FEASIBILITY OF GYPSUM QUARRYING AND GYPSUM-BASED
CONSTRUCTION PRODUCT MANUFACTURING

IN EGYPT

by

JOSEPH LEE PLATNICK

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Signature of Author ____________________________
Department of Civil Engineering
March 14, 1983

Certified by ____________________________
Professor Fred Moavenzadeh
Thesis Supervisor

Accepted by ____________________________
Chairman, Departmental Committee
on Graduate Students

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ABSTRACT

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Submitted to the Department of Civil Engineering on January 21, 1983 in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

This feasibility study of gypsum interior walling products in Egypt covers five basic areas. First, the extent of gypsum deposits in Egypt is surveyed. In addition, the damage caused to agricultural land from the use of Nile River silt in the manufacture of bricks is highlighted. These findings indicate that gypsum panels may provide a viable substitute for Nile-silt brick in the construction of interior partitions.

Second, the supply and demand for two gypsum building products --- plaster and interior partition gypsum panels --- are analyzed. By 1985, as more manufacturers begin production, the markets for both products will be saturated, as demand will fail to grow at a comparable rate. The success of any new interior walling product introduced to the market at this time will be determined by its merits, particularly low cost and ease of installation.

Third, the production system by which gypsum panels are manufactured is studied, encompassing three areas: quarrying, processing, calcining, and panel production. From the many equipment options, an optimum production configuration was selected. For quarrying this system includes a bulldozer with ripper, front-end-loader and off-highway truck. The calcining system includes a hammermill crusher, a roller mill, and two calcining batch kettles. The total capital cost for such a production facility is estimated at 3.18 million Egyptian pounds.

Fourth, a technical and economic feasibility analysis of gypsum panels is performed. Technical feasibility encompasses such criteria as physical characteristics and compatibility with Egyptian building systems. Economic feasibility examines the cost competitiveness of gypsum panels in Egypt and such project implementational considerations as foreign investment laws and the availability of capital and infrastructure.
Fifth, a framework for the analysis and evaluation of the proposed manufacturing facilities is developed. This investment analysis shows that a gypsum panel manufacturing plant, producing 702 thousand square meters of panel would provide an internal rate of return of 16.5 percent. A facility producing only calcined gypsum would provide a rate of return of 21.1 percent. These preliminary results appear to indicate that the operation of these plants could be marginally profitable, given the market for plaster and gypsum panels and the current economic conditions in Egypt.

Thesis Supervisor: Fred Moavenzadeh
Title: Professor of Civil Engineering
The author wishes to dedicate this thesis to his parents, for all of their support and guidance.

The author also wishes to express his sincere appreciation to the other members of the M.I.T. Gypsum Project Team; Professor Albert Dietz, Mr. Charles Helliwell, and Mr. Tarek Selim, for all of their advice and effort throughout the development of this thesis.

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CHAPTER ONE

INTRODUCTION

1.1 Objective

Egypt's rapid population growth, coupled with widespread migration into urban areas, has placed tremendous demands on the Egyptian building industry. As a result, building materials, such as brick and concrete, are frequently in short supply, resulting in the emergence of "black market" economies and the exorbitant prices associated with them. This shortage is further complicated by the continued use of Nile silt, the primary raw material used in the manufacture of traditional red brick. In recent years, in an effort to protect its agricultural lands, the Egyptian government has declared illegal the use of Nile silt. Consequently, alternative raw materials and building products are needed not only to meet current excess demand, but also to substitute for the use of Nile silt bricks.

Current efforts in Egypt aimed at finding new materials and products, include the development of shale and sand-lime brick and lightweight-concrete and gypsum block. These products appear to be economically feasible, however, full-scale manufacturing is several years away.

Prior to 1967, the production of gypsum in Egypt was concentrated in the Sinai Peninsula, as gypsum from other parts of the
country was lower in quality. With the loss of this territory during the 1967 Middle East war, alternative deposits were required to fulfill the country's needs for construction materials and agricultural gypsum. The subsequent geological explorations resulted in the discovery of large deposits of high-grade gypsum ore. Some of these deposits, located in the Western Desert, have total unconfirmed reserves of approximately 200 million tons. These deposits are currently being exploited by the Egyptian Gypsum, Marble, and Quarries Company (GYMCO). Other reserves located in the Suez Canal region and Sinai Peninsula are currently being reopened by the Specialized Contracting and Industrial Company (Osman) and the Sinai Manganese Company. Further explorations west of the Nile have indicated the possibility of additional reserves, particularly within the Fayoum Governorate. Because these reserves within Fayoum are only on the order of 6 to 8 million tons, they are ideally suited for small-scale processing and manufacturing operations (34).

The overall objective of this study is to develop an analytic framework for the preliminary evaluation of a small-scale, totally integrated process for the manufacture of gypsum-based construction products in Egypt. The process will incorporate such activities as quarrying, processing and calcining, and manufacture of products used in residential, commercial, and light industrial construction.

1.2 Scope

This project will be concerned only with an assessment of the gypsum deposits within the Fayoum Governorate and the subsequent
processing and manufacture of the gypsum ore into interior, non-load bearing building partitions.

This assessment can be broken down into five separate areas, each discussed in a separate chapter of this report. Chapter 2 provides general background material on the use of gypsum in Egypt, including that used in construction, agricultural, and industrial applications.

Chapter 3 begins with a review of historical supply and consumption of calcined gypsum. This analysis is used in conjunction with a comprehensive assessment of potential producers, to produce supply and demand forecasts. A similar procedure is employed for deriving forecasts for partition products. This chapter describes the basis for demand forecasts through 1985, as well as several different scenarios for future expected demand. The chapter concludes with a comparison of potential supply and expected demand to determine the possible gap or surplus resulting under each scenario.

Chapter 4 presents a summary and overview of alternative quarrying, processing, and manufacturing methods. For purposes of analysis, the quarrying process is broken down into three stages: (1) removal of overburden, (2) excavation, and (3) haulage. The methods and equipment selected are tailored to the specific job-site conditions of the Fayoum deposits, on the basis of cost, performance, versatility, and adaptability to any conditions which may exist. Processing operations include both ore preparation and calcining. An in-depth review of manpower requirements is also made for all quarrying and processing operations.

Chapter 5 begins by investigating the technical requirements for partitions and walls. Particular attention is given to identifying
and summarizing those requirements which are applicable to Egyptian building methods and existing cultural conditions. This includes a survey of existing products used in partition wall construction, including such factors as physical characteristics and total installed costs. This chapter concludes with an assessment of items related to economic feasibility, including cost and availability of capital, site, and infrastructure.

Chapter 6 presents a case study for an integrated gypsum panel production facility located in the Fayoum Governorate. This section provides cost data and recommendations for the design of quarrying, processing, and product manufacturing systems. These recommendations are based on the specific technical and economic factors highlighted in earlier sections, and serves in the configuration of an optimum production facility.

Chapter 7 concludes with a summary of the previous findings, and presents recommendations for further study.

In order to fulfill its aim, this study has used information and data drawn from both primary and secondary sources. A major portion of Chapters 2, 3, and 4 has been compiled using secondary sources, primarily in the form of government documents, analyses of building industries and materials in Egypt, and feasibility studies for similar type projects. Chapter 5 was researched in a similar manner, however, this was combined with numerous interviews and site visits. The secondary sources used in the preparation of this report are listed in the table of references. All primary sources are listed in a separate appendix at the end of this report.
CHAPTER TWO

GENERAL ASPECTS OF GYPSUM CONSTRUCTION PRODUCTS

2.1 Gypsum Use in Egypt

The per capita consumption of gypsum in Egypt is quite low relative to other countries. Actual per capita consumption is currently 10 kilograms per year. This level of consumption is far below that of other nations as is shown below:

- Spain: 84 kilograms per capita
- Iran: 71 kilograms per capita
- West Germany: 60 kilograms per capita
- United States: 60 kilograms per capita
- United Kingdom: 47 kilograms per capita

If the current Egyptian Five-Year Plan is executed as planned, per capita consumption of gypsum should reach 30 kilograms per year by 1985 (88).

Total gypsum production in Egypt for the years 1971 through 1978 is shown in Table 2.1. This table also shows total production broken down into the three primary areas of usage: agriculture, industrial, and building construction (52).

In agriculture, gypsum is used as a soil conditioner, providing a source of available calcium and sulfate. This gypsum requires minimal crushing and screening and no calcining, and may be produced from either the regular or anhydrous forms. The principal purposes for applying
TABLE 2.1

GYPSUM PRODUCTION SUMMARY

(1000 METRIC TONS)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>TOTAL PRODUCTION</th>
<th>AGRICULTURE</th>
<th>INDUSTRIAL</th>
<th>CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>561</td>
<td>222</td>
<td>212</td>
<td>127</td>
</tr>
<tr>
<td>1972</td>
<td>516</td>
<td>82</td>
<td>239</td>
<td>195</td>
</tr>
<tr>
<td>1973</td>
<td>572</td>
<td>189</td>
<td>219</td>
<td>164</td>
</tr>
<tr>
<td>1974</td>
<td>635</td>
<td>224</td>
<td>216</td>
<td>195</td>
</tr>
<tr>
<td>1975</td>
<td>583</td>
<td>239</td>
<td>213</td>
<td>250</td>
</tr>
<tr>
<td>1976</td>
<td>830</td>
<td>367</td>
<td>213</td>
<td>250</td>
</tr>
<tr>
<td>1977</td>
<td>637</td>
<td>92</td>
<td>240</td>
<td>305</td>
</tr>
<tr>
<td>1978</td>
<td>742</td>
<td>101</td>
<td>293</td>
<td>348</td>
</tr>
</tbody>
</table>

gypsum to agricultural land are to improve the physical condition of the soil by breaking up compacted clays, increase porsity, neutralize sodium compounds in alkaline soils, and stimulate soil microorganisms. Ground anhydrous or dihydrous gypsum may also be added as an ingredient in formulating feeds for beef cattle, dairy cattle, and sheep.

Table 2.1 shows that the consumption of agricultural gypsum has ranged from 35 to 40 percent through 1976. However, over the last five years, agricultural gypsum production has decreased as production has shifted to higher priced building construction gypsum. Current agricultural gypsum production is approximately 15 percent of total production.

Industrial gypsum can be divided into three broad categories: calcined, anhydrous, and uncalcined. Calcined industrial gypsum is used for making molds for the manufacture of sanitary ware and metal casting, and as a cementing agent in oil and natural gas well drilling.

Anhydrous gypsum, with its high affinity for water, is used as a dessicant in laboratory and commercial applications. Additional applications include use as an extender for rubber, artificial wood, plastics, paper, and Keene's cement, and as a carrier for insecticides. Industrial use has varied from 35 to 40 percent of total production through the present time, as industrial consumers have been more willing to absorb the higher prices of recent years.

Uncalcined industrial gypsum, sometimes referred to as "raw" gypsum, is used as a retarder for portland cement. When used in this capacity, it is usually blended with pure anhydrite.

The consumption of gypsum construction products has comprised 20 to 30 percent of the total market through 1976. Over the last five years,
with the advent of gypsum interior walling products, the market share for gypsum as a building material has risen to almost 50 percent. Part of this increase can also be attributed to the ambitious building program of the Egyptian Government, and the increased use of construction materials associated with it. All gypsum employed in building is used in its calcined form, as the primary ingredient in the manufacture of various building products.

Architects and engineers are gradually increasing their use of gypsum products. This has been the result of new methods in designing buildings and housing, which have been based upon more efficient and economical concepts. As a result, these improved methods have introduced new applications and uses for gypsum and its products to the Egyptian market. These applications include blocks, partition board, tiles for suspended ceilings, decorative gypsum products, and plaster.

As will be shown in Chapter 3, the consumption of plaster increased at an average rate of 20 percent per annum over the period 1971-78. Over the last three years plaster consumption has declined. However, because this has resulted from limited supplies as opposed to depressed demand, forecasts for future demand appear to be quite promising. Conservative estimates portray a rate of growth in excess of 7 percent per annum.

The use of gypsum in the construction of interior walls and partitions has been a more recent development. Several firms, including Arab Contractors and GYMCO, are currently manufacturing gypsum blocks. Although production and use are limited, the emergence of gypsum interior partition products is seen as being indicative of future trends. The reduced cost and ease of installation associated with
gypsum blocks and panels can provide manufacturers with lucrative markets for these products. These products and their associated markets will be further examined in later sections.

2.2 Opportunities for Expanded Use

The expanded use of gypsum construction products in Egypt can be attributed to two factors. The first factor, the increased availability of high-grade gypsum ore throughout Egypt has provided manufacturers with an inexpensive and abundant raw material that can be transformed into various building products at a low cost. The high profit margins associated with these products are partially responsible for the plans of manufacturers such as GYMCO and Arab Contractors to either expand or build new production facilities.

The use of these products has also been expedited as the result of governmental efforts to curb the use of Nile Silt brick. As increased pressure from the Egyptian Government causes Nile silt brick prices to rise, architects, engineers, and contractors will continue to search for less expensive substitutes.

2.2.1 Availability of Gypsum Ore - Existing Deposits

Egypt possesses a number of gypsum deposits located throughout the country, in such areas as the northern, or Mediterranean, portion of the Western Desert, the Gulf of Suez, the Sinai Peninsula, Upper Egypt, and the Red Sea. The locations of these deposits are shown in Figures 2.1 through 2.4. Table 2.2 provides a key for use with these maps. All
SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority (Reference No. 51)
FIGURE 2.3
NILE DELTA GYPSUM DEPOSIT LOCATIONS

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority, (Reference No. 51)
<table>
<thead>
<tr>
<th>NUMBER DESIGNATION</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Matrouh</td>
</tr>
<tr>
<td>(2)</td>
<td>Omayed</td>
</tr>
<tr>
<td>(3)</td>
<td>Hammam</td>
</tr>
<tr>
<td>(4)</td>
<td>Gharbianiat</td>
</tr>
<tr>
<td>(5)</td>
<td>El Barkan</td>
</tr>
<tr>
<td>(6)</td>
<td>Maryout</td>
</tr>
<tr>
<td>(7)</td>
<td>Gerza</td>
</tr>
<tr>
<td>(8)</td>
<td>El Boqirat</td>
</tr>
<tr>
<td>(9)</td>
<td>El Shat</td>
</tr>
<tr>
<td>(10)</td>
<td>El Rayana</td>
</tr>
<tr>
<td>(11)</td>
<td>Ras Makarma</td>
</tr>
<tr>
<td>(12)</td>
<td>Wadi Gharandal</td>
</tr>
<tr>
<td>(13)</td>
<td>Ras Malaab</td>
</tr>
<tr>
<td>(14)</td>
<td>Wadi Sudr</td>
</tr>
<tr>
<td>(15)</td>
<td>Abu Samir</td>
</tr>
<tr>
<td>(16)</td>
<td>El Rayana Extension</td>
</tr>
<tr>
<td>(17)</td>
<td>Manzala</td>
</tr>
<tr>
<td>(18)</td>
<td>Gamalia</td>
</tr>
<tr>
<td>(19)</td>
<td>El Ballah</td>
</tr>
<tr>
<td>(20)</td>
<td>El Maasara</td>
</tr>
<tr>
<td>(21)</td>
<td>Koraymat</td>
</tr>
<tr>
<td>(22)</td>
<td>Red Sea Coast</td>
</tr>
<tr>
<td>(23)</td>
<td>Abu Ghouseon</td>
</tr>
<tr>
<td>(24)</td>
<td>El Ringa</td>
</tr>
</tbody>
</table>

**SOURCE:** Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority, (Reference No. 51)
gypsum ore that is used in Egypt is extracted from these deposits. Of the deposits listed in these figures, many have yet to be fully developed (51). The gypsum deposits or quarries in Egypt can be categorized into active, planned, and potential. The active or planned quarries include:

1. **El Barqan - Western Desert**
   This deposit, discovered in 1975 is owned by GYMCO. It is the largest deposit of gypsum ore found in Egypt to date, with 50 million tons of proven reserves, and 200 million tons of potential reserves. The entire deposit has yet to be fully explored. Its location is shown as Area (5) in Figure 2.1.

2. **El Ballah - Suez Canal**
   This is the oldest GYMCO quarry, having been in operation since 1908. This deposit has 3 million tons of confirmed reserves, and 2 million tons of potential reserves. This deposit is designated as Area (19) in Figure 2.3.

3. **Gerza - Helwan**
   This deposit is currently owned by the Kawmia Cement Company. Confirmed reserves are in excess of 3 million tons. This area is designated as Area (7) in Figure 2.1.

4. **Ras Malaab - Sinai Peninsula**
   The Sinai Manganese Company (SMC) holds the
lease for these deposits. Confirmed reserves are estimated at 18 million tons. SMC is currently studying the feasibility of starting operation at this location. This deposit is designated as Area (13) in Figure 2.2.

5. **Gharbaniat - Western Desert**

This deposit supplies the GYMCO processing facility at the same location. This quarry has been flooded by seasonal rains. As a result, ore is supplied by the GYMCO deposit at Omayed. This area is designated as Area (4) in Figure 2.1.

6. **Omayed - Western Desert**

This deposit is owned by GYMCO. These deposits will be exhausted within 3 to 4 years, given the current rate of production at this calcining facility. In future years gypsum ore will be transported to this plant from El Barkan. This area is designated as Area (3) in Figure 2.1.

7. **Maryout - Western Desert**

This deposit, owned by the Alexandria Cement Company, supplies the 10 thousand ton per year production facility located in the same area. This area is designated as Area (6) in Figure 2.1.

Potential deposits include:
1. **Fayoum Governorate**

The area, located 62 kilometers southwest of Cairo, contains four major deposits. Of these four, only one, Gerza, has been claimed by the Kawmia Cement Company. The other three, located at Qaret El Faras, El Tawil, and El Boqirat are currently available. These represent the only available deposits in Egypt that have not been claimed. Preliminary exploration work is still in progress. However, preliminary reserve estimates of 7 million tons have been calculated. These areas are designated as Areas (7) and (8) in Figure 2.1.

2. **Red Sea Shore**

Several deposits have been found in this area. However, no further investigation has been done on any of these deposits. These deposits are designated as Areas (11), (12), and (13) in Figure 2.4.

2.2.2 **Shift from Existing Materials**

Because of the damage caused to agricultural land, the use of Nile silt in the production of bricks has been officially forbidden. As a result, alternate solutions have been proposed. One alternative has been the use of clay as a raw material in the manufacturing of bricks.
Several large clay deposits have been discovered. Four factories designed to produce bricks from this clay are still in the planning stages. Additional plants, consisting of modernized red brick facilities are also being considered. Consequently, the substitution of clay brick for Nile silt brick is many years away. In addition, yards manufacturing shale and sand-lime bricks are few in number and are producing well below full capacity. As the government continues to curtail the production of red bricks and as "black market" prices continue to rise, contractors will be seeking less expensive interior walling products.

Over the next ten years a tendency towards larger housing units and highrise buildings would favor the substitution for brick in the construction of interior partitions, as architects and engineers would desire economy and minimal weight for non-load-bearing partitions. As discussed earlier, Arab Contractors (ICON) and GYMCO have begun to produce gypsum blocks and panels, in an attempt to capture this developing market for alternative partition products. Other manufacturers of gypsum partitions are scheduled to begin production within the next two years. Despite such problems and limitations as poor water resistance, the need for a surface coating, and poor impact resistance, gypsum blocks and panels are gradually being accepted in Egypt. This phenomenon, together with the availability of low cost gypsum ore throughout the country, as was described in Section 2.2.1, suggests that the production of these products in Egypt may be economically feasible.
CHAPTER THREE

MARKET ANALYSIS

This chapter is specifically concerned with the supply and demand of building products used in the construction and finishing of interior partitions. These products include the numerous types of bricks, gypsum blocks and panels, and calcined gypsum or plaster.

The chapter covers two major aspects. The first major aspect is to review the historical supply and consumption of calcined gypsum, and then use these data to make future projections. In addition, a comprehensive profile of suppliers is presented, outlining actual output versus anticipated rates of production.

The second aspect is supply and demand forecasts for both bricks and gypsum partition products, presenting different scenarios for expected supply. A summary will follow, bringing together potential supply with the expected levels of demand to determine the possible gaps or surpluses for these products under different scenarios.

The analysis and conclusions derived in this chapter will be subsequently employed in the case study analysis of Chapter 6. For this later chapter, the demand and supply projections of Chapter 3 will be used in the formulation of a marketing and sales strategy and in determining overall project economic viability.
3.1 Calcined Gypsum

3.1.1 Demand

The first source of gypsum product demand, the demand for plaster, can be derived through the use of the historical average ratio of calcined gypsum to cement consumption. Table 3.1 shows the historical average ratio of calcined gypsum to cement consumption. This ratio has exhibited an upward trend, from 0.04 in 1971 to a maximum of 0.08 in 1978. In addition, the average ratio over the last four years has been 0.07.

This upward trend can be explained by such factors as changes in users' consumption patterns caused by shortages in cement, substitutability of gypsum for cement in certain uses, and price differentials. This third factor, perhaps the most significant, has been brought about by the existence of dual markets. As the gap between officially determined and "black market" cement prices has widened, the demand for plaster relative to that of cement has increased.

Since reaching its peak in 1978, this ratio has undergone a gradual decline. This decline has been effected through all or some of the following factors: (1) changes in building design and planning standards, (2) changes in construction methods, (3) quality control improvements, (4) managerial improvements, (5) reductions in the wastage of materials, and (6) the emergence of a "black market" for plaster. These factors have all generally contributed to relative reductions in calcined gypsum usage.
TABLE 3.1

RATIO OF CALCINED GYPSUM (PLASTER) TO CEMENT CONSUMPTION FOR EGYPT

(metric tons)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PLASTER CONSUMPTION</th>
<th>CEMENT CONSUMPTION</th>
<th>GYPSUM-CEMENT RATIO (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>127,000</td>
<td>2,933,000</td>
<td>0.0433</td>
</tr>
<tr>
<td>1972</td>
<td>147,000</td>
<td>2,952,000</td>
<td>0.0498</td>
</tr>
<tr>
<td>1973</td>
<td>164,000</td>
<td>3,029,000</td>
<td>0.0541</td>
</tr>
<tr>
<td>1974</td>
<td>157,000</td>
<td>3,071,000</td>
<td>0.0511</td>
</tr>
<tr>
<td>1975</td>
<td>191,000</td>
<td>3,712,000</td>
<td>0.0515</td>
</tr>
<tr>
<td>1976</td>
<td>232,000</td>
<td>4,135,000</td>
<td>0.0561</td>
</tr>
<tr>
<td>1977</td>
<td>280,000</td>
<td>4,123,000</td>
<td>0.0679</td>
</tr>
<tr>
<td>1978</td>
<td>329,000</td>
<td>4,138,000</td>
<td>0.0795</td>
</tr>
<tr>
<td>1979</td>
<td>353,000</td>
<td>5,550,000</td>
<td>0.0636</td>
</tr>
<tr>
<td>1980</td>
<td>340,000</td>
<td>5,368,000</td>
<td>0.0633</td>
</tr>
</tbody>
</table>

Average ≈ 0.07

(1) Ratio = Plaster Consumption/Cement Consumption

SOURCE: Construction/Contracting Industry Study
Final Report, Volume 2, July 1981
(Original Source: Ministry of Planning Data)
(Reference: No. 63)
Assuming the continuation of this downward trend, a conservative demand coefficient of 0.07 has been used. This is lower than those used by McKee-Kearny (97) and the Ministry of Housing (98) which use estimates of 0.08 to 0.10 for the ratio of calcined gypsum to cement consumption.

Table 3.2 shows the relationship of plaster to cement consumption in the United States for the same period. The period 1971-76 shows this demand coefficient experiencing a 40 percent decrease, as drywall products have been increasingly substituted for plaster in the construction of interior walls. In recent years this ratio has remained relatively stable (131). It is expected that in future years the ratio for Egypt may come closer to that of the U.S., as more plaster is available and Egyptian contractors adopt the improved construction and management techniques of the U.S. and Europe.

To calculate future levels of plaster demand, cement demand forecasts were taken from the Booz Allen and Hamilton Report (31). The methodology used in these forecasts began with a consideration of past construction volume with respect to Gross National Product (GNP) and investment. These historical data showed that the average ratio of investment to GNP was approximately 0.20 to 1. In addition, the average ratio of net construction volume to total investment was found to be 45.8 percent. These data are shown in Table 3.3. Only the period of 1971-76 has been used in this analysis, as it is indicative of the latest trends in both domestic economic activity and construction demand. The study arrived at a correlation of 8000 metric tons (3333 cubic meters) of cement to one million Egyptian pounds (adjusted to 1975 prices) invested in construction. Scenarios, or
# TABLE 3.2

**RATIO OF CALCINED GYPSUM (PLASTER) TO CEMENT CONSUMPTION FOR THE UNITED STATES**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PLASTER CONSUMPTION</th>
<th>CEMENT CONSUMPTION</th>
<th>GYPSUM-CEMENT RATIO *</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>917,000 (1)</td>
<td>76,908,000 (1)</td>
<td>0.0119</td>
</tr>
<tr>
<td>1972</td>
<td>841,000 (2)</td>
<td>80,777,000 (2)</td>
<td>0.0104</td>
</tr>
<tr>
<td>1973</td>
<td>771,000 (2)</td>
<td>86,200,000 (2)</td>
<td>0.0089</td>
</tr>
<tr>
<td>1974</td>
<td>629,000 (2)</td>
<td>79,027,000 (2)</td>
<td>0.0080</td>
</tr>
<tr>
<td>1975</td>
<td>535,000 (3)</td>
<td>67,112,000 (3)</td>
<td>0.0080</td>
</tr>
<tr>
<td>1976</td>
<td>490,000 (3)</td>
<td>71,150,000 (3)</td>
<td>0.0069</td>
</tr>
<tr>
<td>1977</td>
<td>427,000 (4)</td>
<td>77,240,000 (4)</td>
<td>0.0055</td>
</tr>
<tr>
<td>1978</td>
<td>526,000 (4)</td>
<td>83,331,000 (4)</td>
<td>0.0063</td>
</tr>
<tr>
<td>1979</td>
<td>416,000 (4)</td>
<td>83,357,000 (4)</td>
<td>0.0050</td>
</tr>
<tr>
<td>1980</td>
<td>398,000 (4)</td>
<td>74,349,000 (4)</td>
<td>0.0054</td>
</tr>
<tr>
<td>1981</td>
<td>392,000 (4)</td>
<td>70,074,000 (4)</td>
<td>0.0056</td>
</tr>
</tbody>
</table>

* Ratio = Plaster Consumption/Cement Consumption

**SOURCE:** United States Department of Commerce, *Construction Review.*

(1) November 1977 (Reference: No. 131)
(2) May 1979 (Reference: No. 130)
(3) December 1980 (Reference: No. 129)
(4) March/April 1982 (Reference: No. 128)
### TABLE 3.3

**GDP, INVESTMENT, AND CONSTRUCTION VOLUME**
(1000 Current Egyptian Pounds)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>G.N.P.</th>
<th>INVESTMENT</th>
<th>CONSTRUCTION</th>
<th>INV./G.N.P. (%)</th>
<th>CONSTRUCTION/G.N.P. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969/70</td>
<td>2,552,000</td>
<td>359,520</td>
<td>244,500</td>
<td>14.1</td>
<td>9.6</td>
</tr>
<tr>
<td>1970/71</td>
<td>2,700,500</td>
<td>361,400</td>
<td>245,500</td>
<td>13.4</td>
<td>9.1</td>
</tr>
<tr>
<td>1971/72</td>
<td>2,884,000</td>
<td>374,900</td>
<td>259,000</td>
<td>13.0</td>
<td>9.0</td>
</tr>
<tr>
<td>1973</td>
<td>3,217,000</td>
<td>465,200</td>
<td>277,300</td>
<td>14.5</td>
<td>8.6</td>
</tr>
<tr>
<td>1974</td>
<td>3,751,000</td>
<td>645,100</td>
<td>340,000</td>
<td>17.2</td>
<td>9.1</td>
</tr>
<tr>
<td>1975</td>
<td>4,401,000</td>
<td>1,123,400</td>
<td>521,300</td>
<td>25.5</td>
<td>11.8</td>
</tr>
<tr>
<td>1976</td>
<td>5,396,000</td>
<td>1,115,700</td>
<td>531,500</td>
<td>20.7</td>
<td>9.8</td>
</tr>
</tbody>
</table>

limits, were developed for cement demand. The lower limit was calculated, assuming an annual GNP growth rate of 7 to 9 percent. The upper limit was derived using a GNP growth rate of 10 to 12 percent. Using the ratio of investment to GNP and construction volume to total investment, together with the correlation of cement to construction, the study estimated levels of cement consumption for the period 1982-90 as shown in Table 3.4. These forecasts for cement consumption are translated into plaster demand using the previously defined demand coefficient of 0.07.

Because this report is investigating the feasibility of a panel production facility in the Fayoum Governorate, the analysis of the local Fayoum plaster market is critical. Because data for this region are somewhat sketchy and unreliable, an alternative approach must be employed utilizing other available information.

Table 3.5 presents data for 1980 construction output. These levels of output have been derived according to the 1980-84 Five-Year Plan, showing a breakdown of public sector work by region. These regions are defined in Figure 3.1.

Table 3.5 shows that the expected output of the Fayoum region, referred to as North Upper Egypt, is 33 million Egyptian pounds, or 4 percent of total national output (63). This table also shows that the share of total housing and building construction is 3 percent for this region. This implies that the expected market for construction within the Fayoum region, would range from 3 to 4 percent of national demand. This constitutes a small market, particularly relative to that of Cairo, which consumes approximately 50 percent of all housing and building construction in Egypt.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>Cement Demand Lower Limit (metric tons) (a)</th>
<th>Cement Demand Upper Limit (metric tons) (b)</th>
<th>Plaster Demand Lower Limit (metric tons) (3)</th>
<th>Plaster Demand Upper Limit (metric tons) (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>6,085,000</td>
<td>8,060,000</td>
<td>415,000</td>
<td>551,000</td>
</tr>
<tr>
<td>1983</td>
<td>6,532,000</td>
<td>8,805,000</td>
<td>443,000</td>
<td>599,000</td>
</tr>
<tr>
<td>1984</td>
<td>7,044,000</td>
<td>9,610,000</td>
<td>474,000</td>
<td>650,000</td>
</tr>
<tr>
<td>1985</td>
<td>7,655,000</td>
<td>10,495,000</td>
<td>506,000</td>
<td>701,000</td>
</tr>
<tr>
<td>1986</td>
<td>8,297,000&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>11,460,000</td>
<td>548,000</td>
<td>765,000</td>
</tr>
<tr>
<td>1987</td>
<td>8,566,000&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>12,315,000</td>
<td>566,000</td>
<td>837,000</td>
</tr>
<tr>
<td>1988</td>
<td>9,049,000&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>13,666,000&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>599,000</td>
<td>915,000</td>
</tr>
<tr>
<td>1989</td>
<td>9,533,000&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>14,924,000&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>632,000</td>
<td>1,002,000</td>
</tr>
<tr>
<td>1990</td>
<td>10,018,000&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>16,297,000&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>665,000</td>
<td>1,096,000</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Extrapolated using Booz Allen and Hamilton growth rates.

<sup>(2)</sup> Extrapolated using McKee-Kearney growth rates.

<sup>(3)</sup> Plaster demand determined by multiplying cement demand by average demand coefficient of 0.07 taken from Table 3.1.

**SOURCES:**

(b) Booz Allen and Hamilton, "Strategic Study for Building Materials and Ceramics," Part XII, 1977. (Reference: No. 31)
TABLE 3.5

BREAKDOWN OF CONSTRUCTION OUTPUT IN 1980 ACCORDING TO 1980-84 FIVE YEAR PLAN

(1979 Prices)

<table>
<thead>
<tr>
<th>Regions</th>
<th>Total ***</th>
<th>Land</th>
<th>Industry</th>
<th>Transport</th>
<th>Public Utilities</th>
<th>Housing</th>
<th>Building</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td>Public Sector Allocated...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cairo</td>
<td>339</td>
<td>35</td>
<td>6</td>
<td>5</td>
<td>71</td>
<td>41</td>
<td>84</td>
</tr>
<tr>
<td>Alexandria</td>
<td>203</td>
<td>23</td>
<td>27</td>
<td>33</td>
<td>36</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>Delta</td>
<td>40</td>
<td>9</td>
<td>19</td>
<td>16</td>
<td>18</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Suez Canal</td>
<td>162</td>
<td>17</td>
<td>23</td>
<td>19</td>
<td>15</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>North Upper Egypt</td>
<td>33</td>
<td>6</td>
<td>14</td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>South Upper Egypt</td>
<td>90</td>
<td>9</td>
<td>23</td>
<td>19</td>
<td>15</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Aswan</td>
<td>42</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>14</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Matrouh</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>966</td>
<td>100</td>
<td>119</td>
<td>100</td>
<td>172</td>
<td>100</td>
<td>195</td>
</tr>
</tbody>
</table>

Public Sector Unallocated *** | 199 | 16 | neg | 123 | 4 | 7 | 49 |

Total Public Sector | 1165 | 113 | 172 | 320 | 273 | 100 |

Private Sector | 300 | 27 | 36 | 58 | 11 | 118 |

Total Output of New Work | 1463 | 140 | 208 | 336 | 274 | 318 | 169 |

Repair and Maintenance | 70 | - | - | - | - | - |

Total Output | 1533 | 140 | 208 | 336 | 274 | 318 | 169 |

Per cent of Totals | 100 | 14 | 21 | 19 | 22 | 11 |

* Totals do not necessarily sum to zero due to rounding
** $1 = L.E. 0.36$
*** For definition of sectors see Table 3.2
**** Includes both unallocated and central allocations
L.E.: Million Egyptian Pounds

FIGURE 3.1
THE REGIONS AND GOVERNORATES OF EGYPT
FIGURE 3.1 (continued..)
THE REGIONS AND GOVERNORATES OF EGYPT

1. CAIRO
   Cairo
   Giza
   Kalyubia

2. ALEXANDRIA
   Alexandria
   Behera

3. DELTA
   Menufia
   Gharbia
   Kair El Sheikh
   Damietta
   Dakahlia

4. SUEZ CANAL
   Sinal
   Port Said
   Ismailia
   Suez
   Sharkia
   Red Sea (North)

5. NORTH UPPER EGYPT
   Beni Suef
   Minya
   Fayoum
   Red Sea (Middle)

6. SOUTH UPPER EGYPT
   Sohag
   Kena
   Aswan
   Red Sea (South)

7. ASIUT
   Assiut
   New Valley

8. MATROUH
   Matrouh

SOURCE: Construction/Contracting Industry Study
Final Report, Volume 2, July 1981
(Reference: No. 63)
These levels of output for Fayoum and Cairo can be considered representative of regional demand for plaster and partition products. Thus, for this analysis and the one for partition products, the consumption levels for plaster and partition products around Fayoum and Cairo are taken as 4 and 50 percent of national demand, respectively.

3.1.2 Supply

Historical supply and consumption of calcined gypsum are shown in Table 3.6. These figures cover the period from 1970-71 to 1980. Throughout most of this period domestic suppliers were able to cope with the increasing demand for calcined gypsum. This was evidenced by the small quantities that were exported of 25, 19, and 9 thousand tons in 1977, 1978, and 1979, respectively. The period since 1977 has shown a gradual decline in the surplus of calcined gypsum. This surplus may have turned into a deficit by 1980, as evidenced by the Ministry of Housing's tender offer to import 100 thousand metric tons of plaster in that year. Additional evidence is provided by the increasing divergence between the official price versus the black market price. While the official price ranged from 22 to 25 Egyptian pounds per ton in 1981, the black market price has reached levels as high as 75 pounds per ton.

This shortage of calcined gypsum has apparently urged some existing producers to plan for starting new operations or expanding existing ones.

GYMCO, the dominant supplier of calcined gypsum, with a market share of 75 percent, is currently undertaking five projects:
<table>
<thead>
<tr>
<th>YEAR</th>
<th>PRODUCTION</th>
<th>CONSUMPTION</th>
<th>SURPLUS (GAP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970/71</td>
<td>127,000</td>
<td>127,000</td>
<td>0</td>
</tr>
<tr>
<td>1971/72</td>
<td>195,000</td>
<td>147,000</td>
<td>48,000</td>
</tr>
<tr>
<td>1973 (18 Months)</td>
<td>164,000</td>
<td>164,000</td>
<td>0</td>
</tr>
<tr>
<td>1974</td>
<td>195,000</td>
<td>157,000</td>
<td>38,000</td>
</tr>
<tr>
<td>1975</td>
<td>131,000</td>
<td>191,000</td>
<td>(60,000)</td>
</tr>
<tr>
<td>1976</td>
<td>250,000</td>
<td>232,000</td>
<td>18,000</td>
</tr>
<tr>
<td>1977</td>
<td>305,000</td>
<td>280,000</td>
<td>25,000</td>
</tr>
<tr>
<td>1978</td>
<td>348,000</td>
<td>329,000</td>
<td>19,000</td>
</tr>
<tr>
<td>1979</td>
<td>362,000</td>
<td>353,000</td>
<td>9,000</td>
</tr>
<tr>
<td>1980</td>
<td>340,000</td>
<td>340,000</td>
<td>0</td>
</tr>
</tbody>
</table>

(1) Domestic Consumption = (Domestic Production) - Exports + Imports

SOURCE: McKee-Kearney, Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company, 1979

(Original Source: Booz Allen and Hamilton, "Strategic Study for Building Materials and Ceramics," Part XII, 1977.)

(Reference: No. 97)
1) The addition of one rotary kiln to the production plant at Gharbaniat, increasing annual production by 20,000 metric tons to a total rate of output of 80,000 tons.

2) The addition of one rotary kiln to the processing plant at El Alamein, increasing production by 20,000 tons to achieve a total of 80,000 metric tons per year.

3) The addition of two rotary kilns to the processing facility at El Ballah, increasing annual plaster production from 130,000 to 180,000 metric tons.

4) The construction of a new production facility at Gharbaniat, with an annual productive capacity of 300,000 metric tons. The construction of this plant began in April, 1981. The expected production startup date is April, 1983.

5) The construction of a new production facility at Sadat City. This plant will produce 300,000 metric tons of calcined gypsum per year. Initial contracts between GYMCO and selected contractors were signed in April, 1982. The expected commissioning and startup is scheduled for April, 1984.
The Kawmia Cement Company has already obtained approval from the Ministry of Housing to build a new production facility at Helwan. Gypsum ore will be supplied by existing Kawmia quarries located 60 kilometers south of Helwan at Gerza. Kawmia has access to other deposits in Fayoum, however, these deposits are contaminated with clay. Because the reserves at Gerza are estimated to last for only three more years, Kawmia has contacted the Sinai Manganese Company (SMC) with regard to the supply of raw materials from the SMC quarries at Ras Malaab, located 300 kilometers away.

Another potential producer of calcined gypsum is Mahmoud Osman. This company is expecting to produce 120,000 metric tons per year by 1985. Gypsum ore will be supplied by Osman quarries located at Sidr in Sinai, approximately 50 kilometers from Ras Malaab.

An additional amount of 10,000 metric tons per year is produced by the Alexandria Cement Company, which has no plans for future expansion.

The future production of calcined gypsum by these producers is summarized in Table 3.7 providing a breakdown of these data into existing and additional production. These data provide lower and upper production limits that can be used in the assessment of future plaster supply (97).

3.1.3 Demand/Supply Analysis and Summary

The data derived in the previous two sections are summarized in Table 3.8 and Figure 3.2, showing the lower level of plaster demand and the potential for a substantial plaster surplus by
### Table 3.7
Forecasted Plaster Production Breakdown
(metric tons)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>GYMCO</th>
<th>KADNIA CEMENT COMPANY</th>
<th>ALEXANDRIA CEMENT COMPANY</th>
<th>M. OSHAN</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EXISTING</td>
<td>ADDITIONAL</td>
<td>EXISTING</td>
<td>ADDITIONAL</td>
<td>EXISTING</td>
</tr>
<tr>
<td>1982</td>
<td>250,000</td>
<td>110,000</td>
<td>80,000</td>
<td>-</td>
<td>10,000</td>
</tr>
<tr>
<td>1983</td>
<td>250,000</td>
<td>110,000</td>
<td>80,000</td>
<td>-</td>
<td>10,000</td>
</tr>
<tr>
<td>1984</td>
<td>250,000</td>
<td>335,000</td>
<td>80,000</td>
<td>225,000</td>
<td>10,000</td>
</tr>
<tr>
<td>1985</td>
<td>250,000</td>
<td>590,000</td>
<td>80,000</td>
<td>225,000</td>
<td>10,000</td>
</tr>
<tr>
<td>1986</td>
<td>250,000</td>
<td>669,000</td>
<td>80,000</td>
<td>300,000</td>
<td>10,000</td>
</tr>
<tr>
<td>1987</td>
<td>250,000</td>
<td>710,000</td>
<td>80,000</td>
<td>300,000</td>
<td>10,000</td>
</tr>
<tr>
<td>1988</td>
<td>250,000</td>
<td>710,000</td>
<td>80,000</td>
<td>300,000</td>
<td>10,000</td>
</tr>
<tr>
<td>1989</td>
<td>250,000</td>
<td>710,000</td>
<td>80,000</td>
<td>300,000</td>
<td>10,000</td>
</tr>
<tr>
<td>1990</td>
<td>250,000</td>
<td>710,000</td>
<td>80,000</td>
<td>300,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>

**Source:** McKee-Kearp, Development of Ros Malab Gypsum Deposits for Sinal Manganese Company, 1979. (Original Source: GYMCO Balance Sheets and Ministry of Housing Statistics) (Reference: No. 97)
<table>
<thead>
<tr>
<th>YEAR</th>
<th>PLASTER PRODUCTION LOWER LIMIT (1)</th>
<th>PLASTER PRODUCTION UPPER LIMIT (2)</th>
<th>PLASTER CONSUMPTION LOWER LIMIT (3)</th>
<th>PLASTER CONSUMPTION UPPER LIMIT (4)</th>
<th>SURPLUS GAP-MINIMUM</th>
<th>SURPLUS GAP-MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>340,000</td>
<td>450,000</td>
<td>415,000</td>
<td>551,000</td>
<td>(211,000)</td>
<td>35,000</td>
</tr>
<tr>
<td>1983</td>
<td>340,000</td>
<td>525,000</td>
<td>443,000</td>
<td>599,000</td>
<td>(259,000)</td>
<td>82,000</td>
</tr>
<tr>
<td>1984</td>
<td>340,000</td>
<td>1,002,000</td>
<td>474,000</td>
<td>650,000</td>
<td>(310,000)</td>
<td>528,000</td>
</tr>
<tr>
<td>1985</td>
<td>340,000</td>
<td>1,305,000</td>
<td>506,000</td>
<td>701,000</td>
<td>(397,000)</td>
<td>799,000</td>
</tr>
<tr>
<td>1986</td>
<td>340,000</td>
<td>1,425,000</td>
<td>548,000</td>
<td>765,000</td>
<td>(425,000)</td>
<td>877,000</td>
</tr>
<tr>
<td>1987</td>
<td>340,000</td>
<td>1,470,000</td>
<td>566,000</td>
<td>837,000</td>
<td>(497,000)</td>
<td>904,000</td>
</tr>
<tr>
<td>1988</td>
<td>340,000</td>
<td>1,470,000</td>
<td>599,000</td>
<td>915,000</td>
<td>(575,000)</td>
<td>871,000</td>
</tr>
<tr>
<td>1989</td>
<td>340,000</td>
<td>1,470,000</td>
<td>632,000</td>
<td>1,002,000</td>
<td>(662,000)</td>
<td>838,000</td>
</tr>
<tr>
<td>1990</td>
<td>340,000</td>
<td>1,470,000</td>
<td>665,000</td>
<td>1,096,000</td>
<td>(756,000)</td>
<td>805,000</td>
</tr>
</tbody>
</table>

(1) Assumes that only existing calcined gypsum production will be present in future. From Table 3.7-Column 10.

(2) Assumes all planned future production will proceed as scheduled. From Table 3.7-Column 12.

(3) From Table 3.4-Column 4

(4) From Table 3.4-Column 5


FIGURE 3.2

CALCINED GYPSUM SUPPLY/DEMAND-LOWER LIMIT
(Million Metric Tons)

SOURCES: McKee-Kearney, Development of Ras Malaab Gypsum Deposits for
Sinai Manganese Company, 1979. (Original Source: GYMCO Balance
Sheets) (Reference: No. 97).

Booz Allen and Hamilton, "Strategic Study for Building Materials and
1990. This level of demand is based on a real GNP growth rate of 7 to 9 percent. The upper limit for demand shown in Figure 3.3, assumes a 10 to 12 percent rate of real GNP growth. This graph portrays a lower potential surplus for plaster.

Gross Domestic Product (GDP), has over the last six years increased at an average 8 percent per annum. Between 1980 and 1981, GDP grew an estimated 10 percent, with the petroleum sector and service industries contributing the sharpest gains. For 1982, real GDP growth is expected to decrease to 8.5 percent, due to substantially reduced oil revenues (50). Consequently, a GDP growth rate of 7 to 9 percent appears to be more consistent with current economic forecasts. This implies that the lower limit for calcined gypsum, depicted in Figure 3.2, provides a more reasonable estimate of future demand.

Although the current annual supply of 340 thousand metric tons is expected to triple by 1990, such a substantial increase appears doubtful. GYMCO's addition of two new rotary kilns to the existing production facilities at Gharbaniat, El Alamein, and El Ballah has been delayed by one year, extending completion until late 1983 at the earliest. The construction of new production facilities at Gharbaniat and Sadat City is still in the preliminary stages, with expected completion dates extended to 1986. It is reasonable to assume that the additional production levels for GYMCO from 1982 through 1990 will lag those shown in Table 3.7 by at least two years.

The construction and operation of new production facilities for Kawmia Cement Company and Mahmoud Osman have been delayed by two to three years, as the result of work stoppages and bureaucratic hindrances (142).
FIGURE 3.3
CALCINED GYPSUM SUPPLY/DEMAND-UPPER LIMIT
(Million Metric Tons)

Given the results of this analysis, plaster shortages will occur through 1984, under the assumption that all additional production is delayed by two years and that actual demand is represented by the lower limit shown in Figure 3.2.

3.2 Interior Partition Walling Products

3.2.1 Demand

Because data for the demand for interior partition products are currently unavailable, alternative methods must be used. One such method uses demand forecasts for housing or building units, and converts these data into a reasonable approximation of partition demand. This process begins by multiplying the number of units by the average floor area of a typical housing unit, and subsequently translating this number into wall surface area using Ministry of Housing coefficients. For the purposes of this analysis, two housing unit forecasts are used, each representing different rates of growth for the aggregate housing stock.

One estimate of housing demand comes from the Egyptian Ministry of Housing's "National Policy for Meeting the Housing Problem" (98). This forecast of demand was based on an assessment of census data, taking into account the stock of all existing dwellings, regardless of whether they are officially constructed or not. This unofficial, or informal sector, is defined as all portions of construction output which do not conform to all applicable laws and regulations. Although the exact size of this sector is unknown, it is considered to represent a large share of the output of the private sector.
These Ministry of Housing forecasts for numbers of housing units, referred to as "Scenario I" are shown in Table 3.9. The Ministry of Housing assumes that the average area of a typical housing unit is 56.6 square meters, and uses this coefficient to translate the number of housing units into square meters of floor area. In addition it is assumed that the service buildings described in footnote (2) of Table 3.9 would be required per 1000 new dwelling units. This is roughly equivalent to 3.5 square meters of service building for each new housing unit constructed.

