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UNITED NATIONS INDUSTRIAL
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ASSISTANCE TO CONSOLIDATE AND DEVELOP THE BENGHAZI CEMENT FACTORY

TF/LIB/75/002

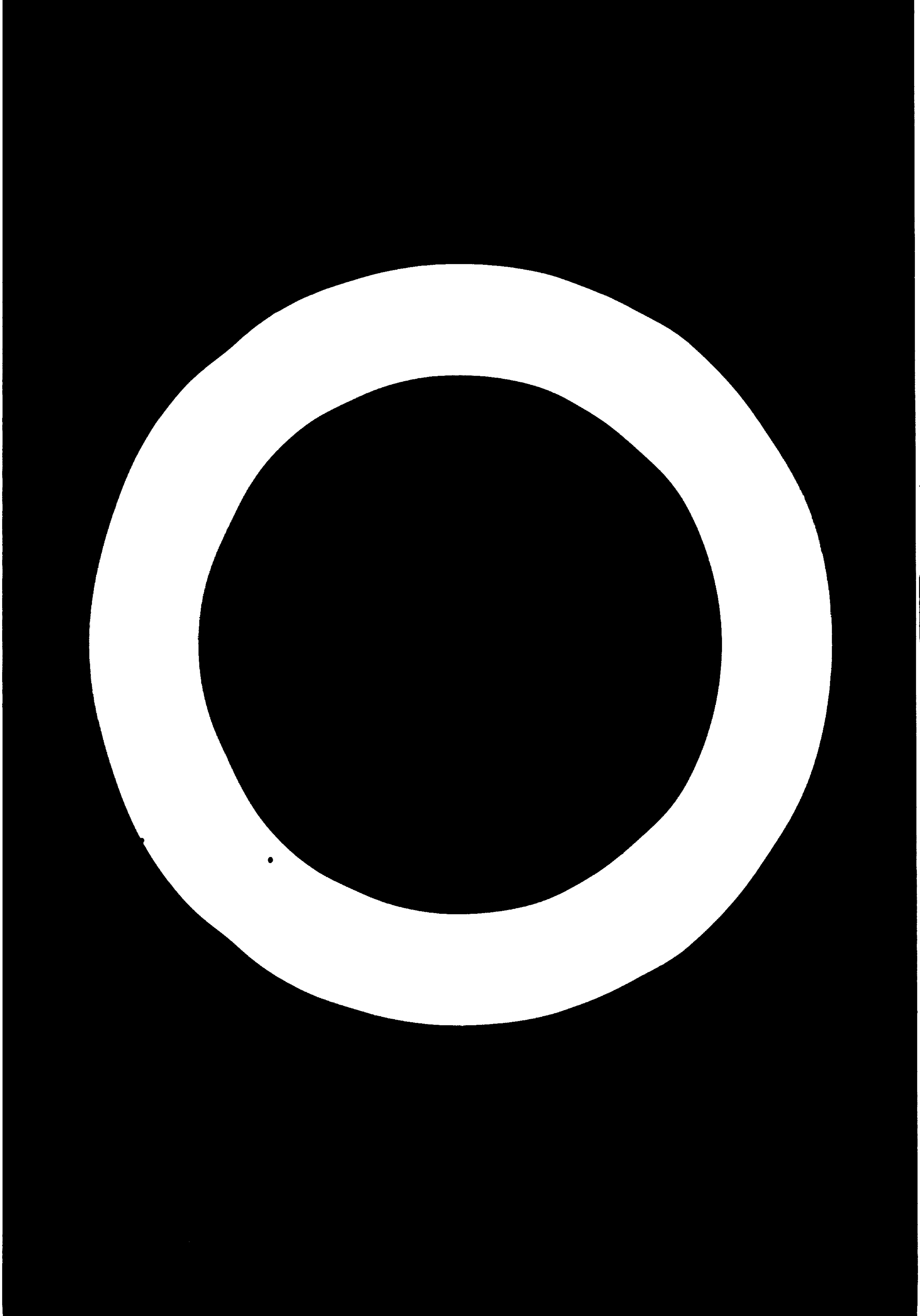
LIBYAN ARAB REPUBLIC

Project findings and recommendations

Prepared for the Government of the Libyan Arab Republic
by the United Nations Industrial Development Organization

Based on the work of Aly Afify, chemical engineer

id.76-2791



Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in the Libyan Arab Republic is the Libyan dinar (LD). During the period covered by the report, the value of the LD in relation to the United States dollar was $1 = LD 0.296.

References to "tons" are to metric tons, unless otherwise specified.

The following abbreviations of organizations are used in this publication:

IDCAS	Industrial Development Center for Arab States
GNOI	General National Organization for Industrialization (Libyan Arab Republic)
LCC	Libyan Cement Company
SUMIS	Souk El-Khamis General Company for Cement and Building Materials (Libyan Arab Republic)

The following abbreviations of foreign companies are used:

G & B	Grün und Belfinger
KHD	Klöckner Humboldt Deutz
PEG	Prospective Engineering Gestion
SF	Siom Forindus
TCH	Technical Center Holderbank
TCWE	Theodor Christ, Water Engineering
TPCC	Toura Portland Cement Company
WEDAG	Westfalia Dinendahl Aktiengesellschaft Groppel

The following abbreviations of technical terms are used:

AM	Alumina modulus
BSS	British Standard Specifications
CaO	Quicklime (calcium oxide)
$Ca(OH)_2$	Slaked lime (calcium hydroxide)

LOI	Loss of ignition
LPS	Loro Parasini screening (station)
l/sec	litres per second
LSF	Lime saturation factor
masl	metres above sea-level
mg/l	milligrams per litre
MS	Mogensen sizers
ppm	parts per million
SR	Silica ratio

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SUMMARY

This is the report of a mission to assist the Government of the Libyan Arab Republic in consolidating the Benghazi cement factory and in advising about the development of the cement industry in general. The assistance was requested by the Government, approved by UNIDO in June 1975 and financed under the UNIDO Trust Fund. The expert's assignment was for a year, to be undertaken at short intervals starting in February 1976. His report gives a detailed account of the cement industry at Benghazi and proposals for follow-up work. His principal recommendations concern strengthening the skilled labour force and assuring the supplies of raw materials, namely limestone and gypsum.

The rapid development of the cement industry in Benghazi (up to 10 times capacity within six years) from start-up of the first production line (200,000 tons per year) in 1972 until the commissioning of the Hawari plant in 1978, bringing the total production to 2 million tons per year has brought about a demand for experienced technical personnel and reserves of raw materials. After a detailed revision of labour distribution, an organigram for technical personnel has been laid out with job descriptions. Labour requirements have been defined for operating the third production line with a surplus to be trained for the Hawari cement plant. A general survey of raw materials has confirmed that whereas sufficient reserves of good quality limestone and clay are assured for the forthcoming 50 years of cement production, exploitable gypsum reserves explored so far are hardly sufficient for 10 years. Further detailed investigations for gypsum reserves must be made.

Questions relating to the water system were checked. Further investigations are required to assure adequate water supply from Wadi Gattara wells after adoption of the sixth well, modification of sequence pumping system, and installation of flow-meter and pressure gauges. Owing to deterioration in the quality of the water, an advanced water demineralisation process will be necessary; a duplication of the demineralisation unit is advisable for more secure operation.

Considerable progress has been made towards establishment of a training and managerial development centre with modern technological facilities. It would be beneficial if technical co-operation could be obtained in this field.

Problems of the Hawari lime plant were also closely investigated, with a study made of bottle-necks and of the deficient supply of sized limestone. Data analysis and screening tests have led to proposals for proper performance and optimum productivity.

Modifications are recommended and explained in detail. The main features of the scheduled extension of the lime plant have been designed to eliminate storage obstacles encountered in the present works.

The problems with raw materials recently experienced at the Souk El-Khamis cement project (1 million tons/year) were studied at the site. Remedies were planned along with investigations of emergency supplementary raw materials, long-term prospection and procedure of quarry opening. Contractual obligations were negotiated with the project management in consultation with the expert.

A general survey was made of the availability of preliminary raw materials in the Marj/Derna area for the installation of a cement project in the eastern zone. Pilot samples of the Marj area are promising, but it is recommended that detailed studies include a recent market study for the selection of suitable site location and project size.

Detailed studies have revealed surplus cement-grinding capacity which can be utilised for production of masonry cement for building purposes, which is economically advantageous for producers and consumers. Possibilities of raw materials and testing facilities were surveyed.

During the mission, various questions were settled in co-operation with national counterparts such as participation in the planning and execution of measures necessary for junction of the third production line with the existing plant; linkage of heat-carrier oil piping of the kiln firing system; clinker reclamation conveyors from clinker storage hall; cement pneumatic convey pipes; and gypsum storage and handling facilities. The old Rajma gypsum quarry was readied for proper exploitation and economical transport. Defects in the physical tests of cement were remedied through proper control of testing conditions and the substitution of worn parts; ultimately successful results were attained. Technological principles were emphasised for programming preventive maintenance of machinery and equipment; systematic ordering of spare parts and production implements based on data of mean lifetime; ordering and minimum amount of stocks; survey of refractory lining with comprehensive register for life history of kiln zones; organization of refilling mills to simplify recharging of grinding media and to control consumption rates.

INTRODUCTION

This is the report of the project "Assistance to the Libyan Cement Company" (TF/LIB/75/002). The expert was assigned for one year to the Government of the Libyan Arab Republic, who requested the assistance. The project was approved by UNIDO in June 1975 and financed under the UNIDO Trust Fund at a cost of $49,000.

The Libyan Cement Company (LCC) has participated in the national industrial development of the country with a major share of transactions. Prospects are favourable for its further contribution under the forthcoming industrialization plans.

LCC started the first cement production line in April 1972 with an annual production capacity of 200,000 tons of normal portland cement. The second production line augmented the cement production capacity to 600,000 tons/year starting in August 1973. The third production line, which is under construction, will increase the yearly output to a million tons by July 1976 (scheduled date of readiness for acceptance tests). Near the present site the Hawari cement plant is being installed with a yearly production capacity of 1 million tons; it is expected to start up by February 1978. In conjunction with cement production, a lime plant with a production capacity of 43,000 tons of hydrated lime per year was erected at the same site; it makes use of sized limestone from crushers of cement production lines. This lime plant went into operation in March 1975; its size is expected to double in the near future. A factory for paper bags was started up in June 1975 with an installed yearly production capacity of 20 million paper bags; it is a complementary service to the cement and lime industry. A new factory for burnt-clay hollow bricks and another for concrete blocks are under construction, thus adding to the industrial national potential and rounding out an industrial estate of allied industries.

With the rapid expansion of industrial projects in diversified fields of activity, LCC has been confronted with a greatly increased need for experienced technical personnel to cope with the dual task of operation and expanding the factories. The management of LCC is planning to introduce major training programmes involving national technical personnel for cement extensions and allied building materials industries and to extend the scope of its activities to cover technical and managerial consultancy for various developing industries. UNIDO has therefore been requested for technical co-operation to help consolidate the Benghazi cement factory and to advise about expanding the cement industry in general. The consultant was sent on an introductory mission of three months starting on 7 February 1976.

According to the job description, the expert was expected:

(a) To supervise the production and engineering departments and to co-ordinate and guide the work in both departments;

(b) To propose production and maintenance plans and to approve and follow-up executive programmes;

(c) To supervise development and simplification studies and to solve problems by utilizing their conclusions;

(d) To propose specifications and standards of good raw materials and equipment, and to control the commitment to such specifications;

(e) To participate in the relevant committees in discussion of matters relating to the departments;

(f) To follow-up and up-date the world research and development in the cement industry and to help make the conclusions in this area available;

(g) To submit periodic reports on the work of the departments;

(h) To propose training requirements for local trainees to replace foreign technicians;

(i) To study projects referred to him by the LCC.

I. FINDINGS AND CONCLUSIONS

Extension projects

Since the LCC project began in 1969, there has been an upsurge of activities evolving from the rapidly growing extensions of the cement industry and the installation of new plants of allied industries. After the start-up of the Benghazi cement extension (the third production line) and of the new Hawari cement works, the yearly production capacity will attain 2 million tons of normal portland cement. This huge volume of production will impose a sizable burden of technical and administrative responsibilities and will call for re-assessment of the labour force and of the prospects for raw materials.

Organization of the labour force

The functions of technical personnel have been carefully defined and the responsibilities of each individual clarified. Promotion channels for various levels of personnel have been established within sections and departments. The questions of administrative, commercial and financial departments are handled by the management and training adviser. An organigram for technical personnel has been drawn up (see annex I). A job description has been outlined for each member of the technical departments. All particulars have been discussed in detail with the responsible technical personnel as well as with the management and training adviser, and certain traditions governing personnel and departmental functions have also been taken into account.

As the third production line will shortly be put into operation, the new requirements for labour have been discussed with the responsible technicians and the productivity and technical skills of individuals have been evaluated The consultant Prospective Engineering Gestion (PEG) was approached on the question of fulfilling labour requirements specified by machine suppliers for proper operation and maintenance. During the last few years some technicians from abroad have been employed to co-operate with local personnel to achieve the optimal functioning of production lines. Considerable numbers of local technicians have learned skills and they are progressively taking over the major responsibilities of operation and maintenance. Many have already substituted for foreign specialists. Nevertheless, the rapid growth of tasks and responsibilities imposed by the successive extensions have exceeded the rate at which local personnel can be trained.

Some of the units of the third production line will be tested in a trial run that was expected to start in June 1976, followed one month later by commissioning and putting into operation with material flow. The date of readiness for acceptance tests was scheduled for 27 July 1976. The new labour force required for operation and maintenance of the third production line is therefore urgently needed. However, it has been arranged with management that some of the better qualified present technical personnel will take over the responsibilities for the operation and maintenance of the third production line, and some of the assistants will be promoted to take on greater responsibilities in the old plant.

Many vacancies will consequently occur which will necessitate proper programming for immediate replacement. Meanwhile, a group of experienced personnel must be formed for the new Hawari plant under construction, thus entailing the employment of an additional number of personnel to allow enough time for on-the-spot training and profit to be gained from scholarships available for upgrading local skills. The present labour situation has been surveyed and a programme for the required reinforcement of the labour force has been proposed, as indicated in the following summary.

Area of work	Number required			Number yet to be employed		
	Benghazi 1 and 2	Ext. 3	Total	Urgent	Second stage	Total
Raw materials	55	32	87	2	30	32
Mills, kilns, packing	159	75	234	17	58	75
Laboratories	21	5	26	3	2	5
Mechanical maintenance and workshop	107	39	146	12	34	46
Electrical maintenance and workshop	31	9	40	2	7	9
Transport	58	16	74	3	10	13
Total	431	176	607	39	141	180

It should be emphasized that the extra personnel recommended will need long-term training for the Hawari cement project which requires a considerable number of well-trained personnel. However, this will not impose an excessively heavy burden on the labour costs in relation to factors of cement cost [illegible]. The impact of the proposed employment may be concluded from the following data in which actual figures of the budget for the preceding year, 1975, are compared with the anticipated labour situation worked out to the maximum labour density with the guaranteed production capacity of machinery and equipment, at present market prices.

Item	Financial year 1975, production lines 1 and 2	Anticipated first year, production lines 1, 2 and 3
Production: quantity (tons)	456,624	1,000,000
value (LD)	5,479,488	12,000,000
Total labour force (number)	569	770
Total payment (salaries, indemnity, social participation and allowances)	1,030,543	1,463,000
Average individual pay (LD)	1,811.148	1,900.000
Payment/production value (%)	18.807	12.192
Productivity/payment (LD)	5.317	8.202
Man hours/ton production	2.351	1.762

It is evident from the table that the major part of improvement in labour productivity may be attributed to the increased production capacity availed by the extension project.

Prospects for raw materials

The rapid development of the cement industry in Benghazi by 10 times within 6 years, starting with the first production line in 1972 with a capacity of 200,000 tons yearly production and growing to a total yearly production capacity of 2 million tons by the start-up of the Hawari cement works in 1978, calls for a thorough reassessment of reserves of raw materials. A general survey of the situation affirms that sufficient reserves of good quality limestone and clay are assured for the forthcoming 50 years, whereas the supply of gypsum has to be replenished.

Limestone and clay

The limestone/clay area extends south of the works site, about 8.5 km south-east of Benghazi along the asphalt road to Soluk. (See orientation sketch, annex II).

The surface of the area is a smooth, gentle slope from east to west which drops off more rapidly in the west where an outcrop of silicified crust at the top of the limestone sequence forms a conspicuous escarpment in the field. Vast areas of red clay extend in the neighbourhood, increasing in thickness (2.5 to 6.5 m) from west to east. It is underlaid by a thick limestone deposit compound of silicified calcareous crust 1 to 3 m thick at the top and a relatively soft and porous chalky layer of limestone at least 30 to 50 m thick at the bottom.

The availability and suitability of limestone and clay were carefully investigated at various stages of the project: at the start of feasibility studies for the original project, for extension production lines 2 and 3, and ultimately for the new cement works at Hawari. Geological prospection and precise analysis were performed by the Swiss consultant firm Technical Center Holderbank (TCH) and the German firm Klöckner Humboldt Deutz (KHD). The final results were again evaluated by the present Swiss consultants PEG.
The investigations proved the homogeneous nature and favourable composition of raw materials suitable for the production of a satisfactory quality of portland cement with no need for any corrective additive material. In virtue of their favourable mineralogical constitution, with only slight variations, the burnability and dust evolution are within reasonable limits. Generally speaking, the limestone is of high quality, 91 to 97% $CaCO_3$. However, in some spots undesirable ingredients (such as magnesia, sulphates, alkalies, chlorides) occasionally occur to various extents. The MgO content is not excessive, and through proper homogenization it can be included in the over-all assessment of reserves; the average MgO content may still be kept in the raw mix within the admissible limits. As the chloride content is subject to considerable variations, fluctuating around 0.4%, allowance was made in the Hawari plant (Humboldt type heat exchange preheater), for hot gases in the kiln to be partly bypassed prior to passing through the heat exchanger, in order to keep the evaporation and condensation cycle of the

alkali chlorides within reasonable limits and to prevent reduction in flowability and the resulting clogging tendency of raw meal in the lowermost stages of cyclones.

Reserves of raw materials in the areas investigated were worked out by KHD in order to estimate their lifetime in relation to the total scheduled production of 2.1 million tons of cement per year. With an average thickness of 5 m for clay, reserves were estimated to be about 44,800,000 tons which would suffice for a period of over 50 years. The limestone exploitation at 40 m thickness was reckoned to be about 213,500,000 tons, which are sufficient for over 100 years of production. These results were reviewed by PEG, who recommended limestone exploitation down to 23 m only, in order to avoid the lower strata of comparatively higher MgO and Cl content. By implication, the upper exploitable part is sufficient to cover requirements for about 50 years. This would secure the advantage of lower chloride content in the raw meal. The kiln bypass could be operated with a smaller amount of kiln gases, and this would reduce the frequency of necessary cyclone cleaning and thus increase the regularity of kiln operation.

Therefore, sufficient materials have been anticipated for the first 50 years at full production with trouble-free prospects. Official measures are being taken to procure the newly investigated areas to add to originally preserved concessions of raw materials. The deposit so far investigated constitutes only a small portion of a region in which the same occurrence of raw materials extends over vast areas.

Gypsum

The prospects for gypsum reserves do not seem to be so convenient. Further detailed investigations for more gypsum reserves would be much appreciated to accomplish a more certain survey of available deposits. After the third cement production line is put into operation (July 1976), and with the start-up of the Hawari cement plant (March 1978), the annual production capacity for cement will be 2 million tons. On the basis of 5% gypsum addition, the appropriate gypsum requirement would then amount to 100,000 tons. Moreover, the Marj/Derna cement project is expected to have a yearly production capacity of 500,000 tons of cement, which would mean a further yearly requirement of 25,000 tons of gypsum, or a total requirement of 125,000 tons of raw gypsum.

The prospection performed so far for raw materials for the Marj/Derna project has not yet disclosed a reliable gypsum deposit in the prospected areas, and it has therefore been reported (by the consulting firm UNICONSULT) that raw gypsum requirements will have to be supplied from the gypsum deposits in the proximity of Benghazi. For a proper project feasibility study, the gypsum requirements for 50 years lifetime should be taken into account, amounting to 6.25 million tons.

