UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

18119

RESTRICTED

20 February 1990
English

STUDY OF PROCESS AND QUALITY CONTROL ROUTINES AND PROBLEMS AT AMRAN CEMENT PLANT JANUARY 1990

SF/YEM/87/001

Prepared for the Government of the Yemen Arab Republic by the United Nations Industrial Development Organization (UNIDO) acting as executing agent for the United Nations Development Programme (UNDP)

The report is presented as draft.

Based on the work of Henrik Carlsen, Quality Control Adviser.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA.

List of Contents

List of Abbreviations

YCC	The Yemen General Corporation for Cement Industry and Marketing, Sana'a, Yemen.
IHI	Ishikawajima-Harima Heavy Industries Co., Ltd. Japan.
UNDP	United Nations Development Programme (New York)
UNIDO	United Nations Idustrial Development Organization (Vienna)

INTRODUCTION

The present report covers the findings of Mr. Henrik Carlsen, quality control adviser, collected during his visit to Amran Cement Plant, North Yemen from 10 to 24 January 1990.

The purpose of the project is defined in the attached job description (Annexe 1), and is summarized as follows:

- examine and evaluate the quarrying and the process control routines prescribed by the supplier.
- examine the routines followed for the application of the cement and the test procedures used to check the end product (the concrete).
- analyse the events that in a period of June 1989 led to the production of sub-standard cement and/or concrete.
- advise on how similar developments can be prevented in the future and particularly elaborate recommendations for possible changes in the process control, and the reporting routines.

The adviser arrived in Sana'a on the evening of the 9th january and visited Amran Cement Plant accompanied by Ms. Giovanna Ferrara from UNDP on the 11th and 13th for introduction to the plant management and for discussion of the programme for the visit.

During the period 14th to 24th january the advisor stayed as a resident in Amran and studied the past and present procedures of operation of the plant in collaboration with the plant management and with the two UNIDO advisers, who are at present working at the plant under the terms of the technical assistence agreement between YCC and UNIDO.

The study comprised all aspects of the process and the quality control procedures for the last two years as well as comparisons between these procedures and the recommendation made by IHI. Especially, the events leading to the production of sub-standard cement in June 1989 were examined in detail, and at the end of the visit samples of raw materials, kiln feed, clinker and cement were taken for control analysis in an independant laboratory.

The findings and the conclusions from the study are given in the following report comprising a brief summary as well as comprehensive discussions of all aspects with relation to the cement quality.

The visitor wishes to express his sincere thanks to the Management and Staff of Amran Cement Plant as well as to the representatives of UNDP in Sana'a and to the UNIDO Experts at Amran for their kind support and very much appreciated collaboration received during the mission.

SUMMARY AND CONCLUSIONS

The laboratory records for the last two years show varying quality of the cement produced at Amran Cement Plant. The most critical production was the sub-standard cement observed in June 1989, but cement with too low strength after 3 days was also produced in other periods, for example in the month of December 1988.

The quality problem was studied during the visit based upon observation of the plant operation and routines as well as information obtained from the plant personnel and extracted from the laboratory and the production records.

The raw materials are described in detail in the comprehensive "Geological Survey Report" prepared by IHI in 1980. From this report it appears, that the limestone deposit now being exploited does not contain any types of raw material, which are harmful to the quality of cement, when added to the raw mix in proportions as specified in the report.

Consequently, any of the different types of raw materials found in the limestone quarry can be used in the raw mix without jeopardizing the quality of the cement, but provided that the raw mix is properly proportioned to have the specified chemical composition.

In part II of the "Geological Survey Report" is given guide lines for the utilization of the raw materials, and it is recommended to prepare the raw mix from high CaO and low CaO material from the limestone quarry with the addition of approximately 7 % of "Sandy Clay" for correction of the silica modulus.

The raw mix could also be prepared exclusively by the use of materials from the limestone quarry, and still be suitable for production of cement of good quality. However, the addition of a moderate proportion of Sandy Clay" is acceptable and has some merit as a correction material with well defined composition and a low content of alkalis.

The most important prerequisite for the production of a good quality of cement is the preparation of a raw mix with adequate chemical composition. In the case of Amran Cement Plant it is recommended to adjust the raw mix to meet the following specification:

Lime saturation factor	LSF	= 0.90 - 0.94
Silica modulus	MS	= 2.3 - 2.7
Iron modulus	IM	= 1.5 - 2.0

In order to satisfy these requirements it is necessary to use not only high CaO limestone, but also some marl and/or other low CaO material in the raw mix. In this way it is possible to prepare mix-bed piles, which with the addition of approximately 5 - 7 % of "Sandy Clay" will produce a raw meal with the desired chemical composition.

However, during the period in June 1989, when sub-standard cement was produced, the raw mix did not have a suitable composition. The content of CaO was far too low, and the lime saturation factor LSF was below 0.80 at which level cement with normal strength properties can normally not be produced.

The deviation from the normal raw mix composition started in the beginning of June 1989, when the X-ray analyzer was stopped for lack of ion exchanger resin for the water cooling circuit. As substitute for the X-ray analyzer was used carbonate titrations, but unfortunately with erroneous results, which caused a serious overdosing of the correction material "Sandy Clay" to the raw mill.

The errors of titration were not revealed until several days later, because the laboratory did not have any established back-up procedure for substitution of X-ray analysis by wet chemical analysis in case of break-down of the X-ray analyzer.

In previous reports on the quality problem in June 1989 it is mentioned, that the mix-bed pile, from which the main component of raw material was extracted during the production of the off-specification cement, contained mainly material from an intermediate open yard store located in the quarry adjacent to the limestone crusher.

The material from this intermediate store contained not only limestone but also marl and some low CaO material, which in the Geological Survey Report is referred to as "Waste Material". The average content of CaO in the pile made from this material was therefore somewhat lower than the target used for the previous pile.

It has been suggested, that the production of poor quality cement was due to the use of the low CaO material in the raw mix. However, there is no evidence to support this hypothesis, because all of the materials are suitable for use in the process provided that the raw mix is adjusted to the correct range of chemical composition.

It is therefore concluded, that the production of the poor quality cement was not caused by the presence of low CaO material in the mix-bed pile, but was due to the failure of the laboratory control and the subsequent overdosing of the correction material "Sandy Clay" to the raw mill.

The effect of a low lime saturation factor is a low content of the main strength giving clinker mineral tricalcium silicate (C3S) and consequently low strength properties. The C3S content in the cement should normally be within a range of 45 - 55 %, but was for the bad cement produced in June 1989 much lower - for some samples even down to 0 % (nil).