An alternative forecast of demand for building has been presented by the Construction/Contracting Industry Study (CIS) Group (63). These forecasts have been derived, taking into account current economic conditions and the capacity of the construction industry in Egypt. The methodology employed in this process was as follows:

1. Previous levels of output were used as a base for estimating future demand
2. The effects of the 1980-84 Five Year Plan on the construction industry were assessed
3. The housing sector and its subsequent demand for construction were analyzed
4. A preliminary estimate of demand was prepared using steps 1 through 3
5. The estimates derived in step 4 were analyzed with regard to various macroeconomic constraints, such as the real rate of growth of the Egyptian
TABLE 3.9
EXPECTED VOLUME OF HOUSING AND OTHER BUILDING FOR 1982-85
FIVE YEAR PLAN - SCENARIO I

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NUMBER OF HOUSING UNITS</th>
<th>AREA OF UNITS SQUARE METERS (1)</th>
<th>AREA OF SERVICES SQUARE METERS (2)</th>
<th>TOTAL AREA SQUARE METERS (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>125,000</td>
<td>7,075,000</td>
<td>437,500</td>
<td>7,512,500</td>
</tr>
<tr>
<td>1983</td>
<td>135,000</td>
<td>7,641,000</td>
<td>472,500</td>
<td>8,113,500</td>
</tr>
<tr>
<td>1984</td>
<td>145,000</td>
<td>8,207,000</td>
<td>507,500</td>
<td>8,714,500</td>
</tr>
<tr>
<td>1985</td>
<td>160,000</td>
<td>9,056,000</td>
<td>560,000</td>
<td>9,616,000</td>
</tr>
</tbody>
</table>

(1) Average area of housing unit is 56.6 square meters.

(2) For every 1,000 dwelling units there are 3,500 square meters of service buildings, assuming:

- 1500 m\(^2\) of combined sex primary school
- 600 m\(^2\) of Mosque
- 1400 m\(^2\) of social, trade, and commercial buildings

(3) Total Area = (Area of Units) + (Area of Services)

SOURCE: Construction/Contracting Industry Study
Final Report, Volume 2, July 1981
(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979) (Reference: No. 63)
economy and the capacity of the construction industry to produce forecasted levels of output.

The past output of the construction industry that is used in step 1 is particularly difficult to estimate, as historical data are generally unreliable. The CIS Report uses the Ministry of Planning adjusted estimates for output, together with an additional estimated 150 million Egyptian Pounds (1979 rates) for the informal sector.

The 1980-84 Five-Year Plan that is used in step 2 can be a useful document, provided adjustments are made, so that it is compatible with actual economic growth. As the primary source of work, the government plays an influential role in support of the domestic construction industry. As a result, the Five-Year Plan can provide information on planned governmental increases in construction output over the five-year period.

Final CIS housing demand projections have been estimated using the previous steps and future levels of output based on provisions for a future population growth of 2.3 percent and the replacement of the existing housing stock. These projections, referred to as "Scenario II", are shown in Table 3.10.

The CIS Group has also provided an alternative set of estimates for service buildings, claiming that the Ministry of Housing has underestimated the demand for these structures. Using the assumption of 3,500 square meters of service building per 1000 new housing units, CIS adds an additional 304 thousand Egyptian pounds (1980 prices) of central service building, to obtain the estimates shown in Column 5 of Table 3.10.
TABLE 3.10
EXPECTED VOLUME OF HOUSING AND OTHER BUILDINGS FOR 1982-85
FIVE YEAR PLAN - SCENARIO II

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NUMBER OF HOUSING UNITS</th>
<th>AREA OF UNITS SQUARE METERS (1)</th>
<th>AREA OF SERVICES SQUARE METERS (2)</th>
<th>TOTAL AREA SQUARE METERS (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>129,700</td>
<td>7,341,020</td>
<td>1,939,080</td>
<td>9,180,100</td>
</tr>
<tr>
<td>1983</td>
<td>133,000</td>
<td>7,527,800</td>
<td>1,862,069</td>
<td>9,389,869</td>
</tr>
<tr>
<td>1984</td>
<td>136,700</td>
<td>7,737,220</td>
<td>1,985,057</td>
<td>9,622,277</td>
</tr>
<tr>
<td>1985</td>
<td>139,700</td>
<td>7,907,020</td>
<td>1,908,046</td>
<td>9,815,066</td>
</tr>
</tbody>
</table>

(1) Average area of housing unit is 56.6 square meters.

(2) Based on revised forecasts taken from current Construction/Contracting Industry study.

(3) Total Area = (Area of Units) + (Area of Services)

SOURCE: Construction/Contracting Industry Study
Final Report, Volume 2, July 1981
(Reference: No. 63)
These estimates assume a breakdown of:

1. School and educational building construction - 33%
2. Health and social service building construction - 13%
3. Administrative and government office building construction - 15%
4. Commercial and retail building construction - 14%
5. Maintenance and repair - 25%

The housing areas shown in Tables 3.9 and 3.10 can be translated into wall surface area using the Ministry of Housing technical coefficient of 55 bricks per one square meter of interior and exterior wall and 9000 bricks per 100 square meters of floor area (98). Calculating the wall area for each 100 square meters of housing yields:

\[
\frac{9000 \text{ Bricks}}{100 \text{m}^2 \text{ Floor Area}} \times \frac{55 \text{ Bricks}}{1 \text{m}^2 \text{ Interior Wall}} = 1.64 \text{m}^2 \text{ of Wall Area per m}^2 \text{ of Floor Area}
\]

This figure is consistent with the field observations and measurements taken of middle income apartments that were visited in Nasr City by the M.I.T. Gypsum Project Group, where it was found that the total surface area was approximately 170 square meters for a 96 square meter apartment. For these typical apartments, the interior partition wall area was 120 square meters, or 70 percent of total wall area. The remaining 30 percent was comprised of exterior walls and window and door areas.

Taking these coefficients as representative of a typical housing unit, a final quantity of 1.12 square meters of interior partition per square meter of housing is derived. Using this ratio, the calculated housing floor areas of Table 3.9 and 3.10 are converted into
demand for interior partitions in terms of area. These demand estimates are presented in Table 3.11.

In order to estimate the technical coefficient for interior partitions in buildings other than housing, a chart, such as that shown in Table 3.12 showing the required number of workers to produce one million pounds of construction must be used. Table 3.12 indicates that the construction of other buildings uses 56 workers or approximately three quarters of the masonry work force for housing (120). Assuming that such a ratio is representative of service building construction, the coefficient for these partitions would be equal to three quarters of that of housing, or 0.86 square meters of partition per one square meter of floor area. The floor areas of Tables 3.9 and 3.10 are translated into partition area through the use of this coefficient. These estimates are shown in Table 3.13.

Because data for the floor area of industrial buildings are unavailable, the CIS Report estimate of 1.5 million square meters of interior partition per year has been used for both scenarios (63).

Summaries of total demand for 1982-85 for Scenarios I and II are presented in Tables 3.14 and 3.15, respectively. Although the projections shown under Scenarios I and II are roughly equivalent by 1985, the rates at which this level of demand is achieved are different. The average increase of 2 percent per annum for scenario II shown in Table 3.15 is quite conservative compared to the average annual increase of 7 percent for Scenario I.
### TABLE 3.11

EXPECTED DEMAND FOR WALLING MATERIALS IN HOUSING

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AREA OF HOUSING UNITS SCENARIO I (1) SQUARE METERS</th>
<th>AREA OF HOUSING UNITS SCENARIO II (2) SQUARE METERS</th>
<th>PARTITION AREA SCENARIO I (3) SQUARE METERS</th>
<th>PARTITION AREA SCENARIO II (3) SQUARE METERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>7,075,000</td>
<td>7,341,020</td>
<td>7,924,000</td>
<td>8,221,942</td>
</tr>
<tr>
<td>1983</td>
<td>7,641,000</td>
<td>7,527,800</td>
<td>8,557,920</td>
<td>8,431,136</td>
</tr>
<tr>
<td>1984</td>
<td>8,207,000</td>
<td>7,737,220</td>
<td>9,191,840</td>
<td>8,665,586</td>
</tr>
<tr>
<td>1985</td>
<td>9,056,000</td>
<td>7,907,020</td>
<td>10,142,720</td>
<td>8,855,362</td>
</tr>
</tbody>
</table>

(1) From Table 3.3 - Column 3
(2) From Table 3.10 - Column 3
(3) Assumes 1.12 square meters of partition per 1 square meter of housing

**SOURCE:** Construction/Contracting Industry Study


(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979) (Reference: No. 63)
### TABLE 3.12

**TYPE OF WORKERS REQUIRED TO BUILD 1,000,000 L.E. OF DIFFERING FACILITY TYPES**

<table>
<thead>
<tr>
<th>TYPE OF WORKER AND SKILL LEVEL</th>
<th>RESIDENTIAL</th>
<th>INDUSTRIAL</th>
<th>OTHER BUILDING</th>
<th>NON BUILDING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WEIGHT</td>
<td>NUMBER (1)</td>
<td>WEIGHT</td>
<td>NUMBER (1)</td>
</tr>
<tr>
<td>Masonry</td>
<td>.140</td>
<td>73</td>
<td>.066</td>
<td>26</td>
</tr>
<tr>
<td>Steel Fixing</td>
<td>.061</td>
<td>32</td>
<td>.031</td>
<td>26</td>
</tr>
<tr>
<td>Carpentry</td>
<td>.111</td>
<td>50</td>
<td>.111</td>
<td>50</td>
</tr>
<tr>
<td>Concrete Fixing</td>
<td>.198</td>
<td>106</td>
<td>.145</td>
<td>53</td>
</tr>
<tr>
<td>Sanitary Works</td>
<td>.160</td>
<td>72</td>
<td>.096</td>
<td>35</td>
</tr>
<tr>
<td>Plastering</td>
<td>.192</td>
<td>95</td>
<td>.181</td>
<td>66</td>
</tr>
<tr>
<td>Painting</td>
<td>.027</td>
<td>14</td>
<td>.013</td>
<td>20</td>
</tr>
<tr>
<td>Dismantle</td>
<td>.126</td>
<td>66</td>
<td>.131</td>
<td>45</td>
</tr>
<tr>
<td>Electrical Works</td>
<td>.015</td>
<td>6</td>
<td>.106</td>
<td>38</td>
</tr>
<tr>
<td>Miscellaneous (2)</td>
<td>.522</td>
<td>265</td>
<td>.490</td>
<td>396</td>
</tr>
</tbody>
</table>

**Total**: 1,000 680 1,000 483 1,000 652 1,000 986

---

(1) Assumes number of workers required to build 1 Million Egyptian Pounds of Facility working 8, 8 hour shifts per week.

(2) Excludes excavation and earthwork.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AREA OF OTHER BUILDINGS SCENARIO I (1) SQUARE METERS</th>
<th>AREA OF OTHER BUILDINGS SCENARIO II (2) SQUARE METERS</th>
<th>PARTITION AREA SCENARIO I (3) SQUARE METERS</th>
<th>PARTITION AREA SCENARIO II (3) SQUARE METERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>437,500</td>
<td>1,839,080</td>
<td>377,300</td>
<td>1,586,023</td>
</tr>
<tr>
<td>1983</td>
<td>472,500</td>
<td>1,862,069</td>
<td>407,484</td>
<td>1,605,848</td>
</tr>
<tr>
<td>1984</td>
<td>507,500</td>
<td>1,885,057</td>
<td>437,668</td>
<td>1,625,673</td>
</tr>
<tr>
<td>1985</td>
<td>560,000</td>
<td>1,908,046</td>
<td>482,944</td>
<td>1,645,499</td>
</tr>
</tbody>
</table>

(1) From Table 3.9 - Column 4
(2) From Table 3.10 - Column 4
(3) Assumes 0.862 square meters of interior partition for every 1 square meter of building.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>HOUSING (1)</th>
<th>OTHER BUILDINGS (2)</th>
<th>INDUSTRIAL (3)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>7,924,000</td>
<td>437,500</td>
<td>1,500,000</td>
<td>9,861,500</td>
</tr>
<tr>
<td>1983</td>
<td>8,557,920</td>
<td>472,500</td>
<td>1,500,000</td>
<td>10,530,420</td>
</tr>
<tr>
<td>1984</td>
<td>9,191,840</td>
<td>507,500</td>
<td>1,500,000</td>
<td>11,199,340</td>
</tr>
<tr>
<td>1985</td>
<td>10,142,720</td>
<td>560,000</td>
<td>1,500,000</td>
<td>12,202,720</td>
</tr>
</tbody>
</table>

(1) From Table 3.11- Column 4
(2) From Table 3.13- Column 2
(3) Because data on this building type are inconclusive, Construction Industry Study Group estimates were used.

TABLE 3.15
EXPECTED TOTAL AREA OF INTERIOR PARTITIONS
SCENARIO II (square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>HOUSING (1)</th>
<th>OTHER BUILDINGS (2)</th>
<th>INDUSTRIAL (3)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>8,221,942</td>
<td>1,586,023</td>
<td>1,500,000</td>
<td>11,307,965</td>
</tr>
<tr>
<td>1983</td>
<td>8,431,136</td>
<td>1,605,848</td>
<td>1,500,000</td>
<td>11,536,984</td>
</tr>
<tr>
<td>1984</td>
<td>8,665,686</td>
<td>1,625,673</td>
<td>1,500,000</td>
<td>11,791,359</td>
</tr>
<tr>
<td>1985</td>
<td>8,855,682</td>
<td>1,645,499</td>
<td>1,500,300</td>
<td>12,001,361</td>
</tr>
</tbody>
</table>

(1) From Table 3.11—Column 5
(2) From Table 3.13—Column 5
(3) Because data on this type of building is inconclusive, Construction Industry Study Group estimates were used.

SOURCE: Construction/Contracting Industry Study
Final Report, Volume 2, July 1981
(Reference: No. 63)
3.2.2 Supply

The supply of interior partition building products in Egypt can be broken down into two major types of products:

1. Bricks and Blocks

2. Gypsum Blocks and Panels

Bricks and blocks include such products as Nile-silt, or red bricks, shale bricks, sand-lime bricks, and hagarite blocks. In this report two major aspects regarding the production of these products will be reviewed. The first aspect is the quantity and location of existing production facilities. The second aspect is the competitive position of individual products relative to the overall market.

Figures for the future production of red brick are not very reliable, one such estimate is shown in Table 3.16. These estimates are based on a study conducted by Booz Allen and Hamilton (BAH) in 1976, which assumed a total of 300 factories, each producing 5 million bricks per year (31). BAH claims that a precise count of the number of brick producing factories at either a governorate or national level is not possible. BAH uses the General Organization for Housing, Building, and Planning Research (GOHBPR) estimates of 120 factories for the Greater Cairo area and 300 for the whole country. In 1976, GOHBPR also estimated that the 120 factories in the Greater Cairo area were producing 600 million bricks per year, giving an average of 5 million bricks per production facility. This 1976 figure of 1.5 billion red bricks per year is more likely related to capacity than to actual levels of production. Thus the forecasted rates of red brick production for future years tend to be unreliable.
### TABLE 3.16

RED BRICK PRODUCTION
(Booz, Allan and Hamilton Estimates)

(number of bricks)

#### EXISTING PRODUCTION

<table>
<thead>
<tr>
<th>YEAR</th>
<th>TRADITIONAL PLANTS</th>
<th>MODERNIZED PLANTS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>175,000,000</td>
<td>1,325,000,000</td>
<td>1,500,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>-</td>
<td>1,500,000,000</td>
<td>1,500,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>-</td>
<td>1,500,000,000</td>
<td>1,500,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>-</td>
<td>1,500,000,000</td>
<td>1,500,000,000</td>
</tr>
</tbody>
</table>

In 1982, GOHBPR completed an extensive field study of present red brick production facilities. This national survey consisted of two steps:

1. Survey questionnaires were sent to all applicable governmental agencies for each governorate, providing data on the number and location of red brick factories, as well as their annual rates of production.

2. An extensive field survey was conducted by GOHBPR officials between September 1981 and February 1982. This included visits to various brick factories within each governorate. The information obtained from these visits was used to estimate the annual production for each region independently, using the following step-wise procedure:

a. The number of brick forming tables per factory was determined. Assuming a forming table production rate of 6000 bricks per 6 hour shift, annual production was defined as:

\[
\text{Annual Production} = \text{Forming Tables} \times 6000 \times \frac{250 \text{ Work Days}}{\text{Year}}
\]
b. The relationship between the number of forming tables and kiln dimensions was determined, giving average estimates of:

i) 120 cubic meters of kiln loading capacity for factories with 1 forming table.

ii) 225 cubic meters of kiln loading capacity for factories with 2 forming tables.

iii) 378 cubic meters of kiln loading capacity for factories with 3 forming tables.

iv) 504 cubic meters of kiln loading capacity for factories with 4 forming tables.

These figures were then translated into future production estimates shown in Table 3.17. These are also related to capacity and may not be indicative of actual rates of production. It is reasonable to assume that red brick production is roughly equal to consumption due to such factors as the short two week time lag between order and delivery, the lack of red brick imports and exports, and the small or nonexistent producer inventories (80).

A cursory inspection of Table 3.17 shows that supply will range from approximately 4.2 to 3.7 billion bricks per year. This overall reduction in red brick manufacturing reflects the continued governmental efforts to curb production. Using the assumption that only 25 percent of all red bricks produced will be used in the construction of interior partition walls, the forecasts of Table 3.17 can be translated into a range of 19.1 to 16.8 million square meters of interior partition.
## TABLE 3.17

RED BRICK PRODUCTION  
(GOHBPR ESTIMATES)  
(number of bricks)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>TOTAL PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>4,202,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>3,924,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>3,818,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>3,702,000,000</td>
</tr>
</tbody>
</table>

(Reference: No. 60)
These projections far exceed any reasonable demand projections for construction activity. Because these estimates are high, they will merely serve as an insight for production capacity, and will not be used in the subsequent forecasts.

Because of the recently diminished availability of Nile Silt, other sources of raw material have been sought. One such source has been found in the numerous shale deposits, located throughout the Egyptian desert. Shale brick offers a viable alternative to red brick. These bricks have been used extensively in other countries, with the manufacturing technology adopted for use with Egyptian shale. The use of these bricks in Egypt has been successful because of their ability to be manufactured with minimum modifications to existing red brick production facilities.

Presently there are plans for eight major production facilities for shale brick. Their forecasted rates of production are shown in Table 3.18. The numbers in this table represent rates of output that would occur if all previously planned production facilities were producing at full capacity. Although the first factory, owned by the Siegwart Company, has gone into production, there is no immediate evidence that any of the other plants are producing according to schedule. Consequently, the output of the remaining seven firms is categorized as additional production.

Sand-lime bricks are also considered a viable substitute for red bricks, particularly in light of the abundance of sand and limestones in Egypt. Currently there are three factories producing sand-lime bricks: Al-Abbasiyah, Nasr City, and Quesna. This production is summarized in Table 3.19. Production at the Nasr City and Quesna facilities has faced
<table>
<thead>
<tr>
<th>Year</th>
<th>Sihawat Company (1)</th>
<th>Egyptian Company for Refractories (2)</th>
<th>Marib Company for Thrustplates (1)</th>
<th>Misr Company for Slate Bricks (2)</th>
<th>Misr Company for Insulating Bricks (2)</th>
<th>Misr El-Ahmyt Company (2)</th>
<th>BHI Subsidiary Company (2)</th>
<th>MARS El-Dek Comp (2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>100,000,000</td>
<td>15,000,000</td>
<td>25,000,000</td>
<td>200,000,000</td>
<td>60,000,000</td>
<td>10,000,000</td>
<td>25,000,000</td>
<td>10,000,000</td>
<td>651,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>100,000,000</td>
<td>15,000,000</td>
<td>50,000,000</td>
<td>200,000,000</td>
<td>60,000,000</td>
<td>10,000,000</td>
<td>25,000,000</td>
<td>10,000,000</td>
<td>680,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>100,000,000</td>
<td>15,000,000</td>
<td>50,000,000</td>
<td>200,000,000</td>
<td>60,000,000</td>
<td>10,000,000</td>
<td>25,000,000</td>
<td>10,000,000</td>
<td>680,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>100,000,000</td>
<td>15,000,000</td>
<td>50,000,000</td>
<td>200,000,000</td>
<td>60,000,000</td>
<td>10,000,000</td>
<td>25,000,000</td>
<td>10,000,000</td>
<td>680,000,000</td>
</tr>
</tbody>
</table>

(1) Existing Production  
(2) Additional Production

(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979)  
(Reference: No. 63)
<table>
<thead>
<tr>
<th>YEAR</th>
<th>Al-Abbasiyah</th>
<th>Nasr City</th>
<th>Qurna</th>
<th>Al-Numayra</th>
<th>Rasheed</th>
<th>El Gharbi</th>
<th>El Abbasiyah</th>
<th>Alexandria</th>
<th>EXISTING</th>
<th>ADDITIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>30,000,000</td>
<td>60,000,000</td>
<td>45,000,000</td>
<td>50,000,000</td>
<td>25,000,000</td>
<td>25,000,000</td>
<td>-</td>
<td>135,000,000</td>
<td>100,000,000</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>30,000,000</td>
<td>60,000,000</td>
<td>45,000,000</td>
<td>50,000,000</td>
<td>30,000,000</td>
<td>50,000,000</td>
<td>25,000,000</td>
<td>135,000,000</td>
<td>155,000,000</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>30,000,000</td>
<td>60,000,000</td>
<td>45,000,000</td>
<td>50,000,000</td>
<td>30,000,000</td>
<td>50,000,000</td>
<td>25,000,000</td>
<td>135,000,000</td>
<td>205,000,000</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>30,000,000</td>
<td>60,000,000</td>
<td>45,000,000</td>
<td>50,000,000</td>
<td>30,000,000</td>
<td>50,000,000</td>
<td>50,000,000</td>
<td>135,000,000</td>
<td>220,000,000</td>
<td></td>
</tr>
</tbody>
</table>

(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979)
(Reference: No. 63)
numerous external and internal technical problems since its start-up, with such problems as lack of spare parts for equipment and machinery, periodic cut-off of water and electrical supply, and lack of skilled labor. Because of these problems, it is assumed that these factories will not produce at the full capacity production levels given in Table 3.19. Some of the problems encountered at the Al-Abbasiah factory are similar to those of the previous two plants. Additional problems include the antiquated age of the plant equipment and the unreliability of the contractor carrying the limestone from the company quarry to the processing plant. Currently this plant is producing at 65 percent of the full capacity stated in Table 3.19. Information on the status of other proposed projects is presently unavailable, making accurate assessment of future production difficult.

Additional types of bricks and blocks include lightweight concrete aggregate and hagarite bricks. Lightweight concrete blocks are made of portland cement and sand. These blocks are used to a limited extent for walls and partitions. Hagarite bricks are a special type of brick that are native to Egypt. Instead of the sand and lightweight aggregate that are used in concrete block, hagarite bricks use portland cement combined with fines and limestone aggregate. The production of those products is shown in Tables 3.20 and 3.21.

The total domestic production of bricks is summarized in Tables 3.22 and 3.23. Table 3.22 shows the estimated local supply, assuming that all plants are operational and operating at 100 percent capacity. An additional column was added for miscellaneous brick types. This category includes mud and stabilized soil bricks. Because of insufficient information on these products, Ministry of Housing
<table>
<thead>
<tr>
<th>YEAR</th>
<th>NASR CITY</th>
<th>KENESHA</th>
<th>NASR CITY (EXTENSION)</th>
<th>RAMESA (EXTENSION)</th>
<th>EL MENTA</th>
<th>ALHARAM</th>
<th>ABBASIA</th>
<th>ALEXANDRIAT</th>
<th>EXISTING</th>
<th>ADDITIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>50,000,000</td>
<td>50,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>50,000,000</td>
<td>-</td>
<td>-</td>
<td>100,000,000</td>
<td>275,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>50,000,000</td>
<td>50,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>50,000,000</td>
<td>-</td>
<td>-</td>
<td>100,000,000</td>
<td>350,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>50,000,000</td>
<td>50,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>50,000,000</td>
<td>-</td>
<td>-</td>
<td>100,000,000</td>
<td>425,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>50,000,000</td>
<td>50,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>75,000,000</td>
<td>100,000,000</td>
<td>450,000,000</td>
</tr>
</tbody>
</table>

### TABLE 3.21

**HAGARITE BRICK PRODUCTION**

*(number of bricks)*

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ABBASIA</th>
<th>EL BASATEEN</th>
<th>OTHER FACTORIES</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>18,000,000</td>
<td>9,000,000</td>
<td>105,000,000</td>
<td>132,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>18,000,000</td>
<td>9,000,000</td>
<td>105,000,000</td>
<td>132,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>18,000,000</td>
<td>9,000,000</td>
<td>105,000,000</td>
<td>132,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>18,000,000</td>
<td>9,000,000</td>
<td>105,000,000</td>
<td>132,000,000</td>
</tr>
</tbody>
</table>

**SOURCE:** Construction/Contracting Industry Study  
Final Report, Volume 2, July 1981  
(Original Source: Ministry of Housing, *The National Policy for Meeting the Housing Problem*, 1979)  
(Reference: No. 63)
TABLE 3.22

ESTIMATED LOCAL SUPPLY OF BRICKS - BY BRICK CATEGORY
(number of bricks)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>RED BRICK (1)</th>
<th>SHALE BRICK (2)</th>
<th>SAND-LIME (3)</th>
<th>LIGHTWEIGHT AGGREGATE (4)</th>
<th>BASALTITE (5)</th>
<th>MISCELLANEOUS*</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>1,500,000,000</td>
<td>465,000,000</td>
<td>235,000,000</td>
<td>375,000,000</td>
<td>132,000,000</td>
<td>50,000,000</td>
<td>2,757,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>1,500,000,000</td>
<td>490,000,000</td>
<td>290,000,000</td>
<td>450,000,000</td>
<td>132,000,000</td>
<td>50,000,000</td>
<td>2,912,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>1,500,000,000</td>
<td>490,000,000</td>
<td>340,000,000</td>
<td>525,000,000</td>
<td>132,000,000</td>
<td>50,000,000</td>
<td>3,037,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>1,500,000,000</td>
<td>490,000,000</td>
<td>355,000,000</td>
<td>550,000,000</td>
<td>132,000,000</td>
<td>50,000,000</td>
<td>3,077,000,000</td>
</tr>
</tbody>
</table>

* This category includes Mud (green) Bricks and Stabilized Soil Bricks

(1) From Table 3.16 - Column 4
(2) From Table 3.18 - Column 10
(3) From Table 3.19 - Columns 10 and 11
(4) From Table 3.20 - Columns 10 and 11
(5) From Table 3.21 - Column 5

(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979) (Reference: No. 63)
## TABLE 3.23

**ESTIMATED LOCAL SUPPLY OF BRICK - BY PLANT CATEGORY**

*(number of bricks)*

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXISTING BRICK PRODUCTION (1)</th>
<th>ADDITIONAL BRICK PRODUCTION (2)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>2,017,000,000</td>
<td>740,000,000</td>
<td>2,757,000,000</td>
</tr>
<tr>
<td>1983</td>
<td>2,017,000,000</td>
<td>895,000,000</td>
<td>2,912,000,000</td>
</tr>
<tr>
<td>1984</td>
<td>2,017,000,000</td>
<td>1,020,000,000</td>
<td>3,037,000,000</td>
</tr>
<tr>
<td>1985</td>
<td>2,017,000,000</td>
<td>1,060,000,000</td>
<td>3,077,000,000</td>
</tr>
</tbody>
</table>

(1) Compiled from:
- Table 3.16 Columns 2 and 3
- Table 3.18 Column 2
- Table 3.19 Column 10
- Table 3.20 Column 10
- Table 3.21 Columns 2-4

(2) Compiled from:
- Table 3.18 Columns 3-9
- Table 3.19 Column 11
- Table 3.20 Column 11


*(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979) (Reference: No. 63)*
estimates of production were used. Table 3.23 gives a production breakdown in terms of existing and additional brick production (31, 135).

As indicated in the beginning of this section, the second source of supply for interior partition wall products is the producers of gypsum blocks and panels. The information collected concerning the existing or potential producers of partition walls is summarized in Tables 3.24 through 3.28. The largest potential producer of gypsum partition wall products is GYMCO, followed by Kuwait Egyptian Company, AZAMCO, ICON and Misro Gypsum. The production of these gypsum-based walling materials is relatively new to the Egyptian market and is still in its early stages, with annual output substantially below that of brick manufacturers.

Table 3.29 summarizes the potential production of interior partitions. The total number of bricks is translated into square meters of interior partition using the assumptions that one square meter of partition requires 55 bricks and that 25 percent of all bricks produced is used in the construction of interior partitions. It was assumed that existing production was comprised of only those production facilities which were operational or for which construction had begun. All other facilities were grouped under the category of additional production.

3.2.3 Demand/Supply Analysis and Summary

A summary presenting different scenarios for interior partition product supply and demand is shown in Table 3.30. These scenarios are represented graphically in Figures 3.4 and 3.5. In these figures, the minimum expected supply of these products represents the
TABLE 3.24

POTENTIAL PRODUCTION OF GYPSUM INTERIOR PARTITION BUILDING PRODUCTS - GYMCO
(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXISTING PRODUCTION</th>
<th>ADDITIONAL PRODUCTION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1983</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1984</td>
<td>-</td>
<td>675,000 (1)</td>
<td>675,000</td>
</tr>
<tr>
<td>1985</td>
<td>-</td>
<td>2,775,000 (2)</td>
<td>2,775,000</td>
</tr>
</tbody>
</table>

(1) Plant to produce this quantity at Gharbaniat; contract already signed.

(2) Includes additional production of 1984. Remainder of additional production to take place at Sadat City. Invitation for bidders appeared in March, 1981.

TABLE 3.25

POTENTIAL PRODUCTION OF GYPSUM INTERIOR PARTITION BUILDING PRODUCTS - KUWAIT
EGYPTIAN INVESTMENT COMPANY
(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXISTING PRODUCTION</th>
<th>ADDITIONAL PRODUCTION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1983</td>
<td>-</td>
<td>665,000</td>
<td>665,000</td>
</tr>
<tr>
<td>1984</td>
<td>-</td>
<td>936,000</td>
<td>936,000</td>
</tr>
<tr>
<td>1985</td>
<td>-</td>
<td>1,170,000</td>
<td>1,170,000</td>
</tr>
</tbody>
</table>

(Original Source: Kuwait Egyptian Investment Company) (Reference: No. 97)
### Table 3.26

**Potential Production of Gypsum Interior Partition Building Products - Misro Gypsum**

(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Existing Production</th>
<th>Additional Production</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>75,000</td>
<td>75,000</td>
<td>150,000</td>
</tr>
<tr>
<td>1983</td>
<td>75,000</td>
<td>75,000</td>
<td>150,000</td>
</tr>
<tr>
<td>1984</td>
<td>75,000</td>
<td>75,000</td>
<td>150,000</td>
</tr>
<tr>
<td>1985</td>
<td>75,000</td>
<td>75,000</td>
<td>150,000</td>
</tr>
</tbody>
</table>

**Source:** McKee-Kearny, *Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company*, 1981.

(Original Source: Misro Gypsum) (Reference: No. 97)
### TABLE 3.27

POTENTIAL PRODUCTION OF GYPSUM INTERIOR PARTITION BUILDING PRODUCTS - AZAMCO

(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXISTING PRODUCTION</th>
<th>ADDITIONAL PRODUCTION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1983</td>
<td>-</td>
<td>216,000</td>
<td>216,000</td>
</tr>
<tr>
<td>1984</td>
<td>-</td>
<td>240,000</td>
<td>240,000</td>
</tr>
<tr>
<td>1985</td>
<td>-</td>
<td>240,000</td>
<td>240,000</td>
</tr>
</tbody>
</table>

**SOURCE:** McKee-Kearny, Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company, 1981.

(Original Source: AZAMCO) (Reference: No. 97)
### TABLE 3.23

**POTENTIAL PRODUCTION OF GYPSUM INTERIOR PARTITION BUILDING PRODUCTS - ICON**  
*(square meters)*

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXISTING PRODUCTION</th>
<th>ADDITIONAL PRODUCTION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>200,000</td>
<td>-</td>
<td>200,000</td>
</tr>
<tr>
<td>1983</td>
<td>250,000</td>
<td>-</td>
<td>250,000</td>
</tr>
<tr>
<td>1984</td>
<td>300,000</td>
<td>-</td>
<td>300,000</td>
</tr>
<tr>
<td>1985</td>
<td>400,000</td>
<td>-</td>
<td>400,000</td>
</tr>
</tbody>
</table>

**SOURCE:** McKee-Kearny, Development of Ras Malaaq Gypsum Deposits for Sinai Manganese Company, 1981.  
*(Original Source: ICON) (Reference: No. 97)*
### TABLE 3.29

POTENTIAL PRODUCTION OF INTERIOR PARTITIONS  
(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXISTING BRICK PARTITION PRODUCTION (1)</th>
<th>ADDITIONAL BRICK PARTITION PRODUCTION (2)</th>
<th>EXISTING GYPSUM PARTITION PRODUCTION (3)</th>
<th>ADDITIONAL GYPSUM PARTITION PRODUCTION (4)</th>
<th>TOTAL EXISTING PRODUCTION</th>
<th>TOTAL ADDITIONAL PRODUCTION</th>
<th>TOTAL PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>9,168,182</td>
<td>1,363,636</td>
<td>275,000</td>
<td>79,000</td>
<td>9,443,182</td>
<td>3,630,636</td>
<td>13,073,818</td>
</tr>
<tr>
<td>1983</td>
<td>9,168,182</td>
<td>4,068,182</td>
<td>325,000</td>
<td>950,000</td>
<td>9,493,182</td>
<td>5,018,182</td>
<td>14,511,364</td>
</tr>
<tr>
<td>1984</td>
<td>9,168,182</td>
<td>6,368,182</td>
<td>1,625,000</td>
<td>1,360,000</td>
<td>9,793,182</td>
<td>6,365,182</td>
<td>16,158,364</td>
</tr>
<tr>
<td>1985</td>
<td>9,168,182</td>
<td>4,818,182</td>
<td>475,000</td>
<td>4,260,000</td>
<td>9,643,182</td>
<td>9,078,182</td>
<td>18,721,364</td>
</tr>
</tbody>
</table>

(1) From Table 3.27 Column 2. Assumes 25% of total brick production used for interior partitions. Also assumes 55 bricks per square meter of partition.

(2) From Table 3.27 Column 3. Assumes 25% of total brick production used for interior partitions. Also assumes 55 bricks per square meter of partition.

(3) Compiled from: Table 3.21-Column 2
Table 3.25-Column 2
Table 3.26-Column 2
Table 3.27-Column 2

(4) Compiled from: Table 3.22 Column 3
Table 3.23-Column 3
Table 3.24-Column 3
Table 3.26-Column 3
Table 3.27-Column 3

**SOURCE:** McKee-Kearny, Development of Ras Malaah Gypsum Deposits for Sina Manganese Company, 1981  
(Reference No. 97)
### TABLE 3.30

**INTERIOR PARTITION CONSUMPTION AND PRODUCTION SUMMARY**

*(square meters)*

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EXPECTED DEMAND (1) FOR PARTITIONS - SCENARIO 1</th>
<th>EXPECTED DEMAND (2) FOR PARTITIONS - SCENARIO II</th>
<th>EXPECTED SUPPLY (4) OF PARTITIONS - MINIMUM</th>
<th>EXPECTED SUPPLY (4) OF PARTITIONS - MAXIMUM</th>
<th>SHORTAGE (CIFS) - MINIMUM</th>
<th>SHORTAGE (CIFS) - MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>9,864,500</td>
<td>11,307,965</td>
<td>9,443,182</td>
<td>12,081,818</td>
<td>(-1,864,832)</td>
<td>3,002,218</td>
</tr>
<tr>
<td>1983</td>
<td>10,530,470</td>
<td>11,530,384</td>
<td>9,491,182</td>
<td>14,507,364</td>
<td>(-4,041,802)</td>
<td>3,984,944</td>
</tr>
<tr>
<td>1984</td>
<td>11,199,340</td>
<td>11,791,150</td>
<td>9,543,182</td>
<td>16,105,546</td>
<td>(-4,148,177)</td>
<td>4,906,706</td>
</tr>
<tr>
<td>1985</td>
<td>12,202,320</td>
<td>12,001,361</td>
<td>9,643,182</td>
<td>18,721,304</td>
<td>(-2,558,118)</td>
<td>6,518,444</td>
</tr>
</tbody>
</table>

*(1) From Table 3.7 - Column 5
(2) From Table 3.8 - Column 5
(3) From Table 3.29 - Column 6
(4) From Table 3.29 - Column 8


(Original Source: Ministry of Housing, *The National Policy for Meeting the Housing Problem*, 1979)
(Reference: No. 63)

(Reference: No. 97)
FIGURE 3.4

INTERIOR PARTITION SUPPLY/DEMAND—SCENARIO I
(Million Square Meters)


McKee-Kearny, Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company, 1981. (Reference: No. 97).
FIGURE 3.5
INTERIOR PARTITION SUPPLY/DEMAND—SCENARIO II
(Million Square Meters)


quantity that would be produced given the existing production facilities. The upper limit of supply represents the quantity of partitions that would be produced if all planned production facilities became operational on the originally scheduled dates.

The supply of red bricks, shown in Tables 3.16 and 3.17 will range between 1.5 and 4.0 billion bricks per year (31, 60). Because this upper limit of red brick production represents ultimate capacity, a more reasonable estimate would be between 1.5 and 2.5 billion bricks per year. Using the numbers given in Section 3.2.1, this would translate into 7 to 11 million square meters of interior partitions. Although contrary to the conclusions reached by GOHBPR, the trends of the last few years suggest that it is unlikely that red brick production will decrease, despite governmental efforts to curtail its production. It is highly probable that production will either remain constant or increase due to the higher prices the market will be willing to bear.

It is expected that the efforts to modernize the red brick facilities to produce bricks from desert shale will proceed slowly. It is unlikely that shale bricks will totally substitute for Nile-silt bricks by 1983, as was originally intended by government authorities. Complete substitution will occur by 1986 at the earliest (31). The only means of diminishing future supplies of red bricks is through stringent governmental pressure to convert from Nile silt to other materials. The likelihood of such an action is small.

Present shale brick production represents less than 20 percent of total brick production. Because of the high density and compressive strength of shale bricks, this product is less likely to be
used in the construction of interior partitions. As a result, only 10 to 15 percent of all shale bricks produced would be used for this purpose. In addition, as indicated in Section 3.2.2, only the Siegwart Company has begun production. All other proposed plants are not producing according to schedule. Presently, less than 25 percent of total anticipated production is being produced. Given these numbers, only 272 thousand square meters of interior partition are constructed using shale brick, a negligible quantity relative to total supply (135).

It is also expected that sand-lime bricks will capture a small market share for reasons similar to those for shale brick. As discussed in Section 3.2.2, many of the existing sand-lime brick production facilities are operating below capacity, due to various technical problems (74). Many of the proposed production facilities shown in Table 3.19 have been delayed. It is expected that actual sand-lime brick production will provide 400 thousand square meters of interior partition annually through 1985.

Lightweight concrete and Magarite blocks represent a small share of the total market for interior partition products. Because both of these blocks are produced from cement, a material in short supply in Egypt, actual production may fall below that shown in Tables 3.20 and 3.21.

Gypsum blocks may represent the strongest direct competition to any new partition product attempting to enter the market. Assuming GYMCO, Kuwait Egyptian, Misro Gypsum, and AZAMCO all proceed with current plans, over 4 million square meters of gypsum partitions will be produced by 1985. These products, as opposed to traditional brick, offer such advantages as reduced cost and ease of handling and
installation. Given the past history of these public-sector firms, it is likely that future production plans will proceed behind schedule.

Despite the numerous problems associated with the production of these walling products, minimum production will be approximately 10 million square meters per year by 1985. It is anticipated that actual production will be significantly higher than this, approximately 12 to 14 million square meters per year. Many manufacturers of gypsum-based products have formulated their future production plans, assuming the existence of a significant production "gap" for bricks (135). Many producers believed that gypsum blocks would fill 50 percent of that perceived "gap", as opposed to providing an economically feasible alternative to brick. This "gap" is most likely an imaginary one, as few buyers of these products within the construction industry have complained about actual shortages (140).

Given the two demand scenarios shown in Figures 3.4 and 3.5, it appears as though production will exceed demand by 1984. Because of this phenomenon, any new product must serve as a substitute for other walling materials. Substitutions within this market will prove to be difficult, in light of the long-standing use of brick in Egypt.

From the analysis of Section 3.1.3, it is possible to calculate the potential demand for these products for Cairo and Fayoum. This can be accomplished through the use of these regional multipliers, assuming that total public sector consumption of housing and building serves as a reasonable proxy for the consumption of plaster and interior partition products.
CHAPTER FOUR

PRODUCTION PROCESS OF GYPSUM CONSTRUCTION PRODUCTS

The production of gypsum construction products can be broken down into four components: exploration, quarrying, processing, and panel production. The data and information derived through the exploration process will ultimately determine the configuration and design of components employed in the later production stages. An exploratory analysis of the prospective quarry will provide information used in the design of a quarrying system that is capable of extracting gypsum ore at the least possible cost. Additional data and information resulting from chemical and physical analyses are employed in the design of the optimum processing and calcining facility.

Quarrying, processing, calcining, and panel production systems offer a wide array of alternatives and associated costs. Because the success of such a project will invariably depend on the capital and operating costs for these components, a detailed analysis of this equipment is essential. Consequently, an overview of the available types of equipment used in these process steps along with their corresponding attributes will be presented in the ensuing chapter.

The procedures and equipment described in this chapter will be used to select the most cost-efficient panel manufacturing process in the case study of Chapter 6. Each viable equipment option that is presented in this chapter will be considered in the design of the optional equipment configuration.
4.1 EXPLORATION PROCESS

4.1.1 Mapping and Survey of Site Conditions

Gypsum exploration can be broken down into two main categories - reconnaissance and target investigation, each of which can be divided into multiple stages as is shown in Figure 4.1.

An exploration sequence begins with the appraisal of large regions (governorates) for the express purpose of selecting those potentially rich in gypsum deposits.

This appraisal is followed by the detailed reconnaissance of these favorable regions in search of target areas. The target areas are investigated in detail, first on the surface, and, if warranted, then by three-dimensional test borings.

Some of these exploration stages may be bypassed depending on the available results of previous gypsum surveys by either individuals, business concerns, or local or regional government authorities.

Some of the preliminary evaluation steps include:

1. The preparation of surface geologic maps and surface sample data including analysis and test work on samples.

2. The review of any previous maps, reports, assays, wells, and drill hole records, and the history of the prospect if recently explored.

3. The preparation of all test boring information and verification that the drill pattern is representative of the actual gypsum quarry.

4. The plotting of all geologic data on general small-scale maps and an estimation of reserve tonnages by priority and
Figure 4.1
Gypsum Exploration Flow Diagram

**STEP #1**

**REGIONAL APPRAISAL**

- **O** - Geologic Computation for "Marketing" Area
- **O** - Photography

**EXPLORATION DECISION**

- **REGION NOT ATTRACTIVE AT THIS TIME**

- **REJECT: REGION UNFAVORABLE**

**STEP #2**

**DETAILED RECONNAISSANCE OF FAVORABLE AREAS**

- **F** - Examination of Outcrops and Sampling
- **F** - Reconnaissance Drilling for Stratigraphy and Chemical Analyses of All Gypsum Samples

**EXPLORATION DECISION**

- **AREA REMAINS FAVORABLE BUT NOT ATTRACTIVE AT THIS TIME**

**STEP #3**

**DETAILED THREE-DIMENSIONAL SAMPLING AND PRELIMINARY EVALUATION**

**EXPLORATION DECISION**

- **UNECONOMIC MINERAL DEPOSIT**

- **ECONOMIC MINERAL DEPOSIT**

**LEGEND**

- **O** - Office Study
- **F** - Field Investigation
- **L** - Laboratory Tests

**SOURCE:** Surface Mining American Institute of Mining, Metallurgical, and Petroleum Engineers, 1972. (Reference: No. 110)
quality grades. This map should include all transportation potentials and should show the extent of the gypsum deposits with respect to property ownership and control.

5. The evaluation of total quarry reserves in relation to the projected annual rate of production and the establishment of the life of the proposed quarry. Answers must be found to such questions as: Are more deposits and land available? Is the deposit open-ended laterally and downward and could more gypsum be added through more exploration.

Because the scale of a general-area map is too small to show the many pertinent features over a very broad area, a general quarry map of medium scale must be prepared. This general quarry map should provide a more detailed delineation of the gypsum deposit, and for reference to detailed quarry maps, cross sections, and tabular data, should show the locations of a few of the drillholes.

A detailed, large-scale quarry map should be prepared to cover the entire quarrying area. This map should contain all data pertinent to the quarrying problem, including depth, quality of gypsum, and character of the overburden. Each drillhole must be located on the map with its identifying number and surface elevation.

4.1.2 Chemical and Physical Testing

Because gypsum requires some post-mine treatment before it can be processed into building products, the process of transforming gypsum into a concentrate through physical and chemical treatments must be studied. This is accomplished through an extensive array of both physical and chemical laboratory tests.

Because of the basic premise that the crusher must be stronger
than the material it must crush, a material's resistance to crushing and its elastic properties must be measured. This is accomplished through uniaxial and triaxial compression, and uniaxial tensile strength tests.

The two most common chemical analyses in Egypt are differential thermal analysis and X-ray diffraction. Differential thermal analysis identifies the presence of particular minerals using the assumption that when certain minerals, such as gypsum, are heated at a uniform rate, endothermic and exothermic reactions take place. These reactions can be recorded through the use of a sensitive thermocouple. A thermally inert substance is subjected to parallel heat treatment as a reference material. A chart is then constructed to record the differential effect between the inert substance and the substance under investigation.

X-ray diffraction can also be used for mineral identification by obtaining a unique X-ray pattern for any particular mineralogical crystalline structure. Records are available through such organizations as the American Society for Testing and Materials (ASTM), showing the relationship between these diffraction patterns and specific minerals.
4.2 QUARRYING PROCESS

There are many factors that can influence the efficiency of a gypsum quarrying operation. One such factor is equipment selection and use.

In the planning stages of a new gypsum quarrying operation, the first task in the proper selection of equipment is the determination of the tonnage and characteristics of the gypsum to be quarried. This involves tests to determine the density, weight, both broken and in-place, of the waste-material, overburden, and gypsum ore.

Beyond the characteristics of the material to be quarried there are other factors to consider.

These include:

- Daily desired production rates
- Available capital
- Haul distance
- The working area available
- Climatic conditions

For maximum efficiency or productivity, it is necessary to balance and match all equipment components to both each other and to haul distance and grade. Because there are different sizes and types of equipment and different methods to do the same job, the final choice will ultimately be based on the equipment and methods which will provide the greatest production at the lowest cost.
4.2.1 *Removal of Overburden and Excavation*

In selecting a particular excavation and overburden stripping method, the ultimate aim is the removal of material at the least possible cost. Accomplishment of this goal requires the careful consideration of various factors, including geologic and topographic information and the proximity of the stripping operation to waste-disposal areas.

Once these factors have been determined, it is possible to determine the key components of the quarrying operation. Such an operation must begin with the preparation of the gypsum ore for moving. This loosening of the ore is usually performed through the use of a tractor-mounted ripper.

The digging of the gypsum ore or overburden follows the basic operation of loosening. The material must be in a manageable form or properly sized to fit the digging part of the earthmoving equipment. This step includes moving the material from its original, natural location to the place for its deposit. The distance involved in this moving may be a matter of only a few feet or several miles.

