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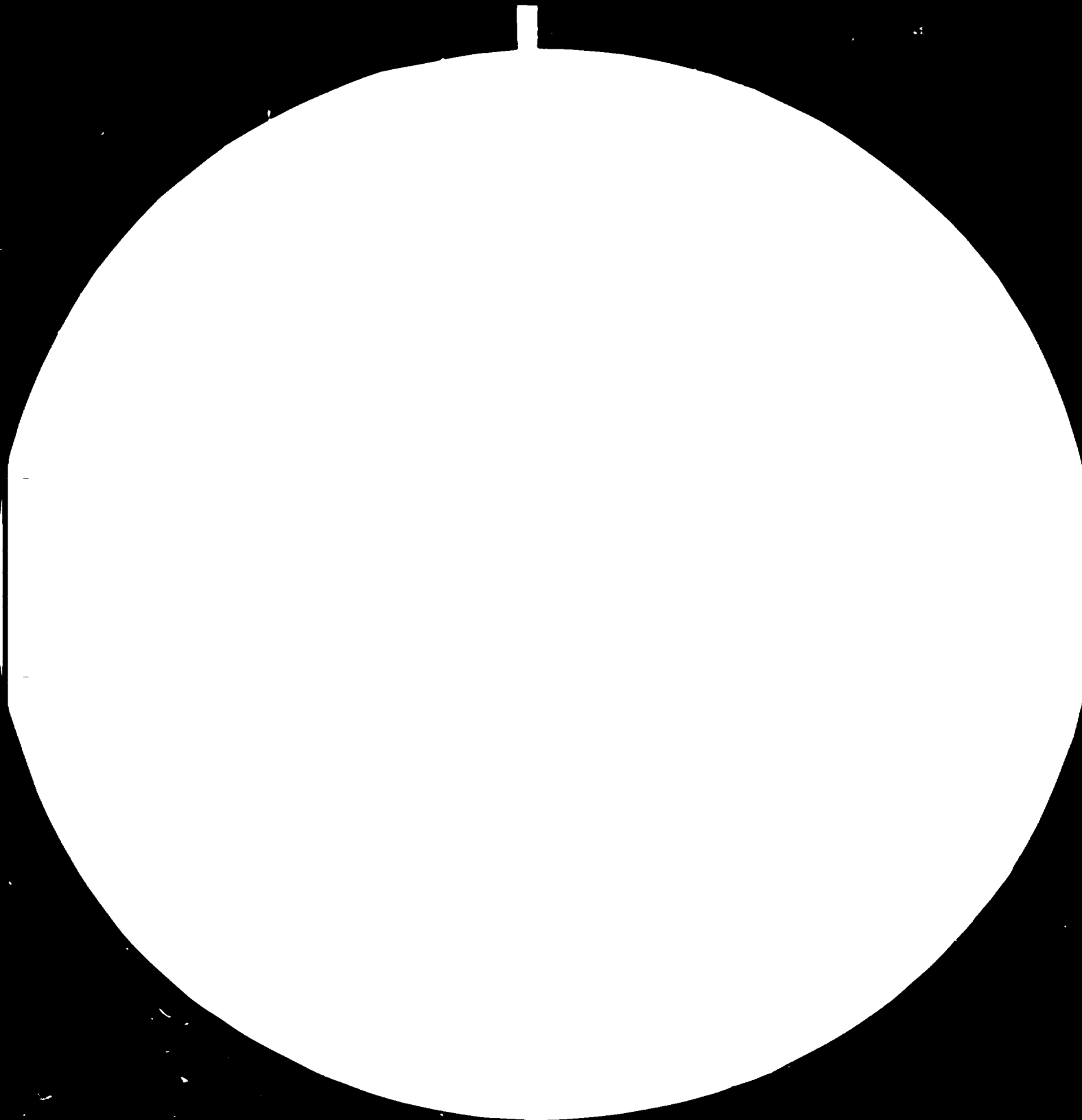