The latest gypsum investigations in the Benghazi area were carried out by Strojexport Geoindustria of Prague, under the permanent field supervision of the Geological and Mining Section, Ministry of Industry. It was reported that the gypsiferous belt situated along the Ragma-Bu Mariam asphalt road reaches the width of 15 km, with the discovery of new gypsum outcrops near an escarpment slope 10 km distant from Hawa Al Barrag and gypsum outcrops near Sidi Mabruk. This investigation led to the conclusion that total available gypsum reserves in the Ragma-Bu Mariam belt and the Hawa Al Barrag area amount to 891,060 tons. An additional amount of 56,201 tons of gypsum was found in Gara, but this deposit could not be recommended for extraction owing to the feeble thickness of the gypsum layer and the proportionally high overburden. In addition, this deposit is the most distant from the factory site with the worst accessibility. It is worth mentioning also that Ar-Ragma 1 deposit, blocks I and II, respectively comprising 18,725 and 49,276 tons of gypsum, are located close to Ar-Ragma village on one side and the military area on the other side. Since gypsum began to be exploited it has been impossible to approach this area and it may become even more difficult to access in the near future. On the other hand, there exist several separate gypsum deposits which were estimated roughly at 200,000 tons, but this must be ascertained through proper prospection. However, the most optimistic assumption is that if all the above-mentioned amounts are completely exploited, the gypsum reserves would total a maximum available quantity of 1,147,261 tons.

In the above-mentioned report it was considered that the situation would permit the construction of a plaster factory having a capacity of 7,000 tons of plaster per year, which was previously recommended by Bellrock International Ltd. in 1965. The last geological report confirmed the proposal for the establishment of a plaster industry for the production of medical plaster, construction plaster, lightened structural elements on a pearlite-plaster basis and others.

The situation is now quite different. A better idea of the sufficiency of these gypsum reserves may be gained from the following data.

	Cement production (tons)	Consumption	
		Gypsum (tons)	Basis of estimate
Apr. 72-Dec.75	1,153,519	70,000	Actual figures
Jan. 76-Jul.76	368,000	18,000	Production lines 1 and 2
Aug. 76-Mar. 78	1,666,000	83,000	Production lines 1, 2 and 3
Apr. 78 + 10 years	20,000,000	1,000,000	Benghazi 1 and Hawari
Total	23,187,519	1,171,000	

This indicates that the exploitable gypsum reserves that have been explored so far are hardly sufficient for 10 years' consumption dating from the start-up of the Hawari cement plant, even with the most optimistic prospects and without taking into consideration the additional demands of the Marj/Derna cement project since the feasibility study of this project is still to be completed. To establish a sound cement project, it is the normal practice to foresee the necessary raw materials for at least 25 years lifetime of the original project plus another 25 years of reserves to account for future unforeseen expansion.

The solution to this critical question of gypsum discrepancy is not yet clear. The consultant would therefore propose a precise reassessment of the whole situation, starting from a more detailed investigation for new gypsum resources in the amount of 6 million tons. After the gypsum reserves are clearly investigated, the situation can then be revised for planning proper solutions. Meanwhile it would be advisable to abandon the aforementioned proposal for plaster production, unless the idea is restricted to the production of medical plaster in a small-scale kettle or autoclave, in view of its minor consumption of gypsum and in virtue of the extreme puurity of fine crystalline gypsum in various deposits.

Water system

The present system for water supply and circulation comprises ground water wells, pressure sand filters, demineralization unit and cooling towers for industrial purposes, sterilisation installation for sanitary utilizations and bacteriological device for treatment of drainage and sewage. All particulars of the system have to be revised to allow for ample expansion to cope with scheduled extensions. The daily water requirement has been estimated to be 400 m^3 at the present stage, to be increased by 250 m^3 for the third production line and 950 m^3 for the Hawari cement plant, the total being 1,600 m^3; this total should be reckoned as 2,000 m^3 to account for future requirements of plants for clay bricks and concrete blocks that are under construction and the scheduled extension of the lime plant and of the residential area. The whole situation may be clarified by the following survey.

Water supply

LCC owns six water wells located at Wadi Gattara, 3 km east of the factory site in the Benghazi Plain, between the industrial area and the escarpment of Ragma plate (as indicated in annex II). The wells are dug to the depth of 110, 110, 110, 110, 106, 103 m. Five wells are provided with submerged water pumps setting at 76, 87, 81, 90.5, 96 m, whereas the sixth is not yet in operation. Hydrogeologists have stated that below the Ragma escarpment water flows to the west through limestone fault zones and subsurface solution systems. Dye tests carried out in the secondary water reservoir on Wadi Gattara suggested high velocity of ground water towards the wells, varying from 7.9 to 15 cm/sec. The static water level in the area varies from 52 to 58 m below land surface and 1 to 4 m from mean sea-level. The rate of discharge fluctuates between 7 and 10 l/sec for the existing pumps.

Some difficulties have been encountered in obtaining water requirements during occasional summer peaks. Investigations have been performed by hydrogeologists of the General Water Authority during November 1975. Pumping tests were conducted on the six wells to study their performance and to evaluate the aquifer parameters. The tests could not be conducted under ideal conditions of controlled long-duration pumping because while one well was being tested other nearby wells were being operated to provide immediate water requirements. Owing to the design of existing pumps, the wells could not be tested at the required low yields, in order to avoid the danger of building up high back pressures.

The chemical analysis of water samples indicated that there was some dilution in the concentration of salts in ground water along Wadi Gattara, and that the water quality deteriorated progressively towards the west and south-west of the LCC well-field area. The total dissolved solids have increased in all wells generally by 80 to 200 ppm over one year (November 1974 to October 1975), entering the range of 580 to 1,040 ppm. The water quality is therefore progressively deteriorating with the high annual extraction of ground water owing to increasing over-all draft combined with the limited annual re-charge of aquifer. Consequently, it is recommended that an advanced water demineralization process be introduced in the near future. Preparatory moni-toring should be adopted through periodical checking of water to ascertain the extent of the deterioration and to determine the quality in general.

The General Water Authority concluded that the yield of the six wells could easily attain 1,500 m^3 per day if the dynamic water levels of the wells were stabilized to yield 3 to 5 l/sec. The resultant daily yield from a well would be considerably higher than under the present system. For securing a combined yield of 1,500 m^3 per day, the automatic system is recommended to allow for operation of the wells, alternatively, Nos. 1, 5 and 6 in one group and Nos. 2, 3, and 4 in another group, and to control the delivery of each well by its gate valve to reduce the yield rate, to check the back pressure on the pump with a pressure gauge and to measure the rate of flow with a flowmeter.

The consultant therefore proposes that the original suppliers of the auto-matic water system (Franz Rittmeyer) be requested to introduce well No. 6 into their system, to adjust the yield rate of each well to the required level, and to adopt the programming of the automatic system to the recommended sequence. After these facilities are provided, final confirmatory tests can easily be performed which will clearly indicate any extra measures to be taken before the start-up of the Hawari plant.

Industrial water

The cooling-water installation comprises the package cooling towers, cooling-water booster pumps, press filters, cooling-water elevated tank, supply pumps, make-up water pumps, storage tanks and a demineralization unit.

The press filters are composed of cylindrical shells charged with 1.2 to 2.0 mm quarts gravel capable of removing foreign insoluble matter down to a residual content of less than 5 mg/l, washable by water back-flow and scavenging, drawn-in air. The maximum admissible degree of fauling is indicated as differential pressure. The cooling water is industrially treated by the demineralisation unit for decarbonation through a weak-acid cation exchanger (Amberlite IRC - 84). After exhaustion of the ion exchanger, regeneration is accomplished with hol acid. The package cooling towers are designed for a cooling range of 38°C. The water evaporation with the dissipated heat leads to progressive concentration of total dissolved solids. Adequate amounts of solids are therefore blown down and the consequent water loss is compensated for by ample make-up fresh water supp The close study indicates that the cooling-water installations have been wor out for ample water velocity and flow-rate to cope with the requirements of the three production lines, except for the demineralization unit. For the latter the consultant suggests a duplication for more secure operation. The existing unit had been supplied by the Swiss firm Theodor Christ, Water Treatment Engineering and Equipment with the first production line; it has an hourly capacity of 12 m^3 and system capacity per regeneration of 300 m^3. It is designed for raw water composition of 18.7° total hardness, 12.5°d carbonatio hardness, 148 ppm sodium and 263 ppm chloride. It is evident that the progressive deterioration of raw water imposes an extra burden on the present demineralization plant. Furthermore, the water losses include evaporation and spray losses in the cooling towers, water consumption in the plant for requirements of the conditioning towers of electrical dust precipitators and the anticipated losses from internal water cooling of cement mills, leakage within the cycle, and blow-down quantities. All these losses are increasing considerably. It is worth mentioning that serious scales are building up within the cooling pipes. Consequently, the blow-down process has to be performed more frequently to dilute the concentration of total dissolved solids. The reinforcement of the demineralization procedure is therefore of primary importance.

Drinking water system

Water for sanitary purposes is sterilized by the aid of ultraviolet rays in a series of U-tubes equipped with exchangable ultraviolet ray bulbs. The drinking water is drawn from the ground reservoir by the supply pump to the drinking-water supply pumps feeding the supply main, which is connected with a hydrophore system for maintaining pressure through an air compressor.

This system was installed with the first production line when the daily consumption was 27 m^3. Consumption is now expected to increase with the three production lines up to 60 m^3, on the assumption that there will be a requirement of 60 litres/per capita/day of sanitary water. The drinking water installation is ample for such an increment. However it is recommended that the chemical laboratory be provided with necessary equipment for performing bacteriological tests to properly control drinking water.

Sewage water treatment

The treatment of sewage water is effected through a biological metoxy plant, comprising successive processes of mechanical disintegration of solid sediments, oxidation of bacteria by vigorous agitation with compressed air, and ultimately sterilization against remanent bacteria by overflowing the supernatant liquid and exposing it to the disinfecting action of ultraviolet rays from special bulbs which can be exchanged when completely fatigued. The sewage water can then be utilized for agricultural purposes without hygienic danger.

This sewage water-treatment device was originally supplied by the Swiss firm METOBAU; it has a daily treatment capacity of 42 m^3 of normal sewage water. With the expected increase in sanitary water consumption in accordance with the growth in the labour force, it would be necessary to extend the present sewage handling facilities either by doubling the existing biological treatment installation or by connecting the site sewage with the main drainage system, to be accomplished by the municipal authorities.

Gypsum storage capacity

During the period of the mission, the writer participated in the planning and execution of measures necessary for junction of the third production line (being built) to the existing plant (Benghazi I and II), without interrupting production. Linkage has been accomplished for various aspects such as the heat-carrier oil piping of the kiln firing system, clinker reclamation from the clinker storage hall by vibrating extractors and rubber belt conveyors, cement-conveying pipes from the mill house pneumatically to cement storage silos in the packing-plant section, and the gypsum storage and conveying facilities. The latter will most probably prove a bottle-neck that will obstruct the continuity of the feed for the cement mills. The gypsum storage bin is of concrete construction with a capacity of 600 tons; it was originally provided with a pendulum switch that signaled on the control panel when the bin was full, and with a vibrating feeder for reclaiming stored gypsum from the discharge chute.

This gypsum bin is expected to serve the third cement mill in addition to the present two. The scheduled modification includes:

(a) Replacement of discharge chute by a sturdy plate construction, with wear plates of polyethylene on chute surfaces, and the modification of the discharge part of the concrete gypsum bin;

(b) Erection of an apron feeder underneath the discharge, 800 x 3,000 m, to be used as a reclaiming belt for the storage bin.

The future daily gypsum requirement for cement grinding is estimated as 5% of 3,000 tons (being the guaranteed daily production of clinker) = 150 tons of raw gypsum. The storage capacity of the gypsum bin was therefore considered sufficient to cover four days of full production. In fact the angle of repose of crushed gypsum is far more than anticipated by the suppliers. Owing to excessive humidity and coarse crystalline texture, the gypsum builds up a steep top cone which imposes premature pressure on the pendulum switch indicators and consequently stops the gypsum supply, leaving a considerable void at the top. During the evacuation of the storage bin the gypsum sticks to the sides, allowing only a slender cone to flow out. The outcrop of the two inverted cones of gypsum which can be discharged from the full gypsum storage bin is normally no more than 300 tons, a supply that hardly suffices for two days of cement grinding. This situation will not be suited to difficult running conditions in case of a longer interruption of crushing for major repairs or emergency cases. After the erection of the extension installation, the new storage capacity should be carefully examined among the particulars of handing over. If the whole amount of stored gypsum is not freely available, the possibility of using vibrators on the bin sides may be studied from mechanical and constructional points of view.

However, in the transition period until the modification is made, one of the compartments of the raw materials storage hall has been devoted to the storage of crushed gypsum, which can be reclaimed by the stope scraper and transferred to rubber belt conveyors leading to the gypsum hoppers of the cement mills. This temporary storage facility affects the clay storage capacity which is accordingly reduced. Still, it is advisable to keep this supplementary gypsum storage until the question of the gypsum storage bin is finally settled.

Training and management development

Experienced labour is the most necessary element for the efficient execution and operation of industrial projects. Owing to the primary importance of promoting national skills for proper participation in the industrial process, the Prime Minister of the Libyan Arab Republic has expressed a special interest in a training and development centre mainly for the cement industry, in view of its strategic importance and generally for the building materials and ceramics industries because of their major impact on the industrial projects scheduled under future development programmes.

The General Director of LCC and the training and management adviser (see annex III) have earmarked this project for prompt execution to conform to the most advanced technological standards. Efforts have been exerted in the following directions:

(a) Detailed study of the available labour force - its nature, efficiency and possibilities - in order to initiate the most effective general strategy for achieving the targets of:

(i) Development of experienced national skills to meet the increasing demand for skilled labour of existing works and future extensions;

(ii) Intensification of present local experience to upgrade technical standards, to raise productivity and to develop efficiency to undertake more elaborate tasks by enabling workers to follow recent technological trends and scientific principles of process improvement, cost reduction and industrial security;

(iii) Stimulation of interest in acquiring further know-how and encouragement of self-education;

(iv) Participation of students and apprentices in reinforcement and development of industrialization facilities;

(b) Meanwhile, there have been parallel efforts for organizing training particulars. The regulations for training procedures have been formulated. Some training programmes have been implemented as an introduction to various fields of training: orientation courses, industrial security, operational instruotions, fundamentals for industrial knowledge (linguistic study, natural science, draughtsmanship, professional skills, instrumentation eto.);

(o) Scientific references, industrial pamphlets and instruction manuals have been collected as a nucleus for a central library. Author and title indioes are being compiled for easy reference. Subscriptions have been made to scientific periodicals, industrial circulars and international statistics. A complete set of technological diapositives has been procured for training demonstration. Workshops for supervisory training are regularly organized;

(d) Major steps have been taken towards establishing a training and management centre to start activities in the cement industry with ample provisions for future expansion and to involve the allied industries of building materials and ceramics. The centre is expected to be equipped with:

(i) Instructors and drawing rooms supplied with slide projectors, overhead projectors, flipcharts. technological boards and specimen objects;

(ii) Linguistic laboratory with intercommunicating system and phonetic facilities for conversational study and practice;

(iii) Physical and chemical laboratories with necessary chemicals, apparatus and elements of standard specifications;

(iv) Mechanical workshop with multi-training unit, working benches, universal workshop machines and their basic tools, annealing facilities, collections of instrumentation etc.;

(v) Production training hall with illuminated mimic diagrams for main prooesses, industrial specimens, and whole and cut-away models for production units;

(vi) Closed-circuit TV video equipment, including miniature studio with video camera for technical design and an adapter lens for photomicrographs.

The scheduled programmes are closely oo-ordinated with the existing training centres and with the organisation of scholarships. In view of the vital importance of suoh efforts for industrial development and in virtue of well-established bases foreseen in training fundamentals, the project may be considered a model specimen for well-planned training facilities. For a reinforcement of this training project, the consultant would recommend that LCC make use of UNIDO technical training aids, industrial information services of practical interest, and research and documentary facilities in the form of:

(a) Training opportunities arranged through UNIDO, regional and inter-regional symposia, expert group meetings, seminars, group training courses including in-plant courses, industrial development workshops, management clinics and other training opportunities. In-plant training helps to bridge the gap between the specific requirements of the factory and knowledge that the participants have acquired through their studies. It also provides the opportunity for an exchange of ideas and experience between technical personnel and research institutes and among trainees themselves;

(b) Circulation of publications issued by UNIDO such as the Industrialization and Productivity Bulletin and Industrial Research and Development News, and information on training for industry services, industrial planning and programming, project formulation and evaluation, and special information publications such as Industrial Development Abstracts and Guides to Information Sources to provide information about the nomenclature of professional organizations, research centres, learned societies, specialized information services, yearbooks, statistics, economic data, bibliographies etc.;

(c) Services of the UNIDO information clearing-house to answer questions concerning industrial problems, to obtain general information on the formulation of industrial development plans and on new breakthroughs in advanced technologies;

(d) Fielding of international experts in maintenance procedures, process technology and quality control, and to conduct on-the-spot training; instructors for programming, specialists in audiovisual aids etc.

The consultant has informed counterparts of the procedures for requesting UNIDO technical co-operation.

Lime factory

The lime plant is installed at the site of the LCC for the economical application of limestone reserves. The sized limestone from the main crusher is utilised for production of quicklime (33,000 tons/year).

The Italian firm Siom Forindus - S.R.L. (SF) has a turnkey project which was put into operation on 15 February 1975. The lime calcination process is based on the normal general operation principles of vertical shaft kilns (Union Carbide patent). Limestone is charged by a skip-hoist at the top of the shaft kiln, where the charging system is automatically controlled by a timer and level-control device. Limestone is calcined as it descends through the kiln through four distinctive zones of storage, preheating, calcining and cooling, and is ultimately withdrawn as lime at the bottom. Heat for calcination is provided by hot combustion gases rising through the stone bed. Fuel is injected by two tires of patented water-cooled burner beams extending across the kiln. Hot gases are drawn up through the kiln by a high-speed fan attached to the gas-exhaust system, arranged to avoid channeling of heat that may create uneven calcination or possible refractory damage.

Problems of existing lime plant

The project has been hampered by the deficiency of sized limestone since the beginning and is still suffering from a shortage in raw supply, which always leads to reduced lime production or sometimes to a complete standstill. This problem has been closely studied by the consultant and his findings are given in the following section.

The limestone preparation is designed to treat limestone of 30-60 mm, sorted out by Mogensen sizers and Loro Parasini vibrating screens (LPS), by screening the crushed limestone from a WEDAG hammer crusher which feeds the first and second LCC production lines, with a crushing capacity of 270 tons per hour. The screening function is effected through a pair of Mogensen sizers set with a mesh width of 100, 80, 50/25 mm. Grain sizes bigger than 30 mm are separated from the material flow and conveyed to the lime plant where LPS vibrating screens separate the limestone lumps below 30 mm and over 60 mm; these lumps are then conveyed to the silo for reject and discarded to the limestone storage hall of the cement plant. The limestone lumps of the required size are led to the raw storage silo of 1,500 m^3 working capacity, maximum content of 2,250 tons of limestone with 1.5 ton/m^3 bulk density. The full content of the raw storage silo represents a maximum working reserve of 275 hours running of the lime kiln, or 2,250 tons storage capacity divided by 8.75 tons hourly consumption at rated kiln output. After the limestone is extracted from the raw storage silo, it is once more screened to separate the limestone lumps above 30 mm from fragments and limestone dust before it is charged into the intermittent limestone skip for transfer to the kiln-feed.

For calculation of the limestone requirements of the lime plant, an average limestone sample may be compared with the theoretical $CaCO_3$ content:

	Total calcium carbonate	Calcium oxide content	Loss on ignition
	(Percentage)		
Theoretical figures	100.0	56.0	44.0
Practical average	94.0	52.6	41.4

The calculation may be based on 2% limestone natural humidity and 1.5% limestone loss as dust hanging with evolved gas. By considering 5% maximum residual CO_2 in the burnt lime, the kiln daily output should be reckoned as 105 tons. For obtaining this amount as product, the lime kiln should be charged with a daily amount of limestone according to the formula:

$$[(100 \times 1.786 \times 56/52.6) + 5] \times 1.015 \times 1.02 = 202.00 \text{ tons}$$

For a safe calculation the suppliers estimate that the lime kiln should be charged with a daily quantity of 210 tons of limestone, which means: 210 x 7 = 1,470 tons of limestone/week, or subtracting week-ends, 1,470/6 = 245 tons of sized limestone per working day. It should be taken into consideration that the limestone crusher is also normally idle during official holidays and during a stoppage of the cement kilns when the limestone storage halls are full. Consequently, the requirements for the lime plant would be about 290 tons of sized limestone for each normal working day of the limestone crusher.