In order to eliminate the risk of any future production of sub-standard cement it is recommended to introduce a number of improvements within the fields of raw mix preparation, frequency of sampling as well as methods and excecution of analyses and physical testing in accordance with the proposals made in the following pages of the present report.

I GENERAL

The Amran Cement Plant is located about 3 km south-south west of Amran city approximately 50 km north of Sana'a. The plant was supplied by Ishikawajima-Harima Heavy Industries Co., Ltd., I.H.I. of Japan through a turn-key Contract and started production in 1983.

The plant has a single production line with a 4-stages cyclone preheater kiln and SF-flash precalciner. The design capacity is 500.000 tpy of Portland cement.

During the commisioning and the first year of production the plant was operated with the assistance of personnel from I.H.I.. Today the plant occupies essentially local employees and workers with the exception of a few expatriate technicians and two Romanian engineers serving under a technical assistance agreement between YCC and Unido.

During the last two years 1988 and 1989 the plant has produced Portland Cement at an average rate of about 450.000 to 460.000 tons/year corresponding to more than 90 % utilization of the nominal capacity. However, the cement has been of varying quality and has at times, and especially in June 1989, failed to meet the BS12 quality specifications.

A brief description of the plant layout and equipment is given in Appendix 4.

II ORGANIZATION

The organization of the plant follows in principle the recommendations given by the equipment supplier in the guidance book for plant operation. This book contains job descriptions for key personnel with indication of the lines of command and the areas of responsibility, according to which the quality control for raw material and cement is the responsibility of the quarry and the laboratory management under supervision by the technical management.

An excerpt of the organization chart and selected articles from the job descriptions with relevance to the quality control are presented in Appendix 8.

The organization of the technical department is in agreement with the principles normally recommended for cement plants, but additional training of personnel is needed in order to ensure satisfactory execution of all the specified duties.

III RAW MATERIALS

The cement production at Amran Cement Plant is based upon the utilization of raw materials from a limestone deposit located in the hill formation about 3 km south-south west of Amran City, as well as the supply of a correction material known as "Sandy Clay", and gypsum by road from deposits north of Sana'a at about 50 and 80 km distance from Amran respectively.

The "Geological Survey Report" prepared by I.H.I. in 1979/80 also describes a deposit of Iron Ore. However, this material has so far not been used in the raw mix.

The raw material deposit at Amran is rather complex containing several different types of material. The formation is part of a hill raising to about 300 m above the horizontal plane of the plant site. Geologically it belongs to the upper jurasic system and contains limestone, marl, mudstone and other materials in relatively thin layers, and with varying chemical composition.

In addition to the sedimentary rock, the deposit contains a minor quantity of basalt occurring as dykes 2 - 10 wide along the faults of the formation.

The deposit is divided by a north-south fault into an east block and a west block, both containing stratified rock in horizontal or slightly inclined layers. In the geological survey report the layers are identified and the formation divided into 26 Units named by letters A to Z from top to bottom.

The chemical compositions of samples from these units are given the geological survey report and are summarized in Appendix 5.

In spite of the complexity of the limestone deposit it is possible, by means of the detailed description given in the geological report, to identify the different types of material in the quarry. It is also possible to elaborate and execute programmes for the quarry operation in such a way, that high CaO and low CaO material is mixed in adequate proportions to produce a suitable composition of the material for the mix-bed piles.

In the geological report, Part II it is recommended to build mix-bed piles with an average CaO content of 40.5 %, which means that the amount of correction material to be added to the raw mill will be within the range of 5 - 7.5 % of high silica material ("Sandy Clay").

If this recommendation is followed, the life of the quarry will be 50 years counted from the year of commissioning and for operation at the rated capacity of the present production line. Furthermore, it will be possible to produce a raw mix with a suitable chemical composition for the manufacture of a good quality of Portland cement and, at the same time, with a moderate silica modulus (SM = 2.3 - 2.7), which offers the best conditions for the clinker burning process and therefore will contribute to efficient operation in terms of high production, low fuel consumption and long life of the kiln refractory lining.

In order to prepare the raw mix in accordance with the recommendations made by the equipment supplier, it is necessary to exploit not only the high CaO limestone and marl, but also part of the material, which in the geological report has unfortunately been classified as "Waste Material".

It is here proposed to replace this designation by the more appropriate term "Low CaO Material", which describes the material without suggesting what to do with it.

The optimum utilization of the different types of raw material in the limestone deposit is an interesting subject, which ought to be persued in a separate study. However, the potential value of the "Low CaO Material" is mentioned in the present report in order to point out, that none of the materials in the limestone quarry contain elements, which are detrimental to the quality of the cement when used in adequate proportions in the raw mix.

The different types of "Low CaO Material" all have chemical compositions, which are normal for cement raw materials. The only disadvantage of using these materials in the raw mix is the slightly higher contents of alkalis (2 - 3 % K2O), but the effect on the alkali content of the kiln feed will be less than 0.1 %, which will have little influence on the quality of the cement or the operation of the kiln.

The effect of alkalis on the cement quality and the kiln operation should be studied in detail by the establishing of alkali and sulphur balances for kiln operation with and without bypass. The behaviour of the alkalis in the kiln system depends mainly upon the temperature in the burning zone, the input of sulphur to the kiln system and operation of the bypass.

At Amran cement plant the alkalis in the raw mix consist mainly of potassium oxide K2O. In the presence of an excess of sulphur in the kiln the K2O will form potassium sulphate, most of which will leave the kiln with the clinker. It is therefore possible to a certain extent to control the circulation of alkalis in the kiln system by means of the input of sulphur in the raw materials and in the fuel.

In plants where the content of alkalis is moderate, as is the case at Amran, it is often an advantage to operate the kiln with enough sulphur to allow the major part of the K2O to leave the kiln with the clinker thus reducing the circulation of alkalis in the kiln and the preheater to a minimum.

One of the arguments against the use of "Low CaO Material in the raw mix is the experience of low initial strengths during a period from September 1988 to May 1989, when the limestone in the mix-bed piles contained some of this material.

However, the laboratory reports from this period show, that the LSF was as low as 0.85 - 0.87, which gives a low content of C3S and hence low initial strengths. For future operation it is recommended to adjust the raw mix to LSF = 92 - 94, at which level satisfactory initial, as well as final strengths will be achieved.

IV PRODUCTION PROCEDURES

1 Limestone quarry.

The limestone, marl and other low CaO materials to be used for the production are quarried from the relevant benches and hauled by dumpster trucks to the limestone crusher for crushing and transportation by the approximately 900 m long belt conveyor to the raw material store in the cement plant.