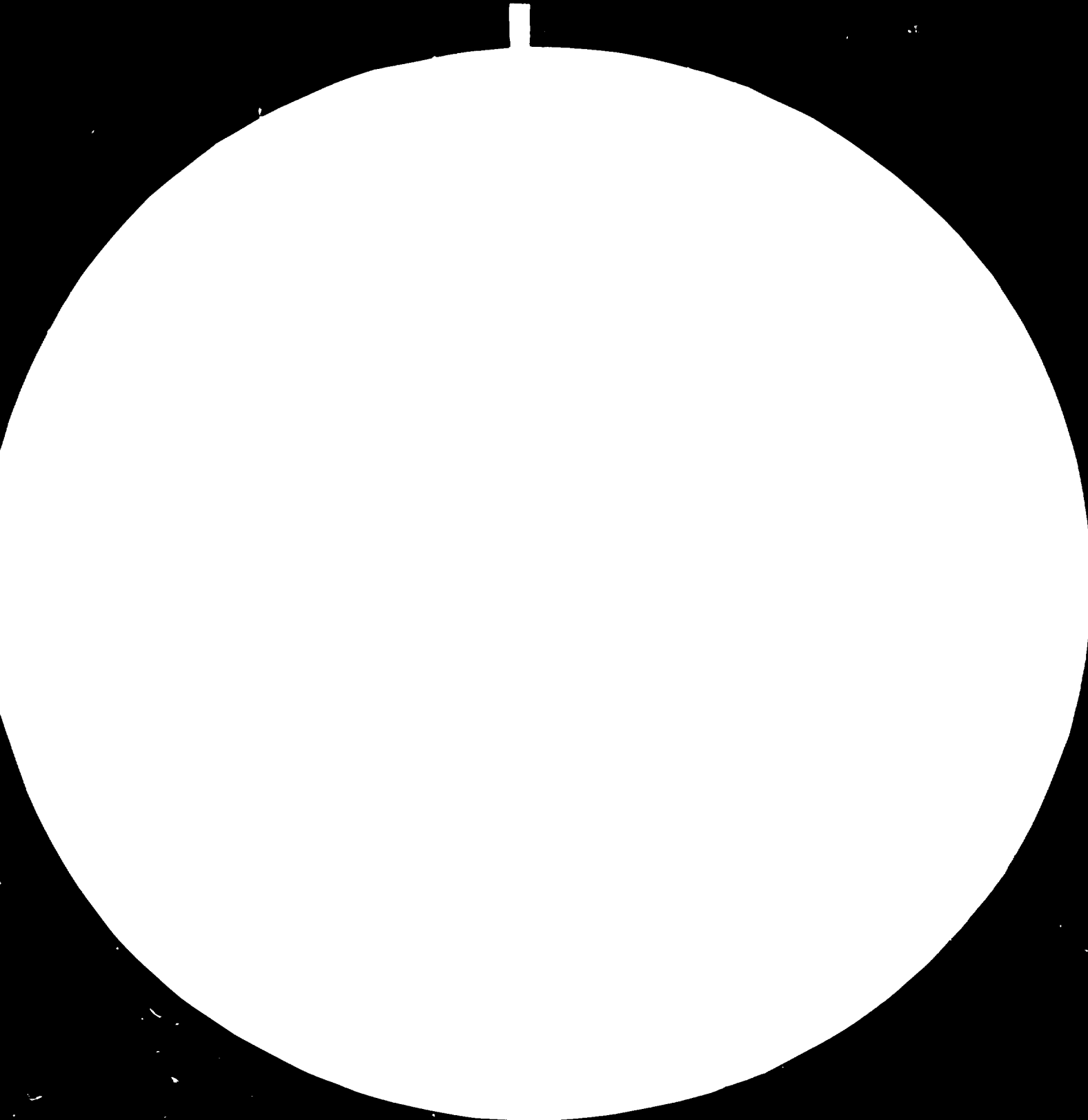

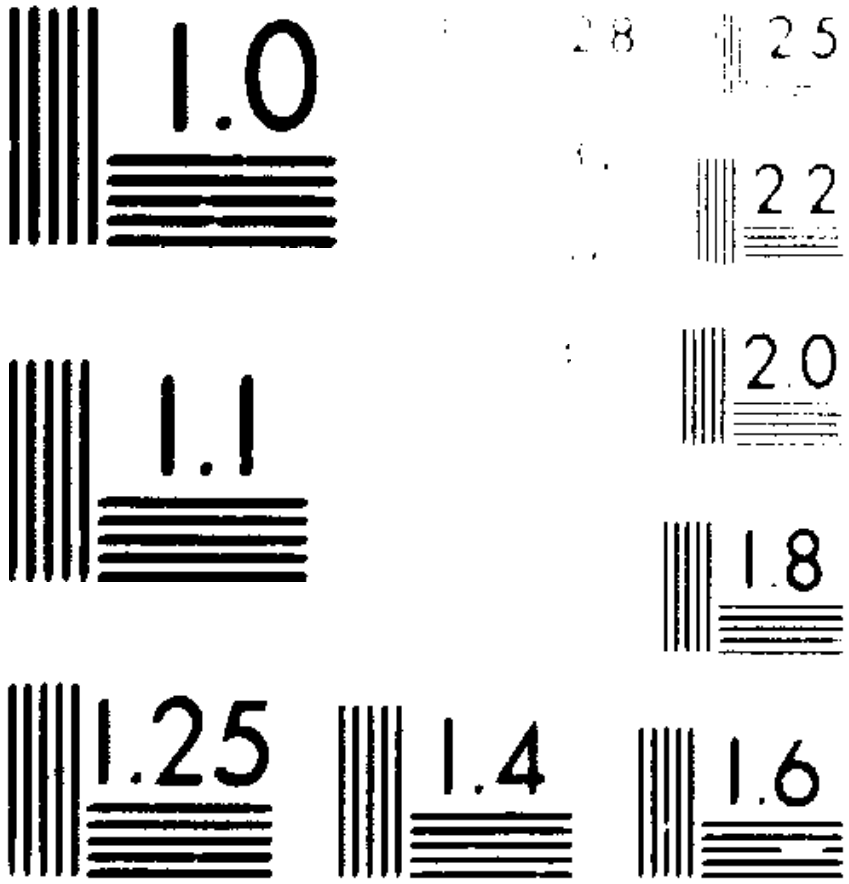
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UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ASSISTANCE TO THE CEMENT INDUSTRY

RP/YEM/81/001

YEMEN

Mission report

# Proposals for the implementation of the Mafraq Cement Plant Project and for overall economy at the Amran and Bajil cement plants

Prepared for the Government of Yemen
by the United Nations Industrial Development Organization

Based on the work of Harald C. Boeck, cement consultant



V. 82-21215

## Explanatory notes

References to dollars ($) are to United States dollars. The monetary unit in Yemen is the rial (YRls). During the period covered by the report, the value of the rial in relation to the dollar was $1 = YRls 4.55.