The final step in an excavation and stripping operation is that of dumping. This material will be deposited in either a general area or truck, depending on its final use. For overburden or other waste, the material will be dumped somewhat haphazardly at a location adjacent to the quarrying site, and will not be handled again, while gypsum ore is loaded in an orderly manner into haulage vehicles.

The work cycle for the equipment involved in this operation can be characterized by the repetitive steps or components of work that are performed over and over again. For a quarrying operation, the primary
work cycle is the loosening-digging-dumping-hauling-return process. This may all be done by one selected type of equipment, or it may be done by a selection of two or more types working as a team. The latter option suggests that each piece or set of equipment has its own work cycle which is interdependent with the preceding or following equipment. A typical quarrying operation is shown graphically in Figure 4.2.

The nature of the gypsum to be excavated and the estimated volume per day will narrow the equipment field to several possibilities. Potentially economically feasible equipment options include bulldozers, rippers, front-end-loaders, scrapers, and draglines. A listing of the attributes of the various types of equipment available will be presented in order to help define and explain the selection possibilities.

Most major equipment manufacturers provide clients with optimal equipment configurations based on required rates of output, and geologic and topographic data. These data are entered into computer simulation and optimization programs, yielding an equipment configuration that is capable of quarrying and transporting gypsum ore at the lowest possible cost.

a Bulldozer

Bulldozers may be subdivided on the basis of their mountings, into crawler-tractor- or wheel-tractor-mounted. Some of the advantages claimed for crawler-mounted bulldozers are:
FIGURE 4.2

TYPICAL QUARRYING OPERATION

SOURCE: Komatsu, Ltd.
Tokyo, Japan. 1982
1. The ability to deliver greater tractive effort, particularly on soft footing.
2. Ability to operate in rock formations, where rubber tires might be severely damaged.
3. Ability to travel over rough terrain, which may reduce the cost of maintaining haul roads.
4. Greater versatility.

Among the advantages claimed for wheel-mounted bulldozers are the following:

1. Higher travel speeds
2. Elimination of hauling equipment to transport the bulldozer to a quarry.
3. Greater output, particularly where considerable travelling is required.
4. Less operation fatigue.
5. Ability to travel on paved surfaces without damage to vehicles.

Under certain conditions bulldozers are satisfactory machines for moving overburden. In general, haul distances should be less than 300 feet. Either a crawler-mounted or wheel-mounted tractor may be used, with a crawler-mounted machine having an advantage on short hauls with soft or loose overburden, and a wheel-mounted machine having an advantage on longer hauls and firm ground (109).

A bulldozer equipped with a ripper attachment, and its corresponding specifications are shown in Figure 4.3. The output of
FIGURE 4.3
KOMATSU D155A BULLDOZER WITH MULTI-SHANK RIPPER ATTACHMENT

GENERAL DIMENSIONS
FIGURE 4.3 (Continued)

KOMATSU D155A SPECIFICATIONS

Drawbar Pull vs. Travel Speed

Flywheel Horsepower
Operating Weight (approx)
   Bare Tractor
   With Dozer
Engine: Model
   Piston Displacement
No. of Track Rollers (each side) 7
Track Shoe Width 22.0" Assembled Single Grouser
Length of Track on Ground 124.0"
Ground Pressure (with dozer) 13.51 PSI/93.2kPa
Ground Contact Area 5,468 sq. in.
Track Gauge 84.3"
Overall Dimensions
   Height (to top of exhaust pipe) 143.3"
   Length (bare tractor) 214.4"
   Length (with dozer) 270.9"
   Width (bare tractor) 110.6"
Blade Width 162.6"
Travel Speed (MPH)
   Forward
      1st 0 - 2.3
      2nd 0 - 4.2
      3rd 0 - 7.3

Reverse
      1st 0 - 2.8
      2nd 0 - 5.1
      3rd 0 - 8.5

320 HP/2000 RPM
59,850 lb
74,270 lb
KOMATSU S6D155-4
19.26 ltr
this bulldozer can be quickly estimated using the performance chart supplied by the manufacturer. Such a chart is shown in Figure 4.4.

The production curves of Figure 4.4 give the maximum uncorrected production for a bulldozer based on the following conditions:

1. 100% efficiency (60 minutes of operation for each hour)
2. Power shift machines with 0.05 minutes fixed times.
3. Dozer cuts for 50 feet, then drifts blade load to dump over a high wall.
4. Soil density is 2,300 lbs/LCY and 3,000 lbs/Bank Cubic Yard.
5. Material swell of 30% (load factor of 0.769).
6. Coefficient of Traction:
   a. Track Machines -0.5 or better
   b. Wheel Machines -0.4 or better
7. Hydraulically controlled blades used.

These curves are based on numerous field studies made under varying job conditions, consequently they represent only general production rates (93). Consequently, these production rates will have to be substantially reduced prior to their use in Egypt.

These curves were derived by Komatsu Ltd. in conformance with Komatsu equipment. Similar types of charts are available from other manufacturers such as Caterpillar, Case and TEREX.

b Ripper

A ripper is a plow like piece of equipment generally mounted on the rear of a crawler tractor, such as the one described in the previous section. It is designed to loosen material at the ground
FIGURE 4.4

KOMATSU DOZER PRODUCTION CURVES

SOURCE: KOMATSU Sales Mates
1981. (Reference: No. 93)
surface by penetrating into and breaking up the ground material as the ripper is pulled along.

Several types of hydraulically operated rippers are available with one to five shanks. The number of shanks used depends on the size of the tractor, the depth of penetration required, the resistance of the material being ripped, and the degree of breakage required (37). Although rippers subject tractors to severe abuse from sudden shocks and overloads, they are gaining in popularity.

A bulldozer equipped with a ripper attachment was shown in Figure 4.3. This picture showed an assembly of a set of ripper attachments on a supporting beam.

The quickest method of estimating ripper production is through the use of seismic velocity charts. These charts supplied by manufacturers, have been developed from field tests conducted in a variety of materials. Because of the extreme variations among materials of a specific classification, these charts must be recognized as being at best only a crude indicator of rippability. A seismic velocity chart for a Caterpillar dozers is illustrated in Figure 4.5. These velocities can be translated into bank cubic yards of production, using the graph shown in Figure 4.6.

c Front-End Loader

Front-end-loaders are used extensively to handle and transport bulk material, such as gypsum ore and overburden, to load trucks and excavate earth. They are both satisfactory and economical when used for such purposes. A typical loading unit and its specifications are shown in Figure 4.7.
FIGURE 4.5
SEISMIC WAVE VELOCITY CHART

FIGURE 4.7
CATERPILLAR 988B WHEEL LOADER

SOURCE: Caterpillar Tractor Company, Peoria, Illinois
FIGURE 4.7 (continued)
CATERPILLAR 988B SPECIFICATIONS

![Diagram of a Caterpillar 988B](image)

**GENERAL DIMENSIONS**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucket Type</td>
<td>lb</td>
<td>21,200</td>
</tr>
<tr>
<td>Capacity, Heaped</td>
<td>yd^3</td>
<td>7.00</td>
</tr>
<tr>
<td>Width</td>
<td>ft</td>
<td>11'11&quot;</td>
</tr>
<tr>
<td>Dump Clearance @ Full Lift and 45° Discharge</td>
<td>ft</td>
<td>11'4&quot;</td>
</tr>
<tr>
<td>Reach @ Full Lift and 45° Discharge</td>
<td>ft</td>
<td>6'3&quot;</td>
</tr>
<tr>
<td>Reach @ 45° Angle</td>
<td>ft</td>
<td>8'0&quot;</td>
</tr>
<tr>
<td>Reach With Lift Arm Horizontal and Bucket Level</td>
<td>ft</td>
<td>11'5&quot;</td>
</tr>
<tr>
<td>Digging Depth</td>
<td>in</td>
<td>2.70&quot;</td>
</tr>
<tr>
<td>Overall Length</td>
<td>ft</td>
<td>34'1&quot;</td>
</tr>
<tr>
<td>Overall Height</td>
<td>ft</td>
<td>22'9&quot;</td>
</tr>
<tr>
<td>Loader Clearance Circle (Bucket in Carry Position)</td>
<td>ft</td>
<td>55'10&quot;</td>
</tr>
<tr>
<td>Static Tipping Load, Full 35° Turn</td>
<td>lb</td>
<td>49,500</td>
</tr>
<tr>
<td>Breakout Force</td>
<td>lb</td>
<td>80,800</td>
</tr>
<tr>
<td>Operating Weight</td>
<td>lb</td>
<td>85,830</td>
</tr>
</tbody>
</table>

There are two types of front-end-loaders, the crawler-tractor-mounted and the wheel-tractor-mounted. They may be further classified by bucket capacities or the weights that the buckets can lift. The production rate of a front-end-loader can be determined using manufacturers charts and will depend on:

1. The fixed time required to load the bucket, shift gears, and dump the load,
2. the time required to travel from the loading to the dumping position,
3. the time required to return to the loading position, and
4. the actual volume of material hauled each trip.

The process of selecting a wheel loader can be broken down into five steps:

1. Determining required rates of production.
2. Determining loader cycle time and cycles per hour.
3. Determining required payload per cycle in loose cubic yards and pounds.
4. Determining required bucket size.
5. Make loader selection using bucket size and payload as the criteria to meet production requirements.

The required rates of production, when calculated, should exceed by a small margin the other critical units in the gypsum quarrying operation (36). Required production should be carefully calculated so that proper machine and bucket selections can be made.
For loader cycle times, a 0.45-0.55 minute basic cycle time is considered reasonable for most articulated loaders driven by a competent operator, particularly when hauling loose granular material over a reasonably smooth operating surface (35). This cycle time includes load, dump, four reversals of direction, full cycle of hydraulics, and minimum travel. Material type, pile height, and other factors may tend to either reduce or improve production, and should be added to or subtracted from the basic cycle time when applicable. These cycle time factors are given in Table 4.1. When hauls are involved, travel times can be estimated using a travel chart, giving the ranges to be used for both haul and return times. Haul and return times can be added to basic cycle time to obtain total cycle time. A typical chart is shown in Figure 4.8.

Track-type loader production can be estimated using methods similar to those employed for wheel loaders. However, cycle time for track loaders must be determined in a different manner. Total cycle time includes load, maneuver, travel, and dump time. Load time can range from 0.03 minutes for uniform aggregates to 0.20 minutes for soil and boulders. Maneuver time includes basic travel, four changes of direction and turning time. Maneuver time generally averages 0.22 minutes at full throttle with a competent operator (36). Travel time in a load and carry operation is comprised of hauls and return times. These times can be determined by using a travel chart, similar to the one shown in Figure 4.8. Dump time is dictated by the size and length of the dump target. For a typical gypsum quarrying operation, typical dump times into either on- or off-highway trucks can range from 0.04 to 0.07 minutes (35).
TABLE 4.1
CYCLE TIME FACTORS

<table>
<thead>
<tr>
<th>Materials</th>
<th>MINUTES ADDED (+) or SUBTRACTED (-) FROM BASIC CYCLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed</td>
<td>+0.02</td>
</tr>
<tr>
<td>Up to 1/8 inch</td>
<td>+0.02</td>
</tr>
<tr>
<td>1/8 inch to 3/4 inch</td>
<td>-0.02</td>
</tr>
<tr>
<td>3/4 inch to 6 inches</td>
<td>0.00</td>
</tr>
<tr>
<td>6 inches and over</td>
<td>+0.03 and up</td>
</tr>
<tr>
<td>Bank or broken</td>
<td>+0.04 and up</td>
</tr>
</tbody>
</table>

Miscellaneous
- Common ownership of trucks and loaders up to -0.04
- Independently owned trucks up to +0.04
- Contract operation up to -0.04
- Inconsistent operation up to +0.04
- Small target up to +0.04
- Fragile target up to +0.05

SOURCE: Caterpillar Performance Handbook
1981, (Reference: No. 35)
FIGURE 4.8

ESTIMATED HAUL AND RETURN TIME CHART - CATERPILLAR 988B

d  Scraper

Scrapers are self-operating to the extent that they can load, haul, and discharge material, and are not dependent on other equipment. If a scraper experiences a temporary breakdown, it is not necessary to stop the job, as could be the case for a machine which is used exclusively for one particular task.

Scrapers are the result of a compromise between loading and hauling machines. Draglines will usually surpass scrapers in loading only, while trucks may surpass them in hauling. However, their ability to load and haul earth gives them a definite advantage.

There are two types of scrapers, based on the type of tractor used to pull them—crawler-tractor-pulled or wheel-tractor-pulled.

For relatively short haul distances the crawler-type tractor, pulling a rubber-tired self-loading scraper is more economical. However, as haul distances increase, the low speed of a crawler tractor can be a disadvantage (38).

For longer haul distances, the higher speed of a wheel-type tractor-pulled scraper is more economical. Although the wheel-type tractor cannot deliver as great a tractive effort in loading a scraper, the higher travel speed will offset the disadvantage in loading when the haul distance is sufficiently long.

Wheel tractor-scarpers are designed and built in four basic configurations, each best fitted to a general set of conditions.

Two-axle tractor-scarpers are designed for the majority of conditions such as average haul distances, moderate to poor grades and
underfoot conditions. Two-axle scrapers can generally develop more tractive effort than a three-axle scraper with the same size engine. Two-axle scrapers are also more maneuverable because the two wheels of the single-axle tractor can pivot about their midpoint.

In contrast three-axle tractor scrapers are designed for stability and long-distance haulage at high speeds on well maintained, near-level roads. In addition, three-axle scrapers are safer to operate in case of the blow-out or trouble with the hitch or other working parts. Lastly, three-axle scrapers offer the advantage of being more versatile for a variety of uses as a tractor when detached from the scraper bowl unit.

Tandem-powered scrapers are available in both three- and two-axle versions. The two-axle models are generally designed for the severest of conditions - steep grades and poor underfoot conditions, average to poor haul roads and short to average haul distances. Three-axle units are generally of high capacity, and are primarily used for large-volume, long-distance hauling on moderate grades and moderate to good haul roads. Both types of tandem-powered units can self-load under favorable conditions.

A typical scraper and its specifications are shown in Figure 4.9.

A scraper is loaded by lowering the front end of the bowl until the cutting edge, which is attached to and extends across the width of the bowl, enters the ground and, at the same time, raising the front apron to provide an open slot through which the earth may flow into the bowl. This operation is continued until the bowl is filled. The size is specified as the heaped capacity of the haul, expressed in cubic yards.
Gradeability/Speed/Rimpull

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flywheel Power</td>
<td>330 HP</td>
</tr>
<tr>
<td>Operating Weight (empty)</td>
<td>66,150 lb</td>
</tr>
<tr>
<td>Scraper Capacity -</td>
<td></td>
</tr>
<tr>
<td>Struck</td>
<td>14 yd³</td>
</tr>
<tr>
<td>Heaped</td>
<td>20 yd³</td>
</tr>
<tr>
<td>Rated Load</td>
<td>48,000</td>
</tr>
<tr>
<td>Weight Distribution -</td>
<td></td>
</tr>
<tr>
<td>Empty</td>
<td>70%</td>
</tr>
<tr>
<td>Drive</td>
<td>70%</td>
</tr>
<tr>
<td>Rear</td>
<td>30%</td>
</tr>
<tr>
<td>Weight Distribution -</td>
<td></td>
</tr>
<tr>
<td>Loaded</td>
<td>55%</td>
</tr>
<tr>
<td>Drive</td>
<td>55%</td>
</tr>
<tr>
<td>Rear</td>
<td>45%</td>
</tr>
<tr>
<td>Rated Engine RPM</td>
<td>1900</td>
</tr>
<tr>
<td>Displacement</td>
<td>893 in³</td>
</tr>
<tr>
<td>Top Speed (loaded)</td>
<td>29 mph</td>
</tr>
<tr>
<td>Non-Stop Turning cycle</td>
<td>36'36&quot;</td>
</tr>
<tr>
<td>Width of Cut</td>
<td>9'11&quot;</td>
</tr>
<tr>
<td>Maximum of Depth of Cut</td>
<td>18.4&quot;</td>
</tr>
<tr>
<td>Maximum Depth of Spread</td>
<td>18&quot;</td>
</tr>
<tr>
<td>Fuel Tank Refill Capacity</td>
<td>135</td>
</tr>
</tbody>
</table>

Manufacturers of scrapers, such as Caterpillar Tractor Company, provide performance charts for each of their units. A typical chart is shown in Figure 4.10. These charts contain information that enables users to analyze the performance of a particular unit under various operating conditions. Scraper performance can be evaluated using the following four steps.

1. Find gross vehicle weight on the lower left horizontal scale.
2. Read up to the slanted total resistance line.
3. From the intersection of the two lines, read horizontally to the right to the intersection with the performance curve.
4. Read down from this intersection to the lower scale to determine the maximum vehicle speed.

This cycle time for a scraper is the time required to load, haul to the fill, dump, and return to the loading position again. Cycle time can be divided into two elements, fixed time and variable time.

The fixed time is the time devoted to other than hauling or returning empty. This includes the time for loading, dumping, turning, accelerating, and decelerating, all of which are reasonably constant under uniform operating conditions. Table 4.2 shows representative time values for each of these fixed-time elements, based on favorable, average, and unfavorable conditions, corresponding to (1), (2), and (3) respectively. From these data, total scraper cycle time can be calculated.

Because scrapers, like other types of quarrying equipment, do not operate 60 minutes out of every hour, operating efficiency and operating factors must be introduced. Based on numerous statistical studies, the operating efficiencies of scrapers may be classified as
FIGURE 4.10
SCRAPER PERFORMANCE CHART - CATERPILLAR 621B

PERFORMANCE CHART

- Engine: GM 12V-71N at 475 hp
- Transmission: CLT-5,960
- Axle ratio: 26.39:1
- Tire size: 37.5 x 33 - 36 ply
- Loaded radius: 44.9 in.

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>5 to 6</th>
<th>8 to 15</th>
<th>15 to 30</th>
</tr>
</thead>
</table>
|                             | favorable    | average      | unfavorable    | favorable    | average      | unfavorable    | favorable    | average      | unfavorable    |%
| Loading                     | 0.8          | 1.0          | 1.4           | 0.8          | 1.0          | 1.4           | 0.8          | 1.0          | 1.4            |
| Dumping-Turning             | 0.4          | 0.5          | 0.6           | 0.4          | 0.5          | 0.6           | 0.4          | 0.5          | 0.6            |
| Accelerating-Decelerating   | 0.3          | 0.4          | 0.6           | 0.6          | 0.8          | 1.0           | 1.0          | 1.5          | 2.0            |
| TOTAL TIME                  | 1.5          | 1.9          | 2.6           | 1.8          | 2.3          | 3.0           | 2.2          | 3.0          | 4.0            |

in Table 4.3. The actual rate of production for a scraper can be
determined by applying the appropriate operating factor to the
maximum rate or production.

Dragline

Draglines can be used effectively in stripping the softer, less
dense overburdens where advantage can be taken of their digging depths
and disposal reach. They are frequently used to cart overburden
directly to a waste-disposal area without the need for auxiliary
haulage equipment.

Draglines are also used to excavate gypsum ore and load it into
hauling units, such as trucks. Draglines offer the distinct advantage
of not having to go into a pit or hole in order to excavate. It may
operate on solid ground while excavating material from a pit with its
bucket. For gypsum ore hauled by trucks, the vehicles do not have to
go into the pit and contend with unsatisfactory job-site conditions.

Draglines consist of three types: crawler-mounted, self-propelled
wheel-mounted, and truck-mounted. A crawler-mounted dragline and its
specifications are shown in Figure 4.11.

The size of a dragline is determined by the size of the bucket,
expressed in cubic yards. Most draglines are capable of handling
multiple bucket sizes, depending on the length of the boom and the
class of material excavated.

Table 4.4 gives approximate dragline excavation and loading cycles
for various angles of swing. All production rates calculated using
this method are based solely on ideal rates of output. Actual output
<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>OPERATING EFFICIENCY (minutes per hour)</th>
<th>OPERATING FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXCELLENT</td>
<td>55</td>
<td>0.92</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>50</td>
<td>0.83</td>
</tr>
<tr>
<td>FAIR</td>
<td>45</td>
<td>0.75</td>
</tr>
<tr>
<td>UNFAVORABLE</td>
<td>40</td>
<td>0.67</td>
</tr>
</tbody>
</table>

FIGURE 4.11

AMERICAN CRAWLER-MOUNTED DRAGLINE

SOURCE: American Hoist and Derrick Company, St. Paul, Minnesota
FIGURE 4.11 (continued)

AMERICAN 4120 SPECIFICATIONS

General Dimensions

A. Width of Cab 9'-0"
B. Height Over Cab 10'-11"
C. Tailswing 11'-0"
D. First Center to Boom Foot Center 3'-0"
E. Grand to Boom Foot Center 4'-4"
F. Grand to Counterweights 3'-2"

H. Clearance Under Base 14"
I. Crawler Bearing Length 12'-7"
J. Crane Center to Tumbler Center 11'-6"
K. Crawler Length 13'-7"
M. Tread Width 28"
N. Crawler Width 10'-8"

CASTING RANGE

<table>
<thead>
<tr>
<th>SIZE OF DRAGLINE BUCKET (cubic yards)</th>
<th>LIGHT SEMI-MOIST CLAY ANGLE OF SWING (degrees)</th>
<th>SAND OR GRAVEL ANGLE OF SWING (degrees)</th>
<th>COMMON EARTH ANGLE OF SWING (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45</td>
<td>90</td>
<td>135</td>
</tr>
<tr>
<td>3/8</td>
<td>16</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>1/2</td>
<td>16</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>3/4</td>
<td>17</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>1 1/4</td>
<td>19</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>1 1/2</td>
<td>21</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>1 3/4</td>
<td>22</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>27</td>
<td>31</td>
</tr>
<tr>
<td>2 1/2</td>
<td>25</td>
<td>29</td>
<td>34</td>
</tr>
</tbody>
</table>

will vary with such factors as depth of cut, angle of swing, job-site conditions, size of hauling units, and operator skill (33).

4.2.2 Haulage

For handling gypsum ore at the proposed Fayoum quarrying sites, trucks can be shown to be most economical. These hauling units, because of their high speeds when operating on suitable or even marginal roads, have high capacities and provide relatively low unit hauling costs. They also provide a high degree of flexibility, as the number in service may be increased or decreased easily to permit modifications in the total hauling capacity of the fleet. Most trucks may be operated over any haul road for which the surface is sufficiently firm and smooth and on which the grades are not excessively steep, such as those found in most parts of Egypt.

Trucks can be classified according to the following factors:

- Size and type of engine - gasoline, diesel, butane, propane
- Number of gears
- Kind of drive - two-wheel, four-wheel, six-wheel, etc.
- Capacity in tons of cubic yards
- On- and off-highway capabilities

Two types of trucks and their specifications are shown in Figures 4.12 and 4.13.

Rear dump trucks are generally the most suitable for use in hauling gypsum ore. The shape of the body, such as the extent of
FIGURE 4.12

INTERNATIONAL F-2600 ON-HIGHWAY TRUCK

FIGURE 4.12 (continued)
INTERNATIONAL F-2600 SPECIFICATIONS

DIMENSIONS
BBC
Cab Width

FRAME

FRONT AXLE & SUSPENSION

REAR AXLE & SUSPENSION

ENGINE
Type
Bore x Stroke (inches)
Displacement (cubic inches)
Compression Ratio
Governed Speed (RPM)
Gross Horsepower
Net Horsepower
Gross Torque (pound-feet)
Net Torque (pound-feet)
Torque Rise
Weight (pounds)

112"
80"

10 x 3 x 1/4" straight-channel, all bolted, 110,000-PSI steel, RBM of 1,177,000

12,000-lb. axle & suspension
34,000-lb. axle & suspension

Cummins 6 cylinder, 4-cycle PT-270
5.5 x 6.0
855
15:1
2100
270 at 2100 RPM
258 at 2100 RPM
1000 at 1300 RPM
970 at 1300 RPM
48%
2520

TRANSMISSION

10-speed manual
FIGURE 4.11
TEREX 33-03B OFF-HIGHWAY HAULER

SOURCE: TEREX Corporation, Hudson, Ohio, 1981
FIGURE 4.13 (continued)

TEREX 33-03B SPECIFICATIONS

General Dimensions

CAPACITY

Struck (SAE) 19.1 yds.$^3$

ENGINE

Gross Vehicle Power @ 2100 RPM 350 HP
Flywheel Power @ 2100 RPM 321 HP
Number of Cylinders 8
Bore and Stroke 4 1/4 x 5 in.$^1$
Piston Displacement 568 in.$^3$
Maximum Torque @ 1525 RPM 970 ft-lb
Fan Diameter 40 in
Radiator Frontal Area 13.2 ft.$^2$

133
sharp angles, corners, and the contour of the rear will allow for ease of flow during dumping.

In loading these trucks, it is desirable to use units whose capacities balance the output of the excavator. If this is not done, operating difficulties will develop and the combined cost of excavating and hauling material may be higher than when balanced units are used.

The productive capacity of a truck is determined by the size of its load and the number of trips it can make in an hour. The size of the load can be easily determined from the specifications furnished by the manufacturers. The number of trips per hour will depend on the width of the vehicle and the horsepower of the engine. These production rates are easily translated into performance charts, such as the one shown in Figure 4.14. Such charts are furnished by manufacturers for their vehicles. The steps in using the chart are the same as those used to estimate scraper performance in Figure 4.9.

4.3 GYPSUM PROCESSING

The processing of gypsum ore can be divided into two basic steps, ore preparation and calcining. The specific means used to accomplish each of these steps will be determined by such factors as the quality of the gypsum ore and the type of product to be manufactured. For the following discussion, general methods and equipment will be presented.

The entire processing procedure is graphically summarized in the flow diagram in Figure 4.15.
FIGURE 4.14
TRUCK PERFORMANCE CHART

FIGURE 4.15
GENERALIZED FLOW DIAGRAM OR GYPSUM PROCESSING

4.3.1 Crushing

Ore preparation begins with primary crushing. This can be accomplished through gyratory, jaw, or impact crushers, with the type used depending upon the original size of the ore, the desired rate of output, and types of subsequent processing.

Gyratory crushers operate with a vertical shaft which follows an eccentric path at its lower end. Power is fed through gears to the working shaft, or in some instances, with a vertical motor coupled to a ball and socket eccentric assembly. The crushing chamber is very steep, allowing for greater throughput (48).

The gyratory crusher is a highly dependable machine that requires infrequent maintenance. This type of crusher does not have the strong ability to handle wet or sticky ore. In addition, initial purchase and installation costs are high. However, the gyratory crusher is the most adaptable and dependable relative to other types of crushers. Slower speeds and limited moving parts mean longer lives for working parts. Settings and crushing chamber designs can be altered to meet widely different conditions (111).

A gyratory crusher is shown in Figure 4.16. Table 4.5 gives representative capacities for this gyratory crusher, expressed in short tons per hour, based on a continuous feed of material weighing 100 pounds per cubic foot when crushed.

Jaw crushers consist of two basic designs - the Blake type and the overhead eccentric.

Blake machines require a large housing and heavy parts. The crushing action of a jaw crusher is similar to that of a swinging
FIGURE 4.16
TRAYLOR GYRATORY CRUSHER

<table>
<thead>
<tr>
<th>SIZE OF CRUSHER (inches)</th>
<th>APPROXIMATE POWER REQUIRED (Horsepower)</th>
<th>1 1/2</th>
<th>1 3/4</th>
<th>2</th>
<th>2 1/4</th>
<th>2 1/2</th>
<th>3</th>
<th>3 1/2</th>
<th>4</th>
<th>4 1/2</th>
<th>5</th>
<th>5 1/2</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>15-25</td>
<td>30</td>
<td>36</td>
<td>41</td>
<td>47</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>25-40</td>
<td>-</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>50-75</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>85</td>
<td>100</td>
<td>133</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>60-100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>160</td>
<td>185</td>
<td>210</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>75-125</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>230</td>
<td>255</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>125-175</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>310</td>
<td>350</td>
<td>390</td>
<td>-</td>
</tr>
<tr>
<td>42</td>
<td>200-275</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>500</td>
<td>570</td>
</tr>
</tbody>
</table>

door, since its swing shaft, or pivot point is fixed. Because of the large flywheels and direct push from the two toggle plates and the pitman, the power relationships are excellent. The straight crushing action means extremely low wear of the crushing surfaces. This advantage is generally outweighed by its high original cost and low overall capacity (48).

Under normal circumstances, gypsum is prescreened prior to entering the jaw crusher. Particle reduction ratios are usually limited to 10:1.

Overhead eccentric jaw crushers are similar to the Blake machine, with one key difference: the pivot point is not stationary. This point follows an eccentric path and creates an elliptical motion, creating a downward push on the material being crushed (108). Higher throughput is generally associated with these machines. The majority of jaw crushers in Egypt are the overhead eccentric type, being, lighter, smaller, and cheaper.

A jaw crusher is shown in Figure 4.17. Table 4.6 shows representative capacities for sizes of jaw crushers.

Impact crushers, or hammermills, rely on impact forces, as opposed to compression for the basic crushing force. Hammermills allow gypsum particles to free fall into a chamber until they are struck by high-velocity forces occurring at right angles to the direction of fall. These shattered particles are thrown against a stationary breaker plate, creating an additional shattering force (108).

The impact action of this type of crusher acts along the material cleavage lines of the gypsum. Sharp reductions in flat gypsum particles are possible. Because gypsum contains a relatively large
### TABLE 4.6
**Representative Capacities of Blake-Type Jaw Crushers**
(tons per hour)

<table>
<thead>
<tr>
<th>Size of Crusher (inches)</th>
<th>Maximum Revolutions per Minute</th>
<th>Maximum Horsepower</th>
<th>1</th>
<th>1 1/2</th>
<th>2</th>
<th>2 1/2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x 6</td>
<td>300</td>
<td>15</td>
<td>11</td>
<td>16</td>
<td>20</td>
<td>25</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 x 20</td>
<td>300</td>
<td>20</td>
<td>14</td>
<td>20</td>
<td>25</td>
<td>34</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 x 24</td>
<td>275</td>
<td>30</td>
<td>27</td>
<td>34</td>
<td>42</td>
<td>50</td>
<td>62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 x 30</td>
<td>275</td>
<td>40</td>
<td>33</td>
<td>43</td>
<td>53</td>
<td>62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 x 36</td>
<td>250</td>
<td>60</td>
<td>46</td>
<td>61</td>
<td>77</td>
<td>93</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 x 36</td>
<td>250</td>
<td>75</td>
<td>77</td>
<td>95</td>
<td>114</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 x 42</td>
<td>200</td>
<td>100</td>
<td>125</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 x 42</td>
<td>175</td>
<td>115</td>
<td>140</td>
<td>160</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 x 48</td>
<td>160</td>
<td>125</td>
<td>150</td>
<td>175</td>
<td>225</td>
<td>275</td>
<td>325</td>
<td>375</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42 x 48</td>
<td>150</td>
<td>150</td>
<td>165</td>
<td>190</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
<td>550</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48 x 60</td>
<td>120</td>
<td>180</td>
<td>165</td>
<td>190</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
<td>550</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>56 x 72</td>
<td>95</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Pennsylvania Crusher Corporation, Broomall, Pennsylvania 1979. (Reference: No. 108)
percentage of softer materials, hammermills are capable of reducing
gypsum to fine particles. Where high percentages of crushed surfaces
are a requirement, as in gypsum processing, impact crushing is
superior. In addition, where gypsum clay particles create a tendency
to clog, the impact breaker offers superior performance in maintaining
particle flows (109).

A hammermill crusher is shown in Figure 4.18. Table 4.7 gives
representative capacities for a hammermill crusher expressed in short
tons of stone per hour for crushed material with a density of 100
pounds per cubic foot.

Secondary crushing is performed through a variety of standard
crushing units, with hammermills and cone crushers being the most
popular units in Egypt (142).

Cone crushers are similar to gyratory crushers, with the only
difference being the angle of the inner crushing surface. This allows
for greater discharge area and throughput.

Fine grinding of both calcined and uncalcined gypsum is usually
accomplished through grinding or roller mills. A grinding mill is a
cylindrical, horizontal, slow-speed rotating drum, using metal bulbs
as grinding media.

The roller mill, in its general form is similar to the grinding
mill, except that the grinding media consist of a set of steel rods,
rolling freely inside the drum, during its rotation to give the
required grinding action.

Both mill types are generally considered to be granular grinding
units, primarily for handling a maximum feed size of 1 to 1 1/2
inches, and grinding to a maximum of 65-mesh.
FIGURE 4.18
NON-REVERSIBLE HAMMERMILL CRUSHER

TABLE 4.7
REPRESENTATIVE CAPACITIES FOR HAMMERMILLS
(tons per hour)

<table>
<thead>
<tr>
<th>SIZE OF FEED OPENING (inches)</th>
<th>SIZE OF FEED (inches)</th>
<th>POWER REQUIRED (horsepower)</th>
<th>1/8</th>
<th>3/16</th>
<th>1/4</th>
<th>3/8</th>
<th>1/2</th>
<th>1</th>
<th>1 1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 1/4 x 9</td>
<td>3</td>
<td>15-20</td>
<td>2.5</td>
<td>3.5</td>
<td>5.0</td>
<td>8.0</td>
<td>10.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 x 15</td>
<td>3</td>
<td>50-60</td>
<td>5.0</td>
<td>13.0</td>
<td>17.0</td>
<td>23.0</td>
<td>29.0</td>
<td>36.0</td>
<td>39.0</td>
</tr>
<tr>
<td>15 x 25</td>
<td>6</td>
<td>100-125</td>
<td>16.0</td>
<td>25.0</td>
<td>31.0</td>
<td>40.0</td>
<td>47.0</td>
<td>65.0</td>
<td>70.0</td>
</tr>
<tr>
<td>15 x 37</td>
<td>6</td>
<td>150-200</td>
<td>27.0</td>
<td>37.0</td>
<td>47.0</td>
<td>60.0</td>
<td>71.0</td>
<td>97.0</td>
<td>105.0</td>
</tr>
<tr>
<td>15 x 49</td>
<td>6</td>
<td>200-250</td>
<td>36.0</td>
<td>50.0</td>
<td>63.0</td>
<td>80.0</td>
<td>95.0</td>
<td>130.0</td>
<td>140.0</td>
</tr>
</tbody>
</table>

4.3.2 Screening

Because natural gypsum is rarely found in its pure form, most gypsum ore requires beneficitation to achieve an acceptable level of purity. The impurities most frequently found in gypsum deposits include anhydrous gypsum, calcium carbonate, magnesium carbonates, silica, clay minerals, and various soluble salts (87).

Consequently, the low purity of Egyptian gypsum ore requires the use of beneficitation techniques. The most common form of beneficitation is simple segregation by particle size through dry screening (48). This method is generally used to reduce the quantity of clay and sand impurities.

Screening is usually conducted during the primary and secondary crushing stages, in part to maximize crushing efficiency and to reduce the amount of ultra-fines produced.

The vibrating screen is the most widely used screen in the production of gypsum (134). Figure 4.19 shows a multiple-deck screening unit of this type.

The capacity of a screen is defined as the number of tons of material that 1 square foot will pass per hour. The capacity will vary with the size of the openings, type of material screened, moisture content, and other factors. Because of the inability to calculate these factors in advance, it is good practice to select a screen whose capacity is 15 to 25 percent greater than the quantity to be screened (108).
FIGURE 4.19.
DOUBLE-DECK VIBRATORY SCREEN

4.3.3 Conveying

Material handling between the previously mentioned types of equipment is achieved through the use of conveyors. Because the characteristics of the material change under different processing stages, different means are available for handling gypsum at any specific stage. The three types of conveying systems used in gypsum processing are belt, bucket, and screw conveyors.

Belt conveyors are comprised of an endless belt operating over idlers.

A screw conveyor consists of a steel conveyor screw or spiral attached to a shaft or ordinary pipe. Its rotation moves material forward in a horizontal or inclined trough.

Bucket conveyors provide a continuous direct lift of bulk materials from one level to another. This type of conveyor is comprised of a single or double strand of conveyor chain to which are attached a series of cast or formed metal buckets.

Feeders are often used in conjunction with conveyors. These machines are used to control the rate of delivery by weight or volume at which material is fed to conveyors.

4.3.4 Calcining

Gypsum (CaSO₄ · 2 H₂O), the dihydrate form of calcium sulfate is the most useful form of calcium sulfate. Anhydrite (CaSO₄) the other principal calcium sulfate mineral has very limited use, and is generally considered to be an impurity.
Although often found in close association, the two minerals have important chemical differences. Gypsum, possessing the two molecules of combined water, will convert to a hemihydrate form ($\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$) given a modest amount of heat. The hemihydrate form, or plaster of paris, as it is commonly called, forms the basis for over 90% of all gypsum end products (87).

Anhydrite, on the other hand, is inert at these same temperatures, limiting its use to only a few specific cases.

The percent compositions for pure anhydrite and the hydrates are shown in Table 4.8.

Two forms of hemihydrate, alpha (a) and beta (B), have been found to exist. The beta form is obtained when the dihydrate is partially dehydrated in a vacuum at 100 degrees C or under conditions where a nearly saturated steam atmosphere does not prevail.

The alpha form is prepared by dehydration of gypsum in water at temperatures above 97 degrees C. Alpha is distinguishable from beta by its lower solubility and energy content. Alpha particles disintegrate very little when mixed with water. In addition, it requires far less mixing water to form a workable slurry. Consequently, it has the ability to produce denser and higher compressive-strength casts and less excess water, beyond the quantity to be removed after hydration is complete.

Because high early strength development is preferred in the production of gypsum wallboard, the more reactive beta hemihydrate is more suitable for this purpose. The use of alpha hemihydrate is generally limited to industrial uses where denser, higher strength casts are preferred (134). A second advantage to beta hemihydrate is its low cost.
<table>
<thead>
<tr>
<th>COMMON NAME</th>
<th>MOLECULAR FORMULA</th>
<th>SULPHUR TRIOXIDE (SO₃)</th>
<th>COMBINED WATER (H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhydrite</td>
<td>CaSO₄</td>
<td>41.22%</td>
<td>58.8%</td>
</tr>
<tr>
<td>Gypsum</td>
<td>CaSO₄ · 2H₂O</td>
<td>32.62%</td>
<td>67.4%</td>
</tr>
<tr>
<td>Hemihydrate</td>
<td>CaSO₄ · 1/2 H₂O</td>
<td>38.62%</td>
<td>61.4%</td>
</tr>
</tbody>
</table>

The manufacturing of calcined gypsum is governed by specific standards which are written by such organizations as the American National Standards Institute, the American Society for Testing and Materials, the British Standards Institution, and the International Standards Organization. The standards and specifications of these organizations are similar. Consequently, those of the American Society of Testing and Materials (ASTM) may be taken as representative.

The most recent compilation of ASTM standards for the production of calcined gypsum includes specifications covering the following areas:


After the gypsum rock from the quarry is crushed and sized, it is used to feed the calcination process for conversion to hemihydrate.

Kettle calcination continues to be the most commonly used method of producing beta hemihydrate. The batch kettle can be operated on either a batch or continuous basis. A typical kettle is shown in Figure 4.20.

The batch kettle consists of a cylindrical steel vessel enclosed in a refractory shell with a plenum between. The kettle is suspended above a heat source from which heated air flows up and into the plenum.
FIGURE 4.20
GENERALIZED SECTION OF A CALCINING KETTLE

(Reference: No. 134)
surrounding the steel vessel and through multiple horizontal flues which completely penetrate the vessel. The plenum and flues provide the heat transfer to the gypsum before the heated air is totally exhausted. An agitator with horizontal arms penetrates the depth of the kettle and is driven from above.

Crushed gypsum is fed from the top, with filling taking approximately 15 minutes. Another 90 to 120 minutes are usually required for the calcining process. Upon completion, the calcined gypsum, or stucco, is discharged by gravity through a quick-opening gate located at the periphery and bottom of the kettle. Approximately 950,000 Btu are required per metric ton of hemihydrate (134).

An innovation to the batch process has been the continuous kettle. The continuous kettle contains a continuous perforated grate charged with a single layer or multiple layers of sized rock, with a bed passing through the machine, drawing hot gasses through the bed. As a result, crushed gypsum is fed into the kettle as a continuous stream of stucco is removed. This technique requires carefully controlled conditions in order to control the degree of dehydration (111).

Other methods used to produce beta hemihydrate include the rotary kiln. Although only 15% of all U.S. production is through the use of rotary kilns, these vessels are popular in both Europe and the Middle East.

Rotary kilns range in size from 5 feet in diameter and 60 feet in length to 20 feet in diameter and over 600 feet in length. The drive is usually of variable speed, giving a range of from one to three minutes per revolution, depending on the size of the kiln. Most rotary kilns have a slope of 1/2 inch per foot. The various makes of
rotary kilns are generally alike, with slight variations in their features of design and construction (19).

Figure 4.21 shows a typical rotary kiln. As this figure shows, a totally enclosed grate is positioned ahead of the rotary kiln. The grate and kiln are connected in sequence so that exhaust gasses from the kiln make two passes through the grate.

In operation, the finely ground gypsum is pelletized and deposited in a layer on the travelling grate. Hot exhaust gasses at 1800 degrees F are drawn from the kiln and pass through the pellets at the discharge end of the grate. This first pass ends with the partial calcination of the pellets.

The second pass, beginning at the feed end of the grate, consists of drying the pellets and filtering dust from the gases. The remaining calcination and final burning take place in the rotary kiln itself (134).

Figure 4.22 shows a general process flow diagram for a complete gypsum processing and calcining plant. This flow diagram and equipment index, shown in Table 4.9, serve as a crude example of the processes and equipment involved in the processing and calcining of gypsum. Plant layout will differ from installation to installation, however, the basic flow-plan will remain essentially the same.

4.4 PANEL PRODUCTION PROCESS

4.4.1 Dryflow Process

In the late 1970s Bevan Associates of London, England developed a fundamentally new method of producing interior gypsum partition
FIGURE 4.21
SCHEMATIC DIAGRAM OF ROTARY KILN SYSTEM

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>Rock Recieving Hopper - The size of the rock received varies from about 4 inches to 6 inches.</td>
</tr>
<tr>
<td>A-2</td>
<td>Rock Feeder(s) - Different types of feeders can be used such as apron conveyors or vibrating pans. Each insures an even feed to the belt conveyor.</td>
</tr>
<tr>
<td>A-3</td>
<td>Rock Receiving Belt Conveyor</td>
</tr>
<tr>
<td>A-4</td>
<td>Rotary Rock Dryer - This may or may not be used depending upon location of the plant and the amount of surface moisture. Washing of the gypsum may be necessary if clay dirt and sand are present in excessive amounts.</td>
</tr>
<tr>
<td>A-5</td>
<td>By-Pass Belt Conveyor</td>
</tr>
<tr>
<td>A-6</td>
<td>Stockpiling Belt Conveyor With Re-Claim Hopper and Rock Feeder</td>
</tr>
<tr>
<td>A-7</td>
<td>Hammermill Belt Conveyor</td>
</tr>
<tr>
<td>A-8</td>
<td>Dust Collector Screw Conveyor - This conveyor sends gypsum dust back to the flow for calcination.</td>
</tr>
<tr>
<td>A-9</td>
<td>Hammermill - Here the 4&quot; to 6&quot; rock is reduced to -1&quot; for feeding to grinding mills.</td>
</tr>
<tr>
<td>A-10</td>
<td>Crushed Rock Bucket Elevator</td>
</tr>
<tr>
<td>A-11</td>
<td>Crushed Rock Screw Conveyor</td>
</tr>
<tr>
<td>A-12</td>
<td>Crushed Rock Storage Bins - A storage bin equipped with a vibrating mechanism to insure proper flow. These bins should hold enough crushed rock for 24 hours of mill operation.</td>
</tr>
<tr>
<td>A-13</td>
<td>Roller Mill Systems - The Roller Mills reduce the rock to 90% passing #100 mesh while reducing the moisture content.</td>
</tr>
<tr>
<td>A-14</td>
<td>Secondary Collectors</td>
</tr>
<tr>
<td>A-15</td>
<td>Collecting Screw Conveyors - These conveyors receive the ground gypsum and convey it to the Kettle Feed Bins.</td>
</tr>
<tr>
<td>A-16</td>
<td>Kettle Feed Bins - Each bin contains enough storage to fill each kettle twice.</td>
</tr>
<tr>
<td>A-17</td>
<td>Twin Screw Kettle Feeders - The twin tubular screw conveyors will vary the fill rate of the kettle from 15 to 30 minutes.</td>
</tr>
<tr>
<td>A-18</td>
<td>Calcining Kettles</td>
</tr>
<tr>
<td>A-19</td>
<td>Kettle Dust Collecting System</td>
</tr>
</tbody>
</table>
TABLE 4.9 (continued...)

PLANT EQUIPMENT KEY

A-20 Hot Pits With Emptier Screw – The pits receive the hot stucco from the kettle after the cycle is completed. Each pit will hold two kettle charges and will empty in 30 to 45 minutes.

A-21 Hot Stucco Collecting Screw Conveyor

A-22 Hot Stucco Elevator

A-23 Stucco Supply Screw Conveyor

A-24 Stucco Reject Conveyor System

A-25 Stucco Reject Storage Bin

A-26 Stucco Storage Bins – At least two bins should be used to allow adequate cooling of stucco before use. Some plants provide stucco coolers and use fewer storage bins.

A-27 Stucco Drag Feeders

A-28 Hot Stucco Recirculating Screw Conveyor

A-29 Stucco Supply Screw Conveyor

A-30 Stucco Supply Bin

A-31 Regrind Mill – Re-grinding of the stucco raises the blaine surface area and alters some of its characteristics.

A-32 Supply Bucket Elevator

A-33 Volumetric Stucco Feed System

A-34 Stucco Recirculating Bucket Elevator

A-35 Mixing Screw Conveyor

A-36 Admix Conveyor – This screw conveyor receives and mixes the stucco and other dry additives from the chemical feeders.

panels, through the use of a dry manufacturing process. This technology, known under the trademarked name of Dryflow, circumvents the numerous mixing, compacting, and drying problems associated with conventional wet processes. This process also enables gypsum panels to be produced from inexpensive raw materials.

A range of products which can be made by this process have been conceived, including hollow cored, glass-fiber reinforced gypsum partitions and liner panels. The reduced cost associated with the production of these panels has opened new market opportunities for the Dryflow process in the United Kingdom. These products are anticipated to be competitive in England on a total erected cost basis. This competitive advantage is derived from the ease of installation and the low production and raw material costs associated with Dryflow panels.

Given the ability to be profitable at low levels of production, a Dryflow plant would be ideally suited for use in Egypt, particularly over the next five years as gypsum partitions become more widely accepted in Egypt.

The Dryflow manufacturing process begins with the placing of longitudinal glass fibers and core formers into position and clamping the tongue and groove edges and mold facings together to close the molds. These molds are grouped in batteries of four or more.

The gypsum feeder deposits dry gypsum hemihydrate powder into the mold while the chopper cuts glass fibers into the desired lengths and deposits them simultaneously with the powder. During this step the mold is vibrated, compacting the gypsum powder and chopped fiber.

When the mold has been filled, the core forming fingers are withdrawn, with the molds being transported to the next position by
means of a carousel. Sprayers are lowered into the hollow core spaces, spraying water against the free standing internal surfaces, converting the gypsum from a hemihydrate to a dihydrate form. Filling and spraying requires approximately seven minutes per mold.