However, some limestone is stored in an open air area adjacent to the limestone crusher to serve as a buffer store between quarry and crusher. The crusher is at times fed with material from this buffer store when material from the quarry benches is not available due to break down of quarry or trucking equipment. Normally this should not disturbe the preparation of the raw mix, but the material deposited into the buffer store should have approximately the same average composition as the material, which is normally fed directly to the limestone crusher.

From time to time a batch of high CaO limestone is crushed and deposited in the separate smaller storage hall, which is reserved for the correction materials "Pure Limestone" and "Sandy Clay". The latter mentioned material is the silicious sand received by road lorries from the quarry at Thuqban.

2 Raw Mix Preparation.

The major raw mix component is the mix of limestone, marl and low-CaO material from the limestone quarry. Although this material is to be prehomogenized in the mix-bed store, it is important to avoid excessive variations of the composition of the crushed material from the limestone crusher, because such variations may cause deviations from the target composition of each pile, and hence a variation in the raw meal composition during the changing from one pile to another.

The composition of each mix-bed pile is calculated from the analyses of the daily average samples from the automatic sampler at the inlet end of the store. However, there is, as explained later in the chapter on quality control, a discrepancy between this value for the CaO content and the value, which is obtained from the analysis of the raw meal corrected for the addition of correction material at the raw mill.

This problem, which can be due to errors of sampling or analysis, has been studied by the laboratory in collaboration with the Experts from Unido, and as a preliminary result, it has been established, that the CaO calculated form the analyses of samples from the mix-bed sampling tower is normally 1 - 2 % lower than the CaO calculated from the raw meal analysis.

Until the reason for the discrepancy has been fully clarified, the difference between the CaO values should be taken into account when setting the target for new mix-bed piles in order to avoid a too high CaO content of the pile and consequently a demand for more than the specified amount of correction material in the raw mix.

The target for the raw mix composition should be set to allow the production of a good quality of cement and - at the same time - to make the kiln feed suitable for the burning process.

In the "Geological Survey Report", Part II, page II-11 the raw mix modules are specified as follows:

Hydraulic Modulus (HM)	2.10
Silica Modulus (SM)	2.6 - 2.7
Iron Modulus (IM)	1.7 - 1.9
Lime Saturation Factor (LSF)	0.91

If this specification is followed, the raw mix will produce a clinker with approximately the following composition of clinker minerals:

Tricalciumsilicate	C3S	52 %
Dicalciumsilicate	C2S	24 %
Tricalciumaluminate	C3A	9 %
Tetracalciumaluminoferrite	C4AF	9 %
Other matter	-	6 %

Clinker with this composition and without excessive contents of magnesia, alkalis, free silica or other harmful material will, when properly ground with gypsum normally produce Portland cement of good quality. Furthermore, the corresponding raw mix will, when ground to normal raw meal fineness, normally be suitable for the burning process in the kiln.

However, the above mentioned specification has not been adhered to during the past operation, but the composition of the raw mix has been allowed to vary considerably, resulting in problems with the kiln operation and the occasional production of a poor quality of cement.

The raw mill operation is normally satisfactory with the exception that it is difficult to dry the raw materials, although the moisture content is normally only 2 - 3 %. However, the limited drying effect of the raw mill is a separate problem, which has little effect on the cement quality, and which is therefore not dealt with in the present report.

The homogenizing effect of the two mix-chamber silos is indicated to be approximately 1:5, which is on the low side but acceptable provided that efficient preblending of the raw material is achieved in the mix-bed store.

However, it is important to ensure that the aeration systems for both silos are maintained in good condition in order to obtain maximum utilization of the aeration effect available. Therefore the silos should be emtied, one at a time, and at regular intervals for inspection and reconditioning of the aeration pipings.

3 Clinker Burning.

The kiln is normally running continuously and the clinker is burned to a low content of free CaO i.e. 0.5 - 1.0 %, which is adequate for the production of a good quality of cement, provided the composition of the kiln feed is normal. From a product quality point of view the kiln is therefore performing satisfactorily, but the clinker is often burned harder than necessary, which causes increased consumptions of fuel oil and electric energy, as well as increased wear of the refractory lining and damage to the cooler grate plates.

Approximately 50 t/d of bypass dust is at present wasted, and it has been suggested to return this dust into the process either to the raw mill or to the cement mill.

It is claimed by the production department, that it is necessary to operate the bypass in order to avoid clogging of the kiln preheater cyclones. However, the bypass dust contains only 2 - 3 % alkalis, and the effect of extracting 50 t/d thereof from the kiln system is hence rather small corresponding to a reduction of the total input of alkalis by less than 5 %.

It is a question if this small effect can justify the continuous use of the bypass. In this connection it should be noted that a similar or perhaps bigger effect could possibly be obtained by reducing the temperature of burning and thereby the volatilization of alkalis in the burning zone. Another way of reducing the concentration of alkalis in the kiln system is to increase of the input of sulphur for combination of more of the K20 as potassium sulphate, which is hard to evaporate and therefore will tend to leave the kiln as a clinker constituent.

The return of bypass dust to the cement mill may have little effect on the quality of the cement, but is not permitted by the BS 12 standard specification. This problem can be avoided by adding the dust to the raw mill, but then the alkalis are reintroduced into the kiln system. The combined effect of removing and reintroducing the dust may therefore be very nearly the same as if operating without the bypass.

Still the proposal to return bypass dust to the raw mix may have some merit. One reason is that some of the volatiles may pass the bypass precipitator with the gases and will therefore not be returned with the dust. Another reason is that the bypass may still help to even out variations in the concentration of volatiles in the kiln. Furthermore, it would be possible to return part of the dust, whereas the volume of gases to the bypass is not adjustable.

The behaviour of the alkalis in the kiln system with or without the use of the bypass should - as mentioned in the chapter on raw materials - be studied by means of material balances for alkalis and sulphur.

4 Cement Grinding.

The cement is ground in closed circuit to normal Portland cement fineness about 3000 to 3400 Blaine with the addition of a good quality of gypsum and at normal mill temperature. There is therefore no evidence, that the operation of the cement mill might have had any negative effect on the quality of the cement.

However, the efficiency of grinding depends upon a number of factors, which should be optimized in order to achieve full utilization of the installed grinding capacity and at the lowest possible energy consumption. Good mill operation does therefore require not only continuous surveillance of the product fineness and the mill temperature controlled by the internal water spray, but also frequent control of the separator efficiency as well as inspection and maintenance of mill diaphragms and ball charges.

V QUALITY CONTROL

The quality of raw materials, clinker and cement is controlled by the laboratory in accordance with the recommendations given by the equipment supplier. The sampling, testing and control procedures are summarized as follows:

1 Shift and chemical laboratory

Raw materials from quarries.

Samples of dust from the drilling of blasting holes are sent to the laboratory by the quarry management for X-ray analysis.