References to tons (t) are to metric tons.

The following acronyms of organizations are used in this report:

| | |
|---|---|
| ACP | Amran Cement Plant |
| BCEOM | Bureau Central d'Etudes pour les Equipements d'Outre Mer |
| BCP | Bajil Cement Plant |
| BRGM | Bureau de Recherches Géologiques et Minières |
| CERILH | Centre d'Etudes et de Recherches d'Industrielles Liants Hydrauliques |
| MCPP | Mafraq Cement Plant Project |

In addition to the common abbreviations, symbols and terms and those accepted by the System of Units (SI), the following have been used:

| | |
|---|---|
| a | year |
| cal | calorie (1 cal = 4.1868 J) |

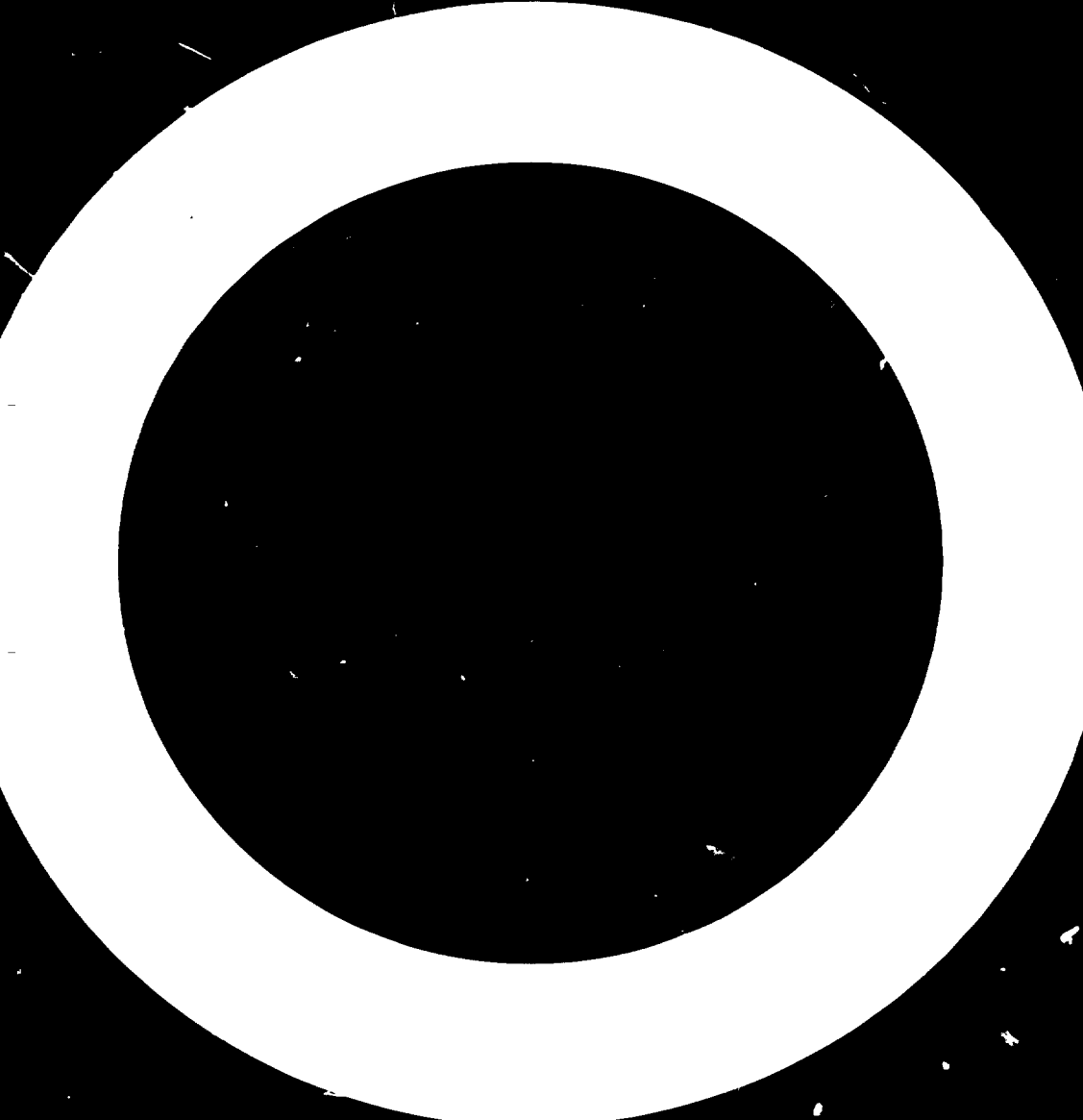
## ABSTRACT

In February 1981, the Government of Yemen requested the United Nations Industrial Development Organization (UNIDO) for technical assistance in the field of cement production, and specifically to make proposals in connection with the implementation of the new Mafraq Cement Plant Project (MCPP). The project "Assistance to the cement industry" (RP/YEM/81/001) was approved on 21 May 1981 and the cement consultant was fielded on 20 November 1981 for a mission of two months. He left San'a on 12 January 1982.