The molds are then moved to the final position where the hardening of the gypsum panels takes place. The molds are opened, and the panels are lifted and stacked by means of an overhead crane. This final step lasts approximately seven minutes. Upon completion of this step the molds are returned to the original position and the operation is repeated. Throughout the duration of this process, other batteries of molds are proceeding through the same steps, resulting in a continuous operation, with sets of panels being produced approximately every seven minutes (28). The process is shown graphically in Figure 4.23.

A typical dry process arrangement calls for three pairs of molds to form a battery producing six panels per cycle. Because each of the three steps takes seven minutes, and the carousel employs three sets of molds, the effective production, or cycle time is seven minutes per panel (26).

Assuming a cycle time of seven minutes, a typical carousel with a ten-gang battery of molds will produce 234,000 square meters (2,523,000 square feet) of 0.9 meters x 2.9 meters (2.0 feet x 9.5 feet) panels per shift per year (28). This rate of production assumes an allowance of 3 percent for wastage and 80 percent utilization capacity for a plant operating 50 weeks per year. For panels weighing 28 kilograms per square meter (5.71 pounds per square foot) the annual consumption of gypsum per carousel is 6,310 metric tons (6940 short
FIGURE 4.23

DRYFLOW PANEL PRODUCTION STEPS

FILLING AND COMPACTATION

CORE WITHDRAWAL

HYDRATION AND SETTING

PANEL EJECTION

tons) (24). Annual production rates are summarized in Table 4.10, for one carousel operating two, eight-hour shifts, three carousels operating two shifts, and six carousels operating three shifts. Manpower requirements are summarized in Tables 4.11 and 4.12.

The essential pieces of equipment used in the dry manufacturing process are a carousel, or rotating platform upon which are placed a gypsum-feeding head, a longitudinal glass fiber feeder, and a chopper. An overhead crane is employed for placing and withdrawing the core formers, placing the sprayers in the hollow cores, and withdrawing and stocking the hardened panels.

Area requirements include covered space for the mold shop, warehousing, office space, stores and similar activities. In Egypt, with its warm dry climate, many of these activities can be performed outside, as they are often done in similar gypsum block manufacturing operations. Sufficient open space will be required for external storage, vehicle accessories, car parking, and general use. These area requirements are summarized in Table 4.13.

Both alpha and beta forms of hemihydrate gypsum may be used in the dry manufacturing process. However, to reduce cycle time, the faster-hardening beta form is preferred (28).

Because the process requires quick hardening, no setting retarder is required. Certain impurities such as marl and clay can be tolerated in quantities up to 20 percent. Salt will not interfere with the production process, however, it may promote the corrosion of metal parts used in the production process.

Ordinary E-glass fibers, or lower-cost A-glass fibers can be used, as the non-alkali gypsum matrix does not corrode glass. These fibers
<table>
<thead>
<tr>
<th>NUMBER OF CAROUSELS</th>
<th>NUMBER OF SHIFTS</th>
<th>ANNUAL PRODUCTION (square meters)</th>
<th>ANNUAL PRODUCTION (square feet)</th>
<th>GYPSUM CONSUMPTION (metric tons)</th>
<th>GYPSUM CONSUMPTION (short tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>468,000</td>
<td>5,045,000</td>
<td>12,636</td>
<td>13,900</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1,404,000</td>
<td>15,135,000</td>
<td>37,908</td>
<td>41,070</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>4,212,000</td>
<td>45,405,000</td>
<td>113,724</td>
<td>125,100</td>
</tr>
</tbody>
</table>

TABLE 4.11
ESTIMATED DRYFLOW MANPOWER REQUIREMENTS

<table>
<thead>
<tr>
<th>NUMBER OF CAROUSELS</th>
<th>1</th>
<th>1</th>
<th>3</th>
<th>3</th>
<th>6</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHIFTS</td>
<td>1st</td>
<td>2nd</td>
<td>1st</td>
<td>2nd</td>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td>NUMBER OFhifts</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>CAROUSEL OPERATORS</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>OVERHEAD CRANE</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>OPERATORS</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>FORKLIFT OPERATORS</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>DISPATCHERS</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>LABORERS</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>FOREMEN</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>MAINTENANCE</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8</td>
<td>5</td>
<td>10</td>
<td>6</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

TABLE 4.12
ESTIMATED DRYFLOW MANPOWER REQUIREMENTS - ADMINISTRATIVE STAFF

<table>
<thead>
<tr>
<th>NUMBER OF CAROUSELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

**PERSONNEL**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing Director</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Manager</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production Manager</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accountant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts Staff and Secretarial</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Sales Representatives</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Production Controller and Staff</td>
<td></td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

| TOTAL                | 11| 18| 23|

(Reference: No. 29)
TABLE 4.13

DRYFLOW PRODUCTION AREA REQUIREMENTS
(square meters)

<table>
<thead>
<tr>
<th>NUMBER OF CAROUSELS</th>
<th>*NUMBER OF SHIFTS</th>
<th>WAREHOUSE (1) AREA</th>
<th>OFFICE (2) AREA</th>
<th>CANTEN (3)</th>
<th>CAROUSEL SHOP</th>
<th>STORES, MAINTENANCE</th>
<th>LANDING BAY</th>
<th>TOTAL AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>400</td>
<td>110</td>
<td>80</td>
<td>70</td>
<td>40</td>
<td>60</td>
<td>760</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1,200</td>
<td>180</td>
<td>96</td>
<td>100</td>
<td>50</td>
<td>80</td>
<td>1,706</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3,600</td>
<td>230</td>
<td>128</td>
<td>140</td>
<td>70</td>
<td>125</td>
<td>4,288</td>
</tr>
</tbody>
</table>

(1) Assumes 200 square meters of warehouse area per carousel per shift

(2) Assumes 10 square meters of office area per staff member

(3) Assumes 8 square meters of canteen area per operator

are commonly used in reinforced plastics and other high-strength applications.

Additives such as sawdust and fine sand may be employed. Although sawdust may contribute to nailability, its hygroscopic nature may result in some cracking, causing humidity induced expansion and contraction (26). Sand has one significant drawback that it can lead to the rapid dulling of saws.

The dry production process offers several advantages over conventional production process. Because very little water goes into the panel, there is no wet mixing. Consequently, material cannot cure in the feed lines and the entire plant can be stopped or started on very short notice.

Even more significant is the ability to use quick-setting gypsum mixes, providing high demolding strengths and extremely fast production rates. Quick setting can be obtained by including 10 percent or more of uncalcined gypsum, or by undercalcining the material during processing (28). This option can represent considerable energy cost savings when totally integrated calcining and manufacturing plants are used.

Because of the small amount of water added after forming, thin walled sections are ready for immediate demolding, without waiting for full chemical cure. These sections can be as small as 2 millimeters in thickness and can contain reinforcing fibers of over 100 millimeters in length.

The basic principals of the dry manufacturing process can be retained even under lower rates of production. Reduced rates can be achieved by reducing the number of molds to a single mold or set,
limiting all production steps to one location instead of moving from station to station, and by simplifying the filling procedure. This last change can be accomplished through the substitution of labor for some of the filling mechanisms. Because of the relatively low present wage scales and availability of labor in Egypt, the increased use of labor-intensive processes and reduced initial capital expenditures are possible. These alternatives are particularly attractive for use in Egyptian markets, where simpler, lower-cost production units could meet the initial low levels of demand. In addition, a low-volume installation would allow for greater experimentation and development in the early stages, than would be possible with full-scale equipment.

4.4.2 Other Processes

The conventional gypsum wallboard manufacturing process begins with the dry components being brought together with water in a high energy mixer. The resulting slurry is deposited on a moving strip of paper, the edges of which have been turned up to form a wide, shallow trough. This mass then moves under a second strip of paper, simultaneously moving between two edge guides and a 24 inch diameter roller, imparting the exact desired board width and thickness. The edges of the bottom paper are turned over to form square or rounded covers while an adhesive is applied so that the top paper is bonded along its edges to the lower. Board thickness can be varied by adjusting the roller (87).

Upon completion of these steps, the fully formed board is transported on a flat conveyor several hundred feet in length. The
speed of this board line will vary with the design of the plant and the specifications of the product being produced. This speed usually ranges between 50 and 150 feet per minute. Board lines are designed to provide time for the gypsum to set (usually 3 to 5 minutes), at which point the continuous strip is cut at desired intervals by a rotating knife, producing individual boards ready for drying. Drying is accomplished through the use of multi-deck continuous hot air kilns. Close control of kilns is required to remove the free moisture without starting to re-calcine the gypsum ore.

After emerging from the kiln, the board is moved through devices that smooth the ends and cut the board to the exact desired length.

Figure 4.24 shows a general process flow diagram for a typical wallboard plant. Such a plant occupies 5 to 7 acres of area.

Over the last few years, the production of gypsum building blocks in Egypt has increased dramatically. These blocks, or partition wall panels are manufactured by several domestic organizations, including ICON and GYMCO.

The basic manufacturing steps are shown in Figures 4.25 and 4.26. The process begins with the feeding of dry hemi-hydrate gypsum from an elevated silo (4.25a) into a mixing trough where it is combined with water. The slurry is then poured into a gang mold (4.25b), equipped with either 18, 15, or 12 cells. These cells are equipped with tongue and groove edge formers. When the cells are filled, the top groove formers, shown resting against the mold (4.25b) are placed and hammered down (4.25c). A hardening period of 10 minutes follows, while the process is repeated on a second gang mold.
FIGURE 4.24

WALLBOARD PLANT FLOW DIAGRAM

FIGURE 4.25
ICON BLOCK PRODUCTION PROCESS

a. ELEVATED SILO FOR GYPSUM POWDER

b. EMPTYING GYPSUM SLURRY INTO GANG MOLD

c. PLACING TONGUE FORMERS IN TOP OF MOLD

d. LIFTING HARDENED GYPSUM BLOCKS

SOURCE: Reference No. 140
FIGURE 4.26
ICON BLOCK PRODUCTION PROCESS

a. FINGERS LIFTING GYPSUM BLOCKS

b. BLOCKS ON TROLLEY

c. PLACING BLOCKS IN STORAGE YARD

d. STRAPPED BLOCKS ON PALLET

SOURCE: Reference No. 140
After hardening, the first mold is opened and the hardened blocks are pushed up (4.25d), lifted by gang fringes (4.26a), and deposited on a dolly (4.26b). The dolly is moved into an open storage yard, where a fork-lift equipped with lifting fingers (4.26c) deposits the blocks on drying racks (4.26d).

The blocks remain on the racks 14 to 21 days in the open air and sun until thoroughly dry, at which time they are strapped and placed upon small pallets for shipment (4.26d).

The block manufacturing process is contained within a small 50 by 50 foot production unit. This small unit has been designed for operation on project-sites and can be erected or dismantled within two days. This plant is intended to serve as a mobile production unit that can be taken to the location where gypsum blocks are being installed (140).

A typical block manufacturing process requires 8 workers per shift, consisting of one plant supervisor and seven manual laborers. Although this quantity of labor is comparable to that required for the Dryflow process, the output per day for GYMCO plants is considerably lower. A block manufacturing process also requires 70 kilograms of gypsum per square meter of block produced, a significantly high quantity when compared to dry process requirements (135).
CHAPTER FIVE

FEASIBILITY ANALYSIS

The introduction of new building products, such as Dryflow panels, often encounters resistance because of the natural reluctance of contractors, owners, and architects to use products that deviate from traditional ones. This universal skepticism will usually persist until considerable hard evidence on performance and cost effectiveness becomes available. At the very least, this entails that these new products are both technically and economically feasible.

Technical feasibility analysis involves an assessment of the product's ability to meet specific physical requirements and its compatibility with existing construction procedures, local cultural considerations, and climatic conditions. Economic feasibility analysis must assess the new product's ability to compete with other products, and the overall project's ability to compete with other investment opportunities. The latter being affected by such implementational factors as the availability and cost of capital, site, and infrastructure.

Chapter 5 begins with an assessment of technical feasibility, listing and summarizing the various technical characteristics and performance requirements for partitions and walls that are inherent to construction in Egypt. These technical requirements that must be met include building standards, codes, and regulations, contract specifications, indigenous building practices and systems, the characteristics and properties of competing products, and cultural and climatic conditions.
The second section will elaborate on the technical characteristics of Dyflow panels, and their ability to meet the requirements previously outlined.

The remainder of Chapter 5 addresses economic feasibility. This will include an analysis of cost competitiveness and key implementational considerations of the type described above.

5.1 Technical Requirements for Partitions and Walls

5.1.1 Building Codes and Regulations

In Egypt building codes are promulgated nationally by the Egyptian government. Many of these codes are merely performance codes, in that the expected behavior of a building is set forth, with the specific means and materials left to the discretion of designers and builders. Some of these performance codes have detailed descriptions of construction methods that comply with international codes. However, in Egypt the methods specified by these codes are not mandatory.

The requirements for partitions and walls in Egypt are generally consistent with those of the American Society for Testing and Materials of the United States (ASTM) and the Building Officials and Code Administration (BOCA) of the United Kingdom. One major requirement is for resistance to fire. Both ASTM and BOCA have defined the codes for fire resistance according to such factors as hours of resistance to fire tests, classes of occupancy, and proximity to other buildings.
The BOCA code for fire resistance is shown in Table 5.1. The maximum standard is 4 hours of resistance to a standard fire test for critical bearing walls in a fire proof building. The minimum standard is zero hours. This standard pertains to specific interior bearing walls and partitions, and many non load-bearing partitions (32).

The two significant ASTM fire codes are:

1. Surface Burning Characteristics of Building Materials (ASTM E-84)


These specifications set standards for flame propagation, smoke density, and temperature gradient over time for building materials. Because of its chemical composition, gypsum is highly resistant to fire. Much of the water in its chemical composition must be driven off before the temperature can rise to a sufficient combustion level. Gypsum walls and partitions can therefore serve as fire barriers with various hourly ratings of fire resistance and can meet all ASTM and BOCA fire codes.

Other major requirements have been established in the BOCA codes by referring to ASTM gypsum product code specifications. Some of the more pertinent with respect to the construction of interior walls are:


<table>
<thead>
<tr>
<th>STRUCTURAL ELEMENT</th>
<th>TYPE OF CONSTRUCTION</th>
<th>TYPE 1</th>
<th>TYPE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1A</td>
<td>1B</td>
</tr>
<tr>
<td>1. Interior Bearing Walls and Partitions</td>
<td>FIREPROOF</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>2. Fire Walls and Party Walls</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3. Fire Enclosure of Exitways, Exitway Hallways and Stairways</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4. Shafts Other Than Exitways</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5. Exitway Access Corridors and Vertical Separation of Tenant Spaces</td>
<td>FIREPROOF</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6. Other Non-Load Bearing Partitions</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>NONCOMBUSTIBLE</td>
<td>2A</td>
<td>2B</td>
</tr>
<tr>
<td></td>
<td>PROTECTED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Interior Bearing Walls and Partitions</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. Fire Walls and Party Walls</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3. Fire Enclosure of Exitways, Exitway Hallways and Stairways</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4. Shafts Other Than Exitways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Exitway Access Corridors and Vertical Separation of Tenant Spaces</td>
<td>NONCOMBUSTIBLE</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6. Other Non-Load Bearing Partitions</td>
<td>NONCOMBUSTIBLE</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>


The specification for gypsum block outlines the requirements for chemical composition, quantity of aggregates and fillers, and physical characteristics and dimensions. The specifications for installation and application define specific procedures and such environmental factors as temperature and humidity.

5.1.2 Contract Specifications

A typical set of contract specifications as put forth by an Egyptian architect/engineer specifies both the technical characteristics for materials and the method of use during the construction process. For example a specification for building lath and plaster covers all work activities products and materials associated with interior furring, lathing, plastering, and related items. All materials must be products of recognized manufacturers engaged in the production of lathing and plastering materials similar to those produced by the United States Gypsum Company of Chicago, Illinois. All gypsum plaster must conform to the ASTM C28 specification referred to in section 4.3 (140).

5.1.3 Installation and Erection Process

The traditional system of wall finishing in Egypt is described in the network diagram shown in Figure 5.1. This diagram shows the many
FIGURE 5.1

INTERFACE NETWORK DIAGRAM - EGYPTIAN INTERIOR FINISHING SYSTEM

(Reference: No. 34)
interrelationships between individual activities, including both those of precedence and hierarchy. Each element, or activity, shown in this diagram is described in Table 5.2.

Any alternative partition system must, at a minimum, be capable of accommodating activities C, E, G, J, K, M, and O. These activities concentrate on the installation of windows, doors, and electrical appliances. Window and door frames for interior partitions in Egypt range from 7.75 to 14 centimeters in thickness. Electrical conduit is of semi-rigid plastic and is usually 13 millimeters in diameter. Electrical boxes are 2.5 centimeters in thickness. Other partition systems must also be compatible with the skills of the laborers used in the construction of traditional brick walls (34).

Figure 5.2 presents a detailed cross-sectional drawing of a typical wall and floor unit, revealing some of the flaws associated with this type of construction. Brick walls in Egypt are frequently rough and out of alignment. Consequently the plaster finish must be sufficiently thick to cover these defects (140). Level points must be installed to establish a point of reference from which plaster surfaces, electrical boxes, and window and door frames can be aligned. Most frames and electrical boxes are aligned from these level points through the use of a plumb bob and cord. This is a delicate process that requires considerable skill, frequently resulting in misalignments (34).

Many of these problems associated with interior wall construction can be attributed to the lack of mandatory and enforceable building codes in Egypt.
### Table 5.2

**Activity Description for Network Interface Diagram**

<table>
<thead>
<tr>
<th><strong>Element</strong></th>
<th><strong>Activity Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Tartasha (plasterer)</td>
<td>Thin plaster mix is splashed onto walls and ceiling.</td>
</tr>
<tr>
<td>B. Level points, walls (plasterer)</td>
<td>Using taut strings and plumb bob, flat gypsum plaster spots are affixed to each wall to establish the plan of the finished wall surface. These are later removed during the applications of the wall plaster.</td>
</tr>
<tr>
<td>C. Electric conduits (electrician)</td>
<td>Channels are chiseled into the brick of walls and the concrete of the ceiling, and plastic conduits and wooden or plastic boxes are affixed with gypsum in such a way that the conduits will be buried securely beneath the plaster, and the boxes will be level with the plaster surface. Interface: These elements must be coordinated dimensionally to the imaginary wall plane established by the level points.</td>
</tr>
<tr>
<td>D. Horizontal level points (carpenter)</td>
<td>A water tube level is used to establish reference marks on columns 1 meter above the plane to which the floor tiles will be laid. These also serve to establish the heights of window and door units.</td>
</tr>
<tr>
<td>E. Door and window frames (carpenter)</td>
<td>Assembled frame units are inserted in rough wall openings, and are affixed by means of metal anchors mortared into openings chiseled from the masonry. Interfaces: Frames must be aligned to level points on the walls so the architraves will fit, and door frames must also be aligned vertically with the horizontal level points.</td>
</tr>
</tbody>
</table>
TABLE 5.2 (continued)

ACTIVITY DESCRIPTION FOR NETWORK INTERFACE DIAGRAM

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F. Plastering</td>
<td>Level strips of plaster are troweled across the level points to establish lines across which a board can be drawn to level the plaster to the required plane. The level points are then dug out and replaced with plaster. The surface is finished with a trowel to the desired texture. <strong>Interfaces:</strong> The plaster touches, and must come up level with, the window and door frames. The plaster embeds the electric conduit and should come up level with the electric boxes. The surface of the plaster plane is established by the level points.</td>
</tr>
<tr>
<td>G. Pull wires</td>
<td>Once the conduit is fully embedded in plaster and the plaster has hardened, electric wires are pulled through the conduits from one box to the next. <strong>Interface:</strong> Electric conduits.</td>
</tr>
<tr>
<td>H. Lay floor tiles</td>
<td>Sand is placed and leveled over the floor slab. A bed of mortar is spread, and tiles are laid in the mortar. <strong>Interfaces:</strong> The surfaces of the tiles must align with the level points for the floor.</td>
</tr>
<tr>
<td>I. Skirting</td>
<td>A plaster skirting is troweled onto the junction between the floor tiles and the wall plaster. <strong>Interfaces:</strong> This skirting must fit tightly to the plaster and to the wall tiles.</td>
</tr>
<tr>
<td>J. Fix sash and architraves</td>
<td>Window sash and doors are fitted into the previously-fixed frames. Architraves are applied over the junction between the plaster and the frames. <strong>Interfaces:</strong> Floor tiles, plaster, frames, skirting.</td>
</tr>
</tbody>
</table>
### TABLE 5.2 (continued)

**ACTIVITY DESCRIPTION FOR NETWORK INTERFACE DIAGRAM**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **K. Install switches**  
(electrician) | Electric switches and receptacles are connected to the wires and screwed to boxes. **Interfaces:** Wires, boxes. |
| **L. Painting undercoat**  
(painter) | First coat of paint is applied to plaster and wood components. **Interfaces** are not of dimensional significance. |
| **M. Fix glass**  
(glazier) | Glass is mounted in the sash. **Interface:** Sash. |
| **N. Painting final coat**  
(painter) | A final coat of paint is applied to all plaster and wood components. **Interface:** Care must be taken at all edges to avoid spoiling of glass, floor tiles, etc. |
| **O. Electric cover plates**  
(electrician) | Plastic or metal plates are affixed electric boxes. **Interface:** These plates must align with the switches and receptacles, with the plaster surface, and with the screw holes in the boxes. |
| **P. Polish Floor**  
(floor tiler) | The floor surface is ground and polished smooth with abrasive stones. **Interfaces:** Care must be taken to avoid damaging skirting and architraves. |
| **Q. Paint skirting** | The skirting is painted. **Interface:** Care must be taken to avoid spoiling of the floor and wall. |

FIGURE 5.2
DETAIL OF FLOOR/WALL INTERSECTION

5.1.4 Characteristics of Competing Products

Because of the lack of a mandatory set of performance codes and specifications in Egypt, new building products are often designed to replicate the characteristics of existing products. Thus these properties merely represent a minimum standard that can be used in the absence of specifications. The properties of these existing materials which were identified in Chapter 3, are outlined in Table 5.3.

Compressive strengths range from 25 to 250 kilograms per square centimeter for the various walling materials (74). It is safe to assume that walling products with compressive strengths above 50 kilograms per square centimeter would be acceptable by Egyptian standards. Although specific sound-blocking characteristics for bricks are not known at this time, they are in the range of 30 to 35 decibels. These ratings are reduced to 28 decibels with the use of doors and any other details that pierce a wall or partition (140).

5.1.5 Cultural/Climate Requirements

The climate in Cairo, the Nile Delta, and northern cities such as Alexandria, Ismailia and Suez ranges from cool in winter to hot in summer, with some rainfall occurring in midwinter. Farther south in Luxor and Aswan, the climate is dry and hot. The moisture susceptibility of gypsum as a result of climatic conditions in Egypt is not a significant problem. Even if these products are exposed to moderate amounts of rainfall, hardness and strength will return upon drying.
<table>
<thead>
<tr>
<th></th>
<th>RED BRICK</th>
<th>SAND-LIME BRICK</th>
<th>SHALE BRICK</th>
<th>LIGHTWEIGHT CONCRETE BLOCK</th>
<th>ICON BLOCK</th>
<th>CYRECO BLOCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAW MATERIAL:</td>
<td>Nile Silt</td>
<td>Sand and Quick Lime</td>
<td>Shale and Sand</td>
<td>Cement and Lightweight Aggregate</td>
<td>Gypsum with Silicon-Based Additive</td>
<td>Gypsum with Silicon-Based Additive</td>
</tr>
<tr>
<td>DIMENSIONS (centimeters):</td>
<td>25x12x6</td>
<td>25x12x6</td>
<td>25x12x6</td>
<td>50x12x20</td>
<td>66x50x8</td>
<td>66x50x7</td>
</tr>
<tr>
<td>AVERAGE COMPRESSION STRENGTH (kilograms/cm²):</td>
<td>45</td>
<td>250</td>
<td>75-120</td>
<td>25</td>
<td>n/a</td>
<td>85</td>
</tr>
<tr>
<td>AVERAGE WEIGHT (kilograms/brick):</td>
<td>2.75</td>
<td>3.2</td>
<td>n/a</td>
<td>7.6</td>
<td>23</td>
<td>14.55</td>
</tr>
<tr>
<td>AVERAGE BULK DENSITY (kilograms/m³):</td>
<td>1446</td>
<td>1835</td>
<td>1300</td>
<td>620</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>SOUND ABSORPTION:</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>50 dB</td>
<td>35 dB</td>
</tr>
<tr>
<td>THERMAL RESISTANCE (m²·°C/ncal):</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0.27</td>
<td>0.20</td>
</tr>
</tbody>
</table>

n/a: Not Available

As is customary in hot climates, ceiling heights are fairly high. In Egypt they are generally about 2.9 meters (74).

Egyptian housewives and maintenance personnel generally clean concrete and terrazzo tile floors by splashing water on them. Often some water comes into contact with the lower parts of partitions and walls. If these are of gypsum, some softening and erosion may occur. Consequently, it is necessary to protect walls and partitions with ceramic tile or similar skirtings, or be built upon plinths of brick, concrete block, or other water-resistant material.

In addition it is customary in Egypt to apply ceramic tile on wall and partition surfaces in baths and kitchens. This necessitates the use of a suitable tile base.

5.2 Technical Characteristics of Dryflow Panels

Dryflow panels cover a wide range of non-load bearing partition and party wall applications. These products consist of hollow-core glass fiber-reinforced gypsum panels, that provide builders with easily handled wall sections. All panel edges are tongued and grooved along the vertical edges for easy assembly and installation. The Dryflow panel system uses a filler bond jointing system which eliminates all joint bettens, nailing, and cover tapes. Panels may be filled with thermal insulating materials to increase the insulating values of walls to which they are attached. In addition, panel cores provide access for services, which can be installed at any point after the panels have been erected (28).
Panel facings vary in thickness, while webs are approximately 6 millimeters thick and spaced 50 millimeters on center. Typical panel cross-sections are shown in Figure 5.3. These sections are usually 90 centimeters in width, with lengths of 235, 240, and 270 centimeters. All panel dimensions can be varied by adjusting the forming molds. As discussed in Section 4.4, Dryflow panels are of gypsum, reinforced with longitudinal continuous glass fibers in the facings, and chopped, transverse fibers in the facings and webs. This is shown diagramatically in Figure 5.4. This glass reinforcement provides the panels with adequate impact resistance, yet allows panels to be cut and sawn using manual tools. By using glass fibers, a totally inorganic construction is possible, resulting in panels which will resist rotting, burning and delamination under moist conditions (28).

Dryflow partition installation may be carried out in several different ways. The first procedure consists of placing a track at the ceiling and a base plate or track at the floor. The panel is pushed against the ceiling track, swinging it to the base plate or over the floor track, and sliding it into place. This can be done against an existing wall or a previously placed panel, as is shown in Figure 5.5. Before the panel is placed into its final position, a polymer-modified gypsum-based adhesive compound is applied to the vertical edges, providing tight joints for adjacent panels, intersections, and covers. All adhesive that is squeezed out is scraped flush with the panel through the use of a spatula or putty knife. Scratches and other blemishes are repaired using the same compound in a similar manner.

The tracks may be of several shapes. These are pictured in Figure 5.6. Alternatively, pairs of moldings or baseboards may be used to hold
WALL PANELS

W1 Lightweight partitions for general housing and commercial applications.

Thickness (cm): 3.5
Weight (kg/m²): 2.3

W2 Heavy duty partitioning and party wall panels.

Thickness (cm): 3.7
Weight (kg/m²): 2.6

LININGS

L1 Lightweight non-insulating general purpose lining.

Thickness (cm): 3.1
Weight (kg/m²): 1.8

L2 Lightweight insulating lining for upgrading traditional cavity walls.

Thickness (cm): 3.1
Weight (kg/m²): 1.9

L3 Insulating factory lining and curtain wall backing.

Thickness (cm): 5.6
Weight (kg/m²): 2.2

FIGURE 5.4

DRYFLOW PANEL CROSS SECTION

FIGURE 5.5
TYPICAL DRYFLOW APPLICATION - PARTITION WALL AND DOORS

SECTION AT 'A'

DRYFLOW INSULATING LINING

DRYFLOW PARTITION

CONVENTIONAL LOAD-BEARING STRUCTURE

END PANEL CUT TO SIZE ON SITE AND JOINT MADE GOOD WITH GYPSUM FILLER BOND COMPOUND

FLUSH FINISHED BONDED TONGUE AND GROOVE JUNCTION

FIGURE 5.6
DRYFLOW ACCESSORIES

(a) Light-Gauge Head Rail

(b) Heavy-Gauge Head Rail

panels in place. These are shown in Figure 5.7. Panels may be flush with the ceiling, or may be free of the ceiling if held by tees with covering moldings or by outside channels.

Tracks and tees may be eliminated by employing dowel spikes driven into the ceiling, or by using clips attached to the upper edges of panels and nailed to the ceiling. High-strength mortar bids may be sufficient to anchor panels at the top and bottom. This is far more practical if the ceiling has been plastered or faced with a building board as is shown in Figure 5.7.

As discussed in Section 5.1, baseboards or skirtings may have to be employed to protect the bottoms of panels from moisture, using such materials as ceramic tile. Where subjected to moderate amounts of moisture, panels should be installed using masonry or other suitable water resistant plinths with hollow cores in order to protect the panels from water, while simultaneously providing alignment for the panels. The hollow cores also serve to accomodate wiring. Such plinths could take the place of baseboards or skirting.

Figure 5.8 shows several typical joints. Figure 5.8a shows the standard tongue-and-groove joint between adjacent panels. A corner section is shown in Figure 5.8b. Where deep cavities occur, a backup strip consisting of foamed polystyrene is wedged in and the joint is subsequently filled with a fibrous compound. Figure 5.8c shows an intersection of two partitions. Figure 5.8d shows a nail stud fastened to a wall, anchoring a partition panel in place. A joint between a grooved or housed door frame and partition is shown in Figure 5.8e where plumbing fixtures, cabinets, or other units are to be supported, strengthening members such as wood battens can be inserted in the hollow
FIGURE 5.7
DRYFLOW PARTITIONS

HOUSE CONSTRUCTION

Normal sole plate detail, with plate to provide nailing base for baseboards. Pre-punched, slotted metal light-gauge head rail. Slots provide free access for vertical services. With ceramic base or skirting, horizontal sole for nailing may be estimated. Panels may be wedged up against ceiling as at (b) below. Head rail may be eliminated by employing dowel nails, clips, or strong mortar bed.

CONCRETE CONSTRUCTION

Panels wedged to head rail and base filled with fibrous base fill compound. Wedges removed on setting to allow base movement in response to "creep" of concrete structure.

DOUBLE LEAF

Sound insulation increases from 30 to 50 dB, by double-leaf construction as shown. Suitable for bathroom areas, requiring increased sound insulation and substantial access for services. Meets requirements for school, hospital and hotel room dividers.

FIGURE 5.8

DRYFLOW JOINTS

(a) Standard Partition Joint

(b) Corner Joint

(c) Intersection of Two Partitions

(d) Joint, Wall, and Partition

(e) Partition to Door Frame

cores prior to panel erection, with the fixtures and other units fastened through the gypsum to the supports. Toggles and other fasteners may also be employed. These are shown in Figure 5.9.

Electrical wiring can be threaded vertically through the hollow cores, or placed in chases and channels cut in the panels. Electrical outlets can be installed in a similar fashion (28). This is shown in Figure 5.9b. Baseboard wiring, with provisions for outlets may be employed as shown in Figure 5.10.

For plumbing vent stacks, double-wall partitions can be used, with a sufficient space between them, as is shown in Figure 5.6.

Exterior walls of buildings may be lined with lining panels to provide a finish identical to that of partitions. Several typical installations are shown in Figure 5.11. A masonry cavity wall is shown in Figure 5.11a, showing an insulated Type L2 lining attached directly by adhesive patches. A solid masonry, or curtain wall, is shown in Figure 5.11b, with a type L3 insulated lining panel held away from the masonry by battens. Figure 5.11c shows an industrial wall, using an insulated L3 panel.

Figure 5.12 shows several details for party walls. All of these walls achieve the desired acoustical rating of 50 decibels. Figure 5.12a shows a traditional block wall, using type L1 linings attached directly using an adhesive. Panels are aligned through their tongue-and-groove joints. Figure 5.12b shows a wall with a single 100 millimeter block. To obtain desired levels of acoustical reduction, type W1 panels are positioned 50 millimeters from the masonry by battens. Figure 5.12c shows a non-loadbearing wall using two W2 panels spaced 200 millimeters apart and supplemented with an insulating quilt to provide an acoustical, thermal, and fire barrier.
FIGURE 5.9

DRIFFLOW ATTACHMENTS AND RECEPtACLES

(a) Various Means of Attachment to Partition.

(b) Electrical Receptacle Set in Bedding Compound.

FIGURE 5.10

DRYFLOW PANELS WITH ELECTRICAL BASEBOARD

CAVITY WALL

Type L2 insulating linings are designed to upgrade cavity walls to meet more stringent thermal requirements. When combined with W1 partitions gives unified finishing system for all interior wall surfaces.

SOLID MASONRY AND CURTAIN WALLS

Type L3 insulating linings provide the inner leaf. Outer leaf is block, non-fines concrete, brick or curtain wall. Suitable for systems based on load bearing outer leaf construction.

INDUSTRIAL LININGS

Type L3 linings designed to span between standard cladding sheeting rails up to 3 meters (10 feet) apart. Demountable when dry jointed and requires no additional metal joint trim or support systems. Meets factory thermal regulations.

FIGURE 5.12

DRYFLOW PARTY WALLS

TRADITIONAL CONSTRUCTION

Type L1 linings bonded directly to traditional block wall, using adhesive dabs at head, base and mid height. Self-aligning T. & G. system eliminates need for nailing pads or battens. Panels sufficiently rigid to be held by base wedging while dabs set.

THIN MASONRY WALL

Full party wall sound insulation achieved with under 100 mm (4 inches) blockwork, if lined with type W1 wall panels set 50 mm (2 inches) from block face. Block thickness then depends on load bearing requirements only.

NON LOAD-BEARING

Sound insulation requirements achieved without any blockwork, using type W2 wall panels set 200 mm (8 inches) apart with built in cavity.

At the time of preparation of this report, tests on full-sized Dryflow panels have not been performed. However, tests on smaller-scale proto-types have been conducted, and data have been extrapolated using standard engineering calculations. These tests were based upon British Property Service Agency requirements which are similar to those of ASTM (23).

Average moment bending capacities for Dryflow panels were approximately 50 kilograms, with a factor of safety ranging from 2.25 to 3.25. These capacities were computed by subjecting panels to predetermined, concentrated transverse center loads. The actual panel deflections were comparable to those of gypsum-based or other metal-stud partitions.

Impact resistance was measured using a test similar to the standard ASTM sandbag test. Additional tests were performed to measure impact resistance to a 50 millimeter steel ball (25). In both instances, resistance compared well with stud wall and gypsum-based systems. Consequently, its use in the construction of residential partitions should not pose any difficulties. For more severe applications, such as industrial, glass-fiber content can be increased, providing higher levels of resistance.

Panels were tested for sound insulation properties in an environment simulating actual conditions, using an acoustical range of 100 to 3150 Hertz. The single- and double-leaf W1 partitions shown in Figure 5.5, provided 30 and 40 decibels of insulation, respectively (25).

Dryflow panels possess adequate fire resistance properties as a result of the nonflammability of gypsum. Dryflow panels are rated at zero flame-spread in accordance with the ASTM specification for fire
resistance (E-84). Dryflow panels provide fire penetration resistance ranging from 0.5 to 1.5 hours. Similar tests on full-scale panels according to ASTM E-84 procedures have yet to be made.

5.3 Analysis and Conclusions Re: Dryflow Panel Ability to Meet Technical Requirement

From the foregoing presentation of physical properties and installation procedures for Dryflow panels, it is possible to conclude that they are feasible for use in Egypt.

Earlier tests by the British Building Research Establishment (BRE) have demonstrated that Dryflow panels can be formulated to give very high strengths. On the basis of these strength tests on small-scale samples and subsequent engineering calculations, the resistance to lateral loads and impact was judged to be adequate for use in Egypt. All Dryflow panels tested were produced using the least expensive gypsum plaster and a minimal quantity of glass fibers. The panels were designed to provide sufficient strength at a minimum cost. Currently, bending moment capacity and matrix crack strength for the 2.9 meter spans are satisfactory. However, these strengths represent a minimum factor of safety. In the future, glass fiber contents may need to be increased by as much as 50 percent, to provide for higher factors of safety.

Dryflow panels, and gypsum in general, have well known fire performance advantages. This has been confirmed through BRE tests, which have also shown that a high glass-fiber content will enhance this performance considerably. For Dryflow partitions used within a dwelling
unit, the Egyptian code provisions should be satisfied. The same is true for both party walls and Dryflow liner panels. In the future, fire tests on full-scale panels will be needed to confirm these preliminary findings. However, it is safe to assume that the fire resistance properties of Dryflow panels are well in excess of Egyptian requirements.

Moisture resistance for Dryflow panels is comparable to that for other gypsum products. The reinforcement in Dryflow panels does not weaken or debond under wet conditions. Although matrix strength is reduced, wet panels can still be handled satisfactorily. There is no progressive weakening under wet conditions and full strength is regained upon drying. The dry climate of Egypt should not present any problems. Where floors are to be washed with water, water resistant plinths and paints can be used effectively.

The installation process, as described in Section 5.2, does not appear to entail any difficult procedures, nor does it require intricate or lengthy training.

Dryflow partitions can be installed in the standard concrete frame and slab construction buildings found throughout Egypt. These panels can be installed through the use of tees and channels, or alternatively using strong mortar bonding, dowel nails, clips, and other similar devices. Outside channels or moldings placed at the tops of panels can be used to accommodate the irregular ceilings found in Egypt. It is anticipated that the installation of Dryflow panels will be compatible with typical Egyptian floor plans.

An attractive feature associated with Dryflow panels is the ability to eliminate the cost of accessories and all specialist labor operations.
associated with these. For Egyptian applications it would be possible
to develop a fixing method which requires no special tools or
accessories, other than the gypsum mortar and the plinths discussed
earlier. In Egypt plinths, such as those described in Section 5.2,
could be eliminated as contractors would have the option of protecting
the lower portion of the wall by carrying the floor tiling up to form a
water resistant skirting detail.

In addition, it is possible to skim coat Dryflow panels with
plaster. This offers an advantage in that rough cutting of panels is
far more compatible with local Egyptian work practices. This would also
guarantee an acceptable finish using existing skills and labor. By
using a skim coat, both sound insulation and strength would increase.

Dryflow panels are compatible with most electrical systems found in
Egypt. The head rails are designed to provide direct access for
electrical services without drilling. Cables from the ceiling cavity
can be inserted directly into the core slots after panel erection,
without requiring conduits. Socket boxes are simply mortared into place
between the webs. Shallow switch boxes can be held by normal plaster
board clips.

An alternative approach is to hack though the outer layer between
the two webs to produce the equivalent of a chased groove. This 30 by
30 millimeter slot could accommodate a normal conduit if this were
required. This approach would be particularly useful for skim coat
applications.

Similar considerations would apply to plumbing pipes, with these
services accomodated in the core slots. However, it is usually
preferable to design the areas requiring services around double leaf
partitions. This would provide sufficient access space for pipes. The additional panel area used for these double leaf zones would be small relative to the total building panel area.

The estimated sound-reduction factor for single-leaf partitions of approximately 30 decibels should be satisfactory for Egypt, even though it is lower than that of the 13 centimeter solid brick and plaster partitions. However, these solid brick partitions and the typical lightweight doors, with their corresponding flanking transmission effects, limit the effective insulation to 28 decibels. These lightweight doors are usually found in the typical mass housing of Egypt. At 27 decibels of effective insulation, Dryflow partitions are 1 decibel less than standard brick. It is reasonable to conclude that this would pose few problems, as the Egyptian mass market would be more easily influenced by price, availability, and convenience, rather than the theoretical specifications given by manufacturers.

5.4 Cost Competitive Analysis

5.4.1 Total Erected Dryflow Cost

The purpose of this section is to summarize and compare the competitive standing of Dryflow products in Egypt. Cost information will be presented on all competing walling products. This information will be used to make a preliminary assessment. The data for Dryflow products are based on minimum per unit product costs. Labor costs are
calculated assuming an average wage rate of 2 Egyptian pounds per man-hour for a typical work crew (140). The costs for head and base rails are based on British costs, using the current official exchange rate in all conversion calculations. In many instances the costs for Dryflow products have been overestimated. The Dryflow products that are compared in this analysis have been limited to non load bearing partitions and party walls. However, the production facilities described in Section 4.4 are also capable of producing the lining and insulating panels described in Section 5.2 should a market exist for these products in Egypt.

A cost summary for the erection of single leaf, 30 decibel, W1 Dryflow panels is shown in Tables 5.4 and 5.5. These estimates assume a two-man work team, consisting of one skilled and one semi-skilled worker, giving an average Egyptian wage rate of two pounds per man hour. These wage rates were furnished by AZAMCO, and apply to a work crew erecting gypsum block partitions. These wage rates were used because of the comparable man-hour and skill requirements. Table 5.4 assumes no skim coating and that the finished joints are ready for decoration, hence requiring 0.70 man hours for panel erection. The skim coating application described in Table 5.5 requires only 0.50 man hours for erection, resulting from the exclusion of all joint filling operations. An additional benefit associated with this practice is the elimination of labor for trades and finishing at corners. Also a large portion of the general making good provision can be transferred to the skim coating operations. These estimates are clearly approximate. However, they are accurate enough when related to the larger labor requirement of 3 man-hours for competing brick construction.
### Table 5.4

**COST SUMMARY – DRYFLOW PANELS (non skim coating applications)**

<table>
<thead>
<tr>
<th>WORK DESCRIPTION</th>
<th>MATERIAL * EGYPTIAN POUNDS PER SQUARE METER</th>
<th>LABOR ** EGYPTIAN POUNDS (HOURS)</th>
<th>LABOR ** EGYPTIAN POUNDS</th>
<th>COST PER SQUARE METER EGYPTIAN POUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Partition Panels (including bonding of vertical joints, taping and finishing both sides)</td>
<td>3.25</td>
<td>0.70</td>
<td>1.40</td>
<td>4.65</td>
</tr>
<tr>
<td>2. Galvanized Steel Head and Base Rails</td>
<td>0.50</td>
<td>0.20</td>
<td>0.40</td>
<td>0.90</td>
</tr>
<tr>
<td>3. General Making Good</td>
<td>0.15</td>
<td>0.23</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td>6.16</td>
</tr>
</tbody>
</table>

---

* Includes 10% profit and contingency

** Assumes average labor wage rate of L.E. 2.00 per hour

---

<table>
<thead>
<tr>
<th>WORK DESCRIPTION</th>
<th>MATERIAL* (EGYPTIAN POUNDS PER SQUARE METER)</th>
<th>LABOR ** (EGYPTIAN POUNDS PER SQUARE METER)</th>
<th>TOTAL COST PER SQUARE METER (EGYPTIAN POUNDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Partition Panel Erection (excluding tracks and finishing at corners)</td>
<td>3.25</td>
<td>0.50</td>
<td>4.25</td>
</tr>
<tr>
<td>2. Galvanized Steel Head and Base Rails</td>
<td>0.50</td>
<td>0.10</td>
<td>0.70</td>
</tr>
<tr>
<td>3. Skim Coat Plastering and General Making Good (both sides)</td>
<td>0.90</td>
<td>1.12</td>
<td>3.14</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>TOTAL</strong></td>
<td><strong>TOTAL</strong></td>
<td><strong>TOTAL</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>8.09</strong></td>
</tr>
</tbody>
</table>

* Includes 10% profit and contingency.

** Assumes labor wage rate of L.E. 2.00 per hour

The procedure for erecting twin leaf, 40 decibel, W1 panels is similar to the previously described process, with the exception of additional costs for larger panels and initial panel erection. The cost per square meter for a wall using twin panels is approximately 8.75 Egyptian pounds for non skim coat and 11.49 pounds for skim coat applications. Likewise, twin leaf, 50 decibel, party walls using W2 Dryflow panels can be installed at a square meter cost of 11.27 and 14.80 Egyptian pounds for non skim coat and skim coat, respectively. Although initially these costs appear to be prohibitive, they represent a small quantity relative to total building panel area. As was stated in Section 5.3, builders are more likely to purchase cheaper single-leaf partitions, being influenced by the lower price and greater convenience associated with these panels. Consequently, double-leaf partitions would be employed sparingly, for use with plumbing services.

5.4.2 Cost of Competing Products

The total erected cost for red bricks is shown in Table 5.6. These estimates are based upon 1978 data and were subsequently adjusted to current rates using information supplied by Arab Contractors of Cairo, Egypt. The erection of brick walls uses substantial man hours of labor, requiring the input of two masons, two unskilled laborers for the transporting of brick, two semi-skilled workers to prepare and transport water, one apprentice to patch, and one skilled scaffold builder. Shale and sand-lime bricks have an approximate total erected cost of 9.50 Egyptian pounds per square meter, or roughly 10 percent lower than that for red brick, resulting from the lower material costs.
TABLE 5.6

COST SUMMARY - RED BRICKS
(Egyptian Pounds)

<table>
<thead>
<tr>
<th>WORK DESCRIPTION</th>
<th>MATERIALS</th>
<th>LABOR</th>
<th>TOTAL COST PER SQUARE METER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Red Brick Wall</td>
<td>2.93</td>
<td>1.74</td>
<td>4.32</td>
</tr>
<tr>
<td>2. Plaster Base</td>
<td>-</td>
<td>-</td>
<td>3.67</td>
</tr>
<tr>
<td>3. Plaster Finish</td>
<td>-</td>
<td>-</td>
<td>2.53</td>
</tr>
</tbody>
</table>

TOTAL 10.52

SOURCE: Reference No. 134.
The 8 centimeter ICON gypsum panels described in section 3.2 can be erected for a total installed cost of 7.50 Egyptian pounds per square meter, of which 4.70 pounds covers materials. The 10 centimeter panels carry a total installed cost of 8.50 pounds per square meter, of which 6.2 pounds covers materials. ICON blocks can be erected by a crew of three workers, consisting of one mortar spreader, one block carrier, and one block layer. The mortar employed in the erection process is comprised of a special gypsum and chemical mix, of which 1.1 Egyptian pounds' worth is used for the installation of one square meter of panel (140).

The GYMCO panels described in earlier sections are significantly more expensive, with a unit price of 11 Egyptian pounds per square meter. These panels can be erected using a two man work crew consisting of one craftsman, or mason, and one assistant (135).

The cost advantages of single-leaf partitions over brick walls and GYMCO panels are apparent from the data presented in this section, offering savings of as much as 45 percent. Although the competitive position of ICON blocks appears initially to be somewhat significant, there are many problems and limitations associated with the use of these blocks in Egypt. Problems such as poor water resistance, poor impact resistance and long and specialized training for work crews has continually hampered the use of this product in Egypt (140). The price summary in Table 5.7 shows that Dryflow panels can compete favorably with the present array of interior walling products in Egypt.
<table>
<thead>
<tr>
<th>Product Description</th>
<th>Price (L.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryflow - Single Leaf (skim-coat applications)</td>
<td>8.09</td>
</tr>
<tr>
<td>Dryflow - Single Leaf (non skim-coat application)</td>
<td>6.16</td>
</tr>
<tr>
<td>Dryflow - Twin Leaf (skim-coat application)</td>
<td>11.49</td>
</tr>
<tr>
<td>Dryflow - Twin Leaf (non skim-coat application)</td>
<td>8.75</td>
</tr>
<tr>
<td>Red Brick</td>
<td>10.52</td>
</tr>
<tr>
<td>Shale Brick</td>
<td>9.50</td>
</tr>
<tr>
<td>Sand-Lime Brick</td>
<td>9.50</td>
</tr>
<tr>
<td>ICON Block (8 centimeter)</td>
<td>7.50</td>
</tr>
<tr>
<td>ICON Block (10 centimeter)</td>
<td>8.50</td>
</tr>
<tr>
<td>GYMCO Panels</td>
<td>11.00</td>
</tr>
</tbody>
</table>

5.5 Implementational Considerations

5.5.1 Availability of Capital

The Egyptian government has tried to control inflation by limiting local capital availability and credit expansion. The government has also implemented International Monetary Fund recommendations for increases in lending rates in an attempt to discourage unproductive investment. Borrowing rates currently range from 13 to 16 percent per annum for ordinary operations and 12 percent for export financing (90).

