued to exploit the ore body. Where project financing arrangements are contemplated a bank would normally not be prepared to loan monies, unless a valid mining license is in place, which covers by lifetime of the project or, at least, gives the holder of the license a secured right to request a renewal thereof.

5.2.2. Milling

a) Licenses to build and operate a plant

Depending on the legal environment in which a mining company is operating, most often a license to build and operate a plant is necessary. Generally, the main terms and conditions of such a license would comprise, inter alia:

- A precise description of the facility which is to be operated;
- The annual production from that facility;
- A "Code of Practice", which lists certain protective actions which the licensee must covenant to carry out within a stated time period;

- Maximum permissable doses of ionising radiation or exposure to radon daughters;
- Information obligations in case of a dosimetric result exceeding the specified limits;
- A variety of other information obligations in case of incidence that results or is likely to result in a hazard to health or safety of an employee;
- Description of the qualified personnel necessary to operate the facility in order to ensure its safe operation at all times;
- Treatment of mine waste, mill tailings and any other contaminated materials; and
- Numerous other provisions as might be appropriate in the specific circumstances.

b) Licence to use surface and ground water

Again, depending in what legal environment a mining company operates, a license to use surface and ground water might be necessary. This will especially be true in an area, where other industries are depending on the use of surface and ground water. There, in order to protect the legitimate interests of other parties, a mine operator will be permitted to use only a certain amount of ground water, or to ensure, that any surface water is permitted a "free flow".

c) Licence to discharge waste water and tailings

The operator of a mine and mill facility has to obtain a licence from the responsible governmental authority to discharge effluents and tailings from said facility. The licence usually is based on applied national or provincial guidelines covering the limitations for the quality of waste water and tailings, whereby individual conditions may be considered for a special case.

There are three (3) types of effluents defined: mine water, mill process effluents and surface drainage, including seepage from treatment ponds, ore and concentrate stock piles, waste rock dumps and other sources of contamination on a mining property.

The tailings disposal area is an unconfined or impounded area where solid and/or liquid tailings are disposed of.

The guidelines for the disposal are based on containment and treatment at source, applying the principles of current best practicable technology.

The parameters of the maximum allowable physical and chemical values for the effluents and tailings are usually defined as well as the sampling procedures and the reference point for taking the samples. The specific sampling procedure and arrangements for obtaining the samples will be at the discretion of the regulatory agency.

The operator will follow a regular monitoring program for sampling and discharging of waste water and tailings for analyzing for the particular parameter and at the frequencies set forth in the licence given by the regulatory agency.

5.2.3. Legal limitations

Ownership - Export Controls - Public Acceptance

a) As regards the issue of ownership, one has to differ between legal ownership and management and control of a project. All mining contracts, be they concession, joint venture or service contracts, illustrate that ownership does not automatically imply effective control and that the function of management can be separated from ownership. While government equity may exceed 50% or even reach in case of service contracts 100%, management may be entrusted to the foreign partner. This organization often reflects the fact that financing institutions are unwilling to contribute capital if they are not assured that an experienced mining company will be in charge of operations and undertake strict completion guarantees. Furthermore, in various countries, there are legal limitations as regards the foreign ownership content in a certain mining project.

b) The observance of export controls and the timely receipt of all necessary permits and licenses is especially important for any mining company dealing in the uranium business. There are numerous bilateral and multilateral agreements which govern and control the move of uranium not only from one country into the other country, but already within one country. These controls are intended to ensure that the uranium is used for non explosive purposes only and that it will not eventually end up in any military device.

c) Public Acceptance of nuclear installations has become a growing concern to mining companies, utilities, and governments alike, especially after the Chernobyl disaster. In view of the - sometimes violent - demonstrations against the construction or continued operation of nuclear power plants and nuclear fuel cycle facilities, it has become increasingly important to convince the general public of the very large advantages of nuclear power from the environmental point of view. The nuclear industry will achieve 'public acceptance' if it can successfully demonstrate that its installations are of the very highest safety standards and that only by permitting nuclear power plants to operate can those valuable resources (e.g. coal, oil, wood) be saved which to save for future generations is the responsibility of the society of today.

5.2.4. Employment aspects

The employment system will change during the phases of development of a project, which usually will start with subcontracted work during the engineering and construction period. During this period the owner of the project may only employ a small crew of administrative and technical managers, while the engineering and construction work will mostly be carried out by specialized third consultants or construction companies working with their own employees and applying their own personnel policy. During the engineering and construction phase 500-1000 engineers, drawers and craftsmen may be employed at anyone time.

For operation of the mine/mill facility a complete new crew of employees will be hired by the operating company applying a company specific work schedule and regulation. The regulations as to working time and compensation will be formulated in a working agreement. During the operating period about 200 to 500 operators may be employed.

During the operation period additional outside services may be necessary, transportation and professional advisory activities for instance.

Those additional services may be subcontracted to third companies and may be handled by the operator in the manner adopted during the engineering and construction phase. There may be about 10-30 people employed for outside services at anyone time.

It is very important to evaluate the availability of craftsman in the area when deciding on developing a project, because of the cost for construction. If there are not enough indigenuos craftsmen available, transfer of people from outside will be necessary which causes installation of housing facilities or a camp. Information on the various craftsmen available can be achieved by the construction company from the local or provincial employment offices or from unions.

There may be some experienced operators available in the area but usually a new operating company will arrange for a training of people interested in the new jobs offered. The training will commence already during the construction period and about some months ahead of the start-up of the facility, whereby the engineering and constructing company carries full responsibility for the start up arrangements and in most cases for the training of the operators, too. The operators, however, are being hired by the operating company according to its own employment scheme and the code of ethics of the company. The company may be interested in employing as much indigenous people as possible in order to create an area oriented work force.

In industrial developed areas most of the auxiliary materials, i.e. power, fuel, reagents and maintenance materials will be supplied from third companies. The transportation will be subcontracted too. Only in remote areas power and reagents, like acid, are produced by the operating company itself. Those remote companies will install their own water wells, diesel or hydro-power plants, boiler and acid plants and will employ and train the relevant specific personnel too. A remote uranium mine/mill facility needs a tonnage of consumable technical materials about seven to ten times as much as the amount of uranium concentrate produced in said facility. The transportation arrangement as to type of road and number of trucks and truck drivers must carefully be engineered technically and economically.

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6. DETAILED FEASIBILITY STUDY

6.1. BACKGROUND

A detailed feasibility study is required for financing. It is assumed that the preliminary feasibility study has shown positive economics for the project.

The first step is to review the prefeasibility study, and recommendation, and to define the scope and organization of the feasibility study. All field data requirements should be committed immediately as these are the time restraints on the study completion.

It is important to remember that the completed feasibility study will be the guide for all actions, and decisions leading to production. This makes it imperative that all participants, including owners, governmental agencies, consultants and specialists, have their input and requirements incorporated in the final document. The feasibility study must address all areas of capital expenditures and operating costs. These should be defined in suitable detail by drawings and written definition to ensure a high level of confidence in the final document. A typical listing of such detailed areas and items is included in Table 1. Adequate drawing preparation is necessary as these drawings form the basis for the capital cost estimates. The drawings and contained data should be to suitable detail to allow detailed engineering and procurement to proceed immediately after project committment. A typical drawing quantity is listed in Table 2.

Some of the areas of work are highlighted in the following sections.

6.2. GEOLOGY

The single most important item is the calculation and definition of the ore reserves. Currently it is preferred to have all drill hole data on a computerized data base which facilitates the calculation of ore reserves. Various cut-off grades can be employed for geostatistical nalysis of ore reserves. These computer programs can also prepare mining plans and sections, by grade and assist in the mine planning phase. The study, should contain all plans and sections with grade variations, preferably, color coded, for ease of third party verification.

6.3. MINING

The geological plans and sections, and the drill logs, form the basis for the selection of mining method(s). For the purpose of this paper an underground mine will be considered.

The mining method and orebody configuration, must be checked to confirm that the annual selected tonnage can be readily achieved. General rules are available based on tonnes per vertical foot.

Mining plans and sections must be prepared to define all preproduction work and costs in development headings. These generally extend for some years after production commences.

Text cont. on p. 66.

TABLE 1. TYPICAL DETAILED AREAS OF STUDY

1. <u>GEOLOGY</u>

- Preparation of plans and sections with all current data;
- All drill hole data should be put on a computerized data base;
- Selections of cut-off grades;
- Computation of ore reserves as "proven", "probable" and "inferred";
- Geostatistical analysis of reserves using different cut-off grades;
- Orebody modeling on a computer.

2. <u>MINING</u>

- Calculate Mineable Ore Reserves with Extraction and Dilution;
- Selection of Mining Methods and Shift Schedules;
- Access; Shaft and/or ramp;
- Ore Pass;
- Primary Crusher;
- Conveyor System;
- Production Hoisting and Conveying;
- Preproduction Development Requirements;
- Underground Ventilation;
- Mine Ventilation and Air Heating;
- Mine Exhaust;
- Mine Electrical Supply and Distribution;
- Capital Equipment Requirements;
- Service Equipment Requirements and Installation;
- Mine Pumping;
- Post Production Capital Additions;
- Waste Disposal;
- Backfill Requirements.

3. <u>HEADFRAME AND ASSOCIATED STRUCTURE</u>

- Size and Type of Hoist;
- Materials of Construction;
- Ore and Waste Bin Capacities;
- Bin House;
- Shaft House.

4. <u>CRUSHING</u>

- Shift Schedules;
- Rate;
- Open or Closed Circuit;
- Maximum Feed Size;
- Ore Storage Capacity;
- Provision for Storage of Crushed Waste;
- Environmental.

TABLE 1. (cont.)

5. MILLING

- Equipment Selections;
- Ancillary Equipment;
- Service Equipment (Cranes, Monorails, etc.);
- Maintenance Equipment;
- Offices, plus Equipment and Furniture;
- Test Laboratory;
- Metallurgical Control Equipment;
- Fire Protection;
- Lighting;
- Potable Water;
- Heating, Air Conditioning and Ventilation;
- Changeroom;
- Central Control Room;
- Instrumentation (Simple or Sophisticated);
- Assay Laboratory.

6. CONCENTRATE STORAGE AND LOADOUT

- Type of Storage;
- Shipping Schedule;
- Shipping Method;
- Car Loading Facilities (on or off site);
- Dock Facilities;
- Ship Loading Facilities.

7. WAREHOUSE

- Size;
- Equipment and Shelving;
- Offsite Availability of Supplies.

8. SHOPS

- Size;
- Degree of Self Sufficiency;
- Type of Work to be Performed;
- Offsite Availability of these Services.

9. ELECTRICAL

- Power Source;
- Transmission Lines;
- Main Substation;
- Surface Distribution;
- Type of Motors;
- Control System;
- Underground Requirements;
- Standby Requirements;
- Construction Requirements;
- Switchroom Ventilation and/or Cooling.

TABLE 1. (cont.)

10. ADMINISTRATION

- People Requirements;
- Furniture;
- Equipment;
- Plant Engineering and Equipment;
- Geology;
- Vault;
- Telephone System External and Internal;
- Telex or Other Communications;
- Employee Training Facilities.

11. MINE DRY

- People Requirements;
- Hooks, Lockers;
- Tool Room;
- Lamp Repair;
- First Aid and Safety.

12. TAILINGS

- Capacity (initial and ultimate);
- Clearing and Grubbing;
- Access Road;
- Reclaim Requirements and Equipment;
- Secondary and Tertiary Ponds and Treatment;
- Dam Construction Regulations;
- Seepage Control;
- Existing Watercourses and Bypasses.

13. WATER SUPPLY AND FIRE PROTECTION

- Total Requirement;
- Fire Regulations and Underwriters Requirements;
- Backfill Requirements;
- Potable Reclaim and Process Systems;
- Hydrant Systems;
- Supply Locations and Availability;
- Approvals.

14. SEWAGE DISPOSAL

- Government Regulations.

15. FUEL SUPPLY

- Availability;
- Type of Fuels;
- Mine Air Heating;
- Surface Heating Systems;
- Storage Requirements.

TABLE 1. (cont.)

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16. ROADS, YARDS, FENCING

- Governmental Assistance;
- Quality of Roads;
- Paving of Roads, Yards, Parking;
- Fence Requirements;
- Yard Lighting and Plug-ins.

17. EXPLOSIVE STORAGE

18. SURFACE MOBILE

- Permanent Requirements;
- Construction Requirements;
- Fire Truck;
- Ambulance;
- Automobiles.

19. ENVIRONMENTAL AND SOCIO-ECONOMICAL

- Project Review, Organization and Scheduling;
- Liaison with Government Agencies, Community Representatives, Business Interests and Special Interest Groups;
- Review and Assessment of Socio-Political and Sensitivities;
- Development and Review of Alternative Engineering Design and Site Layout Options;
- Preparation of Socio-Economic Profiles;;
- Identification of Patterns of Resource Utilization;
- Holding of Public Information Sessions;
- Identification and Response to Concerns of Local Inhabitants;
- Data Base Review and Expansion for Water Quality, Sediment Quality, Fisheries;
- Refinement of Hydrological Data;
- Atmospheric Monitoring and Modelling;
- Identification and Quantification of All Sources of Waste Discharges/Emissions - Transport and Fate;
- Selection and Evaluation of Overland Transportation Corridors;
- Site Evaluation for Ocean Going Off-Loading Facilities;
- Preparation of the "Project Concept Description".

20. TOWNSITE

- Requirements; single and family;
- Transportation;
- School;
- Recreation;
- Shopping;
- Services;
- Governmental Approvals and Assistance.

TABLE 1. (cont.)

21. CONSTRUCTION HOUSING

- Personnel Requirements for:
  Mine Development,
  Administration,
  Surface Construction,
  Supervision,
  Catering,
  Visitors.
- Recreation;
- Site Work;
- Services;
- Camp Catering;
- Purchase or Rental.

22. CONSTRUCTION OVERHEADS

- Temporary Buildings;
- Temporary Services;
- Temporary Roads;
- Temporary Heat - Portable;
- Office Equipment and Supplies;
- Communication;
- Security, First Aid and Fire Protection;
- Small Tools and Consumables;
- Permits;
- Insurance and Bonds;
- Testing Materials;
- Pumping;
- Hoarding;
- Scaffolding and Staging;
- General Site Clean-up;
- Overtime Premium;
- Contractor's Mobilization Costs;
- Aggregate Availability and Cost;
- Batch Plants;
- Hoists;
- Mobile Equipment Rentals;
- Miscellaneous Minor Equipment.

23. OWNER'S SITE COSTS

- Supervision;
- Administration;
- Camp Costs;
- Travel;
- Communications;
- Heat;
- Power;
- Road Maintenance and Snow Plowing;
- Recruiting;
- Insurance;
- Legal;
- Land Costs and Acquisition.

TABLE 1. (cont.)

24. HEAD OFFICE COSTS

- Administration;
- Supervision;
- Travel;
- Communications;
- Consultants.

25. PROJECT MANAGEMENT

- Engineering;
- Procurement;
- Expediting;
- Construction Management;
- Construction Warehousing;
- Site Costs;
- Contract Administration;
- Start-up Assistance (Supplies, Consultants, other).

26. OTHER

- Duties;
- Taxes;
- Royalties;
- Freight.

27. FURTHER STUDIES

- Pilot Plant;
- Drilling;
- Topographical;
- Soils;
- Environmental Baseline and Impact.

28. WAREHOUSE INVENTORY

- Spare Parts;
- Consumables.

29. WORKING CAPITAL

- Surface Stockpile;
- Initial Production Schedule;
- Sales Revenue Timing.

30. INTEREST AND FINANCIAL CHARGES

31. CONTINGENCY

32. ESCALATION

- Schedule;
- Rate.

TABLE 2. TYPICAL DRAWING REQUIREMENTS

GEOLOGY

All plans and Sections

MINE

10	-	Plans and Sections
8	-	Sketches of Typical Stopes and Methods Used
7	-	Plans and Sections on Hoisting and Headframe Arrangements

GENERAL

3	-	Area and Site Plans
8	-	Process Flowsheets Including Mass Balances and Energy Balances
15	-	Process & Instrumentation Diagrams

SITE DEVELOPMENT

1	-	Final Grading Plan
1	-	Storm Water Ponds - Plans & Details

SITE SERVICES

1	-	Water Supply Pumphouse - General Arrangement
1	-	Water Distribution Pumphouse - General Arrangement
1	-	Combined Services Plan

SITE ELECTRICAL

1	-	Single Line Diagram
1	-	HV Distribution Lines

BULK STORAGE

1	-	Fuel Storage Area - Plans and Details

EFFLUENT HANDLING

1	-	Monitoring Ponds - General Arrangement
1	-	Sewage Treatment System - General Arrangement

CRUSHING PLANT AND ORE STORAGE

3	-	Plans and Sections

TABLE 2. (cont.)

CONCENTRATOR

11 - Plans and Sections

ANCILLARY FACILITIES

2 - Administration, Shops, Warehouse, Dry - Plans and Sections

POWER HOUSE

- Power Plant - Plants and Sections

TAILINGS DISPOSAL

1 - Tailings Area Plan
1 - Tailings Dam Sections and Details
1 - Reclaim Water Pump Station - General Arrangement

CAMPSITE

1 - Campsite - Dining Facility
1 - Campsite Recreational Facility
2 - Campsite Accommodation
1 - Campsite Plan
3 - Campsite - Combined Services Plan

ACCESS ROADS

2 - Access Road - Overall Plan, Sections and Details

PORT AND DOCK FACILITIES

2 - Plans and Sections
2 - Storage and Cargo Details
3 - Services - Arrangements and Details

All mining equipment requirements must be defined and costed. This must include all materials handling, crushing, conveying, storage and hoisting.

Ventilation and exhaust requirements in a uranium mine are strictly defined. This plus the use of diesel equipment will define the ventilation, exhaust, heating and cooling, and development requirements.

A detailed schedule should be prepared showing manpower, waste production, development ore production, ore production and heading development well into the production period, and must define post production capital requirements.

Since underground mine development is normally the limiting time factor, it is important that the preparation of the schedule is done in a detailed and knowledgeable manner.

All mine requirements such as water in, water out, power, high pressure air, maintenance warehousing, geology, surveying, and change rooms, must be detailed and costed.

6.4. PROCESSING

All of the process unit operation alternatives were examined in the prefeasibility study with recommendation for further test-work made. This programme should now be initiated in order to optimize the selected process and to provide more detailed data for engineering calculations.

Upon completion of the test programme, detailed design criteria is established and all process equipment is then calculated and costed. Major equipment costs should be letter prices, but may be firm quotes if a project go-ahead decision is imminent. It is important to treat all ancillary equipment in a similar and detailed fashion, this may include all reagent storage and handling, compressors and vacuum pumps, maintenance, and metallurgical control facilities. All detailed material and energy balances must be prepared and process instrumentation diagrams should be done to define and cost all control systems.

Detailed layout drawings are required to define the facilities and to allow for quantity take-off's of piping and cable etc. for capital costs.

All manning charts and consumable lists should be prepared in order to detail the operating cost requirements.

6.5. INFRASTRUCTURE

The infrastructure requirements such as shops, warehouse, powerhouse, pump houses, roads, power supply, transportation, camp sites, housing and logistics must be defined in detail.

Drawings, must be prepared to show all structures and contents and to define all site civil costs and servicing costs. These service areas all require operational manning charts, consumption and maintenance lists and post production capital requirements where indicated.

6.6. CORPORATE STRUCTURE

The corporate structure for a project must be clearly understood as the owner(s) and/or managers must make many non-technical decisions. They must ultimately define the production costs as this is dictated by their marketing requirements.

Operating and employment practices are defined by the project owners. Similarly all contracts and agreements with government agencies are submitted by the owner as it is his responsibility to enforce such agreements and licences.

The owner/manager must define mine development policies with respect to preproduction and post-production requirements. In an underground mine it may be the decision to direct hire or contract development.

The owner/manager controls many site and offsite costs during both the development and operational phases. He must define these for the economic calculations in a feasibility study.

6.7. FINANCIAL EVALUATIONS

The owner/manager must define many of the ingredients in this study except, the capital and operating costs.

Marketing studies including, volume, prices and customers are generally owner supplied. These volume decisions influence the entire study and must be an initial decision. Prices, and customer destination are included in the financial analysis. Project financial analysis must include, equity to debt ratio, cost of capital, all duties, taxes, royalties, payback criteria, and other data which are predominantly owner/manager responsibilities and decision.

The financial evaluation also include, sensitivity analyses using variables derived from both the owner/manager and the engineering data as compiled in the study.

6.8. SUMMARIES

A feasibility study will have a number of volumes as the level of detail required is quite high. Three to six detail volumes are commonly prepared.

All of this data must be presented in a summary volume which presents all of the criteria, data and conclusions in a concise manner. This summary volume must be complete for financial decision making purposes.

A second executive summary may be prepared which very concisely presents the highlights of the study. This usually has a large graphics content to illustrate, location, financial variations, schedules, orebody, and site planning.

6.9. DECISION CRITERIA

The object of the feasibility study is to present the owner with sufficient data, upon, which to make a major financial decision, i.e. to proceed or not to proceed.

The basis of the decision may be on the:

- Technical ease or difficulty;
- Ore reserve limits;
- Return on investment;
- Potential environmental ease or difficulty;
- Current or projected market prices;
- Project risks both technical and financial. Sensitivity analyses highlight financial risk ranges;
- Government and socio-economic stability.

A properly prepared feasibility study will be a major factor in the decision making process and in project financing and execution.

7. PROJECT EVALUATION

7.1. OBJECTIVE OF URANIUM MINING

The primary objective of a mining company - and this includes uranium producers - is to profit from the sales of the product. The same refers to any other industrial activity. The only difference in mining is that mineral deposits are limited in quantity and non-renewable. Thus the profits must provide not only a reasonable return on investment but must also cover the cost of purchasing or conducting exploration for a replacement deposit. The concept of profits is often misunderstood or forgotten by the general public and sometimes by those who are involved in the mineral industry. Without the incentive of profit that is commensurate with risk, the incentive to mine would cease.

To gain a profit, a large number of factors must be considered and overcome. A lot of them are based on a speculative concept that there is:

a) Actually a deposit in the ground of reasonable quantity and quality available for mining; and
b) A market available for the product that guarantees an adequate price.

The uranium market and price development in the recent period of time has shown that predictions on market conditions even of from 5 to 20 years in the future are sometimes wild guesses only.

7.2. OBJECTIVE AND APPLICATION OF ECONOMIC AND FINANCIAL EVALUATIONS

Based on the necessity of a profitable mining operation, the main objective of an economic and financial evaluation is to identify and evaluate the economic outcome of a proposed project so that whatever funds are available can be used to the best advantage. The evaluation is frequently used as the basis for allocating funds by the mining company. Used in this way the evaluation must provide, in a readily understandable form the data needed to reach a sound economic decision regarding the disposition of large sums of money.

The development of a uranium mine is, as with any other mineral, based on a uranium deposit, the geological basis for the mineral production.

Since mineral deposits are initially an unknown, they must be explored prior to a development decision. This search necessitates a long period of investment and a high risk of total loss through failure to discover a deposit. This makes determination of the economic viability of a mineral deposit a particular challenging task.

An economic evaluation is usually made at various stages in an exploration programme. Evaluation may also be used to establish exploration target requirements in terms of tonnage and grade. The studies may be performed at various stages in the detailed exploration programme, for example after certain drilling phases are completed. If successful through the early stages, management will eventually be required to make the final decision (go/no go), based at least in part on the financial evaluation. We have to add that the decision process for a mine investment is actually more complex since in addition to information which can be evaluated in terms of expected profitability and uncertainty, intangible or nonquantifiable information must also be considered. For example the various political influences of a project (i.e. price determinations, export restrictions, nationalization, national uranium policy, etc.) illustrate the importance of intangibles in mining.

Expected profitability and uncertainty criteria can be evaluated by methods described later in more detail. Intangibles can only be evaluated and assessed by judgement. They may, however, sometimes play an important part in the overall decision process.

7.3. METHODS OF ECONOMIC AND FINANCIAL EVALUATIONS

7.3.1 General

The question with regard to the economics and profitability of an investment can be answered by means of several concepts and computing methods, each of it having its own merits and shortcomings.

Which of the methods is the most appropriate depends on:

- Whether we have to chose between two or more alternatives or if the decision is to made on the economics of one project;
- The size of the project, its lifetime and its complexity; and
- Whether we have sufficient project data available and whether the estimations, especially those related to future time periods, are sufficiently precise.

7.3.2 Non-discounting methods

Especially in the case of a preselection between two or more small sized projects with a short lifetime simple non-discounting evaluation methods can be used. Three concepts are given as examples.

a) Concept of cost comparison

This method compares the costs (preferably the costs per unit of product) of different similar projects. Assuming that the specific product revenues are equal, the project with the lowest costs will yield the highest profit and will be the last one that will produce financial losses in weak markets.

This method has the advantage that the estimation of revenues can be eluded. This estimation is normally one of the most difficult ones especially in an early stage of project evaluation, and it has generally the highest influence on project economics.

b) Pay back concept

The pay back period is defined as time period required to recuperate the original investment outlay through the profits earned by the project. Profit is defined as net return after tax. A single project proposal may be accepted if the pay back period is smaller than or equal to an acceptable time period. This period is usually derived from past experience with similar projects.

The merit of the method as a criteria for project selection is its easy calculation. The main shortcoming is that it does not measure the profitability of the project proposal but is mainly concerned with its liquidity.

c) Simple rate of return

This method calculates the ratio of an average yearly profit of full production to the original investment outlay. This ratio (rate of return in %) can be computed either for the total investment or for the equity capital. The higher the ratio, the more advantageous is true investment proposal.