At present Yemen has two cement plants, one at Bajil, about 50 km from Hodeida and another at Amran, about 48 km north-west of San'a. These plants were supplied from Japan and the Union of Soviet Socialist Republics respectively; only the Bajil plant is working (wet process) with one kiln producing about 71,000 t/a of clinker. An expansion of its nominal production capacity by 200,000 t/a is ongoing and will go on-stream in 1983. The Amran Cement Plant is scheduled to start production in August 1982 with a capacity of 525,000 t/a. It is a modern dry-process plant with cyclone preheaters and a flash-furnace precalciner. The new Mafraq Cement Plant will be located in the Mafraq area about 50 km from the Red Sea port of Mocha, and about 40 km west of Taizz.

The expert visited the existing plants and made a number of proposals relating to energy conservation, the utilization of potential pozzolanic resources, and overall economy. In order to improve the operation of the Bajil Cement Plant two local engineers should be trained for one month in a European wet-process plant in order to familiarize themselves with all technical possibilities. The expert also proposes to convert the Bajil plant from wet to dry process.

With regard to the Mafraq Cement Plant Project the expert recommends that, since coal is considerably cheaper than fuel oil, this new plant as well as the 160 MW power station located near Mocha be both coal-fired in order to share coal-storage facilities. The fly-ash from the power plant could be used most advantageously as an additive for the production of pozzolana Portland cement.



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## INTRODUCTION

In February 1981, the Government of Yemen requested the United Nations Industrial Development Organization (UNIDO) for technical assistance in the field of cement production, and specifically to make proposals in connection with the implementation of the new Mafraq Cement Plant Project (MCPP). The project "Assistance to the cement industry" (RP/YEM/81/001) was approved on 21 May 1981 and the cement consultant was fielded on 20 November 1981 for a mission of two months. He left San'a on 12 January 1982. His job description is given in annex I.

The Government of Yemen expects that the demand of cement in the country will have a growth rate of at least 10% per year for the next 5 to 10 years. In 1981 the consumption reached about 800,000 t, and the present installed capacity of the two existing cement plants at Bajil and Amran is 71,000 + 525,000 = 596,000 t/a of clinker. The Amran Cement Plant (ACP) will start production by the end of 1982, and by the end of 1983 the expansion of the Bajil Cement Plant (BCP) may add some 200,000 t/a of clinker bringing the total capacity up to almost 800,000 t/a. By adding about 5% of gypsum, the cement production will reach 840,000 t/a of Portland cement in 1984.

In order to meet the growing demand the Government has decided to establish a third cement plant in the Government of Taizz with a capacity of at least 500,000 t/a of clinker. The project is called "Mafraq Cement Plant Project" (MCPP), and the plant will be located about 40 to 45 km west of Taizz. The new cement plant is expected to go into operation by mid-1985.

Imported cement is landed at the Red Sea ports Hodeida and Mocha at a price of approximately $75/t. Selling price in San'a is about $158/t or YRls 36/bag. The transportation cost from Hodeida to San'a (226 km) is about YRls 0.40/t-km ($0.09/t-km).

Energy costs in Yemen are extremely high; therefore one of the main concerns in connection with the new Mafraq Cement Plant is to minimize energy consumption. The report contains recommendations for the reduction of energy consumption and costs not only for MCPP, but also for ACP and BCP. When comparing the price of bunker C fuel oil (mazut) of $36.60 per Gcal with that of coal, which is about $14 to $17 per Gcal landed at the plant, it seems a "must" to convert all plants from fuel oil to coal. At least Bajil and the new Mafraq plant will have the best possibility to produce cement at a low cost.

As cement production also calls for a rather high consumption of electric power (90 to 140 kWh/t), the Government should seek ways of reducing the cost of electricity produced by all power plants, specifically by those at Hodeida and Mocha and consider an oil-to-coal conversion. An additional benefit of such a conversion would be the possibility of using the fly ash at the Bajil and Mafraq cement plants for the production of fly-ash cement.

## FINDINGS

### A. Mafraq Cement Plant Project

A feasibility study made in 1979 by the French consortium Bureau Central d'Etudes pour les Equipements d'Outre Mer (BCEOM) in association with the Centre d'Etudes et de Recherches d'Industrielles Liants Hydrauliques (CERILH) and the Bureau de Recherches Géologiques et Minières (BRGM), indicates that sufficient quantities of raw materials for cement production are available in the Mafraq area except gypsum and silica sand; however, for a 500,000 t/a cement plant only about 250,000 to 30,000 t/a of gypsum and roughly the same quantity of sand will be needed.

The location of the future plant should not create any problems, the site being near the highway Mocha - Taizz, and situated half-way, i.e. about 45 km each from these towns.

Road conditions are very good; the newly built road to Mocha is excellent for the transportation of coal received at that Red Sea port; and the road to Taizz, though a little mountainous, is also very good. The transportation cost for a ton of cement to the market at Taizz should not exceed about YRls 0.40/km, i.e. YRls 18 to 20/t, equal to YRls 1/bag of cement.

Water is available in sufficient quantity.

### B. Amran Cement Plant

The Amran Cement Plant is still under construction and is scheduled to go into operation in August/September 1982.

Supplier and general contractor is the Japanese company Ishikawajima-Harima Heavy Industries Co. Ltd. (IHI). It is a 100 per cent turn-key supply and financed through suppliers' credit. Consultant firm is the French company BCEOM.

The expert visited the plant for about two hours, but no real assessment can be made based on such a short visit. All cement plants look fine during construction. It is a highly technical, single-unit plant with its own power station; thus the maintenance level will be very high.