Crushed limestone to mix-bed.

The limestone passes an automatic belt weigher and a "Minemet" automatic sampling plant before entering the mix-bed pile. The average samples for each day are collected by the laboratory for X-ray analysis.

Raw meal and kiln feed.

Samples are extracted by automatic screw samples and collected every 2 hours for determination of sieve residue on 88 micron, titration and X-ray analysis.

Clinker.

Samples are collected manually from the cooler outlet every 2 hours for determination of free CaO and for X-ray analysis on daily composite samples. The clinker literweight is determined by the production department.

Cement.

Samples are extracted by automatic screw sampler and collected every 2 hours for determination of residue on 88 micron, Blaine and SO3 content. X-ray analysis is made daily on composite sample.

Other materials.

Samples of "Sandy Clay", Gypsum and Fuel Oil are analysed from time to time, and material from the 4th stage preheater cyclone and from the bypass precipitator is collected every day for determination of SO3, alkalis and chloride.

2 Physical Testing

Cement from the automatic sampler after the cement mill and spot samples from the bagging plant are tested daily in accordance with British Standards BS 12:1978.

The procedures are with a few exceptions similar to those adopted by most other modern cement plants. The exceptions are the relatively low frequency of testing of samples of raw meal, kiln feed, clinker and cement, and the lack of storage boxes for samples of the last 24 hours clinker production to be saved for visual inspection and analysis as and when required.

The relatively low frequency of testing is acceptable if the continuous working premixing and homogenizing systems and the process control instrumentation are in good condition, but hourly testing of raw meal and clinker is recommended in order to provide earlier warning about possible anomalities.

Whereas the sampling and testing procedures are in general acceptable, it appears from the laboratory records, that the results of analysis do not always satisfy normal requirements with regard to accuracy and reliability. Titrations, X-ray analyses and wet chemical analyses often produce different results, and little seems to be done in order to identify and correct the reasons for these discrepancies.

The differencies between the results of analysis made by X-ray and by wet chemical analysis are illustrated in Appendix 6 showing a comparison of the results from a number of analyses made by either method.

Another example of inconsistency of the results of analysis is the differences between the calculated average analysis of a mix-bed pile and the analysis calculated from the raw meal analysis taking into account the proportion of correction material added at the raw mill inlet. The reason for these differencies may be a sampling error or an X-ray analyzer calibration error. In order to study the accuracy of the X-ray analysis further the visitor received a set of samples of raw materials, kiln feed, clinker and cement for analyses in an independent laboratory.

The method used at Amran Cement Plant for determination of CaO by titration produces an "apparent CaO", which is the combination of CaO and the CaO-equivalent content of MgO from magnesium carbonate. This figure should not by used directly to represent the true CaO content of the sample, but should be corrected for the MgO content determined by a MgO titration or deducted from X-ray analyses of samples from the same source of material. A method for determination of CaO as well as MgO by carbonate titration is given in appendix 7.

3 Laboratory Equipment

The laboratory is located in a one storey building located near the centre of the plant between the mix-bed store and the Central Control room. It is divided into separate rooms for chemical analysis, X-ray analysis and physical testing as well as a sample preparation room, a curing room with thermostat temperature control, a reagent store and an office.

The chemical laboratory has equipment and reagents for the execution of carbonate titrations, wet analysis using EDTA titration for CaO and MgO, determination of SO3, alkalis and free CaO, and for fuel analysis. The equipment includes analytical balances, electrical furnaces and a flame photometer. However, only few analyses are carried out because all relevant elements for the quality control are normally available from the X-ray analyzer.

The X-ray analyzer is a Shimadzu X-ray Quantometer type VXQ-150 with equipment for preparation of pressed pellets or fused beads using Lithium borate as the fusing agent.

Pressed pellets are used for determination of the four main elements (Ca, Si, Al and Fe) in raw meal and clinker, and the same components plus S (SO_3) in cement. Fused beads are used for determination of 9 elements in samples from the quarries and in the daily average samples of raw meal, clinker and cement.

The laboratory depends very much upon the availability of the X-ray analyzer. It is therefore important to maintain a stock of the necessary materials and parts for the operation of this equipment. However, it is not possible to ensure 100 % availability of this type of analyzer, and it is consequently also important to have reliable back-up routines for performing analysis by the wet method.

The physical laboratory is equipped with standard devices for the testing of cement according to BS 12:1978, and the machinery, tools and moulds all seemed to be in a good condition.

VI Off-SPECIFICATION CEMENT

The laboratory records for the last two years show varying quality of the cement produced at Amran Cement Plant. The most critical production was the sub-standard cement observed in June 1989, but cement with too low strengths after 3 days was also produced in other periods, for example in the month of December 1988.

The strength of cement depends mainly only upon one or more of the following factors:

- the chemical composition of the raw mix
- the fineness of the raw mix
- the degree of burning of the clinker
- the fineness and the granulometry of the cement
- the quality and the proportion of gypsum added to the cement mill
- the content of water soluble alkalis in the cement
- the degree of prehydration of the cement

The influence of these parameters were studied on basis of the laboratory and production records, and it was found that only the chemical composition of the raw mix showed deviations from normal conditions to the extent, which could explain the abnormal cement quality observed in June 1989.

The study also revealed, that the cement strength can be correlated to the lime saturation factor of the kiln feed not only for the period from May to July, 1989, when the cement strength failed completely, but also for a comparison of two other months with high and low initial strength figures respectively.

The figures used for this comparison are given in a table and two graphical presentations enclosed as Appendix 9.

From the table it appears, that the lowest initial strength figures were found in June 1989, when the LSF was as low as 0.80. In December 1988 the 3 days strength was in average 19.9 (i.e. below the BS 12 requirement of 23 N/mm2) and the LSF was 0.85, which is still much lower than the recommended rage of 0.90 to 0.94.

The other figures for the months of May, July and October in 1989 all show 3 days strength figures above the BS requirement, and the LSF values are here in the range 0.87 to 0.90.

As mentioned previously in this report the analyses of the various raw materials found in the limestone quarry as presented in the Geological Survey Report do not show any contents of elements, which are detrimental to the quality of cement, when added to the raw mix in adequate proportions. It is therefore concluded, that the quality problem is due to the use of raw mixes with too low LSF, and is not related to the use of one or another type of the available raw materials in the raw mix.

In part II of the "Geological Survey Report" is given guide lines for the utilization of the raw materials, and it is recommended to prepare the raw mix from high CaO and low CaO material from the limestone quarry with the addition of approximately 7 % of "Sandy Clay" for correction of the silica modulus.