All firms in Egypt, particularly those formed under Law 43, can obtain local and foreign exchange from either private, joint-venture, or state-owned banks. Public-sector firms may deal with joint-venture and state-owned banks, although they may not do business directly with private of completely foreign-owned banks. Private-sector firms are free to deal with any bank (35).

Of the four state-owned banks in Egypt, the largest is the National Bank of Egypt. This bank handles the greatest volume of foreign trade operations, and owns 51 percent of joint ventures with Chase Manhattan (United States), and Societe Generale and Credit Lyonnais (France). The second bank, Bank Misr, is oriented towards development banking and serves as a holding company for a number of industrial enterprises. Bank Misr also holds a 51 percent joint venture with the First National Bank of Chicago (United States), UBAF Bank Ltd. (France), and Banco di Roma (Italy). Bank Misr is also a partner in
Misr International Bank, Misr-Iran Development Bank, and Misr-Rumanian Bank. The third state-owned bank is the Bank of Alexandria. This institution is responsible for the majority of public industrial-sector financing. The Bank of Alexandria has 51 percent equity in a joint venture with American Express International Corporation (United States), with authorized local capital of $30 million. The last bank is the Bank of Cairo, which deals primarily with the service and construction sectors. It has a 50 percent joint venture with Barclays International (United Kingdom) and small equity shares with Banque Nationale de Paris and Banque du Caire et Paris (France).

The largest of these joint ventures between the state banks and foreign banks is the Chase National Bank. This bank, being majority-owned by Egyptians can operate in both Egyptian pounds and dollars. Other joint-venture banks have applied to become 51 percent locally owned, since that would give them the right to operate in local currency. These applications have been delayed, as the government is reconsidering its policies toward minority-owned banks and may soon allow them to deal in local currency.

Two additional banks that were set up to deal exclusively with foreigners and in local currency are the Arab International Bank and the Arab African International Bank. These banks are exempt from Central Bank control, taxes, and disclosure requirements (85).

Short-term funds can be borrowed from most of the above banks. These are usually in the form of drafts on letters of credit. These are primarily used to finance working capital and seasonal needs. Despite the high inflation rate in Egypt, short-term interest rates are low. The Central Bank discount rate is currently 12 percent, and borrowers can usually obtain funds at 13 to 15 percent (136-139).
The primary source of medium- and long-term credit is from the state-owned Development Industrial Bank. Hard-currency loans are currently 11 percent per annum, while local-currency loans range from 11 to 13 percent. These funds mainly come in the form of loans from foreign countries. Most borrowers of these funds, desiring to finance imports, are tied to the suppliers from the lending country.

Additional sources of long-term capital include the Misr Iran Development Bank, a joint venture between Misr Bank and Iranian capital, and two private banks, the Cairo-Far East Bank and Mohandes Bank. A summary of the terms and conditions for some of these lending institutions is shown in Table 5.8.

Most banks require at least a 1.5 to 1 debt-to-equity ratio. One exception to this is Chase National Bank which will go as high as 2 to 1, contingent upon long-term cash flow streams (138). Some public sector banks will go as high as 4 to 1. Most banks prefer a medium-term duration of 3 to 5 years. Occasionally, through a decision from the bank's board of directors, this will be extended to 7 years. The grace period varies considerably, but generally ranges from 3 to 18 months, with 6 to 12 months from the start of production being the most common.

All banks grant interest rates on foreign currency of 1.5 to 2.5 percent above London Interbank Overnight Rates (LIBOR). Commitment fees are generally negotiable. The current interest rate for local currency loans, as determined by the Central Bank of Egypt, is 13 percent per annum for all industrial projects. Fees on these loans, also set by the Central Bank, are currently 0.5 mille per month.

Once long-term loans have been negotiated, most banks will extend working capital loans in the form of letters of credit for the firm, which usually include overdraft accounts (137).
<table>
<thead>
<tr>
<th></th>
<th>MISR/IRAN</th>
<th>CAIRO-PAR EAST</th>
<th>CHASE NATIONAL</th>
<th>MOHANDES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>debt/equity ratio</strong></td>
<td>1.5:1</td>
<td>1.5:1</td>
<td>1.7-2.0:1</td>
<td>1.5:1</td>
</tr>
<tr>
<td><strong>duration. (max)</strong></td>
<td>3-5 years</td>
<td>3-5 years</td>
<td>3-5 years</td>
<td>3-5 years</td>
</tr>
<tr>
<td><strong>FOREIGN CURRENCY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interest rates</td>
<td>LiBor</td>
<td>LiBor</td>
<td>LiBor</td>
<td>LiBor</td>
</tr>
<tr>
<td>fees</td>
<td>2%</td>
<td>2%</td>
<td>1/2 per mille</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>per month</td>
<td></td>
</tr>
<tr>
<td>commitment fees</td>
<td>none</td>
<td>N/A</td>
<td>1% on balance</td>
<td></td>
</tr>
<tr>
<td>grace period</td>
<td>1 year</td>
<td>1/2-1 year</td>
<td>1/2 year</td>
<td>3-6 months</td>
</tr>
<tr>
<td><strong>LOCAL CURRENCY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interest</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
</tr>
<tr>
<td>fees</td>
<td></td>
<td></td>
<td>1/2 mille per</td>
<td>(both set by Central Bank)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>month</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>consistent with foreign currency loans</td>
</tr>
</tbody>
</table>

**SOURCE:** Reference Nos. 136, 137, 138, and 139.
A major obstacle that currently exists, regarding banks' ability to lend capital, is the ceiling imposed by the Central Bank of Egypt that requires a loan-to-deposit rate of 65 percent (90). As a result, banks exhaust their supplies of capital early in the fiscal year.

To secure credit, Egyptian banks require that the borrower provide a feasibility study, detailing the economic feasibility of the product, cost breakdowns, sales and financial projections, a list of the firms covenants and officers, and information on equipment suppliers with regard to financial history and credit worthiness. In addition, loans usually require some sort of guarantee, either mortgages on land or buildings, or in the case of foreign subsidiaries, a guarantee from the parent company or a foreign bank (138).

Equity capital represents another source of funding in Egypt. This represents an important source of capital, in light of the 1:1 debt-to-equity ratio required under Law 43. Both Misr-Iran Bank and Cairo Far East Bank provide equity capital. Misr Iran Bank will provide up to 20 percent of total equity. Cairo-Far East Bank requires shareholders to raise 20 to 25 percent of equity. Both banks make their participation contingent upon the shareholders' ability to raise a minimum portion of the required equity (136, 137).

The best major source of long-term financing is through arrangements with foreign equipment manufacturers. Most exporting countries offer some form of export promotion device that allows domestic firms to compete in international markets. In the majority of instances, countries provide lines of credit to companies exporting equipment to Egypt. The terms and availability of this credit are often
influenced by the relationship between the Egyptian government and that of the exporting nation. Presently, the United States is the largest aid donor to Egypt, followed by the European Economic Community countries and Japan. Because the equipment of the United States, Japan, and the United Kingdom is the most cost-competitive, only the aid programs of those countries will be described.

The United States offers aid through the Agency for International Development (AID). The terms and conditions offered by the AID program are generally the most attractive. AID is the only foreign agency that has set up an official program to target the Egyptian private sector. This has been accomplished through the commodity import program, which covers all AID financed capital and intermediate goods. The program finances projects by selling foreign exchange, through the Egyptian government, to private-sector firms at the official exchange rate. Currently, only public-sector commercial and specialized banks are the only participants in the program. These banks grant loans for 75 percent of the transaction amount with a maximum term of three years. A loan guarantee is secured by AID in the United States, and the suppliers deliver the equipment to Egypt after a letter of credit has been extended in the United States. Interest rates for end users are presently 10 percent per annum and 12 percent for wholesale traders (50).

Jointly-owned companies, formed under Law 43 are not eligible for these loans. Although this program has spent $137 million over the last five years, it is currently undergoing major changes, and its programs are expected to be significantly revised for fiscal year 1983. In revising the policies of this program, AID will attempt to include
both joint-venture and private-sector-banks. The two major problems associated with this program are that Egyptian banks require collateral to exceed the down payment by 25 percent and that bank lending fees are excessive, ranging from 6 to 12 percent (122).

A similar program is available for public-sector firms. The terms under this program are 10 percent and 5 years for capital goods and 5 percent and 3 years for intermediate goods. This program will also be revised for fiscal year 1983. The only major change will be to lower the duration of these loans and to raise interest rates to a level more compatible with those for loans extended to the private sector.

The Export-Import Bank of the United States also provides long-term financing assistance for U.S. exports. This financing takes the form of either a direct loan to an overseas buyer, or a financial guarantee assuring repayment of a private credit. The Export-Import Bank will frequently combine these two forms of support into a single financing package. This bank will provide credit for up to 65 percent of the U.S. export value. The bank requires a cash payment from the buyer to the U.S. seller of at least 15 percent of the export value. The balance of the financing is usually provided by private lending sources.

Repayment of principal and interest normally begins six months from the date of delivery of the products or completion of the project. Terms generally range from five to ten years. The bank's interest rates are fixed for the life of the loan at the time of authorization. The current interest rate for these loans is 10 percent.

The United Kingdom does not currently have a program for assisting Egyptian private sector firms. The only source for financing private sector purchases of UK equipment is through the Egypt Credit
Guarantee Department (ECGD). The exporter is responsible for initiating this process in the United Kingdom under the export credit guarantee policy. The present terms for capital goods under this policy are 5 years and 10 percent, with a down payment of 20 percent. The terms of this policy allow for 10 percent of the value to be in local capital goods (120). In Egypt, this could be applied to the erection of gypsum plant facilities.

Japan offers two types of loans to Egyptian firms. The first type is extended only to public-sector firms. These are similar to AID loans, and offer terms of 3 percent and 30 years. The other source of loans is through the Japanese Export/Import Bank. The policy of this bank is to extend a line of credit to the Egyptian Ministry of Investment and International Cooperation, giving the Ministry the responsibility of allocating funds to various projects. The current rate for these loans is 9 percent per annum, and a down payment of 25 percent, with the loan duration and grace period being negotiable (76).

5.5.2 Foreign Investment and Tax Laws

In April, 1974, President Sadat presented a Working Paper to the Egyptian People's Assembly. This document was subsequently approved in a national referendum in May of the same year. The fundamental changes in economic policy, expressed in this Working Paper, led to the enactment of Law Number 43 of 1974. This represented a departure from its stance toward foreign investment in the 1960's, during which time the government nationalized foreign investments in most sectors of the economy.
The majority of foreign investors who have shown an interest in Egypt were motivated by the promulgation of this law, and its subsequent amendment in 1977. This law encouraging foreign investments, offers such incentives as guarantees against expropriation, exemption from many of the nuisance provisions that apply to local firms, and other favorable legislation on banking, foreign-currency dealings, and commercial representation. In addition, Law Number 59 of 1979 provides a ten year or longer tax holiday for all joint ventures located in the new communities. This legislation has since made foreign capital and technology more easily available to the Egyptian economy (50). The following review summarizes the three major provisions of Law Number 43.

1. Ownership

All projects must be established jointly, with Egyptian capital supplied by either public or private sector firms. A minimum percentage of local participation is not required.

2. Inflow and Outflow of Funds

All invested capital in the form of foreign currency, brought into Egypt shall be transferred at the highest prevailing exchange rate, as declared by all applicable Egyptian authorities. All invested capital may be re-exported or disposed of in full to the extent of the credit balance in the foreign exchange account or "if the investors had disposed of such capital in exchange for free foreign currency."

Invested capital is defined as free foreign currency, machinery and equipment, intangible assets, and all free foreign currency spent on preliminary studies, research, and incorporation costs. All earlier restrictions affecting the marketability of equity have been abolished. This may be done provided that five years have elapsed from the date of
importation of the capital. The Investment Board will waive this condition if a project cannot be implemented or continued for reasons that are beyond the control of the investor. The transfer of invested capital abroad must be done in five annual equal installments at the rate of exchange prevailing at the time of transfer. Invested capital may be exchanged in full if the investor had disposed of said capital in exchange for free foreign currency actually transferred into Egypt. All investment in favor of a third party shall transfer the privileges of Law 43, only if the purchase is made in free foreign currency. If the divestment is made in local currency, the purchaser is denied those privileges of Law 43 enjoyed by the divesting party (85).

To receive exemption from exchange control regulations, a project may maintain a bank account(s) in foreign currency with one of the authorized banks in Egypt. On the credit side of such accounts shall be entered all free currency received from abroad, purchased from local banks, or received from sales made to the local market in foreign currencies. This account is utilized for the payments of imported investment goods and commodities necessary for the operation of the project, interest and principal of foreign loans, and any other necessary project expenses (90).

3. Incentives and Guarantees

All profits are exempt from all taxes on commercial, industrial, and undistributed profits. Distributed profits, or dividends, are exempted from General Income Tax, proportional stamp duty, and the tax on the revenues for movable capital. The exemption from the General Income Tax is conditional upon such income not being transferred. These exemptions are valid for a period of five years (90).
All interest due on foreign loans made by the project shall be exempt from all Egyptian taxation.

Tax exempt status for a period of ten years will be extended to projects established in new cities outside the agricultural area and the perimeters of existing cities. This period may be extended to fifteen years with the approval of the Investment Authority Board (53).

All capital assets and components required by projects may be exempted from, or granted the privilege of deferred or installment payments for all or part of the customs duties. If any exempted items are disposed of within five years from the date of import, all taxes and duties previously exempted must be paid. All exemptions and deferments must be negotiated with the Investment Board (55).

Disadvantages associated with operating under Law 43 are that electricity and fuel costs are at current international prices and that debt-to-equity ratios must be at least one to one. An alternative to incorporation under this law is to incorporate under existing local laws. By incorporating under Law 159, firms may purchase fuel and electricity at subsidized prices, and may have any debt-to-equity ratio within the limitations of the lending institutions. In addition, mining companies formed under this local law receive a five-year tax holiday (54). Disadvantages associated with Law 159 are difficult access to import markets and foreign exchange and stringent labor laws and duty regulations.

Despite these problems, it may still be advantageous to incorporate under Law 43, particularly if a financial institution would be willing to participate in the equity portion of the project along with the individual shareholders. Under these circumstances a one to
one debt-to-equity ratio restriction would pose few problems. However, it may be feasible to incorporate under local laws if a firm's interaction with the import market is not going to be great and if the one to one ratio is too restrictive.

The new corporate tax law effective January 1, 1981 has greatly simplified Egypt's corporate tax structure, establishing a flat 32 percent tax rate. This tax applies to all undistributed profits and as a withholding tax on distributed profits. All dividends paid out are deductible from taxable income. All losses may be carried forward for five years (53).

Depreciation rates vary both by item and according to area of use. Industrial machinery and equipment allowances range from 5 to 8 percent. Vehicles for road transportation range from 8 to 25 percent. Firms may use either straight-line or the declining balance method. Depreciation may not be delayed until after the tax holiday, because it is calculated on actual depreciation during the company's fiscal year (53).

5.5.3 **Availability of Infrastructure**

An assessment of the local infrastructure can be divided into three areas, water, electric power, and transportation. Currently the Fayoum governorate lags behind the regions of northern Egypt in these areas, as most of the infrastructural network has exceeded its estimated life and is unable to cope with present demand.

Fayoum presently relies on two sources for its water supply, the water treatment plants at Kahafa and El Azab. The water treatment
plant at Kahafa, established in 1926, feeds the northern portion of Fayoum City. The plant at El Azab feeds both the southern portion of Fayoum City and the remainder of the Fayoum Governorate. In principal the plant at Kahafa was to feed the entire city of Fayoum, while the El Azab plant would feed all areas within the governorate located outside of Fayoum City.

The plant at Kahafa consists of four pumps with a total capacity of 470 liters per second. However, because of frequent breakdowns, average outflow is only 200 liters per second. The function of these high pressure pumps is to pump the purified water through the distribution nets of the governorate. Because the needs of Fayoum City are 450 liters per second, an additional 200 liters per second must be directed from El Azab to the city, leaving a shortage of 50 liters per second.

The water needs of the governorate far exceed the current level of production. Many areas within the governorate are not reached by the distribution networks. The only adequate water supply within close proximity to the quarrying site is located five miles away. This water supply is usually sufficient, however, at certain times of the day there is either inadequate water pressure or a complete stoppage of water flow. Because only small quantities of water are required for gypsum calcining and Dryflow production, it appears as though the local water supply will be adequate.

The electric current feeding the Fayoum governorate is fed from the Fayoum substation. This substation produces a voltage output of 66/11 kilo-volts and a power output of 30 mega-watt amps. This substation is fed by the substation at Beni Suef (66/11kv and 132 Mw-A).
through a dual, 66 kv overhead line. One transformer at the Fayoum substation is used to feed the water purification plant, while the other two substation transformers feed Fayoum City and the surrounding area, including the mining site at Gerza.

Future construction plans include a 20 mega-watt gas generation station supplying 1lkv and a 220/66/11 kv transformer station in the Darma area. This latter station will receive 220 kv through an aerial line from Cairo. It is expected that this station will be completed by late 1984 and will replace the present line at Beni Suef. It is expected that power output will keep pace with increased future levels of demand, as total output will increase from a current 30 MV-A to 90 MV-A by the year 2000 (44). Given present conditions, the electric power supply in Fayoum will be adequate for the operation of a gypsum plant.

The network of roads, including those between Fayoum City and Beni Suef and Cairo, appears to be more than adequate for the transport of gypsum ore and its finished products. The roads connecting the many towns and villages of the governorate are also adequate, and would pose few problems.

5.5.4 Availability of Site

The availability of the quarrying sites at Fayoum is governed by the rules and regulations of Law Number 86. According to this law, all persons, whether natural or nominal, have the right to explore for minerals on any uncontested quarry property in Egypt, as long as all necessary permits are secured. Egyptian nationals have priority over
foreigners with respect to quarry exploration (59). Currently, no such claims exist for most of the gypsum quarry sites in Fayoum.

Exploration contracts are then issued by the Ministry of Industry for the time duration requested by the applicant. The contract length must exceed one year and be for no more than thirty years. Expired contracts may be renewed for a period no longer than fifteen years. These contracts may be renewed a maximum of two times. Additional renewals may be granted by the Ministry of Industry. All contracts will be revoked for any work stoppages greater than 90 days. Exemption from cancellation will be granted by the Department of Mines and Quarries under extenuating circumstances.

Royalties must be paid every six months at the rate of 0.5 Egyptian pounds for each ton of Gypsum or Anhydrite quarried or 0.075 pounds for each cubic meter quarried. Choice of payment is left to the discretion of the owner. The licensee must pay in advance an annual rent payment determined by the Minister of Industry and Commerce. In addition, the Department of Mines and Quarries requires an annual rent payment on areas used by the licenses outside the area of exploration for service buildings or other related activities. Rents are collected at the following rates:

1. 5 Egyptian pounds per hectare or portion thereof used for storage or manufacturing facilities.

2. For water or compressed air pipelines, aerial electric lines or public roads, a fee of 0.1 Egyptian pounds per meter for the first kilometer, and 0.05 pounds per meter thereafter.

For quarries that have both rent and royalty obligations, only the higher of the two must be paid (59).
5.6 **Summary and Conclusions**

From the preceding analysis it is possible to conclude that Dryflow panels are both technically and economically feasible for use in Egypt. Preliminary tests for compressive strength, and impact and fire resistance have shown that Dryflow panels either meet or surpass all Egyptian requirements for interior partitions. The simple installation procedures associated with these panels enables contractors to use this product without resorting to specialized labor. Tradesmen, such as masons and apprentices can be easily taught the few basic panel installation steps. In addition, the installed panel system will not be subject to the defects associated with brick wall construction as were outlined in Section 5.1.

The cost summary shown in Table 5.8 shows total installed cost savings of up to 45 percent for single leaf Dryflow panels. It is assumed that as Dryflow panels become more accepted in Egypt, contractors will switch to less expensive non skim-coat applications, being influenced by its reduced cost and greater ease of handling. Although double-leaf partitions are more expensive, their use would be strictly limited to plumbing service enclosures.

Capital, whether in local or foreign currency, is available to most credit-worthy investment opportunities. Currently, many options exist for the borrowing of capital, including leveraging structure and lending institution. Two options are presently available for incorporation in Egypt, each with its own inherent advantages. These options will be assessed individually in Chapter 6, carefully weighing the benefits and
disadvantages for a wide array of financial scenarios. In addition, the cost and availability of the quarrying site and infrastructure, as previously described, will be used in the following project analysis.
CHAPTER SIX

GYPSUM-BASED CONSTRUCTION PRODUCT MANUFACTURING IN THE FAYOUm GOVERNORATE - A CASE STUDY

To determine the profitability of gypsum-based product manufacturing facilities, a case study framework is developed in Chapter 6. This case study is applied to two integrated production facilities, the first producing only calcined gypsum and the second producing both calcined gypsum and Dryflow panels.

For the purposes of this analysis, a gypsum quarrying site located within the Fayoum Governorate has been selected. This general area was selected on the basis of its accessibility to the markets of Cairo and Fayoum, and its immediate availability to potential investors.

Chapter 6 presents this case study in three steps as follows. Firstly, a summary of the pertinent market data and conclusions of Chapter 3 is presented, providing information on future market demand for plaster and panels. Secondly, optimal quarry sites and equipment configurations are determined, showing detailed investment and production cost breakdowns for all selected equipment. The chapter concludes with a comprehensive financial feasibility analysis.
6.1 Market Assessment for Gypsum-Based Construction Products

6.1.1 Gypsum Plaster

Based on the data in Chapter 3, Table 6.1 has been constructed showing three scenarios for calcined gypsum demand through 1992. These data are shown graphically in Figure 6.1. The "pessimistic" level of demand, as derived by McKee-Kearny (97) is based on a real GNP growth rate of 7 to 9 percent for the Egyptian economy. The "optimistic" forecast, formulated by Booz Allen and Hamilton (31), assumes a 10 to 12 percent real rate of growth. The "most likely" forecast was calculated as an average of the two limits. These three scenarios will be incorporated into the financial feasibility analysis of Section 6.4.

Actual real Gross Domestic Product (GDP) growth has averaged 8 percent per annum over the past six years. In 1981, real GDP grew an estimated 9.3 percent, with the petroleum sector growing at 12 percent. Agriculture and manufacturing each advanced by only 4 percent, thus dampening GDP growth. It is expected that future growth will slow to 7 to 8 percent, due to reduced tourist and oil revenues (90). Consequently, it can be assumed that future real rates of GNP growth will fall within the limits set by the previous scenarios. The actual level of GNP growth will depend on such factors as revenues from oil and the growth of the local service industries (85).

Because the demand forecasts of Chapter 3 were provided only through 1990, an ordinary least squares linear trend line was employed to obtain data for 1991 and 1992.

As shown in Chapter 3, the markets of Cairo and Fayoum consume approximately 50 and 4 percent respectively (63), of the national total. Plaster consumption data for these regional markets are shown in Tables
<table>
<thead>
<tr>
<th>YEAR</th>
<th>DEMAND - OPTIMISTIC (a)</th>
<th>DEMAND - MOST LIKELY</th>
<th>DEMAND - PESSIMISTIC (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>599,000</td>
<td>521,000</td>
<td>443,000</td>
</tr>
<tr>
<td>1984</td>
<td>650,000</td>
<td>562,000</td>
<td>474,000</td>
</tr>
<tr>
<td>1985</td>
<td>701,000</td>
<td>603,500</td>
<td>506,000</td>
</tr>
<tr>
<td>1986</td>
<td>765,000</td>
<td>656,500</td>
<td>548,000</td>
</tr>
<tr>
<td>1987</td>
<td>837,000</td>
<td>701,500</td>
<td>566,000</td>
</tr>
<tr>
<td>1988</td>
<td>915,000</td>
<td>757,000</td>
<td>599,000</td>
</tr>
<tr>
<td>1989</td>
<td>1,002,000</td>
<td>817,000</td>
<td>632,000</td>
</tr>
<tr>
<td>1990</td>
<td>1,096,000</td>
<td>880,500</td>
<td>665,000</td>
</tr>
<tr>
<td>1991</td>
<td>1,129,000*</td>
<td>912,000</td>
<td>695,000*</td>
</tr>
<tr>
<td>1992</td>
<td>1,196,000*</td>
<td>961,000</td>
<td>726,000*</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line applied to existing data.


(b) McKee-Kearny, "Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company," 1981. (Reference: No. 97)
FIGURE 6.1
CALCINED GYPSUM DEMAND - THREE SCENARIOS

(Reference: No. 31)

McKee-Kearny, Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company," 1981.
(Reference: No. 97)
6.2 and 6.3.

Currently, the Kawmia Cement Company (KCC) is supplying the local market of Fayoum with plaster at a price of L.E. 30 per metric ton. KCC is the only plaster producing firm located within close proximity to these markets, as all other producers are located in Northern Egypt. Because of the poor quality of its reserves in Fayoum, KCC will not be able to extract gypsum ore from these quarries after 1984. Consequently, KCC has signed a contract with the Sinai Manganese Company (SMC) for the transport of gypsum from the SMC quarries at Ras Malaab to Fayoum, a distance of 300 kilometers (97). Because of the additional transportation costs associated with this, KCC will no longer be able to provide plaster at their current price. Eventually, KCC will be forced to sell plaster at a price approaching that of their competitors, currently 40 pounds per metric ton (143).

As a result, the proposed calcined gypsum production facility selling plaster at a lower price could capture the entire Fayoum market, which according to Table 6.3 could likely reach 38 thousand metric tons per annum by 1992.

Plaster demand in the Cairo region is currently met by three producers: GYMCO, KCC, and the Alexandria Cement Company (97). With the existing level of supply, some private-sector consumers have complained about intermittent plaster shortages. This phenomenon is further substantiated by the existing "black market" in Cairo, where prices periodically reach 75 to 90 Egyptian pounds per metric ton (143). It is assumed that these conditions will prevail, as larger public-sector contractors continue to absorb a disproportionate share of total output.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>DEMAND - OPTIMISTIC (a)</th>
<th>DEMAND - MOST LIKELY</th>
<th>DEMAND - PESSIMISTIC (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>299,500</td>
<td>260,500</td>
<td>221,500</td>
</tr>
<tr>
<td>1984</td>
<td>325,000</td>
<td>281,000</td>
<td>237,000</td>
</tr>
<tr>
<td>1985</td>
<td>350,500</td>
<td>301,750</td>
<td>253,000</td>
</tr>
<tr>
<td>1986</td>
<td>382,500</td>
<td>328,250</td>
<td>274,000</td>
</tr>
<tr>
<td>1987</td>
<td>418,500</td>
<td>350,750</td>
<td>283,000</td>
</tr>
<tr>
<td>1988</td>
<td>457,500</td>
<td>378,500</td>
<td>299,500</td>
</tr>
<tr>
<td>1989</td>
<td>501,000</td>
<td>408,500</td>
<td>316,000</td>
</tr>
<tr>
<td>1990</td>
<td>548,000</td>
<td>440,250</td>
<td>332,500</td>
</tr>
<tr>
<td>1991</td>
<td>564,500*</td>
<td>456,000</td>
<td>347,500*</td>
</tr>
<tr>
<td>1992</td>
<td>598,000*</td>
<td>480,500</td>
<td>363,000*</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line applied to existing data.

**SOURCE:**

(b) McKee-Kearney, "Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company," 1981. (Reference: No. 97)
<table>
<thead>
<tr>
<th>YEAR</th>
<th>DEMAND - OPTIMISTIC (a)</th>
<th>DEMAND - MOST LIKELY</th>
<th>DEMAND - PESSIMISTIC (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>23,960</td>
<td>20,840</td>
<td>17,720</td>
</tr>
<tr>
<td>1984</td>
<td>26,000</td>
<td>22,480</td>
<td>18,960</td>
</tr>
<tr>
<td>1985</td>
<td>28,040</td>
<td>24,140</td>
<td>20,240</td>
</tr>
<tr>
<td>1986</td>
<td>30,600</td>
<td>26,260</td>
<td>21,920</td>
</tr>
<tr>
<td>1987</td>
<td>33,480</td>
<td>28,060</td>
<td>22,640</td>
</tr>
<tr>
<td>1988</td>
<td>36,600</td>
<td>30,280</td>
<td>23,960</td>
</tr>
<tr>
<td>1989</td>
<td>40,080</td>
<td>32,680</td>
<td>25,280</td>
</tr>
<tr>
<td>1990</td>
<td>43,840</td>
<td>35,220</td>
<td>26,600</td>
</tr>
<tr>
<td>1991</td>
<td>*</td>
<td>36,480</td>
<td>27,800</td>
</tr>
<tr>
<td>1992</td>
<td>*</td>
<td>38,440</td>
<td>29,040</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line applied to existing data

**SOURCE:**


(b) McKee-Kearny, "Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company," 1981. (Reference: No. 97)
As highlighted in Section 3.1, GYMCO and KCC are currently expanding existing facilities or are constructing new ones in an effort to increase capacity. However, the execution of these plans has been subject to various delays, extending start-up times by at least two years (97).

In formulating their future production plans, the Mahmoud Osman Company has forecasted a 15 percent Cairo market share for all plaster manufactured by its production facilities in the Sinai (143). This figure can be regarded as being somewhat optimistic in light of the substantial production increases planned by the three existing producers for later years. A more conservative market share of 5 percent appears to be more reasonable. Assuming a new calcined gypsum production facility located in Fayoum would be capable of capturing that amount, total sales to the Cairo market could very likely reach 26 thousand metric tons per year by 1992.

The annual quantities of gypsum plaster that could be sold to the local markets of Cairo and Fayoum are summarized in Table 6.4. The data shown in this table play an integral role in determining the optimal plant output and subsequent configuration in Section 6.3.

6.1.2. **Building Partitions**

The future demand for partition products has been calculated using the data of Chapter 3 as a basis for forecasting. Because these earlier data have been estimated only through 1985, a least squares line has been fitted to the existing data and used to forecast future values. The data for two scenarios through 1992 are shown in Table 6.5.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>FAYOUM MARKET</th>
<th>CAIRO MARKET</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>10,420</td>
<td>13,025</td>
<td>23,445</td>
</tr>
<tr>
<td>1984</td>
<td>11,240</td>
<td>14,050</td>
<td>25,290</td>
</tr>
<tr>
<td>1985</td>
<td>24,140</td>
<td>15,088</td>
<td>39,228</td>
</tr>
<tr>
<td>1986</td>
<td>26,260</td>
<td>16,413</td>
<td>42,673</td>
</tr>
<tr>
<td>1987</td>
<td>28,060</td>
<td>17,538</td>
<td>45,598</td>
</tr>
<tr>
<td>1988</td>
<td>30,280</td>
<td>18,925</td>
<td>49,205</td>
</tr>
<tr>
<td>1989</td>
<td>32,680</td>
<td>20,475</td>
<td>53,155</td>
</tr>
<tr>
<td>1990</td>
<td>35,220</td>
<td>22,013</td>
<td>57,233</td>
</tr>
<tr>
<td>1991</td>
<td>36,480*</td>
<td>22,788</td>
<td>59,268*</td>
</tr>
<tr>
<td>1992</td>
<td>38,440*</td>
<td>24,025</td>
<td>62,465*</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line, applied to existing data.


McKee-Kearny, "Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company," 1981. (Reference: No. 97)
### TABLE 6.5

**FORECASTED DEMAND FOR INTERIOR PARTITIONS**

(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>DEMAND - SCENARIO I (a)</th>
<th>DEMAND - SCENARIO II (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>10,530,420</td>
<td>11,536,984</td>
</tr>
<tr>
<td>1984</td>
<td>11,199,340</td>
<td>11,791,359</td>
</tr>
<tr>
<td>1985</td>
<td>12,202,720</td>
<td>12,001,361</td>
</tr>
<tr>
<td>1986</td>
<td>12,871,640*</td>
<td>12,243,058*</td>
</tr>
<tr>
<td>1987</td>
<td>13,640,898*</td>
<td>12,476,514*</td>
</tr>
<tr>
<td>1988</td>
<td>14,410,156*</td>
<td>12,709,971*</td>
</tr>
<tr>
<td>1989</td>
<td>15,179,414*</td>
<td>12,943,427*</td>
</tr>
<tr>
<td>1990</td>
<td>15,948,672*</td>
<td>13,176,883*</td>
</tr>
<tr>
<td>1991</td>
<td>16,717,930*</td>
<td>13,410,340*</td>
</tr>
<tr>
<td>1992</td>
<td>17,487,188*</td>
<td>13,643,796*</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line applied to existing data.

**SOURCE:**

(a) Construction/Contracting Industry Study


(Original Source: Ministry of Housing, The National Policy for Meeting the Housing Problem, 1979)

(Reference: No. 63)

(b) Construction/Contracting Industry Study


(Reference: No. 63)
Scenario I, taken from the Ministry of Housing's (MOH) forecasts (98), takes into account the current housing stock, both official and informal. The MOH estimates are derived by assuming that annual gross investment in housing units is approximately equal to the fraction of the housing stock that deteriorates each year and must be replaced.

The method used to obtain these forecasts incorporates a simple accelerator-capital stock relationship. Although this type of acceleration relationship provides a reasonable estimate, it does not fully consider the amount of available capital, government spending, or the capacity and rate of growth of the local construction industry. Consequently, these estimates may be biased upwards, and are believed to exceed future levels of ultimate capacity for the construction industry in Egypt. Previous MOH estimates have frequently exceeded actual output.

Many of the shortcomings associated with the MOH forecasts have been eliminated in the Construction/Contracting Industry Study (CIS) estimates (63). These estimates take into account both the official and informal sectors. The CIS Report also assumes that the current housing stock deteriorates at a given rate. The final forecasts are calculated based on the 1980-84 Five-Year Plan, and expected population growth and family formation. These figures are subsequently revised to correspond to a realistic level of economic growth and the actual capacity of the local construction industry. These estimates appear to be more consistent with the forecasted growth of the Egyptian economy.

Consequently, the MOH forecasts have been substituted in this analysis with estimates derived from the more realistic CIS forecasts.
Data for the "most likely" scenario have been taken from these CIS estimates. Upper and lower limits, or "optimistic" and "pessimistic" scenarios, have been calculated as plus or minus 15 percent of this mean forecast. These limits are within the above CIS constraints. The data for the three scenarios are shown in Table 6.6. Figure 6.2 shows these data graphically.

Despite the numerous problems associated with the production of interior partition products given in Chapter 3, production may exceed demand as early as 1983. Because of this phenomenon, Dryflow panels must serve as a substitute for other walling materials. The degree to which Dryflow panels can penetrate this existing market can be ascertained by examining the performance of other new building products in Egypt. Currently, the only information available for new product penetration rates comes from production data for CANALTEX floor tiles. These floor tiles, made of PVC resin and asbestos, offer a lightweight and inexpensive alternative to traditional cement floor tiles. Like Dryflow panels, the CANALTEX flooring system offers the advantages of reduced cost and ease of installation. The CANALTEX Company began operations in 1964 in Ismailia. During this first year of production 8200 square meters of floor tiles were sold to a total market of approximately 125 thousand square meters. This represented a 6.6 percent market share. Since that time, sales growth has averaged 50 percent per annum through 1976, resulting from the impact of severe cement shortages on producers of competitive products (31). Because the production schedules of competitors were highly erratic, the actual growth of market share for CANALTEX tiles has also been highly erratic.

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### TABLE 6.6

REVISED FORECASTED DEMAND FOR INTERIOR PARTITIONS  
(square meters)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>DEMAND - OPTIMISTIC (+15%)</th>
<th>DEMAND - MOST LIKELY</th>
<th>DEMAND - PESSIMISTIC (-15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>13,267,532</td>
<td>11,536,984</td>
<td>9,806,436</td>
</tr>
<tr>
<td>1984</td>
<td>13,560,063</td>
<td>11,791,359</td>
<td>10,022,655</td>
</tr>
<tr>
<td>1985</td>
<td>13,801,565</td>
<td>12,001,361</td>
<td>10,201,157</td>
</tr>
<tr>
<td>1986</td>
<td>14,079,517 *</td>
<td>12,243,058 *</td>
<td>10,406,599 *</td>
</tr>
<tr>
<td>1987</td>
<td>14,347,991 *</td>
<td>12,476,514 *</td>
<td>10,605,037 *</td>
</tr>
<tr>
<td>1988</td>
<td>14,616,467 *</td>
<td>12,709,971 *</td>
<td>10,803,475 *</td>
</tr>
<tr>
<td>1989</td>
<td>14,884,941 *</td>
<td>12,943,427 *</td>
<td>11,001,913 *</td>
</tr>
<tr>
<td>1990</td>
<td>15,153,415 *</td>
<td>13,176,883 *</td>
<td>11,200,351 *</td>
</tr>
<tr>
<td>1991</td>
<td>15,421,891 *</td>
<td>13,410,340 *</td>
<td>11,398,789 *</td>
</tr>
<tr>
<td>1992</td>
<td>15,690,365 *</td>
<td>13,643,796 *</td>
<td>11,597,227 *</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line applied to existing data

**SOURCE:** Construction/Contracting Industry Study  
Final Report, Volume 2, July 1981  
(Reference: No. 63)
FIGURE 6.2
INTERIOR PARTITION DEMAND - THREE SCENARIOS

SOURCE: Construction/Contracting Industry Study (reference: No. 63)

MILLION SQUARE METERS

YEAR
The AZAMCO Company, in formulating their marketing strategy for the sale of gypsum block, uses an initial market share of 5 percent (143). AZAMCO has used this conservative estimate because of the long-standing use of brick in Egypt and the saturation of the existing partition market with these products. A market share of 5 percent for a product such as Dryflow panels appears to be realistic in light of the experiences of these producers of new building products. Consequently, this market share will be used to calculate the number of Dryflow panels that can be effectively sold. These sales forecasts derived from the data of Table 6.6 are shown in Table 6.7.

6.2 Gypsum Resources in Fayoum

6.2.1 General Description of Four Deposits

Four areas of gypsum deposits within the Fayoum Governorate were selected for further investigation. These areas, which include Qaret El Faras, Gerza, El Tawil, and El Boqirat, are designated as areas 1 through 4, respectively in Figure 6.3. The location of these areas with respect to Cairo is shown in Figure 6.4. The following section analyzes these four areas on the basis of location and accessibility, topography, nature of deposit, and chemical composition. Because of the preliminary nature of this investigation, extensive chemical analyses were not performed. Only tests, such as x-ray diffraction and thermogravimetric analysis, as were described in Section 4.1, were performed as part of this feasibility study.
### TABLE 6.7

**FORECASTED DRYFLOW PANEL SALES FOR PROPOSED PRODUCTION FACILITY**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>OPTIMISTIC</th>
<th>MOST LIKELY</th>
<th>PESSIMISTIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>663,377</td>
<td>576,849</td>
<td>490,322</td>
</tr>
<tr>
<td>1984</td>
<td>678,003</td>
<td>589,568</td>
<td>501,133</td>
</tr>
<tr>
<td>1985</td>
<td>690,078</td>
<td>600,068</td>
<td>510,058</td>
</tr>
<tr>
<td>1986</td>
<td>703,976*</td>
<td>612,153*</td>
<td>520,330*</td>
</tr>
<tr>
<td>1987</td>
<td>717,400*</td>
<td>623,826*</td>
<td>530,252*</td>
</tr>
<tr>
<td>1988</td>
<td>730,823*</td>
<td>635,499*</td>
<td>540,174*</td>
</tr>
<tr>
<td>1989</td>
<td>744,247*</td>
<td>647,171*</td>
<td>550,096*</td>
</tr>
<tr>
<td>1990</td>
<td>757,671*</td>
<td>658,844*</td>
<td>560,018*</td>
</tr>
<tr>
<td>1991</td>
<td>771,095*</td>
<td>670,517*</td>
<td>569,939*</td>
</tr>
<tr>
<td>1992</td>
<td>784,518*</td>
<td>682,190*</td>
<td>579,861*</td>
</tr>
</tbody>
</table>

* Extrapolated using trend line applied to existing data.

**SOURCE:** Construction/Contracting Industry Study Final Report, Volume 2, July 1981
(Reference: No. 53)
FIGURE 6.3
LOCATION OF GYPSUM DEPOSITS IN FAYOUM

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
SOURCE: Road Map of Egypt. (Reference: No. 94)

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1. Qaret El Faras

The gypsum deposits are found throughout the area in the form of thin layers capping isolated hills and terraces. These layers are approximately 0.2 to 0.9 meters thick, and are located under an average of 10 centimeters of overburden. A geologic map of this area is shown in Figure 6.5. This area is enclosed between the latitudes North 29 degrees-33' and 29 degrees-41' and the longitudes East 30 degrees-58' and 31 degrees-05'. These deposits lie nearly midway between Giza and Fayoum City, and to the east of the highway connecting the two cities. Many of these deposits are contaminated with a considerable amount of detritus, consisting of sand, silt, clay, and gravel. These deposits cover approximately 13 square kilometers. The total geological reserves for this area were estimated to be approximately 7 million metric tons. Of this quantity, only 3.7 million tons of usable coarse gypsum are present.

The results of the chemical analysis for three representative samples from this deposit are shown in Tables 6.8 and 6.9. The chemical analysis shows that these three samples are primarily comprised of gypsum materials (CaSO$_4$ - $2\text{H}_2\text{O}$ and CaSO$_4$ - H$_2$O) and free silica, the latter comprising the majority of the contaminants. These deposits are characterized by relatively high dihydrous gypsum (CaSO$_4$ - $2\text{H}_2\text{O}$) contents, ranging from 57.87% to 78.82%. Sixty percent of this deposit has a dihydrous gypsum content greater than 60%, while 10% of this deposit has a dihydrous content greater than 70%. Because of a relatively high salt (NaCl) content, only 60% of this deposit is suitable for agricultural use (51).
FIGURE 6.5
GEOLOGICAL MAP OF QARET EL FARRAS

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
### Table 6.8

QARET EL FARAS—CHEMICAL ANALYSIS ELEMENT BREAKDOWN

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>SAMPLE (1)</th>
<th>SAMPLE (2)</th>
<th>SAMPLE (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>24.76</td>
<td>19.19</td>
<td>14.10</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>0.56</td>
<td>0.37</td>
<td>0.32</td>
</tr>
<tr>
<td>Total Fe</td>
<td>0.58</td>
<td>0.66</td>
<td>0.72</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>0.83</td>
<td>0.94</td>
<td>1.03</td>
</tr>
<tr>
<td>MgO</td>
<td>0.58</td>
<td>0.25</td>
<td>0.82</td>
</tr>
<tr>
<td>CaO</td>
<td>25.67</td>
<td>25.76</td>
<td>27.39</td>
</tr>
<tr>
<td>SO$_3$</td>
<td>26.92</td>
<td>36.22</td>
<td>36.66</td>
</tr>
<tr>
<td>Cl</td>
<td>00.08</td>
<td>0.30</td>
<td>0.17</td>
</tr>
<tr>
<td>H$_2$O$^+$</td>
<td>0.27</td>
<td>0.30</td>
<td>0.17</td>
</tr>
<tr>
<td>H$_2$O$^-$</td>
<td>12.11</td>
<td>15.17</td>
<td>16.50</td>
</tr>
</tbody>
</table>

**SOURCE:** Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
### Table 6.9

QARET EL-FARAS—CHEMICAL COMPOSITION BREAKDOWN

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>SAMPLE (1)</th>
<th>SAMPLE (2)</th>
<th>SAMPLE (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO$_4$·2H$_2$O</td>
<td>57.87</td>
<td>70.68</td>
<td>78.82</td>
</tr>
<tr>
<td>2CaSO$_4$·H$_2$O</td>
<td>-</td>
<td>6.06</td>
<td>-</td>
</tr>
<tr>
<td>CaCO$_3$</td>
<td>12.24</td>
<td>0.73</td>
<td>3.09</td>
</tr>
<tr>
<td>MgCO$_3$</td>
<td>1.22</td>
<td>0.52</td>
<td>1.72</td>
</tr>
<tr>
<td>NaCl</td>
<td>0.13</td>
<td>0.49</td>
<td>0.28</td>
</tr>
<tr>
<td>SiO$_2$ + Silicates</td>
<td>24.76</td>
<td>19.19</td>
<td>14.10</td>
</tr>
</tbody>
</table>

**Source:** Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
2. Gerza

This area is designated as Area Number 2 in Figure 6.3, and lies between the Nile Valley and the agricultural areas of the Fayoum Governorate. A geologic map of this area is shown in Figure 6.6. This area is located between the latitudes North 29 degrees-24'-30" and 29 degrees-08'-30", encompassing an area of approximately 7.5 square kilometers. The northern side of this area is located within close proximity of the paved Gerza to Tamia road. Several desert roads cross this area en route to the Nile Valley.

Most of this area is relatively flat, with the exception of several terraces, with a maximum height of 75 meters.

The gypsum layers range in thickness from 0.2 to 2.1 meters, and are covered with an average of 10 centimeters of overburden, consisting of sand and silt. These deposits cover approximately 6.5 square kilometers. The average thickness of these gypsum seams is 1.5 meters (51). Because much of this area already has been claimed by the Kawmia Cement Company, investigative research has been limited and chemical analyses were not performed.

3. El Tawil

This area is located approximately 3 kilometers from the eastern edge of the agricultural land of the Fayoum Governorate and is designated as Area Number 3 in Figure 6.3. This area lies between the latitudes North 29 degrees-10' and 29 degrees-20' and longitudes East 31 degrees-02' and 31 degrees-06', an area of approximately 9.5 square kilometers. These deposits are connected to the eastern villages of the Fayoum Governorate and those of the Nile Valley through various desert
FIGURE 6.6
GEOLOGIC MAP OF GERZA

LEGEND
Old Lake Beach
Alluvium Deposits
Gypsum
Ravine Beds
Qarun Formation
Pliocene Sediments
Pliocene-Pleistocene
Cultivated Land
Sand & Gravels

and Mining Authority. (Reference: No. 51)
roads scattered throughout the areas (51).

The deposits at El Tawil are topographically similar to those of Gerza, consisting of numerous flat areas, with several terraces, approximately 125 meters high, interspersed among them. The deposit layers generally range between 0.2 and 0.6 meters in thickness, with an average of 0.4 meters. These deposits are covered with 0.2 meters of alluvial overburden (51). Further studies of reserve estimates are currently in progress for this area.

The results of the chemical analysis for three representative samples taken from El Tawil are shown in Tables 6.10 and 6.11. These tables show that the gypsum found in El Tawil is of generally poor quality, and does not warrant further investigation. The percentage of dihydrous gypsum ranges between 26.44% and 55.05%, while anhydrous gypsum ranges between zero and 43.10%. Free silicates range from 10.89% to 59.27%.