Concerning the raw materials the expert found that only about 800 m of core drillings have been made, which is about one third of what normally is considered necessary for a 525,000 t/a cement plant. Nevertheless, the supplier seems to be in a strong position and will happily run the plant for one year fulfilling the easy guarantees.

In most developing countries problems with new cement plants start after about two to three years of operation, many times with heavy losses due to some savings in initial costs during construction, specifically in the field of raw material investigations and quarry opening.

## C. Bajil Cement Plant

The Bajil Cement Plant was supplied by the Union of Soviet Socialist Republics and went on-stream on 28 March 1973 with its first kiln, a wet-process kiln of 2.5 m ø x 75 m with a rated capacity of 50,000 t/a of clinker. The plant is being extended by another wet-process kiln of 4.6 m ø x 150 m with a rated capacity of 200,000 t/a. This second kiln is scheduled to go into operation in 1983.

The expert paid a three-day visit to the plant (23 to 25 December 1981) in order to investigate the possibility of reducing the high fuel consumption at the plant, which is about 1,640 kcal/kg of clinker (6,866 kJ/kg). The plant is in general working very well. Kiln No. 1 is in an outstanding good condition and today producing 71,000 t/a due to an improvement made by the local technical staff. The only problem is the high fuel consumption, which could be considerably reduced by converting the plant from wet to dry process. By an investment of about $30 million, savings in fuel could reach about $10 million per year.

The plant may reach a total capacity of more than 400,000 t/a.

## D. Energy costs

The cost of energy in Yemen is extremely high in spite of the relatively good port facilities at the Red Sea ports of Hodeida and Mocha. The fuel prices are listed below.

| | Price per t | |
|---|---|---|
| | YRls | $ |
| Gasoline<br>0.73 kg/litre, 10,000 kcal/kg | 3,630 | 798 |
| Diesel fuel<br>0.84 kg/litre, 10,000 kcal/kg | 1,670 | 367 |
| Bunker C fuel oil (for cement kilns)<br>0.95 kg/litre, 9,500 kcal/kg | 1,580 | 347 |
| Coal, 6,500 kcal/kg (estimated) | 455 | 100 |

| | Price per Gcal | |
|---|---|---|
| | YRls | $ |
| Gasoline | 363.09 | 79.80 |
| Diesel fuel | 166.99 | 36.70 |
| Bunker C fuel oil | 166.21 | 36.53 |
| Coal (estimated) | 70.00 | 15.38 |

Electric power in San'a costs YRls 1.10/kWh or $0.24/kWh.

## RECOMMENDATIONS

### A. Mafraq Cement Plant Project

Consulting services

In the drafting of the proposed terms of reference for the consulting services for the MCPP (annex III), special attention has been given to the advanced implementation scheme of the project.

It is assumed that the prospective supplier will provide financing for 60 per cent or more of the complete coal-fired cement plant on a 100 per cent turn-key basis. The plant is expected to go on stream by mid-1985.

It is recommended that the Yemeni Ministry of Economy and Industry, hereinafter named "the Client", signs a "Letter of Intent" with the sucessful tenderer, hereinafter named "the Contractor", at a rather early stage.

The Contractor shall undertake all raw materials investigations, including sufficient core drillings, and also select the plant site after having carried out all necessary subsoil investigations. The plant layout and equipment design shall also be provided by the Contractor.

Great care should be exercised in the selection of an appropriate consulting firm for the MCPP. Unfortunately, several cement plants - especially in developing countries - have been poorly designed and are thus very difficult to operate and economically and technically unsatisfactory due to the choice of a consulting firm with insufficient knowledge in cement manufacture and energy conservation.

It is extremely important that the prospective consulting firm matches with the prospective Contractor. Thus no contract should be made or signed with a consulting firm before the successful Contractor is known. It has been seen in several cases that prospective tenderers for a certain cement plant project finally did not participate in the tender due to lack of confidence in the consulting firm involved.

The responsibility of the consulting firm should be confined to the proposed terms of reference given in annex III.

Coal- versus oil-fired plant

Since the cost of energy in Yemen is very high (see p.9) a study should be carried out investigating the benefit of using coal instead of bunker C fuel oil. It is a matter of transportation and handling costs. The coal price ex-mine is about $14 to $20/t. Savings could therefore be considerable, but depend on the size of shipments that can be received in the Red Sea port of Mocha.

Tender invitation

Due to the urgent need to implement the MCPP, it is recommended to invite a few but powerful prospective suppliers from the following industrialized countries: Denmark, France, Germany, Federal Republic of, Japan and United States of America. Annex IV contains a proposal for a tender invitation, which should be sent to the suggested five countries through their embassies or consulates in Yemen.

Implementation scheme

The implementation of the MCPP should be split into four phases as follows:

Phase I: Tender invitations (budget proposals); selection of supplier (general contractor) and consulting firm;

Phase II: Raw material investigations, including fuel and electric power supply; marketing study;

Phase III: Final agreement for a 100 per cent turnkey supply and supplier's credit of 60-100 per cent;

Phase IV: Implementation; commissioning.

This scheme which is detailed in the following table, is aimed at implementing the MCPP within a minimum of time and ensuring production by ~~mid-1985.~~ ~~However, this can only be~~ done by means of supplier's credit extended by a powerful and reputable general contractor. The proposal to select a general contractor at an early stage and to sign a "Letter of Intent" will keep the contractor interested and will most probably speed up the engineering work, as he is ensured the final contract provided the project proves technically and economically feasible.