The main shortcomings of this method are the question of the "average" year and that it does not take into account the timing of the cash inflows and outflows during the project life.

7.3.3. Discounting methods

In analyzing one or more projects/project alternatives with a certain size and lifetime the discounted cash flow method is generally recognized as a logical way to analyze and compare alternative investment opportunities involving different time periods and generating different cash flows. Cash flow and time value are the basic concepts used in this technique, resulting in the criteria of present value ratio and the rate of return.

Cash flow measures the total income derived from an investment per unit time after all real costs - operational as well as capital expenditures - have been deducted.

An investment project may be regarded as a time distribution of cash flows as shown in Fig. 1. The cash flows will be negative during the exploration, development and construction period and then positive during the production period.

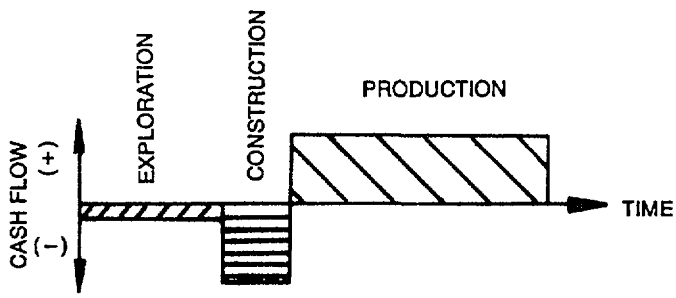

FIG. 1. Time distribution of average cash flows for an ore deposit.

During the production period cash flow is simply revenue per unit time minus all real costs. This cash flow represents the total amount of money generated by the project and available for other uses. Cash outflows are actual out of pocket expenditures, cash inflows are similar to money in the bank. The determination may be complicated by rules governing the derivation of tax payments and/or royalties. The following table may be used as a simplified example for the determination of cash flow for a mine:

	Revenue
minus	Operating Expenses
equals	Net Profit before Depreciation, Depletion and Amortization
minus	Depreciation, Depletion, and Amortization
equals	Taxable Income
minus	Income Tax
equals	Net Profit after Tax
plus	Depreciation, Depletion, and Amortization
equals	Cash Flow
minus	Capital Expenditures
equals	Net Cash Flow

Depreciation, depletion and amortization are allocations of previous expenditures and, therefore, not current cash costs. These allocations are added back to net profit after tax after calculation of income tax liability.

It must be emphasized that cash flow is not the same as profit. Cash flow represents only the difference between total cash receipts from the operation and the total cash outlays incurred in carrying out these operations.

As money has a time value, differences in the time distribution of cash flows are of importance. Therefore, in the financial analysis the present value of a future cash flow is determined. This conversion is known as "discounting".

The formula is:

$$P = \frac{C}{(1 + r)^i}$$

Where:

P	=	Present Value of a sum of money
C	=	Future cash flow equivalent to present sum P
r	=	Interest rate per interest period
i	=	Number of interest periods

Taking this philosophy into account, the following major investment criteria are available and widely in use:

- Internal rate of return (i.e. discounted cash flow rate of return or DCF-ROI or marginal efficiency of capital);
- Net present value (acquisition value, wealth growth rate, benefit--cost ratio);
- Pay back period.

The investment criteria and the respective formula are shown in Fig. 2.

a) Net present value

The net present value (NPV) is the sum of the discounted cash flows as shown in the formula in Figure 2. In this way it represents the difference of all cash outflows and inflows accruing throughout the life of a project at a fixed predetermined interest rate. This difference is discounted to the point of production start up.

Net Present Value (NPV)

$$NPV = \sum_{i=0}^{t} \frac{CFi}{(1+r)^i}$$

Net Present Value Ratio (NPVR)

$$NPVR = \frac{\sum_{i=0}^{t} \frac{CFi}{(1+r)^i}}{\sum_{i=0}^{p} \frac{CFi}{(1+r)^i}}$$

Discounted Cash Flow Return on Investment (DCF-ROI)

$$\sum_{i=0}^{t} \frac{CFi}{(1+DCF\text{-}ROI)^i} = 0$$

Payback-Period (P)

$$\sum_{i=0}^{n} CFi = \sum_{i=n+1}^{p} CFi$$

Symbols

CFi	=	Cash Flow in year i
i	=	year
n	=	year ending preproduction period
r	=	cost of capital or required rate
t	=	total life of property
p	=	preproduction period in years

FIG. 2. Investment criteria.

The discount rate should be equal to the cost of capital (interest on long term loans) or be a minimum rate of return belowwhich the investor considers that it does not pay for him to invest.

Although it is not normally employed as an accept/reject criteria, NPV is very useful in determining the acquisition value of a project.

NPV does not necessarily reflect expected profitability because a higher value may result from a larger capital investment. Therefore, net present value is divided by the absolute present value of the negative cash flows (discounted investment) to determine the net present value ratio (NPVR):

$$NPVR = \frac{NPV}{NPVi}$$

Where: NPV = Net present value as defined in Figure 2
NPVi = Net present value of the investment

Using this method the investment alternative with the highest net present value ratio is preferred with respect to expected profitability. When only one project is considered, a positive choice should only be made if the NPVR is greater than or equal to zero.

In summary, it can be concluded that the NPV has great advantages as a discriminatory method compared with other methods. The shortcoming of the NPV is the difficulty in selecting the appropriate discount rate.

b) Discounted cash flow return on investment (DCF-ROI) (Rate of return)

This method - the criteria commonly named as rate of return - is widely employed in the mining industry.

The DCF-ROI equates the present values of cash outflows (negative) and inflows (positive) as shown in Figure 2. It results in the discount rate that produces a zero present value.

The investment alternative with the highest rate of return is preferred on the basis of expected profitability. A project would be accepted if the DCF-ROI exceeds some required rate "r". This may be the cut off rate which is the lowest acceptable interest rate for the invested capital.

The procedure used to calculate the DCF-ROI is the same as the one used to calculate the NPV. Instead of discounting cash flows at a predetermined rate, several discount rates may have to be tried until the rate is found at which the NPV is zero. Thus it is usually determined by trial and error method.

The DCF-ROI indicates the actual profit rate of the total investment and if required of the equity capital. For the latter purpose a project cash flow on equity capital invested has to be calculated. The rate of return of total investment can also be used to determine the conditions of loan financing since it indicates the maximum interest rate that could be paid without creating any losses for the project.

The merits of the DCF-method is that it embodies the concept of time value of money and employs cash flows. Critics of the method state that the implicit assumption of reinvestment of cashflows at the DCF-ROI is unrealistic and exaggerates returns. However, the advantages of the method are such that it is widely selected as the investment criteria in the mining industry.

c) <u>Pay back period</u>

This method is generally discussed under 7.3.2 in connection with simple methods of evaluations. The pay back period as a screening device is frequently used in conjunction with DCR-ROI.

The pay back period is defined as the time required to recoup the investment from cash flow (Figure 2). Time is usually measured from start of production.

The concept is particularly useful for risk analysis. Projects with a pay back greater than a specific number of years may be rejected.

7.3.4 Sensitivity analysis

With the help of sensitivity analysis it can be demonstrated how the profitability of an investment alters with given changes in an input variable. For example sensitivity analysis may evaluate the effect of changes in:

- Prices/revenues
- Operating costs
- Investment costs
- Uranium head grades
- Production rate

Normally these changes are calculated and displayed in graphicformm as regression curves.

A synoptical graph of several investigations (Fig. 3) shows the order of sensitivity for the various parameters evaluated. In this way it is possible to define those input variables to which profitability is most sensitive. These strategic variables should then be given special attention in the investment decision process.

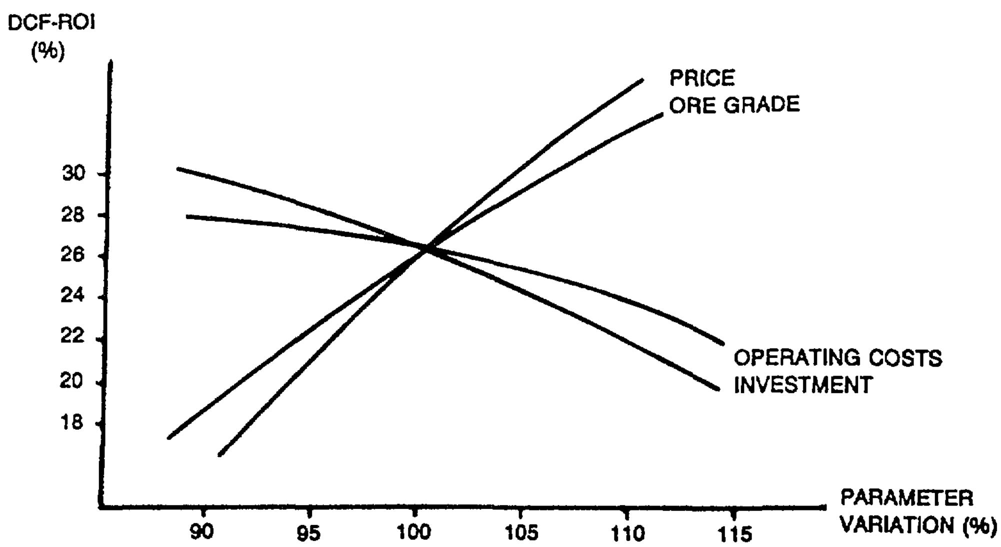

FIG. 3. Example of sensitivity analysis. Change of DCF-ROI due to variations *of major input parameters.*

One should not forget, however, that this method is simplifying some relationships. When changing a parameter in the calculation the other variables remain unchanged. In reality most of the technical parameters are related to others and there is alwayss a certain interdependence. For example changes in ore head grade may be due to more or less dilution in the mining processs which means lower or higher mining costs.

Furthermore, the sensitivity analysis does not measure the uncertainty of an investment alternative because it does not consider the probability of the given change in an input variable and, thus, does not measure the probability of changes in the expected profitability. Insofar, the usefulness of sensitivity analysis is limited. Measures to quantify uncertainty will be discussed later.

7.3.5. Problems connected with discounted cash flow analysis

Results of a DCF-calculation - especially when done by computerized methods - often create the impression of very high precision. However, this impression is often misleading. Actually the calculations are necessarily connected more or less withproblems and uncertainties. For example, the geological and technical base parameters are limited in precision. The production parameters will often change during the long lifetime of a mining project. Changes in metal content and recoveries during the production period necessitates additional investments and/or changes in the estimated operating costs.

The escalation of costs can only be estimated with a certain degree of confidence and the rate of escalation is often different in the various cost categories. The same refers to the project revenues. This parameter as well as the investment has normally the highest influence on the results of an economic evaluation.

Generally, there are two areas of weak points in a DCF calculation:

- The more or less low degree of precision in estimating the input parameters;
- The implicit omission of aspects which can only be qualified but not quantified, for example, the changes of the legal/administrative framework in which the project is integrated and the influence of these changes during the project lifetime.

To overcome these weak points additional methods of risk analysis have been developed. This will be discussed later. Furthermore, as a supplement to a DCF analysis the simplified concept of cost comparison is in use for the decision process. As already mentioned under 7.3.2 this concept bypasses the problems with regard to estimation of revenues (prices, markets).

The concept compares the estimatedd production cost of aplanned project for the time of production start up with production costs of already existing mines or potential competitors. Assuming that cost escalations in real terms and metal price fluctuations will influence all mines at a comparable level, the project with favourable production costs will survive in the long run.

Despite the inherent problems connected with the DCF calculations, most mining companiess are using the method as a basis for their investment decisions, however, they try to combine this concept with other criteria to avoid the shortcomings of the calculation.

7.4. PROBABILITY ANALYSIS

Monte Carlo Simulation Method

The results of the above discussed financial evaluations are based on estimates of the expected values for all relevant input figures - ore reserves, mining costs, product prices, etc.

These estimates are uncertain and so is the derived expected profitability indicator, for example the DCF-ROI. To measure this uncertainty, risk analysis methods are developed and in use, especially when deciding on big investments based on a feasibility evaluation. Generally, the methods attempt not only to forecast variables from optimistic and/or pessimistic estimates but to determine the probability of occurrence for each value of a variable. Thus, the overall effect of probable variations in the estimated values of all project parameters on the DCF-ROI of the mining project can be determined. This effect is expressed as a probability profile which shows the likelihood of actual DCF valuesgreater or less than estimated.

A commonly used method for the performance of a risk analysis is by means of the Monte Carlo Simulation Method.

The first step in the performance of this method is to define probability distribution values for the various parameters. When performing a risk analysis individual random numbers are subsequently obtained from each distribution related to the various parameters using the Monte Carlo Method. Then the cash flows for the combination of these values obtained by random choice are calculated and repeated as often as desired by using different combinations. The statistical distribution of the results is presented in graphic form and serves as a basis for risk estimate. The distribution shows a mean value as well as an upper and lower value. These graphs are a measure for the probability at which the investment will result in a DCF-ROI value above or below the originally expected value.

Details of the procedure are given in Refs [3] and [6]. Problems of realistic applications of the method are associated with the estimation procedures that produces the required input parameters. Obviously the result of a risk analysis depends on the quality of such subjective estimates. The method usually assumes all parameter variations to be mutually independent of variations in other parameters, which assumption is not appropriate to what is experienced in practice.

To minimize these problems, the RSS-method (root sum of squares) has been developed and proposed by O'Hara [6] in to improve the performance of risk analysis. This method is based on"skew" probability distribution.

7.5. COMPUTERIZATION IN ECONOMIC AND FINANCIAL EVALUATIONS

The application of DCF-ROI analysis is connected with a great deal of computation work. Although the results can be obtained by "manual" calculations using trial and error methods, the use of computers is highly recommended and nearly indispensable when performing sensitivity and risk analysis. The use of personal computers in connection with suitable softwaree has facilitated the application of the method.

7.6. COST ESTIMATION AND CODING OF ACCOUNTS

Before any mine can be developed an estimate of capital and operating costs must be made so that it can be established that the operation should operate at a net profit. Capital and operating costs are normally established in the project feasibility study. The estimation is usually done using a code system of accounts. Such a system is important to facilitate computerization of cost estimation and later cost control during realisation and operation of the project. Based on an actual project the following discussion will give an overview with regard to capital and operating cost parameters and their coding.

7.6.1. Capital costs

The capital cost of a project is true total amount of money invested. It consists of two major components: the fixed capital and the working capital, that tied up in day-to-day expenses. The subdivision of a capital cost estimate is shown in the following example of an actual uranium project under development. In this estimate approximately 2,500 cost components were detailed in the chart of accounts. The chart is based on a nine digit alpha-numeric code. The first three digits of the code identify the Project Area.

The first digit classifies the project into major areas as follows:

1. Power and Communications
2. Mining
3. Metallurgical Plant
4. Support Services
5. Township
6. Bulk Transport and Handling Facilities
7. Support Facilities
8. Project Management and Engineering
9. Construction Facilities and Services
10. Project Overheads

The second digit further classifies each major area into minor areas. For example, the second digit allocation Project Area 3 (Metallurgical Plant) is as follows:

30 Metallurgical Plant
31. Ore Processing
32. Solution Clarification, Precipitation, and Refining
33. Barren Liquor and Reagents
34. Plant Site Development
35. Plant Services
36. Control Building
37. Pipe Rack

The third digit identifies the particular facility within the project area. For example, project area 310 (Metallurgical Plant-Ore Processing) is as follows:

300 Metallurgical Plant
310 Ore Processing
311 Ore Receiving and Crushing
312 Grinding
313 Leach Feed
314 Leaching
315 Counter Current Decantation (CCD)
316 Tailing Disposal

The following summary of the Project Capital Costs may serve as an example for the capital cost distribution (in percent):

Summary by Major Area		%
100	Power and Communication	5
200	Mining	5
300	Metallurgical Plant	20
400	Support Services	3
500	Township	9
600	Bulk Transport + Handling Facilities	6
700	Support Facilities	3
	Total Direct Work Costs	51
800	Project Management and Engineering	7
900	Construction Facilities and Services	6
1000	Project Overheads	2
	Total Direct & Indirect Costs	66
1080	General Contingencies	6
	Total Capital Cost Excluding Escalation	72
1090	General Escalation Allowance	28
	Total Capital Cost Including Allowance for Escalation	100

Some remarks should be added with regard to this summary:

- The cost item "Project Overhead" (1000) includes i.a. unallocated freight costs, insurance, permits and fees, and owner's project administration costs.
- Contingencies (1080) are assessed on the total direct and indirect costs. They are calculated by using a risk analysis method (Monte Carlo Analysis). A 25% probability of overrun (or 75% probability the actual cost will be less than the estimated cost plus contingency) was chosen. This probability of overrun results in an 8.5% contingency.
- The escalation allowance accounts for price and cost changes during the development programme. In this case 10 - 12% has been used. All cost estimates were timewise based on the point of estimation.

7.6.2. Operating costs

The subdivision of Operating Costs is illustrated in the following example:

The Operating cost estimate includes costs in seven majorcategories, related to the timeframe of the project development:

- Commissioning Costs
- Initial Inventory Costs
- Preproduction Costs
- Production Costs
- Replacement Capital Costs
- Incremental Capital Costs
- Recommissioning and Rehabilitation Costs

The concept for the structure of costing is the creation of cost centres for every major function for which cost information is required. The breakup of costs within a cost centre is obtained by the use of expense items. The combination of a cost centre and an expense item is the basis of all cost collection and coding.

A cost centre is identified by a four digit number, the first digit of which indicates the division of the operation in which the cost centre is located. These are:

1. Geology;
2. Mine Operations;
3. Metallurgical Plant;
4. Engineering Maintenance;
5. Management and Administration.

An expense item is identified by a three digit number. The first digit indicates the expense item to which the expense is allocated.

The expense items are:

1. Labour
2. Fuel and Lubricants
3. Reagents
4. Operating Supplies (Other Than Reagents)
5. Operating Expenses
6. General Expenses
7. Contract Expenses
8. Radiation Safety Expenses
9. Recoveries
10. Royalties
11. Owner's Costs in Relation to Marketing and Finance

The coding combines the cost centre and the expense item, as illustrated in the following example:

Cost Centre	Expense Item	Combined Cost Code
Ore Drilling (Mining) 2000	Operating Labour 160	2200.160
Plant Change Room 3100	Cleaning Supplies 640	3100.640

The following Table lists the relative percentages of the cumulative operating costs over the life time of a project with three years of preproduction costs and 25 years of production including decommissioning.

Cost Category	Percent of Cost
Commissioning	0.1
Initial Inventory	0.7
Pre-production	2.4
Production	84.7
Replacement Capital	3.6
Incremental Capital	5.0
Decommissioning & Rehabilitation	3.5
Total	100.0

Escalation and contingency would be based on the same principles as discussed in the capital cost schedule.

REFERENCES

[1] AKIN, H., GATZWEILER, R., Zur Praxis der Wirtschaftlichkeitsbetrachtung in den Frühen Phasen der Lagerstätten-Projektbewertung, Erzmetall 38 (1985) Nr. 9 419.

[2] GOCHT, W. , Wirtschaftsgeologie, Springer-Verlag, Berlin, Heidelberg, New York (1978).

[3] MACKENZIE, B.W., Evaluating the economics of mine development, Can. Min. J. (1970).

[4] McCREA, J.L., Notes on the economic evaluation of exploration projects, presented at Mineral Industry Economics Course, McGill University, Jan. 1970.

[5] United Nations, Manual for the preparation of industrial feasibility studies, United Nations, New York, 1978.

[6] O'HARA, T.A., Analysis of risk in mining projects, CIM Bull. 75 (1981) No. 843 84.

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8. PROJECT PLANNING

8.1. OBJECTIVES

The objectives of the Project Planning are laid down in the preparation of a Project Procedure Manual, the purpose of which is:

- To define the Scope of Work;
- To outline the procedures to be followed;
- To provide a ready reference on administration and procedural matters;
- To serve as a guide for the Owner and Engineer's personnel engaged in the work.

The manual is not a contractual document and i subject to change and revision at any time.

A typical Table of Contents for a Project Procedures Manual is shown in Table 1.

TABLE 1. PROJECT PROCEDURES MANUAL (TABLE OF CONTENTS)

SECTION

1. GENERAL

2. PROJECT SCOPE

3. RESPONSIBLE PERSONNEL

    3.1. Owner
    3.2. Engineering Company
    3.3. Consultants
    3.4. Project Organization Chart

4. MAILING ADDRESSES, TELEPHONE, INDEX

5. CORRESPONDENCE

6. FILING SYSTEM

TABLE 1. (cont.)

7. NUMBERING SYSTEMS

7.1. Area Numbers
7.2. Drawings and Bills of Material
7.3. Equipment numbering
7.4. Performance Specifications
7.5. Engineering Quotation Requests
7.6. Requisitions

8. MEETINGS

9. CODE OF ACCOUNTS

10. ENGINEERING PROCEDURES

10.1. General Issue of Drawings
10.2. Design Calculations
10.3. Change Notices
10.4. Project Information Memos
10.5. Engineering Work Orders
10.6. Information Requests
10.7. Vendor & Contractor's Drawings

11. PROCUREMENT, EXPEDITING AND INSPECTION

11.1. Scope
11.2. Commercial Documents
11.3. Engineering Quotation Requests
11.4. Inquiry
11.5. Quotations
11.6. Bid Analysis
11.7. Recommendation for Purchase
11.8. Requisitions
11.9. Purchase Orders
11.10. Expediting
11.11. Inspection
11.12. Customs Clearance
11.13. Material Receiving and Deficiency/Damage
11.14. Procurement Status Reports

12. PLANNING, SCHEDULING AND ENGINEERING CONTROL

12.1. Preliminary Objectives Schedule
12.2. Project Summary Schedule
12.3. Area Summary Schedule
12.4. Construction Manpower Requirements Schedule
12.5. Contract and Procurement Control
12.6. Detailed Work Schedule

TABLE 1. (cont.)

12.7. Schedule Monitoring
12.8. Manhour Estimates
12.9. Monthly Budget Report
12.10. Drawing Control
12.11. Drawing Schedules
12.12. Project Punchlist Report
12.13. Critical Item Report

13. ESTIMATING AND PROJECT COST CONTROL AND PROJECT ACCOUNTING

13.1. Project Budget Estimate
13.2. Project Change Orders
13.3. Project Cost Analysis Summary
13.4. Cash Flow Forecast
13.5. Project Accounting

14. REPORT TO CLIENT

14.1. Project Status Report

15. INVOICES TO CLIENT

15.1. Invoice
15.2. Approval

16. CONTRACTS ADMINISTRATION

16.1. Construction Contracts
16.2. Monthly Progress Estimates & Payments
16.3. Changes to Construction Contracts
16.4. Completion of Contracts
16.5. Holdbacks

APPENDICES

<u>Description</u>

Telephone Conversation Record
Transmittal
Inter-Office Transmittal

Filing Key

Drawing Area Index
Standard Dwg. Title
List of Work Classification

Equipment Ledger
Performance Specification
Engineering Quotation Requests
Requisition to Purchase

Conference Reports

List of Area Numbers

Specification Control Register
Design Calculation
Register of Design Calculations
Change Notice
Project Information Memo
Engineering Work Orders
Information Requests

Vendor Data Requirements
Bid Analysis
Order Status Report
Inspections/Expediting Report
Purchase Order
Instructions to Bidders
General Purchasing Conditions
Instructions to Vendors
Quotation Summary
Inquiry Covering Letter

Procurement Control
Contract Control
Estimate Summary
Monthly Budget Report
Drawing Control
Project Punchlist Report
Critical Item Report
Field Work Order
Contract Change Order
Progress Payment Certificate
Change Bulletin
Monthly Field Work Order Report
Contractor's Declaration of Substantial Completion
Substantial Completion Certificate
Contractor's Declaration of Completion
Completion Certificate

8.2. SCHEDULE

a) Project objectives schedule

Planning and Scheduling work is initiated at the beginning of a project by the preparation of a Project Objectives Schedule. This schedule indicates the starting dates, duration and milestone completion dates of the major project activities.

It is issued to the Engineering and Construction groups as early as possible to provide the initial basis for scheduling of the work and for manpower planning.

b) Master project schedule

The Master Project Schedule is developed as soon as possible in the project, utilizing critical path Planning and Scheduling techniques. It is a multi-sheet, fully detailed schedule prepared by areas and indicates the Engineering, Procurement and Construction program for the project, complete with milestones.

The Master Project Schedule is prepared in Timelogic format which sets forth all work activities in proper sequence together with durations and interactions with other project activities. The schedule takes into account all available information on equipment and material deliveries and all other factors which can affect the project schedule, with the objective of pinpointing critical items which will affect or govern the project completion date.

The Master Project Schedule is monitored and updated monthly.

8.3. PROJECT ORGANIZATION

General - There are three basic types of organization commonly used for engineering projects:

- Task force
- Departmental
- Matrix

a) Task force

In a task force organization, all individuals assigned to a project are formed into a group and usually placed in one location to work exclusively on one project. The members of the task force work together as one unit under the direction of the Project Manager. The supervisors of the various departments, who have assigned personnel to the task force, are responsible for standard and the quality of work and general administration of their personnel, but they are not responsible for day-to-day direction and supervision of individuals assigned to the task force.

The main advantage of a task force organization are easier communication and coordination and total commitment of people to the project. The disadvantages are: relocation of personnel, less departmental supervision of quality of work and less flexibility in accommodating varying work loads.

b) Departmental system

In a departmental organization of a project, the individuals working on the project are located in their own departments and re-directed by their department supervisors in accordance with objectives set by the Project Manager and project engineers. All formal communication is through the department supervisor.