The raw mix could also be prepared exclusively by the use of materials from the limestone quarry, and still be suitable for production of cement of good quality. However, the addition of "Sandy Clay" in a moderate proportion is recommended for the following reasons:

1) The "Sandy Clay" has a well defined chemical composition and a high silica modulus, which make it suitable for addition to the raw mill for correction of the material from the mix-bed pile.

2) The "Sandy Clay" has a low content of alkalis.

The paramount prerequisite for the production of cement of good quality is the preparation of a raw mix with adequate chemical composition. In the case of Amran Cement Plant it is recommended to adjust the raw mix to meet the following specification:

Lime saturation factor	LSF	= 0.90 - 0.94
Silica modulus	MS	= 2.3 - 2.7
Iron modulus	IM	= 1.5 - 2.0

In order to satisfy these requirements it is necessary to use not only high CaO limestone, but also some marl and/or other low CaO material in the raw mix. In this way it is possible to prepare pre-mix piles, which with the addition of approximately 5 - 7 % of "Sandy Clay" will produce a raw meal with the desired chemical composition.

However, during the period in June 1989, when sub-standard cement was produced, the raw mix did not have a suitable composition. The content of CaO was far too low, and the lime saturation factor LSF was below 0.80 at which level cement with normal strength properties can normally not be achieved. The deviation from the normal raw mix composition was caused by erroneous proportioning of correction material to the raw mill which was based upon unreliable titration analyses in the lack of X-ray analyses.

The series of events, which led to the production and eventually the release of sub-standard cement is summarized as follows:

- building up of a mix-bed pile using low CaO limestone from the open yard storage area near the limestone crusher. This was done in order to meet the demand for raw material in spite of shortage of trucks for transportation of limestone in the quarry. (Comment: Although the composition of this pile differed from the composition of normal piles, it could easily have been corrected to the desired lime saturation by the addition of a small proportion of "pure limestone" at the raw mill following the normal procedures, if correct analyses had been available).

- the X-ray analyzer was stopped on 6th June. (Commment: The reason for stopping the analyzer was according to the laboratory management the lack of ion exchanger resin for the cooling water circuit. It was correct to stop the analyzer in order not to cause damage to the equipment, but the inventory and procurement functions have failed in insuring the availablity of replacement resin).

- the carbonate titrations started to produce wrong result simultaneously with the stopping of the X-ray analyzer. (Comment: Could easily have been detected by routine titrations on standard samples, which, however, were not carried out).

- during the 20 days of operation without the X-ray analyzer no wet analyses were made. (Comment: The laboratory is equipped for the execution of wet analyses for determination of the main elements Ca, Mg, Si, Al, and Fe. If these facilities had been used properly, the off-specification composition of the raw mix would have been detected within the 5 hours it takes to perform a wet analysis.

- the kiln was allowed to produce a poor quality of clinker for several days before the lack of physical strength properties was observed at the testing of cement from the cement mill.
  (Comment: The poor quality of clinker could have been detected earlier by hourly inspection of the clinker, monitoring of the clinker literweight and by the preparation of mortar pats of ground clinker every day).

In conclusion all information collected during the visit clearly indicates, that the production of sub-standard cement in June, 1989 was due to inadequate testing and control procedures and routines in the plant and especially in the laboratory. It is recommended to introduce a number of improvements within the fields of raw mix preparation, frequency of sampling, methods and excecution of analyses and physical testing as follows:

1. Set the target for the CaO content of the mix-bed piles to produce a raw mix with LSF = 0.92 when prepared with 5 - 7 % "Sandy Clay".

2. Establish routines for checking the results of X-ray analysis by use of standard samples and inter-laboratory comparisons.

3. Introduce regular executions of back-up analysis by wet chemical analysis.

4. Correct CaO titrations for MgO content (ref. Appendix 7).

5. Collect samples of raw meal every hour for determination of CaO by X-ray or by titration.

6. Save clinker samples during 24 hours f r visual inspection.

7. Check the hydraulic properties of clinker or cement at least once per day for example by the preparation of pats for boiling test (ref. DIN 1164 - part 6).

8. Introduce a programme for alternating use of silos for clinker and cement in order to prevent accidential shipping before results from initial strength tests are known.

9. Improve laboratory performance by upgrading of equipment and housekeeping as well as by the implementation of systematic calibration and recording procedures and by supplementary training of personnel.

C. Rydeng/ns
Quality

14 November 1989

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION

TF/GLO/87/011/11-51/J 13419

Post title	Quality Control Adviser
Duration	Four weeks
Date required	As soon as possible
Duty Station	Amran and Sana'a
Duties	The expert will be assigned to the government of the Yemen Arab Republic and delegated to the Yemen General Corporation for Cement Industry and Marketing where he will assist the management in examining process and quality control routines and problems experienced in the past in the Amran Cement Factory.

Specifically the expert will be expected to:

- examine and evaluate the quarrying and the process control routines prescribed by the supplier.
- examine the routines followed for the application of the cement and the test procedures used to check the end product (the concrete).
- analyse the events that in a period of June 1988 led to the production of sub-standard cement and/or concrete.
- advise on how similar developments can be prevented in the future and particulary elaborate recommendations for possible changes in the process control, and the reporting routines.

The expert is further expected to advise and assist within his entire capacity and at the end of his mission to prepare a technical report on his findings, observations and recommendations.

Qualifications	Cement Expert with extensive experience in production of cement from a management position and specific experience in quality and process control.
Language	English
Background information	The development of the cement industry in Yemen Arab Republic started in 1973 with the establishment of cement production in the Bajil Cement Plant situated 50 km east of Hodeida. Since the whole planning of the Bajil Cement Factory took place when fuel oil was not expensive this factory was constructed as a wet process factor with two production lines supplied from the Soviet Union. The two lines consist of two kilns with production capacities of 71,000 and 200,000 TPA clinker respectively. The second line started its production in 1983. The Amran Cement Plan is located about 3 km south-south west of Amran city, some 50 km north of Sana's. This plant was established and the equipment were supplied by a Japanese Company (Ishikawajima Harima Heavy Industries Co., Ltd., I.H.I.) through a turn-key contact. The Amran Cement Plant is of capacity of 1/2 million TPA and is a modern dry process plant applying cyclone preheaters of 4-stages and a flash furnace pre-calciner. It started its production in 1983. It is scheduled and planned that a new plant with a production capacity of 1/2 million TPA will be established in El Mufraq area situated about# 50 km from the Red Sea Port of Mocha and about 40 km west of Taiz.