**Implementation Scheme**
**(x = 10 days)**

| | 1982 J F M A M J J A S O N D | 1983 J F M A M J J A S O N D | 1984 J F M A M J J A S O N D | 1985 J F M A M J J A S O N |
|---|---|---|---|---|
| Phase I | | | | |
| Nomination of Project Manager and administrative team (government officials) | xxx | | | |
| Tender/budget proposal invitation for supply and consultancy services | xxxxxx | | | |
| Award contract for consultancy services | xx | | | |
| Selection of General Contractor | xxx | | | |
| Signature of Letter of Intent for the General Contractor | xxx | | | |
| Phase II | | | | |
| Mapping | xxxxxxxxxx | | | |
| Drilling campaign | xxxxxxxxxxxxxxxxx | xxxxx | | |
| Chemical analysis | xxxxxxxxxxxxxx | xxxxxxxx | | |
| Coal facility study | xxxxxxxxxx | | | |
| Updated marketing study | xxxxxxxxx | | | |
| Techno-economical feasibility study | xxxxxxx | xxxxxxx | | |
| Site selection | xxx | | | |
| Final reports | | xxxxxx | | |
| Phase III | | | | |
| Preparation of final turn-key contract including performance guarantees and penalties | | xxx | | |
| Signature of final contract | | xxx | | |
| Phase IV | | | | |
| Engineering | | xxxxxxxxxxxxxxxxxxx | | |
| Equipment manufacture | | xxxxxxxxxxxxxxxxx | xxxxxxxxxxxx | |
| Civil works | | xxxxxxxxxxxxxxxxx | xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx | |
| Equipment supply | | | xxxxxxxxxxxxxxxxxxxxxxxxx | |
| Mechanical erection | | | xxxxxxxxxxxxxxxxxxxxxx | xxxxxxxxx |
| Electrical erection | | | xxxxxxxxxxx | xxxxxxxxxxxxxxxx |
| Quarry opening | | | | xxxxxxx |
| Commissioning | | | | xxxxxxxxx |

## B. Amran Cement Plant

### Electric power supply

It is recommended that the power station of the plant be connected to the national grid (Hodeida) in order to run the power station more economically by selling power to other consumers.

### Oil-to-coal conversion

A feasibility study should be carried out of the possibility of using coal instead of fuel oil for the kiln. In spite of some 277 km haulage from Hodeida to Amran it could prove feasible. With a cost per km of about YRls 0.40/t, the total transportation cost would be YRls 110.80/t. This means that coal could be delivered C+F Amran for about $125/t, which is equal to $19.23/Gcal for coal with a calorific value of 6,500 kcal/kg. The price C+F Hodeida would be $100/t.

Compared with the afore-mentioned price for fuel oil of $36.53/Gcal, the fuel cost for the kiln could be reduced by nearly 50%.

### Pozzolana Portland cement

A search for pozzolana should be made, i.e. for some natural volcanic material having pozzolanic properties. By pozzolanic properties is meant the ability of a material to combine with lime (CaO) at normal temperature and in the presence of water and to produce compounds having hydraulic properties.

Pozzolana Portland cement contains less than 20% of pozzolana. It does not necessarily satisfy the test for pozzolanicity. Up to 20% of the volcanic material can be added directly to the cement mill together with clinker and gypsum and decrease the production cost of cement by 10 to 15%.

## C. Bajil Cement Plant

### Improvement of existing wet-process kiln

An immediate improvement of the existing kiln production, and probably also fuel consumption, can be achieved by increasing the kiln speed and moving the burner a little backwards, about 0.3 to 0.5 m. However, the satellite cooler may become very hot and the best solution must be sought as compromise between highest possible production and an acceptable working temperature of the cooler.

In order to improve fuel economy the following modifications are recommended:

(a) Install new slurry pumps in order to decrease the water content;

(b) Provide a new chain system in the kiln with partly chrome-nickel chains at the "hot" end;

(c) Increase kiln speed;

(d) New burner designed for 3 to 5% primary air;

(e) High-pressure fan for primary air for kiln oil burner;

(f) Reduce water content in slurry.

Annex V contains an estimate of costs and savings.

Conversion from wet to dry process

If an agreement could be reached between the Government and the Soviet contractor regarding an immediate conversion of the new wet-process extension of BCP, considerable savings in production costs could be achieved.

The erection of the new extension has not yet started; thus it is still time for such an important decision.

A conversion from wet to semi-wet process calls for a careful study. The pressure filter for this process is rather expensive. However, the slurry seems suitable for dehydration by pressure filter. Conversion to dry process is preferable.

In annex V an estimate of costs and savings for both processes is indicated.

## D. Further UNIDO assistance

Short-term consulting services

The Yemeni cement industry will for some time be in the need of short-term consulting services. In connection with the MCPP an updated marketing study would be very important; also, a coal facility study and a techno-economic feasibility study should be carried out as soon as possible. UNIDO assistance would be most helpful in that respect.

Fellowships and training

Specifically the Bajil Cement Plant is in urgent need of assistance regarding improvement of their existing wet-process kiln, since the fuel consumption is excessive.

It is therefore recommended to send one or two of their technical staff on a study tour to manufacturers and designers of advanced heat exchangers for wet-process kilns. Since BCP has scheduled brick relining of their kiln in September 1982, at which time a new chain system could be installed, the study tour is urgently needed.