The departmental type of project organization gives the departments more flexibility in allocation of work and makes it easier to deal with varying work loads. On the other hand, the communication and coordination is not as efficient as in the task force, and department supervisors who have to deal with many projects can become over burdened and the commitment to one project is diluted.

c) Matrix system

The project organization used most frequently by engineering companies is the matrix system. In the matrix system, like in the departmental system, the individuals working on a project stay with their respective departments. However, they are allocated specifically to the project and work under the direction of a leader assigned by their department. This leader provides the liaison between the department and the Project Engineer who coordinates the project.

Under the matrix system, the supervisors of the various departments are responsible for the quality of work and general administration of their personnel, but they do not get involved in the day-to-day dealings with Project Engineers or the liaison with other departments.

A typical organization chart is shown in Fig. 1.

8.4. PROJECT PARTICIPANTS AND RESPONSIBILITIES

The following is a listing of the key personnel involved in a project along with their responsibilities.

Project Manager - The Project Manager will be directly responsible for the successful fulfillment of all functions required for the project. The Project Manager is the principal contact for the Owner on matters pertaining to the Engineers overall performance. He is responsible for review and approval of project budgets and schedules, approval of major purchases and contracts and the preparation and issuing of monthly progress reports. As the main project activities begin to shift to construction, the Project Manager will place proportionately more of his emphasis on construction related activities.

Metallurgist - The Metallurgist is responsible to the Project Manager for the metallurgical design aspects of a project with particular emphasis on

- Assembling and analyzing available metallurgical design data and the recommendation and supervision of any additional test work deemed necessary;
- Establishment of process and preparation of process flowsheets, materials balance and energy requirements;

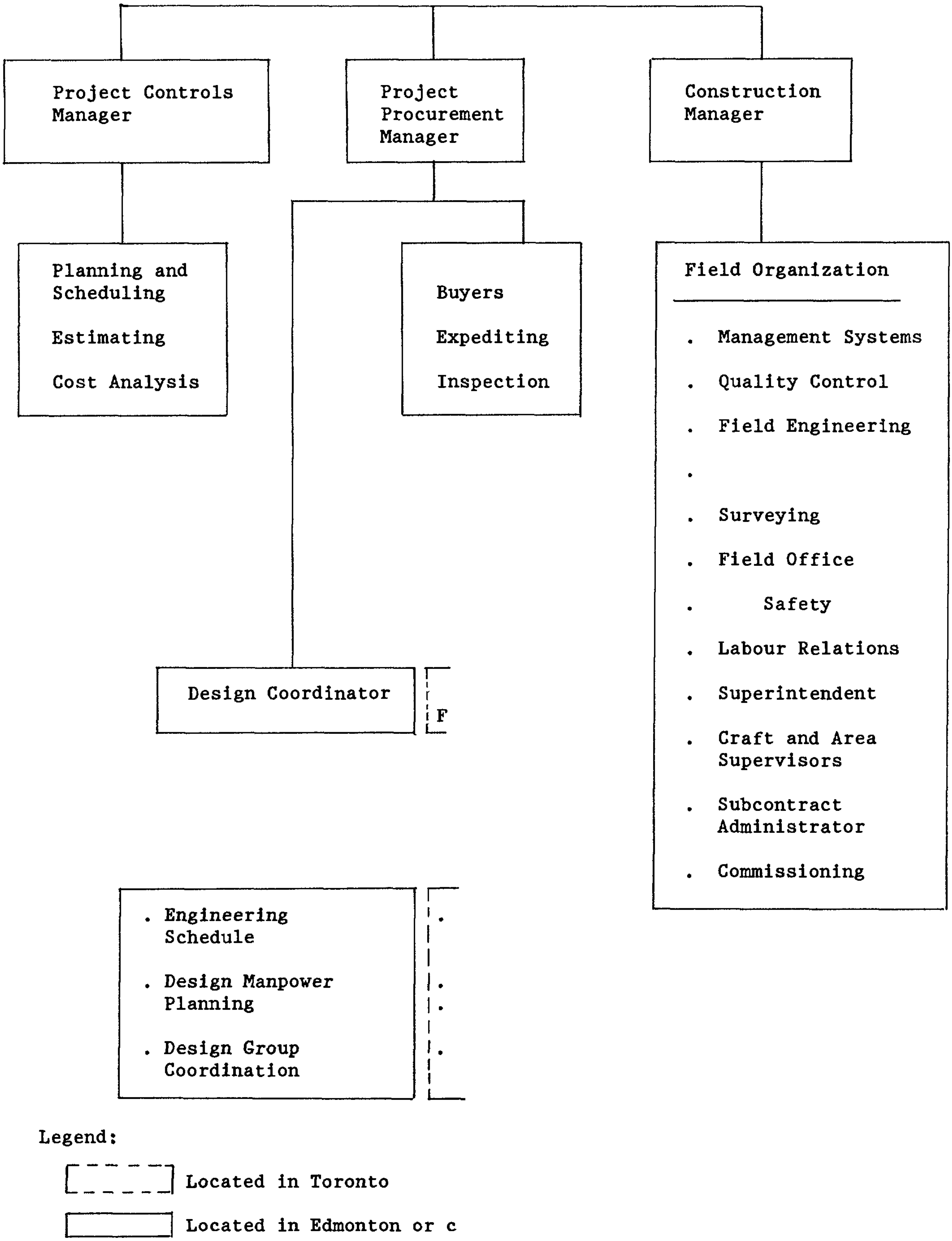


FIG. 1. Project organization.

- Cooperating with the Environmental personnel to review if the process design meets applicable regulations;

- Cooperating with the Project Manager to review if the requirements of the process design are met;

- Cooperating and maintaining liaison with the Owner's Metallurgist;

- Participating as required in check out and acceptance procedures and start-up operations.

Project Engineer - The supervision of the engineering activities on a project rests with the Project Engineer. He works with and relies on the Group and Section Leaders for the technical reliability of the work. He furnishes Construction with drawings, specifications, data and consulting service needed to complete the project. He is the chief liaison between departments for basic information and changes. The Project Engineer keeps the Project Manager fully informed concerning job progress, changes in scope, delays, and any other factors that could affect Owner relations, the job schedule or costs.

The Project Engineer must watch closely for factors that affect total job costs. These include engineering manhours, quantity and cost of materials and equipment, and the cost of their installation.

Manager, Project Controls - The Manager, Project Controls is responsible to the Project Manager for the project service aspects of the project with particular emphasis on:

- coordination of service functions including estimating, cost control, planning and scheduling and project accounting,
- timely issue of project control documents

Project Construction Manager - The Project Construction Manager is responsible to the Project Manager for the construction aspects of the project with particular emphasis on:

- Identifying the tasks and responsibilities of the necessary construction management and services;
- Implementing and coordinating the requirements for safety and security of the project;
- Verifying that contractors and suppliers finalize and adhere to construction schedules;
- Evaluating contractor's requests for payments and providing the necessary approvals and certification, providing field data and participating in evaluating contractor's claims for additional payments;
- Holding regular meeting with contractors to review status and progress of work and to generally coordinate the activities of the contractors;
- Arranging that contracts are satisfactorily completed and the close-out documentation and payment certification are carried out;
- Arranging that contractors provide information for the preparation of record drawings;
- Arranging for the pre-operational check-out and testing of the work to be carried out prior to start-up of any facility.

8.5 DESIGN CRITERIA

A document is prepared at the start of a project detailing the Design Philosophy, Process Description, Design Criteria and general design Parameters. The following lists the headings of the individual design criteria.

- Geographical & Climatic Data
- Painting of Equipment
- Painting of Structural Steel and Miscellaneous Steel
- Metallurgical Data
- Hoisting and Underground
- Architectural
- Fire Protection
- Building Services
- Structural
- Materials Handling
- Mechanical/Electrical Equipment Standards
- Process and Utility Piping
- Piping Material Specifications
- Instrumentation and Controls
- Electrical
- Underground Control & Monitoring Systems
- Dust and Emission Control
- Civil/Environmental

A portion of a typical metallurgical design criteria (crushing) is shown in Table 2.

TABLE 2. CRUSHING

CRUSHING

Parameter	Units
Headframe Storage (Minimum)	t
Coarse Ore Storage Bin	t
Fine Ore Storage	t
Underground Crusher Setting	c.s.mm
Coarse Ore Feeders	type
Ore Bulk Density	dry t/m^3
Ore Moisture	%
Conveyor Angles	rad
Crushing Rate	t/h
Required Rate	max. t/:7d
Crushing Schedule	h/7d
	shifts/7d
Finished Product Size	100% past mm
	80% past mm
Dust Collectors - crushing	type
- milling	

8.6. CODING SYSTEM

The code of accounts is the filing index for all project related costs. It is prepared at the beginning of each project so that costs are accumulated in an orderly and accurate manner. Account numbers shall have up to three components arranged as follows:

1.	xxxx	Project No.
2.	xxx	Area No.
3.	.xxx	Work Classification No.

Area numbers which refer to physical plant areas, are three digit immediately preceding the decimal point and range from 100. to 900. A typical breakdown preceding the decimal point is shown for Area 100 along with the Summary of Area Accounts on the following pages.

The work Classification No. divides the project into main categories, this is also shown in Table 3.

TABLE 3. STANDARD CODE OF ACCOUNTS

Area Numbers

SUMMARY OF AREA ACCOUNTS

100	General and Yard 110. 120. etc.	Refer to following page for typical breakdown preceding decimal point for area account 100.
200	Mining Facilities 210. 220. etc.	
300	Process Area 310. 320. etc.	For area accounts 300 through 600., subdivide as necessary preceding decimal point for related facilities generally according to physical location and process flow
400	Process Area 410. 420. etc.	
500	Process Area 510. 520. etc.	

600 Process Area
610.
620.
etc.

Area Numbers

700 Distributable Costs
710.
720.
etc.

800 Owner's Costs

900 Construction Indirects

1000 Engineering & Construction Management

Typical Breakdown Preceding Decimal Point for Area Account 100.

100 GENERAL AND YARD

110. Site Development

111. General Sitework Incl. Surface Drainage, Slope Protection, Finish Grading, etc.
112. Railroads
113. Roads
114. Parking
115. Fencing

120. Misc. Yard Utility Systems (Yard sanitary sewers and disposal facilities, yard fire system, yard domestic water distribution, yard air distr., etc.)
121.
122.
etc.

130. Yard Water Supply System (Pumping stations, wells, storage tanks and pipelines to within 5 feet of building walls and other raw water supply facilities).
131.
132.
etc.

140. Yard Electrical and Distribution System (Incoming power, substations, power distribution to within 5 feet of building walls, yard lighting, plant communications)
141.
142.
etc.

150. FUEL STORAGE AND DISTRIBUTION

160.

170.

Etc.

Typical Breakdown Preceding Decimal Point for Area Account 700.

700. DISTRIBUTABLE COSTS

710. Plant Start-up Assistance
720. Bulk Stock Holding Account
730. Inventory and Capital Spares
740.
etc.

Cost Code (Decimal Account Breakdown)

(A) .X Work Classification No.

(B) XX Work Index No.

(A) The Work Classification No. divides the project into the following main categories:

.100 Sitework and Improvements
.200 Building Structures
.300 Building Services
.400 Mechanical Equipment - Process
.500 Process Piping
.600 Electrical Power
.700 Instrumentation

TABLE 3. (cont.)

.800	Mining
.900	Construction Indirects and Engineering

NOTE:

1) The degree of subdivision of decimal accounts is generally dependent on the relative size or cost of a facility.

2) Decimal accounts .1 to .7 are used with area accounts 100. to 700., .8 is normally for area 200. only, .9 is for area 900.

3) In certain cases, areas will be unsuitable for breakdown into decimal accounts and will have 000 after the decimal point.

(B) The Work Classification No. is subdivided according to the Work Index No. as follows:

.110	<u>Sitework</u>
.110	Site preparation including excavation and backfilling if required.
.120	Excavation for building foundations.
.130	Backfill for building foundations.
.140	Dewatering and drainage.
.150	Utilities
.160	Piling if required.

8.7. COST CONTROL SYSTEM

<u>Project budget</u>- The Capital cost estimate prepared by the Engineer for the project and submitted to the Owner for capital appropriation purposes form the basis for all cost control activities.

This estimate is recast as soon as possible after project release to align all line items with either a construction contract or a procurement package. In this way the total project funds are tied to a complete execution plan.

<u>Revised budget</u>- The total funds contained within the project budget can only be changed on written approval of the Owner.

Changes can occur due to various circumstances such as:

- Concept changes - covered stockpile replaces open pile,
- Conditions change - structural piling required instead of spread footings,
- Schedule change - hours worked in field increased from 40 to 50.

A Project Change Order is prepared and issued to the Owner for approval of any change to project budget. A Project Change Order Estimate is prepared to support the Project Change Order.

<u>Commitments and expenditure</u> - As commitments are made via construction contract and purchase order awards the amounts will be entered to the database by the Cost Controller.

Expenditures including accruals are entered into the data base by the project accountant against a formalized contract or purchase order.

Expenditures as issued at the end of each month will represent the best estimate of work done to date. This will include invoices received and paid, invoices received but not yet paid and estimates of work done, but not yet invoiced.

Commitment and Expenditure information is issued monthly.

<u>Analysis and forecast to complete projections</u> - Proposed commitments are compared to the budget on an ongoing basis. Funds are retained within the forecast to complete portion should a commitment represent only part of the scope covered by an estimated amount.

Any difference between total forecast and total budget amounts appears as a variance.

<u>Monthly cost report</u> - A summary report is produced for inclusion in the monthly progress report to the Owner. Budgets, commitments, expenditures and forecasts at completion are present in summary form so that variances are identified. A typical summary report is shown in Table 4.

TABLE 4. PROJECT COST ANALYSIS REPORT - SUMMARY BY AREA

Area	Description	Budget	Commitments To Date	Expenditures To Date	Forecast At Completion	Variance
111	General Site	478000	0	0	478000	0
121	Potable Water	15000	0	0	15000	0
122	Fire Water	100000	0	0	100000	0
123	Fresh Water Distribution	85920	0	0	85920	0
131	Main Substation	1075000	0	0	1075000	0
151	Sewage Disposal	32496	0	0	32496	0
241	Concentrator Building & Services	10929794	0	0	10929794	0
246	Flotation	6164431	0	0	6164431	0
247	Regrind	5660143	0	0	5660143	0
250	Thickening	894727	0	0	894727	0
252	Leaching	3708479	0	0	3708479	0
254	Solution Purification	1121298	0	0	1121298	0

8.8. STANDARDS

The standard codes and specifications listed below are typical of those used in North America. Various countries will usually use the equivalent standards, e.g. DIN or British etc.

Civil

- National Building Code of Canada (N.B.C.), 1980, latest edition
- Canadian Institute of Steel Construction (C.I.S.C.)
- Code of Practice for Structural Steel for Buildings
- Canadian Sheet Steel Building Institute (CSSBI) Standards and Bulletins
- Canadian Standards Association (C.S.A.)

CAN3-S16.1-M78	Steel Structures for Buildings
A23.3, 1973	Codes for the Design of Plain or Reinforced Concrete Structures
S136, 1974	Cold Formed Steel Structural Members
086, 1976	Code for Recommended Practice for Engineering Design in Timber
W47.1, 1973	Certification of Companies for Fusion Welding of Steel Structures
W48.1, 1976	Mild Steel Covered Arc - Welding Electrodes
W55.2, 1957	Resistance Welding Practice
W59, 1977	General Specification for Welding of Steel Structures
A165.1, 1972	Concrete Masonry Units
S304, 1977	Masonry Design and Construction for Buildings

- Reinforcing Steel Institute of Ontario, Reinforcing Steel - A Manual of Standard Practice, 1983.

- American Petroleum Institute (API)

- Recommend Rules for Design and Construction of Large Welded Low-Pressure Storage Tanks (API 620-1973).

- Welded Steel Tanks for Oil Storage (API 650-1973).

- American Water Works Association (AWWA)

- Steel Pipe Manual (AWWA M11-64)

- Standard for Fabricated Electrically Welded Steel Water Pipe (AWWA C-200-75)

- Standard for Prestressed Concrete Pipe, Steel Cylinder Type for Water and Other Liquids (AWWA C306-72)

- Standard for Reinforced Concrete Water Pipe-Noncylinder Type, not prestressed (AWWA C302-74)

- Reinforced Concrete Culvert, Storm Drain and Sewer Pipe (ASTM C76-75).

- Reinforced Concrete Low Head Pressure Pipe (ASTM C361-75).

- Applicable Standards for the various construction materials specified in Civil/Structural Specifications

- ASTM, ACI, AISC and AWWA Codes and Standards used as Supplements where required.

Piping/Mechanical

ACGIH	-	American Conference of Governmental Industrial Hygienists
AFBMA	-	Antifriction Bearing Manufacturers Association
AGMA	-	American Gear Manufacturer's Association
AISI	-	American Iron and Steel Institute
AMCA	-	Air Movement and Control Association
ANSI	-	American National Standards Association
API	-	American Petroleum Institute
ARI	-	Air Conditioning and Refrigeration Institute
ASHRAE	-	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	-	American Society of Mechanical Engineers
ASTM	-	American Society for Testing Materials
AWS	-	American Welding Society
AWWA	-	American Water Works Association
CAGI	-	Compressed Air and Gas Institute
CEMA	-	Conveyor Equipment Manufacturers Association
CISC	-	Canadian Institute of Steel Construction
CMA	-	Canadian Manufacturers Association
CMMA	-	Crane Manufacturers Association of America
CSA	-	Canadian Standards Association
CUA	-	Canadian Underwriters Association
CWB	-	Canadian Welding Bureau
FM	-	Factory Mutual
HI	-	Hydraulics Institute
HMI	-	Hoist Manufacturers Institute
IGCI	-	Industrial Gas Cleaning Institute
MSS	-	Manufacturers Standardization Society
MPTA	-	Mechanical Power Transmission Association
NFPA	-	National Fire Protection Association
NIMA	-	National Insulation Manufacturers Association
NRCC	-	National Research Council of Canada
	-	Plumbing Code
PFI	-	Pipe Fabrication Institute
RMA	-	Rubber Manufacturers Association
SMACNA	-	Sheet Metal and Air Conditioning Contractors National Association
TIMA	-	Thermal Insulation Manufacturers Association
UL	-	Underwriters Laboratory

Electrical

- Canadian Electrical Code Handbook of Rules Governing The Operation of Mines (Canada)
- Canadian Standards Association (C.S.A.)
- Electrical Equipment Manufacturers Association of Canada (EEMAC)

Instrumentation

- Instrument Society of America (I.S.A.)

9. ENGINEERING

9.1. GENERAL

Engineering is the detailed part of the development which forms the basis for procurement, fabrication, construction, commissioning, operation and control of a mining project. Detailed engineering commences immediately after the project is committed.

Most mining projects are "fast-tracked" with various phases of the design, engineering, procurement, fabrication and construction occurring simultaneously. The engineering schedule must meet the milestone schedule for the project in order to allow the construction to proceed as planned.

Engineering includes the design, specification preparation, detailed drawing preparation, bills of materials, vendor and contractor drawing reviews. Detailed engineering is performed by engineering companies equipment suppliers, material fabricators, system suppliers and contractors. All of these must be reviewed, coordinated, and checked to ensure that construction can proceed in the field without delays and field retrofits.

The projection of engineering drawings is pyramidal in nature. Decisions are required as they are encountered. Delays in these decisions may influence many drawings at a later date. As an example, delays in purchasing equipment means that certified drawings will be late and all structural, electrical piping, instrumentation and layout drawings, in the area of the equipment, may require revisions. This inevitably will lead to construction delays and retrofits.

The following sections highlight some of the engineering considerations for the major areas of a mining project.

9.2. SITE

Site location drawings are an early requirement. These drawings should include all permanent buildings, all access roads, tailings ponds, topographic data, and drainage patterns. They will form the basis of the drawings for contracting cleaning and grubbing.

The second site contract will probably be for site preparation and must include all cut and fill quantities, grading elevations, drainage patterns, culverts and roads. It is imperative to ensure that all permanent facilities are clearly defined to avoid temporary facilities being wrongly located.

Site and local hydrology must be calculated. There is generally sufficient data available to extrapolate to the project site. All drawings and ditching requirements are then designed. A common design criteria is back to back 100 year precipitation and flows or a single 200 year occurrence.

Whenever possible, the permanent sewage facilities should be installed initially as they can be used throughout the construction period.

It may not be possible to do all of the final site preparation immediately. An intermediate stage may be required where all of the construction facilities are overlaid. These must avoid all permanent structures, but must include all buildings, laydown areas, access roads, yards and in many cases a construction camp.

9.3. INFRASTRUCTURE

The project infrastructure should be designed and constructed at the earliest opportunity. All of these items will reduce time and cost during the development period.

Good transportation access should be one of the first items addressed. Transportation may be road, air, or water. Permanent facilities should be designed and constructed in accordance with country standards. Maintenance can then be performed by the relative government agency.

A potable water supply is needed early and should be the permanent supply. Fire protection requirements are also very essential during the construction period.

Permanent energy installations are essential for cost effective construction and development operations. This is true whether the energy source is hydro power, oils, or natural gas. In remote areas, bulk fuel deliveries are seasonal and the bulk storage should be erected as soon as possible.

The permanent maintenance and warehouse facilities will enhance the construction operation. It is very costly to mobilize and demobilize all of these as temporary facilities. This becomes very important to service mine development activities. Engineering requirements for some of these items and buildings may be a specification for a prefabricated building bid package. In other cases the requirements preclude such an approach and detailed engineering, procurement and construction services are required in order to construct such facilities.

9.4. MINE DESIGN

Underground mine design includes the layout and planning of all drifts, raises, stopes, ore and waste passes, transportation and storage systems, loading, haulage and skip loading. It also includes the specification and selection of all equipment.

Mine ventilation and exhaust systems in a uranium mine require careful planning and design. Regulations are available governing radiation and diesel exhaust requirements. Heating or cooling of ventilation air may also be required.

The rock mechanics studies should be continued during mine development. Not only is this a safety measure, but it may also allow more economical stope sizes and development openings.

Part of the transportation scheme is the design of the headframe with its adjacent bit house and shafthouse. The transportation scheme may also affect the mine compressed air supply requirements.

Hoist and rope diameters, safety devices, rope connection and failure and catchment devices are all defined by regulatory agencies. These must be strictly maintained and adhered to in both the engineering and operating phases.

9.5. PROCESS PLANT

Process layouts should reflect ease of operation with unit operations laid out in an orderly manner. Buildings should have suitable cranes, hoists and accesses for ease of operations and maintenance.

Process buildings and structures must be of suitable materials to give a long, minimum maintenance life. Concrete surfaces should have protective coatings to minimize acid attack.

Structural steel and floors require special coatings in an acid environment. This is particularly important on structural steel under floors and equipment where inspection of facilities is difficult. Siding should have a prepainted interior coating as a minimum requirement. Uranium mill building ventilation requires a higher air change capacity than most other mills.

The design, specification and selection of the mechanical equipment will be the single largest factor in successful start-up and operation. Of these, poor material handling design for wet and sticky solids is the single most difficult problem to overcome. Experience is essential to the successful design and operation of chutes, belt conveyors, bins, hoppers, screw conveyors, bucket elevators and launders. Belt conveyor design should be limited to speeds of approximately 100 m/min with a design loading of approximately 70% of the volumetric capacity.

Acidic slurries and solutions enhance the need for durable linings. Not only must they be abrasion resistant but they also must resist acid attack.

The evaluation and selection of mechanical equipment such as crushers, mills, pumps, agitators, etc. should be based primarily on proven performance in operation. The evaluations should also consider cost variations in supports, services, installation requirements, and maintenance costs. The lowest bid price is not necessarily the priority for equipment selection.

There is extensive operating and maintenance experience available worldwide on all equipment which may be incorporated into a uranium process plant. Request for operating experience along with bid requests as well as any additional data required should be sought before making commitments.

Electrical engineering and design should use voltages and equipment which are the most common in the mine and mill area. This holds true even if the project generates its own power. Electrical design requirements are generally well specified in building codes. Electrical motors may have special coatings and/or seals for corrosive environments.

Electrical cable runs are either pulled in conduit or run with corrosion resistant armoured cable. This choice should be made early in the project.

Most projects have a standby power supply to ensure continuity of building heat, some agitators and pumps, and possible slow speed man hoisting, and mine dewaterimg pumps.

Today a central control room with all push button stations and a central process start-up capability is common. In any event local start-stop buttons are usually required by law for maintenance and safety purposes. The degree of central control is an early decision and may not be considered in remote areas where service and maintenance is not readily available.

Instrumentation and control has undergone dramatic changes with the increasing application of computers. There are some disadvantages as the capabilities of small computers have led to dramatic over installation of controls, sensors and monitors without a corresponding increase in technical capability for maintenance and operational programming.

Before finalizing an instrumentation and control philosophy, the type of systems used in the area and their state of operability should be considered. Sensors and in-line instruments should be kept to a minimum of essential devices at startup. As process, calibration and maintenance knowledge is gained, additional sensors, controls and control function can be readily added. The initial system should be capable of such additions.

9.6. ANCILLARIES

Most mills will require process heat, and nearly all must install product drying. Energy balances should evaluate all potential opportunities for fuel conservation and waste heat recovery. Design calculations must, however, consider that initial operations will not achieve maximum heat recoveries or minimum energy consumption because it takes operating experience to minimize energy requirements.