A sound calculation of crusher performance is worked out as a proportional function of cement clinker output. The clinker production capacity is 600 + 1,200 = 1,800 tons per day for kilns Nos. I and II, or 600,000 tons of clinker per year of 330 days co-efficient of utilisation. For a practical approach to the calculation of crusher output, the actual performance was revised over one year's operation. As indicated in annex IV, the cement kiln performance during the year 1975 amounted to 73% of the installed production capacity, viz: 438,528 tons of clinker compared with a target of 600,000 tons.

This reduces the requirement of crushed limestone to about 500,000 tons, out of which theoretically 450,000 tons should be applied to clinker production plus sized 50,000 tons for lime production. As a matter of fact, the actual figures for the year 1975 amounted to 506,461 tons of limestone from the crusher, out of which only 29,208 tons were sorted out for lime production, or only 5.8% of the total crushed limestone. This may be divided by 330 working days to give a daily average of 1,535 tons of limestone out of the crusher, from which the sized limestone for the lime plant would be 154 tons average daily delivery. This amount would suffice for the production of only 75 tons of quicklime, if 10% of the crushed limestone is sorted out by the screening device for the lime plant during the year 1975 as illustrated in annex V, meaning a further reduction of the possibilities for lime production. The deficient supply of sized limestone has been encountered since the beginning, even during the handing-over tests. As a consequence, lime production either has had to be frequently interrupted or seriously reduced.

Various screening tests were performed for the present study, as demonstrated in annex VI and graphically represented in annex VII. Furthermore, the consultant has investigated the particle size distribution in the limestone directed to the lime plant from the Mogensen sizes, as well as the reject returned from the lime plant to the limestone storage hall and from these data he has made the following findings:

(a) The quantity of raw crushed limestone produced by the hammer crusher is not sufficient for yielding an adequate percentage of sized limestone for the lime plant. This deficiency is owing to the reduced rate of clinker production, which amounted to 73% of the installed capacity in 1975. This will certainly improve if the target for clinker production up to the total guaranteed figures is reached;

(b) The portion of sized limestone (30-60 mm) actually delivered is in fact much lower than anticipated in the feasibility studies. As may be seen from annexes VI and VII, the preliminary screening test of the crushed limestone performed by the consultant TCH indicated the utilisable percentage for lime manufacture as 17%. After the lime factory went into operation in February 1975, this percentage turned out to be only 10%. The present study has shown a figure of about 15%. This discrepancy is mainly owing to the variable texture of the quarried limestone - from hard siliceous limestone in the top layer to friable, chalky limestone in the lower strata. However, in actual practice during the year this percentage dropped down to about 6%. This may be attributed to normal leaks in effectiveness of performance. In this sense losses can be represented by such things as blockage of the limestone chute leading to the LPS vibrating screen and delays in screening resumption after daily intervals of gypsum crushing. In order to verify the optimum running conditions, a strict control was adopted for two weeks by responsible personnel. It proved to be possible to attain 10% size limestone regularly over different shifts, as indicated in annex VIII. In this respect it is recommended that the LPS limestone chute be enlarged from a 25 cm to a 40 cm opening, and that a permanent control be organized by the general shift foreman to avoid any leaks of the sort;

(c) From the screening tests on the sized limestone over Mogensen sizers, and the reject returned to the cement works, the interrelation between these portions indicate that a considerable amount of sized limestone is progressively rejected and consequently the portion availed to the lime kiln is reduced. It is evident that the deep fall of sized limestone into the storage silo causes the lumps to break or even crumble into dust. As may be seen from annex VIII, the low limestone stock in the raw storage silo creates a deep fall of 12 to 16 m which increases the self-crushing potential, thus diminishing the limestone stock. It is therefore recommended that the raw limestone storage silo be kept full to reduce the height of the fall and consequently retain the required size. However, during long stoppages of one of the cement kilns, the raw-mix silos are quickly full, the limestone crusher is consequently stopped, and the raw supply to the lime plant is interrupted. In such cases the level of sized limestone in the raw-storage silo unavoidably drops. As a safeguard against deep fall in such cases, a spiral chute may be erected inside the raw-storage silo to lead the sized limestone down without vigorous impact or appreciable loss;

(d) The deficiency of adequate size limestone within the total crushed material may be overcome by adjusting the screening dimensions to make up an ample amount for securing regular operation of the lime plant at a reasonable production rate. Starting with the WEDAG hammer crusher, the gap setting was adjusted to the best yield of grain size 30-60 mm. A considerable improvement of kiln-feed material may be achieved by the extension of the size range from 30-60 mm to 25-70 mm, which augments material flow for lime production by about 5% of the total crushed limestone, as may be concluded from the grain-size distribution curve (annex VII). For practical local manufacture, the lower screens can be made of 5-mm steel plate perforated by a 25 ∅ drill. The upper screens can be set from 8 mm ∅ reinforcement steel to be spot-welded at 70 mm apertures.

It is worth noting that within the supplier's project documents (estimate No. 4206, page 19) it is plainly stated that the "kiln can be tailored to handle either limestone or dolomite in sizes as small as 25 mm or as large as 175 mm. The only requirement is that the ratio between the top and bottom sizes should be no more than about 2:1". The sieving results and proposed modifications were discussed with the representatives of suppliers during their visit to Benghazi (12-15 April 1975) and they agreed to the proposed procedure. However, these modifications should be adopted quite gradually and with extreme caution. Each step is to be adapted to the actual working conditions before the next step is tackled. A precise follow-up should be conducted on all particulars for assuring quick reaction in proper time. The smaller grain size will choke the kiln, and therefore the burning process should be treated with extreme care. The bigger lumps will require more intensive burning for proper calcination of particle cores through more voluminous cross sections. This difficulty eventually leads to a tendency to higher calorific consumption, more CO_2 content, and consequently lower CaO content in the product. According to the German Standard Specifications DIN 1060 (which is in force for the time being), CO_2 should not exceed 5% and CaO + MgO should not be lower than 80%. According to the performance guarantees of machine supplies, the specific heat consumption is anticipated for 1,300 kcal/kg of burnt lime. The revision of actual data for the burning process at full operation is quite promising and can easily allow for the expected tolerance, even though these factors have to be followed up with extreme care. Meanwhile the probable rise in the calorific consumption will certainly be well compensated for by the greater economy of higher production.

Expansion of lime production

With the vast development programmes scheduled by the Libyan Arab Republic, an increasing demand on lime has been created, which will require doubling the existing lime production capacity of LCC to 33,000 tons/year of quicklime, equivalent to 43,000 tons/year of slaked lime for building purposes.

Moreover, there exist further good prospects for lime requirements for industrial works. The present extensions in limestone crushing capacity support the feasibility of expanding lime production by installing a second lime production line similar in capacity to the present plant, and of establishing an equilibrium in limestone crushed to proper industrial sizes with secure supplies both for the present and proposed lime plants. This trend is supported by the following facts:

(a) Limestone available from present exploited and future Hawari quarries is satisfactorily pure, thus yielding extra qualities of lime. As has been illustrated by raw material prospection in the present concessions, it is sufficient for 50 years of full production and for further extensions of the same quality. The good quality is also emphasised by practical experience in the present production, being superior to requirements of standard specifications. The third cement production line and the Hawari project will yield a considerable proportion of crushed limestone to the appropriate dimensions with the least investment for quarrying, crushing and conveying equipment. The expansion in lime production is therefore economic for both cement and lime industries;

(b) The existing lime plant suffers from bottle-necks in storage capacities. Lime production is consequently reduced whenever the output of the limestone crusher is diminished for any reason;

(c) The proposed lime extension represents an ideal solution to such a problem since the present and future storage can be interconnected with such facilities to eliminate bottle-necks and secure smooth performance notwithstanding an eventual crusher stoppage;

(d) The undesirable ingrediente of limestone, such as magnesia content, which are so harmful to the cement industry may be tolerated in lime manufacture where the maximum limit of magnesia content is 10%. The quarrying process can therefore be organised in the most economical way.

The proposed main lines for the extension project are summarized in annex IX. The estimated execution period is about 20 months from the date of contracting until readiness for acceptance tests.

Souk El-Khamis cement project

This project is maintained by Souk El-Khamis General Company for Cement and Building Materials (SUMIS). Its activities started with a lime plant of 90,000 tons/year of quicklime which is already being commissioned and handed over. The new cement plant of 1 million tons yearly production capacity, under construction by the German consortium Humboldt Wedag/Grün und Belfinger, is expected to be ready for acceptance tests by February 1977. Serious raw materials problems arose recently, threatening the soundness of future cement production. As an introduction to the study of this question, a brief account of the background is given below.

In 1971 Toura Portland Cement Co. (TPCC) was entrusted with performing a study for the installation of a lime plant in the Souk El-Khamis area (see orientation maps, annexes X and XI). In the area investigated the known potential limestone reserves suitable for quicklime industry were estimated as 10,104,000 tons net proved and 3,716,000 tons net probable, or 13,820,000 tons total, with an average composition of 89.35% $CaCO_3$, 3.34% $MgCO_3$, 4.61% SiO_2 and 1.65% R_2O_3. For installation of a lime factory with a yearly production capacity of 90,000 tons of quicklime, necessitating the quarrying of approximately 200,000 tons of limestone, the available reserves would cover the stipulated requirements for over 60 years. The investigation was accomplished mainly for the establishment of the lime industry. Besides, it was anticipated that there was the possibility for the erection of a cement factory of 200,000 tons of cement per year, necessitating extraction of about 360,000 tons of limestone.

The calcareous material proposed for the cement industry was estimated to be about 31,134,000 tons net proved and 5,356,000 tons net probable, or 36,490,000 tons total. The average analysis was reported to be 82.40% $CaCO_3$, 2.24% $MgCO_3$, 8.30% SiO_2, 4.05% R_2O_3, and 0.047% Cl. At the proposed rate of production, the lifetime of the field would be about 100 years. Inferred reserves of considerable magnitude were expected to exist in an area south of the area investigated and below the plains which was recommended for further drilling to enlarge the category of potential reserves. The spacing of the drilled holes was not done to fit into a regular grid. The sites of the holes were intended for an investigation of the features of the hills and extensions, as well as for tying up some of the widely separated exposures without a much deeper approach to closer particulars. However, it was emphasized that should it be decided to establish the cement industry in the area, more detailed raw materials investigations should be accomplished and the deeper limestone strata should be explored.

By the end of 1972 it was decided to install a cement factory in the area with a yearly production capacity of 500,000 tons of cement. Accordingly, the Italian firm Renardet - SAUTI was employed to make a raw materials study and a project evaluation, to prepare an international tender, analyse offers, and supervise execution. The consultant began by checking in detail the report of TPCC on raw materials reserves and relevant geology. SAUTI affirmed the findings of TPCC as regards the estimated quantity of calcareous materials without reserves; as regards the quality of material defined suitable for a cement industry, a more cautious partial composition of samples was recalculated with new criteria of the proportionality of various thicknesses. According to the new estimate, the northern sector of the southern zone was reckoned to comprise a quantity of about 22,016,000 tons net proved and 4,119,000 tons net probable, or 26,135,000 tons total, with an average composition of 86.32% $CaCO_3$, 3.18% $MgCO_3$, 5.29% SiO_2, 2.02% Al_2O_3, 1.05% Fe_2O_3, and 1.2% alkalies. SAUTI concluded that reserves were sufficient for a project of 500,000 tons per year of portland cement clinker for 25 years; they still recommended an additional boring campaign to ascertain further reserves. It was affirmed that average composition of raw mix from the investigated limestone area with clay from Bu Gheilan field had acceptable physical and chemical properties for manufacturing portland cement of good quality; they proposed the following raw-mix design (85.3% limestone and 14.7% clay):

	Limestone x 6	Clay x 1 (Percentage)	Raw mix	Clinker
SiO_2	31.74	63.01	13.53	20.97
Al_2O_3	12.12	15.94	4.01	6.21
Fe_2O_3	6.30	6.39	1.81	2.82
CaO		2.57	41.80	64.79
MgO	9.54	2.64	1.74	2.70
Alkalies	7.20	2.70	1.41	2.18
Cl	0.24	0.10	0.05	0.08
LOI		6.56	35.47	-
$CaCO_3$			74.7	-
SiR				2.34
AM				2.20
LSF				0.95
C_3S				58.56
C_2S				16.03
C_3A				11.69
C_4AF				8.57
Liquid phase at 1,450°C				23.85

The project was tendered and, on 12 June 1974, its execution was entrusted to the consortium Humboldt Wedag/Grün und Belfinger as a turnkey cement plant with a yearly production capacity of 1 million tons of cement. It was stipulated in the general contract that the contractor must perform his own revision of raw materials investigations and submit a report within 60 days about final findings as to the suitability of available raw materials for cement manufacture. In case of positive results the contract would come into force; otherwise, the contract would be automatically cancelled without reservations. On 12 August 1974, the said report stated that the analysis performed by KHD coincided on the whole with the limestone analysis of TPCC and the clay analysis of SAUTI, whereas it differed quite widely from the limestone analysie of SAUTI. Some differences have been attributed to lateral variations of MgO content. However, KHD stated that the quality of raw materials was suitable for production of portland cement in accordance with BSS 12/1958. The KHD report added that since the chemical composition of the limestone might be subject to considerable lateral variations, it would be indispensable to have another series of boring made on a close mesh-grid.

KHD prescribed a good homogenization of raw materials connected with a continuous chemical quality control, and proposed a raw mixture composed of 83.5% limestone and 16.5% clay (from Bu Ghaylan), with the main constituents calculated as follows:

	Percentage		Percentage
SiO_2	12.93	LOI	35.98
Al_2O_3	4.11	Alkalies	1.12
Fe_2O_3	1.72	Cl	0.01
CaO	41.18	SiR	2.2
MgO	2.50	AM	2.4
SO_3	0.25	LSF	0.975

KHD commented that the raw mix would have normal composition, suitable moduli and favourable sintering properties. The MgO, SO_3 and Cl content kept within acceptable limits, even though the system of heat exchanger was designed with a bypass system in order to avoid higher amounts of circulating alkali chlorides and sulphates. KHD ultimately re-estimated limestone reserves with a conservative calculation of 17.5 million tons, which would be sufficient for 12 years running with 1 million tons annual production of cement. Accordingly, the required raw materials investigations were entrusted to the Polish consulting firm Polservice in December 1975. Meanwhile, KHD selected the neighbourhood of bore-hole BH 5 for which test results entirely coincided. Grün und Belfinger (G & B) opened the quarry in fulfilment of contractual stipulations. KHD analysed samples from the new quarry front and declared that the chemical and geological situation was different from that expected on the basis of drillings. It was emphasised that the abundant occurance of MgO would impose an abnormal stripping and necessitate laborious selective quarrying. Furthermore, an igneous layer of 2-3 m thick tuff traversed the quarry front with a volcanic ash composition of:

	Percentage
$CaCO_3$	7.5
$MgCO_3$	0.4
SiO_2	82.5
Al_2O_3	1.5
Fe_2O_3	8.0

Consequently, KHD proposed to apply the tuff instead of clay component in the raw mix, although it would display different burning characteristics than the clay of Bu Ghaylan owing to different mineralogical composition. Mixing proportions would then be 83.4% limestone and 16.6% tuff, yielding the following raw-mix composition:

	Percentage		Percentage
SiO_2	12.99	K_2O	0.84
Al_2O_3	4.21	Na_2O	0.38
Fe_2O_3	1.57	LSF	100.00
CaO	42.39	SiR	3.09
MgO	1.45	AM	2.69
SO_3	0.11		

A correction has been recommended through addition of iron oxide (0.4-0.8% Fe_2O_3) for lowering the relatively high silica ratio and alumina modulus (AM). This raw-mix design reflects the situation at the existing quarry front which will be subject to changes during future exploitation. KHD eliminated limestone strata of undesirable MgO content, and the residual accessible limestone would therefore be hardly sufficient for two years' production. With respect to the remaining limestone reserves, KHD asked for the initiation of additional check drillings within the area previously investigated. A new calculation of reserves can be carried out only after the test results of the new drillings are available. Finally, KHD asked for mutual negotiation of modifications proposed for the new circumstances, with subsequent price revision and time schedule for execution. The results of the negotiations may be summarised as follows:

(a) Urgent raw material investigations should be performed to disclose more suitable limestone reserves for start-up of the factory. Drilling should be started immediately in the vicinity of the opened quarry front to determine detailed characteristics for the near future, together with drillings in the neighbourhood of the existing lime quarry located in the northern part of the prospection area. This part represents an uplifted member to the north of a major fault extending north-east - south-west. The limestone reserves already studied in this area amount to 13 million tons of good quality; only the northern part of the area has been devoted to lime production. The southern continuation of this area appears to be a geological extension of the prospected part. The preliminary estimate for limestone reserves in the proposed area would amount to 12 million tons;

(b) Further drilling should be extended in the middle area, between the lime quarry and the new cement quarry, to investigate this area as soon as the urgent stage is over. This study may be considered an intermediate stage. This area was formerly overlooked on the assumption that its probable reserves might not be of major magnitude, but actually all possibilities should be explored;

(c) Long-term investigations should then be accomplished by extending the drilling work in the neighbourhood, starting with the areas to the south of the cement quarry and in the plains. Reserves of raw materials should be assured for at least 25 years of production at the scheduled rate and 25 years more as a provision for probabilities of future extensions;

(d) The first stage of urgent investigations should be accomplished within a maximum elapse of two months. Only then can the true image for the start-up raw-mix design be finalised. It is hoped that the good quality limestone to be disclosed may be mixed with available limestone from the newly opened quarry together with the layer of tuffs, in order to reduce the total percentage of MgO and to avoid complications of sorting out. The Bu Ghaylan clay addition will then have to be reduced to an extent depending on the amount of igneous rocks included;

(e) It is therefore advisable to carry on with the preparation of the new quarry front as previously scheduled, after correcting the procedure for exploitation according to the actual dip of the limestone strata. In the present stage, it is unnecessary to make modifications involving additional machinery and time, for a quarry front that may change within a few months of its initial exploitation or for reserves that may suffice only for two years according to the latest estimate. The general contractor may be addressed on this basis and in respect of his report of 12 August 1974, which composes a part of the general contract.

Green mountain cement project

The Government of the Libyan Arab Republic has intended to establish an extension of the cement industry in the eastern zone, in order to cope with increasing cement demands in the area and to secure a surplus for export. On 21 February 1974, the General National Organization for Industrialization (GNOI) contracted with the Swedish firm UNICONSULT (architects and consulting engineers) for studies for the installation of a cement plant in the Marj/Derna region, with an annual production capacity of 500,000 tons of cement.

Investigations accomplished so far in Marj, Beida, Susa, Sirena, Derna, and Um Arrasam areas have proved limestone deposits of ample quantity and quality in the main region of Marj and Derna, mainly of Miocene limestone. Locations of the areas are shown on the sketch in annex XII. Most suitable clay deposits were found only in the Marj area whereas the others were not promising; some places are entirely devoted to agricultural projects and in others the clay is unsuitable for the project since it is embedded in huge strata of dolomitic limestone, or it is not homogeneous with occasional traces of undesirable ingredients such as magnesia, sulphate, alkalies and chlorides, irregularly pronounced at various levels which would be difficult to avoid. Investigations have not revealed any appreciable economically accessible gypsum deposits in both regions. The nearest gypsum formations exist in areas of Bajma, Hawa El-Barag, Bu Mariam and El-Gara; all these areas are in the vicinity of or at least nearer to Benghasi.

The pilot investigation work was carried out in a total area of 60 km^2 distributed over 12 separate areas of major interest. Preliminary work was concluded: geological surveying, topographical mapping, pilot trenching and drilling, sampling and analyses. Pilot conclusions are summarised in the following section.

Area DC 2/DC 3

This area is situated around the village of Um Arrasam at an altitude of 60-80 m above sea-level (masl). The clay has a high content of chlorides which would create inconveniences for the dry process. It underlies an overburden of 10-15 m of limestone with a very high content of MgO which renders the access to clay impracticable.