Concerning further training programmes, reference is made to the special mission to Yemen of Mehmet Başman, UNIDO cement consultant, who was at Sana from 25-31 December 1981 in order to investigate the training needs of the local cement industry.1/

1/ Mr. Başman's report is in preparation.

Annex I

JOB DESCRIPTION
RP/YEM/81/001/11-01/32.1.A.

| | |
|---|---|
| Post title | Cement expert |
| Duration | 2 months |
| Data required | As soon as possible |
| Duty station | San'a with travel in the country |
| Duties | The expert will be attached to the Ministry of Economic Development to advise and assist the authorities in preparing further for the development of the cement industry.<br><br>Specifically he will be expected to:<br><br>(a) Review documents and technical specifications available to the authorities and the cement company;<br><br>(b) Evaluate possible training requirements and propose appropriate action;<br><br>(c) Support and advise the national cement experts on all matters within his competence.<br><br>The expert will also be expected to prepare a final report setting out the findings of his mission and his recommendations to the Government on further action which might be taken. |
| Qualifications | Cement expert with long experience in the cement industry |
| Language | English |
| Background information | Yemen Arab Republic is at present going through a rapid expansion of the cement industry, which within a short time may bring the total production capacity up to or above 2 million tons per year.<br><br>In 1973 production was only 50,000 tons and the rapid expansion has put the few with experience from the cement industry under extreme pressure.<br><br>It has therefore been decided to request UNIDO assistance for support in the preparations for the planned expansion. |

Annex II

PERSONS MET

| | |
|---|---|
| **Ministry of Economy and Industry** | |
| Mohamed Hizam Al-Shohaty | Minister of Economy and Industry |
| Mohamed Ahmad Al-Saidi | Deputy Minister of Economy and Industry |
| W.H. Nakhla | UNIDO Expert-in-Charge |
| Abdulrahman Al-Morair | Mechanical Engineer, Counterpart |
| **Yemen Cement Industry Corporation, Bajil** | |
| Mohamed Al-Samawi | Chairman, Board of Directors |
| Mohamed Al-Ansi | General Manager |
| Ammed Magam | Technical Manager, Electrical Engineer |
| Mohamed Shamsan | Technology Manager |
| **Amran Cement Plant** | |
| Hussein A. Kabiry | Project Manager |
| Soulier | BCEOM (consulting firm) |
| Gilbert Monay | Resident Chief Engineer Supervision Team, BCEOM |

## Annex III

### TERMS OF REFERENCE FOR CONSULTING SERVICES FOR MCPP

1. Coal facility study

The consultant shall undertake a coal facility study containing following items:

Prospective coal suppliers (countries)

Coal qualities

C+F coal price Mocha port

Port facilities Mocha

Coal-handling facilities at Mocha port

Projected coal-fired 160 MW power plant

Coal consumption for the MCPP and new power plant at Mocha (possibly 50% fuel oil and 50% coal)

Coal and fly-ash transportation Mocha - Mafraq

Coal price for coal landed at Mafraq Cement Plant

2. Updated cement marketing study

Population growth rate

Gross national product (GNP)

Cement consumption related to population growth rate and GNP

Cement consumption related to total investment in the construction sector

Five-year plant(s) of Yemen

Projection of expected cement demand in the Taizz area for the period 1985-2000

3. Chemical double-check of core samples

Perform six-component analysis (five oxides + LOI) and/or 11-component analysis (five oxides, LOI, $Cl^-$, S, $Na_2O$, $K_2O$ and $P_2O_5$) as a double-check of analysis made by the contractor

Undertake the decision of when sufficient core drillings have been satisfactorily performed by the contractor

Investigate the possibilities of producing different kinds of low-cost cement such as pozzolana Portland cement (less than 20% pozzolana) or pozzolanic cement (up to 40% pozzolana)

4. Techno-economic feasibility study

Undertake a techno-economic feasibility study of a coal-fired versus oil-fired cement plant based on information provided by the contractor and findings from items 1, 2 and 3

5. Final contract between client and contractor

Draw up, in mutual agreement between the client and the contractor, a final contract for the supply of a coal-fired cement plant on a hundred per cent turn-key and financial-package basis. Special attention shall be given to: the time schedule for delivery, performance guarantees, energy-consumption guarantees and penalty clauses.

6. Drawings and technical specifications

Undertake approval of drawings and technical specifications for all civil works as well as mechanical and electrical equipment, with special regard to local regulations

7. Inspection

Undertake inspection of manufacture and shipment of mechanical and electrical equipment with monthly progress report to the client

8. Supervision

Undertake supervision of the civil works and the erection of mechanical and electrical equipment with monthly progress report to the client

9. Commissioning

Undertake - on behalf of the client - the commissioning of the entire cement plant

Annex IV

PROPOSED TEXT FOR TENDER INVITATION
FOR THE MCPP

The Government of Yemen intends to build a 500,000 t/a coal-fired cement plant at Mafraq about 40 km west of Taizz.

You are among the few companies selected to make a budget proposal as soon as possible whether you are in principle interested in participating in a tender for the above cement plant project on a turn-key basis under following tentative conditions:

(a) Undertake a complete raw material investigation. About 2,000 m of core drillings should be considered;

(b) Undertake a subsoil investigation for the plant site;

(c) Process equipment and plant lay-out at your choice and convenience inclusive quarry equipment, civil works, emergency power station for raw mill and kiln, infrastructure, dwellings, erection, commissioning, training and at least two years management of the plant;

(d) Your financial proposal as suppliers credit should be 60% or more.