Power consumption can be reduced by using high efficiency motors, variable speed drives, capacitors and power factor-correction. Economic evaluations should consider each of these options.

Acid consumptions are significant in uranium mills. Sulphuric acid is normally supplied as a liquid of 93 to 98% content. It may also be produced on site by burning sulphur or pyrite; this approach also provides the potential for appreciable waste heat recovery. Whatever acid supply is selected, it requires careful design as an integral part of the process.

Similarly lime is a high consumption reagent. It is usually supplied as quicklime (CaO) or hydrated lime ($Ca(OH)_2$) and sometimes can be partially replaced with ground limestone. Bulk storage of large quantities of lime in remote and seasonal delivery areas is difficult and costly. Installing a small lime kiln may offer economic advantages. Since it forms an integral part of the operations, the kiln design must conform to high operating standards.

Various other reagents used in the process should be purchased in bulk whenever practical. The design should minimize labour requirements, and most reagents should be added via remote controlled metering devices.

9.7. TAILINGS

Uranium process tailings require better deposition and control practices than most other mining projects. Regulatory approval will probably require evaluation of several alternatives. Both site selection and impoundment design are critical. Guidelines must be followed for dam design, impermeability of the area, treatment facilities and discharge quality of water. If the area is net evaporative, required tailings pond designs may emphasize measures to reduce or minimize dusting.

The area must be cleared and grubbed and the dam area must be sealed to bedrock. Various sealing methods have been used such as grout curtains, bentonite trenches, excavation to bedrock with grouting of porous rock, synthetic membrane linings, bentonite and gravel linings and natural clay. Whatever the method it must be engineered to meet the permit requirements. Lined dams will generally be raised via downstream construction methods, and downstream monitoring wells will normally be mandatory. Excess water will require barium precipitation of radium. Water quality specifications may also require removal of arsenic, heavy metals and other impurities which exceed guidelines. These treatment processes must be engineered to the same standards as the uranium extraction process.

Tailings deposits containing over 1% total sulphides may become acidic as the results of bacterial or chemical oxidation. This reactivity should be thoroughly considered in the design of impounding and treatment facilities.

9.8. MANPOWER

Properly designed facilities help to attract and retain quality personnel in competition with other companies. Minimal design requirements for personnel are set out in labour codes or other statutes. The facilities provided may be different for various work areas at a minesite. Underground workers will require a hook and basket arrangement for work clothes and a clean locker with a walkthrough shower area separating them. The change area should be designed for ease of cleanliness and maintenance.

Mill and surface maintenance workers also generally have clean locker - dirty locker areas with showers separating them. The engineering design must incorporate provisions for radiation monitoring of employees as they leave the change rooms. Lockers for storage of personal items may be provided for other employees.

In some cases, the company will supply coveralls and launder them on a daily or frequent basis. This minimizes radiation effects from solids contamination on the clothes.

Lunch rooms are usually provided for employees on day shift where a lunch break is part of the schedule. Regulations may also require that shift workers be provided with lunch areas that are detached from their work station.

A fully equipped first aid room, staffed by qualified personnel, is required at all mine sites. Provisions for evacuation of injured personnel must also be defined. Frequently the emergency station is equipped with an ambulance and a fire truck.

All underground mines train mine rescue teams. They are mobilized whenever an accident occurs in the mine area.

9.9. CONTROLS AND REPORTING

Engineering involves more than the preparation of detailed drawings. It is the link between project commitment and construction and must coordinate with all others to ensure that the project is completed "on time" and "on budget". Some of the various controls and reporting techniques are illustrated as follows:

Scheduling: Engineering must be scheduled carefully. It is controlled at the onset by the criteria, scope, equipment purchase and decision making and it must on the other hand meet the construction schedule demands. Its controls and product are, therefore, usually specified by general contract requirements than by local decisions at the site.

Designs: All designs must be recorded and kept in a project ledger. They are reviewed for compliance to the codes and practices and also to the project design criteria.

Specifications: All technical specification for the bidding and purchasing of process equipment and supplies are early requirements of engineering. They form the basis of bids and purchases and must be expedited as designers and drawings must wait for purchasing and certified equipment drawings. The preparation, review, bid, approval and commitment status of all specifications are recorded.

Equipment ledger: This is set up at the start of the project from the detailed capital cost ledger of the feasibility study. It is kept up-to-date with respect to purchases, sizes, quantities, supplies, motor data' drawing status and delivery.

Bills of material: These are prepared from the drawings for purchase of fabricated items and for bulk purchase of pipe, cable, valves, fittings, and other - such general supply items.

Vendor & contractor drawings: Engineering must review all drawings received from equipment suppliers and contractors for compliance with the specifications and the codes and criteria for the site. These drawings may have to be altered to suit when non-conformance with the project requirements are apparent. The supplier will make the appropriate changes and issue certified drawings for design and engineering.

The data on these certified drawings form the final basis for design of supports, access, power, piping and other detailed designs for the project.

Engineering prepares all technical specifications incorporated into field contract documents.

Drawings: The preparation and issuing of drawings is considered the backbone of engineering production on the project. Without drawings, no construction can take place. The actual task of doing a drawing is only 15-20% of the overall time spent in design and engineering. Table 1 lists the drawings by discipline and other technical requirements of a typical 1500 tpd underground mine in a cold climate. This does not include data from vendors or contractors. An extended version of this Table is the drawing register. The drawing register is the result of an engineering man-hour estimate produced using the project scope and design criteria as a base. It serves a number of functions:

a) It categorizes the project drawings by engineering disciplines.

b) It categories the drawings into physical areas for easier engineering overview.

c) It categorizes the drawings to suit construction package (Contract) requirements.

d) It identifies individual drawing releases as to purpose, recipient, format and date.

Table 2 shows a typical page from monthly summary report that gives the status of structural drawings in the primary crushing area. The drawing progress report monitors and reports the progress of the drawing production for a predetermined physical area by listing each drawing by its number and description, and assessment of its completion status and remaining man-hours.

TABLE 1

AREA	Layout	Architectural	H.V.A.C. Handling	Structural	Mechanical	Piping	Instrumentation	Electrical	Civil
Headframe & Hoisting	3	5	3	19	6	2	1	5	1
General Standards	6	–	–	6	16	12	–	–	1
Site Development	–	–	–	–	–	–	–	1	3
Site Services	–	–	–	2	–	–	–	1	10
Site Electrical	–	–	–	3	–	–	–	15	1
Conveying & Ore Storage	1	2	3	14	14	–	–	1	–
Concentrator	7	5	15	37	37	42	11	10	–
Office, Warehouse & Changerooms	–	4	7	3	–	–	–	3	–
Shops	–	4	5	3	–	–	–	1	–
Laboratory	–	4	6	2	–	–	–	1	–
Tailings Disposal and Reclaim	–	–	–	2	–	–	–	1	8
Mine Ventilation	1	1	3	4	–	–	–	1	1
Mine Shaft & Services	–	–	–	4	–	5	1	6	–
Crushing & Materials Handling	2	–	–	6	12	2	6	4	–
U/G Development	12								
	32	25	42	105	85	63	22	50	24
									448
Contract Documents		25							
Equipment Specifications		190							

TABLE 2

REPORT NAME:

****
** DRAWING PROGRESS REPORT **
** DETAIL BY DEPARTMENT **
****

DIST'N :

PAGE NO. :

RUN DATE :
DATA DATE:
RUN TIME :

	FORECAST REMAINING MANHOURS	DRAWING STATUS: RELATIVE NO COMP	DRAWING STATUS: TOTAL REQUIRED	DRAWING STATUS: PERCENT COMPLETE
STRUCTURAL — AREA 232 PRIMARY CRUSHING — TOTAL	53.0	3.60	4.00	90.00
FUNCTION 01 - DRAFTING TOTAL	16.0			

DRAWING NUMBER	REV	DRAWING TYPE	DRAWING DESCRIPTION	DWG % COMP	REMAINING MANHOURS	REMARKS
232-14-001-0	00		PRIMARY CRUSHING ROOF AND FLOOR PLANS,ANCHOR BOLT PLAN	90	4.0	
232-14-002-0	00		PRIMARY CRUSHING SECTIONS, ELEVATIONS AND STAIR DETAILS	90	4.0	
232-14-003-0	00		PRIMARY CRUSHING HOPPER PLAN; SECIONS AND DETAILS - SHEET #1 OF 2	90	4.0	
232-14-004-0	00		PRIMARY CRUSHING HOPPER PLAN; SECTIONS AND DETAILS - SHEET #2 OF 2	90	4.0	

	FORECAST REMAINING MANHOURS
FUNCTION 02 - DESIGN TOTAL	37.0
FUNCTION 03 - SPECS V/DATA TOTAL	0.0
FUNCTION 04 - MEETINGS TRIPS TOTAL	0.0
FUNCTION 05 - SUPERVISION TOTAL	0.0

In addition, other functions associated with the production of drawings, such as design, vendor data review, supervision, etc. are identified. Without reporting controls such as this, it would be extremely difficult to meet construction schedule. Table 3 illustrates a monthly summary man-hour report on a given project for the drafting office. It identifies drafting office budget and adjustments by engineering disciplines, man-hour expenditures and forecasts. Included is a summary of the total number of drawings required and the relative number completed. Similar summaries are prepared for all other engineering and management control functions.

TABLE 3

REPORT NAME: MONTHLY BUDGET REPORT — SUMMARY — BY DEPARTMENT

DIST'N:

PAGE NO. :
RUN DATE :
DATA DATE:
RUN TIME :

DEPT NO	DESCRIPTION	MANHOURS: BUDGET ORIGINAL	BUDGET ADJUST	BUDGET LATEST	ACTUAL CURR	ACTUAL TODATE	REMAINING BY BUDGET	REMAINING BY FORECST	FORECAST TOTAL	(+)UNDER (-)OVER BUDGET	PERCENT COMPLETE BY BUDG	PERCENT COMPLETE BY WORK	DRAWINGS: REL NUMB COMP	NUMB REQ'D	PER-CENT COMP
10	GENERAL LAYOUT	277.0	0.0	277.0	83.0	576.0	-299.0	46.0	622.0	-345.0	208	93	10	11	95
11	ARCHITECTURAL	74.0	0.0	74.0	54.5	107.5	-33.5	40.0	147.5	-73.5	145	73	2	2	75
12	BUILDING SERVICES	210.0	0.0	210.0	131.0	154.0	56.0	59.0	213.0	-3.0	73	72	1	2	55
14	STRUCTURAL	2300.0	0.0	2300.0	500.0	2325.5	-25.5	405.0	2730.5	-430.5	101	85	19	21	89
16	MECHANICAL	2665.0	0.0	2665.0	532.0	2214.5	450.5	780.0	2994.5	-329.5	83	74	23	28	82
17	PIPING	310.0	0.0	310.0	87.0	229.0	81.0	105.0	334.0	-24.0	74	69	4	5	79
18	INSTRUMENTATION	600.0	0.0	600.0	132.0	465.0	135.0	369.0	834.0	-234.0	78	56	8	14	55
19	ELECTRICAL	2000.0	0.0	2000.0	368.0	1320.5	679.5	883.0	2203.5	-203.5	66	60	18	29	62
30	CIVIL ENGINEERING	490.0	0.0	490.0	6.0	159.5	330.5	120.0	279.5	210.5	33	57	1	1	100
37	IGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0
44	ENG'G MANAGEMENT	250.0	0.0	250.0	41.5	116.5	133.5	133.5	250.0	0.0	47	47	0	0	0
	DRAWING OFFICE	9176.0	0.0	9176.0	1935.0	7668.0	1508.0	2940.5	10608.5	-1132.5	84	72	86	113	76

10. PROCUREMENT AND CONSTRUCTION

10.1. GENERAL

The implementation of procurement and construction depends mainly on the type of contract used for the whole project. The most frequent types of contracts are: Lump sum, Unit Price, Combined Lump Sum and Unit Price, Cost Plus Fixed Fee, Turnkey, Bonus/Penalty, etc. Each one has advantages and drawbacks and they must be carefully considered when a project is started, according to the characteristics of the project.

Planning, scheduling and cost control are important aspects of procurement and construction but will not be considered here since they are discussed in Chapter 8.

10.2. PROCUREMENT

10.2.1. Criteria

When commencing the procurement function the following must be considered and ascertained before tendering documents are prepared.

a) A survey of the availability of the necessary types of equipment and materials must be carried out to ascertain which items can be purchased locally and which will be on a world wide purchasing basis. Project Financing may dictate purchasing sources.

b) The Codes and Standards to be applied to the manufacture of equipment and materials must be decided with a view to the ease of maintenance, intended operating life and allowances for future expansion. The Codes and Standards selected should also conform to local or national standards of the country concerned.

c) The Quality Assurance procedures which should apply are those planned and systematic actions necessary to provide adequate confidence that an item or component will perform satisfactorily in service.

It is important that the Inquiry makes a positive statement of requirements in respect to:

Manufacturers Quality Plan
Customer inspection and test
Statutory and Third Party Inspection

The Purchase Order to be placed must contain a fully agreed technical specification with the stated Quality Assurance requirements.

d) Performance norms
The performance required from items of equipment must be detailed in the performance specification and should be such that the supply of equipment is not limited to one supplier/manufacturer but allows competitive bidding to ensure competitive pricing from reputable suppliers/manufacturers who have experience in the types of equipment being tendered. Bids on major items should contain a user's list for reference if it is deemed necessary.

e) The appointment (by competitive bidding) of a "common" reputable packaging company located in the country where the majority of equipment items are being purchased should be considered.

The "common packers" will work in close liaison with the Freight forwarder from a scheduling viewpoint.

f) Freight forwarding

As with packaging, the appointment of a "common" freight forwarder by contract, located in the country where the majority of goods are originating and selected by competitive bidding, is most desirable.

This procedure avoids each manufacturer/supplier in the originating country(ies) arranging his own shipment and can effect substantial savings by consolidated items for shipping.

The Owner must be prepared to set up an imprest bank account (or a similar arrangement) with drawing rights held by the freight-forwarder in order to pre-pay the freight carriers, and for ocean freight these amounts are usually substantial.

If possible, the Owner should select an established freight forwarder with experienced connections in the Owner's country, to ensure the smoothest transfer possible of the goods and the necessary documentation.

g) Transportation

The Owner must be prepared to assist in the actual importation and be prepared to off-load and put into safe storage the goods as they arrive on jobsite.

The Owner (or his Agent) must advise the manufacturers/suppliers and the Freight forwarder of the name, address, etc., of his Customs Broker, in order for early contacts to be established.

Finally, if "manufacturer's agents" are required by the laws of the Owner's country, he must advise the shippers of the procedure they must follow to appoint such an "agent" if they do not already have one.

h) Carriage insurance

The Owner (or his Agent) should ensure that insurance to the full value of the goods is in existence for goods "in-transit" to his jobsite. The risks to be covered generally include loss or damage from various causes with exceptions only for natural causes, riots, war and insurrection.

One widely-used method is to include a clause in the Construction All-risks policy that is normally placed with a reputable insurance company by Owners for their own protection. If the Freight forwarder is covering this insurance with the ocean carriers the Owner (or his Agent) should be made aware of such coverage, in order to check for possible duplication of coverage. It should be decided which method to use before commitments are made.

In some areas of the world, ocean carriers are imposing a war-risk insurance charge in addition to bunker charges (to cover the additional fuel costs) and possible incentive charges (to take part loads to a little-used port). These charges, together with harbour dues, off-loading, stevedoring, and storing (demurrage) charges make it imperative that the Owner has close co-operation with the Freight forwarder to acquaint himself with the potential costs that are involved.

10.2.2. Tender and contract documents

The following lists what has to be included in the Tender and Contract Documents.

a) Form of agreement

This document describes the terms of the Contract between the Owner and Contractor, identifies them both and the Engineer, and also identifies all the documents which together form the Contract. It defines the work to be performed, compensation for it and the time required for completion.

b) Instructions to tenders

This document will be prepared for the entire project and contains information and conditions for tendering and describes conditions affecting the award of contract.

Important points which must be included in the Instructions to Tenderers are:

- Project identification;
- Information to enable contractor to receive and return all contract documents;
- Instructions to thoroughly examine the contract documents and the jobsite;
- Procedure for withdrawal of tenders;
- Procedure for clarification of errors or ambiguities in the contract documents;
- Reasons for which tenders may be rejected or disqualified without evaluation;
- Tender deposit requirements;
- Bonding requirements.

c) General conditions

The "General Conditions" is a standardized (often preprinted) portion of the contract and groups together all or most of the contractual - legal material pertinent to the contract. Most engineering companies have their own general conditions tailored to suit their Contract Administration procedures.

The best known General Conditions (International) are those provided by FIDIC.

d) Supplementary general conditions

The supplementary general conditions will contain contractual-legal material which takes precedence over the information contained in the general conditions. The supplementary general conditions are therefore used to amend articles in the general conditions which the Owner or Engineer finds undesirable, or to add material not covered in the general conditions. Items which commonly appear in the supplementary general conditions are insurance, labour agreements, pay scales, safety and security regulations. Only one set of supplementary general conditions shall be prepared for a project to include Owner requirements jobsite conditions etc.

The supplementary general conditions should not be changed from contract to contract on any one project.

e) Tender forms

Tender forms are prepared for each contract following one of three standard formats for stipulated price contracts, unit price contracts or cost plus contracts.

The Tender Form should provide space for identification of project and the contract and for legal identification of tender and for insertion of prices and timing applicable to the work.

Additional information to aid in Tender evaluation and to be used after award for purposes of contract administration will also be provided on the tender forms. This will include:

- Price breakdowns
- Additional unit prices
- Basis of payment
- Statement of key personnel to be employed on the contract
- Proposed sub-contractors
- Related experience
- Statement of equipment and rental rates

The tender forms will also provide for the tenderer to confirm his agreements to bond and to identify his bonding company.

f) Scope of work

This document describes the site and how access to site is obtained, it also includes a description of the works contained in the contract and defines the major items of work.

Also to be included is information on any geotechnical investigation which may have been performed and reference made to any report which may have been generated and where a copy, if not attached to the documents may be obtained or viewed.

g) General requirements

The general requirements should include details of applicable Codes and Standards which are referred to throughout the documents. Other requirements included are "As Built" drawings. Temporary facilities - what is provided by Owner and what has to be provided by Contractor, materials supplied by others and Owner and what has to be provided by contractor, and details of unloading, handling, storage, warehousing procedure and protection of materials, provision of scaffolding, ladders, handrails, barricades, and similar items of protection and access, clean up of site and its environs, progress schedules and reports required and job meeting requirements.

h) Tender evaluations and award

The terms of the financing package will determine the procedures which must be carried out to control the analysis of tenders, recommendations and award of contracts.

Typical flowcharts for Tenders and Contract Award and for Contract Administration are shown in Figures 1 and 2.

10.2.3. Purchasing

a) Purchasing functions

Purchasing functions include the following:

- Investigation and evaluation of proposed Vendors for major orders in terms of their capabilities, capacity and financial stability;
- Preparation of lists or proposed vendors for each category of equipment and material supply;

Text cont. on p. 121.

CONSTRUCTION SERVICES
TENDERS AND CONTRACT AWARD

RESPONSIBILITY / PROCEDURE	CLIENT	PROJECT MANAGER	CONTRACTS ADMINISTRATOR	PROJECT ENGINEER	SPECIFICATIONS	ENGINEERING DESIGN	COST CONTROL	SCHEDULING	TENDERER -CONTRACTOR
CONTRACT POLICIES	ESTABLISH CONTRACTING POLICIES, TERMS AND CONDITIONS OF CONTRACTS								
			DEFINE NUMBER AND SCOPE OF CONTRACTS					DEVELOP PROJECT CONSTRUCTION SCHEDULES	
					PREPARE INDIVIDUAL CONTRACTS				
					PREPARE STANDARD TENDER AND CONTRACT DOCUMENTS				
TENDER DOCUMENTS			DEFINE SITE MANAGEMENT PROVISIONS	PROVIDE SCOPE OF WORK, SOILS DATA, OTHER PROJECT INFORMATION		DRAWINGS BILLS OF MATERIALS DESIGN DATA		PROVIDE SCHEDULING DATA	
					PREPARE DRAFT CONTRACT SPECIFICATIONS				
			REVIEW		ISSUE FOR REVIEW	REVIEW			
					REVISE AND PROCESS FINAL DRAFT SPECIFICATIONS				
			ESTABLISH TENDER PROCEDURES		PREPARE TENDER FORM AND INSTRUCTIONS		PROVIDE TENDER QUANTITIES IF APPLICABLE		
			REVIEW		ISSUE FOR REVIEW REVISE / PROCESS				
				ISSUE DRAWINGS	ASSEMBLE TENDER DOCUMENTS APPEND STANDARD DOCUMENTS				
	REVIEW AND APPROVAL AS REQUIRED	REVIEW AND FORWARD	PREPARE LIST OF PROPOSED TENDERERS	INVITATION FOR TENDER					
TENDER CALL	OPTIONAL CLIENT MAY ISSUE TENDER DOCUMENTS			ISSUE TENDER DOCUMENTS					DIRECT ENQUIRIES TO CONTRACT ADMINISTRATOR
					REPLY TO ENQUIRIES				
			COMMUNICATIONS WITH TENDERERS						
			ISSUE ADDENDA		ADDENDA IF REQUIRED				
									PREPARE AND SUBMIT TENDER
	CONTRACT ADMINISTRATOR WILL NORMALLY RECEIVE AND OPEN INVITED TENDERS								
							CONTRACT ESTIMATE OR BUDGET VALUE		
			ARRANGE AND CHAIR PREAWARD MEETING WITH LOW TENDERERS		TENDER EVALUATION AS REQUIRED				
	REVIEW AND ACCEPTANCE	RECOMMENDATION WITH EVALUATION	TENDER EVALUATION AND RECOMMENDATION						
CONTRACT AWARD			INSTRUCTION TO PREPARE CONTRACT		PREPARE CONTRACT DOCUMENTS FOR SIGNING				
	ISSUE LETTER OF INTENT TO SUCCESSFUL TENDERER		PREPARE LETTER OF INTENT						ACKNOWLEDGE LETTER OF INTENT TO CLIENT
	SIGN CONTRACT		FORWARD CONTRACT DOCUMENTS						SIGN AND RETURN CONTRACT
			DISTRIBUTION OF EXECUTED CONTRACT DOCUMENTS TO CLIENT, PROJECT MANAGER AND CONTRACTOR	DISTRIBUTION	PREPARE CONFORMED COPIES OF CONTRACT DOCUMENTS				

FIG. 1.