Area DL 1 (Derna)

This area extends between the upper border of the escarpment and the Mediterranean Sea, bounded in the east by Wadi Naga and in the west by Wadi an Tagah. The predominant kind of rock is composed of different kinds of limestone. Except for the uppermost 30-40 m, the rock is of good quality for cement manufacture.

Area DC 4 (km 23)

This location is 23 km south-east of Derna where the main road Derna-Tobruk crosses Wadi Martubah, at an altitude of 220 masl. Clay deposits yielded negative results, since they are only occasionally of a thickness corresponding to the depth of the Wadi and are restricted by its slopes.

Area DC 5 (Ghawt el Quanabi)

This area is about 5 km west of the village of Martubah at an altitude of about 320 masl. No appreciable clay was found except for superficial amounts in the central parts.

Area DC 6 (km 19)

This area is 19 km south-east of Derna at an altitude of about 260 masl. A great layer of pure consistency is embedded deep below 30 m of dolomitic limestone of the same geological formation as that in Um Arrazam. Access to the clay is therefore impractical.

Areas ML 3/ML 4 (Marj)

These areas are situated on the south-eastern bordering slope towards the Marj plateau, respectively 6 and 5 km south-east and south of the city of Old Marj. Crystalline limestone is the predominant kind of rock. There are huge amounts of pure limestone with a low content of magnesia, alkalies and chlorides.

Areas MC 8/MC 10/MC 11 (Marj)

These areas are on the slope of Marj Plateau, to the north 290-330 masl, to the north 300-320 masl, and to the north-west 290-370 masl. The amount of clay increases from the north to the south where it attains a considerable thickness up to 7-20 m. The clay is pure and free from gravel, except MC 11 where a thin horizon of limestone underlies thin superficial clay.

Area G1 (Al-Himadah)

This area is in the vicinity of the village of Al-Himadah, about 25 km west of Marj at an altitude of 300-375 masl. Gypsum is found occasionally as crystalline aggregates located in caves on the tops of hills, which would limit their extension, or in flat plains. At the surface there are no indications where to find gypsum, which makes the geographical distribution somewhat haphazard.

From the above-mentioned pilot survey the most feasible areas seem to be ML 3 for limestone and ML 7 or ML 10 for clay within the Marj area, about 90 km to the east of Benghazi. A preliminary indication is given in annex XIII of the average limestone and clay analysis for Marj pilot prospection. For a more precise idea of various possibilities of raw-mix composition from these raw materials, more detailed investigations would be required. A more elaborate, detailed investigation in the Green Mountain has been undertaken by GNOI, among the international consulting firms. In this connexion the consultant would recommend that various facts be included in a sound feasibility study. It would be of vital importance to initiate a precise market study, taking into consideration the most recent trends in cement demand based on the prospectives of national industrialization plans, as well as on the latest view of the export market especially in the Mediterranian countries and in middle and west African regions. It is worth mentioning that the information obtained at the latest Amman Conference, which was organized by the Industrial Development Center for Arab States (IDCAS), threw light on the present boom in extensions of the cement industry which will certainly be reflected in the cement export market. In West Africa an industrial complex is being projected for the production of cement sufficient to meet development programmes in the area. This project is a transaction among several West African countries and may be financed by the World Bank. Furthermore, in the Great Sahara, adjacent to the Libyan Arab Republic on its southern frontiers, the Republic of Niger is preparing an extension of the cement industry up to 10 times the local requirements. Niger is therefore negotiating for a common export market with Nigeria through the Economic Commission for Africa (ECA). The feasibility study recommended will certainly help decision makers to select the most suitable site location and determine the most appropriate project size. This study may also take into consideration the possibilities of future extensions of the Benghasi works, in virtue of the ideal circumstances of raw materials, export facilities, experienced labour force and other techno-economic advantages.

In the course of the present tendering for a raw materials study in the Marj/Derna area, LCC was approached to have kiln No. 1 used to make pilot tests for the semi-industrial investigations of samples of the raw materials related to Marj/Derna cement project. In this connexion, the consultant recommends that any discussions should take into basic consideration all factors affecting security of machinery and continuity of good quality production without any interruption. The most important questions to be clarified are:

(a) Investigations of the composition of raw materials, with special reference to undesirable ingredients, raw-mix design with subsequent moduli, expected impact of each factor on performance of machinery and quality of product;

(b) Guarantees against possible deviations from optimal procedures, involving probable incidents of material damage, process failure, unbalanced performance, defective products, or production loss. This necessitates a detailed account of:

- (i) Measures to be taken to assure well-qualified technical personnel, experienced and in sufficient number to immediately rectify any abnormal phenomena;
- (ii) Liabilities for replacement of damaged material, compensation for defective or lost production in cases such as clogging of mills, blockage of heat exchangers, abnormal wear of lining, massive clinker coating promoting ring formation, excessive dust recirculation, side effects of undesirable ingredients.

In view of all the above-mentioned risks, it would be more feasible to arrange for a semi-industrial test in a well-equipped pilot plant in accordance with established technological practice.

Sundry questions

During the three months' mission, various daily problems were encountered. Through close co-operation with the national counterparts, the consultant kept informed of the particulars of process operation and maintenance. The procedure of tackling problems was through discussion and systematic investigation. Proper solutions were consequently found and adopted. The following are some examples of such problems.

Gypsum quarries

Raw gypsum was being quarried from Ar-Ragma quarries 39 km to the east of Benghasi in the vicinity of Ar-Ragma village (see annexes XIV and XV). The gypsum stock in the factory was gradually diminishing and a partial reduction of the output of the cement mills was threatening production.

The problem originated from transport difficulties owing to complications involving the connecting side road to the new Ragma gypsum quarry. The LCC gypsum transport had to take a longer route along a bumpy passage in the desert off the paved main road, which together with special local restrictions in the area was reducing the productivity of the plant.

To secure the gypsum necessary for cement grinding without a deficiency and consequent interruption, the consultant organised a plan for exploitation of the old Ragma quarry during a transitional period in which there would be ample time for securing cement grinding, making up a suitable gypsum stock in the factory site, and solving problems of additional road length to the new Ragma quarry. To execute the plan a new convenient entrance was blasted to make a short passage to the neighbouring asphalt road. Obstacles were removed by clearing away limestone barriers. The gypsum handling was thus restricted to a paved road and economical transport, and the situation was ameliorated.

However, the gypsum reserves in the old Ragma quarry are limited, and the consultant recommends that it be exploited only as a standby in emergency cases. Quarrying should be resumed in the old Ragma quarry after the road transport problem has been properly settled.

Cement physical tests

One of the most important questions that worried personnel in charge of quality control was the remarkably low results of compression-strength tests performed in the LCC physical laboratory. As may be seen from annex XVI, most cement samples had strength figures that did not comply with requirements of the British Standard Specifications (BSS 12/1958). After detailed investigations of procedures of quality control and a general survey of process particulars, the testing conditions were carefully revised. The quality of testing sand and the quantity of guaging water were first checked. The hydraulic compression-strength testing machine was calibrated by an external pressure gauge belonging to the concrete crushing machine of G & B. The speed and rate of vibrations of the standard vibrating machine (cube) were controlled and its exhausted springs were replaced by a new set that could be manufactured in the workshop of a sister cement factory. Meanwhile the mortar mixer was provided with a rectified mixing paddle with an adjusted clearance. Ultimately, the ideal testing conditions were established, and the proper testing results were attained. As indicated in annex XVII, the compression-strength test results consequently showed crushing figures of 256 kg/cm^2 for 3 days, and 375 kg/cm^2 for 7 days in the average for the month of March 1975 after rectification of testing conditions. This meant about a 60% advantage for the cement produced over the requirements of standard specifications, which indicates the superior quality of production.

Production of masonry cement

The recent trend towards acceleration of national development plans in the Libyan Arab Republic has created an increased demand for cement. Several extension projects are being executed, while investigations are being performed for the installation of new cement plants. During the transition period until local cement production will be sufficient for covering local consumption, it would be more economical to produce masonry cement. This would represent a more economical application of natural resources and would add supplementary products to the national potential. LCC can produce masonry cement at an economical cost/price and consequently a lower sales price, still with more profit. Moreover the production capacity increases considerably with the same number of rotary kilns. It is also economical for cement consumers since they can apply cheaper cement for various purposes such as plain concrete, mortar for building bricks, and plastering work, which do not necessarily require high-resistance cement.

The high-grinding capacity installed in the existing works and extension project provides a good possibility for production of masonry cement which requires more grinding units in view of the finer grinding and bigger quantities. If figure of 25% is taken as a proportion for mixing the added ingredient in the masonry cement - as a preliminary estimate for calculation of necessary grinding units - the grinding scheme may be programmed as follows:

(a) The production capacities of the two existing production lines and the extension (Benghazi 3 to be started up within the next few months):

	Clinker production		5% gypsum retarder (tons)	Production capacity (tons normal portland cement)
	(tons/day)	(tons/year)		
Production line I	600	200,000	10,000	210,000
Production line II	1,200	400,000	20,000	420,000
Production line III	1,200	400,000	20,000	420,000
Total	3,000	1,000,000	50,000	1,050,000

(b) Available grinding possibilities may be expressed as follows:

	Cement mills		Grinding capacity	Surplus available
	(Tons/h x 22	h/day	x 330 working days)	(Grinding units)
Production line I	45	990	326,700	116,700
Production line II	90	1,980	653,400	233,400
Production line III	90	1,980	653,400	233,400
Total	225	4,950	1,633,500	583,500

The above-mentioned data clearly indicate that the grinding facilities could handle about 55% more material than the available production capacities can supply. In other words about 36% of the available grinding capacity is idle and can therefore be utilised for extra grinding of new types of cement.

If the application of masonry cement is restricted to purposes other than reinforced concrete construction, it may be foreseen that about 40% of cement consumption would be of the masonry type. The production scheme can therefore allow for the following material handling:

Type	Clinker	Additive	Gypsum	Cement	Grinding units
Normal	670,600	-	35,400	706,000	706,000
Masonry	329,400	118,000	23,600	471,000	589,000
Total	1,000,000	118,000	59,000	1,177,000	1,295,000

Masonry cement can be produced only after a detailed investigation is made for suitability of local raw materials for the purpose. Before the new product is introduced to the local code of practice, a comprehensive study should be performed to prove the perfection of the quality which should be determined with national research centres and approved by the authorities concerned. The consultant therefore recommends a detailed study for the production of masonry cement on a laboratory scale. One of the promising mixing ingredients could be the siliceous hard limestone forming the top 1-2 m layer in the limestone quarry, which can be exploited in a separate bench. The testing facilities are available in the laboratory where there is already a pilot jaw-crusher with a feed opening of 60 mm and a laboratory test ball-mill with a tube content of 50 l. The final results can also be verified by a small industrial test and the resulting pilot sample should be used in the masonry works before the findings are officially submitted.

Maintenance of machinery and equipment

The procedure of preventive maintenance is one of the most important operations in the Benghazi cement works. The efficiency of the machinery and equipment and productivity depend mainly on the sufficiency of maintenance activities as well as the correctness of operational processes. The process personnel must take care of cleanliness of all parts of production units to maintain the proper environment for effective maintenance. The maintenance and lubrication personnel may not be able to perform their task satisfactorily if they are confronted by inconveniences such as dusty channels, blocked passages, and bearings and gears contaminated with dust.

The operational personnel cannot attain optimum productivity if the preventive maintenance is not effectively organised and punctually performed. The task of cleaning may become impracticable with flowing chutes because of excessive wear of the steel lining, dusty handling if the filters do not function properly, an accumulation of stagnant dust blocking the horizontal dedusting pipes, and eventual leakage from various conveyors. The production and raintenance processes are interrelated. A fruitful step has been to have the maintenance and operational instructions manuals of the main machine suppliers translated into arabic for training activities. Preventive maintenance particulars should be tabulated in a simplified comprehensive schedule. It is also recommended that specified groups of maintenance personnel be assigned for every group of machinery with well-defined responsibilities for timing of periodic inspection, revision checking, routine maintenance and general over-hauling with special reference to man hours per operation and average lifetime of wearing parts.

For example, one of the mills and related conveyors should be stopped for inspection and maintenance one day a week in order to cover the whole group of mills and their accessories consecutively in a week. This would assure more intensive maintenance than performing the maintenance of all mills in one day, which might occupy all personnel and still not cover emergency cases in other production sections.

The existing production lines have not been in operation long; they are still considered as good as new. But shortly various mechanical and electrical inconveniences will occur as a result of the usual wear and tear encountered in normal practice as machines age. New sorts of serious difficulties may occur if protective maintenance is not kept up to the best technological standards. For some specialised technologies the know-how of the machine supplier is valuable to assure the best results. It is therefore recommended that a specialist be invited from Carl Schenck, AG, Darmstadt, West Germany to check maintenance and repair of Schenk balances and constant weigh feeders; and an expert from H & B, Mess- und Regeltechnik, Frankfurt, Federal Republic of Germany, to revise, control and calibrate fine measuring equipment, and a high calibre, experienced mechanical engineer from KHD, Industrieanlagen, Köln, Federal Republic of Germany, to rationalise a general revision and inspection of machinery and equipment with special stress on the following:

(a) Programming of preventive maintenance and regular inspection and periodic overhauling, tabulating the timing, securing the necessary material, and estimating the labour force for each operation;

(b) Systematization of the procedure for ordering spare parts, starting with the identification of average lifetime for each wearing part and, consequently, the recommended minimum stock;

(c) Revision of kiln alignment and consequent readjustment of roller supports if necessary. In this connexion the life ring of the outlet of kiln II seems to exert abnormal stresses, indicated by symptoms of stripping off of the lateral holding pieces of the life ring;

(d) Inspection of gearing systems with subsequent rectification of meshing, turning or substitution of any gear or pinion if required. One of the most striking examples is the pinion of the main drive for cement mill II, which suffers from abnormal wear;

(e) Survey of the balancing of bucket elevators. It should be mentioned that the chain of the clinker bucket elevator (P 109) has been exerting severe friction against its steel shaft so that the latter is seriously perforated. P 109 and P 306 are each supposed to have a 90 tons/hour lifting capacity. One should handle the production of the two old kilns (I and II: installed production capacity = 25 + 50 tons/h successively); consequently, the other elevator is considered as standby. Actually, one elevator alone is insufficient for clearing away the production of both kilns. The two clinker bucket elevators should therefore run together all the time, thus allowing no chance for regular maintenance.

The above-mentioned specialists should make yearly visits after spare parts and implements required for the operations in question have been prepared.

Supplies of spare parts

Spare parts reserves should be sufficient to secure the proper functioning of machinery and equipment. A missing spare part can easily cause a standstill in production. With the progressive aging of old production lines, more parts will show symtoms of wear and will break down more frequently than during the guarantee period. The spare parts supply should be rationalised through systematic procedure of ordering in accordance with minimum stocks data. A considerable effort has been made to register minimum and ordering stocks on stock cards in the main stores. But owing to the shortage of reliable information about the main features of wearing parts in terms of average lifetime and probable eventualities these figures of minimum and ordering stocks should be revised from time to time according to practice and the advice of machine suppliers. The system of spare parts should not be subject to hazard or depend on the care of someone whose memory may not be entirely reliable. It would be advisable to make a general order at the beginning of each calendar year. This operation would profit from reference to the general inventory which is normally performed by a reliable committee at the year's end. Another phase of ordering on a smaller scale may follow during the year if excessive application reduces a particular item to the ordering stock. The storekeeper would then notify the technical person concerned who would investigate the reasons for the additional requirement and readjust according to practical experience and special working conditions. The rectified quantities would then be passed to the purchase department for quotations and the issue of official orders in time. In case the stock figure attains the minimum or critical stock, special emergency measures would have to be taken to speed up procurement.

It is advisable to keep up a stock of two years' consumption of imported spare parts, taking into consideration the time necessary for: submission of the requisition; exchange of correspondence; working out of quotation; evaluation and issue of official order with credit opening; delivery time of 6-12 months; and packing, shipment and clearance from customs. A precise register should be kept in the main stores, including the life history of each operation in the form of follow-up from the first purchase request through stages of technical revision, submission of requisition or tender, procurement of quotations, evaluation and approval, opening of credit, issue of the official order, confirmation of suppliers, delivery and shipment, arrival to local port, customs clearance of consignment, to reception with revision and quality control and ultimately classification in the proper bin. Each step should be clearly marked out with data and reference number, and delays should be made up in time. This procedure would eliminate the risk of surprises with missing spare parts and would also avoid blockage of the purchase procedure at any of the import stages.

Survey of refractory lining

During the period of the mission kiln No. II was stopped to reline the burning zone with magnesite fire bricks (MZ) and the transition zone with magnesite chrome fire bricks (MC). It was noted that the required dimension (B 420) was intermingled with intrusive dimension (B 320) owing to faulty packing into wooden crates marked the same (B 420). Meanwhile kiln No. I was stopped for maintenance of the Füller clinker cooler. The inspection of fire bricks revealed some weak points in the calcination zone of 42% Al_2O_3, but the relining was hampered by the insufficiency of adequate bricks of the sort. A full survey was made of the situation, and the incident was taken as an instance pointing to the necessity for reorganization. The stock of fire bricks was revised and an up-to-date inventory was established. Based on the original kiln data, guide figures for minimum and ordering stocks were drawn up, and a requisition was submitted for ordering the necessary bricks to make up complete lining sets (annex XVIII).

The procedure for following up life history refractory lining was discussed with the technical personnel responsible. A register was started to give the particulars of refractory relining, starting with dimensions of inlet, calcination, transition, sintering, and outlet zones, with relevant refractory types, reference particulars, number of bricks per ring and total number off per zone (see annex XIX). For every relining operation a linear representation has to be indicated in the relined spot, with registration of the relining date, worked length, type and number of applied fire bricks. The accumulated series of linear representations in one relining after another will illustrate the life history of fire bricks at every point along the kiln. Subsequent information can therefore be concluded for mean lifetime of refractory material in every spot, the average consumption of firebricks per ton of realized clinker production, and deviations from normal rates in relation to abnormal burning conditions. This information would be of great value for rationalizing the application of firebricks, economy of refractories consumption, and systematization of ordering operations.

Organization of refilling mills

Adequate measures must be taken to keep up the recommended optimum charges of grinding media in the raw and cement mills. A discrepancy in the mill charge leads to reduced output owing to lack of grinding power. Moreover, it makes for excessive wear on the lining plates and grinding bodies because of the increased fall of steel balls instead of the designed cascading motion.

The case study of raw mill No. II is an exemplification of checking procedure. Inspection of the mill showed a lower charge level. The lining plates showed symptoms of excessive wear. As a consequence, the classifying action of lining plates was reduced to some extent, and the steel balls were evidently segregated. Steel balls of the largest diameters are concentrated along the first five rows of lining plates in the second compartment right after the diaphragm. This position consequently shows heavy wear, which is aggravated by a peculiar phenomenon of breakage of lining plates. In this connexion it would be advisable to fill in the hollow back of the lining plates with asbestos cement mortar. The grinding features of raw mill No. II are graphically represented in the particle distribution grindability curve (annex XX), which shows the feeble rate of disintigration because of the lower charge and the sharp break after the middle diaphragm because of the segregation. It is therefore recommended that profit be made of the next stoppage of kiln No. II to sort out steel balls of raw mill No. II, re-weigh the classified dimensions and fill up the mill with the recommended charge of grinding bodies. Refillings have to be regularly registered in the follow-up sheet shown in annex XXI. Ultimately, from the interrelation between various data the average wear of grinding bodies may be determined per ton production, and the average electrical power drop for the consumption of each ton of grinding media. After a few years' practice the final average figures can be applied for further refillings; with the mill inspection the situation is revised and the refilling is performed accordingly:

(a) The total output of the mill is added up since the previous filling, this production tonnage is then multiplied by the average figure for wear of grinding bodies per ton of ground material: gm media wear/ton x tonnage production = required charge filling;

(b) The total drop in the rated kW consumption of the mill proper (excluding accessories) is worked out in terms of tonnage of corresponding grinding media: kW drop x tonnage media per kW = required charge refilling. The same result may also be obtained from the mill amperage which can be worked out according to the relation:

$$N = \frac{VA\ 1.732}{1000}\, n \cos \phi \text{ (in kW)}$$

Where N = power of motor, V = voltage, A = amperage, n = efficiency of motor (0.88-0.9), and cos ϕ = power factor, dependent on the phase displacement of the motor (the value of this rating is indicated on the rating plate of the motor);

(c) The charge of steel balls is measured in each mill compartment, by measuring the empty section or by counting the circumferential rows of lining plates. The volume of charge is then calculated according to the equation:

$$V = L\left(\frac{a}{180} r^2 \pi - \frac{bh}{2}\right)$$

Where V = volume of charge, L = length of compartment, r = radius, b = breadth of charge, a = angle from central column, and h = perpendicular distance to center.