Travel and Work Schedule

Post: TF/GLO/87/011/11-51/J13419
Title: Quality Control Adviser
Name of expert: Mr. Henrik Carlsen
Duration: 9 january - 2 february 1990

09 jan 1990	Departure from Copenhagen for travel to Sana'a, Yemen Arab Republic.
10 jan	Meeting at UNDP, Sana'a.
11 jan	Visit to Amran Cement Plant, meeting with Technical Manager and with Unido Experts.
12 jan	Study of documentation received during visit to Amran.
13 jan	Visit to Amran Cement Plant, meeting with Deputy General Manager, visit to quarry.
14 - 24 jan	Stay at Amran Cement Plant for study in detail of plant operation and quality control.
22 jan	Sampling of raw materials from the limestone quarry and from the plant store for Sandy Clay. The samples were hand carried to Copenhagen for analysis. Lecture on the subject of Quality Control. Submitted preliminar report to the technical management.
24 jan	Departure from Sana'a for Vienna.
25 - 26 jan	Debriefing at Unido, Vienna.
26 jan	Departure from Vienna for Copenhagen.
27 jan - 2 feb	Elaboration of final report in Copenhagen.

List of Officials and Management Staff Personnel met during the Mission.

Name	Title
Mohamed Al Anesy	General Manager, Amran Cement Plant
Aly Giubary	Deputy General Manager
Mohamed Muharam	Technical Manager
Mansoor Abdulgany	Laboratory Manager
Husin Hasani	Production Engineer
Constantin Sitaru	Chemical Engineer, Unido Expert
Cristache Anton	Mining Engineer, Unido Expert
Giovanna Ferraro	Junior Professional Officer, UNDP in Sana'a.

AMRAN CEMENT PLANT

List of Main Equipment

1. Quarry and Crushing

(I) Limestone Crushing

a) Crushing method

Open circuit with compound impact crusher (Hazemag)

b) Performance

Capacity	500 t/h
Particle size, feed	Max. 1300 mm
product	10 % res. 25 mm
Operating time	7 h/d x 6 d/week

(II) Sandy Clay and Gypsum Crushing

a) Crushing method

1st stage: Open circuit (Toothed roll type with grizzly)
2nd stage: Open circuit (Toothed roll type with screen)

b) Performance

Capacity:	Sandy Clay:	Max. 135 t/h
	Gypsum:	Max. 35 t/h

Particle size:

Sandy Clay, feed	Max. 40 mm
product	10 % res. 25 mm
Gypsum, feed	Max. 400 mm
product	10 % res. 25 mm

Operating time:

Sandy Clay	3 h/d x 6 d/week
Gypsum	3 h/d x 6 d/week

2. Raw Material Grinding and Homogenizing

(I) Mix bed (for limestone)

a) Type: Sheltered type, Chevron stacking pattern (MVT)
b) Size: 30.5 m wide x 172 m long x 13.5 m high

c) Storage capacity: 20.000 tons x 2 piles

d) Reclaiming, type: Bridge mounted scraper with harrow
capacity: Max. 220 t/h

(II) Storage Yard (for Sandy Clay and Pure Limestone)

a) Type: Sheltered stock pile

b) Storage Cap.: Pure Limestone: 1.000 tons
Sandy Clay: 1.300 tons

(III) Raw Material Grinding

a) Type: Closed circuit 2 comp. compound mill with air separator

Mill size: 4.2 x 12.31 m
Mill drive: 2.900 kW center drive

b) Performance

Cap. on dry basis:	145 t/h
Feed size:	25 mm, 90 % passing
Product fineness:	10 % res. on 4900 mesh
Operating time:	24 h/d x 6 d/week

(IV) Raw Material Homogenizing and Storage

a) Type: Mixing chamber type
b) Storage cap.: 4.500 tons x 2 silos
c) Kiln feed cap.: Max. 140 t/h
d) Raw meal homogeneity: Standard deviation of $CaCO_3$ is max. 0.4 as mean value during 24 hours at outlet of the equipment, or 1/5 of that at inlet of the equipment.

3. Clinker Burning

(I) Clinker burning

a) Type: Dry process short kiln with IHI-SF Preheater

b) Performance

Clinker output:	1.750 t/d
Operating time:	24 h/d x 7 d/week

c) Clinker cooler

Type:	Horizontal grate cooler (Fuller-Babcock-Hitachi)
Temp. of product:	50 deg.C above ambient

(II) Bypass System

a) Performance

Bypass rate	25 % (Max.)

4. Cement Handling

(I) Cement Grinding

a) Type: Closed circuit, 2 comp. compound mill with air separator

Mill size:	4.4 x 13.81 m
Mill drive:	3.500 kW center drive

b) Performance

Cap.:	95 t/h
Product fineness:	3.000 Blaine (cm2/g)
Operating time:	24 h/d x 6 d/week

(II) Cement Storage

a)	Type:	Reinforced concrete made
b)	Storage cap.:	12.000 tons x 2 silos
c)	Discharge cap.:	Max. 110 t/h x 3 sets for packer max. 110 t/h x 1 set for bulk loading

(III) Cerent Packing and Loading

a) Type: 6 filling spouts rotary type (Claudius Peters)

b) Performance:

Bagging cap.: 1800 bags/h x 3 sets (50 kg bags)
Operating time: 8 h/d x 6 d/week

c) Bag loading: By 6 lanes of mobile loader conveyor

(2 lanes for each one packer)

5. Power Plant

a) Type: Diesel generator

b) Capacity: 5.700 kW x 4 sets

--- 0 ---

Table 7. Ore reserves and Waste Quantity of Amran Limestone Deposit. (table 7,1)