4. El Boqirat

This area is located approximately 7 kilometers from the western edge of the agricultural land of the Fayoum Governorate, at the Hanna Habib village, and 4.5 kilometers from Qaret El Faras to the north. This area is designated as Area Number 4 in Figure 6.1, and lies between latitudes North 29 degrees-18'–40" and 29 degrees-20'–20" and longitudes East 30 degrees-26' and 30 degrees-29'–45", covering an area of approximately 7 square kilometers. This area is connected to the western villages of Fayoum through a series of desert roads (51). A geologic map of this region is shown in Figure 6.7.

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TABLE 6.10

EL TAWIL-CHEMICAL ANALYSIS ELEMENT BREAKDOWN

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>Oxide Percentage by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SAMPLE (1)</td>
</tr>
<tr>
<td>SiO₂</td>
<td>59.27</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.87</td>
</tr>
<tr>
<td>Total Fe</td>
<td>1.25</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.79</td>
</tr>
<tr>
<td>MgO</td>
<td>0.25</td>
</tr>
<tr>
<td>CaO</td>
<td>9.00</td>
</tr>
<tr>
<td>SO₃</td>
<td>12.25</td>
</tr>
<tr>
<td>Cl</td>
<td>2.19</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td>0.41</td>
</tr>
<tr>
<td>H₂O⁻</td>
<td>5.52</td>
</tr>
</tbody>
</table>

### TABLE 6.11

EL TAWIL—CHEMICAL COMPOSITION BREAKDOWN

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>SAMPLE (1)</th>
<th>SAMPLE (2)</th>
<th>SAMPLE (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO(_4\cdot2)H(_2)O</td>
<td>26.44</td>
<td>55.05</td>
<td>29.31</td>
</tr>
<tr>
<td>2CaSO(_4\cdot3)H(_2)O</td>
<td>-</td>
<td>9.16</td>
<td>43.10</td>
</tr>
<tr>
<td>CaCO(_3)</td>
<td>2.37</td>
<td>20.48</td>
<td>1.27</td>
</tr>
<tr>
<td>MgCO(_3)</td>
<td>1.39</td>
<td>0.86</td>
<td>1.89</td>
</tr>
</tbody>
</table>

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
FIGURE 6.7
GEOLOGIC MAP OF EL BOQIRAT AREA

LEGEND

- Lacustrine Deposits
- Ravine Formation
- Birket Qarun Formation
- Qasr El-Sagha Formation
- Gypsum
- Cultivated Land
- Mokattam Formation
- Sand Dunes

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
The topography of this area is similar to that of Gerza and El Tawil. Several short roads pass through this area, dividing the region into five blocks. The maximum elevation of this area is 65 meters (51).

The deposits found in this area are crystalline in nature and exist in two layers. These layers are usually adjacent or are separated by loose conglomerated detritus. The upper layer thickness ranges between 0.2 and 2.0 meters, and is contaminated with fragments of mud, gravel, and limestone. The thickness of the lower layer ranges between 0.2 and 1.4 meters. Current reserves for this area are estimated at 4.2 million metric tons (51). The results of the chemical analysis for six representative samples taken from El Boqirat are shown in Tables 6.12 and 6.13. This analysis shows that the gypsum found in this region is of poor to marginal quality, ranging from 6.64 percent to 63.4 percent, with free silicates ranging from 2.66 percent to 23.22 percent.

6.2.2 Selection of Most Promising Deposit

A summary of the characteristics for the four quarry sites is shown in Table 6.14. Although the gypsum deposits within the Fayoum Governorate are of a low grade, two deposits within this region appear to have some potential for economically feasible production. These are Qaret El Faras and El Boqirat.

Although both are comparable with respect to gypsum content, Qaret El Faras offers superior road access, being within close proximity to a paved road. Although quarrying gypsum at this site will be difficult due to the sporadic occurrence of the gypsum seams, this situation will
TABLE 6.12
EL BOQRAT - CHEMICAL ANALYSIS ELEMENT BREAKDOWN
Percentage by Weight

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>SAMPLE (1)</th>
<th>SAMPLE (2)</th>
<th>SAMPLE (3)</th>
<th>SAMPLE (4)</th>
<th>SAMPLE (5)</th>
<th>SAMPLE (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>23.22</td>
<td>19.28</td>
<td>13.04</td>
<td>15.94</td>
<td>20.18</td>
<td>2.66</td>
</tr>
<tr>
<td>MgO</td>
<td>1.35</td>
<td>1.52</td>
<td>2.06</td>
<td>1.35</td>
<td>2.15</td>
<td>1.43</td>
</tr>
<tr>
<td>CaO</td>
<td>28.38</td>
<td>31.77</td>
<td>31.52</td>
<td>34.53</td>
<td>30.26</td>
<td>34.53</td>
</tr>
<tr>
<td>SO₃</td>
<td>29.27</td>
<td>34.79</td>
<td>37.59</td>
<td>35.00</td>
<td>33.70</td>
<td>41.14</td>
</tr>
<tr>
<td>Cl</td>
<td>0.63</td>
<td>0.28</td>
<td>1.30</td>
<td>0.38</td>
<td>0.78</td>
<td>0.48</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.44</td>
<td>0.31</td>
<td>0.39</td>
<td>0.43</td>
<td>0.43</td>
<td>0.37</td>
</tr>
</tbody>
</table>

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>SAMPLE (1)</th>
<th>SAMPLE (2)</th>
<th>SAMPLE (3)</th>
<th>SAMPLE (4)</th>
<th>SAMPLE (5)</th>
<th>SAMPLE (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO₄ - 2H₂O</td>
<td>20.17</td>
<td>11.47</td>
<td>17.34</td>
<td>6.64</td>
<td>16.91</td>
<td>63.40</td>
</tr>
<tr>
<td>2CaSO₄ - H₂O</td>
<td>36.04</td>
<td>-</td>
<td>53.15</td>
<td>-</td>
<td>-</td>
<td>21.12</td>
</tr>
<tr>
<td>CaSO₄</td>
<td>-</td>
<td>50.07</td>
<td>-</td>
<td>54.25</td>
<td>43.92</td>
<td>-</td>
</tr>
</tbody>
</table>

SOURCE: Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51)
### Table 6.14

**Quarry Site Summary**

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>SITE 1 QARET EL FARAS</th>
<th>SITE 2 GERZA</th>
<th>SITE 3 EL TAMIL</th>
<th>SITE 4 EL BOQIRAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Ore Purity: (CaSO₄·2H₂O)</td>
<td>58 - 79%</td>
<td>N/A</td>
<td>26 - 55%</td>
<td>N/A</td>
</tr>
<tr>
<td>Seam Thickness: (meters)</td>
<td>0.2 - 0.9</td>
<td>0.2 - 2.1</td>
<td>0.2 - 0.6</td>
<td>0.2 - 2</td>
</tr>
<tr>
<td>Nature of Overburden:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sand/gravel</td>
<td>0.1 meters</td>
<td>0.1 meters</td>
<td>0.2 meters</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>sand/silt</td>
<td>sand/silt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topography:</td>
<td>flat w/ isolated terraces</td>
<td>flat w/ isolated terraces</td>
<td>flat w/ isolated terraces</td>
<td>flat w/ isolated terraces</td>
</tr>
<tr>
<td>Accessibility:</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Estimated Usable Reserves:</td>
<td>3.7</td>
<td>N/A</td>
<td>N/A</td>
<td>4.2</td>
</tr>
<tr>
<td>(million tons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N/A: Not Available

**Source:** Evaluation of Gypsum Deposits in El Fayoum Governorate, Egyptian Geological Survey and Mining Authority. (Reference: No. 51).
be partially mitigated by the negligible overburden.

6.3 Recommended Facilities, Equipment, and Manpower

Given the data of Table 6.4 and the analysis and conclusions presented in Section 6.1.1, the optimal capacity for a calcining plant would be 62 thousand metric tons per year. This quantity would represent a realistic level of output given the previous market assessment as applied to a ten-year project. Such a rate of output represents a minimum level, and must be subsequently adjusted to reflect less than 100 percent utilization and a certain degree of wastage.

The optimal annual rate of output for a Dryflow panel production facility, as specified in Section 6.1.2, would most likely range from 577 to 682 thousand square meters over a ten-year period. A panel production facility producing 682 thousand square meters per year would require an additional 18 thousand tons of calcined gypsum. Hence, a totally integrated plaster and panel production facility would require approximately 80 thousand metric tons of stucco per year by 1992.

Using an average gypsum ore purity of 65 percent for Qaret El Faras and a 5 percent wastage factor, required quarry output would be approximately 131 thousand metric tons of gypsum ore. A stand-alone calcining plant would require an annual ultimate quarry capacity of only 100 thousand tons. The output of these two types of production systems is summarized in the flow diagrams of Figures 6.8 and 6.9.

Given these required rates of output, quarrying, processing, and calcining systems will be selected in the following sections.
FIGURE 6.8

CALCINED GYPSUM PRODUCTION FACILITY - PRODUCTION SUMMARY

QUARRYING

1 Shift per Day
8 Hours per Shift
230 Days per Year
100,000 Metric Tons
Gypsum Ore

PROCESSING AND CALCINING

3 Shifts per Day
8 Hours per Shift
230 Days per Year
62,000 Metric Tons
Plaster
FIGURE 6.9
PLASTER AND PANEL PRODUCTION FACILITY - PRODUCTION SUMMARY

QUARRYING
- 1 Shift per Day
- 8 Hours per Shift
- 300 Days per Year
- 131,000 Metric Tons
  Gypsum Ore

PROCESSING AND CALCINING
- 3 Shifts per Day
- 8 Hours per Shift
- 300 Days per Year
- 80,000 Metric Tons
  Plaster

DRYFLOW PANEL PRODUCTION
- 62,000 Metric Tons
  Plaster
- 3 Shifts per Day
- 8 Hours per Shift
- 290 Days per Year
- 682,000 Square Meters
  Dryflow Panels
6.3.1 Quarrying

a. Configuration

The mining method proposed for the gypsum quarrying sites in Fayoum is comprised of four steps: overburden removal, ripping, loading of gypsum, and haulage and transport. Of the five alternative pieces of equipment listed in Chapter 4 which can be employed in such a process, two can be eliminated in the preliminary stages. The job-site conditions present at Qaret El Faras do not warrant the use of a dragline, as these machines are better suited for applications requiring greater digging reach and less bearing pressure per unit of area. In addition, it is more difficult to dump a load from a dragline on a target such as a truck bed than with a front-end loader. The large investment cost associated with these machines requires 24-hour per day use in order to keep unit costs competitive with alternative systems (109).

Scrapers may also be eliminated, as these units become economically unfeasible for haul distances greater than 4000 feet (1220 meters) (38).

The removal of overburden will be performed through the use of a tractor dozer, equipped with a three-shank ripper and a straight cutting blade. Because of the low quantity of overburden at the Qaret El Faras quarries, the majority of it can be removed through ripping and dozer stripping. A bulldozer offers the additional advantage of being able to move waste and overburden to nearby disposal and dump sites.
Using the procedures of analysis outlined in Section 4.2, the process of ripper and bulldozer selection is shown in Figures 6.10. These rates are calculated for a totally integrated facility. For the purposes of this analysis, Komatsu products will be used, as this manufacturer provides equipment that is the least expensive on a cost/performance basis, offers favorable credit terms, and provides adequate repair and maintenance facilities throughout Egypt.

The calculation of required hourly overburden removal and subsequent dozer selection is constrained by the required hourly gypsum ore production rate. Hence, the first portion of Figure 6.10 is devoted to the calculation of this rate. Because of the occurrence of negligible overburden, the smallest size ripping unit, the Komatsu D65-E, was selected and used in this analysis. Because of this constraint on tractor size, Figure 6.10 shows a somewhat inefficient 90 percent rate of utilization. For normal quantities of overburden, the seismic velocity charts shown in Section 4.2 would be employed in an analysis of this nature.

The gypsum ore will be extracted by means of the ripping unit and a wheel-mounted front-end-loader. The rates of production for this process are shown in Figures 6.10 and 6.11. The front-end loader will be used to load the ripped gypsum ore into a haulage vehicle for shipment to the processing facility. The analysis of Figure 6.11 shows that a loading unit with a bucket capacity of 0.54 cubic meters and an operating capacity of 882 kilograms would be required. Using these criteria, a Komatsu W30 loader has been selected.
FIGURE 6.10

DOZER AND RIPPER PRODUCTION ANALYSIS

1. Assumptions:
   Average Density of Gypsum Ore (Loose) = 1800 kg/m$^3$
   Average Density of Gypsum Ore (Bank) = 3200 kg/m$^3$
   Average Density of Overburden (Loose) = 1400 kg/m$^3$
   Average Density of Overburden (Bank) = 1700 kg/m$^3$
   Average Gypsum Seam Thickness = 0.5 meters
   Average Overburden Thickness = 0.1 meters
   Annual Quarry Output (includes 5% waste factor) = 131,000 metric tons per year
   Number of Work Days per Year = 300
   Hours per Work Day = 8
   Average Overburden Haul Distance = 90 meters

2. Gypsum Ore Production:
   Required Hourly Production = \frac{131,000}{(300)(8)} = 54.6 metric tons per hour
   Required Hourly Volume = \frac{54,600 \text{ kg/hr.}}{1,800 \text{ kg/m}^3} = 30.3 \text{ m}^3 / \text{hr.}
   Area Excavated Per Hour = \frac{30.3 \text{ m}^3 / \text{hr.}}{0.5 \text{ m}} = 60.6 \text{ m}^2 / \text{hr.}

3. Overburden Removal-Ripping:
   Required Hourly Area to be Cleared = 60.6 \text{ m}^2 / \text{hr.}

Assume:

   Average Dozer and Ripper Speed = 1.7 km/hr. = 28.3 m/min.
   Distance Between Ripper Passes = 1 meter
   Every 100 Meter Requires 1/4 Minute
   to Raise, Pivot, Turn, and Lower
   Ripper After Each Pass
FIGURE 6.10 (Continued)

Area Ripped = 100m x 1m = 100m² per pass

Time per Pass = \(\frac{100m}{28.3\text{m/min.}} + 0.25\) min. (turn time) = 3.78 minutes per pass

Time Required to Fulfill Area Requirements = \(\frac{60.6m²/\text{hr.}}{100m²} \times 3.78\) min. = 2.3 minutes/hr.

Corrected Required Time Using Factor of 30% = \(\frac{2.3\ \text{min/hr.}}{0.7} = 3.3\ \text{min/hr.}\)

Hourly Utilization Rate = \(\frac{3.3\ \text{min/hr}}{60\ \text{min/hr.}} = 5.45\%\)

4. Overburden Removal-Dozing:

54 Metric Tons per Hour Gypsum Ore Production = \(60.6m²/\text{hr} \times 0.1\ m = 6.06m³/\text{hr. of Overburden}\)

Output of Komatsu D65-E for Average Haul Distance of 90 meters = 19.1 m³/hr.

Dozer Utilization Rate = \(\frac{6.06m³}{19.1\ m³/\text{hr.}} = 0.32\ \text{hr.} = 19.04\ \text{min.}\)
FIGURE 6.10 (Continued)

Correction Factors:
1. Poor Operator  = 0.6
2. Job Efficiency  = 0.67

Corrected Output = $\frac{19.02 \text{ min.}}{0.6 \times 0.67} = 47.35 \text{ min/hr.}$

Hourly Utilization Rate = $\frac{47.35 \text{ min/hr.}}{60 \text{ min/hr.}} = 78.9\%$

5. Gypsum Ore Excavation - Ripping:
Required Hourly Area to be Cleared = $60.6^2/\text{hr.}$

Assume:

Average Dozer and Ripper Speed is equal to 1.5 km/hr. = 25 m/min.

Distance Between Ripper Passes = 1 meter

Area Ripped = 100m x 1m = $100^2$ Per Pass

Time Per Pass = $\frac{100\text{m}}{25\text{m/min.}} + 0.25 \text{ min.} = 4.25 \text{ Minutes Per Pass (turn time)}$

Time Required to Fulfill Area Requirement = $\frac{60.2^2/\text{hr.}}{100^2} = 42.5 \text{ min.} = 2.6 \text{ Minutes/Hr.}$

Corrected Required Time Using Komatsu Correction Factor of 30% = $\frac{2.6 \text{ min/hr.}}{0.7} = 3.7 \text{ min/hr.}$

Hourly Utilization Rate = $\frac{3.7 \text{ min/hr.}}{60 \text{ min/hr.}} = 6.19\%$

SOURCE: Komatsu Sales Mates, Komatsu Ltd., Tokyo, Japan (Ref. No. 93.)
FIGURE 6.11
LOADER PRODUCTION AND SELECTION ANALYSIS

Required Hourly Loader Production $= 30.3\text{ m}^3/\text{hr.}^*$

Cycle Time

Basic Time (Load, Dump, Maneuver) $= 0.6 \text{ min.}$

Correction Factors:

- Common Truck Ownership $= -0.4$
- Inconsistent Operation $= +0.04$
- Small Target (Truck) $= +0.05$
- Total $= 0.65 \text{ min/cycle}$

Assume:

- Operator Works 40 Minutes Per Hour
- Bucket Fill Factor - Gypsum Ore $= 90\%$
- Gypsum Ore Density $= 1800 \text{ kg/m}^3$

Loader Cycles Per Hour $= \frac{60 \text{ min/hr.}}{0.65 \text{ min/cycle}} = 92.3 \text{ cycles/hr.}$

Production Cycles for 40 Minutes Per Hour Efficiency

$92.3 \text{ cycles/hr.} \times 0.67 = 61.5 \text{ cycles/hr.}$

Required Volume Per Loader Cycle

$\frac{30.3\text{ m}^3/\text{hr.}}{61.5 \text{ cycles/hr.}} = 0.49\text{ m}^3/\text{cycle} \approx 0.64 \text{ yd}^3/\text{cycle}$
Required Rated Bucket Capacity =
\[
\frac{0.49 \text{m}^3/\text{cycle}}{0.9 \text{ Fill Factor}} = 0.54 \text{m}^3/\text{cycle}
\]

Required Operating Capacity =
\[
0.49 \text{m}^3 \times 1800 \text{ kg/m}^3 = 883 \text{ kg}
\]

*Taken from Table 6.10

SOURCE: Komatsu Sales Mates, Komatsu Ltd., Tokyo, Japan (Ref. 93).
The gypsum ore will be transported by means of one off-highway truck. The truck selection analysis is shown in Figure 6.12. These calculations show that a truck with a heaped capacity of 22.2 cubic meters would be required. This analysis has assumed that the ore will be hauled over negligible grades of a maximum of 4 percent. Given this required payload, a Komatsu HD460 has been selected (93).

These proposed equipment requirements are based on operating 300 days per year with one 8 hour shift per day. These production requirements have been based on the amount of gypsum ore required for the proposed integrated plaster and panel production facility. Because some of the components selected in this analysis represent minimum size production units, their use can be extended to that for a calcining plant requiring only 101 thousand metric tons of gypsum ore. This rate of output would represent 77 percent of the output required for a totally integrated facility. Hence, a stand-alone calcining plant would require 231 days of quarry production.

b. Investment Cost

The investment costs for all equipment specified in the preceding analysis are shown in Table 6.15. The costs include all freight charges and tariffs. An additional item required is the construction of a service shop building in an area within close proximity to the processing facility. This shop will consist of a 12 by 15 meter building with an equipment bay for light repair and maintenance of quarrying equipment. Any major overhauls or repairs will be
FIGURE 6.12

TRUCK PRODUCTION AND SELECTION ANALYSIS

Required Annual Gypsum Ore Production = 131,000 metric tons per yr.

Required Daily Output \( \frac{131,000 \text{ tons/yr.}}{300 \text{ days/hr.}} = 437 \text{ tons/day} \)

Average Truck Velocity for 4 Percent Grade = 30 km/hr.

Average Distance: Quarry to Processing Facility = 8 km

Average Travel Time: One-Way = \( \frac{8 \text{ km}}{30 \text{ km/hr.}} = 0.27 \text{ hr.} \)

Average Load Time = 5 Minutes = 0.08 hr.

Average Dump Time = 6 Minutes = 0.1 hr.

Total Time for Complete Cycle = (0.27 x 2) + 0.08 = 0.72 hr.

Cycles Per Day = \( \frac{8 \text{ hr/day}}{0.72 \text{ hr.}} = 11 \text{ cycles/day} \)

Required Payload Per Cycle = \( \frac{437 \text{ tons/day}}{11 \text{ cycles/day}} = 40 \text{ tons/cycle} \)

Required Volume Per Cycle (Gypsum: 1800 kg/m\(^3\)) = \( \frac{40 \text{ tons/cycle}}{1.8 \text{ tons/m}^3} = 22.2 \text{ m}^3/\text{cycle} \)

SOURCE: Komatsu Sales Mates, Komatsu Ltd., Tokyo, Japan (Ref. 93).
### TABLE 6.15

**QUARRY INVESTMENT COST SUMMARY**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>MANUFACTURER</th>
<th>COST (1982 EGYPTIAN POUNDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bulldozer</td>
<td>Komatsu D65-E²</td>
<td>LOCAL</td>
</tr>
<tr>
<td>Three-Shank Ripper</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 Front-End Loader</td>
<td>Komatsu #30</td>
<td>-</td>
</tr>
<tr>
<td>1 Off-Highway Truck</td>
<td>Komatsu HD460</td>
<td>-</td>
</tr>
</tbody>
</table>

| Freight Charges (c.i.f., Alexandria) | - | 30,000 (2) |
| Freight Charges - Foyoum | 448 (3) | - |
| Tariffs (15%) | 15,000 (4) | - |
| L.E. 15,448 | L.E. 330,000 |
| 1 - 15 x .12 Meter Service Facility | 20,426 | - |
| (180m² @ L.E. 115.48/m²) | L.E. 37,100 | L.E. 330,000 |
| Engineering & Design (as of total installed Cost) | 1,226 (5) | - |
| Contingency (10%) | 3,710 | 33,000 |
| **SUB-TOTAL** | L.E. 40,810 | L.E. 363,000 |

* Dozer Selection Analysis Presented in Figure 6.10
** Loader Selection Analysis Presented in Figure 6.11
*** Truck Selection Analysis Presented in Figure 6.12
**** Assumes 1982 Cost of L.E. 1.80 per ton plus L.E. 0.05 per ton-kilometer (6)

**SOURCE:**
1. Price quote obtained from interview with I. Bibara, Sales Rep., Komatsu, Ltd. Dokki-Cairo, Egypt, August, 1992. (Reference: No. 144)
2. Freight allowance for heavy equipment; approximate estimate only. Coefficient supplied by Source (1) above. (Reference: No. 144)
3. Taken from costs supplied by Egypt Intercity Transportation Study, Technology Adaptation Program, Massachusetts Institute of Technology, Cambridge, MA.
4. Tariff allowance for heavy equipment; approximate estimate only. Coefficient supplied by Source (1) above. (Reference: No. 144)
performed at dealer service facilities located elsewhere. Because no per unit building costs for such structures in Egypt exist, a separate cost analysis has been performed.

Table 6.16 shows a 1976 cost per square meter for a typical Egyptian apartment building as constructed by a private-sector contractor of 34.1 Egyptian pounds (148). Means "Building Systems Cost Guide" for 1982 (147) shows that the cost for a maintenance facility including all mechanical equipment on a per unit basis is approximately 93 percent of that for a similar type apartment building, using United States data. Assuming that this relationship is approximately representative of construction in Egypt and that construction costs escalate at an average of 20 percent per year (63), the 1983 cost for a maintenance facility is estimated at 113.62 Egyptian pounds per square meter.

For engineering and design costs, this analysis employs a figure of 6 percent of building costs. This figure has been taken from "The Housing and Construction Industry in Egypt - Interim Report and Working Papers 1978" (158).

c. Operating Cost

All operating costs for the proposed quarry are shown in Table 6.17. The manpower requirements and wages for this type of quarrying system are shown in Table 6.18. Because data for some of the labor categories shown in Table 6.18 are unavailable, wage rates for these categories were interpolated using available data for job categories requiring comparable skill levels (150).
TABLE 6.16
PRIVATE SECTOR CONSTRUCTION COSTS FOR A TYPICAL APARTMENT BUILDING
(1976 Egyptian Pounds)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>201.6</td>
</tr>
<tr>
<td>Grading</td>
<td>100.8</td>
</tr>
<tr>
<td>Concrete</td>
<td>742.7</td>
</tr>
<tr>
<td>Reinforced Concrete</td>
<td>5,998.5</td>
</tr>
<tr>
<td>Masonry</td>
<td>1,275.5</td>
</tr>
<tr>
<td>Damp-proofing</td>
<td>354.6</td>
</tr>
<tr>
<td>Stairs</td>
<td>340.2</td>
</tr>
<tr>
<td>Flooring</td>
<td>1,586.6</td>
</tr>
<tr>
<td>Plastering and Painting</td>
<td>3,146.8</td>
</tr>
<tr>
<td>Metalwork</td>
<td>10.3</td>
</tr>
<tr>
<td>Carpentry</td>
<td>3,504.9</td>
</tr>
<tr>
<td>Plumbing</td>
<td>1,452.4</td>
</tr>
<tr>
<td>Electrical</td>
<td>507.5</td>
</tr>
<tr>
<td><strong>SUB TOTAL</strong></td>
<td><strong>19,212.3</strong></td>
</tr>
<tr>
<td>Overhead and Profit (20%)</td>
<td>3,842.5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>23,054.8</strong></td>
</tr>
<tr>
<td>Floor Area (Square Meters)</td>
<td>675.0</td>
</tr>
<tr>
<td>Cost per Square Meter</td>
<td>L.E. 34.16</td>
</tr>
</tbody>
</table>

SOURCE: Ministry of Housing - Arab Republic of Egypt
      Joint Housing Team MOHR/USAID
      Immediate Action Proposals for Housing in Egypt,
      June, 1976. (Reference: No. 146)
Table 6.17
Quarry Operating Costs - 131,000 Metric Tons of Ore per Year
(Egyptian Pounds)

<table>
<thead>
<tr>
<th>OPERATING COST ITEM</th>
<th>QUANTITY UNITS</th>
<th>QUANTITY PER YEAR</th>
<th>COST PER UNIT</th>
<th>COST PER YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarry Wages</td>
<td>Hours</td>
<td>2400</td>
<td>L.E. 5.30 (1)</td>
<td>L.E. 12,720</td>
</tr>
<tr>
<td>Benefits (25% of Wages)</td>
<td></td>
<td></td>
<td></td>
<td>L.E. 3,180</td>
</tr>
<tr>
<td>Diesel Fuel:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Dozer</td>
<td>Liters</td>
<td>33,600**</td>
<td>L.E. 0.25 (2)</td>
<td>L.E. 8,400</td>
</tr>
<tr>
<td>- Loader</td>
<td>Liters</td>
<td>18,400**</td>
<td>L.E. 0.25 (2)</td>
<td>L.E. 4,600</td>
</tr>
<tr>
<td>- Truck</td>
<td>Liters</td>
<td>72,000*</td>
<td>L.E. 0.25 (2)</td>
<td>L.E. 18,000</td>
</tr>
<tr>
<td>Maintenance Materials***</td>
<td></td>
<td></td>
<td></td>
<td>L.E. 15,000</td>
</tr>
<tr>
<td>- Tires</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lube Oils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Grease</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Undercarriage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Ripper/HiPs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bucket Teeth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>L.E. 61,900</td>
</tr>
</tbody>
</table>

* Assumes operation 300 days per year at 8 hours per day

** Fuel Requirements:
- Dozer 16 Liters/hr x 2100 hr/year
- Loader 8 Liters/hr x 2300 hr/year
- Truck 30 Liters/hr x 2400 hr/year

*** Derived using Komatsu factor of 5% of total equipment cost. (2)


(2) McKee-Hearny, Development of Ras Malab Gypsum Deposits for Sinai Manganese Company. 1981 (Reference No: 97)
TABLE 6.18

QUARRY WAGE SUMMARY
(Egyptian Pounds per Hour)

<table>
<thead>
<tr>
<th>Position</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dozer Operator</td>
<td>0.70</td>
</tr>
<tr>
<td>1 Loader Operator</td>
<td>0.70</td>
</tr>
<tr>
<td>1 Loader and Dozer Oilier</td>
<td>0.50</td>
</tr>
<tr>
<td>1 Truck Driver</td>
<td>0.70</td>
</tr>
<tr>
<td>3 Miscellaneous Quarry Labor</td>
<td>0.40</td>
</tr>
<tr>
<td>1 Equipment Mechanic</td>
<td>0.80</td>
</tr>
<tr>
<td>2 Mechanics Helpers</td>
<td>0.50</td>
</tr>
<tr>
<td>1 Mine Superintendent</td>
<td>1.00</td>
</tr>
</tbody>
</table>

TOTAL 5.30

SOURCE: Netherlands Engineering Consultants. 
Egypt National Transport Study - Final Report, 1981 - Phas II. Holland. (Reference: No. 148)
All costs shown in Table 6.17 are based on an annual rate of output of 131 thousand metric tons of gypsum ore. This level of output includes the previous 5 percent wastage factor.

6.3.2 Processing and Calcining

a. Configuration

The processing and calcining plant selected is one designed and fabricated by Combustion Engineering of Abilene, Kansas. This plant is a typical one, similar to that described in Section 4.3. The furnishing and construction of this plant will be provided on a turn-key basis by the manufacturer. Such a contractual arrangement has been devised in an effort to shorten construction times and avoid added project cost overruns.

The scope of work under such a contract includes all work and services, ranging from preliminary studies, engineering design, construction, supply and erection of equipment and machinery, to commissioning the plant and adjusting it to the desired rate of output and the quality of its products. The contract also includes the training of all plant personnel, technical and managerial supervision of the installation, and assisting the management of the plant for the first year of operation. Also included are the supply of spare parts and replacements, and advisory services required for the successful execution of the project. Combustion Engineering provides its own construction management personnel and uses local labor and equipment in
carrying out all the construction related activities. The only
exception to this is the erection of structural steel which is performed
by local contractors (145).

The proposed facility has an ultimate capacity of 80 thousand metric
tons per year, assuming 80% efficiency and utilization, a 5% waste
factor, and operation 24 hours a day for 300 days per year. Processing
and calcining can be considered the limiting production factor. Because
it is economically unfeasible to operate calcining equipment on a
non-continuous basis, three shifts of production are required to support
one or two shifts of quarry and panel production. Figure 6.13 shows a
flow diagram for the proposed plant.

Raw gypsum ore from the quarry is delivered to the processing
facility by truck where it is emptied into either a receiving hopper or
an adjacent stockpile. Ore is fed into the main plant by means of an 80
foot bucket elevator connecting the hopper to a vibrating grizzly
feeder. The grizzly feeder feeds the ore onto a belt conveyor where it
is subsequently discharged into a hammermill crusher. The hammermill
crusher reduces 4 to 6 inch rock to one inch. The crusher discharge is
conveyed to a three-deck vibrating screen, where the impurities are
separated from the actual gypsum ore. All waste materials are disposed
of by means of a small front-end loader which transports the material to
an appropriate disposal site. This loader serves the additional
function of providing gypsum ore to the processing facility from the raw
material stockpiles adjacent to the plant. A Komatsu WA30-1 front-end
loader with a heaped bucket capacity of 0.4 cubic meters has been
selected for this application.
FIGURE 6.13
PROCESSING AND CALCINING PLANT - PROCESS FLOW DIAGRAM

* Key to flow diagram contained on following page

SOURCE: Combustion Engineering
Abilene, Kansas
1983.
FIGURE 6.13 (continued)

PROCESSING AND CALCINING PLANT - PROCESS FLOW DIAGRAM

PLANT EQUIPMENT KEY

1 - Rock Receiving Hopper
2 - Rock Feeder
3 - Belt Conveyor
4 - Belt Conveyor
5 - Belt Conveyor
6 - Hammermill Crusher
7 - Crushed Rock Bucket Elevator
8 - Crushed Rock Screw Conveyor
9 - Crushed Rock Storage Bins
10 - Roller Mills
11 - Secondary Collectors
12 - Collecting Screw Conveyors
13 - Kettle Feed Bins
14 - Kettle Dust Collecting System
15 - Twin Screw Kettle Feeders
16 - Calcining Kettles
17 - Hot Stucco Collecting Screw Conveyor
18 - Hot Pits
19 - Hot Stucco Bucket Elevator
20 - Stucco Supply Screw Conveyor
21 - Stucco Storage Bins
22 - Stucco Drag Feeders
23 - Hot Stucco Recirculating Screw Conveyor
The purified ore is conveyed by means of a 64 foot bucket elevator to 100 ton storage bins. This material is then directly fed into a roller mill crusher. After crushing to Number 100 mesh size, the ore is fed into a kettle feed bin by means of screw conveyors, where it is ready for feeding to the calcining kettles.

The calcining process consists of taking the crushed ore and heat treating it a 120 degrees centigrade in a cylindrical, enclosed vessel 12 feet high by 12 feet in diameter. The kettle was selected over the rotary kiln because it provides a more consistent and superior quality product. Rotary kilns are extremely difficult to control, and produce substantial over- and under-dehydration. Rotary kiln feed must be closely sized, or else over-dehydration of the particle surface occurs along with under-dehydration within the core.

To ensure high kettle thermal efficiency, the unit has been externally insulated in order to limit heat losses due to radiation. In addition the calcining area is provided with a dust collection system, consisting of an electrostatic precipitator, a bag collector with a screw conveyor, an exhaust fan, and a device connecting the unit to the calcining kettle.

This type of kettle design allows for the future expansion of capacity by the addition of parallel kettles and crushing equipment. Other equipment configurations employing 12 by 12, and 10 by 13 kettles and their associated capacities and capital costs are shown in Table 6.19. The economies of scale associated with increased rates of production are highlighted in this table.
<table>
<thead>
<tr>
<th>NUMBER OF UNITS</th>
<th>CAPACITY (metric tons/hr)</th>
<th>CAPACITY (metric tons/year)*</th>
<th>TOTAL INSTALLED COST L.E.</th>
<th>CAPITAL COST PER TON L.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.8</td>
<td>42,000</td>
<td>L.E. 1,500,000</td>
<td>L.E. 35.71</td>
</tr>
<tr>
<td>2</td>
<td>11.6</td>
<td>84,000</td>
<td>L.E. 1,950,000</td>
<td>L.E. 23.21</td>
</tr>
<tr>
<td>3</td>
<td>17.4</td>
<td>126,000</td>
<td>L.E. 2,400,000</td>
<td>L.E. 19.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NUMBER OF UNITS</th>
<th>CAPACITY (metric tons/hr)</th>
<th>CAPACITY (metric tons/year)*</th>
<th>TOTAL INSTALLED COST L.E.</th>
<th>CAPITAL COST PER TON L.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.4</td>
<td>32,000</td>
<td>L.E. 1,400,000</td>
<td>L.E. 43.75</td>
</tr>
<tr>
<td>2</td>
<td>8.8</td>
<td>64,000</td>
<td>L.E. 1,750,000</td>
<td>L.E. 27.34</td>
</tr>
<tr>
<td>3</td>
<td>13.2</td>
<td>96,000</td>
<td>L.E. 2,100,000</td>
<td>L.E. 21.88</td>
</tr>
</tbody>
</table>

L.E. Egyptian Pounds

* Assumes 300 days per year operation at 24 hours per day

** Represents estimated cost, excludes freight and tariffs. To be used for Comparison purposes only.

The calcined gypsum moves by means of a bucket elevator to storage bins with a 150 ton capacity. This capacity corresponds to approximately 2.5 days of Dryflow panel production. These bins are connected to a packing plant by a screw conveyor and a bucket elevator. The packing plant is equipped with a sack filling and dispatch loading unit. The sacks are transported manually to an adjacent storage area. A structural drawing for the proposed plant is shown in Figure 6.14 (145).

Electricity will be supplied to that plant by means of a transformer connected to the 30 kilowatt high-tension power line that runs parallel to the proposed site. This transformer will step-down the available power supply to an operating voltage of 220/380 volts. A standby diesel generating set of 750 kilowatt-amp capacity, will be available to come into immediate operation in the event of a power failure, ensuring that the machinery will not be damaged by a sudden interruption in the main power supply.

The water required for this plant will be pumped from a well located close to the site boundary of the plant.

b. Investment Cost

The 1983 investment cost for the proposed plant, excluding foundations, buildings, delivery, and installation is 1.41 million Egyptian pounds. The total installed price is 2.78 million Egyptian pounds (145). This cost includes such additional items as a small front-end loader, structural steel, maintenance tools, the services and
SOURCE: Combustion Engineering, Inc.
Abilene, Kansas. 1983.
installation associated with these items, and such maintenance materials as wearing steel, lubricants, and other consumable items. Building costs for this plant were computed in a manner similar to that used in Section 6.3.1b, using data from the Ministry of Housing (148) and Means (147), and CIS (63) cost escalation factors. These costs are detailed in Table 6.20.

c. Operating Cost

The operating costs for this plant, expressed in 1983 prices, are shown in Table 6.21. Because only 80 thousand metric tons per year of calcined gypsum are required for an integrated manufacturing facility, it is assumed that the proposed plant will operate at 95 percent utilization. This rate has been estimated using the data of Table 6.20. Such a rate of utilization will allow for a 5 percent wastage factor, when operating a total of 7200 hours per year. Table 6.22 shows a breakdown of the labor and wage requirements for the proposed plant. These wages were computed in a manner similar to that used for computing Quarry wages. The operation and maintenance of this plant can be entrusted to local labor, thus ensuring reduced wage rates. Excluding maintenance and supervisory personnel, shift work in the processing and calcining plant requires only four operators in attendance.


<table>
<thead>
<tr>
<th></th>
<th>Cost (1982 Egyptian Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>LOCAL</strong></td>
</tr>
<tr>
<td><strong>BUILDINGS</strong></td>
<td></td>
</tr>
<tr>
<td>1400m$^2$ @ L.E. 63.54/m$^2$</td>
<td>88,960$^{(1)}$</td>
</tr>
<tr>
<td><strong>CALCINING PLANT</strong></td>
<td></td>
</tr>
<tr>
<td>(Turnkey Project)</td>
<td></td>
</tr>
<tr>
<td><strong>Equipment:</strong></td>
<td></td>
</tr>
<tr>
<td>2 - 12 x 12 Batch Kettles</td>
<td>-</td>
</tr>
<tr>
<td>1 - Hammermill Crusher</td>
<td>-</td>
</tr>
<tr>
<td>1 - Roller Mill Crusher</td>
<td>-</td>
</tr>
<tr>
<td><strong>Misc. Equipment - Described in Figures 6.13 and 6.14</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Engineering and Design</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Construction Management</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Freight (c.i.f. Alexandria)</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Freight (c.i.f. Fayoum)</strong></td>
<td>1,500$^{(3)}$</td>
</tr>
<tr>
<td><strong>Tariffs (5%)</strong></td>
<td>97,500$^{(2)}$</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>L.E. 187,960</td>
</tr>
<tr>
<td><strong>1 Komatsu WA30-1</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Front-End Loader (0.4 yd$^3$ capacity)</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Freight (c.i.f. Alexandria)</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Freight (Fayoum)</strong></td>
<td>2,500$^{(4)}$</td>
</tr>
<tr>
<td><strong>Tariffs (5%)</strong></td>
<td>L.E. 190,560</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>L.E. 213,260</td>
</tr>
<tr>
<td><strong>Transformer</strong>**</td>
<td>20,000$^{(2)}$</td>
</tr>
<tr>
<td><strong>Diesel Generator</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Freight (15%)</strong></td>
<td>1,350$^{(2)}$</td>
</tr>
<tr>
<td><strong>Tariffs (5%)</strong></td>
<td>1,350$^{(2)}$</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>L.E. 234,590</td>
</tr>
</tbody>
</table>

Contingency (10%) 21,330 231,220

**SUB-TOTAL**

L.E. 234,590

L.E. 2,543,420

289
TABLE 6.20 (Continued)

PROCESSING AND CALCINING PLANT INVESTMENT COST

* Includes foundations, structural steel, and related services.

** Assumed to be 15 percent of total installed cost.

*** 198 tons at 1981 cost of L.E. 1.8/ton plus an additional L.E. 0.018/ton-km. Cost escalated 20 percent to reflect 1982 cost.

**** Includes all messenger cable and installation.


(2) Data obtained from telephone interview with P. Mullenax, Sales Rep., Combustion Engineer, Inc. Abilene, Kansas. November 1982. (Reference: No. 142)

(3) Taken from costs supplied by Egypt Intercity Transportation Study. Technology Adaptation Program, Massachusetts Institute of Technology. Cambridge, MA.


### TABLE 6.21
PROCESSING AND CALCINING OPERATING COSTS - 84,000 METRIC TONS OF STUCCO PER YEAR
(Egyptian Rounds)

<table>
<thead>
<tr>
<th>OPERATING COST ITEM</th>
<th>QUANTITY UNITS</th>
<th>QUANTITY PER YEAR</th>
<th>COST PER UNIT</th>
<th>COST PER YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Wages</td>
<td></td>
<td>Hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefits (25% of Wages)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>MWH</td>
<td>7,860 (2)</td>
<td>60.0 (b)</td>
<td>471,600</td>
</tr>
<tr>
<td>Water</td>
<td>Liters</td>
<td>13,100 (3)</td>
<td>0.20 (b)</td>
<td>2,620</td>
</tr>
<tr>
<td>#6 Fuel Oil</td>
<td>10^6 Btu</td>
<td>79,800 (4)</td>
<td>0.75 (b)</td>
<td>59,850</td>
</tr>
<tr>
<td>Diesel Fuel</td>
<td>Liters</td>
<td>4,800 (5)</td>
<td>0.25 (c)</td>
<td>1,200</td>
</tr>
<tr>
<td>Maintenance Materials (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Wearing Steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lubricants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Hand Tools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Consumable Items</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyethylene Lined</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stucco Bags</td>
<td>1 Bag</td>
<td>400,000 (7)</td>
<td>0.25 (b)</td>
<td>100,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>765,170</td>
</tr>
</tbody>
</table>

(1) Assumes operation 300 days per year at 24 hours per day.
(2) Process requires approximately 0.06 MWH of power for each metric ton of ore processed.
(3) Process requires approximately 0.01 liters of water for each metric ton of ore processed.
(4) Kiln requires 950,000 Btu per ton of stucco produced.
(5) Assumes front-end loader consumes 4 liters per hour of diesel fuel per hour of operation and operates 1200 hours per year.
(6) Assumes 50 kilogram capacity.

**SOURCE:**
(b) Data obtained from interview with Aiman El Sakka, AZAMCO, Ltd. Cairo, Egypt. September, 1982. (Reference: No. 143)
(c) Komatsu Sales Mates. Komatsu, Ltd. Tokyo, Japan. (Reference: No. 97)
(d) Data obtained from telephone interview with P. Milenax, Sales Rep., Combustion Engineering, Inc. Abilene, Kansas. November, 1982 (Reference: No. 142)
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Machine Operators (4 x L.E. 0.40)</td>
<td>1.60</td>
</tr>
<tr>
<td>1 Maintenance</td>
<td>0.50</td>
</tr>
<tr>
<td>1 Loader Operator</td>
<td>0.50</td>
</tr>
<tr>
<td>1 Foreman</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>TOTAL L.E.</strong></td>
<td><strong>3.60</strong></td>
</tr>
</tbody>
</table>

6.3.3 Panel Production

a. Configuration

The panel production facility used in this project will conform to the description and specifications given in Section 4.4. The basic plant will consist of an automated carousel unit, a gypsum-feeding apparatus, a glass-fiber feeder, a chopper and an overhead crane. For 300 days per year, with three shifts per day, annual output would be approximately 702 thousand square meters, assuming 80 percent utilization (28).

b. Investment Cost

Table 6.23 shows the total investment costs for a complete panel production facility. The total installed 1982 cost for this plant, including all plaster and finished product handling equipment, carousel units, and other accessories is 1.25 million Egyptian pounds. Adding all buildings, fees, freights, and tariffs gives a total plant cost of 1.81 million pounds (28). Building Costs were calculated using the method employed in earlier sections.

c. Operating Costs

A breakdown of all panel production plant operating costs is shown in Table 6.24. The labor and wage requirements for this facility
### TABLE 6.23

PANEL PRODUCTION PLANT INVESTMENT COST SUMMARY

<table>
<thead>
<tr>
<th>Cost (1982 Egyptian Pounds)</th>
<th>Local</th>
<th>Foreign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caronsels and Production Accessories:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Plaster Handling Equipment</td>
<td>-</td>
<td>140,000 (1)</td>
</tr>
<tr>
<td>- Caronsels and Accessories</td>
<td>-</td>
<td>700,000 (1)</td>
</tr>
<tr>
<td>- Finished Product Handling Equipment</td>
<td>-</td>
<td>95,000 (1)</td>
</tr>
<tr>
<td>- Services (Electrical and Mechanical)</td>
<td>-</td>
<td>50,000 (1)</td>
</tr>
<tr>
<td>Erection, Installation of Services and Commissioning</td>
<td>-</td>
<td>150,000 (1)</td>
</tr>
<tr>
<td>Buildings:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Caronsel Shop (70m² @ L.E. 64/m²)</td>
<td>4,480 (2)</td>
<td>-</td>
</tr>
<tr>
<td>- Stores/Maintenance (40m² @ L.E. 64/m²)</td>
<td>2,560 (2)</td>
<td>-</td>
</tr>
<tr>
<td>- Canteen (80 m² @ L.E. 120/m²)</td>
<td>9,600 (2)</td>
<td>-</td>
</tr>
<tr>
<td>- Office Area (110 m² @ L.E. 153/m²)</td>
<td>16,830 (2)</td>
<td>-</td>
</tr>
<tr>
<td>- Design Services (6%)</td>
<td>2,010 (3)</td>
<td>-</td>
</tr>
<tr>
<td>License Fee</td>
<td>-</td>
<td>100,000 (1)</td>
</tr>
<tr>
<td>Technical Services</td>
<td>-</td>
<td>150,000 (1)</td>
</tr>
</tbody>
</table>

| L.E. 35,480 | L.E. 1,385,000 |

| Contingency (10%) |       |         |
|                   | 3,550  | 138,500  |
| **Total:** | **L.E. 39,030** | **L.E. 1,523,500** |

**SOURCE:**


TABLE 6.24

PANEL PRODUCTION PLANT OPERATING COSTS
702 THOUSAND SQUARE METERS PER YEAR

<table>
<thead>
<tr>
<th>OPERATING COST ITEMS</th>
<th>QUANTITY UNITS</th>
<th>QUANTITY PER YEAR</th>
<th>COST PER UNIT</th>
<th>COST PER YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Wages Benefits</td>
<td>Hours</td>
<td>7,200</td>
<td>4.30 (1)</td>
<td>30,960</td>
</tr>
<tr>
<td>(25% of Wages)</td>
<td></td>
<td></td>
<td></td>
<td>7,740</td>
</tr>
<tr>
<td>Glass Fiber*</td>
<td>kg</td>
<td>126,360</td>
<td>2.50 (2)</td>
<td>315,900</td>
</tr>
<tr>
<td>Electricity**</td>
<td>MWH</td>
<td>3,600</td>
<td>60.00 (3)</td>
<td>216,000</td>
</tr>
<tr>
<td>Water***</td>
<td>Liters</td>
<td>842,400</td>
<td>0.20 (3)</td>
<td>168,480</td>
</tr>
<tr>
<td>Maintenance****</td>
<td></td>
<td></td>
<td></td>
<td>45,000 (2)</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>616,500</td>
</tr>
</tbody>
</table>

* Assumes 0.18 kilograms of glass-fiber per square meter of panel.
** Assumes power requirement of 0.5 MHW per hour of panel production.
*** Assumes 1.2 liters of water per square meter of panel.
**** Estimated at 5 percent of total plant cost.