CONSTRUCTION SERVICES
CONTRACT ADMINISTRATION

RESPONSIBILITY / PROCEDURE	CLIENT	PROJECT MANAGER	CONTRACT ADMINISTRATOR	PROJECT ENGINEER	SITE CONSTRUCTION MANAGER	CONSTRUCTION ENGINEERS AND SUPERVISORS	ESTIMATING AND SCHEDULING	PROJECT ACCOUNTING	CONTRACTOR
CONTRACT START-UP	INSURANCE CERTIFICATES	REVIEW AND APPROVE CONTRACTOR S SCHEDULES	INITIAL LETTER TO CONTRACTOR CHECK INSURANCE COVERAGE DISTRIBUTE COPIES OF APPROVED SCHEDULES APPROVED SCHEDULE OF VALUES				REVIEW SCHEDULE OF VALUES & CONSTRUCTION SCHEDULES		SUBMIT CONSTRUCTION SCHEDULES SCHEDULE OF VALUES INSURANCE CERTIFICATES
PROGRESS PAYMENTS	PAYMENT BY KILBORN AS AGENT OR BY CLIENT CONFIRM	AUTHORIZE CHEQUE REQUEST FOR PAYMENT			REVIEW/REVISE /ACCEPT PROGRESS ESTIMATE APPROVE PROGRESS PAYMENT CERTIFICATE	INSPECTION REPORTS MEASUREMENTS & RECORDS		PREPARE CHEQUE REQUEST FILE FOR REFERENCE	MONTHLY PROGRESS ESTIMATE/BILLING REVISE AS REQUIRED
CONTRACT CHANGES	CLIENT REQUEST FOR DESIGN CHANGE REVIEW AND APPROVE OR REJECT CHECK, SIGN AND RETURN CHANGE ORDER	REVIEW AND APPROVE DESIGN CHANGES REVIEW AND RECOMMENDATION CHECK AND APPROVE CHANGE ORDER	REVIEW QUOTATION NEGOTIATE TERMS IF REQUIRED PREPARE CHANGE ORDER DISTRIBUTE CONFORMED COPIES OF CHANGE ORDER	ENGINEERING REQUEST FOR DESIGN CHANGE PREPARE CHANGE BULLETIN APPEND DRAWINGS AND SPECIFICATIONS	SITE REQUEST FOR DESIGN CHANGE REVIEW AND COMMENT AS FOR PROGRESS PAYMENTS	FIELD WORK ORDERS (REQ APPR OF CLIENT SITE REP)	COST ESTIMATE & SCHEDULE EVALUATION IF REQUIRED		SUBMIT PRICE FOR DESIGN CHANGE CLAIMS FOR ADDITIONAL PAYMENT OR TIME SUBMIT PRICES/COSTS OF FIELD WORK ORDERS SIGN CHANGE ORDER ADD APPROVED CHANGE ORDERS TO PROGRESS BILGS
COMPLETION AND CLOSE OUT		ISSUE CERTIFICATE OF SUBSTANTIAL COMPLETION ISSUE CERTIFICATE OF FINAL COMPLETION WITH REQUEST FOR DOCUMENTS REQUIRED FOR RELEASE OF HOLDBACK	NEGOTIATE OUTSTANDING WORK IF APPLICABLE AND FORWARD NEGOTIATE OUTSTANDING WORK IF APPLICABLE AND FORWARD		ORDERS INSPECTION REVIEW AND COMMENT EVALUATE DEFICIENCIES CERTIFY BILLING FOR PAYMENT PROCESS AS ABOVE FOR PROGRESS PAYMENTS ORDERS INSPECTION REVIEW AND COMMENT CERTIFY FINAL BILLING PROCESS AS ABOVE FOR PROGRESS PAYMENTS	INSPECTION AND LIST OF DEFICIENCIES INSPECTION AND LIST OF DEFICIENCIES			NOTICE OF SUBSTANTIAL COMPLETION ACT ON DEFICIENCIES BILLING FOR PARTIAL RELEASE OF HOLDBACK NOTICE OF FINAL COMPLETION ACT ON DEFICIENCIES SUBMIT FINAL BILLING AND REQUIRED DOCUMENTS

FIG 2

PURCHASING FLOW CHART
ENGINEERING PURCHASES

PRELIMINARY TO REQUISITION FOR PURCHASES REQUIRING BID ANALYSIS AND PURCHASES SUBJECT TO CLIENT APPROVAL

RESPONSIBILITY / FUNCTION	CLIENT	PROJECT MANAGER	PROJECT ENGINEER	ENGINEERING	PURCHASING MANAGER	PURCHASING PROJECT BUYER	COST CONT. OR ASSIGN. ALTERNATIVE	BIDDER VENDOR
GENERAL	PRESELECTED BIDDERS LIST VENDOR DATA REQUIRE--MENTS MASTER LIST REVIEW & APPROVE		LISTING OF BIDDERS ON EQR PREPARES VDR TO ACCOMPANY TECH DOC		RECOMMENDED BIDDERS PREPARE COMMERCIAL DOCUMENTS	FOR PURCHASING DOCUMENTS		
ENGINEERING QUOTATION REQUEST	REVIEW & APPROVE (IF REQUIRED)		ASSEMBLE TECHNICAL DOCUMENTS PREPARE EQR (ALTERNATIVE) & ISSUE WITH TECH--NICAL DOCUMENTS	TECH DOC., DWG. BOM'S SPECIFICATIONS ETC		RECORD & PROCESS EQR	COPY OF EQR ONLY TO QUOTATION	
INQUIRY	COPY IF REQUIRED		COPIES FOR DISTRIBUTION			PREPARE INQUIRY APPEND TECHNICAL DOCUMENTS & COMM DOCUMENTS & ISSUE COMMUNICATIONS WITH BIDDERS		RECEIVE INQUIRY
QUOTATIONS			COPIES OF ALL QUOT'S & BID ANALYSIS FORM			RECEIVE & OPEN QUOT'S & RECORD PREPARE BID ANALYSIS FORM WITH COMMERCIAL DATA	ASSIGN COST ACC T CODE & BUDGET VALUE	PREPARE & SUBMIT QUOTATION
BID ANALYSIS			TECHNICAL EVALUATION TECH COMMUNICATION WITH BIDDERS COMPLETE BID ANALYSIS & SELECT VENDOR			COMM COMMUNICATIONS WITH BIDDERS		COMMUNICATIONS REVISE / CORRECT DATA REQUOTE IF REQUIRED
REQUISITION	REVIEW & AUTHORIZE	REVIEW & APPROVE FORWARD	PREPARE REQUISITION REISSUE TECH DOC * SEE NOTE			RECORD & PROCESS REQUISITION	MONITOR COST ACC T CODE & PRICE / BUDGET	
PURCHASE ORDER	SIGNATURE IF REQD.					PREPARE P O APPEND TECHNICAL DOCUMENTS & COMM DOCUMENTS & ISSUE GENERAL DISTRIBUTION OF P O ISSUE OF P O TO VENDOR RETAIN ACKNOWLEDGE--MENT COPY		SIGNATURE - RETAIN ONE SIGNED COPY & RETURN SIGNED AC--KNOWLEDGEMENT COPY

AUTHORIZATION TO PURCHASE WILL DEPEND ON DOLLAR VALUE
* MAY ORIGINATE FROM REQUISITION

FIG 3

PURCHASING FLOW CHART
CONSTRUCTION PURCHASES

RESPONSIBILITY / FUNCTION		CLIENT	PROJECT MANAGER	PROJECT ENGINEER	CONSTRUCTION COORDINATOR OR MANAGER	SITE MANAGER	SITE ENGINEER	PROJECT BUYER	BIDDER VENDOR
GENERAL	SEE ENGINEERING PURCHASES FLOW CHART				CONTRIBUTES TO PRE-SELECTED BIDDERS LIST				
COST CONTROL	AS FOR ENGINEERING PURCHASES								
ENGINEERING QUOTATION REQUEST	PRELIMINARY TO REQUISITION FOR PURCHASES REQUIRING BID ANALYSIS AND PURCHASES SUBJECT TO CLIENT APPROVAL	REVIEW AND APPROVE (IF REQUIRED)	FOR REVIEW ISSUE	ADD DRAWINGS AND OTHER TECHNICAL DOCUMENTS FROM ENGINEERING AS REQUIRED	DEFINE TECHNICAL REQUIREMENTS AND PREPARE EQR			RECORD & PROCESS EQR	
INQUIRY		COPY IF REQUIRED		COPIES FOR DISTRIBUTION				PREPARE INQUIRY APPEND TECHNICAL DOCUMENTS AND COMMERCIAL DOCUMENTS AND ISSUE	RECEIVE INQUIRY
QUOTATIONS				COPIES OF ALL QUOTATIONS AND BID ANALYSIS FORM				COMMUNICATIONS WITH BIDDERS RECEIVE AND OPEN QUOTATIONS & RECORD PREPARE BID ANALYSIS FORM WITH COMMERCIAL DATA	PREPARE AND SUBMIT QUOTATIONS
BID ANALYSIS			REVIEW AND APPROVE	TECHNICAL EVALUATION TECHNICAL COMMUNICATION WITH BIDDERS	COMPLETE BID ANALYSIS & SELECT VENDOR			COMMERCIAL COMMUNICATIONS WITH BIDDERS	COMMUNICATIONS REVISE / CORRECT DATA REQUOTE IF REQUIRED
REQUISITION	AUTHORIZATION TO PURCHASE WILL DEPEND ON DOLLAR VALUE MAY ORIGINATE FROM REQUISITION MAY ORIGINATE FROM SITE	REVIEW & AUTHORIZE	FORWARD ISSUE COPY		PREPARE REQUISITION APPEND TECHNICAL DOCUMENTS (SEE NOTE)	REVIEW AND APPROVE	REQUISITION FOR SITE PURCHASE (SEE NOTE) DISTRIBUTION	AUTHORIZED SITE BUYER PREPARES AND ISSUES P O DISTRIBUTION RECORD AND PROCESS REQUISITION	SIGNATURE AND ACKNOWLEDGEMENT
PURCHASE ORDER		SIGNATURE						PREPARE P O APPEND TECHNICAL DOCUMENTS AND COMMERCIAL DOCUMENTS AND ISSUE GENERAL DISTRIBUTION OF P O ISSUE OF P O TO VENDOR RETAIN ACKNOWLEDGEMENT COPY	SIGNATURE RETAIN ONE SIGNED COPY AND RETURN SIGNED ACKNOWLEDGEMENT COPY

FIG 4

PROCUREMENT SERVICES

EXPEDITING

RESPONSIBILITY / FUNCTION	PROJECT MANAGER	PROJECT ENGINEER	ENGINEERING	EXPEDITING AND INSPECTION SECTION HEAD	EXPEDITING AND INSPECTION PROJECT EXPEDITOR	PROJECT BUYER	VENDOR	SITE MANAGEMENT
PURCHASE ORDER	COPY	COPIES OF PURCHASE ORDERS FOR PROJECT DISTRIBUTION		REVIEWS FORWARDS TO EXPEDITOR	*ESTABLISHES FILE FOR EACH* PURCHASE ORDER FORWARDS COPIES OF PURCHASE ORDERS TO INSPECTOR WHEN REQUIRED	ISSUE OF PURCHASE ORDER TO VENDOR GENERAL DISTRIBUTION OF P.O. *ISSUES REVISIONS WHEN* APPLICABLE	ACKNOWLEDGES RECEIPT PROCEEDS TO FULFILL P.O.	
VENDOR DATA SHOP DRAWINGS, WELDING PROCEDURES, MANUALS ETC.					RECEIVES ALL COPIES OF VENDOR DATA LISTS ALL ITEMS RECEIVED PREPARES INTEROFFICE TRANS-MITTAL FORWARDS WITH COPIES FOR REVIEW		PREPARES SHOP DRAWINGS AND OTHER VENDOR DATA SUBMITS FOR REVIEW	
INTEROFFICE TRANSMITTAL	DETERMINES REVIEW RESPONSIBILITIES	RECEIVES APPLIES REVIEW STAMP TO ALL COPIES FORWARDS TO ENGINEERING CLERICAL SECTION	ENGINEERING CLERICAL DISTRIBUTES COPIES TO SECTIONS/ PERSONNEL RESPONSIBLE FOR REVIEW *RESPONSIBLE PERSONNEL NOTE* REVISIONS/COMMENTS AND INITIAL		MONITORS REVIEW PROCESS NOTIFIES PROJECT ENGINEER IF DELAY IS CRITICAL TO SCHEDULE		REVISIONS	
VENDOR DATA TRANSMITTAL		CHECKS THAT REVIEW STAMP COMPLETED RETURNS DATA COPY OF TRANSMITTAL			CHECKS THAT DOCUMENTS ARE READY FOR RETURN TO VENDOR PREPARES VENDOR DOCUMENT TRANSMITTAL AND ISSUES WITH REVIEWED DATA		REVISES AND RESUBMITS DATA AS REQUIRED ACKNOWLEDGES RECEIPT OF RETURNED DATA	
SUPPLY AND FABRICATION EXPEDITING REPORT	RECEIVES REPORTS ON REQUEST TAKE ACTION AS REQUIRED	TAKE ACTION AS REQUIRED COPY TO COST CONTROLLER		ADVISES, TAKES ACTION ON CRITICAL ITEMS	MONITORS PROGRESS BY PLANT VISITS OR TELEPHONE PREPARES AND ISSUES REPORTS ON VENDOR DATA, FABRICATION AND DELIVERY STATUS MONITORS PROGRESS AGAINST INSTALLATION SCHEDULES SERIOUS DELAYS REPORTED ISSUE INSTRUCTION		PROCEEDS TO FABRICATE TO FINAL DRAWINGS AND DATA TAKES REMEDIAL ACTION	PROVIDES SITE SCHEDULE DATA COPIES RECEIVED BY MANAGER OF CONSTRUCTION AND SITE MANAGER
STATUS LETTER					PREPARED AND ISSUED FOR VENDOR'S SCHEDULE COMMITMENTS, MONTHLY REVIEW AND FILE		COMPLETES DATA AND RETURNS	
ORDER STATUS REPORT	RECEIVES REPORT FORWARDS COPY TO CLIENT TAKES ACTION WHEN REQUIRED	HANDLES PROJECT DISTRIBUTION TAKES FOLLOW UP ACTION INDICATED		RECEIVES REPORT TAKES ACTION WHEN REQUIRED	PREPARES PROJECT ORDER STATUS REPORT MONTHLY AND ISSUES (FREQUENCY AND DISTRIBUTION PER PROJECT PROCEDURES)			COPIES RECEIVED PER PROJECT PROCEDURES
SHIPMENT	REQUEST SHIPPING INFORMATION AS NECESSARY TO COORDINATE PROJECT				OBTAINS SHIPPING INFORMATION NOTIFIES PROJECT AND SITE MANAGEMENT		PROVIDES SHIPPING DATES, AGENTS, ARRANGEMENTS PROVIDES BILLS OF LADING *CERTIFICATES OF ORIGIN ETC.* FOR EXPORT/IMPORT SHIPMENTS	ARRANGE FOR OFF LOADING COORDINATE WITH INSTALLATION CONTRACTORS

FIG. 5.

PROCUREMENT SERVICES

SHOP INSPECTION

RESPONSIBILITY / FUNCTION	PROJECT MANAGER	PROJECT ENGINEER	ENGINEERING	EXPEDITING AND INSPECTION SECTION HEAD	EXPEDITING AND INSPECTION EXPEDITOR	EXPEDITING AND INSPECTION INSPECTOR	VENDOR
GENERAL	ESTABLISHES INSPECTION GUIDELINES AND OBTAINS CLIENT APPROVAL INPUT FROM SHOP INSPECTION, ENGINEERING AND QUALITY ASSURANCE SECTIONS		ADVISES ON EQUIPMENT REQUIRING INSPECTION	ADVISES ON INSPECTION STANDARDS AND PROCEDURES REVIEWS, COMMENTS ON AND APPLIES GUIDELINES		ACTS ON GUIDELINES	
VENDOR / BIDDER QUALIFICATIONS	PRESELECTED BIDDERS LISTS, INPUT FROM PURCHASING AND ENGINEERING			REVIEWS, COMMENTS ON AND FORWARDS		CONDUCT PLANT SURVEYS OF VENDOR / BIDDERS DATA TO PURCHASING AND PROJFCT MANAGEMENT	
PURCHASE ORDER CONSTRUCTION CONTRACT	REVIEWS P.O./CONTRACT REQUIREMENTS AND PROVISION FOR INSPECTION	COORDINATES TECHNICAL DOCUMENTS ISSUES TO PROJECT BUYER OR CONTRACTS ADMINISTRATOR	DRAWINGS AND SPECIFICATIONS SPECIFIES PRODUCT STANDARDS, MATERIAL VERIFICATION TESTS AND SPECIFIC INSPECTION REQUIREMENTS IN P O./CONTRACT DOCUMENTS	ADVISES ON SPECIFIC INSPECTION PROCEDURES RECEIVES, REVIEWS COPY OF P O./ CONTRACT DIRECTS INSPECTION	RECEIVES FILES FORWARDS COPIES OF P O.	REVIEWS, IMPLEMENTS INSPECTION REQUIREMENTS	
VENDOR DATA (SEE EXPEDITING FLOW CHART) VENDOR'S INSPECTION, QUALITY CONTROL, WELDING PROCEDURES ETC.					FORWARDS COPIES OF FINAL SHOP DRAWINGS ETC	REVIEWS PREPARES PLAN OF ACTION REVIEWS VENDOR S SHOP PROCEDURES AND WELDER QUALIFICATIONS FOR ADEQUACY TO MEET P O /CONTRACT PROVISIONS	REVIEWS / DISCUSSES INSPECTORS COMMENTS, MODIFIES PROCEDURES AS REQUIRED PROCEEDS TO FABRICATE TO FINAL DRAWINGS, DATA AND PROCEDURES
INSPECTION				SEE 'INSPECTION REPORTS		INITIAL SHOP VISIT TO CONFIRM MATERIAL SUPPLY, STANDARDS, SHOP SCHEDULES, PROCEDURES, WELDER QUALIFICATIONS	REVIEW, CONFIRM, AMEND
POSITIVE MATERIAL IDENTIFICATION (P M I)						REVIEWS DATA PROVIDED FOR CONFORM-ANCE WITH P O / CONTRACT SPECIFICATIONS CHECKS MARKING / TAGGING / CERTIFICATION ON MATERIALS FOR CONFORMANCE WITH SPECIFICATIONS	RESPONSIBLE FOR PROVIDING POSITIVE IDENTIFICATION OF MATERIALS AT SOURCE OR WAREHOUSE OR VENDOR'S STOCK
INSPECTION REPORTS	COPIES OF REPORTS	DISTRIBUTES PER PROJECT PROCEDURES	COPY TO METALLURGIST / PROCESS ENGINEER / DESIGNER	RECEIVES, REVIEWS, APPROVES INSPECTION REPORTS	RECEIVES P O STATUS INFORMATION	PROGRESSIVE SHOP VISITS TO MONITOR FABRICATION AND INSPECTION / QUALITY CONTROL PREPARES INSPECTION REPORT ON EACH VISIT OR GROUP OF VISITS / INSPECTIONS	CORRECTS DEFICIENCIES IN WORK OR PROCEDURES NOTED BY INSPECTOR OR REJECTED BY VENDOR'S QUALITY CONTROL
REJECTION REPORTS		COPIES AS PER INSPECTION REPORTS		RECEIVES, REVIEWS COPY OF REPORT		PREPARES WHEN REJECTIONS BY INSPECTOR MUST BE DOCUMENTED ISSUES	RECEIVES REPORT REPLACES OR CORRECTS REJECTED WORK
REJECTION RELEASE		COPIES AS PER INSPECTION REPORTS		RECEIVES, REVIEWS COPY OF REPORT		PREPARES RELEASE REPORT WHEN DEFICIENCIES ELIMINATED OR DEVIATION APPROVED ISSUES	RECEIVES REPORT
TESTS						WITNESSES TESTS OR OBTAINS CERTIFIED COPIES OF TEST RESULTS INCLUDES TEST DATA WITH INSPECTION REPORTS	PERFORMS TESTS PRESCRIBED IN P O / CONTRACT AND IN VENDOR S INSPECTION / QUALITY CONTROL PROCEDURES REPLACES OR CORRECTS DEFICIENCIES DISCLOSED BY TEST RESULTS
INSPECTION ACCEPTANCE		COPIES AS PER INSPECTION REPORTS		RECEIVES, REVIEWS, APPROVES INSPECTION ACCEPTANCE	RECEIVES NOTICE OF COMPLETION, SHIPPING INFORMATION WEIGHTS ETC	FINAL INSPECTION PREPARES INSPECTION ACCEPTANCE REPORT	

FIG. 6.

- Obtaining bids from approved Vendors for equipment and for major bulk materials;
- Carrying out commercial analyses of the bids received;
- Negotiating with Vendors to obtain the most favourable terms of payment, best methods of shipping and proposed schedule;
- Placing order, preparing and issuing Purchase Order with commercial terms defined and the necessary technical documentation;
- Preparation and processing of import/export documentation, shipping arrangements and customs requirements;
- Assisting in administration of special project funding;
- Preparation of records and reports to monitor the status of purchasing for a project.

b) Purchasing documents

Uniform and fair policies and purchasing terms are established and consistently applied to all vendors. Based on these policies, a form of purchase order, terms and conditions of tendering and purchasing and other commerical documents are prepared.

c) Inquiry

The Inquiry generally consists of a form type letter which provides instructions covering submittal of quotations and accompanies the following documents:

- Instructions to Bidders;
- Instructions to Vendors;
- General Purchasing Conditions;
- Technical Document;
- Vendor Data Requirements - to include manufacturers tests and certification requirements.

The documents which accompany an inquiry vary with the nature of the items to be purchased.

d) Bid analysis

The terms of the financing package will determine the procedures which must be carried out to control the analysis of bids, recommendations and award of purchase orders.

e) Purchase order

The formal Purchase Order is issued on a preprinted form approved by the Owner. This form is accompanied by the documents issued with the Inquiry less those instructions which pertain only to bidding.

Flowcharts showing the purchasing activities for engineering purchases and construction purchases are shown in Figures 3 and 4.

10.2.4. **Expediting** (see Figure 5)

a) Expediting functions must include the following:

- Checking whether Vendor's work loads will allow for scheduled production of the equipment and commodities being purchased;
- Checking whether Vendor's shipping arrangements will meet limiting dates or shipping seasons for delivery to project site on schedule;
- Expediting Vendor's drawings and other data for Engineer's review and monitoring the progress of data through Engineers organization;
- Expediting production through Vendor's workshops;

- Monitoring all Vendor activities to maintain the contractual delivery time of materials and equipment;
- Acting promptly on deficiency notices received from project site to expedite replacement of shortages and damaged merchandise.

b) Expediting schedule

As soon as a purchase order for equipment or commodity material has been placed, the Expeditor contacts Vendor in order to set up schedules to expedite the agreed upon due dates for technical data and material shipment. The Expeditor closely follows the preparation of Vendor drawings, procedures and engineering data to see that these are received on schedule to meet engineering requirements.

Expediting functions continue until goods are received at the project site complete, in good condition and until all Vendor data has been received.

c) Shop inspection (see Figure 6)

The basis of the inspection programme, unless otherwise specified by the Owner will be to the standards established by the appropriate authorities having jurisdiction.

Shop inspection and related functions must include, where applicable:

- Carrying out plant surveys to evaluate Vendor's shops as to their capability to meet required quality standards;
- Advising engineering design groups on fabrication and inspection requirements;
- Reviewing Vendor's welding procedures and welder's qualification;
- Performing visual checks on fabrication;
- Checking that approved Vendor quality assurance programme is applied;
- Witnessing function and performance tests;
- Witnessing hydrostatic tests;
- Witnessing and/or verifying non-destructive tests;
- Reviewing correctness of inspection and material certificates;
- Preparing inspection reports.

The Expediting and Shop Inspection flowcharts are included (Figures 5 and 6) to illustrate the principal functions in summary form and to show the responsibilities and relationship of project personnel involved in these functions.

10.3. CONSTRUCTION

When preparing for the construction activities of any project, the following must be considered for the tender and contract documents and also for the construction and installation aspects.

10.3.1. Site organization

The project site organization should be established and outlined initially during the engineering proposal stage.

The make up of the site organization and number of personnel should be determined:

a) To suite size, complexity and nature of project;
b) To provide client with economical construction of project;

c) To satisfy the client and consultant responsibilities and commitments as defined and related to the consultant prepared and client approved drawings, specifications, contracts, conditions and budgets applicable to the project.

The site personnel listed are indicative of a site organization of satisfy projects of major scope and capital cost proportions rather than any specific project. The site management functions shall be scaled to satisfy actual client requirements and the consultants contracted responsibilities of the particular project.

Typical make-up of the site personnel for a major project would include:

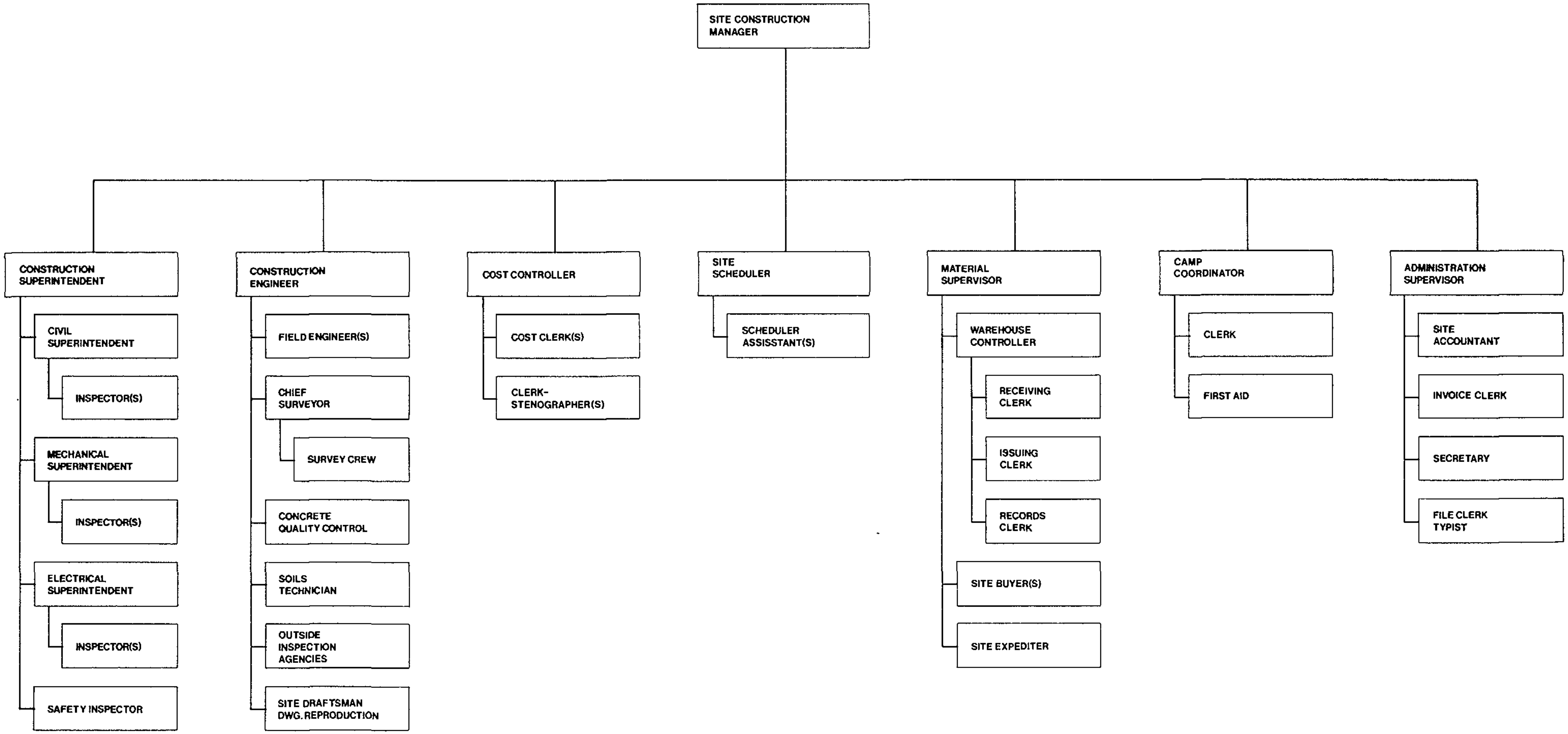
Site Construction Manager	1
Construction Engineer	1
Field Engineer	1
Chief Surveyor	1
Rodman and Chainman	2
Site Draftsman	1
Construction Superintendent	1
Superintendent (Civil)	1
Superintendent (Mechanical)	1
Superintendent (Electrical)	1
Inspectors	3
Adminstration Supervisor	1
Site Accountant (Invoices, etc.)	1
Secretary	1
Clerk-Typist	1
First Aid Attendant	1
Material Supervisor (Field Purchasing)	1
Warehouse Controller	1
Material Receiving Clerk	1
Material Issuing Clerk	1
Site Buyer/Expediter	1
Cost Controller	1
Cost Clerk	1
Site Scheduler	1
Scheduler Assitant	1
Camp Co-ordinator	1
Safety Inspector (including Security)	1
Additional Clerks (as required)	

Outside (sub-Contracted) Inspection Services

Soils Technician
Concrete Control and Testing
Structural Steel Inspection (Radiography, etc.)
Special Materials Inspection
Manufacturers Representative (various)

A typical Field Organization chart (Figure 7) indicates the make up and working relationship usually established for construction management of a major project.