Consulting services might be partly provided by the United Nations. Financial package, appropriate technology and low-energy equipment are important factors. The Government of Yemen is considering signing a Letter of Intent with the successful tenderer and proceed immediately with the project. Closing date for your proposal/offer is 1982 at 1200 hrs. at the Ministry of Economy and Industry, San'a, Yemen.

The commercial attaché at your embassy/consulate at San'a is informed and will be at your service if needed.

## Annex V

### BAJIL CEMENT PLANT - PROPOSAL FOR IMPROVED FUEL ECONOMY, ESTIMATED COSTS AND SAVINGS

### A. Improvement of the wet process

| | Thousands of $ |
|---|---|
| New chain system in the kiln | 100 |
| Increased kiln speed | 10 |
| New slurry pumps for thick slurry | 10 |
| Production loss | 400 |
| Subtotal | 520 |
| Contingencies, physical/economical, 30% | 156 |
| Total installation cost | 676 |

Expected reduction in fuel consumption from 1,640 to 1,400 is 240 kcal/kg of clinker. Actual fuel cost is $36.60/Gcal ($8.74/GJ). Expected yearly clinker production unchanged 71,000 t/a.

| | $ |
|---|---|
| Gross savings in fuel per year 71,000 x 36.6 x 0.24 | 623,664 |
| Interest and depreciation, 20% | 135,200 |
| Net savings in fuel per year | 488,464 |

Pay-off period: 16-18 months.

### B. Conversion from wet to semi-wet process

| | Thousands of $ |
|---|---|
| Slurry filter, slurry 18-20% $H_2O$ | 1,000[a/] |
| Cross system for the kiln | 200 |
| Production loss | 400 |
| Subtotal | 1,600 |
| Contingencies, physical/economical, 30% | 480 |
| Total installation cost | 2,080 |

Expected reduction in fuel consumption from 1,640 to 1,100 is 540 kcal/kg of clinker. Actual fuel cost is $36.60/Gcal ($8.74/GJ). Expected yearly clinker production unchanged 71,000 t/a.

---

a/ This figure can vary considerably.

| | $ |
|---|---|
| Gross savings in fuel per year 71,000 x 36.6 x 0.54 | 1,403,244 |
| Interest and depreciation, 20% | 416,000 |
| Net savings in fuel per year | 987,244 |

Pay-off period: 25-27 months

C. Conversion from wet to dry process

| | Thousands of $ |
|---|---|
| Slurry filter | 1,000 |
| Dryer-crusher | 600 |
| Cross system in the kiln | 200 |
| Subtotal | 1,800 |
| Contingencies, physical/economical, 30% | 540 |
| Production loss | 400 |
| Interest during construction, 14% | 250 |
| Total installation cost | 2,990 |

Expected reduction in fuel consumption from 1,640 to 1,000 is 640 kcal/kg of clinker.

Actual fuel cost is $36.60/Gcal ($8.74/GJ). Expected yearly clinker production about 78,000 t/a.

| | $ |
|---|---|
| Gross savings in fuel per year 78,000 x 36.6 x 0.64 | 1,827,072 |
| Interest and depreciation, 20% | 598,000 |
| Net savings in fuel per year | 1,229,072 |

Pay-off period: 29-31 months

D. Conversion from wet to dry process by means of a two-stage preheater

It should be considered and decided as soon as possible to convert both kilns from wet to dry process, and also to change from oil to coal firing.

The total expected clinker production would be about 400,000 t/a and fuel consumption reduced from 1,640 to 950 kcal/kg of clinker.

The following additional equipment would be required:

| | Thousands of $ |
|---|---|
| Preblending bed | 3,000 |
| New raw mill | 2,200 |
| Homogenization silos | 2,400 |
| Two-stage preheater, cross system after-cooler for clinker | 1,000 |
| Electrostatic precipitator | 1,200 |
| Coal mill and handling | 8,000 |
| Subtotal | 17,800 |
| Contingencies, physical/economical, 30% | 5,300 |
| Production loss | 1,900 |
| Interest during construction | 2,500 |
| Total installation cost | 27,500 |

Assumed fuel prices:

| | |
|---|---|
| 40% mazut + 60% diesel fuel, 9,800 kcal/kg, | $36.60/Gcal |
| Coal, 6,300 kcal/kg $100/t, (Fuel oil price = $359/t) | $15.87/Gcal |

| | |
|---|---|
| Fuel costs by wet process (mazut) 400,000 x 36.60 x 1.64 | 24,009,600 |
| Fuel costs by dry process (coal) 400,000 x 15.87 x 1.0 | 6,348,000 |
| Gross savings in fuel per year | 17,661,600 |
| Interest and depreciation, 20%[b/] | 5,500,000 |
| Net savings in fuel by using coal | 12,161,600 |

Pay-off period: 27-29 months

| | $ |
|---|---|
| Fuel costs by wet process (mazut) | 24,009,600 |
| Fuel costs by dry process (mazut) 400,000 x 36.60 x 0.95 | 13,908,000 |
| Gross savings in fuel per year | 10,101,600 |
| Interest and depreciation, 20%[b/] | 3,900,000 |
| Net savings in fuel by using mazut | 6,201,600 |

Pay-off period: 53-55 months (4 1/2 years)

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b/ Added costs for manpower and maintenance are not taken into consideration, as the plant is overstaffed.