SOURCES:
(3) Data obtained from interview with Aiman El Sakka, AZAMCO, Ltd. Cairo, Egypt. September, 1982 (Ref. 143).
have been calculated using the previous method and are detailed in Table 6.25. The requirements for laborers are higher than those given in Table 4.23, as those relate to production facilities using totally automated carousel units. In Egyptian plants using inexpensive manual labor, automatic stacking could be eliminated in favor of manual means. This requirement could be satisfied through the addition of one extra laborer. In addition, the longitudinal glass-fiber handling system—would require its own operator.

6.3.4 Project Cost and Expense Summary

a. Fixed Capital Investment Costs

A totally integrated Dryflow panel production facility consists of United States, United Kingdom, Egypt and Japan sourced goods and services. The total project fixed capital investment cost rounded to the nearest integer can be summarized on a 1982 cost basis as follows:

1982

(1000 Egyptian Pounds)

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>UK</th>
<th>JAPAN</th>
<th>ARE</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Equipment Cost</td>
<td>2483</td>
<td>1711</td>
<td>424</td>
<td>377</td>
<td>4994</td>
</tr>
</tbody>
</table>
### TABLE 6.25

**PANEL PRODUCTION PLANT WAGES (L.E./Hr)**  
(Egyptian Pounds Per Hour)

<table>
<thead>
<tr>
<th>Position</th>
<th>Wage (L.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Carousel Operator</td>
<td>0.60</td>
</tr>
<tr>
<td>2 Dispatch Laborers (2 x 0.40)</td>
<td>0.80</td>
</tr>
<tr>
<td>2 Miscellaneous Labor (2 x 0.40)</td>
<td>0.80</td>
</tr>
<tr>
<td>1 Maintenance</td>
<td>0.50</td>
</tr>
<tr>
<td>1 Fiber Handler Operator</td>
<td>0.60</td>
</tr>
<tr>
<td>1 Foreman</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**TOTAL L.E.**  
4.30

A breakdown of the above investment costs is shown in Table 6.26. These capital costs have been based on vendor quotations obtained by the MIT Gypsum Project Team. These costs include all equipment, materials, subcontracts, indirect construction costs, plant startup costs, and the cost of all professional services involved in the plant design and installation.

All equipment costs shown are quoted in 1982 Egyptian pounds. The official exchange rates of 0.8 Egyptian pounds to one U.S. dollar and L.E. 1.45 to one British pound were used in all calculations.

The costs for a facility producing only calcined gypsum would be equivalent to the previous costs, with the exception of the cost of a panel production facility. The total costs for such a plant, including a 10 percent contingency can be summarized as follows:

1982

(1000 Egyptian Pounds)

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>UK</th>
<th>JAPAN</th>
<th>ARE</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Equipment Cost</td>
<td>2483</td>
<td>-</td>
<td>424</td>
<td>274</td>
<td>3181</td>
</tr>
</tbody>
</table>

b. Working Capital Investment Costs

The working capital costs for a totally integrated facility are summarized in Table 6.27. These costs have been determined by deducting current liabilities from the sum of current assets. The second step
TABLE 6.26

FIXED CAPITAL INVESTMENT COST SUMMARY

<table>
<thead>
<tr>
<th>QUARRYING</th>
<th>U.S.</th>
<th>U.K.</th>
<th>JAPAN</th>
<th>A.R.E.</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dozer and Ripper</td>
<td>-</td>
<td>-</td>
<td>120(1)</td>
<td>-</td>
<td>120</td>
</tr>
<tr>
<td>Front-End Loader</td>
<td>-</td>
<td>-</td>
<td>60(1)</td>
<td>-</td>
<td>60</td>
</tr>
<tr>
<td>Truck</td>
<td>-</td>
<td>-</td>
<td>120(1)</td>
<td>-</td>
<td>120</td>
</tr>
<tr>
<td>Service Facility</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>21.7(2)</td>
<td>21.7</td>
</tr>
<tr>
<td>Freight Charges</td>
<td>-</td>
<td>-</td>
<td>30(1)</td>
<td>-</td>
<td>30.4</td>
</tr>
<tr>
<td>Tariffs</td>
<td>-</td>
<td>-</td>
<td>15(1)</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>330</td>
<td>37.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROCESSING &amp; CALCINING</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>89(2)</td>
<td>89</td>
</tr>
<tr>
<td>Calcining Plant</td>
<td>1950(4)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1950</td>
</tr>
<tr>
<td>Loader and Electrical</td>
<td>12(5)</td>
<td>-</td>
<td>50(1)</td>
<td>-</td>
<td>20(4)</td>
</tr>
<tr>
<td>Equipment</td>
<td>295.2(4)</td>
<td>-</td>
<td>5(1)</td>
<td>-</td>
<td>1.5(3)</td>
</tr>
<tr>
<td>Tariffs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>101.4(4)</td>
<td>101.4</td>
</tr>
<tr>
<td></td>
<td>2257.2</td>
<td>-</td>
<td>55</td>
<td>211.9</td>
<td>2524.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PANEL PRODUCTION</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carousels and Production</td>
<td>-</td>
<td>-</td>
<td>1135(6)</td>
<td>-</td>
<td>1135</td>
</tr>
<tr>
<td>Accessories</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33.5(2)</td>
<td>33.5</td>
</tr>
<tr>
<td>Buildings</td>
<td>-</td>
<td>-</td>
<td>250(6)</td>
<td>-</td>
<td>250</td>
</tr>
<tr>
<td>License and Technical Fees</td>
<td>-</td>
<td>-</td>
<td>170.3(4)</td>
<td>-</td>
<td>171.3</td>
</tr>
<tr>
<td>Freight</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>56.8(4)</td>
<td>56.8</td>
</tr>
<tr>
<td>Tariffs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>1555.3</td>
<td>-</td>
<td>1555.3</td>
</tr>
<tr>
<td>Contingency (10%)</td>
<td>1757.2</td>
<td>385</td>
<td>342.3</td>
<td>4539.8</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>2482.9</td>
<td>1710.8</td>
<td>423.5</td>
<td>376.5</td>
<td>4993.7</td>
</tr>
</tbody>
</table>

SOURCE:
(1) Price quote obtained from interview with L. Hibbs, Sales Rep., Komatsu, Ltd. Daddi-Cairo, Egypt, August. 1982. (Reference: No. 144)
(3) Taken from costs supplied by Egypt Intercity Transportation Study. Technology Adaptation Program, Massachusetts Institute of Technology. Cambridge, MA.
TABLE 6.27
WORKING CAPITAL INVESTMENT COST SUMMARY
(Egyptian Pounds)

<table>
<thead>
<tr>
<th>Inventory:</th>
<th>Days</th>
<th>Coefficient of Turnover</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster Bags</td>
<td>15</td>
<td>24</td>
<td>4,170(1)</td>
</tr>
<tr>
<td>Finished Goods</td>
<td>90</td>
<td>4</td>
<td>445,830</td>
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<tr>
<td>Quarry Maintenance Materials</td>
<td>180</td>
<td>2</td>
<td>7,500(2)</td>
</tr>
<tr>
<td>Processing Plant Maintenance</td>
<td>180</td>
<td>2</td>
<td>48,750(3)</td>
</tr>
<tr>
<td>Maintenance Materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel Production Plant</td>
<td>180</td>
<td>2</td>
<td>22,500(4)</td>
</tr>
<tr>
<td>Maintenance Materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Accounts Receivable</td>
<td>60</td>
<td>6</td>
<td>336,560</td>
</tr>
<tr>
<td>Accounts Payable</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL:</td>
<td></td>
<td></td>
<td>L.E.865,310</td>
</tr>
</tbody>
</table>

SOURCES:
(1) Data obtained from interview with Aiman El Sakka, AZAMCO, Ltd., Cairo, Egypt, September, 1982. (Ref. 143).
McKee-Kearny, Development of Ras Malaals Gypsum Deposits for Sinai Manganese Company. 1981. (Ref. 97).
involved determining the coefficient of turnover for these cost components by dividing 360 days by the number of days of minimum coverage.

c. Operating Costs

Per unit production costs can be summarized as follows:

QUARRY WAGES

The 1982 aggregate wage rate for all quarry labor including benefits as summarized in Table 6.17 is L.E. 6.63 per hour (142, 150). For an hourly rate of ore production of 54.6 metric tons, this labor cost translates into a unit labor cost of L.E. 0.12 per ton.

PROCESSING AND CALCINING PLANT WAGES

1982 hourly plant wages, including all benefits are estimated at L.E. 4.50 per hour of production (142, 150). Assuming a production rate of 11.7 metric tons of calcined gypsum per hour, this labor rate translates into a unit labor cost of L.E. 0.4 per ton.

PANEL PRODUCTION PLANT WAGES

Panel production plant wages have been estimated at L.E. 5.38 per hour. This labor rate converts to a unit cost of L.E. 0.06 per square meter of Dryflow panel produced.

DIESEL FUEL

Per unit diesel fuel costs were calculated (142) as follows:
A. Quarrying

1. Dozer and Ripper - 16 liters/hr. x 2100 hr/year x  
   L.E. 0.25/liter = L.E. 8,400

2. Front-End Loader - 8 liters/hr. x 2300 hr/year x  
   L.E. 0.25/liter = L.E. 4,600

3. Off-Highway Truck - 30 liters/hr. x 2400 hr/year x  
   L.E. 0.25/liter = L.E. 18,000

\[ \frac{L.E. \ 31,000 \text{ / yr}}{131,000 \text{ tons-ore per yr.}} = L.E. \ 0.24/\text{ton of ore} \]

B. Calcining

Front-End Loader - 6 liters/hr. x 800 hr/year x  
0.25/liter = L.E. 1,200

\[ \frac{L.E. \ 1,200 \text{ / yr}}{80,000 \text{ tons-stucco per year}} = L.E. \ 0.015/\text{ton of stucco} \]

#5 FUEL OIL

Fuel Oil costs were calculated on a unit cost basis  
(97,142) as follows:

\[ 950,000 \text{ Btu/ton-stucco} \times \text{L.E. } 0.75/10^6 \text{ Btu} = \text{L.E. } 0.71/\text{ton stucco} \]
ELECTRICITY

Per unit electricity costs (44,97) can be summarized as follows:

1. Processing and Calcining -

\[
\frac{0.06 \text{ MWH/ton ore} \times 131,000 \text{ tons ore} \times (\text{L.E. 60/MWH})}{80,000 \text{ tons stucco}} = \text{L.E. 5.90/ton stucco}
\]

2. Panel Production -

\[
\frac{3600 \text{ MWH/year}}{702,000 \text{ m}^2 / \text{year}} = 0.005 \text{ MWH/m}^2 \times \text{L.E. 60/MWH} = \text{L.E. 0.31/m}^2
\]

WATER

Water costs were estimated using an allowance of 0.1 liters per ton of ore processed and 1.2 liters per square meter of panel (28,145). The total annual cost for this usage is L.E. 13,100 for 80,000 tons of plaster production and L.E. 168,480 for 702 thousand square meters of panel production. Unit costs can be translated to L.E. 0.16 ton for processing and calcining and L.E. 0.24 per square meter of panel. These estimates assume a water cost of L.E. 0.20 per liter.
GYPSUM PACKING BAGS

Polyethelene-lined packing bags for calcined gypsum with a 50 kilogram capacity cost 0.25 Egyptian pounds per bag (97,142). The proposed production facility requires 400,000 bags, at a total 1982 cost of L.E. 100,000, or a unit cost of L.E. 1.19 per ton of stucco.

GLASS FIBER

These fibers must be imported from the United Kingdom at a cost of L.E. 2.50 per kilogram, assuming an exchange rate of L.E. 1.45 to one British pound. It is assumed that 0.18 kilograms of glass fiber are required per square meter of panel giving a unit fiber cost of L.E. 0.45 per square meter (28).

MAINTENANCE

Unit maintenance costs were calculated (145,146) as follows:

1. Quarry -

   5% of total equipment cost (L.E. 300,000)/yr. = L.E. 15,000/yr.

   \[
   \frac{L.E. \ 15,000/yr.}{131,000 \ \text{tons ore/yr.}} = L.E. \ 0.11/\text{ton/ore}
   \]
2. Processing and Calcining -

5% of total plant equipment cost (L.E. 1,950,000) = L.E. 97,500

\[
\frac{\text{L.E. 97,500/yr}}{80,000 \text{ tons stucco/year}} = \text{L.E. 1.16/ton stucco}
\]

3. Panel Production -

5% of total plant equipment cost (L.E. 1,135,000) = L.E. 56,750

\[
\frac{\text{L.E. 56,750/yr}}{702,000 \text{ m}^2/\text{year}} = \text{L.E. 0.08/m}^2
\]

d. Miscellaneous Costs, Overheads, and Expenses

ADMINISTRATIVE WAGES

The 1982 aggregate labor cost for all administrative personnel has been estimated at L.E. 33,500 per year (142,143). Table 6.28 provides a breakdown of this cost. Total annual costs, including a 25 percent benefit allowance have been estimated at L.F. 41,880.
TABLE 6.28

ADMINISTRATIVE WAGE SUMMARY
(1982 Egyptian Pounds)

<table>
<thead>
<tr>
<th>Position</th>
<th>Salary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Managing Director</td>
<td>5,000</td>
</tr>
<tr>
<td>1 - Sales Manager</td>
<td>4,000</td>
</tr>
<tr>
<td>1 - Production Manager</td>
<td>4,000</td>
</tr>
<tr>
<td>1 - Accountant</td>
<td>3,000</td>
</tr>
<tr>
<td>3 - Secretarial (3 x 1500)</td>
<td>4,500</td>
</tr>
<tr>
<td>2 - Sales Representatives (4 x 2500)</td>
<td>10,000</td>
</tr>
<tr>
<td>1 - Production Controller</td>
<td>3,000</td>
</tr>
</tbody>
</table>

TOTAL L.E. 33,500

SOURCE: Data obtained from interview with E. El Sattar, GYMCO. Gharbaniat, Egypt. September, 1982. (Reference: No. 142)
TRANSPORTATION

Transportation costs for both calcined gypsum and panels were calculated as follows:

Fixed Charge = 1.80 x Number of Tons
Variable Charge = 0.05 x Number of Tons x Distance (kilometers)

Assuming:
1. Production Plant to Fayoum city = 45 kilometers
2. Production Plant to Cairo = 125 kilometers

These costs have been taken from data supplied by the "Intercity Transportation Study," conducted under the Technology Adaptation Program at M.I.T.

LIGHTING

Lighting requirements for office and canteen areas have been estimated using data from Means "Systems Cost Guide - 1982" (147). Means provides an allowance of 3 watts per hour per square foot (32.3 watts per square meter) of lighting for a typical office and canteen area. For a total area of 190 square meters operating 24 hours per day
and 360 days per year, this translates into an annual requirement of 4.9 MWH. For a current cost of L.E. 60 per MWH (97,142), the annual cost is estimated at L.E. 295.

TELEPHONE/OFFICE SUPPLIES

Because current data are unavailable for these costs, an allowance of L.E. 20,000 per year was used. This cost is based on one provided by a preinvestment study for the GYMCO project at Gharbaniat (142).

INSURANCE

The cost of insurance has been estimated using the McKee-Kearny allowance of one percent of total plant cost (97). Using this coefficient provides an annual cost of approximately L.E. 50,000.

MARKETING

Marketing costs excluding wages for all sales personnel have been estimated at L.E. 60,000 per year. This figure has been taken from the GYMCO preinvestment study, and includes the cost of product literature, mailings, and sales presentations (142, 143). These costs would also include the cost of an erection advisory service. This service would be available to make on-site visits to users in order to ensure that the cost and time savings claimed by Dryflow panels are fully achieved by the user.
These overhead costs are summarized in Table 6.29.

DEPRECIATION

Depreciation for all equipment was calculated using straight line methods for the following periods (55):

1) Quarrying Equipment - 5 Years
2) Processing, Calcining, and Panel Production Equipment - 10 years
3) All Buildings - 20 years

Using the above durations, the following depreciation expenses were determined:

1) Quarrying Equipment - L.E. 69,080 per year
2) Processing, Calcining, and Panel Production Equipment - L.E. 404,820 per year
3) All Buildings - L.E. 7310 per year

TAXES

Taxes were excluded because of the ten to fifteen year tax exemption granted under Law 43 and the New Communities Act (53, 55).
### TABLE 6.29

**OVERHEAD COSTS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative Wages</td>
<td>L.E. 33,500</td>
</tr>
<tr>
<td>Benefits</td>
<td>L.E. 8,375</td>
</tr>
<tr>
<td>Lighting (4.9 MWH @ L.E. 60/KWH)</td>
<td>L.E. 295</td>
</tr>
<tr>
<td>Telephone/Office Supplies</td>
<td>L.E. 20,000</td>
</tr>
<tr>
<td>Insurance</td>
<td>L.E. 50,000</td>
</tr>
<tr>
<td>Marketing</td>
<td>L.E. 60,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>L.E. 172,170</strong></td>
</tr>
</tbody>
</table>

**SOURCE:** Data obtained from interview with E. El Sattar, GYMCO. Gharbaniat, Egypt. September, 1982. (Reference: No. 142)

*Mckee-Kearny, Development of Ras Malaab Gypsum Deposits for Sinai Manganese Company. 1981. (Reference: No. 97)*
ROYALTIES

Royalties payable to the Egyptian Government were calculated (59) according to the guidelines set forth in Section 5.5. Royalties were computed as follows:

Production Royalties

\[ 131,000 \text{ tons ore} \times \text{L.E. } 0.041/\text{ton} = \text{L.E. } 5371 \]

Rent-Land \[ = \text{L.E. } 20 \]

Service Royalties-Electricity and Water \[ = \text{L.E. } 400 \]

TOTAL \[ = \text{L.E. } 5791 \]

6.4 Financial and Economic Evaluation

This portion of the study addresses the financial feasibility of the quarrying, processing, calcining, and panel production facilities outlined in Section 6.3. The viability of the two proposed production facilities has been judged on the basis of the results from the Interactive Financial Planning System (IFPS) computer simulation program. This software is available on the PRIME 850 minicomputer available at the MIT Sloan School of Management. IFPS is a simple modeling language that is capable of performing most financial computations in a fast and convenient manner. IFPS contains such built-in financial analysis capabilities as net present value, internal rate of return, depreciation, loan amortization, risk analysis, and forecasting and mathematical functions. A listing of the IFPS financial simulation programs used in this report are presented in Appendix I.
6.4.1 Calcined Gypsum Production Facility

a. Selection of Optimal Leveraging and Incorporation Strategy

The first step of the financial feasibility analysis required financial simulations under an assortment of scenarios. Six scenarios, or leveraging and incorporation options, were analyzed. The first three scenarios consisted of debt-to-equity ratios of 1:1, 2:3, and 1:2 under the foreign investment law, Law No. 43 that was discussed in Section 5.5. The remaining scenarios were derived using debt-to-equity ratios of 2:1, 1:1, and 1:2 under the local incorporation law, Law No. 159. These six scenarios along with the terms and sources of credit are highlighted in Tables 6.30 and 6.31.

The rate of return for incorporation under Law No. 159, with a debt-to-equity ratio of 1 to 2 was found to be the most satisfactory. The rates of return and net present values associated with each of the six scenarios are summarized in Table 6.32. Although this rate exceeds those calculated under Law No. 43, there are several disadvantages associated with local incorporation. Under local incorporation laws, investors are subject to numerous foreign currency and legal restrictions and to the restriction which specifies that 49 percent of the firm must be owned by Egyptian nationals. Under Law No. 43, investors are not subject to these restrictions.

Having determined these optimal parameters, the second evaluation phase concentrates on some of the more pertinent financial calculations used to assess overall project viability, including net present value,
<table>
<thead>
<tr>
<th>EQUIPMENT FINANCED</th>
<th>SOURCE OF LOAN</th>
<th>LOAN AMOUNT (Egyptian Pounds)</th>
<th>INTEREST RATE (%)</th>
<th>DURATION (Years)</th>
<th>DOWN PAYMENT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
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<tr>
<td>2. Processing and Calcining</td>
<td>U.S. Agency for International Development</td>
<td>1,862,175</td>
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<td>25</td>
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<tr>
<td>Equipment</td>
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<td>309,540</td>
<td>15</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Scenario 1 Debt/Equity = 2:1</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
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<td>9</td>
<td>5</td>
<td>25</td>
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<tr>
<td>2. Processing and Calcining</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 2 Debt/Equity = 1:1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining</td>
<td>U.S. Agency for International Development</td>
<td>927,045</td>
<td>10</td>
<td>5</td>
<td>25</td>
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<tr>
<td>Equipment</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Scenario 3 Debt/Equity = 1:2</td>
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</table>

SOURCE: Reference Nos. 39, 76, 117, 126, and 149.
<table>
<thead>
<tr>
<th>EQUIPMENT FINANCED</th>
<th>SOURCE OF LOAN</th>
<th>LOAN AMOUNT (Egyptian Pounds)</th>
<th>INTEREST RATE (%)</th>
<th>DURATION (Years)</th>
<th>DOWN PAYMENT ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Export/Import Bank</td>
<td>1,517,715</td>
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</table>

<table>
<thead>
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<th>LOAN AMOUNT (Egyptian Pounds)</th>
<th>INTEREST RATE (%)</th>
<th>DURATION (Years)</th>
<th>DOWN PAYMENT ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
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<table>
<thead>
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<th>SOURCE OF LOAN</th>
<th>LOAN AMOUNT (Egyptian Pounds)</th>
<th>INTEREST RATE (%)</th>
<th>DURATION (Years)</th>
<th>DOWN PAYMENT ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Export/Import Bank</td>
<td>927,045</td>
<td>10</td>
<td>5</td>
<td>35</td>
</tr>
</tbody>
</table>

SOURCE: Reference Nos. 39, 76, 117, 126, and 149
TABLE 6.32

FINANCIAL CALCULATIONS FOR SIX LEVERAGING AND INCORPORATION SCENARIOS - CALCINED GYPSUM PRODUCTION FACILITY

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>NET PRESENT VALUE (EGYPTIAN POUNDS)</th>
<th>INTERNAL RATE OF RETURN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Law No. 159</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:1</td>
<td>492,140</td>
<td>20.9</td>
</tr>
<tr>
<td>1:1</td>
<td>581,678</td>
<td>20.9</td>
</tr>
<tr>
<td>1:2</td>
<td>635,399</td>
<td>21.1</td>
</tr>
<tr>
<td>Law No. 43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:1</td>
<td>272,233</td>
<td>17.7</td>
</tr>
<tr>
<td>2:3</td>
<td>276,465</td>
<td>17.8</td>
</tr>
<tr>
<td>1:2</td>
<td>297,953</td>
<td>17.9</td>
</tr>
</tbody>
</table>
internal rate of return, pro forma cash flow statements, pay back period, breakeven analysis, and sensitivity analysis. A summary of the program's output data is described in the following sections.

b. Revenues

Total project revenues are defined as those revenues which are accrued through the sales of calcined gypsum, or plaster. The three scenarios, optimistic, pessimistic, and most likely, were derived using the data of Tables 6.2 and 6.3. Table 6.4 shows the data used for the "most likely" scenario. For this analysis it was assumed that 5 percent of the Cairo market, and after 1985, 100 percent of the Fayoum market could be captured.

Plaster is sold to the Cairo market at the 1982 government regulated price of 40 Egyptian pounds per metric ton. The remainder of the plaster produced is sold in the local markets of Fayoum and Beni Suef at the current price of 30 pounds per ton.

Total project revenues for the three scenarios are shown in Table 6.33.

c. Pro Forma Cash Flows

Pro forma cash flow statements for all three scenarios are shown in Tables 6.34 through 6.36. Because plant construction occurs in the first year of the project, these tables show cash flow from revenues starting in 1984. These tables also include data for total revenues,
TABLE 6.33
REVENUE STREAMS - CALCINED GYPSUM PRODUCTION FACILITY

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMISTIC:</td>
<td>1,040,000</td>
<td>1,542,200</td>
<td>1,683,000</td>
<td>1,841,400</td>
<td>2,013,000</td>
<td>2,204,400</td>
<td>2,411,200</td>
<td>2,483,800</td>
<td>2,631,200</td>
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<tr>
<td>MOST LIKELY:</td>
<td>899,200</td>
<td>1,327,800</td>
<td>1,444,400</td>
<td>1,543,400</td>
<td>1,665,400</td>
<td>1,799,400</td>
<td>1,937,200</td>
<td>2,006,000</td>
<td>2,114,200</td>
</tr>
<tr>
<td>PESSIMISTIC:</td>
<td>758,400</td>
<td>1,113,200</td>
<td>1,205,600</td>
<td>1,245,200</td>
<td>1,317,800</td>
<td>1,390,400</td>
<td>1,463,000</td>
<td>1,582,000</td>
<td>1,597,200</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>104000</td>
<td>154300</td>
<td>160400</td>
<td>184100</td>
<td>201300</td>
<td>220400</td>
<td>241100</td>
<td>240100</td>
<td>263100</td>
</tr>
<tr>
<td><strong>Total Operating Costs</strong></td>
<td>439000</td>
<td>640600</td>
<td>699100</td>
<td>764900</td>
<td>816200</td>
<td>856200</td>
<td>915700</td>
<td>1001700</td>
<td>1041873</td>
</tr>
<tr>
<td><strong>Overall Costs</strong></td>
<td>172100</td>
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<td>172100</td>
<td>172100</td>
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<tr>
<td><strong>Total Equity</strong></td>
<td>2400</td>
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<tr>
<td><strong>Debt Service</strong></td>
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<tr>
<td><strong>Cash Flow</strong></td>
<td>107199</td>
<td>399647</td>
<td>40164</td>
<td>574954</td>
<td>673924</td>
<td>1111640</td>
<td>1232116</td>
<td>1274411</td>
<td>1460215</td>
</tr>
</tbody>
</table>
### TABLE 6.35

PRO FORMA CASH FLOWS - CALCINED GYPSUM PRODUCTION FACILITY

**Scenario: Most Likely**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Revenues</td>
<td>899,200</td>
<td>1,327,000</td>
<td>1,444,400</td>
<td>1,543,400</td>
<td>1,665,400</td>
<td>1,799,400</td>
<td>1,937,200</td>
<td>2,066,000</td>
<td>2,144,200</td>
</tr>
<tr>
<td>Total Operating Costs</td>
<td>571,016</td>
<td>654,622</td>
<td>660,863</td>
<td>641,191</td>
<td>691,076</td>
<td>747,533</td>
<td>804,272</td>
<td>853,319</td>
<td>874,576</td>
</tr>
<tr>
<td>Other Bar Costs</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
<td>172,169</td>
</tr>
<tr>
<td>Total Royalty</td>
<td>2110</td>
<td>3054</td>
<td>5285</td>
<td>5481</td>
<td>3724</td>
<td>3989</td>
<td>4284</td>
<td>4399</td>
<td>4644</td>
</tr>
<tr>
<td>Debt Service</td>
<td>32,6311</td>
<td>32,6211</td>
<td>32,6211</td>
<td>32,6211</td>
<td>32,6211</td>
<td>32,6211</td>
<td>32,6211</td>
<td>32,6211</td>
<td>32,6211</td>
</tr>
<tr>
<td>Cash Flow</td>
<td>26,001</td>
<td>2,744</td>
<td>3,416,22</td>
<td>4,003,47</td>
<td>4,714,70</td>
<td>8,757,10</td>
<td>9,559,76</td>
<td>9,869,54</td>
<td>10,999,1</td>
</tr>
</tbody>
</table>

operating and overhead costs, royalties, and debt service.

The revenue streams shown in these tables are based on the following financing arrangements:

1. Goods from the United States, including the calcining and processing plant and all services are financed through a loan with the United States Agency for International Development (AID) at a rate of 10 percent per annum and a down payment of 25 percent. The loan duration is 5 years with no grace period. Loan: L.E. 927,045.

2. The bulldozer, quarry loader, calcining plant loader, and off-highway truck imported from Japan are financed at 25 percent down, no grace period, and 9 percent over a period of five years on a loan extended by the Japanese Export/Import Bank. Loan: L.E. 317,625.

The remaining balance of L.E. 2,489,340 is financed through company equity. Table 6.37 shows the debt service schedule for these loans.

d. Net Present Value

Net present values for the equity capital for the ten year period 1983 through 1992 were generated using a discount rate of 15 percent for each of the three production scenarios. These data are shown in Table 6.38. The results, ranging from a low of L.E. -527,519 to a maximum of L.E. 1,122,090, show that it is possible for profitability to fall below the cutoff rate.

The calculation of the net present value for the total investment costs shows a range of L.E. -1,512,904 to L.E. 121,060.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL REVENUE</strong></td>
<td>758400</td>
<td>1113200</td>
<td>1205600</td>
<td>1245200</td>
<td>1317800</td>
<td>1390400</td>
<td>1463000</td>
<td>1524000</td>
<td>1592000</td>
</tr>
<tr>
<td><strong>TOTAL OPERATING COSTS</strong></td>
<td>313576</td>
<td>462469</td>
<td>550856</td>
<td>517307</td>
<td>547468</td>
<td>577630</td>
<td>607791</td>
<td>634000</td>
<td>663514</td>
</tr>
<tr>
<td><strong>DIRECT LABOR</strong></td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
<td>172169</td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td>1852</td>
<td>2639</td>
<td>2639</td>
<td>2639</td>
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<td>2639</td>
<td>2639</td>
<td>2639</td>
<td>2639</td>
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<tr>
<td><strong>INFLATION</strong></td>
<td>326211</td>
<td>326211</td>
<td>326211</td>
<td>326211</td>
<td>326211</td>
<td>326211</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TAXES</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SERVICE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CASH FLOW</strong></td>
<td>55420</td>
<td>149274</td>
<td>206152</td>
<td>226622</td>
<td>260917</td>
<td>637423</td>
<td>679718</td>
<td>712979</td>
<td>759200</td>
</tr>
</tbody>
</table>

**TABLE 6.36**

**PRO FORMA CASH FLOWS - CALCINED GYPSUM PRODUCTION FACILITY**

**SCENARIO:** PESSIMISTIC
<table>
<thead>
<tr>
<th>PERIOD</th>
<th>QUARRY EQUIPMENT</th>
<th>PROCESSING &amp; CALCINING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANNUAL PAYMENT</td>
<td>PRINCIPAL</td>
</tr>
<tr>
<td>1</td>
<td>81,659</td>
<td>53,073</td>
</tr>
<tr>
<td>2</td>
<td>81,659</td>
<td>57,849</td>
</tr>
<tr>
<td>3</td>
<td>81,659</td>
<td>63,056</td>
</tr>
<tr>
<td>4</td>
<td>81,659</td>
<td>68,751</td>
</tr>
<tr>
<td>5</td>
<td>81,659</td>
<td>74,917</td>
</tr>
<tr>
<td>TOTAL</td>
<td>408,295</td>
<td>317,625</td>
</tr>
</tbody>
</table>

*Numbers may not sum due to rounding*
<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>NET PRESENT VALUE (EGYPTIAN POUNDS)</th>
<th>INTERNAL RATE OF RETURN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimistic</td>
<td>1,122,090</td>
<td>24.9</td>
</tr>
<tr>
<td>Most Likely</td>
<td>635,399</td>
<td>21.1</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>-527,519</td>
<td>9.5</td>
</tr>
</tbody>
</table>
Because these rates are based on a discount rate of 15 percent, individual investors and lenders should be encouraged to calculate net present values based on their own particular discount rates.

e. Internal Rate of Return

Because the selection of an appropriate discount rate is often difficult when calculating net present value, the internal rate of return (IRR) is used in an effort to avoid this difficulty. Data for the IRR for the equity capital outlay for the three scenarios are shown in Table 6.38. The lowest value, that associated with a "pessimistic" scenario, is 9.5 percent.

The "most likely" value of 21.1 percent is somewhat below the generally accepted cutoff, or hurdle rate for firms presently investing in Egypt. Whether such a rate of return is above the lowest acceptable investment rate must be left to the discretion of individual investors.

The internal rate of return for the total investment outlay ranges from 2.9 to 15.8 percent. This rate of return is somewhat below the cutoff of many lending institutions.

One fallacy associated with this analysis technique is the assumption that the cash flow received in any year can be reinvested at the calculated rate of return until the end of the investment. It is unlikely that any rate of return calculated at this time will remain unchanged in the future.

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f. Pay Back Period

The project pay-back period represents the number of years over which the investment outlay will be recovered or paid back from project profits. These profits are defined as net profit after tax, with financial costs and depreciation deducted.

This variable has one significant drawback in that it does not take into account the magnitude or timing of cash flows during the payback period. Instead, it merely considers only the recovery period as a whole. Pay back periods for the three scenarios are as follows:

   Optimistic: 5.8 years
   Most Likely: 6.8 years
   Pessimistic: 9.4 years

These moderately long pay back periods indicate that the proposed project is somewhat risky and is characterized by a low level of liquidity. The early recovery of invested funds will not be possible for this particular project. These payback periods are better suited as a constraint for individual investors than as a profitability measure.

   g. Breakeven Analysis

Breakeven analysis determines the breakeven point, or the point of production at which sales revenues equal production costs. The breakeven point is determined by the relationship between fixed costs and the difference of the unit sales price and variable unit costs.
For a per-unit sales price of 30 Egyptian pounds per metric ton, the breakeven point occurs at approximately 12.6 thousand tons. For a price of 40 pounds, the breakeven point is 7.3 thousand tons. Figure 6.15 shows graphically the relationship between price and breakeven quantity.

These relatively low breakeven points are the result of differences between the sales price and the variable unit costs. For this case the fixed cost is rapidly absorbed through this difference.

These breakeven production rates represent 15.8 and 9.1 percent of full plant capacity, respectively.

h. Sensitivity Analysis

For financial calculations, some items have a greater influence on the final result than others. For this specific project it is important to determine the items that have an important influence on the final results so that they can be subjected to special scrutiny. The technique used to do this is commonly referred to as sensitivity analysis.

To use this technique, each cost element was independently varied by 25 percent. The resulting variations in the internal rates of return were measured for each cost element.

The sensitivity of the internal rate of return for the "most likely" scenario is summarized as follows:
FIGURE 6.15

CALCINED GYPSUM PRODUCTION FACILITY - BREAKEVEN ANALYSIS
<table>
<thead>
<tr>
<th>CHANGE IN VARIABLE</th>
<th>(percent)</th>
<th>IRR CHANGE</th>
<th>(percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Plaster Sold</td>
<td>-25 to +25</td>
<td>-37 to +34</td>
<td></td>
</tr>
<tr>
<td>Quarry Equipment Capital Cost</td>
<td>-25 to +25</td>
<td>+2.3 to -2.2</td>
<td></td>
</tr>
<tr>
<td>Calcining Plant Capital Cost</td>
<td>-25 to +25</td>
<td>+24.6 to -17.8</td>
<td></td>
</tr>
<tr>
<td>Working Capital Cost</td>
<td>-25 to +25</td>
<td>+2.9 to -2.8</td>
<td></td>
</tr>
<tr>
<td>Quarry Production Cost</td>
<td>-25 to +25</td>
<td>+1.3 to -1.3</td>
<td></td>
</tr>
<tr>
<td>Calcining Production Cost</td>
<td>-25 to +25</td>
<td>+15.8 to -16.3</td>
<td></td>
</tr>
<tr>
<td>Transportation Cost</td>
<td>-25 to +25</td>
<td>+10.4 to -10.6</td>
<td></td>
</tr>
<tr>
<td>Overhead Cost</td>
<td>-25 to +25</td>
<td>+11.1 to -11.4</td>
<td></td>
</tr>
</tbody>
</table>

As expected plaster quantity, processing and calcining plant capital cost, and calcining production costs have the greatest impact on internal rate of return. If these costs should deviate substantially from those that were estimated in this report, the overall project viability could be severely impacted. Costs for utility services, fuel, and transportation are stringently controlled by the Egyptian government. In light of this fact and the lower sensitivity values associated with these costs, any impacts resulting from increases in these costs could be negligible.

Plaster price has been omitted from this analysis because of the similar governmental price controls placed on this product.

i. Probabilistic Analysis

For the probabilistic calculation of project net present value
and internal rate of return, Monte Carlo simulations were used. Monte Carlo simulations are highly appropriate, because of the difficulty encountered in assigning a deterministic value to a variable such as cost. Using this method, values for all cost variables are obtained from probabilistic distributions which describe the behavior of the variable. The cost variables used in this analysis have been incorporated into probabilistic distributions in an effort to capture overall project risk. These distributions represent variations in cost resulting from such factors as changes in prices and foreign currency exchange rates and inflation. Because reliable historical data for these costs were unavailable, crude approximations were used for distributional variance. Despite this, these simulations provide a valuable mechanism for assessing the merits of a risky investment.

Because of the virtual non-existence of down-side risk for costs and Egyptian pound exchange rates, a skewed triangular distribution was used. For this distribution, the lower limit was bounded within a one-half standard deviation of the mean, while the upper limit was bounded within two standard deviations. Such a distribution is shown in Figure 6.16.
FIGURE 3.16
10/90 TRIANGULAR DISTRIBUTION

Net present values for a ten year period and their corresponding distributions were generated using a discount rate of 15 percent for the "most likely" production scenario. The statistics for these values, including mean, standard deviation, and 10 and 90 percent confidence intervals are shown in Table 6.39. A frequency table of percentile values for net present value is also presented in Table 6.39. The results shown in this table, showing a net present value of L. E. 93,703 appear to be only marginally satisfactory. The distribution for this value is generally characterized by a large dispersion, indicating that a high degree of inherent risk is present for such an investment venture.

A distribution for IRR is shown in Table 6.40. The IRR of 13.9 percent with a standard deviation of 16.8 shows the overall financial risk associated with such a project.

6.4.2 Integrated Panel Production Facility

a. Selection of Optimal Leveraging and Incorporation Strategy

The financial evaluation of a plant producing both plaster and Dryflow panels has been performed in a manner similar to that employed in the analysis of the plaster production facility of Section 6.4.1.

Six scenarios, utilizing a variety of leveraging and incorporation schemes were analyzed. The first three scenarios consisted of debt-to-equity ratios of 2:1, 1:1, and 1:2 under the local incorporation law. The remaining three scenarios were derived using
### Table 6.39

**MONTE CARLO SIMULATION RESULTS - NET PRESENT VALUE** (Egyptian Pounds)

#### Sample Statistics

<table>
<thead>
<tr>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>SKEWNESS</th>
<th>KURTOSIS</th>
<th>10% CONFIDENCE INT.</th>
<th>90% CONFIDENCE INT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>93703</td>
<td>1125964</td>
<td>0.1</td>
<td>3.0</td>
<td>10443</td>
<td>176913</td>
</tr>
</tbody>
</table>

#### Frequency Table

**Probability of Value Being Greater Than Indicated**

<table>
<thead>
<tr>
<th>Value</th>
<th>Probability</th>
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</thead>
<tbody>
<tr>
<td>-1,231,000</td>
<td>90</td>
</tr>
<tr>
<td>-818,000</td>
<td>80</td>
</tr>
<tr>
<td>-517,000</td>
<td>70</td>
</tr>
<tr>
<td>-254,000</td>
<td>60</td>
</tr>
<tr>
<td>45,000</td>
<td>50</td>
</tr>
<tr>
<td>319,000</td>
<td>40</td>
</tr>
<tr>
<td>613,000</td>
<td>30</td>
</tr>
<tr>
<td>1,134,000</td>
<td>20</td>
</tr>
<tr>
<td>1,568,000</td>
<td>10</td>
</tr>
</tbody>
</table>
TABLE 6.40

MONTE CARLO SIMULATION RESULTS - INTERNAL RATE OF RETURN (percent)

SAMPLE STATISTICS

<table>
<thead>
<tr>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>SKEWNESS</th>
<th>KURTOSIS</th>
<th>10% CONFIDENCE INT.</th>
<th>90% CONFIDENCE INT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.92</td>
<td>16.36</td>
<td>-4.1</td>
<td>28.5</td>
<td>12.68</td>
<td>15.17</td>
</tr>
</tbody>
</table>

FREQUENCY TABLE

PROBABILITY OF VALUE BEING GREATER THAN INDICATED

<table>
<thead>
<tr>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>6.9</td>
<td>9.9</td>
<td>12.5</td>
<td>15.4</td>
<td>17.9</td>
<td>20.6</td>
<td>25.0</td>
<td>28.8</td>
</tr>
</tbody>
</table>
ratios of 1:1, 2:3, and 1:2 under the foreign investment law, Law No. 43. These six scenarios and the associated terms and sources of credit are highlighted in Tables 6.41 and 6.42.

The rate of return under local incorporation, or Law No. 159, with a ratio of 1:2 was again found to be the most satisfactory. These rates of return and their associated net present values are shown in Table 6.43.

b. Revenues

Total revenues are defined as those revenues resulting from the sale of plaster and Dryflow panels. The revenue streams for each of the three scenarios are shown in Tables 6.44 through 6.46.

Plaster is sold to the Cairo and Fayoum markets at the 1982 government regulated prices of 40 and 30 Egyptian pounds per ton, respectively. This analysis, in determining total plaster sales, uses quantities identical to those used in the previous analysis of Section 6.4.1.

For the purposes of this analysis it is assumed that Dryflow panels will be sold at an ex-factory price of 1.90 Egyptian pounds per square meter. This represents a 20 percent mark-up over the total manufactured cost of 1.58 pounds. The three production scenarios have been derived using the partition consumption data of Table 6.7.
<table>
<thead>
<tr>
<th>SCENARIO 1</th>
<th>DEBT/EQUITY = 2:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Agency for International Development</td>
</tr>
<tr>
<td>3. Panel Production Equipment</td>
<td>U.K. E.C.G.D.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCENARIO 2</th>
<th>DEBT/EQUITY = 1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Agency for International Development</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCENARIO 3</th>
<th>DEBT/EQUITY = 1:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Agency for International Development</td>
</tr>
</tbody>
</table>

SOURCE: Reference Nos. 39, 76, 117, 126, and 149
<table>
<thead>
<tr>
<th>EQUIPMENT FINANCED</th>
<th>SOURCE OF LOAN</th>
<th>LOAN AMOUNT</th>
<th>INTEREST RATE</th>
<th>DURATION</th>
<th>DOWN PAYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Export/Import Bank</td>
<td>1,368,640</td>
<td>10</td>
<td>5</td>
<td>35</td>
</tr>
</tbody>
</table>

**SCENARIO 5**

Debt/Equity = 2:3

<table>
<thead>
<tr>
<th>EQUIPMENT FINANCED</th>
<th>SOURCE OF LOAN</th>
<th>LOAN AMOUNT</th>
<th>INTEREST RATE</th>
<th>DURATION</th>
<th>DOWN PAYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Export/Import Bank</td>
<td>1,368,640</td>
<td>10</td>
<td>5</td>
<td>35</td>
</tr>
</tbody>
</table>

**SCENARIO 6**

Debt/Equity = 1:2

<table>
<thead>
<tr>
<th>EQUIPMENT FINANCED</th>
<th>SOURCE OF LOAN</th>
<th>LOAN AMOUNT</th>
<th>INTEREST RATE</th>
<th>DURATION</th>
<th>DOWN PAYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarrying Equipment</td>
<td>Japan Export/Import Bank</td>
<td>317,625</td>
<td>9</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2. Processing and Calcining Equipment</td>
<td>U.S. Export/Import Bank</td>
<td>1,368,640</td>
<td>10</td>
<td>5</td>
<td>35</td>
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</tbody>
</table>

SOURCE: Reference Nos. 39, 76, 117, 126, and 149
TABLE 6.43

FINANCIAL CALCULATIONS FOR SIX LEVERAGING AND INCORPORATION
SCENARIOS - PLASTER AND PANEL PRODUCTION FACILITY

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>NET PRESENT VALUE (EGYPTIAN POUNDS)</th>
<th>INTERNAL RATE OF RETURN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Law No. 159</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:1</td>
<td>-9,235</td>
<td>14.9</td>
</tr>
<tr>
<td>1:1</td>
<td>70,653</td>
<td>15.9</td>
</tr>
<tr>
<td>1:2</td>
<td>222,543</td>
<td>16.5</td>
</tr>
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<td>Law No. 43</td>
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<td>1:1</td>
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<td>2:3</td>
<td>-295,520</td>
<td>11.8</td>
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<td>1:2</td>
<td>-127,246</td>
<td>13.4</td>
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<tr>
<td>-------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>PLASTER REVENUE</td>
<td>1,040,000</td>
<td>1,542,200</td>
</tr>
<tr>
<td>PANEL REVENUE</td>
<td>1,288,200</td>
<td>1,311,152</td>
</tr>
<tr>
<td>TOTAL REVENUE</td>
<td>2,328,200</td>
<td>2,853,352</td>
</tr>
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<tr>
<td>Plaster Revenue</td>
<td>899,200</td>
<td>1,327,800</td>
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<tr>
<td>Panel Revenue</td>
<td>1,120,183</td>
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<td>Total Revenue</td>
<td>2,019,383</td>
<td>2,467,933</td>
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<td>Plaster Revenue</td>
<td>758,400</td>
<td>1,113,200</td>
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<tr>
<td>Panel Revenue</td>
<td>952,147</td>
<td>969,114</td>
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<tr>
<td>Total Revenue</td>
<td>1,710,547</td>
<td>2,082,314</td>
</tr>
</tbody>
</table>
c. Pro Forma Cash Flows

Pro forma cash flow statements for the three scenarios are shown in Tables 6.47 through 6.49. As in the previous section, these statements also include data for total revenues, operating and overhead costs, royalties, and debt service.

These revenue streams have been based on the following financing arrangements:

1. All United States sourced goods, including plaster production equipment and all related services are financed through a U.S. AID loan. This loan is provided at a rate of 10 percent per annum and a down payment of 25 percent. The duration of this loan is 5 years with no grace period. Loan: L.E. 1,635,375.

2. All Japan sourced quarrying equipment, and calcining plant loader are financed through a loan extended by the Japanese Export/Import Bank. The terms of this loan are 5 years and 9 percent, with a 25 percent down payment and no grace period. Loan: L.E. 317,625.