Appendix 5 - table 1

Ore Reserves

Area	Unit	East Block Volume (m^3)	East Block Density	East Block Reserves (t)	West Block Volume (m^3)	West Block Density	West Block Reserves (t)	Total Volume (m^3)	Total Reserves (t)	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	SO_3	P_2O_5	Cl	Ig Loss
Upper compartment	A	217,050	2.6	564,300	124,330	2.6	323,200	341,380	887,500	48.8	1.8	4.8	1.6	0.9	0.35	0.05	0.10	0.040	0.02	41.17
	B	895,740	2.6	2,328,900	572,910	2.6	1,489,500	1,468,650	3,818,400	45.9	4.1	4.4	1.2	0.9	(0.47)	(0.06)	(0.11)	(0.028)	(0.02)	42.17
	Sub-total	1,112,790		2,893,200	697,240		1,812,700	1,810,030	4,705,900	46.4	3.7	4.5	1.3	0.9	0.45	0.06	0.11	0.030	0.02	41.98
Lower compartment	E				4,820	2.6	12,500	4,820	12,500	48.6	1.8	4.9	1.7	1.4	(0.48)	(0.05)	(0.10)	(0.040)	(0.02)	40.73
	G				122,290	2.6	317,900	122,290	317,900	50.7	2.2	2.6	0.8	1.0	(0.42)	(0.04)	(0.12)	(0.030)	(0.01)	42.38
	J	10,180	2.6	26,400	2,481,920	2.6	6,452,900	2,492,100	6,479,300	48.4	2.4	4.5	1.5	1.1	0.35	0.05	0.13	0.027	0.013	41.37
	K	40,820	2.6	97,900	757,980	2.6	1,819,100	798,800	1,917,000	36.0	2.3	16.6	5.8	3.0	1.13	0.07	0.09	0.086	0.015	34.01
	N	675,520	2.6	1,756,300	3,547,680	2.6	9,223,900	4,223,200	10,980,200	46.6	1.4	7.3	2.5	1.4	0.61	0.06	0.22	0.054	0.010	39.32
	O	306,370	2.6	735,200	1,184,240	2.6	2,842,100	1,490,610	3,577,300	35.7	1.9	17.1	6.5	2.8	(1.38)	(0.05)	(0.03)	(0.072)	(0.017)	33.53
	Q	588,730	2.6	1,412,300	1,513,090	2.6	3,631,400	2,101,820	5,043,700	35.8	3.6	15.6	5.9	2.7	1.38	0.05	0.03	0.072	0.017	34.40
	R	617,690	2.6	1,605,900	1,555,130	2.6	4,043,300	2,172,820	5,649,200	48.6	1.7	4.9	1.6	1.1	0.25	0.05	0.34	0.021	0.017	40.83
	Sub-total	2,239,310		5,634,000	11,167,150		28,343,100	13,406,460	33,977,100	44.0	2.1	9.1	3.3	1.7	0.74	0.05	0.16	0.050	0.014	38.35
Total		3,352,100		8,527,200	11,864,390		30,155,300	15,216,490	38,683,000	44.3	2.3	8.5	3.0	1.6	0.70	(0.06)	(0.16)	(0.048)	(0.015)	38.79

Waste Quantitv

Table 7. Ore reserves and Waste Quantity of Amran Limestone Deposit. (table 7.2)

Area	Unit	East Block Volume (m^3)	East Block Density	East Block Reserves (t)	West Block Volume (m^3)	West Block Density	West Block Reserves (t)	Total Volume (m^3)	Total Reserves (t)	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	SO_3	P_2O_5	Cl	Ig Loss
Upper compartment	b_1	52,350	2.4	125,600	26,180	2.4	62,800	78,530	188,400	26.5	6.0	18.9	6.9	3.1	(1.76)	(0.13)	(0.14)	(0.091)	(0.003)	33.05
	b_2	79,610	2.4	191,000	53,120	2.4	127,400	132,730	318,400	28.4	6.9	15.8	6.1	3.5	(1.61)	(0.08)	(0.14)	(0.067)	(0.006)	34.59
	Basalt				64,960	2.7	175,400	64,960	175,400											
	Sub-total	131,960		316,600	144,260		365,600	276,220	682,200	27.7	6.6	17.0	6.4	3.4	1.67	0.10	0.14	0.076	0.006	34.0[illegible]
Lower compartment	F				60,880	2.4	146,100	60,880	146,100	23.1	7.2	23.6	8.5	4.2	(1.98)	(0.14)	(0.09)	(0.090)	(0.006)	29.7[illegible]
	H				513,770	2.4	1,233,000	513,770	1,233,000	24.2	3.8	25.7	9.9	4.8	(1.98)	(0.14)	(0.09)	(0.090)	(0.006)	27.8[illegible]
	I				309,470	2.4	742,700	309,470	742,700	9.6	1.7	47.2	14.9	5.7	(2.51)	(0.15)	(0.15)	(0.117)	(0.005)	16.4[illegible]
	L	32,950	2.4	79,000	541,280	2.4	1,299,000	574,230	1,378,000	4.3	1.6	58.9	13.4	4.4	(3.43)	(0.39)	(0.04)	(0.074)	[illegible]	[illegible]
	M	32,700	2.4	78,400	447,580	2.4	1,074,100	480,280	1,152,500	32.4	1.6	20.6	7.1	3.8	(1.25)	(0.06)	(0.11)	(0.052)	(0.011)	31.[illegible]
	P	247,340	2.4	593,600	875,050	2.4	2,056,900	1,122,390	2,650,500	26.4	5.6	26.0	8.1	4.3	(1.71)	(0.07)	(0.10)	(0.088)	(0.05)	[illegible]
	Sub-total	312,990		751,000	2,748,030		6,551,800	3,061,020	7,302,800	21.1	3.6	33.4	9.9	4.5	2.09	0.15	0.09	0.083	0.023	[illegible]
Total		444,950		1,067,600	2,892,290		6,917,400	3,337,240	7,985,000	21.5	3.8	32.3	9.7	4.4	2.06	0.15	0.09	0.081	0.022	
Grand total		3,797,050		9,594,800	14,756,680		37,073,200	18,553,730	46,668,000	40.3	2.6	12.7	4.2	2.1	0.94	0.08	0.15	0.054	0.016	

Note: Figures in parentheses show value estimated on a hypothesis that CaO component relates more or less to most of other components.