The weight is worked out from the specific weight to be practically determined. Guidelines for specific weights may be taken as:

Diameter of steel balls (mm):	30	40	50	60	70	80
Specific weight of bulk (kg/m^3):	4,900	4,740	4,600	4,560	4,490	4,400

The weight of actual charge is related to the recommended charge, and the deficit is concluded by the difference. Ultimately, the three aforementioned alternatives are combined for attaining the most reliable conclusion, according to which the refilling is accomplished up to the optimum charge. The latter is calculated according to percentage loading, to be multiplied by the clear cross-sectional area in m^2 x length of the mill, or specific compartment in metres x bulk density of grinding media in kg/m^3.

This procedure simplifies the refilling operation without need for frequent re-weighing. A general revision may thus be sufficient once every year for rectifying any accumulated error and sorting out deformed, split and worn-out grinding bodies. The aforementioned registration system systematizes the refilling proceedings, allows an evaluation to be made of the qualities of various makes of grinding media, and ensures ample ordering of yearly requirements according to the scheduled production.

II. RECOMMENDATIONS

The following recommendations are based on the findings and conclusions of this report:

1. It would be advisable for LCC to strengthen the labour force as detailed in annex XXII, thus making available the technical personnel required to operate the third production line and sufficient also for the Hawari cement works. Some of the best qualified present operators and maintenance attendants can take care of the third production line, and some of the assistants may be promoted to take on more elaborate responsibilities in the old plant.

2. The available gypsum reserves are sufficient only for 10 years' cement production, whereas at least 25 years' lifetime should be assured. Detailed investigations for new gypsum resources are necessary. The former proposal for the establishment of a plaster industry in the region might be postponed further until the results of present investigations assure at least 6 million tons of raw gypsum for cement industry.

3. It is essential to secure the required water supply for the expanding industries up to 2,000 m^3 per day. The sixth water well in Wadi Gattora should be operated and connected to the automatic control system, which is to be adjusted to a working sequence in two consecutive groups with adequate pressure gauges and flow meters. Further confirmatory tests are needed to indicate extra measures to be taken before the start-up of the Hawari plant.

4. It is evident that the progressive deterioration of raw water imposes an extra burden on the present demineralisation plant. The blow-down process must be performed more frequently to dilute the concentration of total dissolved solids. Reinforcement of the demineralisation procedure is therefore of primary importance.

5. With the foreseen increase in sanitary water consumption in accordance with the growth of the labour force, it is necessary to extend the present sewage handling facilities, either by doubling the existing biological treatment installation or by connecting the site sewage with the main drainage system, to be accomplished by the municipal authorities.

6. The gypsum storage bin may not suffice for more than two days' cement grinding with the three cement mills. It would be advisable to keep in one

compartment of the raw materials storage hall a supplementary gypsum storage, which can be reclaimed by the stope scraper and transferred to rubber belt conveyors leading to the gypsum hoppers of the cement mills.

7. For fruitful reinforcement of the project for the training and managerial development centre LCC might make use of technical training aids, industrial information services, research and documentary facilities arranged by UNIDO.

8. To attain optimum production in the existing lime plant it would be advisable to increase the range of sized limestone to 25-70 mm, maintain a strict control over crusher performance, enlarge the screening delivery chute, and keep the raw storage silo full to avoid limestone crumbling owing to deep fall.

9. In the course of planning particulars for the extension of the lime plant, profit should be made of the huge limestone crushing capacity of the third cement production line and the Hawari cement plant. Bottle-necks in present storage capacities should be remedied with adequate storage extensions.

10. For a closer approach to solving the problems of raw materials in the Souk El-Khamis cement project, urgent drilling should be done in the vicinity of the opened quarry front near the lime quarry and the intermediate region; this should be followed by long-term investigations in the southern area and plains to assure reserves for at least 25 years' production.

11. For a proper evaluation of the Marj/Derna cement project the scheduled detailed raw materials study should be backed up with a complete feasibility study that would include a recent market study to select the most suitable site location and to determine the most appropriate project size. This study may also consider possibilities of future extensions of the Benghazi cement industry, in virtue of the ideal circumstances of raw materials, export facilities, experienced labour force and other techno-economic advantages.

12. In virtue of excessive surplus cement-grinding capacity, it is recommended that masonry cement be produced after performance of a detailed investigation to determine the suitability of local raw materials for the purpose.
Before the product is introduced to the local code of practice, a comprehensive study should be made to prove the perfection of the quality which is to be negotiated with national research centres and approved by the concerned authorities.

13. As the gypsum reserves in the old Ragma quarry are limited, and because of favourable conditions in this quarry, its exploitation should be kept as standby only in emergency cases. It is therefore proposed to resume quarrying in the new Ragma quarry after the road transport conditions have been improved.

14. Preventive maintenance particulars should be tabulated in a simplified comprehensive schedule. A group of maintenance personnel with well-defined responsibilities should be selected for every group of machinery; this personnel would be responsible for timing of periodic inspection, revision checking, routine maintenance and general overhauling with special reference to man-hours per operation and average lifetime of wearing parts.

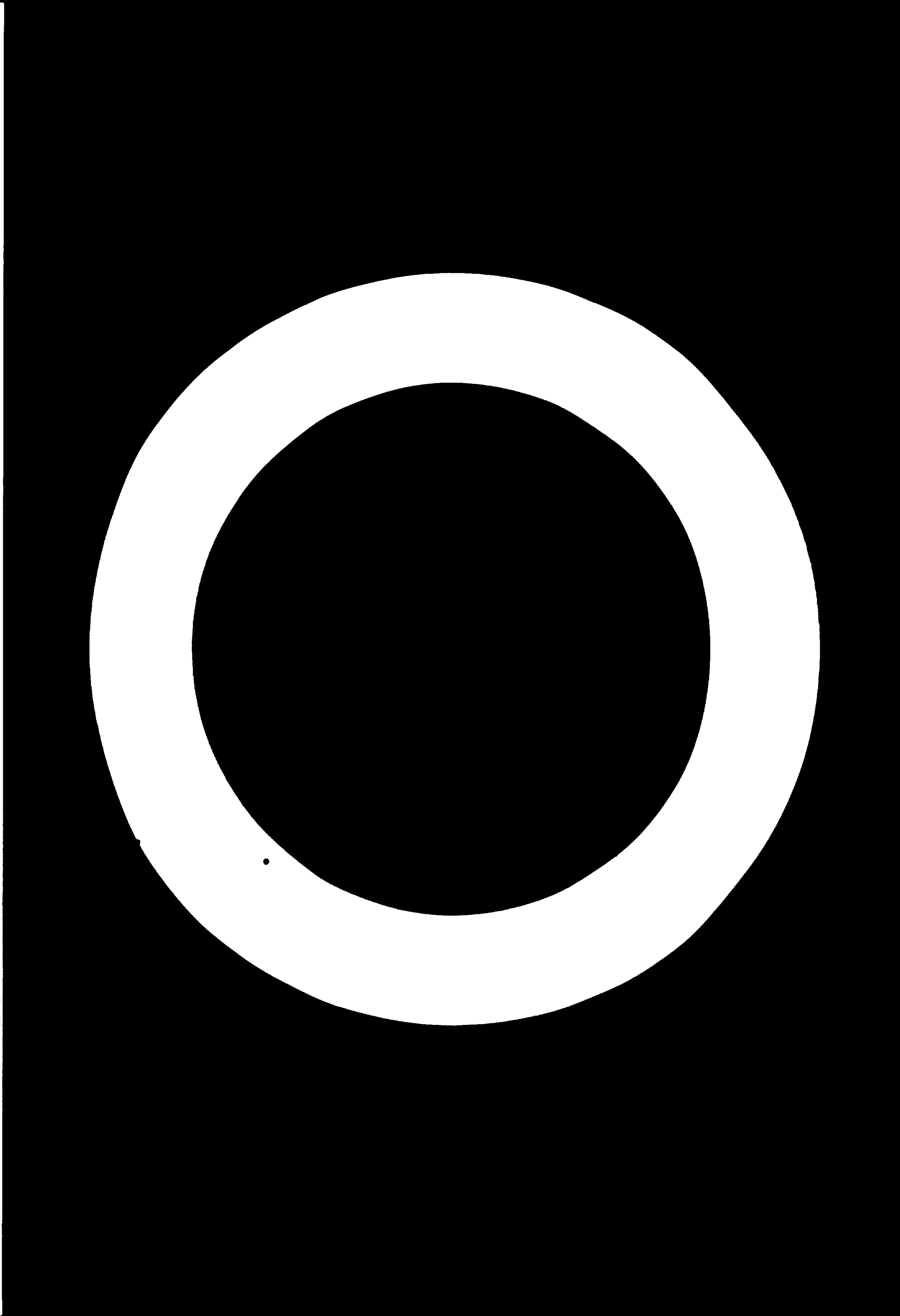
15. Arrangement should be made for a specialist from Schenck to make a yearly inspection and overhauling visit to check maintenance and repair of Schenck balances and constant weigh feeders; an expert from H & B to revise, control and calibrate fine measuring equipment; and a high calibre, experienced mechanical engineer from KHD to rationalize a general revision and inspection programme for preventive maintenance, to systematize the ordering of spare parts, to revise the alignment, and to inspect the gearing systems and the balancing of the bucket elevators.

16. Provision of spare parts should be rationalized with a systematic procedure of spontaneous ordering in accordance with ordering and minimum stocks data. It would be advisable to make a general order at the beginning of each calendar year, profiting from the inventory of the year's end. Another phase of ordering on a smaller scale might follow during the year if excessive wear and tear reduces the stock of a particular item. A precise register should be kept in the main stores giving the history of each operation as a follow-up until reception with revision and quality control.

17. A register should be kept giving particulars of refractory relining, with a linear representation of every relining operation. The accumulated series of registration would illustrate the lifetime of refractory material in every spot, the average consumption of firebricks per ton of realized clinker production, and deviations from normal conditions.

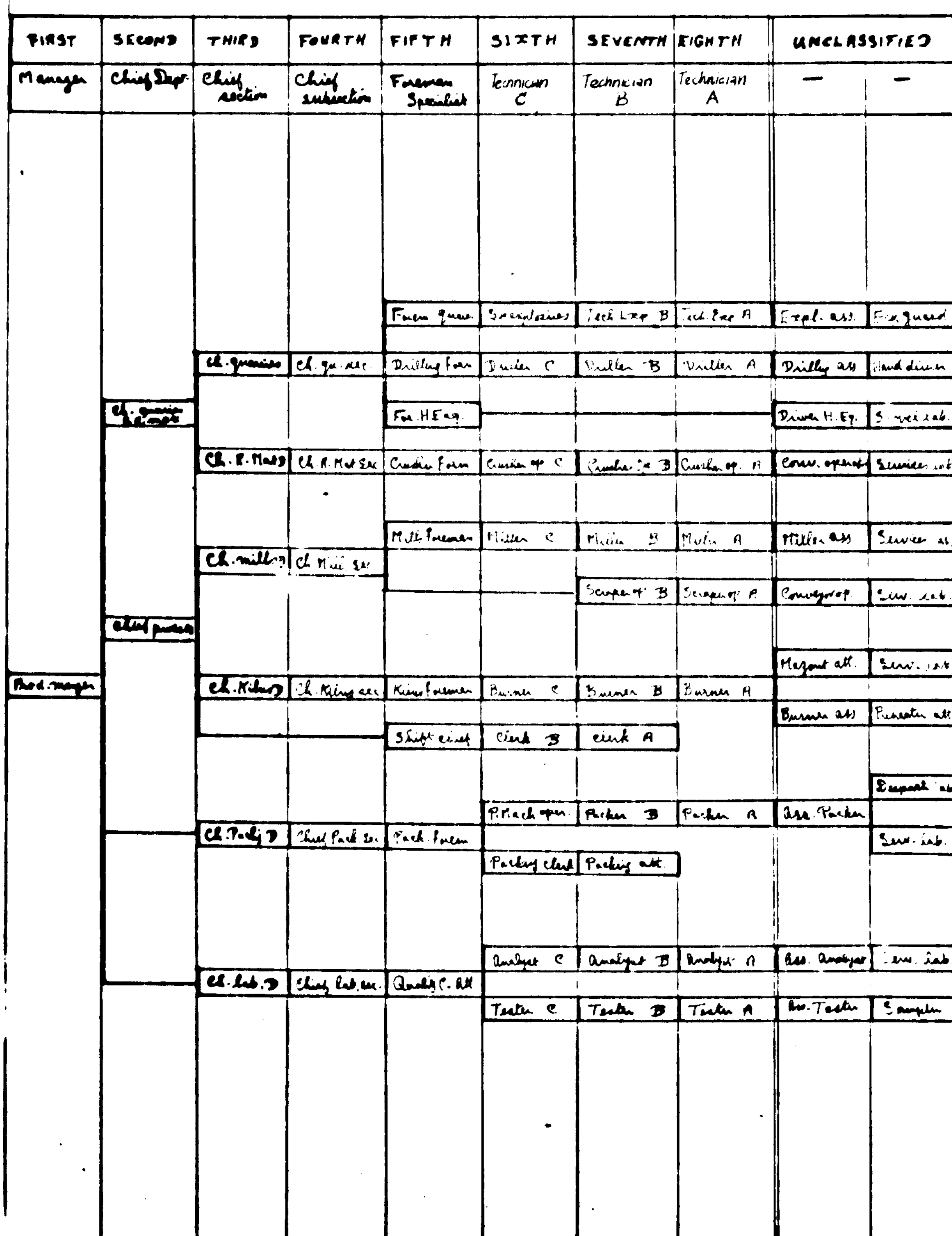
18. Adequate measures should be taken for keeping up the recommended optimum charges of grinding media in the raw and cement mills. Refillings should be registered regularly on a follow-up sheet. The interrelation between various

data should be studied to figure out the average wear of grinding bodies per ton of production, and the average electrical power drop for each ton of consumption of grinding media. These conclusions can be utilised as guidance for further mill refillings.



Annex I

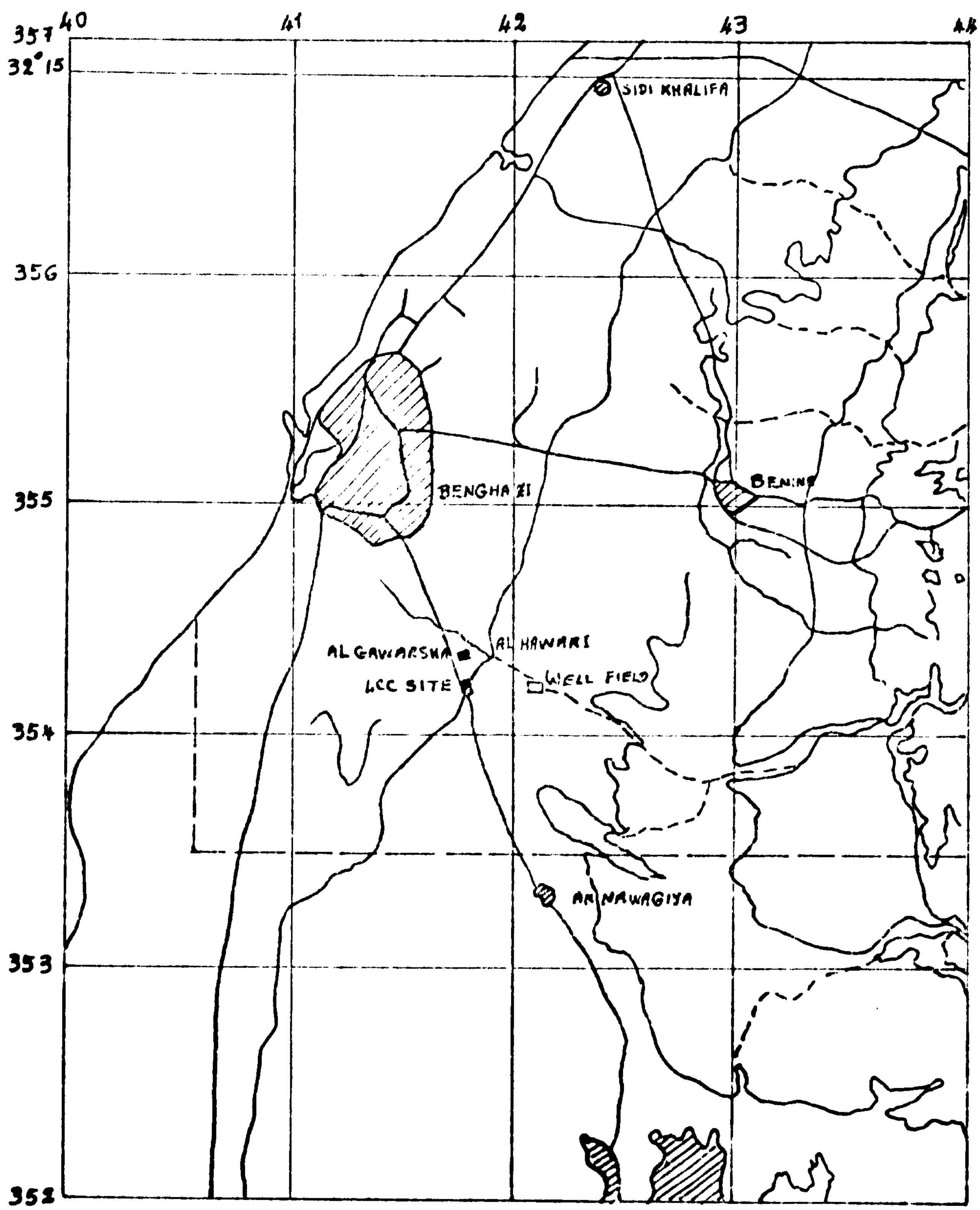
PROPOSED ORGANIGRAM FOR TECHNICAL PERSONNEL



FIRST	SECOND	THIRD	FOURTH	FIFTH	SIXTH	SEVENTH	EIGHTH	UNCLASSIFIED	
Manager	Chief Dept.	Chief Section	Chief Subsection	Foreman Specialist	Technician	Technician	Technician	—	—
				Greasy Fore.	Greaser C	Greaser B	Greaser A	Greas. ass.	
		Ch. section mech. main	Ch. Subsec. mech. main		Fitter C	Fitter B	Fitter A	Ass. Fitter	
				Mech.m. Fore.	Welder C	Welder B	Welder A	Ass. welder	
	Ch. Dept. Main & W. Mech				Fitter C	Fitter B	Fitter A	Ass. Fitter	
					Welder C	Welder B	Welder A	Ass. welder	
					Platesmith C	Platesmith B	Platesmith A	Ass. Plates.	
		Ch. section mech. W/Shp	Ch. Subsec. mech. W/Shp	Foreman mech. W/Shp	Machinist C	Machinist B	Machinist A	Ass. mach.	
					Pipesmith	Pipesmith	Pipesmith	Ass. Pipe S.	
					Blacksmith C	Blacksmith B	Blacksmith A	Ass. Blacks.	
					Turner C	Turner B	Turner A	Ass. Turner	
Chief Eng.			Ch. Subsec. Elect main	Foreman Elect main	Electrician C	Electrician B	Electrician A	Ass. Elect.	
		Ch. Section Elect main			App. spec. C	App. spec. B	App. spec. A	Ass. App. spe.	
	Ch. Dept. Elec. Main & W.		Ch. Subsec. App. & Control	Specialist App. & Control	App. elect. C	App. elect. B	App. elect. A	Ass. App. elect.	
		Ch. Section Elect. W/Shp	Ch. Subsec. Elect. W/Shp	Foreman Elect. W/Shp	Electrician C	Electrician B	Electrician A	Ass. Elect.	
			Ch. Tech. Sec.	Draughtsman					
		Ch. Planning S.			Carpenter C	Carpenter B	Carpenter A	Ass. Carp.	
			Ch. Sub. I. Ser.	For. Ind. Serv.	Mason C	Mason B	Mason A	Ass. Mason	Ind. Serv. Lab.
					Painter C	Painter B	Painter A	Ass. Painter	
		Ch. Sec. H. Eq.	Ch. Subs. H. Eq.	For. H. Eq.	Mechanic C	Mechanic B	Mechanic A	Ass. Mechanic	
	Ch. Dept. Transport			Traffic Fore.		Clerk		Veh. driver	
		Ch. Traffic Sec.	Ch. Traf. Subs.						
				For. Veh. main	Mechanic C	Mechanic B	Mechanic A	Ass. Mech.	
							Tyre Fitter	Serv. Lab.	
						Mech. inspector			
						Veh. Electrician			