Typical flowcharts for the Site Administration Functions are shown in Figure 8.



TYPICAL FIELD ORGANIZATION
CONSTRUCTION MANAGEMENT

FIG. 7.

RESPONSIBILITY / FUNCTION	HOME OFFICE	SITE CONSTRUCTION MANAGER	CONSTRUCTION SUPERINTENDENTS	CONSTRUCTION ENGINEER	SITE CONTROL: COST CONTROLLER SITE SCHEDULER MATERIAL SUPERVISOR	ADMINISTRATION SUPERVISOR CAMP COORDINATOR	CONTRACTORS
SITE ORGANIZATION	MANAGER OF CONSTRUCTION DEFINES SITE ORGANIZATION REQUIRED FOR PROJECT AND APPOINTS SITE CONSTRUCTION MANAGER IN CONSULTATION WITH MANAGER OF PROJECT, MANAGEMENT & OTHER SENIOR PERSONNEL PROJECT MANAGER RESPONSIBLE FOR OVERALL MANAGEMENT OF PROJECT & ESTABLISHING PROJECT PROCEDURES	INITIATES & ADMINISTERS SITE CONSTRUCTION PROGRAM PER PROJECT PROCEDURES	DIRECTION, COORDINATION & INSPECTION OF CONTRACTORS' WORK — CONTRACT ENFORCEMENT	RESPONSIBLE FOR ENGINEERING DOCUMENTS CONTROL, SITE QUALITY CONTROL, SURVEYS, SUPERVISORY REPORTING AND ENGINEERING COORDINATION		ADMINISTRATION SUPERVISOR: ESTABLISHES & ADMINISTERS SITE OFFICE PERSONNEL RECORDS AND TIME RECORDING RESPONSIBLE FOR SITE ACCOUNTANT CAMP COORDINATOR RESPONSIBLE FOR OPERATION OF CONSTRUCTION CAMP	
CONSTRUCTION REPORTS - BY KILBORN DAILY PERFORMANCE		RECEIVES REPORT	INSPECTORS DAILY REPORTS AREA SUPERINTENDENT CONS'N SUPERINTENDENT	- COPY	COPY EACH		
WEEKLY PROGRESS	REPORT TO PROJECT MANAGER COPY TO CLIENT, IF REQUESTED	RECEIVES REPORT	CONS'N SUPERINTENDENT PREPARES WEEKLY SUMMARY REPORTS COPY AREA SUPERINTENDENT	COPY	PREPARE TIME, COST PROGRESS/SCHEDULE DATA FOR REPORTS		
FORECAST	REPORT TO PROJECT MANAGER	RECEIVES REPORT	COPY	COPY	JOINTLY PREPARE FORECAST MANPOWER AND PROGRESS REPORT	COPY TO CAMP COORDINATOR	
FIELD WORK ORDERS REPORT	REPORT TO PROJECT MANAGER COPY TO CONTRACT ADMINISTRATOR	COPY		PREPARES — MONTHLY SUMMARY OF FIELD WORK ORDERS ISSUED AND DATA COST			
EQUIPMENT RENTAL, MANPOWER CHECK TIME CLOCK RECORDS		COPY	FIELD CHECKERS & CLERKS RECORD & REPORT COPY SUPERINTENDENTS		RECEIVE REPORTS, MONITOR DATA, CHECK CONTRACTORS BILLINGS		
CONSTRUCTION REPORTS - BY CONTRACTOR DAILY PERFORMANCE		RECEIVES REPORT	COPIES TO CONSTRUCTION SUPERINTENDENT AREA SUPERINTENDENT		COPY EACH		PREPARES & SUBMITS DAILY REPORT
WEEKLY SUMMARY	REPORT TO PROJECT MANAGER	RECEIVES REPORT	COPIES TO CONSTRUCTION SUPERINTENDENT AREA SUPERINTENDENT	COPY	COPY EACH	COPY TO CAMP COORDINATOR	PREPARES & SUBMITS WEEKLY SUMMARY REPORT
MANPOWER REPORT - LABOUR CONTRACT		COPY	COPIES TO CONSTRUCTION SUPERINTENDENT AREA SUPERINTENDENT		RECEIVE REPORT AND MONITOR		ON LABOUR CONTRACT — RECORDS AND SUBMITS DAILY REPORT ON MANPOWER USED
SITE PROTECTION AND CONTROL	CAMP & OTHER TEMPORARY STRUCTURES PROVIDED WITH FIRE PROTECTION OFFSITE STAFF & VISITORS SUBJECT TO SITE SAFETY & SECURITY REGULATIONS	RESPONSIBLE FOR LIAISON WITH LOCAL FIRE DEPARTMENT ORDERS REMEDIAL ACTION UPON FAILURE OF CONTRACTORS TO MEET SITE SAFETY & SECURITY REQUIREMENTS	SAFETY INSPECTOR RESPONSIBLE FOR SITE SAFETY PROGRAM MONITORS SAFETY PRACTICES OF CONTRACTORS, SUPERVISES SECURITY GUARDS/PATROLS SUPERINTENDENTS MONITOR DAY TO-DAY HOUSEKEEPING GATE SECURITY GUARD PREPARES DAILY REPORT TO SAFETY INSPECTOR			CAMP COORDINATOR MONITORS FIRE PROTECTION IN CAMP FACILITIES	ISSUE NO'D EMPLOYEE IDENTIFICATION BADGES MAINTAIN UP TO DATE LISTS EACH CONTRACTOR RESPONSIBLE FOR COMPLIANCE WITH SAFETY REGULATIONS, HOUSEKEEPING AND PROTECTION OF PROPERTY AND WORKS UNDER HIS CONTROL
SITE MATERIAL CONTROL & WAREHOUSING	SEE SEPARATE "FIELD MATERIAL CONTROL" FLOW CHART						

FIG. 8.

CONSTRUCTION SERVICES
SITE ADMINISTRATION II

RESPONSIBILITY / FUNCTION	HOME OFFICE	SITE CONSTRUCTION MANAGER	CONSTRUCTION SUPERINTENDENTS	CONSTRUCTION ENGINEER	SITE CONTROL: COST CONTROLLER SITE SCHEDULER MATERIAL SUPERVISOR	ADMINISTRATION SUPERVISOR CAMP COORDINATOR	CONTRACTORS
CONSTRUCTION CAMP	CLIENT, KILBORN S MANAGER OF CONSTRUCTION AND PROJECT MANAGER DETERMINE BASIC CAMP REQUIREMENTS. PROJECT MANAGEMENT & PROCUREMENT — CONTRACT SUPPLY OF TEMPORARY CAMP BUILDINGS & FACILITIES — CONTRACT CATERING SERVICE FOR CAMP					CAMP COORDINATOR COMPILES LIST OF CONTRACTORS' CONSTRUCTION MANAGEMENT & OTHER PERSONNEL TO BE ACCOMMODATED IN CAMP MONITORS FOOD SUPPLIES, CATERING SERVICES, CAMP RECORDS ENFORCES CAMP REGULATIONS ADMIN SUPERVISOR ASSISTS WITH RECORDS, REPORTS AND ADMINISTRATION	CAMP CATERER PROVIDES MEALS, ROOM & LAUNDRY SERVICES & MAINTAINS FULL CAMP RECORDS
INSPECTION DAILY INSPECTIONS		RECEIVES REPORT	REPORT ON WORK INSPECTED INCLUDED WITH INSPECTORS DAILY REPORTS	COPY	COPY EACH		COPY
CONCRETE PLACING			PRE-POUR CHECK BY CIVIL INSPECTOR				PREPARES "CONCRETE POUR REQUEST" — JOINT PRE-POUR CHECK WITH INSPECTOR
			APPROVAL OF CIVIL SUPERINTENDENT WHO DISTRIBUTES REQUEST WITH CHECK REPORT TO CONST'N SUPERINTENDENT	COPY			
			CIVIL INSPECTOR PREPARES RECORD OF CONCRETE PLACING		RECEIVES & MONITORS INFORMATION		
			RESULTS OF CONC TESTS TO CIVIL CONSTRUCTION SUPERINTENDENT — TAKES ACTION TO HAVE REMEDIAL WORK PERFORMED IF NECESSARY	CONCRETE TEST CYLINDERS TAKEN & TESTED BY TESTING LABORATORY RECORD OF TEST CYLINDERS PREPARED & DISTRIBUTED TO CONSTRUCTION ENG R			
INTERIM INSPECTION			AREA SUPERINTENDENT JOINTLY WITH CONTRACTOR DEFINES INTERIM INSPECTION				CONTRACTOR'S SUPERINTENDENT PREPARES REQUEST FOR INSPECTION ON "INTERIM INSPECTION REPORT" FORM
	REPORT TO PROJECT MANAGER	RECEIVES REPORT	INSPECTION CARRIED OUT REPORT COMPLETED & ISSUED	COPY	COPY EACH		RECEIVES REPORT ACTS TO CORRECT DEFICIENCIES RECORDED IN REPORT
			COPY TO CONSTRUCTION SUPERINTENDENT				
FOR PROGRESS PAYMENT			AREA SUPERINTENDENT AND INSPECTOR REVIEWS/CONFIRMS WORK COVERED BY BILLING	CHECKS MEASUREMENTS TO CONFIRM QUANTITIES INCLUDED IN BILLINGS			PREPARES MONTHLY PROGRESS BILLING
							AMENDS AS REQUIRED
		REVIEWS/REVISES/ACCEPTS BILLING					
		APPROVES PROGRESS PAYMENT CERTIFICATE					
COMPLETION		ORDERS INSPECTIONS	INSPECTS WORK REVIEWS DWG S & SPECIFICATIONS TO ESTABLISH IF WORK IS COMPLETED PREPARES LIST OF DEFICIENCIES	REVIEWS CONTRACTS TO DETERMINE IF CONTRACTOR HAS FULFILLED OBLIGATIONS PREPARES LIST OF DEFICIENCIES			PREPARES & SUBMITS NOTICES OF COMPLETION (SUBSTANTIAL & FINAL)
		REVIEWS/COMMENTS, FORWARDS TO PROJECT MANAGER FOR CERTIFICATE OF COMPLETION					ACT TO CORRECT DEFICIENCIES
		FOR FINAL COMPLETION — WORK NOT COMPLETED DUE TO CONDITIONS BEYOND CONTRACTOR'S CONTROL TO BE DEFINED					

FIG. 8. (cont.)

10.3.2. Insurance

The insurance to be provided by the contractor should be specified in the Supplementary General Conditions.

The Owner may choose to provide insurance covering the Project. The extent and type of coverage by client's insurance can vary widely. The contractor will be expected to provide the necessary coverage beyond the scope of client's insurance.

The types, limits and terms of insurance provided by client and by contractors and the expiry dates and payment of premiums must be clearly established and carefully monitored in order to maintain effective insurance coverage of all operations at the site.

In general, insurance to be provided by the contractor will include the following types of policies subject to owner's requirements:

- Comprehensive general liability;
- Automobile (owned and non-owned);
- Property (Builders Risk, course of construction or installation floaters);
- Boiler and Machinery;
- Aircraft and/or watercraft (owned and non-owned);
- Contractor's equipment and tools.

Insurance certificates must be checked and monitored on a continuous basis.

10.3.3. Labour survey

A labour survey should be carried out in the general area of the project to ascertain the capabilities and the supply of experienced tradesmen, if there are insufficient tradesmen or there is a lack of experience, the labour will have to be imported from within the country or from overseas.

10.3.4. Construction camp

A construction camp shall be established at the project site when the project is located in an area (remote or otherwise) which cannot be adequately serviced by means of daily travel to and from site of craft labour, operators and administrative personnel.

The size of and facilities for the camp must adequately reflect the construction manning schedules with provision for peak load on the camp facilities.

The facilities to be considered for a construction camp include:

- Bunkhouse accommodation	- for the contractor labour personnel
- Staff accommodation	- for Site Management personnel
	- for Visiting Staff Personnel
	- for Contractor Supervisory Personnel
	- for Nursing and Female Personnel

- Kitchen/Diner
- Recreation Hall
- First Aid Clinic

10.3.5. Codes and standards

The construction specifications shall refer to codes and standards to establish minimum acceptable standards of materials and workmanship where the specifications do not otherwise establish such standards. These documents should:

- Comply with the latest published edition and supplements at the date of submission of the Tender unless otherwise stated in the Sepcifications;

- Provide materials and workmanship which meet or surpass the specifically named code or standard;

- Perform the work in accordance with the applicable codes, law and regulations of the country and any other acts pertinent where the work is performed.

The codes and standards to be used must be specified by the engineer and be listed in the Design Criteria.

10.3.6. Inspection

The inspection must be carried out with regard to the codes and standards included in the Engineers Design Criteria.

- Concrete test cylinders must be taken to check that concrete placed meets design strength requirements and to describe locations of concrete tested so that defective concrete can be accurately located for corrective work if necessary.

- Equipment installation must be inspected in accordance with the attached Inspectors Check List (see Figure 9).

- Pipe testing - welds should be subjected to the following tests, Full Radiography or spot radiography, hydrostatic or pneumatic testing.

10.3.7. Site materials control and warehousing

The Field Material Control flowchart (Figure 10), summarizes the main functions related to materials control and warehousing and indicates the personnel who are involved in the functions.

The on-site material control functions must comprise the following:

- Inspecting and monitoring the delivery and unloading of equipment and materials and checking quality and quantity against the respective purchase orders;
- Monitoring delivery documentation to see that details are entered into the stock control record;
- Arranging for and operating temporary warehousing and storage facilities as required;
- Monitoring receipts against the control and scheduling documentation for all equipment and materials to achieve efficient progress control of the project;
- Monitoring construction contractors methods of requisitioning and recording of materials received;

INSPECTORS CHECK LIST

REPORT No. ______

CONTRACT NAME ______ No. ______ DATE ______

CONTRACTOR'S NAME ______ ADDRESS ______

CONTRACTOR'S REP. ______ K.L. INSPECTOR ______

LOCATION OF INSPECTION AREA ______

SPECIFIC ITEM INSPECTED ______

DRAWING REFERRED TO ______

______

______

LUBRICATION SPECIFIED ______

" COOLING PROVIDED ______

" HEATING PROVIDED ______

SPECIFICATION REFERRED TO ______

______

______

EQUIPMENT ALIGNMENT ______

" ROTATION DIRECTION ______

" R.P.M. ______

" VIBRATION ______

SPECIAL CODE REQUIREMENTS ______

______

______

______

TEMPERATURE RANGE ______

EQUIPMENT HANDBOOK ______

PIPE & VESSEL TESTS ______

TEST METHOD ______

TEST PRESSURE ______

WATER REQUIRED ______

FREEZING PRECAUTION ______

DRAINED AT END OF TEST ______

WELDING PROCEDURE ______

SAFETY CHECK ______

FIRE EQUIPMENT AVAILABLE ______

ACCESS & EGRESS SAFE ______

EXPLOSIVE CONDITION ______

ELECTRICAL CONDITION ______

SCHEDULE CHECK ______

MANPOWER PER SCHEDULE ______

MATERIALS PER SCHEDULE ______

PHYSICAL PROGRESS ______

LOCATION CHECK ______

CENTER LINE CORRECT ______

ELEVATION CORRECT ______

ORIENTATION CORRECT ______

MATERIAL CHECK ______

SPECIFIED MATERIAL ______

MATERIAL INSTALLED ______

CONCRETE SPECIFIED ______

CONCRETE INSTALLED ______

SPECIAL INSTRUCTIONS ______

WEATHER PROTECTION ______

SOIL COMPACTION ______

DELIVERY VOUCHERS RECEIVED ______

INSPECTOR'S COMMENTS (USE ADDITIONAL SHEETS IF REQUIRED)

SUPERVISOR ______

(SIGNATURE)

FIG. 9.

CONSTRUCTION SERVICES
FIELD MATERIAL CONTROL

RESPONSIBILITY / FUNCTION	PROJECT ACCOUNTANT	H/O PROCUREMENT SITE BUYER/ EXPEDITER	SITE CONSTRUCTION MANAGER	MATERIAL SUPERVISOR	WAREHOUSE CONTROLLER	WAREHOUSE CLERKS	VENDOR	CONTRACTOR
PROCUREMENT	COPY	PREPARES / DISTRIBUTES PURCHASE ORDER EXPEDITES PURCHASES REPORTS ON STATUS	RECEIVES & MONITORS TAKES ACTION AS REQUIRED	COPY CHECKS STATUS OF P.O. AGAINST STATED DELIVERY & CONSTRUCTION SCHEDULES			SIGNED ORIGINAL SUPPLY / FABRICATE	
WAREHOUSE RECORDS FILES CARDEX EQUIPMENT LEDGER				RECEIVES MAINTAINS FILES OF PURCHASE ORDERS WITH BACKUP, DELIVERY DATA ETC. COPY OF EQPT LEDGER OBTAINED FROM PROJECT MANAGEMENT	PREPARES & MAINTAINS CARDEX SYSTEM TO RECORD / CONTROL INVENTORY OF MATERIALS: DELIVERY — STORAGE — ISSUE RECORD / CONTROL INVENTORY OF EQUIPMENT: DELIVERY — STORAGE — ISSUE	INPUT INFO ON MATERIAL FLOW		
DAILY RECEIVING REPORT	COPY	COPY TO PURCHASING COPY TO EXPEDITING	COPY		PREPARES REPORT LISTING MATERIAL & EQUIPMENT REC'D NOTES DEFICIENCIES. FILE — COPY TO PROJECT MANAGER — DISTRIBUTION AS INDICATED			
DELIVERY					DIRECTS PLACING OF DELIVERED ITEMS TO STORAGE CHECKS AGAINST MRR & PURCHASE ORDER ORIGINAL OF MRR TO FILE	MATERIAL RECEIVING CLERK CHECKS DELIVERED ITEMS AGAINST CONSIGNMENT, NOTES AND PURCHASE ORDERS AND FOR DAMAGE PREPARE MATERIAL RECEIVING REPORT & DISTRIBUTION	DELIVER — ATTACH CONSIGNMENT NOTES (I.E. PACKING SLIP, BILL OF LADING ETC.)	
MATERIAL RECEIVING REPORT (MRR)	COPY OF MRR WITH COPY OF CONSIGNMENT NOTES	COPY TO EXPEDITING		COPY		NOTE DEFICIENCIES, IF ANY, ON CONSIGNMENT NOTES	RECEIPT COPY OF CONSIGNMENT NOTES DEFICIENCIES NOTED IF APPLICABLE	
DEFICIENCIES MATERIAL DEFICIENCY REPORT (MDR)	COPY COPY	COPY TO PURCHASING COPY TO EXPEDITING COPY		COPY FOLLOW UP COPY	ORIGINAL & 2 COPIES — ONE COPY TO VENDOR — ONE COPY TO CARRIER OR AGENT OF VENDOR WITHIN 5 DAYS RECORD & FILE	MATERIAL RECIEVING CLERK PREPARES MATERIAL DEFICIENCY REPORT & DISTRIBUTES REPORT ON REPLACEMENTS OR BALANCE OF ORDER RECEIVED	VENDOR TO ACT TO CORRECT DEFICIENCIES	
MATERIAL RETURN REQUEST LETTER					IF ITEMS TO BE RETURNED TO VENDOR, CONTROLLER INDICATES ACTION BY REQUESTING AUTHORIZATION AND SHIPPING INSTRUCTIONS FROM VENDOR.		AUTHORIZATION ACCEPTS / CONFIRMS DELIVERY OF RETURN	
ISSUE AND INSTALLATION						MATERIAL ISSUING CLERK CHECKS / IDENTIFIES / MONITORS ITEMS REQUISITIONED AGAINST P.O. / SPECS AND RECORDS		PREPARES REQUISITION IDENTIFYING MATERIAL OR EQUIPMENT REQUIRED FOR INSTALLATION COUNTERSIGNED BY KILBORN SUPERINTENDENT
MATERIAL RELEASE FORM					ORIGINAL ISSUES ITEMS TO CONTRACTOR	PREPARES MATERIAL RELEASE FORM, DISTRIBUTES COPY TO COST CONTROLLER & TO FILE		COPY COUNTERSIGNS ORIGNINAL OF MATERIAL RELEASE INSTALLATION

FIG. 10.

- Inspecting the care and handling of equipment and materials in accordance with purchase order and Vendor instructions;
- Co-ordinating all available data to give accurate advance information about the availability of equipment and material.

10.3.8. Construction safety

Safety procedures are established in the terms of the various contracts.

a) Job safety

The Safety Co-ordinator must make a general inspection of the jobsite daily to check whether Contractors are complying with safety directives. Offending parties are notified that unsafe work practices or conditions are to be corrected. Recognizing that a clean, tidy site is essential for safety and efficiency, considerable emphasis must be placed on housekeeping activities by Contractors.

The use of hard hats, safety glasses and protective clothing and footwear must be enforced by the Contractors' safety officers and management. A speed limit for vehicles on site is established, posted and enforced, together with other traffic controls. Special hazards such as storage and use of explosives, operation of heavy equipment, handling of flammable, corrosive and other dangerous materials, etc. must be monitored on an individual application/operation basis.

b) Accident procedure/First aid

The project site must be provided with a first aid room, equipped to government standards and staffed by qualified first aid personnel. A list of emergency telephone numbers is prominently posted at key locations on site. Procedures for handling dangerous situations and accidents must be established, and periodically reviewed to consider changes which may become necessary to meet changing conditions. Action to limit spread of damage and injury and to effect rescue of personnel receive special consideration. Procedures for accurately recording safety infractions and the basic facts concerning occurrences must be established.

c) Fire safety

Fire fighting measures and fire prevention procedures must be established. If a local fire department is available arrangements and procedures must be discussed with them and if necessary local fire fighting equipment supplemented. Where such a public service is not available, firefighting equipment must be supplied and maintained until the permanent fire system is usable.

d) Site security

Site Security must be established with the purpose of preventing entry of external sources of risk to personnel and property through vandalism etc. The extent of security and number of guards/watchmen will depend on the size of location of the site and local terrain. A site admission gate with security guard is set up as soon as the main access road is open. Contractors are responsible for providing numbered identification badges for all their personnel employed on the site, maintaining a complete up-to-date listing of their employees and the badge numbers for inspection and verification.

10.3.9. Progress payments

Progress payment procedures are established under the terms of the various contracts.

The Schedule of Values obtained from the contractor is a breakdown of the contract amount into values for various items of work on the progress schedule and shall form the basis for the Progress Billings which are broken down into the same items, with the same evaluations as appear in the Schedule of Values.

At the end of each month, the contractor shall prepare a Progress Estimate based on the Schedule of Values and on actual progress of the work and shall submit for approval, in accordance with the terms of the contract.

a) Firm Price contract
- Inspector's Reports
- Visual Observation of the Work

b) Unit Price Contract
- Field measurement of work underway and work completed
- Inspector's Reports
- Surveyor's Reports

c) Cost Plus Contracts
- Invoices (with receiving slips)
- Payroll Sheets and Time Cards
- Daily Equipment Work Reports and Agreed or Contract Rental Rates

Except in unusual circumstances and on cost plus contracts, material supplied by contractor is not included in Progress Estimates until it has been installed or incorporated in on-site fabrication.

Based on the Progress Estimate the contractor shall prepare his Progress Billing and submit to the Site Manager for approval.

Time Limits are stipulated in the contract agreement and general conditions for the checking, approval and payment of progress billings. These time limits must not be exceeded.

11. START-UP

11.1. RESPONSIBILITIES

Usually the owner of the facility will take the reponsibility for the implementation of the start-up procedures. His operators have to be trained in advance of start-up at the job site while the contractor is completing the construction work and the mechanical function of the equipment installed is being checked.

Nowadays very seldom a turnkey arrangement is contracted to the engineering and construction company whereby the start-up phase is included. In such an arrangement the contractor would be responsible for the implementation of the start-up procedures. The contractor thus would hand over a running mill to the owner. The change in the management of the facility sometimes will be arranged for at a certain recovery rate, say at 70%.

11.2. STRATEGY

The mill feed ore for start-up will be taken from a stockpile of ore blended to uniform grade. Initially the grade may be below average in order to avoid uranium losses. But in the second to third month ore with average grade will be fed to the mill. Fluctuating grades of mill feed will be avoided during start-up. Different ore types and charging ore grade from selective mining, for instance, will be blended to average quality in order to get good control over the mechanical arrangements during start-up.