The debt service schedule for these loans is shown in Table 6.50. The remaining balance of L.E. 3,906,010 is financed through company equity.

d. Net Present Value

Net present values for equity capital were generated through 1992 using a discount rate of 15 percent for each of the three production scenarios. These data are shown in Table 6.51. These
### Table 6.47

**Pro Forma Cash Flows - Plaster and Panel Production Facility**

**Scenario:** Optimistic

*In Egyptian Pounds*

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Total Revenue</td>
<td>2320200</td>
<td>295352</td>
<td>3020562</td>
<td>3204460</td>
<td>3401558</td>
<td>3618475</td>
<td>6050735</td>
<td>3786090</td>
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<td>Total Operating Costs</td>
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<td>1573012</td>
<td>1649130</td>
<td>1731732</td>
<td>1819672</td>
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<td>513057</td>
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<tr>
<td>Debt Service</td>
<td>513057</td>
<td>513057</td>
<td>513057</td>
<td>513057</td>
<td>513057</td>
<td>513057</td>
<td>513057</td>
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<tr>
<td>CASH FLOW</td>
<td>287913</td>
<td>590452</td>
<td>681242</td>
<td>742507</td>
<td>891001</td>
<td>1324688</td>
<td>1554275</td>
<td>1704165</td>
<td>1791367</td>
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</table>
### TABLE 6.48

**PRO FORMA CASH FLOWS - PLASTER AND PANEL PRODUCTION FACILITY**

**SCENARIO: MOST LIKELY**

*(Egyptian Pounds)*

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>TOTAL</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>REVENUE</strong></td>
<td>20,193,03</td>
<td>24,660,93</td>
<td>16,608,405</td>
<td>27,586,666</td>
<td>28,728,650</td>
<td>30,290,234</td>
<td>31,889,996</td>
<td>32,799,888</td>
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<td><strong>OPERATING COSTS</strong></td>
<td>17,111,70</td>
<td>16,296,404</td>
<td>14,208,901</td>
<td>14,024,377</td>
<td>15,709,921</td>
<td>16,181,900</td>
<td>16,900,451</td>
<td>17,398,633</td>
<td>17,930,820</td>
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<td>17,001,10</td>
<td>12,200,10</td>
<td>12,001,900</td>
<td>12,001,900</td>
<td>12,001,900</td>
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<tr>
<td><strong>DEBT SERVICE</strong></td>
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<td>0</td>
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<td>0</td>
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<tr>
<td><strong>CASH FLOW</strong></td>
<td>15,787,90</td>
<td>4,161,70</td>
<td>4,916,45</td>
<td>5,564,71</td>
<td>6,449,35</td>
<td>12,335,91</td>
<td>13,214,14</td>
<td>13,603,30</td>
<td>14,005,10</td>
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<td>2194227</td>
<td>2252679</td>
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<td>1319147</td>
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<td>3851</td>
<td>4013</td>
<td>4175</td>
<td>4377</td>
<td>4484</td>
<td>4649</td>
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<td>Net Income</td>
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<td>513067</td>
<td>513067</td>
<td>513067</td>
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<tr>
<td>Cash Flow</td>
<td>27849</td>
<td>241759</td>
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<td>378867</td>
<td>940187</td>
<td>988437</td>
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<td>1070414</td>
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<td>PERIOD</td>
<td>QUARRYING EQUIPMENT</td>
<td>PROCESSING &amp; CALCINING</td>
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<td></td>
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<td>INTEREST</td>
<td>ANNUAL PAYMENT</td>
<td>PRINCIPAL</td>
<td>INTEREST</td>
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<td>28,586</td>
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<td>57,849</td>
<td>23,810</td>
<td>431,408</td>
<td>294,657</td>
<td>136,750</td>
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<td>Period 3</td>
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<td>63,086</td>
<td>18,603</td>
<td>431,408</td>
<td>324,123</td>
<td>107,285</td>
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<td>Period 4</td>
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<td>68,731</td>
<td>12,928</td>
<td>431,408</td>
<td>356,535</td>
<td>74,872</td>
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<td>Period 5</td>
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<td>74,917</td>
<td>6,742</td>
<td>431,408</td>
<td>392,189</td>
<td>39,219</td>
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<td>TOTAL</td>
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<td>317,625</td>
<td>90,670</td>
<td>2,157,040</td>
<td>1,635,375</td>
<td>521,665</td>
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*Numbers may not sum due to rounding
<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>NET PRESENT VALUE (EGYPTIAN POUNDS)</th>
<th>INTERNAL RATE OF RETURN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimistic</td>
<td>1,277,322</td>
<td>22.8</td>
</tr>
<tr>
<td>Most Likely</td>
<td>222,543</td>
<td>16.5</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>-833,587</td>
<td>9.1</td>
</tr>
</tbody>
</table>
results, which range from a minimum of L.E. -833,587 to a maximum of L.E. 1,277,322, are slightly below those obtained for a facility producing only calcined gypsum.

Net present values for total investment outlay were also calculated. These values ranged from L.E. -2,352,862 to L.E. -1,313,890 for the three scenarios. These values are generally below the cutoff of most lending institutions.

e. Internal Rate of Return

Internal rates of return for the three scenarios are also shown in Table 6.51. The lowest value, 9.1 percent, falls below the most pessimistic forecast for a plant producing plaster. The "optimistic" forecast for IRR of 22.8 percent is also below the lowest acceptable investment rate for many investors.

f. Pay Back Period

Pay back periods for the three scenarios as follows:

Optimistic: 6.4 years
Most Likely: 7.5 years
Pessimistic: 9.2 years

These long pay back periods are indicative of a project with considerable risk and low liquidity. As in the previous example, the early recovery of invested funds is generally not possible for this type of project.
g. Breakeven Analysis

Breakeven points have been determined in a manner similar to that used in Section 6.4.1. For a unit sales price of 30 Egyptian pounds per metric ton of plaster, the breakeven point occurs at approximately 4,900 thousand metric tons. For a price of 40 pounds, the breakeven point is 2,800 thousand tons. Figure 6.17 shows the relationship between price and breakeven quantity graphically. These levels of production represent 6.1 and 3.5 percent of full plant capacity, respectively.

The breakeven point for Dryflow panel sales, given a unit price of L.E. 1.90 per square meter, occurs at approximately 328 thousand square meters. This rate of production represents 47 percent of full plant capacity. Figure 6.18 shows the relationship between breakeven quantity and price.

h. Sensitivity Analysis

The sensitivity of the internal rate of return for the "most likely" scenario is summarized as follows:
FIGURE 6.17

PLASTER AND PANEL PRODUCTION FACILITY - BREAKEVEN ANALYSIS
FIGURE 6.18

PLASTER AND PANEL PRODUCTION FACILITY - BREAK-EVEN ANALYSIS
<table>
<thead>
<tr>
<th>Change in Variable (percent)</th>
<th>IRR Change (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel Price</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Quantity of Panels Sold</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Quantity of Plaster Sold</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Quarry Equipment Capital Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Calcining Plant Capital Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Panel Production Plant</td>
<td></td>
</tr>
<tr>
<td>Capital Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Working Capital Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Quarry Production Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Calcining Production Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Panel Production Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Transportation Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Overhead Cost</td>
<td>-25 to +25</td>
</tr>
<tr>
<td>Utilities and Fuel Cost</td>
<td>-25 to +25</td>
</tr>
</tbody>
</table>

As is evidenced by the above data, panel price, plaster quantity sold, panel production costs, and utilities and fuel cost have the most significant impact on project internal rate of return. The costs for utilities, fuel, and transportation are subject to price controls and are heavily subsidized by the Egyptian government. Should these prices achieve parity with current international rates, overall project feasibility will be somewhat impacted. However, even under these circumstances, a project such as this will still provide a
satisfactory rate of return.

1. Probabilistic Analysis

This probabilistic analysis has been performed in a manner similar to that of Section 6.4.1. All cost variables have been assigned probability distributions which describe the behavior of the variable. A skewed triangular distribution has been used in this analysis, with the lower limit bounded within a one-half standard deviation of the mean and the upper limit bounded within two standard deviations.

Table 6.52 shows a probabilistic estimate of net present value and its corresponding distribution, using a discount rate of 15 percent. Table 6.52 shows a frequency table for these values. The results shown in this table, show a net present value of L.E. -716,456. Table 6.52 shows a high standard deviation, indicating that there is a high probability of achieving a negative net present value.

A distribution for internal rate of return is shown in Table 6.53. The IRR of 8.35 percent with a standard deviation of 16.1 shows the riskiness of such a project.
TABLE 6.52

MONTE CARLO SIMULATION RESULTS - NET PRESENT VALUE  
(1000 Egyptian Pounds)

SAMPLE STATISTICS

<table>
<thead>
<tr>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>SKEWNESS</th>
<th>KURTOSIS</th>
<th>10% CONFIDENCE INT.</th>
<th>90% CONFIDENCE INT.</th>
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</table>

FREQUENCY TABLE

PROBABILITY OF VALUE BEING GREATER THAN INDICATED

<table>
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<tr>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
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<tr>
<td>-2,615,000</td>
<td>-1,902,000</td>
<td>-1,443,000</td>
<td>-1,122,000</td>
<td>-753,000</td>
<td>-410</td>
<td>56,000</td>
<td>489,000</td>
<td>1,229,000</td>
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TABLE 6.53
MONTE CARLO SIMULATION RESULTS - INTERNAL RATE OF RETURN
( percent )

SAMPLE STATISTICS

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<th>90% CONFIDENCE INT.</th>
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</table>

FREQUENCY TABLE

PROBABILITY OF VALUE BEING GREATER THAN INDICATED

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<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.3</td>
<td>1.7</td>
<td>5.1</td>
<td>7.3</td>
<td>10.2</td>
<td>12.4</td>
<td>15.4</td>
<td>18.1</td>
<td>22.3</td>
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</table>
CHAPTER SEVEN

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Dryflow partition panels are a relatively recent innovation that are characterized by a unique dry production process. This process offers several advantages over conventional production processes. Because very little water goes into the panel, the wet mixing that is associated with the manufacture of brick, traditional gypsum block, and drywall is eliminated. The Dryflow process provides users with substantial time and energy savings.

Through multiple configurations, Dryflow panel production facilities are economical at all levels of production. A small-scale Dryflow plant could be effectively adapted for use in Egypt. Given the emerging acceptance of gypsum partitions in Egypt, the operation of a Dryflow plant appears to be economically feasible.

The demand for gypsum construction products in Egypt can be disaggregated into two building materials: gypsum plaster and gypsum blocks or panels. The demand for calcined gypsum, or plaster, is generally taken as a function of the demand for cement. Over the last ten years the ratio of plaster consumption to cement consumption has remained relatively stable. It is anticipated that future ratios will
not change significantly. In light of this phenomenon, it appears as though future cement demand can be used effectively to forecast demand for plaster. Cement demand will ultimately be influenced by economic growth and the resulting demand for construction.

Current economic forecasts predict that real GDP for Egypt will grow at a rate of approximately eight percent per annum for the coming years. Given this rate of growth, demand for plaster will reach 665 thousand metric tons per year by 1990.

Plaster production is currently at 340 thousand metric tons per year. GYMCO, the largest producer of calcined gypsum in Egypt, is currently in the process of expanding production. The Kawmia Cement Company and Mahmoud Osman are also in the process of either expanding existing facilities or building new ones. Despite these ambitious plans, many of the proposed expansion operations have been subject to numerous delays. Consequently, future demand will exceed supply at least through 1985 and perhaps even several years longer.

Gypsum blocks and panels are currently competing in the market for interior paritions against such traditional products as Nile-silt brick, shale brick, sand-lime brick, and lightweight concrete aggregate block. Gypsum blocks are presently being produced by ICON, GYMCO, Kuwait Egyptian, Misro Gypsum, and AZAMCO. Because of the many interior walling products that are either present or are on the verge of entering, it is anticipated that this market will be saturated by 1984. This implies that the successful marketing of Dryflow panels in Egypt will be contingent upon its lower costs and greater ease of handling relative to other products.
Given the alternative quarrying, processing, and calcining systems available, a configuration producing calcined gypsum at the lowest per unit cost was selected. The quarrying system, consisting of a dozer with ripper, a wheel-mounted front-end-loader, and an off-highway truck, is capable of extracting 131 thousand metric tons of gypsum ore per year. The total 1982 capital cost for such a system, including a 10 percent contingency is estimated at 404 thousand Egyptian pounds.

The processing and calcining plant, consisting of a hammermill crusher, a roller mill, and two batch kettles, carries a total installed cost of 2.78 million Egyptian pounds. Such a plant, operating three shifts per day is capable of producing 80 thousand metric tons of stucco per year, assuming a 5 percent wastage factor and an average ore purity of 65 percent. A Dryflow production facility adds an additional 1.8 million Egyptian pounds to the total capital costs.

Implementational considerations such as infrastructure and capital availability appear to be favorable. Sufficient power and water are available within close proximity to the proposed site. Capital is available through either local banking institutions or foreign export credits.

Two types of production facilities have been financially and economically analyzed. The first, producing only calcined gypsum, has a total investment cost of approximately 3.7 million, including the costs of quarry, plant, and working capital. Per unit manufacturing costs for the individual units are:

- **Quarrying**
  - L.E. 1.38 per metric ton of plaster

- **Processing and Calcining**
  - L.E. 17.18 per metric ton of plaster
These costs include the costs associated with personnel, transportation and infrastructure.

Based on local incorporation under Law No. 159, a debt to equity ratio of 1:2, and 1982 selling prices and capital costs, the "most likely" internal rate of return for this project is 21.1 percent.

For a plant producing both plaster and Dryflow panels, total investment costs in 1982 prices are approximately 5.9 million Egyptian pounds. Per unit manufacturing costs for plaster are comparable to those presented above. Dryflow panel production costs have been estimated at 0.88 Egyptian pounds per square meter, giving a total unit cost of 1.58 pounds per square meter.

For an integrated production facility, incorporated under Law No. 159, with a debt to equity ratio of 1:2, the "most likely" internal rate of return is 16.5 percent. Although this rate is lower than that shown for a facility producing only plaster, it is possible to obtain rates of return that are beyond this level. The analysis of Section 6.4.2h shows that the internal rate of return for an integrated production facility is extremely sensitive to changes in the price of Dryflow panels. For the purposes of this analysis a price of L.E. 1.90 per square meter was used. This price represents a 20 percent mark-up over production costs. The analysis of Section 5.4 shows that Dryflow panels can be sold at prices over three pounds per square meter and can still remain cost competitive. Such an analysis confirms that a totally integrated production facility represents the more viable investment opportunity.

A small-scale Dryflow production facility would offer the following additional advantages:
1. Because the ultimate Dryflow plant capacity of 702 thousand square meters for a facility with one carousel represents approximately 5 percent of the aggregate interior partition market, all panels produced at this rate should encounter little difficulty clearing the market. This statement assumes that the demand for partition products will grow at a rate comparable to that forecasted in Section 6.1.2.

2. Revenues from plaster sales could also be realized within one year of project initiation. While Dryflow panels penetrate the existing markets, plaster sales would be generating significant revenues early in the project.

3. Quarry operations can be expanded to three shifts, providing continuous daily production of 24 hours. Any surge production resulting from this expansion can be stockpiled at sites adjacent to the quarry, for use as agricultural gypsum. This gypsum offers the advantage of not requiring further processing or calcining. A market for this product currently exists in Egypt. The revenues resulting from the sale of this product could conceivably outweigh the incurred costs of production.

4. Additional batch kettles could also be added to the present calcining facility. Such an expansion
could increase plaster production at a low marginal cost. Any excess plaster produced from such an expansion could conceivably clear the market through 1986 under a worst-case scenario.

The success of this project in Egypt will depend heavily on the premise that Dryflow panels can compete effectively on a cost/performance basis with existing products. Much of this will be contingent upon the success of the marketing and sales program, and the reduced reluctance of users to convert to gypsum partitions.

Any successful marketing strategy for Dryflow products must include a means of convincing potential buyers of Dryflow's inherent advantages. All of these advantages must be emphasized through evidence of material properties and characteristics, and comparisons with other traditional materials. In addition, cost data for material and installation must be provided so that buyers may assess the tradeoffs between the various products. Such information will ultimately show the time and cost savings associated with Dryflow panels.

The traditional method for introducing new building products to Egypt is through large scale presentations, sales visits to the offices of prospective buyers, and newspaper advertisements. Of these three, only the first two are regarded as being effective. Large-scale presentations are given for the benefit of local architects, engineers, and contractors, with attendance often in excess of three hundred people. Most, if not all of these presentations are given in the Cairo area. Frequently, sales personnel make follow-up visits to the offices of presentation attendees. Local newspaper advertisements are usually
employed in the marketing of such traditional products as cement and plaster. Rarely are they used for new products such as Dryflow (140).

The quickest way for Dryflow to capture this market is through the utilization of a marketing strategy that initially focuses on architects and engineers only. Because these individuals specify what products are to be used in all building construction, the success of Dryflow panels in Egypt will be contingent upon their acceptance of such a product.

In an effort to increase market penetration rates, it is recommended that the above strategy be supplemented with special supply arrangements with local Egyptian contractors.

Although it would take several years to obtain large scale commitments from these companies, this would be compensated for by increased market penetration rates. The rate at which these firms would adopt Dryflow panels would probably depend on the price discounting offered with these special orders.

There are currently two directions in which future research on the feasibility of Dryflow panel production facilities in Egypt might take and which this study might serve as an integral part.

The first, the preparation of a full-scale feasibility analysis, would provide a more in-depth document that would provide definitive conclusions on all the basic project issues. Such an analysis would begin with extensive geologic exploration and testing. This process generally requires many of the procedures associated with large-scale target investigations. These steps include detailed three-dimensional test borings, and the construction of small-scale, general area, and large-scale quarry maps. These steps have been previously outlined and
summarized in Figure 4.1.

Additional up-to-date information on the plans and progress of all competitors must be obtained. This includes information on the status of pending projects for producers of calcined gypsum, shale brick, sand-lime brick, concrete aggregate block, and gypsum blocks and panels.

Lastly, this analysis must also explore two additional areas that may have a significant impact on overall project viability. The first factor concerns the price and availability of locally produced processing and calcining equipment. In the past, the cost for such equipment has been 20 to 30 percent below that for equipment imported from abroad. Because processing and calcining capital costs constitute more than 50 percent of total costs for a project of this nature, a reduction in these costs can contribute to increased project profitability.

The other area of investigation involves an analysis of the market in Egypt for agricultural gypsum. The revenues received from the sales of such a product could be significant should such a market exist.

The second direction in which future research might take would be an analysis of this project within the economic framework of Egypt. Such research would go beyond such simple microeconomic criteria as profitability that are used in the investment analysis portion of this report. Such a study would analyze the benefits of such plants in a macroeconomic context, or more definitively, the effect and role of such plants in the development priorities of countries such as Egypt.
APPENDIX I

IFPS FINANCIAL SIMULATION PROGRAMS

Figures I.1 and I.2 present a listing of the IFPS computer simulation program used in the financial calculations of Chapter 6. Both programs have been broken down into twelve modules that correspond with specific parts of Section 6.4. The structure of the two programs is similar, with variations resulting from differences in input data and the omission in one program of all cost modules pertaining to Dryflow panel production. The twelve program modules include:

1. Revenue Module

   This module computes total revenues, which are comprised of either plaster or plaster and panel revenues. The number of tons of plaster sold in the Fayoum and Cairo markets is given in Table 6.4. It is assumed that plaster is sold to the Cairo market at the government regulated price of 40 Egyptian pounds per metric ton. All other plaster is sold in the local Fayoum market at 30 pounds per ton. The panel quantity shown in the listing of Figure I.2 is for the "most likely" scenario that was given in Table 6.7. Panel prices are assumed to be 1.90 pounds per square meter with no price differential for different regional markets.

2. Quarry Investment Cost Module

   This module calculates all quarry fixed capital investment costs as
FIGURE I.1
IFPS FINANCIAL SIMULATION PROGRAM - CALCINED GYPSUM PRODUCTION FACILITY

5 PERIODS 1
8
10 COLUMNS 1984-1992

12 *
13 *

REVENUE MODULE

15 ****************************************************
20 TOTAL REVENUE=PLASTER REVENUE+0
30 PLASTER REVENUE=(CAIRO PLASTER*40)+(FAYUM PLASTER*30)
40 *
45 *
47 *
49 *
50 AA=14050,15090,16415,17540,18925,20475,22015,22790,24025
51 CAIRO PLASTER=AA&DUMMY1
52 BB=11240,24140,26260,28060,30280,32680,35220,38480,38440
53 FAYUM PLASTER=BB&DUMMY1
60 *
61 *
70 PLASTER QUANTI=CAIRO PLASTER+FAYUM PLASTER
72 PLASTER QUANT=PLASTER QUANTI#1
75 DUMMY1=NORRAND(1+.25)
80 *
90 ****************************************************
100 *
110 *

QUARRY INVESTMENT COST MODULE

120 *
130 ****************************************************
140 DOZER COST=120000
150 LOADER COST=60000
160 TRUCK COST=120000
165 EQUIPMENT FREIGHT COST=(DOZER COST+LOADER COST+TRUCK COST)*0.1
166 LOCAL FREIGHT COST=450
167 EQUIPMENT TARIFFS=(DOZER COST+LOADER COST+TRUCK COST)*0.05
170 SERVICE BUILDING COST=180*113.50
175 BUILDING DESIGN COST=0.06*SERVICE BUILDING COST
176 JAPAN QUARRY INVEST COST=SUM(L150 THRU L165)
177 ARE QUARRY INVEST COST=SUM(L166 THRU L175)
178 ****************************************************
179 *
180 *

PROCESSING AND CALCNINE PLANT INVESTMENT COST MODULE

181 *
182 ****************************************************
183 BATCH KETTLE COST=350000
184 CRUSHER COST=300000
185 MISC EQUIPMENT COST=650000
186 INSTALLATION AND DESIGN=750000
187 FREIGHT COST=292500
188 PLANT BUILDING COST=1400*63.50
189 PLANT LOADER TARIFFS=2500
190 *
191 GENERATOR FREIGHT COST=2700
192 PLANT TARIFFS=97500
193 TRANSFORMER COST=200000
194 LOADER LOCAL FREIGHT COST=100
195 ELECTRICAL LOCAL FREIGHT COST=2700
196 PLANT LOADER TARIFFS=2500
197 DIESEL GENERATOR COST=12000
198 PLANT LOADER COST=50000
199 PLANT LOADER FREIGHT COST=5000
200 US CALC PLANT INVEST COST=SUM(L183 THRU L187)
201 ARE CALC PLANT INVEST COST=SUM(L188 THRU L194)
202 JAPAN CALC PLANT INVEST COST=SUM(L197 THRU L199)

364
FIGURE I.1 (continued)

IFPS FINANCIAL SIMULATION PROGRAM -
CALCINED GYPSUM PRODUCTION FACILITY

40 *
242 **********
246 WORKING CAPITAL INVESTMENT COST MODULE
250 *
252 ****************************************************
260 WORKCAP COST1=PLASTER BAG COST/24
270 WORKCAP COST2=(QUARRY PRODUCTION COSTS+PLASTER PRODUCTION COSTS+OVERHEAD COSTS)/4
280 WORKCAP COST3=QUARRY MAINTENANCE/2
290 WORKCAP COST4=PLANT MAINTENANCE COST/2
300 *
310 WORKCAP COST6=0
320 WORKCAP COST7=TOTAL REVENUE/6
330 TOTAL WORKING CAPITAL=SUM(L280 THRU L320)
331 ****************************************************
332 *
333 LOAN AMORTIZATION MODULE
334 *
335 ****************************************************
340 JAPAN INT=NORDRAND(.09,.02)
350 AID INT=NORDRAND(.10,.02)
360 UK INT=NORDRAND(.10,.02)
370 *
380 LOCAL INT=NORDRAND(.15,.02)
390 AMORT(XX,0,JAPAN INT,5,1,1,PAY1,PAYINT1,PRIN1,BAL1)
400 XX=T1090RAND(311273,317625,397030)
410 AMORT(YY,0,AID INT,5,1,1,PAY2,PAYINT2,PRIN2,BAL2)
420 YY=T1090RAND(1824932,1862175,2327720)
430 *
440 *
450 *
460 *
470 *
480 AMORT(HH,0,LOCAL INT,5,1,1,PAY5,PAYINT5,PRIN5,BAL5)
485 HH=T1090RAND(303350,309540,386925)
490 INTEREST PAYMENT=PAYINT1+PAYINT2+PAYINT5
495 *****************************************************
500 *
510 EXPENSE MODULE
520 *
530 *****************************************************
540 SLINE DEPR(TOTINV1,0,5,DEPR1,BKVAL1,CUMDEPR1)
545 TOTINV1=345400,0
550 SLINE DEPR(TOTINV2,0,10,DEPRECIATION2,BKVAL2,CUMDEPR2)
555 TOTINV2=2435100,0
560 SLINE DEPR(TOTINV3,0,20,DEPRECIATION3,BKVAL3,CUMDEPR3)
565 TOTINV3=110700,0
570 QUARRY ROYALTY=0.041*131000*(PLASTER QUANT/80000)

365
FIGURE I.1 (continued)

IFPS FINANCIAL SIMULATION PROGRAM -
CALCINED GYPSUM PRODUCTION FACILITY

572 SERVICE ROYALTY=400
575 LAND ROYALTY=20
577 TOTAL ROYALTY=SUM(L570 THRU L575)
578 DEPRECIATION1=DEP1+DEPRECIATION2+DEPRECIATION3
579 DEPRECIATION=DEPRECIATION*DUMMY2
580 DUMMY2=T1090RND(.98,1.1.25)
585 *******************************************************
590 * QUARRY PRODUCTION COST MODULE
591 *
595 *******************************************************
617 QUARRY WAGES=2400*3.30
619 QUARRY WAGE BENEFITS=QUARRY WAGES*.25
620 *
621 DOZER FUEL COST=33600*0.25*.75*.85
623 LOADER FUEL COST=18400*0.25*.75*.85
625 TRUCK FUEL COST=72000*0.25*.75*.85
627 QUARRY MAINTENANCE=15000
628 QUARRY PROD COST=SUM(L617 THRU L627)
629 QUARRY PRODUCTION COSTS1=QUARRY PROD COST*(((0/37.04)+PLASTER QUANT)/80000)
630 *******************************************************
632 * PROCESSING AND CALCINING PRODUCTION COST MODULE
633 *
638 *******************************************************
640 PLANT WAGES=7200*3.60
641 PLANT WAGE BENEFITS=PLANT WAGES*.25
644 ELECTRICITY COST=7860*60.00*.75*.85
644 WATER COST=13100*60.20*.75*.85
646 FUEL OIL COST=79800*0.75*.75*.85
648 DIESEL FUEL COST=48000*0.25*.75*.85
650 PLANT MAINTENANCE COST=97500
652 PLASTER BAG COST=100000
653 COSTS=SUM(L640 THRU L652)
654 PLASTER PRODUCTION COSTS1=COSTS*(((0/37.04)+PLASTER QUANT)/80000)
656 *
658 *
660 *
662 *
664 *
666 *
668 *
670 *
672 *
674 *
676 *
678 *
680 *
681 *
682 *
683 *
684 *******************************************************
686 * OVERHEAD COST SUMMARY
688 *
690 *
692 *******************************************************
694 ADMINISTRATIVE WAGES=33500
696 ADMINISTRATIVE WAGE BENEFITS=ADMINISTRATIVE WAGES*.25
699 LIGHTING COST=4.9*60.00
700 OFFICE SUPPLIES=20000
702 INSURANCE=50000
704 MARKETING=60000
706 OVERHEAD COSTS1=SUM(L694 THRU L704)
710 QUARRY PRODUCTION COSTS=QUARRY PRODUCTION COSTS1*DUMMY2
720 PLASTER PRODUCTION COSTS=PLASTER PRODUCTION COSTS1*DUMMY2
730 OVERHEAD COSTS=OVERHEAD COSTS1*DUMMY2

366
FIGURE I.1 (continued)

IFPS FINANCIAL SIMULATION PROGRAM -
CALCINED GYPSUM PRODUCTION FACILITY

760 *
770 TRANS COST1=CAIRO PLASTER*7.8
780 TRANS COST2=FAYDUM PLASTER*4.05
790 TOTAL TRANS COST1=SUM(L770 THRU L780)
795 TOTAL TRANS COST=TOTAL TRANS COST1#DUMMY2
800 **********************************************************************
810 * NPV AND IRR CALCULATION MODULE*
820 *
830 *
840 **********************************************************************
841 TOTAL OPERATING COSTS=QUARRY PRODUCTION COSTS*1+PLASTER PRODUCTION COSTS*1'
842 *TOTAL TRANS COST1
850 BEFORE TAX PROFIT=TOTAL REVENUE-OVERHEAD COSTS*1-TOTAL OPERATING COSTS-TOTAL ROYALTY'
851 -DEBT SERVICE-DEFRECIATION
860 AFTER TAX PROFIT=BEFORE TAX PROFIT-(BEFORE TAX PROFIT*TAAX RATE)
865 TAX RATE=0
870 CASH FLOW=AFTER TAX PROFIT+DEFRECIATION
880 NPV CASH FLOW=NPVC(CASH FLOW+.15+EQUITY)
890 IRR CASH FLOW=IRR(CASH FLOW+EQUITY)
895 INVESTMENT COST=JAPAN QUARRY INVEST COST*1+ARE QUARRY INVEST COST'
896 +US CALC PLANT INVEST COST*1+ARE CALC PLANT INVEST COST+JAPAN CALC PLANT INVEST COST'
897 +1*TOTAL WORKING CAPITAL
900 EQUITY=INVESTMENT COST/PRCINT*0.0,0.0,0.0,0.0,0.0
910 PRCNT=3
920 *
930 *
940 *
950 *
960 *
FIGURE I.2

IFPS FINANCIAL SIMULATION PROGRAM -
PLASTER AND PANEL PRODUCTION FACILITY

5 PERIODS

10 COLUMNS 1984-1992

11******************************************************************************
12 *    REVENUE MODULE
13 *
14 *
15******************************************************************************
20 TOTAL REVENUE=PLASTER REVENUE+PANEL REVENUE
30 PLASTER REVENUE=(CAIRO PLASTER*40)+(FAYUM PLASTER*30)
40 PANEL REVENUE=PANEL QUANT*PANEL PRICE
45 *
47 *
49 PANEL PRICE=1.90
50 AA=14050+15090+16415+17540+18925+20475+22015+22790+24025
51 CAIRO PLASTER=AA&DUMMY1
52 BB=11240+2140+26260+38060+30280+32680+35220+36480+38440
53 FAYUM PLASTER=BB&DUMMY1
60 PANEL QUANT=589570+600070+612150+623825+635500+647170+658840+670520+682190
61 PANEL QUANT=PANEL QUANT&DUMMY1
70 PLASTER QUANT=CAIRO PLASTER+FAYUM PLASTER
72 *
75 DUMMY1=NORRAND(1,25)
80 *
90******************************************************************************
100 *    QUARRY INVESTMENT COST MODULE
110 *
120 *
130******************************************************************************
140 DOZER COST=120000
150 LOADER COST=60000
160 TRUCK COST=120000
165 EQUIPMENT FREIGHT COST=(DOZER COST+LOADER COST+TRUCK COST)*0.1
166 LOCAL FREIGHT COST=450
167 EQUIPMENT TARIFFS=(DOZER COST+LOADER COST+TRUCK COST)*0.05
170 SERVICE BUILDING COST=180*113.50
175 BUILDING DESIGN COST=0.64*SERVICE BUILDING COST
176 JAPAN QUARRY INVEST COST=SUM(L150 THRU L165)
177 ARE QUARRY INVEST COST=SUM(L166 THRU L175)
178******************************************************************************
179 *
180 *    PROCESSING AND CALCINING PLANT INVESTMENT COST MODULE
181 *
182******************************************************************************
183 BATCH NEPTILE COST=350000
184 CRUSHER COST=200000
185 MISC EQUIPMENT COST=650000
186 INSTALLATION AND DESIGN=750000
187 FREIGHT COST=292500
188 PLANT BUILDING COST=1400*63.50
189 PLANT LOADER TARIFFS=2500
190 *
191 GENERATOR FREIGHT COST=2700
192 PLANT TARIFFS=97500
193 TRANSFORMER COST=20000
194 LOADER LOCAL FREIGHT COST=100
195 ELECTRICAL LOCAL FREIGHT COST=2700
196 PLANT LOADER TARIFFS=2500
197 DIESEL GENERATOR COST=12000
198 PLANT LOADER COST=50000
199 PLANT LOADER FREIGHT COST=5000
200 US CALC PLANT INVEST COST=SUM(L183 THRU L187)
201 ARE CALC PLANT INVEST COST=SUM(L188 THRU L196)
202 JAPAN CALC PLANT INVEST COST=SUM(L197 THRU L199)

368
FIGURE I.2 (continued)

IFPS FINANCIAL SIMULATION PROGRAM - PLASTER AND PANEL PRODUCTION FACILITY

******************************************************************************
* PANEL PRODUCTION PLANT INVESTMENT COST MODULE *
******************************************************************************

PLASTER HANDLING EQUIP COST=140000
CAROUSELS COST=700000
PROD HANDLING EQUIP=95000
SERVICES=50000
PLANT INSTALLATION=150000
LICENSE FEE=100000
TECHNICAL SERVICES=150000
BUILDING SHOP COST=7064
BUILDING COST=4064
CANTEEN BUILDING COST=80120
OFFICE BUILDING COST=110153
DESIGN COST=2010

UK PANEL PLANT INVEST COST=SUM(L216 THRU L228)
ARE PANEL PLANT INVEST COST=SUM(L230 THRU L238)
******************************************************************************

WORKING CAPITAL INVESTMENT COST MODULE
******************************************************************************

JORKCAP COST1=PLASTER BAG COST/24
WORKCAP COST2==(QUARRY PRODUCTION COSTS+PLASTER PRODUCTION COSTS+PLANT PRODUCTION COSTS

WORKCAP COST3=QUARRY MAINTENANCE/2
WORKCAP COST4=PLANT MAINTENANCE COST/2
WORKCAP COST5=MAINT COST/2
WORKCAP COST6=0
WORKCAP COST7=TOTAL REVENUE/6
TOTAL WORKING CAPITAL=SUM(L280 THRU L320)
******************************************************************************

LOAN AMORTIZATION MODULE
******************************************************************************

JAPAN INT=NORRAND(.09,.02)
AID INT=NORRAND(.10,.02)
UK INT=NORRAND(.10,.02)

LOCAL INT=NORRAND(.15,.02)
AMORT(XX,0,0,0,0,0,FAY1,FAYINT1,PRIN1,BAL1)

XX=T1090RAND(311273,317625,397030)
AMORT(YY,0,0,AID INT,5,1,1,FAY2,FAYINT2,PRIN2,BAL2)
YY=T1090RAND(1824932,1862175,2327720)

AMORT(HK,0,UK INT,5,1,1,FAY4,FAYINT4,PRIN4,BAL4)
HK=T1090RAND(1341267,1368640,1710800)
AMORT(HH,0,LOCAL INT,5,1,1,FAY5,FAYINT5,PRIN5,BAL5)

HH=T1090RAND(350230,357380,446720)

INTEREST PAYMENT=FAYINT1+FAYINT2+FAYINT4+FAYINT5

******************************************************************************

EXPENSE MODULE
******************************************************************************

STLINE DEPR1(TOTIN1,0,5,DEPR1,BKVAL1,CUMDEPR1)
STLINE DEPR1(TOTIN2,0,10,DEPRECIATION2,BKVAL2,CUMDEPR2)
STLINE DEPR1(TOTIN3,0,20,DEPRECIATION3,BKVAL3,CUMDEPR3)
STLINE DEPR1(TOTINV,0,0,EQUITY,0,0)

QUARRY ROYALTY=-0.041*(((PANEL QUANT/37.04)+PLASTER QUANT)/90000)*131000

******************************************************************************
FIGURE I.2 (continued)

IFPS FINANCIAL SIMULATION PROGRAM -
PLASTER AND PANEL PRODUCTION FACILITY

572 SERVICE ROYALTY=400
575 LAND ROYALTY=20
577 TOTAL ROYALTY=SUM(L570 THRU L575)
579 DEPRECIATION =DEPR1+DEPRECIATION2+DEPRECIATION3
580 DEPRECIATION1=DUMMY2
580 DUMMY2=T1090AND((.98+1.25)
585 ******************************************************
590 *
600 # QUARRY PRODUCTION COST MODULE
610 *
615 ******************************************************
617 QUARRY WAGES=2400*5.30
619 QUARRY WAGE BENEFITS=QUARRY WAGES*.025
620 *
621 DOZER FUEL COST=33600*0.25*1*.85
623 LOADER FUEL COST=18400*0.25*1*.85
625 TRUCK FUEL COST=72000*0.25*1*.85
627 QUARRY MAINTENANCE=15000
629 QUARRY PROD COST=SUM(L617 THRU L627)
629 QUARRY PRODUCTION COSTS1=QUARRY PROD COST*(((PANEL QUANT/37.04)+PLASTER QUANT)/80000)
630 ******************************************************
632 *
634 # PROCESSING AND CALCINING PRODUCTION COST MODULE
636 *
639 ******************************************************
640 PLANT WAGES=72000*3.60
641 PLANT WAGE BENEFITS=PLANT WAGES*.025
642 ELECTRICITY COST=76400*60.00*.85
644 WATER COST=131000*0.20*1*.85
646 FUEL OIL COST=79800*01*.75*.85
648 DIESEL FUEL COST=48000*0.25*1*.85
650 PLANT MAINTENANCE COST=97500
652 PLASTER BAG COST=100000
654 COSTS=SUM(L640 THRU L652)
654 PLASTER PRODUCTION COSTS1= COSTS*(((PANEL QUANT/37.04)+PLASTER QUANT)/80000)
656 ******************************************************
658 *
660 # PANEL PRODUCTION COST MODULE
662 *
664 ******************************************************
666 PANEL PLANT WAGES=72000*4.30
668 PANEL WAGE BENEFITS=Panel PLANT WAGES*.025
670 GLASS FIBER COSTS=126360*.25
672 PLANT ELECTRIC COSTS=36000*60.00*.85
674 PLANT WATER COST=842400*0.20*1*.85
676 MAINT COST=45000
678 *
680 *
681 TOTAL PANEL COSTS=SUM(L666 THRU L676)
683 PLANT PRODUCTION COSTS1=TOTAL PANEL COSTS*((PANEL QUANT)/702000)
684 ******************************************************
686 *
688 # OVERHEAD COST SUMMARY
690 *
692 ******************************************************
694 ADMINISTRATIVE COSTS=33500
696 ADMINISTRATIVE WAGE BENEFITS=ADMINISTRATIVE COSTS*.025
698 LIGHTING COST=4.9*60.00
700 OFFICE SUPPLIES=20000
702 INSURANCE=50000
704 MARKETING=60000
706 OVERHEAD COSTS1=SUM(L694 THRU L704)
708 QUARRY PRODUCTION COSTS=QUARRY PRODUCTION COSTS1*DUMMY2
710 PLASTER PRODUCTION COSTS=PLASTER PRODUCTION COSTS1*DUMMY2
712 PLANT PRODUCTION COSTS=PLANT PRODUCTION COSTS1*DUMMY2

370
### FIGURE 1.2 (continued)

**IFPS FINANCIAL SIMULATION PROGRAM - PLASTER AND PANEL PRODUCTION FACILITY**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>740</td>
<td>OVERHEAD COSTS=OVERHEAD COSTS1*Dummy2</td>
</tr>
<tr>
<td>750</td>
<td>TRANS COST1=CAIRO PLASTER*7.8</td>
</tr>
<tr>
<td>770</td>
<td>TRANS COST2=FAYDUM PLASTER*4.05</td>
</tr>
<tr>
<td>780</td>
<td>TRANS COST3= PANEL QUANT*0.20</td>
</tr>
<tr>
<td>790</td>
<td>TOTAL TRANS COST=SUM(L760 THRU L780)</td>
</tr>
<tr>
<td>795</td>
<td>TOTAL TRANS COST=TOTAL TRANS COST1*Dummy2</td>
</tr>
</tbody>
</table>

**NPV AND IRR CALCULATION MODULE**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>810</td>
<td><strong>TOTAL OPERATING COSTS=QUARRY PRODUCTION COSTS1+PLASTER PRODUCTION COSTS1</strong></td>
</tr>
<tr>
<td>841</td>
<td><strong>+PLANT PRODUCTION COSTS1+TOTAL TRANS COST1</strong></td>
</tr>
<tr>
<td>850</td>
<td>BEFORE TAX PROFIT=TOTAL REVENUE-OVERHEAD COSTS1-TOTAL OPERATING COSTS1-TOTAL ROYALTY1</td>
</tr>
<tr>
<td>851</td>
<td>DEBT SERVICE-DEPRECIATION</td>
</tr>
<tr>
<td>860</td>
<td>AFTER TAX PROFIT=BEFORE TAX PROFIT-(BEFORE TAX PROFIT*TAX RATE)</td>
</tr>
<tr>
<td>865</td>
<td>TAX RATE=0</td>
</tr>
<tr>
<td>870</td>
<td>CASH FLOW=AFTER TAX PROFIT-DEPRECIATION</td>
</tr>
<tr>
<td>880</td>
<td>NPV CASH FLOW=NPV(CASH FLOW*.15+EQUITY)</td>
</tr>
<tr>
<td>890</td>
<td>IRR CASH FLOW=IRR(CASH FLOW+EQUITY)</td>
</tr>
<tr>
<td>895</td>
<td>INVESTMENT COST=JAPAN QUARRY INVEST COST1+ARE QUARRY INVEST COST1</td>
</tr>
<tr>
<td>896</td>
<td>+US CALC PLANT INVEST COST1+ARE CALC PLANT INVEST COST1+JAPAN CALC PLANT INVEST COST1+UK PANEL PLANT INVEST COST1+ARE PANEL PLANT INVEST COST1+TOTAL WORKING CAPITAL1</td>
</tr>
<tr>
<td>899</td>
<td>*</td>
</tr>
<tr>
<td>900</td>
<td>EQUITY=INVESTMENT COST/PRCNT*0.01+0.01+0.01+0.01+0.01+0.01+0.01</td>
</tr>
<tr>
<td>910</td>
<td>PRCNT=3</td>
</tr>
<tr>
<td>920</td>
<td>*</td>
</tr>
<tr>
<td>930</td>
<td>*</td>
</tr>
<tr>
<td>940</td>
<td>*</td>
</tr>
<tr>
<td>950</td>
<td>*</td>
</tr>
<tr>
<td>960</td>
<td>*</td>
</tr>
</tbody>
</table>
were described in Section 6.4. This module concludes by breaking down quarry investment costs into foreign and domestic components.

3. Processing and Calcining Plant Investment Cost Module

This module calculates processing and calcining investment costs in a manner similar to that employed for computing quarry investment costs.

4. Panel Production Plant Investment Cost Module

All panel production plant investment costs, including costs for carousels, product handling equipment, technical services, and service buildings are factored into both foreign and local currency costs.

5. Working Capital Investment Module

Working Capital requirements are computed in conformance with the procedure outlined in Section 6.3.4.

6. Loan Amortization Module

This module calculates all loan amortization payments for the outstanding loans described in earlier sections. These loan payments are subsequently broken down into interest and principal.

7. Expense Module

All depreciation expenses are computed in this module, including annual depreciation, book value, and cumulative depreciation. Total royalty payments are also calculated, based on the rates given in Section 5.5.
8. Quarry Production Cost Module

9. Processing and Calcining Production Cost Module

10. Panel Production Cost Module

11. Overhead Cost Summary

   All individual production and overhead costs outlined in Section 6.3 are factored to compute total costs.

12. Net Present Value and Internal Rate of Return Calculation Module

   This module calculates project before and after tax profits, cash flow, net present value, and internal rate of return. The output resulting from these calculations is presented in Tables 6.19 through 6.28 of Section 6.4.

   Readers interested in using this program on-line should consult the "IFPS Users Manual" shown in the list of references (89). Further questions regarding the implementation of this program on other computer systems should be directed to:

   Execucom Systems Corporation

   3409 Executive Center Drive

   Austin, Texas 78731

   (512) 345-6560
APPENDIX II
LIST OF INTERVIEWS AND OTHER SOURCES

The following is a list of the names and addresses of all firms and
organizations that were interviewed or provided information to the
M.I.T. Gypsum Project Team, between April and November, 1982. These
entries are broken down as follows:

1. Local Government Agencies

   Dr. Mahmoud A. Zatout, Chairman
   Geological Survey and Mining Authority of Egypt
   Cairo, Egypt

   Mr. Tag El Deftar, Director
   Fayoum Geological Survey
   Fayoum, Egypt

   Dr. Mohamed Ramez
   General Organization for Housing, Building, and Planning
   Research
   Cairo, Egypt

   Mr. Monir El Kholy
   Arab Consulting Bureau
   Cairo, Egypt

2. Quarrying, Processing, Calcining, and Panel Production Equipment
   Manufacturers and Dealers

Quarrying:

   Mr. Nashat Boutros, Division Manager
   Electessadia (International Truck)
   Cairo, Egypt

   Ms. Iman Bibars, Sales Administrator
   Komatsu
   Dokki-Cairo, Egypt

   Mr. Graham Lythgoe
   International Sales Division
   Caterpillar Tractor Corporation
   Peoria, Illinois
   (Telephone Interview)

   Mr. J. W. Kell
   Middle East Sales Division
   TEREX Corporation
   Hudson, Ohio
   (Telephone Interview)
Construction Equipment Division
J.I. Case, Inc.
Racine, Wisconsin

Ms. Rita Carlson
International Sales Division
American Hoist and Derrick, Inc.
St. Paul, Minnesota
(Telephone Interview)

Mr. Joseph Hagemann
International Sales Division
WABCO Trade Company
Peoria, Illinois
(Telephone Interview)

Processing and Calcining:

Mr. Christopher Rettew
Pennsylvania Crusher Corporation
Broomall, Pennsylvania
(Telephone Interview)

Mr. Thomas Mulanax
Raymond Division
Combustion Engineering, Inc.
Abilene, Kansas
(Telephone Interview)

Mr. Felix Baldas
The Fuller Company
Bethlehem, Pennsylvania
(Telephone Interview)

Babbitless, Ltd.
Paris, France

Panel Production:

Mr. G. G. Bevan
C.G. Bevan Associates, Ltd.
London, England

3. Gypsum Building Products/Manufacturers

Mr. M. Fahmy
Engineering and Projects Sector
Egyptian Gypsum, Marble, and Quarries Company (GYMCO)
Dokki-Cairo, Egypt

Arab Contractors
ICON Block Production Facility
Helwan, Egypt
4. Gypsum Building Products/End-Users

Mr. Ibrahim Osman
Construction Division
Arab Contractors
Cairo, Egypt

5. Sources of Credit

Mr. Robert Van Horne, Director
Division of Public Sector Financing
United States Agency for International Development
American Embassy
Garden City-Cairo, Egypt

Mr. William Binns, Director
Investment and Finance Division
United States Agency for International Development
American Embassy
Garden City-Cairo, Egypt

Mr. Gary Imhoff
Office of Industrial Resources
United States Agency for International Development
American Embassy
Garden City-Cairo, Egypt

Mr. Michael Harvey, Commercial Attache
British Consulate
Cairo, Egypt

Mr. Hans-Jochen Schmidt, Commercial Attache
Embassy of the Federal Republic of Germany
Dokki-Cairo, Egypt

Mr. Olivier Mauny, Commercial Attache
French Embassy
Cairo, Egypt

Mr. Masayoshi Amano, First Secretary
Japanese Consulate
Cairo, Egypt

Mr. Seif El Kilani
Citibank N.A.
Garden City-Cairo, Egypt

Mr. Samir El Seloviri
Misr Iran Development Bank
Cairo, Egypt

Mr. Safwat Rashed
Cairo-Far East Bank
Cairo, Egypt

Mr. M. Nawar
Mohandes Bank
Cairo, Egypt
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44. Development, Resource, and Technological Planning Center, Cairo


Cairo, 1956. (Arabic).


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96. Mahmoud, Fouad Mostafa. The Group of Laws and Decrees for Import
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    August 1981.

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    Cairo, 1979. (Arabic)


100. Ministry of Housing. New Ameriab City, Master Plan, "Technical


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    Authority "Geology of the Red Sea Coast Between Ras Shaya and Mersa
    Allam" Cairo, 1966.

103. Ministry of Planning, Arab Republic of Egypt, "The Five Year Plan

104. "Mining Activity in Sinai—A Survey" Cairo Today, Volume 3, No. 4


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140. Interview with Employees At Arab Contractor's Icon Panel Production Plant. Helwan, Egypt. April 8, 1982.


143. Interview with Aiman El Sakka, Project Manager. AZAMCO. Cairo, Egypt. September 7, 1982.

144. Interview with Iman Bibars, Sales Administrator, Komatsu Ltd. Dokki-Cairo, Egypt. September 7, 1982.