Annex II

SITE ORIENTATION SKETCH: LIBYAN CEMENT COMPANY (LCC)



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Annex III

NAMES AND FUNCTIONS OF PROJECT COUNTERPARTS

H. Najib Lathram	Chairman
A. M. El-Gheriani	General director
I. Shaglouf	Director of administrative affairs
A. Mukraz	Administrative manager
M. El-Naihoum	Financial manager
M. Berruin	Commercial manager
R. Lotfy	Management and training adviser
S. Awad	Financial adviser
A. Hakam Gamal El Din	Legal adviser
A. Fathi	Chief process department
A. Bakr El Saltany	Chief process department
E. Shehata	Chief mechanic, maintenance department
A. Belruein	Chief mechanic, maintenance section
M. Tueima	Chief mechanic, workshop
S. Hikal	Chief electrician, maintenance department
A. Latif Gomaa	Electrical maintenance engineer
E. Din Abdel Rehman	Electrical maintenance engineer
M. Eleyan	Electrical maintenance engineer
M. Ahmed	Chief, laboratory department
K. El Ubeidi	Chief, laboratory section
M. Ben Zablah	Chief, crushing section
S. Bekhit	Chief, quarries section
M. Ben Shoroud	Chief, mills section
B. Ali	Kiln engineer
I. El-Fallah	Chief, kiln section
M. Gamal Azouz	Chief, packing section
F. El-Dilih	Chief, transport section
M. Abdel Mukdi	Chief, lime plant
A. Imtiaz	Project engineer
A. Siddiq	Shift engineer
I. El-Degawi	Chief, stores section

Annex IV

CLINKER AND CEMENT PRODUCTION IN RELATION TO INSTALLED CAPACITY IN 1975

	Clinker production				Cement production			
	Monthly		Accumulated		Monthly		Accumulated	
	Tons	%	Tons	%	Tons	%	Tons	%
Prod. Capacity	50 000				52 500			
January	35 662	71.3	35 662	71.3	35 835	68.2	35 835	64.4
February	22 823	45.6	58 485	58.4	38 643	73.6	74 478	70.9
March	30 280	60.5	88 765	59.1	39 338	74.9	113 816	72.2
April	41 201	82.4	129 966	64.9	51 033	97.0	164 849	78.5
May	27 573	55.0	157 539	63.0	34 157	65.0	199 006	75.8
June	40 090	80.2	197 629	65.9	31 975	60.9	230 981	73.3
July	43 578	87.1	241 207	68.9	44 287	84.3	275 268	74.9
August	38 446	76.9	279 653	69.9	35 125	66.9	310 393	73.9
September	36 163	72.3	315 816	70.2	37 444	71.3	347 837	73.6
October	39 504	79.0	355 320	71.0	33 998	64.7	381 835	72.7
November	32 006	64.0	387 326	70.4	45 945	87.5	427 780	74.0
December	51 202	102.4	438 528	73.0	37 786	72.0	465 566	73.9
	438 528	73.0	438 528	73.0	465 566	73.9	465 566	73.9

Annex V

SUFFICIENCY OF CRUSHED AND SIZED LIMESTONE
IN 1975

Period 1975	Crushed limestone			Sized limestone		Quicklime	
	Actual tonnage crushed	Deficiency (tons below guarantee)	Deficiency (% below guarantee)	Delivered (tons to lime plant)	Percentage of crushed limestone	Total production (tons)	Percentage of installed capacity
January	41 011	25 649	38.5	-	-	-	-
February	35 453	31 207	46.8	2 413	6.8	1341	48.7
March	44 130	22 530	33.8	2 622	6.0	1457	53.2
April	36 840	29 820	44.7	2 050	5.6	-	-
May	43 532	23 128	34.5	3 468	7.9	1927	70.4
June	41 745	24 915	37.3	2 050	4.9	-	-
July	49 924	16 736	25.1	3 951	7.9	1795	65.2
August	43 740	22 920	34.4	3 312	7.6	1487	54.1
September	34 940	31 720	47.5	1 500	4.3	643	23.5
October	43 520	23 140	34.5	2 242	5.2	607	22.1
November	34 433	32 227	48.5	3 100	9.0	1400	50.9
December	57 193	9 467	14.2	2 500	4.4	1013	36.9
Total and average	506 461	293 459	36.7	29 208	5.8	11670	38.6

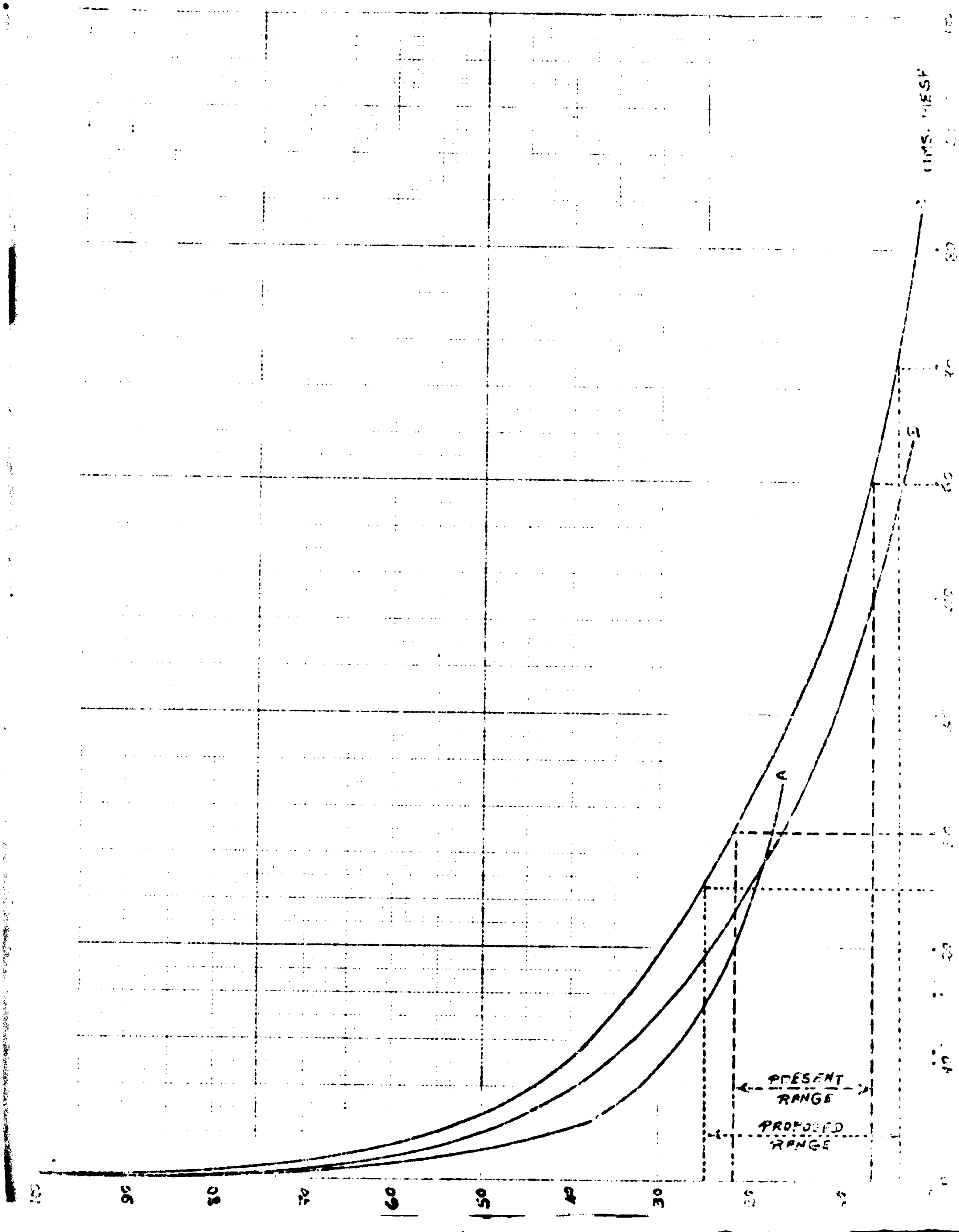
Annex VI

SCREENING TESTS OF CRUSHED LIMESTONE

Grain size (mm)	Crushed limestone from crusher						Sized limestone Mogensen sizer		Limestone rejects	
	(A) March 1971 (TCH tests)		(B) March 1975 (TCH tests)		(C) March 1976 (present study)		March 1976 (present study)		March 1976 (present study)	
	R %	R % Δ	R %	R % Δ	R %	R % Δ	R %	ΔR %	R %	ΔR %
Over 80					1.70	1.70	4.75	4.75	3.35	3.35
70 - 80					5.50	7.20	4.12	8.87	5.38	8.73
60 - 70			3.32	3.32	0.00	7.20	6.75	15.62	2.87	11.60
50 - 60			3.08	6.40	3.61	10.81	12.90	28.52	3.67	15.27
40 - 50			4.87	11.27	4.75	15.56	9.48	38.00	0.78	16.05
30 - 40	17.49	17.49	5.17	16.44	7.54	23.10	19.55	57.55	2.67	18.72
20 - 30	3.73	21.22	7.65	24.09	6.47	29.57	23.80	81.35	27.30	46.02
8 - 20	11.02	32.24	18.99	43.08	15.78	45.35	12.50	93.85	28.90	74.92
4 - 8	8.56	40.80	56.92	100.00	6.95	52.30	1.25	95.10	5.30	80.22
- 4	59.20	100.00			47.70	100.00	4.90	100.00	19.78	100.00

Annex VII

GRAIN-SIZE DISTRIBUTION OF CRUSHED LIMESTONE



Annex VIII

CONTROLLED LIMESTONE SIZING FOR LIME MANUFACTURE IN THE SECOND HALF OF MARCH 1976

Date	Sized LS silo		Total output of LS crusher (tons)			LS applied by lime factory (tons)			Sized LS % of crusher output		
	Metres empty	Stock (tons)	First shift	Second shift	Total output	First shift	Second shift	Total applied	First shift	Second shift	Total percentage
15.3.76	15.60	440	1000	1760	2760	97	190	287	9.7	11.0	10.4
16.3.76	13.85	615	1240	1400	2640	126	153	279	10.2	10.9	10.6
17.3.76	12.20	780	1200	400	1600	132	54	186	11.0	14.7	11.7
18.3.76	11.60	840	1320	700	2020	142	104	246	11.8	14.8	12.3
19.3.76	-	-	-	-	-	-	-	-	-	-	-
20.3.76	12.00	800	720	1160	1880	62	74	136	8.4	6.4	7.4
21.3.76	12.20	780	-	760	760	-	100	100	-	13.2	13.2
22.3.76	12.70	730	1260	1000	2260	150	100	250	11.9	10.0	11.1
23.3.76	12.00	800	940	-	940	97	-	97	10.3	-	10.3
24.3.76	12.30	770	1360	-	1360	142	-	142	10.4	-	10.4
25.3.76	12.45	755	980	-	980	97	-	97	9.9	-	9.9
26.3.76	13.00	700	-	-	-	-	-	-	-	-	-
27.3.76	14.60	547	1380	600	1980	104	54	158	7.6	9.0	8.0
28.3.76	14.80	552	-	-	-	-	-	-	-	-	-
29.3.76	16.15	386	1000	840	1840	92	86	178	9.2	10.2	9.7
30.3.76	15.80	420	1160	1020	2180	90	110	200	7.7	10.8	9.2
31.3.76	15.00	500	920	360	1280	62	34	96	6.8	9.5	7.5
			14 480	10 000	24 480	1 363	1 089	2 452	9.4	10.9	10.0

Annex IX

PROPOSAL: BASIC DATA FOR EXTENSION OF LIME PLANT

Feasible production capacity: 43,000 tons/year of hydrated lime: $Ca(OH)_2$

Production capacities of main items:

Lime kiln. Nominal capacity of 100 tons/24 hours of quicklime (CaO), complying with BSS and DIN 1060; products to be utilized for building purposes with provisions allowing for various industrial purposes. The supplier should select the burning design most suitable for the limestone quality, which he has to investigate himself through available data and representative samples.

Lime hydrating plant. 12 tons/h of $Ca(OH)_2$, operating time 16 hours, six days/week.

Packing plant. Two two-spout packing machines of 15 tons/h each, operating period 8 hours, six days/week.

Storage capacities. Storage facilities to be installed of suitable material and design matching type of supplied units:

Raw limestone (sieved dimensions)	4,000 m^3
Waste materials (undersize limestone)	1,000 m^3
Kiln discharge (CaO service bunker)	100 m^3
Lime hydrate ($Ca(OH)_2$)	2,500 m^3

Available raw limestone. To be procured from crushing products of:

Hammer crusher: capacity 275 tons/h, delivered by KHD for Benghazi third production line under extension for LCC; starting date July 1976.

Hammer crusher: capacity 550 tons/h, KHD delivery to Hawari cement plant under construction; starting date March 1978.

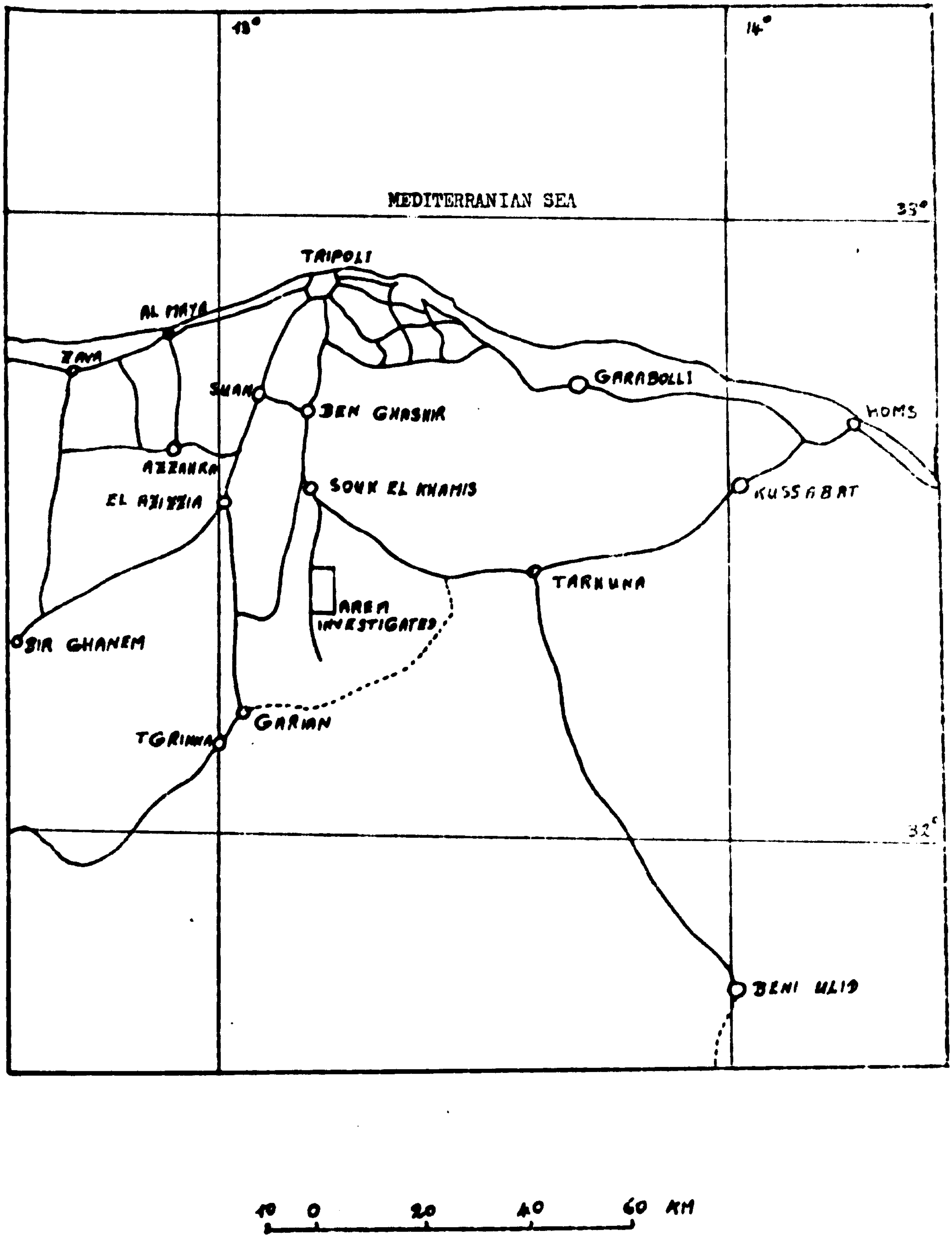
Vibrating screens and conveying systems. These are to be designed to profit from possibilities for providing both production lines (existing and extension) with raw stone with required dimensions. Accessory machinery, including crushing, grinding and conveying systems, should be foreseen with surplus of 50% more than guaranteed capacities of main production units.

Process technology. This should be adapted to substantials of the existing plant, including heavy furnace fuel, 6KV electrical power supply and available water resources.

Process technology. This should be adapted to substantials of the existing plant, including heavy furnace fuel, 6KV electrical power supply and available water resources.