11.3. START-UP SCHEDULE

The start-up of a facility to full production will take about 6 months to one year. It commences in the mine when building-up the stockpile. The capacity of the stockpile may be in the range of one half a year production of ore. This amount of ore may represent the average uranium grade of the ore and may already be representative for the mechanical strength of the ore to be mined and milled.

The start-up schedule will describe the individual and sequential procedures to be used by the operators and to be controlled in the individual or combined control centers. The schedule usually is presented as a timetable or as a bloc diagram or as a diagram according to the critical path method (CPM). The latter demonstrates the interdependence between the individual start-up procedures. The sequence of activities must be strictly observed in order to avoid malfunction of the facility.

The main categories of activities for mill start-up are commissioning, testing and start-up of commercial operations. Commissioning means the mechanical shake down of the individual equipment items in order to check their mechanical/electrical functioning. No feed will be provided to the circuit.

Testing means checking the performance of the equipment items. Pumps for instance will be tested by pumping water to the next receiving equipment item. This test is also called the "cold" test.

Following the equipment testing feed material will be charged to the circuit first as slurry without chemicals and heat, thereafter adding both sequentially. This test is also called the "hot" test. The hot test may be performed for the different process areas individually, for instance for the crushing and grinding area different to the leaching area, and the latter different to the solid liquid separation and to the solvent extraction. The last phase to be tested will be precipitation and drying.

Once all areas have been tested individually the start-up of the complete facility will be arranged by adding one individual area to the preceding one. It is very important that enough storage capacity is provided for between the main areas to allow a smooth start-up of the complete plant without overflow of solutions.

The goal of the start-up phase is to achieve a flow capacity of about 70 - 90% at a recovery rate of about 80%. After some months the operator may call the engineering and construction company for demonstrating the performance test of the plant.

11.4. TRAINING OF PERSONNEL

The operators employed may have some experience from working in other uranium plants but any plant has its own design and needs training to operate it. Some months may be needed to become acquainted to the job. There may be about 50 - 220 operators being employed in a uranium plant.

Training will preferably be carried out at the job site and during the finalizing of the construction work in order to get information about the local arrangements and the mechanical design of the equipment items.

The mine operators will have to be trained on the drilling facilities for rock and ore. They also have to be trained in blasting, excavating, and hauling with mostly new types of equipment.

The mill operators usually are responsible for one confined area like crushing, leaching, solid liquid separation, extraction or precipitation/drying/packaging of yellow cake. The mill operators will study the flowsheet in detail for their specific area of responsibility. They will be trained in controlling the mechanical functioning of the equipment and in controlling the chemical reactions. They will be trained how to react on mechanical malfunctioning and on abnormalities of the readings for the chemical process.

The operators will work according to the operating manuals, which are to be distributed to the operators when employed. The operating manual to each area of operation contains:

- Names, addresses and phone numbers of all people with responsibilities to the project area;
- First aid instructions and safety rules;
- Drawing for the general arrangement of the area;
- Flowsheet for the project area and flow data;
- Description of the process for the total plant and for the area;
- List of machinery installed with drawings, specifications, material of construction, connected power;
- Description of operating procedures (opening, shut down, regulating);
- Description of installations (capacity, heating, agitation, feeding outlet);

- Implementation of radiation protection at control centres;
- Emergency actions (fire, water, injuries).

The maintenance technicians and craftsmen will receive a maintenance manual which contains in addition to the operating manual, the following information:

- Tools to be used;
- Maintenance for the workshop installations;
- Routine inspection and services;
- Lubricants and suppliers to be used;
- Location of files for the norming systems;
- Protective measures at the job sites;
- Guide to warehouse and lay down yard for supplies needed.

11.5. MATERIALS FOR START-UP

For the start-up the ore, reagents, consumable material and supply will be taken from stock. The ore stockpile will have a capacity of about six months mine production. This stockpile ore is - if necessary - sorted to average grade, to higher grade and to low grade. This is a most preferable way for easy adjustments in milling unusual ore types.

The reagents needed for milling a quantity of 60,000 tons per month of standard uranium ore which may have a uranium content of 0.3% U_3O_8 and which plant may use sulphuric acid for leaching may be in the following range:

sulphuric acid	3,000 - 5,000 t
lime for neutralization	2,000 - 3,000 t
flocculants	20 - 30 t
ammonia	40 - 70 t
organic for solvent extraction	2 - 3 t
kerosene	20 - 40 t
barium chloride for radium precipitation	1 t
dryer fuel (propane)	50 - 60 m^3
grinding balls	50 - 90 t
drums for yellow cake	700
yellow cake produced	350 000 lbs

Consumable material for maintenance and adjustments may be in the range of 200-500 tons at total cost of about US $500 000 to US $1 Million.

11.6. THE START-UP PROCESS

The duration of the start-up depends mostly on th complexity of the ore and on the climatological conditions at the project area.

Some plants have been operated at design capacity after only 6 months of start-up but most of the plants processing complex uranium ores and which were put on stream since 1975 needed more than 12 - 18 months to achieve design capacity and design recovery. Consequently the individual phases of the start-up had an average duration of 1 - 6 months.

The individual phases are:

- Mechanical equipment shake down to prove mechanical functioning;
- Cold test of process systems with water only;
- Hot test of process systems with ore and reagents;
- Instrumentation and control to follow the readings for the process parameters;
- Product quality control to prove whether the product is according to the specification of the conversion facilities;
- Environmental monitoring to prove the quality of the effluents of the plant;
- Performance test to prove whether the plant performs according to design.

The start-up process usually will be performed by the operating company. Assistance of consultants and experts from the suppliers of equipment may be asked for - if necessary.

11.7. START-UP COSTS

The specific cost for start-up - expressed in dollars per pound uranium concentrate - may be in the range of double to triple of the operating cost when compared to the costs incurred during the same length of time for the regular operation.

The total cost for start-up thus may range between US $30 Million and 100 Million.

The total cost may consist of :

30% labour and supervision;
30% reagents and energy;
30% materials of supply plus mechanical adjustments to the plant constructed;
10% general expenses for transportation, outside experts, contingency.

The start-up costs will be allocated to the capital cost of the plant and depreciated after commencement of production. It may be decided that commencement of production starts when throughput and recovery is 95% of the design criteria.

12. OPERATIONS

After exploration has defined the ore body, and the feasibility study has demonstrated potential economic benefits, the mine-mill complex is designed and constructed. When a properly designed complex is placed in operation, production steadily increases until the output level reaches design parameters. To maintain smooth operation of the mine and processing plant a reliable and continuous supply of all operating supplies must be ensured. Continued training of the staff is also needed to make certain that each employee is fully aware of his/her job responsibilities within the framework of the organization. Operating management is charged with achieving these objectives.

Due to the nonhomogeneity of most uranium ores, uranium mining and processing are by no means routine operations. The mining requirements, the quality of the ore, and the metallurgical amenability of the ore may vary significantly over the life of the mine. Therefore, all operations must be continuously adjusted to meet the changing conditions of the ore body.

Radioactivity is a particular feature of uranium mining and processing; it introduces unique implications related to the exposure and protection of the operating staff and the public. The economic impact of these implications affects every phase of a uranium processing operation.

12.1. ORGANIZATION AND MANAGEMENT

A mining company, as any other commercial operation, is founded to fulfil specific objectives. Experience has demonstrated that achieving these objectives requires an organizational structure with defined levels of responsibility and authority.

The organization is headed by a board of directors, which represents the interests of the funding the company. The board establishes policy and provides direction to the executive level. In the mining industry and especially in the uranium production, the participation of several share holding companies has proved to be favourable. This structure divides the inherent risks of mining and can provide market contacts.

The executive level is headed by a chief executive officer (CEO), who is appointed by the board of directors. Commonly, the company is organized into several divisions, such as Operations, Administration, Finance, and Marketing. Each division is headed by an executive manager. The CEO coordinates the functions of the executives, each of which is relatively autonomous within their own area of responsibility. All subordinate management and supervisory functions are organized within this framework.

12.1.1. Organization chart

The Organization Chart depicts the company structure in graphic form. The chart shows both the vertical and interconnecting horizontal structure of the information flow needed for decision making. Supplemental documents are developed to describe details of individual authority and responsibility.

12.1.2. Manning table

The Manning Table lists the staffing requirements. The listing is subdivided into the various categories needed to manage and operate the mining and milling complex. Categories include functions such as management and administrative staff, operating staff, engineering staff, etc. The list must also include support staff and in particular crucial activities such as safety and environmental functions needed to meet regulatory requirements. The Manning List is developed to ensure that the optimum staff required to meet production schedules is available.

12.1.3. Job descriptions

Job descriptions detail the scope and responsibility of individual jobs within an organization. In addition to the specific functions of a job, interrelationships with other components of the organization are outlined. Job descriptions may also provide a schematic diagram showing the relationship of a specific job or activity to the overall operation.

12.2. MINING

The objective of uranium mining is the safe and optimum removal of the ore with minimum costs. In uranium mining the radiological safety of the mine employees requires special attention.

12.2.1. Mining methods

The ore body characteristics, its shape, size, grade, and location, determine the method used to mine the ore. Both "conventional" and "unconventional" methods are used. The term "conventional" refers to both (1) underground mining with access by shafts, tunnels, or ramps; and (2) open pit mining. The in situ mining technique, used to leach some sandstone type uranium ores, is classified as "unconventional" mining.

12.2.2. Mine planning

The mine planning process includes design of the mine. The design process takes into account a number of factors including the characteristics of each ore body, the host rock, surface features, the land use, and also the technical and economic requirements defined by the feasibility study. The design objective is to provide an efficient mining operation including ancillary operations and waste disposal facilities.

The most important planning criterion is the mining method. Principal considerations include the size, slope, dip, and location of the ore body. Open pit mining applies to large ore bodies, either outcropping or covered by overburden. The ratio of overburden thickness to the ore body thickness is referred to as the "stripping ratio". Another parameter, which influences open pit mining, is the slope angle of the pit wall. The maximum possible slope is determined by the rock characteristics, the pit depth, and the height of the benches.

For an underground mine the principal problem is to gain access to the ore body and at the same time provide for haulage and ventilation. This requirement is achieved by vertical or inclined shafts, tunnels, or ramps.

Ore body characteristics can vary considerably as mining progresses; and therefore, the mine design must also include provisions for removal of the ore by different mining methods. Typical mining method variations include: (1) room and pillar mining for flat lying ore bodies in competent host rock, and (2) shrinkage stoping or cut-and-fill mining for steeply dipping narrow veins. Each mine is relatively unique, however, and the mining process must be taylored to fit the deposit.

Operating mines require both short-range and long-range plans. The plans develop a mining sequence in accordance with safety and mill feed requirements.

Short range plans vary from mine to mine but normally cover periods of from 2 months to 2 years. The short-range plans identify specific portions of the ore body and select the required staff, equipment, supplies, and support systems.

Long-range plans are designed to determine the area to be mined over a period of 2 - 5 or even 5 - 10 years. This planing includes all preparatory work and development work that will be needed.

12.2.3. Mine operation

Mining is the process of extracting the ore and necessary waste rock from their natural environment and hauling the ore to the processing plant and transporting the waste to a disposal site. Support activities include radiological monitoring, quality control, and in underground mining, ventilation and dewatering.

The production of uranium ore from a mine includes a variety of operations such as the following:

- Development Operations
- Mining
- Haulage

Detailed exploration develops an improved understanding of the homogeneity of the ore body. By increasing the sampling density, improved distinctions can be made between the mineable ore and regions of waste. Geophysical measurements help to develop a comprehensive picture of the geometry and quality of the ore body.

Mining by blasting and loading is used in many uranium mining operations because the ore occurs in hard, strong rock. The number and depth of the drill holes required for blasting depends on the properties of the rock.

Open pit mining of relatively unconsolidated sandstone ores often uses rippers, scrapers, and shovels.

Ore transport takes place in one or more phases. The term one-phase transport is used when the loaded ore is transported directly to the processing plant by means of dumpers or trucks. One-phase transport is used mainly in open pit mining. In two-phase transport the mined ore is transported first to underground or surface bunkers by mine cars, trucks, or belt conveyors and from there to the processing plant by truck.

Quality control based on radioactivity measurements is nearly always included in the mining and haulage operations. The measurement system is designed the determine the quality of the excavated rock; and thereby, reduce the amount of waste to be handled. The ore at the face and in each transport vehicle is tested radiometrically. In one-phase transport, the ore is tested before leaving the mine. In two-phase transport it is tested before entering the bunker. The smaller the transport vehicle the better the selection, especially for non-homogeneous ores. The radioactivity measurements are backed up by standard chemical analyses.

The support required for mine excavations is an inherent part of mining. There is no difference between uranium mines and other similar operations. The support system is designed in accordance with general safety practice and applicable mining regulations.

Ventilation is an essential component of nearly all underground mining operations. However, because of the special implication of radioactivity in uranium mining, ventilation is particularly critical. Chapter 13 discusses mine ventilation within the framework of radiation protection.

12.3. PROCESSING

Most of the current industrial operations are based on adaptions of the general acid leach flowsheet shown in Fig.1. The size reduction, the leaching steps, and the solid-liquid separation steps of many uranium processing operations are quite similar. Nearly all operations have used either ion exchange or solvent extraction for the purification and concentration steps. Precipitation technology varies primarily in the choice of precipitation reagent used.

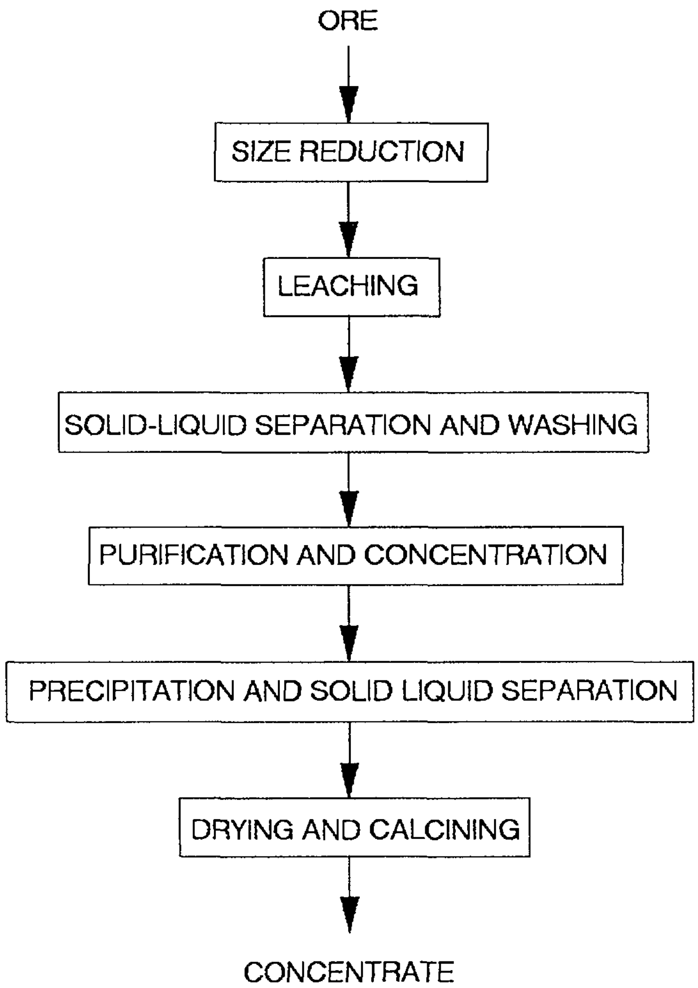


FIG. 1. Generalized process for the extraction of uranium from its ores.

12.3.1. Size reduction

The primary objective of the crushing and grinding operations is to produce the degree of liberation required for effective leaching. A secondary objective is to produce a material that can be slurried and pumped through the processing circuits. The degreeof grinding required to achieve these objectives for different ores may vary considerably. Sandstone ores normally require only that the sand grains be broken apart so that the grain surfaces are exposed to the action of the leaching agents. For ores containing refractory minerals it may be necessary to break the grains. Depending upon the mineralogy and the type of ore being processed, the required grind may vary from 3 to 200 mesh. Each ore source must be evaluated to determine the degree of grinding required for optimum operation.

12.3.2. Leaching

The leaching characteristics of an ore are determined by the mineralogical composition, but only broad generalization is possible. Experimental studies are required to determine the most applicable leaching conditions because the chemistry of the leaching operation can be relatively complex.

Heap leaching has been used on both low grade and medium grade ores. In this process ore heaps are formed over a collection system underlain by an impervious membrane. Dilute sulphuric acid solutions are distributed over the top surface of the heap. As the solutions seep down through the heap, they dissolve a significant (50 - 75%) of the uranium in the ore. If the effluent has a low uranium content, it can be recycled. The uranium is recovered from the heap leach product liquor by ion exchange or solvent extraction.

12.3.3. Purification and concentration

The solutions obtained from the leaching operation contain a complex mixture of cations and anions. Ore mineralogy determines the leach liquor composition, but the solutions always contain some aluminum, iron, magnesium, and silica. The leach solutions can also contain a variety of other metals such as titanium, vanadium, selenium, molybdenum, lanthanons, and thorium.

Organic exchange agents are used to recover and concentrate the uranium. Both resin ion exchange (IX) and solvent extraction (SX) technology are used. Each system consists of two fundamental steps or operations. In the first step, the liquor is contacted with the organic extractant and the uranium transfers, quite selectively, into the organic phase. This transfer is termed the absorption stage in IX and the extraction stage in SX. In the second step, the organic phase is contacted with an aqueous solution of such a nature that it strips the uranium back into a high grade, relatively pure uranium solution. In IX this is termed the elution and in SX the stripping stage. The process produces considerable concentration of the uranium. Although both the IX and SX processes are quite selective, small quantities of contaminants such as silicon, iron, titanium, molybdenum, phosphorous, and vanadium can be present in the product solutions. For some ores the flowsheet may require additional purification steps.

12.3.4. Precipitation and drying

The final stage of the acid leach process is precipitation from the high grade solution. The precipitation process consists essentially of converting uranyl cation into an insoluble precipitate. This precipitate, which is usually called yellow cake, can be a mixture of compounds, such as, hydrated uranium oxides, basic sulphates, and uranates. The yellow cake products are usually dried at 400 to 500 °C. The drying temperature must be controlled because temperatures above 600 °C can produce refractory compounds that will not dissolve in subsequent refining operations.

12.3.5. Production planning

The planning for mill capacity must consider many factors including the grade and metallurgical characteristics of the ore as well as the variability of the ore in the uranium deposit. The mine and mill operational schedules must be balanced. Mines often operate for a single shift while almost all mills operate continuously to maximize equipment utilization. Requirements for storage capacity between the mining and milling operations must be carefully evaluated. Contingencies such as providing for unexpected mine or mill shutdowns should be considered. Selective stockpiling and blending to produce a uniform the mill feed may also be necessary for some operations. Procedures for disposal of the tailings and other mill wastes must be addressed during all phases of the planning process. Waste disposal is likely to be a major capital and operating cost. Each uranium mining and processing operation has unique waste disposal aspects.

12.4. SUPPORTING SERVICES

Planning for a successful mine-mill operation must include provisions for adequate support services such as:

12.4.1. Maintenance and warehouse facilities

Thorough maintenance is critical necessity for establishing, maintaining, and improving productivity. Increasing mechanization and automation has reduced the direct labour to production ratio, but the required ratio of maintenance labour to production is increasing.

The long-term maintenance strategy should strive to assure:

- ° The continuous and reliable operation of equipment;
- ° Minimum downtime due to maintenance delays;
- ° Increased hours of equipment operation;
- ° Provisions for both planned maintenance and emergency repairs.

Maintenance planning should provide for regular inspections and maintenance for the following types of equipment:

- ° Machines and other equipment subject to inspections by regulatory requirements;
- ° Machines and equipment of critical importance to the operation;
- ° High cost machines or equipment with high operating costs.

Maintenance records are of critical importance. A record should be kept for each piece of equipment. The record should include all normal or preventive maintenance and special documentation for major repairs.

A properly qualified and equipped staff is required for all maintenance operations and particularly for emergency repairs. Maintenance management should develop detailed emergency plans for responding to unexpected breakdowns.

In general, maintenance is simplified and costs reduced by standardization of machines and equipment. Computer-aided maintenance record systems are both technically and economically desirable.

Warehousing and storage space must be provided not only for spare parts and normal supplies but also for all processing reagents. Safety considerations are particularly important when designing storage space for chemicals such as oxidants and acids. Separate storage areas are required. Equipment for safe handling of chemicals should also be provided.

The availability of spare parts for all equipment is particularly important. Adequate supplies, particularly of long delivery items must be available.

12.4.2. Analytical laboratory

Timely and accurate analytical results are a crucial requirement for successful mine-mill operations. Determining the operating efficiency of the processing operation requires accurate analyses because the composition of the materials passing through the process varies in each phase of the operation. Provisions for adequate analytical support must be an intrinsic component of the planning process. Prompt analyses of all operating samples are desirable, but results for operating samples such as leach circuit tailings, leach product liquors, and solvent extraction raffinates are particularly critical

Operating personnel must develop detailed sampling and sample handling procedures for uranium mining and milling operations. Changes in the quantity and quality of the process streams are a function of time; therefore, the sampling frequency should be selected accordingly.

Proven analytical methods such as radiometry, atomic absorption, polarography, tritrimetry, X-ray techniques are available. Both off-line and on-line methods can be used. In the off-line method, the sample taken from the process stream is taken to the laboratory for analysis. The on-line method uses in situ measurements and analyses. The two methods are illustrated schematically in Fig.2.

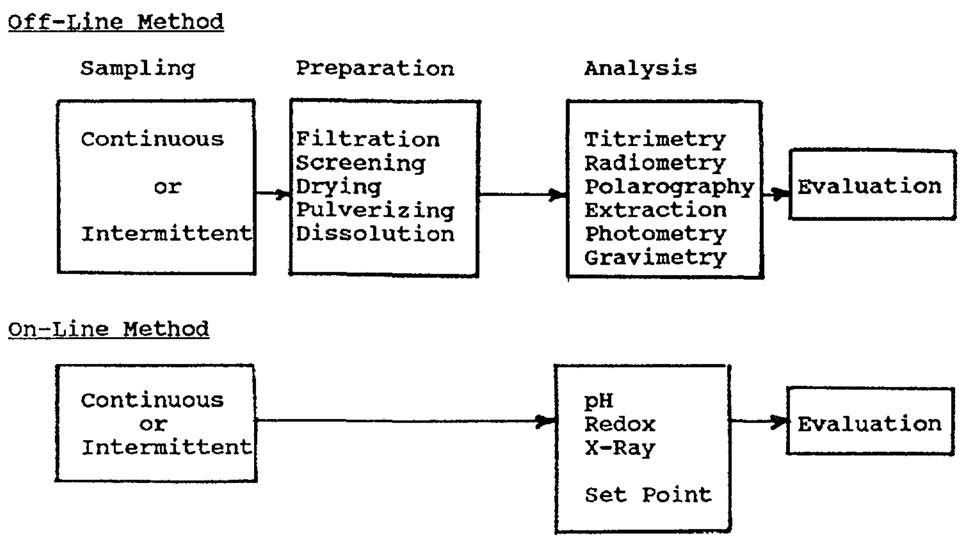


FIG. 2. Off-line and on-line analyses.

Recently, computer-aided process control systems have become more available. These systems not only carry out on-line detection and evaluation, but also initiate corrective actions. All detection data and results are transmitted to a control centre by the system.

12.4.3. Metallurgical laboratory

Every processing operation requires the support of a metallurgical testing laboratory. Experience has confirmed that continuing bench-scale leaching , solvent extraction, and precipitation tests can improve both the quality of the plant operation and reduce costs. Parallel testing using procedures developed during the original metallurgical investigation or pilot-plant operations permits correlation of overall metallurgical results and builds confidence in the operating data.

The scope of the metallurgical laboratory responsibilities can include:

- Mineralogical characterization of ore, gangue, and process residues;
- Sampling and checking crushing, grinding, and ore blending operations;
- Extraction tests to determine maximum possible leach recoveries;
- Determination of optimum parameters for solid-liquid separations, ion exchange/solvent extraction separations, yellow cake precipitation, etc;
- Evaluation of process reagent quality;
- Evaluation of waste management and environmental protection systems.

The primary responsibility of the metallurgical laboratory is (1) to develop information and data needed to maintain effective and economical processing operations, and (2) to improve the process technology. The process is continuously tested to find the cause of process upsets and develop corrective strategies. Process improvements can include a variety of changes, such as, reducing reagent requirements, improving solid-liquid separations by modified control procedures, and developing methods for improving product quality. All of these functions can contribute significantly to lower operating costs.

12.4.4. Personnel training

In any operation where continuous attention to operating practice is required because of changing mining or processing requirements, continuous training of the staff is necessary. The training system can be a combination of independent or superimposed units to provide the following types of training:

- Operator Training - The staff is instructed and updated on changes in operating details including corrective actions and their results;
- Professional Training - The supervisory and professional staff is kept informed on developments and improvements in their special fields and on the potential economic impacts of these changes;
- Special Training - Specialized training is required where in depth knowledge of safety practices, environmental controls, and regulatory information.

Experience has shown that continuous training of the staff can significantly improve day to day operations and reduce overall processing costs.

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13. RADIATION PROTECTION

Uranium mining and processing exposes the operating staff and support personnel to radiation of different types and intensities. Appropriate radiation protection must be provided for all personnel [1 - 5].