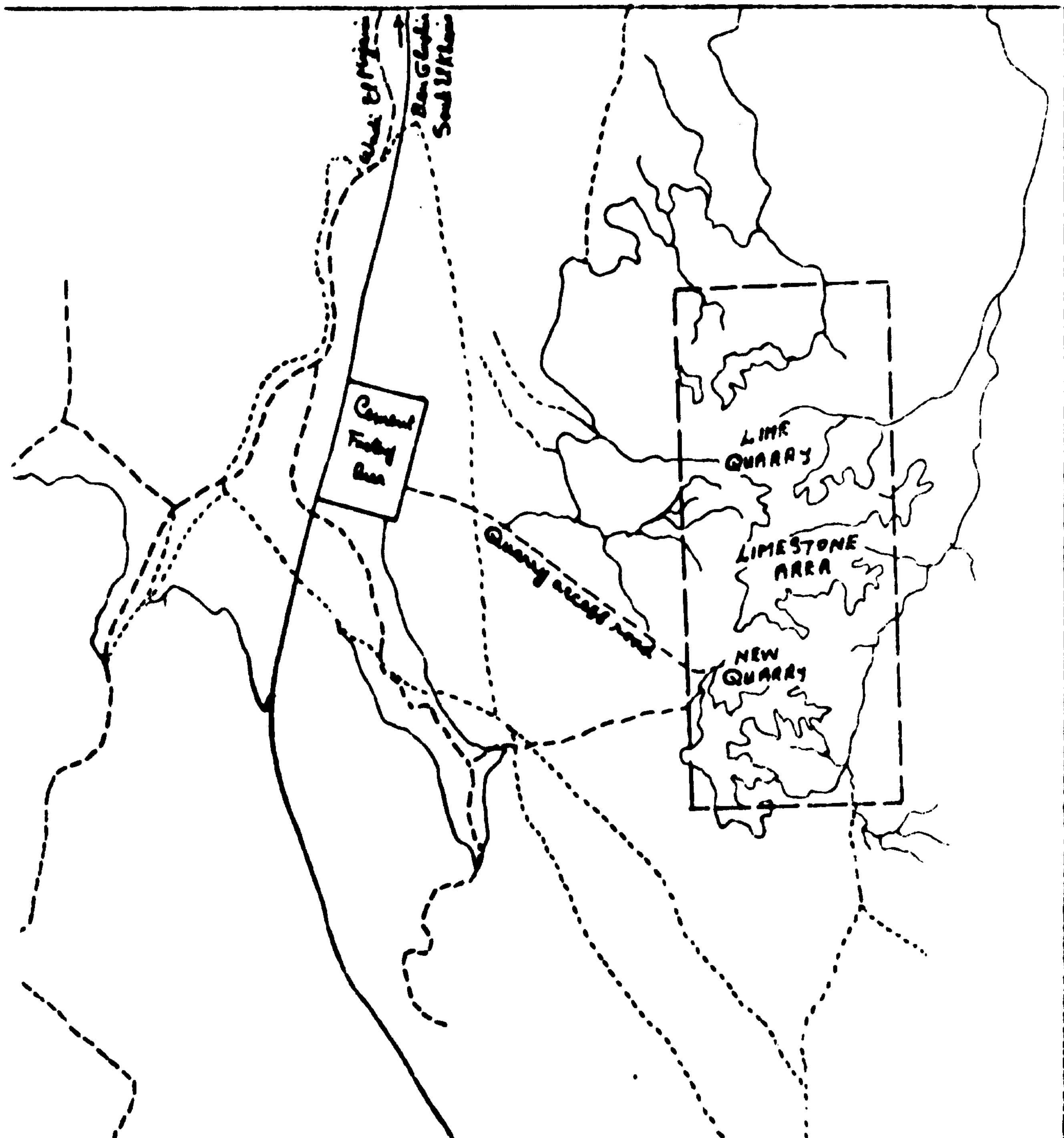
Annex X

SITE LOCATION OF SOUK EL-KHAMIS PROJECT



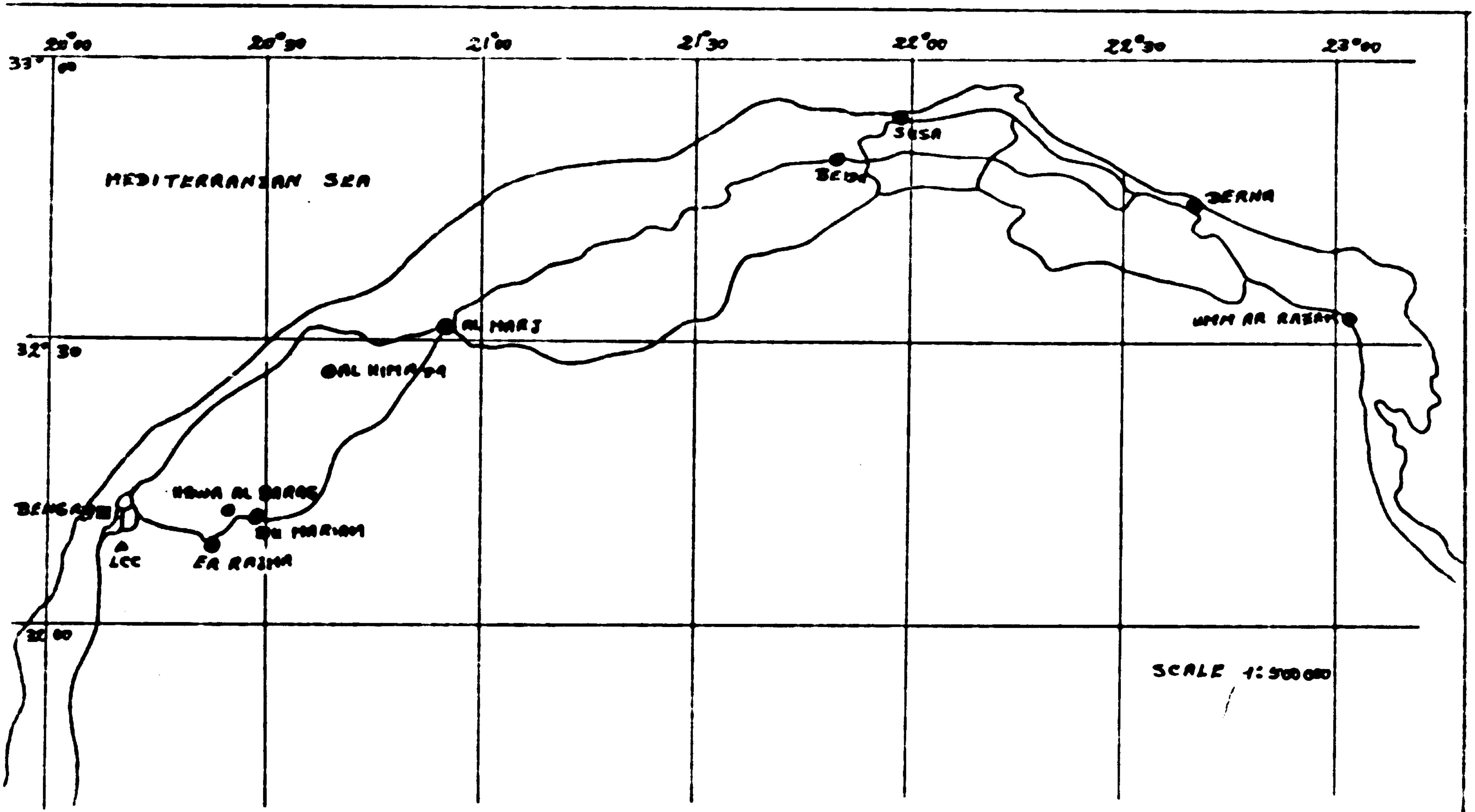
Annex XI

SITE LOCATION OF SOUK EL-KHAMIS PROJECT



Annex XII

PROSPECTION PILOT AREAS IN THE GREEN MOUNTAIN



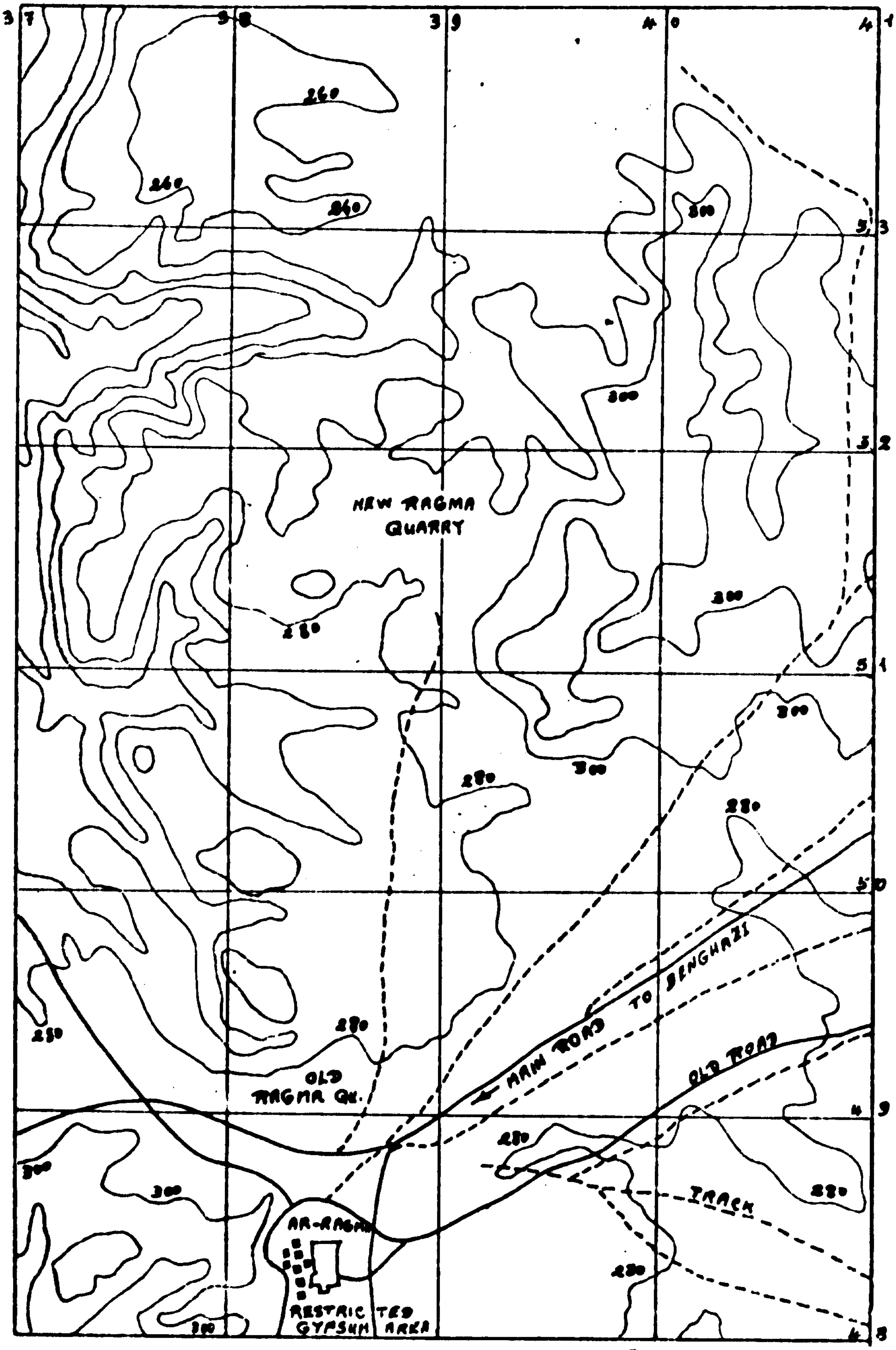
Annex XIII

LIMESTONE AND CLAY ANALYSES OF MARJ/DERNA DRILLINGS

Material/area	Bore hole No.	Thickness bed m	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl
LIMESTONE area ML 3	1	50.7	0.8	0.2	0.10	49.3	0.3	-	0.3	-	-
	2	50.0	1.3	0.4	0.15	53.0	0.3	-	0.2	0.03	-
	Aver.		1.1	0.3	0.13	51.2	0.3	-	0.3	0.02	-
CLAY Area MC 7	1	23.7	43.1	19.6	9.6	4.7	3.9	-	0.2	2.7	0.03
	2	18.4	42.4	21.3	10.8	4.9	1.6	-	0.1	2.4	0.02
	3	16.0	36.5	14.4	6.6	16.8	1.8	0.1	0.2	3.0	0.02
	4	6.5	36.1	18.7	8.9	11.0	1.6	0.1	0.2	2.6	0.02
	5	2.0	27.0	10.9	4.4	28.8	1.5	-	0.1	1.4	0.01
	6	2.0	48.0	20.7	10.0	3.1	1.6	-	0.3	2.9	0.03
	7	2.0	39.8	17.4	7.8	10.0	1.2	-	0.2	2.3	-
	Aver.		39.9	17.6	8.3	11.3	1.9	-	0.2	2.5	0.02
CLAY Area MC 10	1	22.7	32.4	10.8	4.8	23.7	1.5	-	0.3	1.8	0.08
	2	7.3	35.4	11.2	4.8	20.6	1.6	-	0.3	2.6	-
	3	2.0	48.8	21.1	10.2	4.5	1.1	-	0.3	2.6	0.20
	4	1.0	44.2	24.2	13.4	1.0	1.4	-	0.1	2.4	0.10
	Aver.		40.2	16.9	8.3	12.5	1.4	-	0.3	2	0.10

Annex XIV

AR-RAGMA GYPSUM DEPOSITS



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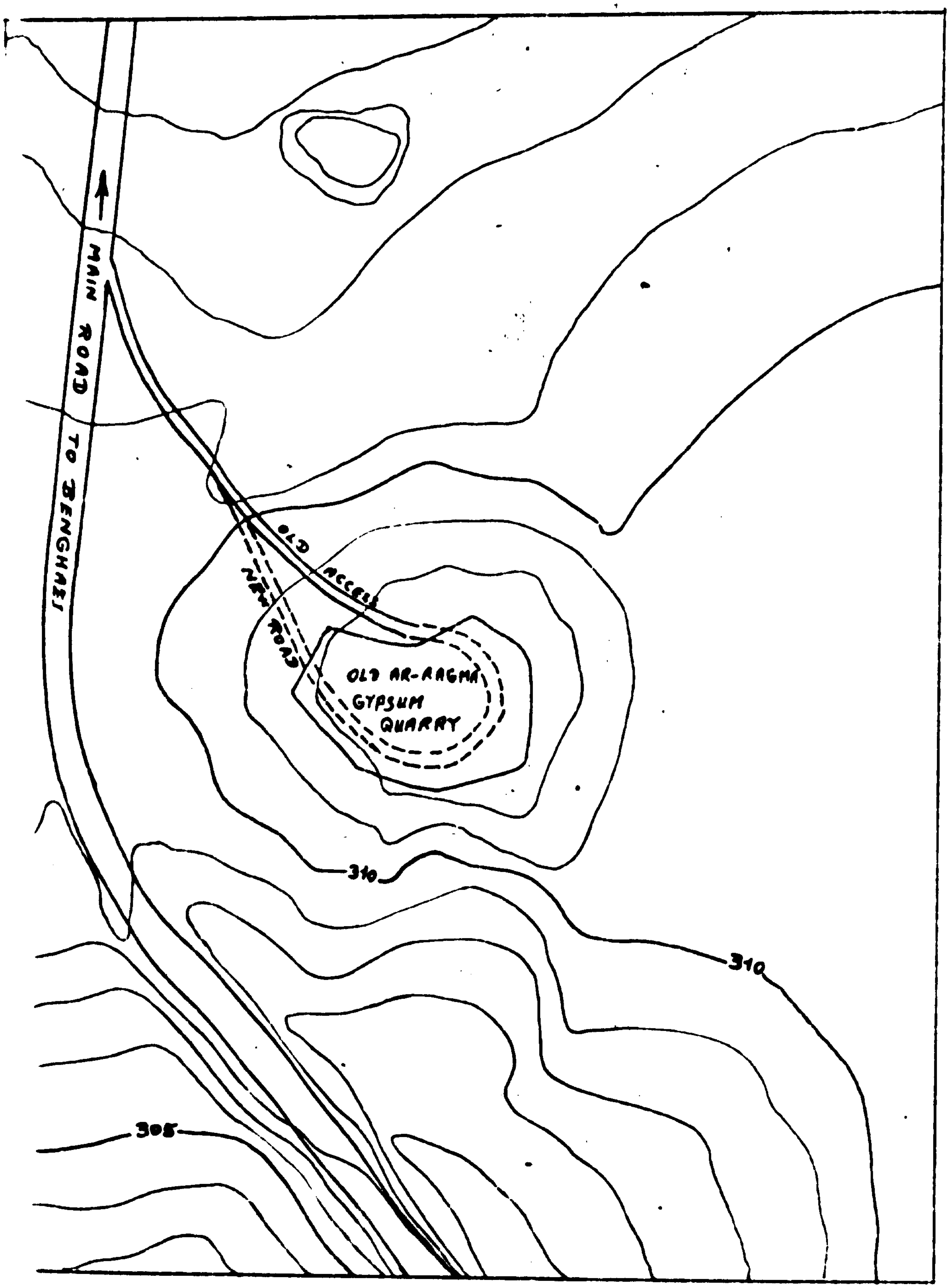
Annex XV

OLD AR-RAGMA GYPSUM QUARRY



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Annex XVI

CEMENT PHYSICAL TESTS BEFORE REVISION OF TESTING EQUIPMENT

Testing date	Blaine (cm^2/gm)	Gauging water (%)	Le Chatelier (exp. mm.)	Setting time		Compression strength (kg/cm^2)	
				Initial	Final	3 days	7 days
BSS 12/1958	2250	N.	10	0.45	10.00	154	239
2.2.76/I	2790	26.8	2	3.10	4.55	100	111
3.2.76/I	2650	27.0	1	3.25	4.50	124	232
4.2.76/II	2880	26.0	1	3.30	4.45	180	225
7.2.76/P	3120	25.6	1	2.50	4.15	165	264
8.2.76/I	2690	26.4	2	2.10	4.25	150	248
9.2.76/II	2980	25.8	2	2.35	3.40	131	200
10.2.76/II	3100	25.6	1	2.55	3.35	164	251
11.2.76/II	2380	25.6	1	2.50	4.05	180	275
12.2.76/II	3010	25.4	1	2.40	3.45	188	250
15.2.76/II	2820	26.0	0	3.15	4.35	210	256
16.2.76/II	2890	25.6	1	3.05	4.20	156	190

Testing date	Blaine (cm^2/gm)	Gauging water (%)	Le Chatelier (exp. mm)	Setting time		Compression strength (kg/cm^2)	
				Initial	Final	3 days	7 days
BSS 12/1958	2250	N.	10	0.45	10.00	154	239
17.2.76/II	3010	25.8	2	2.30	3.55	216	250
18.2.76/II	2820	26.0	2	3.00	4.10	180	292
19.2.76/II	2930	25.8	1	2.50	3.50	180	250
20.2.76/II	2890	25.8	1	2.40	3.50	232	348
21.2.76/II	2860	25.6	0	2.50	4.05	220	300
22.2.76/II	2930	25.8	1	3.00	4.05	188	300
23.2.76/II	2910	25.8	1	2.40	3.50	208	270
24.2.76/II	2840	25.8	1	2.55	4.25	150	260
25.2.76/II	3010	25.8	1	2.50	4.10	170	252
26.2.76/II	3070	25.8	1	3.05	4.15	192	288
28.2.76/II	3150	26.3	1	3.20	4.25	188	304
AVERAGE	2930	25.9	1	2.55	4.10	176	244

Annex XVII

CEMENT PHYSICAL TESTS AFTER RECTIFICATION

Testing date	Blaine (cm^2/gm)	Gauging water (%)	Le Chatelier (exp. mm)	Setting time		Compression strength (kg/cm^2)	
				Initial	Final	3 days	
BSS 12/1958	2250	[illegible]	10	0.45	10.00	154	239
2.3.76/II	2890	25.8	1	3.15	4.20	244	328
3.3.76/II	3230	25.8	1	3.00	4.10	222	363
4.3.76/II	2790	25.6	1	2.50	4.00	2.58	394
6.3.76/II	2930	25.6	1	3.05	4.10	264	400
7.3.76/II	2820	25.6	0	3.05	4.20	266	393
8.3.76/II	2800	25.6	1	2.55	4.15	256	386
9.3.76/II	2970	25.6	1	2.35	3.50	278	409
10.3.76/II	2720	25.6	1	2.40	4.15	245	346
11.3.76/II	2920	25.6	1	2.50	4.10	279	407
12.3.76/II	2665	25.0	1	2.15	3.20	213	341
15.3.76/II	2910	26.0	1	3.15	4.20	263	381
16.3.76/II	3180	26.0	1	3.00	3.50	307	434
17.3.76/II	2890	26.0	1	3.10	4.10	252	403
18.3.76/II	3090	26.2	2	2.35	3.35	200	368

Testing date	Blaine (cm^2/gm)	Gauging water (%)	Le Chatelier (exp. mm)	Setting time		Compression strength (kg/cm^2)	
				Initial	Final	3 days	7 days
BSS 12/1958	2250	h.	10	0.45	10.00	154	239
19.3.76/II	2810	25.6	0	2.55	3.50	237	363
20.3.76/II	2530	25.7	1	2.55	4.15	242	311
21.3.76/II	2970	25.6	1	2.15	3.10	300	374
22.3.76/II	2980	25.6	1	3.10	4.05	275	400
23.3.76/II	3060	25.8	1	3.10	4.05	265	404
24.3.76/II	2940	25.6	1	2.55	3.50	257	390
25.3.76/II	2680	25.6	1	3.10	4.00	224	361
26.3.76/II	2700	25.8	1	3.00	3,55	270	370
27.3.76/II	2700	25.8	1	2.55	4.00	272	373
28.3.76/II	2510	25.8	1	2.50	3.55	224	335
30.3.76/II	2820	25.0	1	2.45	3.35	246	355
31.3.76/II	2640	25.4	0	3.15	4.20	259	359
Average :	2850	25.7	1	2.55	4.15	256	375

Annex XVIII

FIRE BRICKS LINING OF KILN NO. 1

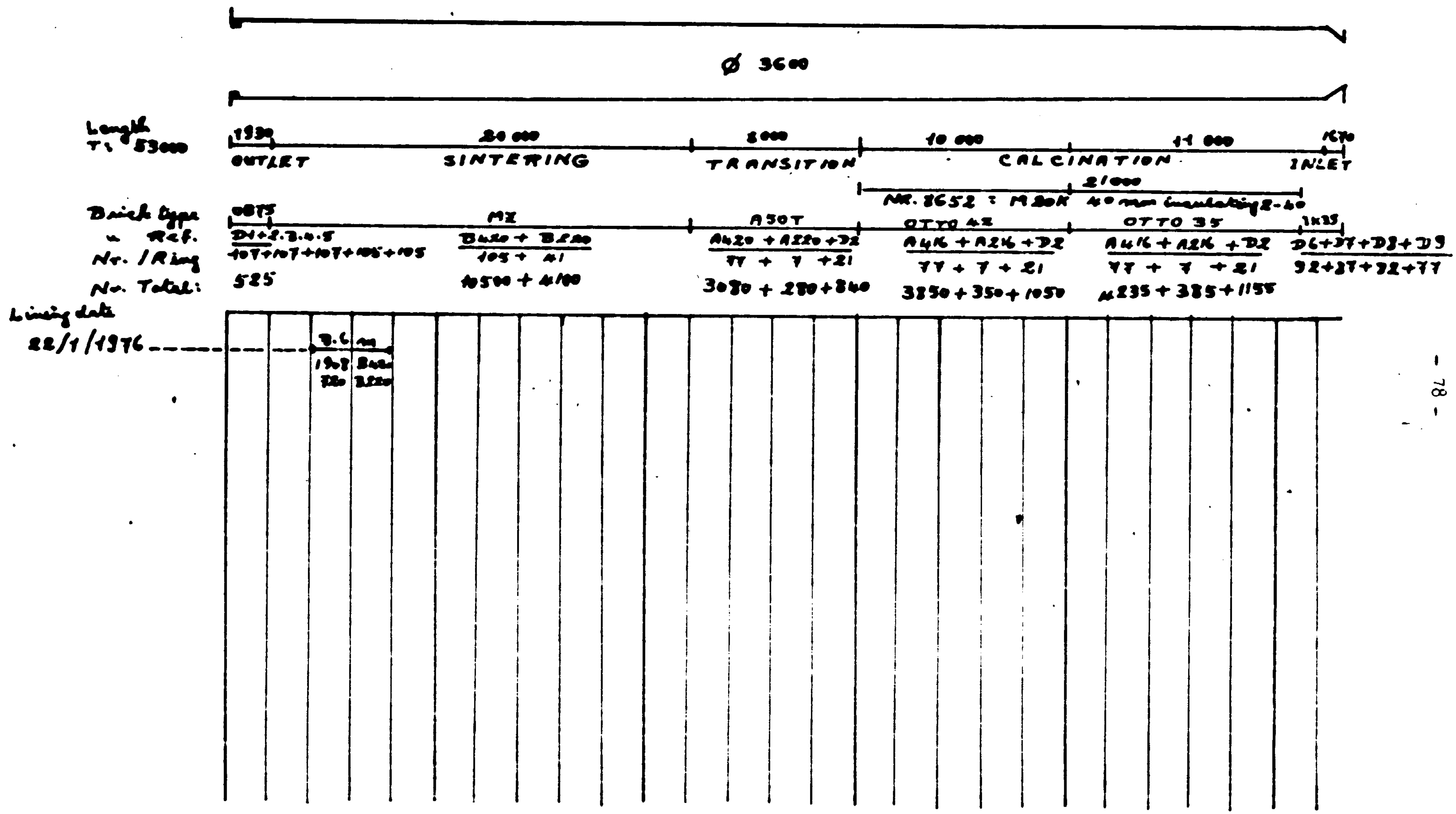
(General survey and recommended orders)

Fire brick type	Ref No.	Number per ring	Total number off	Number required	Stock 1/4/76	Recommended order	Ordered stock	Minimum stock
OB 75	D 1	107	107	450	633	-	450	230
	D 2	107	107	450	596	-	450	230
	D 3	107	107	450	567	-	450	230
	D 4	105	105	450	483	-	450	230
	D 5	105	525	1100	873	300	1100	550
MZ	B420	105	10500	23000	4712	18000	23000	11000
	B220	41	4100	8500	15216	-	8500	4500
	B 20	4	400	1000	372	600	1000	500
A50T	A420	77	3080	7000	-	7000	7000	3500
	A220	7	280	600	-	600	600	300
	D 20	21	840	1800	-	1800	1800	900
Otto 42	A416	77	3850	4000	2016	2000	4000	4000
	A216	7	350	500	200	300	500	500
	D 2	21	1050	1200	540	700	1200	1200
Otto 35	A416	77	4235	4500	-	4500	4500	4500
	A216	7	385	400	-	400	400	400
	D 2	21	1155	1200	-	1200	1200	1200
IK 39	D 6	92	92	100	220	-	100	100
	D 7	87	87	100	-	100	100	100
	D 8	82	82	100	-	100	100	100
	D 9	77	77	100	-	100	100	100
M 20 K	Insul.	103	8652	9000	-	9000	9000	9000

Annex XIX

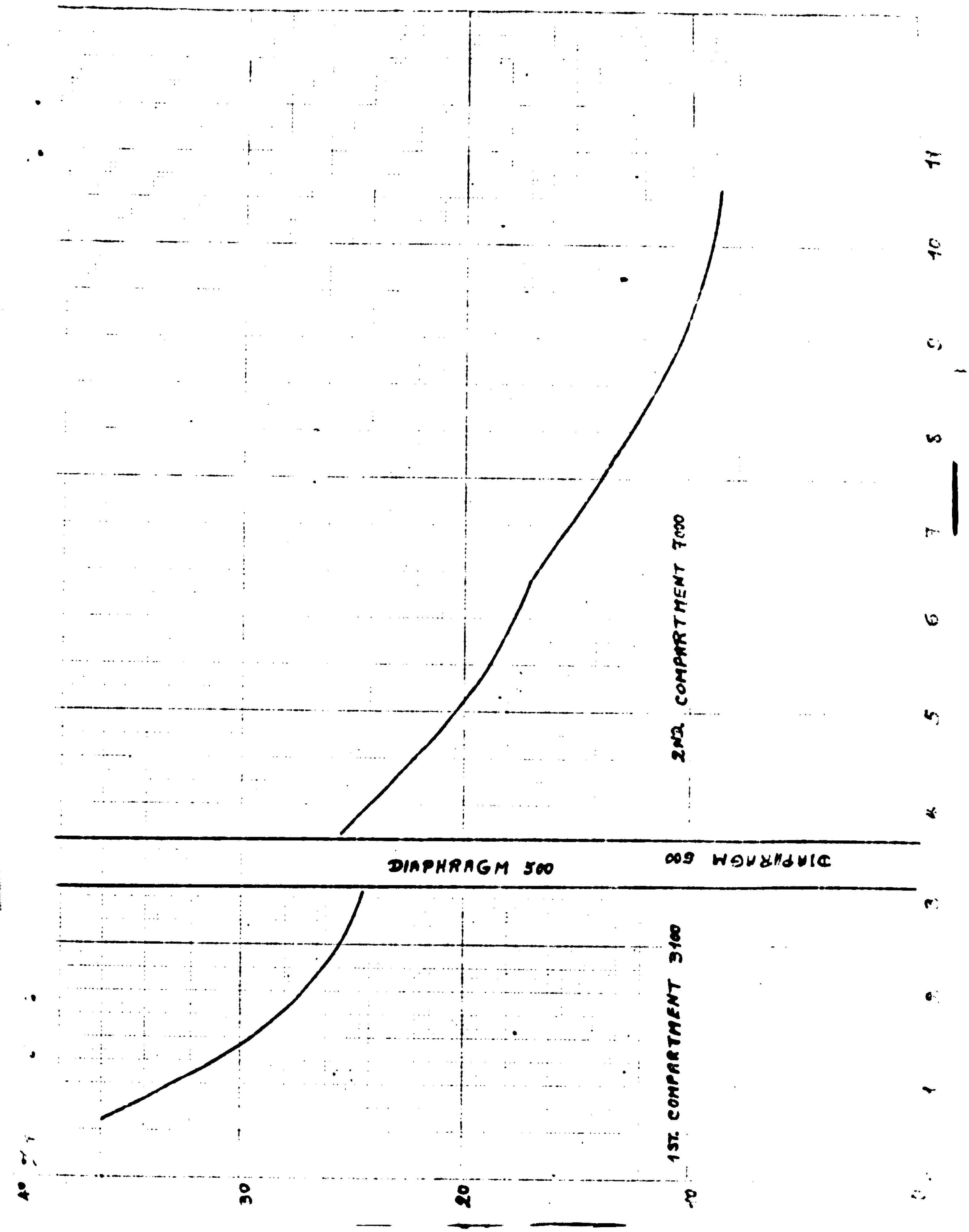
REFRACTORY LINING SHEET

(Fire bricks lining kiln No.1)



PARTICLE DISTRIBUTION GRINDABILITY CURVE

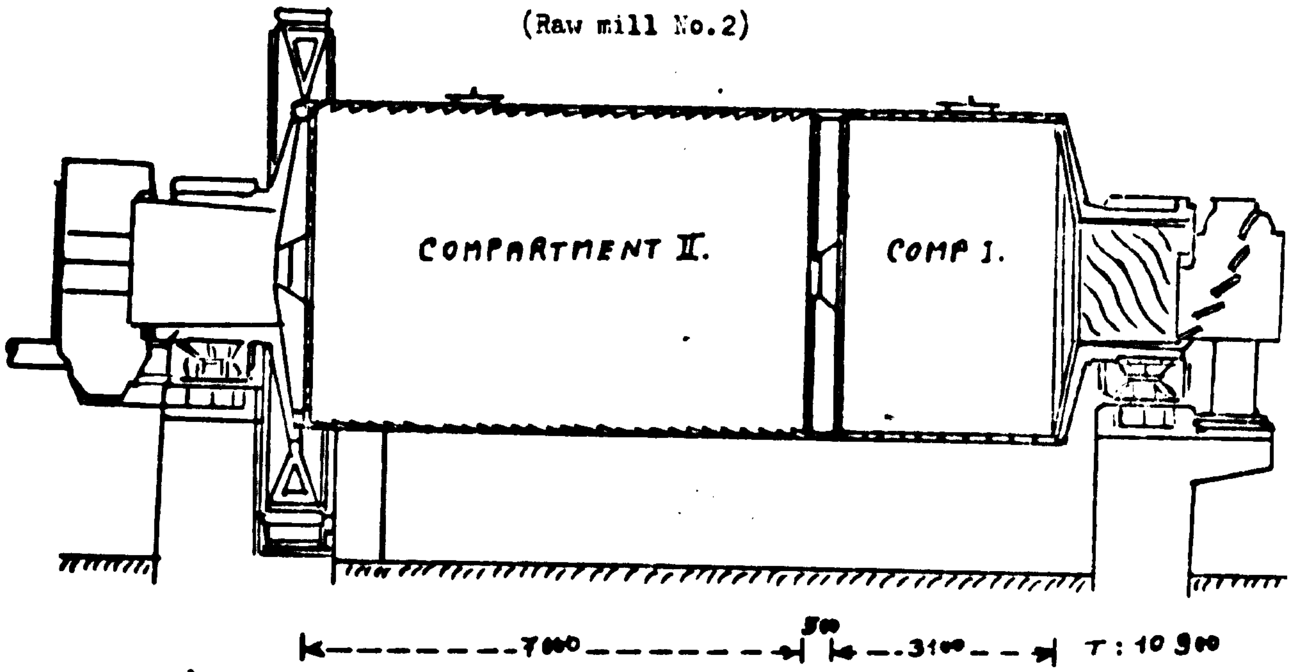
(Raw mill No.2)



Annex XXI

FOLLOW-UP SHEET FOR MILL REFILLING

(Raw mill No.2)



DATE	PRODUC. TS. RA.	COMPARTMENT NO. II.							COMP. NO. 1				TOTAL CHARGE
ORIGINAL CHARGE				25 14	30 50	40 30	50 28	60 8	60 8.5	70 12	80 18	90 25	BALLS ∅ 63.5 + 130 = 193.5
INITIAL				10	25	35	35	20	6	12	16	17	51 + 125 = 176.0
REFILLING													

Annex XXII

PROPOSED REINFORCEMENT OF LABOUR FORCE

Position	Actual number	Number required			To be employed		
		Benghazi 1 and 2	Extension 3	Total	Immediate	Second stage	Total
RAW MATERIALS :							
Chief raw mat. dept	-	-	-	-	-	-	-
Chief quarry section	1	1	-	1	-	-	-
Chief quarry Subsec.	-	-	-	-	-	1	1
Foreman R.Mat.Shift	1	1	1	2	-	-	-
Blasting Specialist	-	-	-	-	-	-	-
Blasting Operaton AB	2	2	-	2	-	-	-
Blasting Assistant	2	2	-	2	-	-	-
Explosives Guard	4	4	-	4	-	-	-
Chief Crusher Sec.	-	-	-	-	-	-	-
Chief Crusher SubSec.	-	-	-	-	-	-	-
Crusher's Foreman	1	1	-	1	-	-	-
Crusher Operator ABC	3	3	2	5	-	2	2
Crusher Assistant	3	3	2	5	-	2	2
Conveyor Operator	3	3	4	7	-	4	4
Common Labourer	7	7	7	14	-	7	7
Drilling Foreman	1	1	-	1	-	-	-
Mech. Driller ABC	2	2	-	2	-	-	-
Hand Driller	2	2	2	4	-	2	2
Driller Assistant	3	3	2	5	-	2	2
Foreman Heavy Equip.	-	-	-	-	-	-	-
Driver Heavy Equip.C1	12	12	4	16	2	2	4
Driver Heavy Equip. C2	6	6	6	12	-	6	6
Mech. Shovel Asst.	2	2	2	4	-	2	2
PROCESS :							
Chief Process Dept.	2	1	-	1	-	-	-
Chief Mill Sec.	1	1	-	1	-	-	-
Chief Mill Subsec.	1	1	-	1	-	-	-
Mills Foreman	1	1	-	1	-	-	-
Mill Operator ABC	10	12	4	16	2	4	6
Miller Assistant	7	10	6	16	3	6	9
Conveyor Operator	6	6	4	10	-	4	4
Common Labourer	7	10	6	16	3	6	9
Scraper Operator AB	-	-	-	-	-	-	-
Scraper Assistant	10	10	7	17	-	7	7

Postion	Actual number	Number required			To be employed		
		Benghazi 1 and 2	Extension 3	Total	Imme-diate	Second stage	Total
Chief Kiln Section.	1	1	-	1	-	-	-
Chief Kiln Subsection.	1	1	-	1	-	-	-
Kiln Foreman.	1	1	-	1	-	-	-
Burner ABC	10	10	5	15	5	-	5
Assistant Burner	8	10	5	15	4	3	7
Cyclone Attendent	13	10	5	15	-	2	2
Conveyors Attendent	17	16	4	20	-	3	3
Fuel Attendent	2	2	-	2	-	-	-
Services Labourer	2	2	1	3	-	1	1
Chief Packing Section	-	-	-	-	-	-	-
Chief Packing Subsec.	1	1	-	1	-	-	-
Packing Foreman	1	1	-	1	-	-	-
Despatch Attendant	1	1	-	1	-	-	-
Packing Operator ABC	4	4	2	6	-	2	2
Packing Operator Asst.	15	15	8	23	-	8	8
Loading Labourer	34	28	16	44	-	10	10
Services Labourer	4	4	2	6	-	2	2
Shift Supervisor	4	4	-	4	-	-	-
Shift Foreman	-	-	-	-	-	-	-
Clerk B	-	-	4	4	-	1	1
Clerk A	-	-	-	-	-	-	-
LABORATORIES :							
Chief Of Lab. Sec.	1	1	-	1	-	-	-
Chief Lab. Subsec.	1	1	-	1	-	-	-
Quality Control Supervisor.	-	-	1	1	-	1	1
Analyst ABC	6	6	-	6	-	-	-
Analyst Assistants	-	-	-	-	-	-	-
Tester ABC	5	5	3	8	3	-	3
Tester Assistant	-	-	-	-	-	-	-
Sample Fetcher	8	8	-	8	-	-	-
Services Labourer	1	1	1	1	-	1	1

Position	Actual number	Number required			To be employed		
		Benghazi 1 and 2	Extension 3	Total	Immediate	Second stage	Total
Chief Engineer		1	-	1	-	1	1
Chief Maint. & Wp. Dept.	1	1	-	1	-	-	-
Chief Mech. Maint. Sec.	1	1	-	1	-	-	-
Chief Mech. Maint. Subsec.	-	1	-	1	-	1	1
Lubrication Foreman	-	1	-	1	-	-	-
Lubrication Attendent ABC	1	3	1	4	-	3	3
Lubrication Assistant	9	9	-	9	-	-	-
Mech. Maint. Foreman	3	4	-	4	-	1	1
Fitter ABC	23	25	8	33	10 o	-	10
Assistant Fitter	11	11	10	21	-	10	10
Welder ABC	3	3	2	5	2 o	-	2
Assistant Welder	3	3	1	4	-	1	1
Mech. Wp. Sec. Chief.	1	1	-	1	-	-	-
Mech. Wp. Subsec. Chief.	-	-	1	1	-	1	1
Mech. Workshop Foreman	4	4	1	5	-	1	1
Fitter ABC	6	6	4	10	-	4	4
Assistant Fitter	3	3	3	6	-	3	3
Welder ABC	6	6	-	6	-	-	-
Assistant Welder	2	2	2	4	-	2	2
Smith ABC	3	3	2	5	-	2	2
Assistant Smith	-	-	2	2	-	2	2
Wp. Machine Attendant ABC	1	1	1	2	-	1	1
Wp. Machine Attendant Asst.	1	1	1	2	-	1	1
Pipe Fitter ABC	4	4	-	4	-	-	-
Assistant Pipe Fitter.	1	1	-	1	-	-	-
Black Smith ABC	2	2	-	2	-	-	-
Assistant Black Smith	2	2	-	2	-	-	-
Turner ABC	7	7	-	7	-	-	-
Assistant Turner	1	1	-	1	-	-	-
Chief Planning Dept.	1	1	-	1	-	-	-
Tech. Secr. Subsection	-	-	1	1	-	1	1
Draftsman	-	-	-	-	-	-	-
Ch. Indust. Serv. Sec.	-	-	-	-	-	-	-

Position	Actual number	Number required: Benghazi 1 and 2	Number required: Extension 3	Number required: Total	To be employed: Immediate	To be employed: Second stage	To be employed: Total
Foreman Indust. Serv.	1	1	-	1	-	-	-
Carpentor ABC	1	1	-	1	-	-	-
Assistant Carpenter	1	1	1	2	-	1	1
Mason ABC	1	1	-	1	-	-	-
Assistant Mason	-	-	1	1	-	1	1
Services Labourer	-	-	6	6	-	6	6
Painter ABC	-	-	-	-	-	-	-
Assistant Painter	2	2	-	2	-	-	-
Ch. Indust. Security	-	-	-	-	-	-	-
Attendant Indus. Security	1	1	-	1	-	-	-
Chief Transport deptt.	-	-	-	-	-	-	-
Ch. H. Equip. Subsec.	-	-	-	-	-	-	-
Foreman H. Equip.	1	1	-	1	-	-	-
Mechanic ABC	6	5	3	8	-	2	2
Assistant Mechanic	10	8	-	8	-	-	-
Chief traffic Section	-	-	-	-	-	-	-
Chief traffic subsection	1	1	-	1	-	-	-
Traffic Foreman	1	1	-	1	-	-	-
Vehicle driver	31	31	6	37	-	6	6
Vehicle maint. foreman	-	-	1	1	-	1	1
Mechanic ABC	2	2	2	4	1	1	2
Assistant machanic	5	5	2	7	1	1	2
Veh. Electrician ABC	-	-	1	1	1	-	1
Techn. Inspection	-	-	-	1	-	-	-
Tyre mechanic	-	-	-	1	-	-	-
Traffic Clerk	-	-	-	1	-	-	-
Services Labourer	-	-	1	2	-	1	1
Ch. Elec. m. & wp. deptt	1	1	-	1	-	-	-
Ch. Elec. m. Section	1	1	-	1	-	-	-
Ch. Elec. m. Subsection	1	1	-	1	-	-	-
Instr. specialist	4	4	-	4	-	-	-
Electrician ABC	9	9	2	11	-	2	2
Assistant Electrician	6	6	-	6	-	-	-
Ch. meas. h contr.Sub	1	1	-	1	-	-	-
Meas. & contral specialist	2	2	1	3	-	1	1
Inst. electr. ABC	-	-	2	2.	1	1	2
Assistant Inst. electrician	-	-	2	2	1	1	2
Ch. elec. wp. section	1	1	-	1	-	-	-
Ch. elec. wp. subsection	-	-	-	-	-	-	-
Foreman elec. wp.	1	1	-	1	-	-	-
Electrician	2	2	2	4	-	2	2
Assistant Electrician	2	2	-	2	-	-	-

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