13.1. INTERNAL AND EXTERNAL RADIATION EXPOSURES

The radiation environment in a uranium mining and ore processing operation is complex and diversified. The environment includes external gamma radiation, a very low level of beta radiation, airborne radon and its decay products as well as radioactive dust produced in blasting, transport, crushing, grinding, etc. The level of external gamma radiation is, a priori, higher in the mine where personnel are in direct contact with the ore. The level of external exposures including both gamma and beta radiation is in general low and does not vary significantly with time in either the mining or processing operations. The gamma radiation is to some degree predictable on the basis of ore grade.

In uranium mines the most hazardous radiation exposure comes from the relatively high concentration of radon and its daughter products in the mine air. Radon, an inert gas produced by the decay process of ^{226}Ra in the ore, diffuses through the rock and enters the mine atmosphere. The concentration can be particularly high immediately after blasting and in poorly ventilated underground workings. Adequate ventilation requires careful design and also continuous operating attention. Radioactive dust is produced primarily when the rock is mined, crushed, conveyed. Dust control and collection must be a major design criteria.

13.1.1. Measurements

A variety of measurements are required to determine the exposure of the staff and to generate the data needed to maintain an effective radiation protection system.

Exposure resulting from external gamma radiation is relatively minor, but should be measured periodically. At the working places, exposure measurements are typically made at a distance of 0.8 to 1.0 m from the rock face or processing equipment [6, 7]. At least four measurements should be made at each location. At low grade ore faces exposure measurements should be repeated halfyearly. If the radiation level at any location lies near or above the permissible value, exposure should be measured weekly. The IAEA Safety Series No. 26 [5] presents limits for various radiation exposures. For example, the recommended limit on annual effective dose equivalent (H_E) is 50 mSV (5 rem). Details on secondary and derived limits are also defined.

Beta radiation exposures are usually not required in uranium mining and ore processing.

Radioactive dust and radon concentrations, the largest sources of danger, must be measured at frequent intervals. Gross-alpha activity techniques are used to determine the concentration of radioactive dust. Radon levels are measured by determining the alpha activity concentration of the radon daughter products. Permissible levels are specified by regulatory requirements and may differ from country to country.

The allowable radon exposure is based on exposures accumulated throughout a year. This means, for example, that a recommended Working Level can be exceeded occasionally provided this exposure is compensated for by a period of low exposure. The total annual exposure must not exceed the permissible limit. The IAEA recommendation is 5 working level months (WLM) per year [5, 6].

Radon levels should be measured at locations where the most time is spent by the staff, e.g. at a distance of 1 to 3m from the working face in underground mines. Measurements should also be made in haulage drifts at regular intervals. The frequency of area monitoring should be determined by the Radiation Protection Officer in consultation with the Ventilation Officer and approved by the competent authority [5].

Radon and radioactive dust measurements can be carried out by specially trained staff or by a dosimetry service. Individual dosimeters are desirable for staff that must work in several different areas.

13.1.2. Record keeping and evaluation

The results of dosimetric measurements shall be recorded; a personal exposure record must be kept for each individual exposed to radiation. These records should contain:

- The gamma intensity measured at the working place (half yearly);
- The value of gross alpha activity measured at the working place (monthly or quarterly);
- The radon concentration and the cumulative yearly exposure.

The annual radon exposure is the sum of the monthly measurements. If other than a personal dosimeter is used, the exposure is calculated on the bases of measurements at the working place and the number of shifts at that location.

Permanent records of all radiation exposures should be maintained. Also, both monthly and annual summary reports on radiation exposures in both the mining and milling operations should be prepared.

13.2. PREVENTION

It is the quantity of radioactive material intake that must be minimized in uranium mining and processing operations. In effect this means that the radioactive concentration in the mine and mill atmosphere should be as low as possible.

13.2.1. Dust control

In the mine, dust may be suppressed most reasonably by water. Wet drilling can be used, and access to the working face is restricted for a specific time after blasting. In some mines loose rock can be removed by water blasting. Sprays can help to control dust generation at locations such as conveyor transfer points.

Wet cleaning should also be used in the processing plant. All equipment and floors should be designed for washing with a jet of water. In areas where significant dust protection is needed, the operators must wear suitable protective clothing. The protective clothing should be changed and cleaned regularly. In areas where dust is produced, operating procedures should require a shower after each shift, and it may be necessary to monitor the radioactivity of the body surface at regular intervals.

Dust collection systems should be engineered to minimize operator exposure, but in some instances properly fitted dust respirators may still be needed, particularly for emergency situations. After any suspected dust leakage in the yellow cake product drying and packing areas, urine samples should be taken from the operators at the end of the shift. Results from these tests must be recorded in the permanent exposure records for each employee.

13.2.2. Radon control

Ventilation is the most applicable and effective means for controlling radon concentrations in a mining operation. The amount of ventilation required is a function of the radon concentrations. Outside air is delivered into the mine by the main ventilation fans and distributed within the mine by the auxiliary ventilation system. To avoid recirculation, air locks are installed as needed. Abandoned faces are significant sources of radon contamination. Thorough sealing of these areas can appreciably reduce ventilation requirements.

In open pit operations, dust control and protection is usually the primary requirement, but periodic radon measurements should be made. Pit designs for some very high grade operations have provided for maximum natural air flow through the pit.

13.2.3. Radiation protection staff

A radiation protection service must be maintained at any operation involving radiation hazards. The scope of the service includes all monitoring and record keeping requirements. Staffing depends on the magnitude and scope of the job. A continuing training programme for both the radiation protection staff and all operational personnel should be maintained. Direct management responsibilities for the service are usually assigned to the safety officer. Some operations have contacted the monitoring functions to specialized radiation protection services.

13.2.4. Environmental measurements

Both surface and ground waters in the vicinity of uranium mines and processing operations must be monitored. Off-site dust and radon measurements will be required for almost all uranium operations. Soil and vegetation analyses may also be needed. The type and analytical measurements are usually specified by regulatory requirements. These data are used to calculate the annual radioactive effluent releases [3]. Water contaminated by radioactive material must be collected and decontaminated to meet regulatory requirements before release to the environment. Mining and Processing waste management will be discussed in Chapter 14.

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14. MINING AND PROCESSING WASTE MANAGEMENT

Since uranium usually occurs as a very minor element in ores, the waste products from uranium mining and milling operations consist primarily of:

- Waste rock from mining
- Liquid effluents
- Solid wastes from the processing operations

Liquid effluents present the most immediate concern in uranium operations. Failure to properly control and treat liquid effluent can lead to spillage into the open environment and may damage the flora and fauna. Such accidents are the most visible to the public. Uranium plants take great care to avoid loss of control of liquid streams. Most operations must treat mine water before discharge to the environment. This treatment often has the added benefit of some uranium recovery from mine water. Wash water used within the plant is carefully controlled and recycled to join the main process stream. Barren effluent from the process are neutralized to the pH 8 range, normally with lime, and further treated with barium chloride to precipitate radium as an insoluble salt. Final effluents are normally channelled through large ponds to allow settling of precipitates. In some operations pond overflows are filtered on sand filters before discharge.

Both the mine waste rock and the mill tailings may contain: (1) sulphides that can oxidize to sulphuric acid, (2) low level radioactivity that can give rise to radon emanation to the atmosphere; and (3) physically unstable components such as clay, which can lead to structural failure of waste piles. To avoid problems arising from these factors, the project developer must use care and attention in limiting weathering action, in controlling runoff water, and ensuring structural competence.

Dusts are generated at several points in uranium operations. Dusts arise from mining operations, in crushing and grinding operations, and in handling yellow cake. Ventilation, dust collection equipment, good housekeeping are all required to minimize the impact of dusts on the working environment.

Solid tailings from the milling operation are largely the insoluble leach residues with small amounts of valueless precipitates such as iron cake. Mill tailings volumes are large. Although they are the insoluble residues, they still may present problems in the long term. Constituents such as pyrite and other metal sulphides and minerals can slowly oxidize and lead to high acidity and the presence of heavy metals in seepage from the tailings. Considerable care and attention must be paid to the design, development, operation, and abandonment of tailings. The technology is not straightforward and is heavily dependent on site specific factors such as weather, terrain, proximity to other industrial activities and population centres, and the sensitivity of the local ecology.

The challenge to the uranium project developer is to understand the present condition, to design a competent system fortreatment and control, and to anticipate factors which could militate against abandonment after shutdown. The developer must undertake environmental baseline studies to establish the preoperational condition. The process design must include proper treatment procedures to avoid environmental damage. Good ecological engineering is required to provide long-term environmental protection. It is highly unlikely that man-made structures will withstand the ravages of weather and climate for any long term. As a result, tailings will leak contaminants into the environment. The concept of ecological engineering is to encourage the local environment to provide a "buffer zone" between the tailing and the open environment. The development of microbial and plant life in an environmental buffer zone is seen as an applicable concept for long-term tailings abandonment.

This discussion provides only an introduction to the problems and concerns of environmental protection. The reader is encouraged to refer to the attached bibliography for more detailed information.

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15. DECOMMISSIONING

15.1. OBJECTIVE

Decommissioning is the work required for the planned retirement of a uranium or thorium mine, mill or waste management facility from active service. The objective of decommissioning a mining and milling operation should be to modify the site so that the social and environmental impacts are at a low enough level not to be of concern at any point in time. Implicit in this objective is the concept that little or no human intervention will be required to maintain this acceptable state. A decommissioning plan should be prepared for each mine, mill, and waste management facility and approved by the competent authority before construction of that facility.

Regulations vary widely from jurisdiction to jurisdiction. These regulations have generally been derived from requirements for the operational phase of mining and milling. The concept appears to be that if the emissions do not exceed existing criteria and the technology can ensure a consistent level into the future, then the decommissioning plan is acceptable. Although a decommissioning plan will have to take into account site specific characteristics, there are general guidelines such as the IAEA Code of Practice for Safe Management of Wastes from the Mining and Milling of Uranium and Thorium Ores [1] which can be used universally. This Code includes requirements for the management and control of solid, liquid, and airborne wastes. It also delineates requirements for the decommissioning and rehabilitation of mines, mills, and related waste management facilities identifies. Subsequent surveillance and maintenance requirements are also addressed. All general guidelines, however, must be applied carefully to ensure that the predicted impacts are well within the existing regulatory guidelines.

Even after a technically sound decommissioning plan has been developed it may be necessary to take into account social considerations. These social pressures may be light in large countries where the mines are situated in remote areas. In countries where land is a premium there will be a strong pressure to return the land to some useful function. Many jurisdictions, require that tailings sites be contoured and vegetated.

15.2. DESIGN

Ideally the design of a conceptual decommissioning programme should be done prior to the development of the mine and mill. This will ensure that site-specific characteristics are recognized and taken into account. It will also enable the proponents to have an opportunity to estimate the cost and therefore make allowance for the decommissioning in their overall financial strategy. It is possible that the cost of decommissioning in an acceptable way will exceed the revenues generated by the mining operation. Under these conditions the mine should not be developed unless changes can be made to reverse this imbalance.

In the past, mines and mills have often been made operational without a long-term decommissioning plan in place. In many cases, therefore, base line data from an on site investigation are not available. Satisfactory programmes can still be undertaken, but it is likely they will be more expensive than those designed prior to mine start up.

Certain fundamental principles must be reviewed in the design process. Major considerations for the movement of radionuclides and other contaminants from the waste materials to the environment can be grouped into related categories. For example, both radionuclide contaminated dust particles and radon gas are contributors to the final dose dispersed through the air. This pathway becomes increasingly more significant in arid climates, and in desert like conditions it is the predominant pathway. Where annual precipitation is high enough to result in a surface-water system then this pathway becomes very significant and may predominate. Saturated tailings however are less likely to cause dust and radon problems. Associated with the surface-water flows are the ground water component although this only has an impact when it becomes part of the surface-water system (either naturally, or through activities such as digging wells). There are other mechanisms for the transfer of radionuclides and other heavy metals through the environment to mankind. These are generally more or less important on a site specific basis. These latter pathways would include uptake by vegetation or shellfish.

Many of the world's uranium deposits are associated with substantial amounts of sulphide bearing minerals such as pyrite. These sulphides eventually report to the tailings or waste masses , where they can oxidize, especially when conditions are suitable for bacterially catalyzed oxidation to take place. This depresses the pH and increases the dissolution rate of a number of components of concern. Sufficient pyrite is often present to make this an on-going process into the far future.

15.3. IMPLEMENTATION

If the concept of decommissioning has been properly considered during the planning of the mine, then work for decommissioning will start during mine and mill construction. This allows the operator to take advantage of local conditions to minimize both the environmental impact and the total cost. Although the major volume of waste material will be tailings (with or without waste rock) the decommissioning plan should include both the surface and underground installations. In many jurisdictions there are requirements that surface installations be dismantled, mine shafts filled in, and roads be removed.

15.3.1. Tailings

The approach to final decommissioning will be governed by the physical confinement method used during operations. Typically tailings are deposited on the surface and, depending on the local typography are held in place by a dam or series of dams. Other options are to return some of the material underground, or into mined-out pit (or specially dug pit), or to place the tailings in the bottom of a deep lake.

For surface deposited tailing there are several techniques that can be considered for the development of the decommissioning strategy. These can be split into three basic approaches; the use of solid cover, the use of liquid cover, and a combination of these two.

a) Solid Cover

Applying some form of solid cover to the surface of a tailings pile will eliminate the dispersion of radionuclide bearing dust, and, depending on the depth and type cover applied, a considerable reduction in radon emanation. It will also reduce the uptake of radionuclides into vegetation and therefore movement through the food chain pathways. Properly applied cover that has been correctly contoured can also minimize the penetration of water and therefore reduce the subterranean dissolution of radionuclides, and prevent their entry to the surface-water system.

The amount and type of cover required for reduction of radon levels to an acceptable level varies with the climate. In the arid south-western United States radon proved to be the predominant contributor to dose. The U.S. UMTRA Project [2] designed and applied covers to reduce this radon level. Additionally these covers also eliminated any dusting problem and greatly reduced the possibility of minor intrusions by humans and animals.

Solid covers can be made from a variety of materials. Typically naturally occurring materials such as sand, clay, crushed or waste rock, gravel, or soil have been used alone or in combination. The characteristics of the available material must be determined so that the correct mixture of layers and the optimum thickness of each can be calculated.

Other cover possibilities are asphalt, concrete or sheet plastic. The first two have not been used extensively due to cost, but the last, plastic sheet, has seen a lot of service. Liners of sturdy, heavy-duty plastic can be used under the tailings to prevent groundwater contamination, as the core of earthen dams or as a cover to prevent infiltration of the exhalation of radon. The two key questions about liners is the ability to maintain their integrity during construction and the life expectancy, considering it has to last for hundreds of years.

In moister climates radon does not constitute a major problem. When the tailings pile is saturated for a large proportion of its depth the radon dissolves in this interstitial water for a sufficient period that it has decayed to its solid daughters. This does not completely eliminate the escape of radon and above background readings can be obtained near the surface of the tailings pile. However radon disperses rapidly and within a short distance from the surface or edge of the pile the increment is not detectable above background.

Without any form of cover the very near surface can dry out and become a source of dust particles, particularly in arid and semi-arid climates. Some tailings surfaces in these regions have been vegetated and this vegetation cover does protect against dust. Vegetation does not appear to make significant changes in the amount of water penetrating the tailings mass.

Tailings areas in wet climates normally contain a certain amount of pore water. Depending on the chemistry of the pile it is possible to have considerable concentrations of radionuclides and other elements of concern in solution. Any precipitation will eventually result in the passage of water through the tailings pile and the subsequent transport of these materials either to the ground water or surface water systems. As stated previously vegetation does not normally have a major impact on the quantity of water flowing through, although properly designed and contoured cover systems may well reduce this to a minimum. At some operations where the decommissioning plan has been designed prior to the operation of the mill efforts are being made to deposit tailings in a succession of layers. The objective is to promote the horizontal movement of water while minimizing the downward migration. Water running across the surface of the pile obviously would not pick up contaminants from within the pore water system. Other techniques such as coning, where the tailings are piled in such a fashion as to be self-draining and provide a maximum surface run off potential are also being tried.

Those ore bodies which contain sulphides have more complex problems. The tailings that are pumped from an operating mill have normally been blended with lime and will be alkaline. If iron sulphide is present it is slowly oxidized chemically by atmospheric oxygen; this reaction produces ferrous iron and sulfuric acid. Initially the acid produced is neutralized by the excess lime in the treated tailings. However after a period of time (generally a few years) this neutralizing capacity is consumed and the tailings become acidic. This leads to enhanced bacterial activity. Bacteria such as Thiobacillus ferroxidans oxidize ferrous iron to form ferric. The ferric iron then reacts with the sulphide minerals to give more ferrous iron and further increases an acidity. Under these conditions the pile eventually reaches an pH of approximately 2 - 3.

The mechanisms for sulphide oxidation have been researched extensively. It has now become clear that to prevent sulphide oxidation for the long term the key is to prevent the ingress of oxygen until there is less than 5% of the oxygen concentration at saturation (i.e. 0.5 mg/L). Typically 1-2 metres of cover would be required to achieve this level. Although oxidation can take place at and below this point the rate is so slow that the environment is capable of handling any subsequent consequences. If the oxidation is allowed to continue then the subsequent production of sulphuric acid will increase the dissolution rate of many of the radio-nuclides and will promote their movement into the surface water environment. The proper addition of covers can reduce this oxidation potential to an acceptable level and by combining it with proper placement and contouring can reduce the water flux at the same time.

Temporary inhibition of the bacterially mediated oxygenation of sulphides can be achieved by the use of bactericides. However, at best, these only last for a few years and cannot be used for a long-term stabilization. They do however provide a useful operating tool and a temporary resolution of problems while long-term solutions are being implemented.

At any tailings site decommissioning the design of the covers will be based on the technical characteristics along with the economics of transportation. Beyond understanding the fundamental properties research needs to be done to establish the long-term stability of these characteristics and the effects of physical treatment, such as compaction and chemical amendment, such as the addition of sodium bentonite.

Some tailings sites show a considerable efflorescence at the surface. This indicates the transport of soluble salts and their subsequent precipitation at the tailings-air boundary. It is not clear whether this mechanism will continue to exist with a cover in place. Capillary breaks should be installed between tailings and the final cover material.

While covers will prevent the ingress of oxygen, thereby eliminating oxidation by aerobic bacteria, it will promote the reduction of sulphates to sulphides by anaerobic bacteria. Some work has been done to show that this will result in release of hydrogen sulphide and, because of the reduction in sulphate ion concentration a greater mobility for Radium-226. Typically, tailings piles have high sulphate concentrations but insufficient work has been done to show what the long-term effect of maintaining this high sulphate mass under anaerobic conditions.

b) Liquid cover

A flooded uranium tailings pile, even if the depth is only a few centimetres of water will not emanate radon or be a source of dust. Such a situation would also discourage intrusion. Radon is sufficiently soluble that it will have decayed to its daughters before any significant proportion is released to the atmosphere. Obviously physical covering of tailings by water would not allow any escape of dust except at the margins. The water cover would have to be substantially deeper for tailings containing sulphur. The depth would depend on the site specific characteristics but the key would be to reduce the oxygen level at the tailings surface to less than 0.5 mg/L noted above.

The disadvantage of such a water cover is that it creates a hydraulic pressure on the pore water system allowing any dissolved material to move into the ground or surface water systems. In addition if the water level is maintained by an artificial structure, such as a dam, then the long-term integrity of that structure has to be maintained. Should the dam fail and the water cover be lost, then the entire protection system breaks down. Once drained the tailings would release radon, dusting would become a problem and all the discharge water would form a major pollution source. Also erosion could occur which would move the tailings themselves to undesirable and uncontrolled new locations.

An alternative is to place the tailings in a natural waterbody sufficient to contain the estimated tailings production of the facility. This decision has to be made prior to mill opening, as it is not likely to be economical to move an existing tailings mass into a deep lake. Although this is a promising technology there are normally considerable social pressures at "sacrificing" a lake for waste disposal. Additionally little research has been done on the long-term movement of radionuclides from such a system. The potential for success of deep lake disposal is very high and further research into its long-term applicability should be encouraged.

c) Combinations of technologies

Some attempts are now being made to use a raised water table in combination with cover materials. These materials have generally been of the type that can be generically called wetlands. The concept is to raise the phreatic line so that a base wetland cover material can be applied and the typical wetlands vegetation be encouraged to grow. The hope is that the growing vegetation will continue to augment the cover with the result that in the long term the tailings mass continues to be buried. For this to happen of course it is necessary to maintain the biological conditions that allow for continued vegetative growth this will again raise the questions of the longevity of the structures in place to maintain those conditions.

For non-uranium tailings piles other cover mechanisms are also being tried. These include the use of municipal garbage, wood waste and other mining or smelter residues as cover materials. The basic concept is still to reduce the ingress of oxygen and water. These techniques, if successful, are only applicable in areas wherethe cover material is economically available.

15.3.2. Waste rock

In many locations quantities of rock containing below economic grade amounts of uranium have been mined along with the actual ore. These have been placed in waste rock piles, and in some locations constitute more of a problem than the tailings themselves. Waste rock seems to have attracted less research attention than tailings and the impact of this material is only now being realised. It is anticipated that the chemistry of the waste rock system will be similar to that of its associated tailings. However the technology for controlling the impact of waste rock on the environment is likely to be quite different from that of tailings. It is anticipated that studies just begun will define the problems encountered and the magnitude of the research required.

15.4. BUILDINGS AND EQUIPMENT

Although the tailings normally represent the main effort at close-out, the other parts of the mine-mill complex will have to be decommissioned as well. The mine shaft must be blocked to prevent access. It may be possible to place some of the tailings or waste rock in the unused shaft, if they do not pose grounwater pollution problems.

Mine and mill equipment can normally be cleaned and sold for reuse, provided regulatory requirements are met. The minor amount of unsalvageable material remaining can usually be buried in the tailings. If the mine and mill buildings cannot be dismantled and sold, then they will have to be razed and buried. Waste rock is a possible cover material.

15.5. EVALUATION

Once a decommissioning plan has been proposed, whether it is part of the original design or as a requirement for closing down the operation, it will have to be evaluated to judge its effectiveness in meeting the objectives. There are normally three ways that this evaluation can take place. One is non-mathematical, while the other two use forms of mathematical predictive techniques.

In the traditional engineering approach, an essentially non-mathematical method, the concepts of the proposal are compared to accepted engineering experience. The engineering evaluation approach relies on extending the knowledge that has been gained in the past, with the use of experienced judgement, into the future. This assumes that the experience at any particular site and its interpretation is valid. It also assumes that such experience modified by judgement can be used at other locations. In many cases uranium tailings sites have only existed for a relatively short period of time (up to 100 years). However in the broader engineering sense tailings piles and similar engineering structureshave been around for many centuries. For many of these items particularly in the physical sense, such an extrapolation is valid. However this kind of evaluation does not allow for dramatic changes that may occur some time in the future (such as the change in the tailings chemistry due to reaction with oxidation products).

The other two approaches are based on providing specific information that can be compared directly with a set of evaluation criteria (such as the regulatory limits). These are both mathematical computer modelling techniques. The first of the mathematical techniques is an attempt to avoid some of the problems associated with the standard engineering evaluation. Here a conceptual model is pieced together that shows all the interacting components of the tailings system and its interaction on the environment. This model is then translated into computer code and is used to evaluate the choice of close out technologies. For this a set of data is accumulated that is meant to be representative of the site in question. Most frequently, to preserve the conservatism normally applied to radiological dose assessment, the worst case values have been chosen. This means that there is a single output which is easy to relate to the regulatory levels. However this output is usually biased high, although it may not take into account major catastrophic events. In theory, as long as the "worst case" possibilities are below the regulatory index then the close out method is acceptable.

More recently work has been underway to adapt these modelling techniques to a more realistic sense. This has been achieved by developing a probabilistic predictive model. Once again the conceptual models have been used to develop computer codes which reflect the chemistry, physics, and engineering of the tailings pile. Within the code inter-reactions (such as precipitation or re-dissolution) can be linked together so that dramatic changes such as future times can be accounted for. Instead of feeding in specific or worst case values a distribution of the input parameters is used. By using a random selection technique for a value from the input parameter distribution, one can develop an output histogram of the probable frequency of some event taking place (e.g. the frequency that any specific dose is likely to occur). This method means that extreme values, whether high or low, are still included in the assessment. However, as their probability of occurrence is very low they will have only a small effect on the output distribution curve. This also means that the most likely occurring consequences will be represented by the largest portion of the area under the distribution curve. Although this process takes all possibilities into account, it allows for major changes within the system with time, and thus the output itself raises a new problem. Traditionally we have been used to comparing a single output value against a specific regulatory limit. The output from a probabilistic predictive model is a distribution function and it is more difficult to compare that to a single value. The regulatory agencies have yet to come to any decisions on the interpretation of this output relative to close out criteria.

15.6. POST-DECOMMISSIONING

The radioactive components in mining and milling wastes have long half-lives. Therefore, regardless of the technology used there will have to be a monitoring period after decommissioning. It is essential to inspect the facility at regular intervals after decommissioning to confirm that it was done correctly. It is also necessary to validate the concepts that gave rise to the decommissioning technology. This can only be done by setting up a properly designed monitoring programme that will measure radon emanation rates, dust dispersion, surface and ground water flows along with contaminant concentrations, erosion patterns and similar characteristics as appropriate for a particular site. It is likely that this will be the responsibility of the mining company for a certain number of years. However the ultimate control will in all probability eventually return to the government authority. Any jurisdiction must therefore be prepared for some type of long-term monitoring plan for decommissioned sites. They must also be prepared for the institutional control required to prevent intrusion that would alter the inplace technology to such an extent that it no longer remained as an environmental safeguard.

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