Appendix 5, table 2

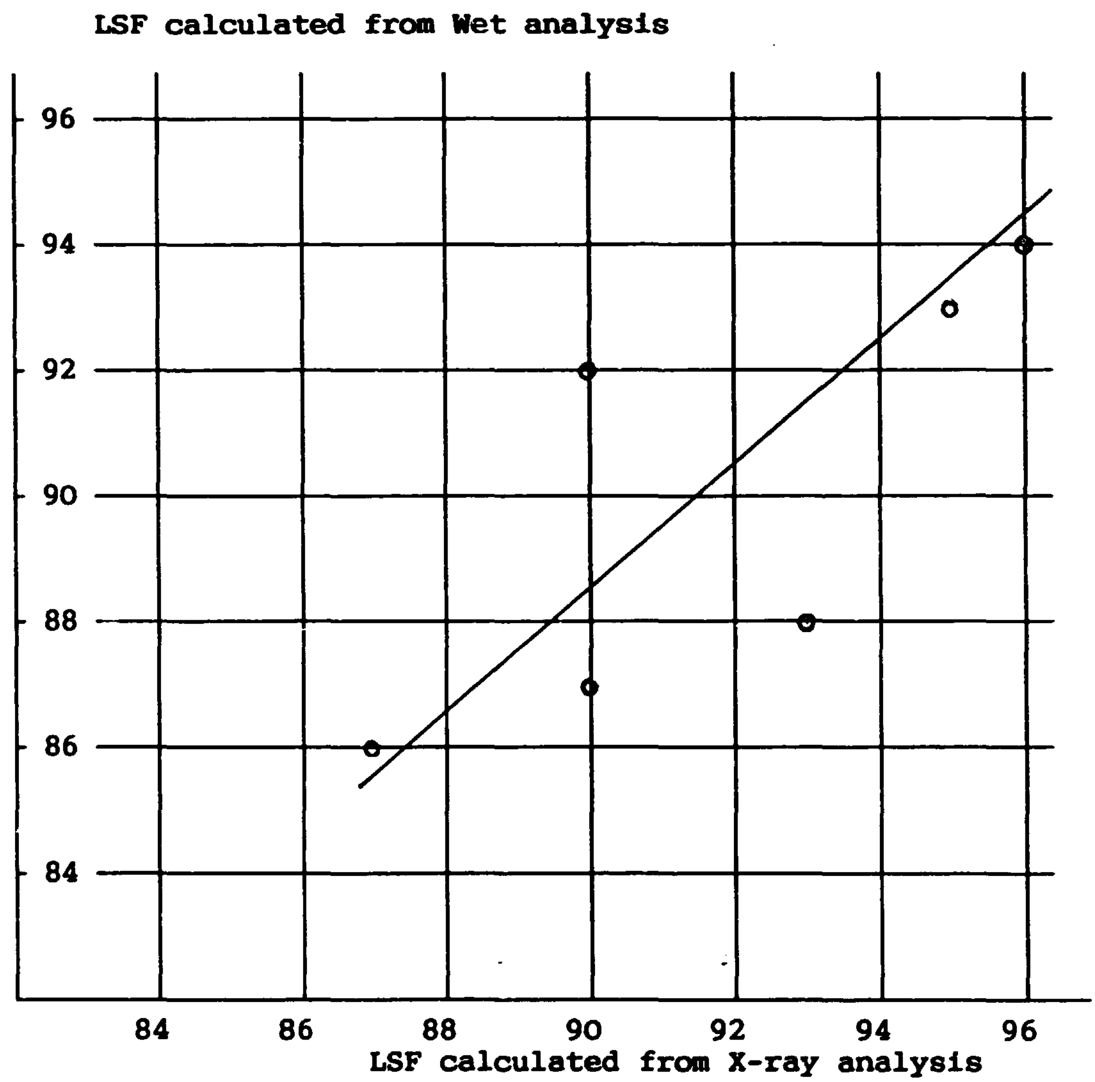
Table 1.
Comparison between X-ray and Wet Analyses.

Sample	clinker 23.09.89		clinker 24.09.89		clinker 04.12.89	
Method	X-ray	Wet	X-ray	Wet	X-ray	Wet
SiO2	20.9	20.7	21.2	21.9	20.3	20.9
Al2O3	5.9	5.5	5.4	7.2	5.7	6.4
Fe2O3	3.1	3.3	3.2	3.4	3.0	3.2
CaO	64.0	62.3	63.2	63.4	62.7	63.9
MgO	2.2	1.8	2.1	1.9	3.0	2.4
SO3	.38	-	.35	-	.36	-
Na2O	.26	-	.26	-	-	-
K2O	1.18	-	1.15	-	1.03	-
total	97.92	93.60	96.86	97.80	96.09	96.00
HM	2.14	2.11	2.12	1.95	2.16	2.10
SM	2.32	2.35	2.47	2.07	2.33	2.18
IM	1.90	1.67	1.69	2.12	1.90	2.00
LSF	.95	.93	.93	.88	.96	.94

Table 2.
Comparison between X-ray and Wet Analyses.

Sample	cement 23.09.89		cement 24.09.89		cement 25.09.89	
Method	X-ray	Wet	X-ray	Wet	X-ray	Wet
SiO_2	20.9	21.2	20.4	20.9	20.9	21.2
Al_2O_3	6.7	7.0	5.7	5.1	5.7	7.1
Fe_2O_3	3.1	3.2	3.0	3.1	3.0	3.3
CaO	61.1	61.8	60.7	62.7	62.4	62.3
MgO	2.5	2.2	1.2	2.0	2.1	2.1
SO_3	1.98	-	1.85	-	2.12	-
Na_2O	.25	-	.24	-	.23	-
K_2O	1.08	-	1.07	-	1.05	-
total	97.61	97.38	94.16	93.80	97.50	96.00
HM	1.95	1.92	2.04	2.11	2.06	1.92
SM	2.13	2.08	2.34	2.55	2.40	2.04
IM	2.16	2.19	1.90	1.65	1.90	2.15
LSF	.87	.86	.90	.92	.90	.87

Graph 1.
Comparison between X-ray and Wet Analyses.



Determination of $CaCO_3$ and $MgCO_3$ by carbonate titration.

Chemical reactions.

The total of carbonate present in the sample is determined by dissolution in hydrchloric acid and back-titration with sodium hydroxide, using phenolphtalein as indicator. (pH 8.3 - 10).

The content of $MgCO_3$ is now determined by addition of base to colour change with tymolphtalein (pH 9.3 - 10.5). The magnesium is hereby precipitated as hydroxide, and the surplus of base is then back-titrated with acid.

Reagents.

Acid	0.5 N HCl
Base	0.25 N NaOH
Phnolphtalein	2 % in 96 % alcohol solution
Tymolphtalein	4 % in 96 % alcohol solution

Procedure.

The sample is dried for 1 hour at 110 deg. C.

0.5000 g is weighed and transferred to a 250 ml conical flask. After moisturing with destilled water add 25 ml 0.5 N HCl and spray the flask inside wall with destilled water. Boil for precisely 3 minutes, cool to about 40 deg. C, add 4 drops of the phenolphtalein solution and titrate during 2 minutes with NaOH to beginning red colouring (c ml).

The solution is again heated to boiling, and after addition of 4 drops of the tymolphtalein solution the boiling solution is titrated to beginning blue coloring and a surplus of 3 ml NaOH is added (in total d ml).

The titration should be performed in precisely 2 minutes. After boiling the solution for further 3 minutes (by stop watch) it is cooled by water and the surplus of base is titrated with 0.5 N HCl to beginning red colouring (e ml).

Determination of $CaCO_3$ and $MgCO_3$ (continued).

Notes.

1. When boiling the liquid with excess of base place the flask on a ceramic triangle to avoid boiling over.

2. The back-titration with HCl is to be completed without delay. It should not be taken into account, that the blue colour later returns.

Calculation.

$$\% \; MgCO_3 = \frac{(d \times Nn - e \times Nh) \times 42.17}{10 \times G}$$

$$\% \text{ total carbonate} = \frac{(d \times Nn - e \times Nh) \times 5}{G}$$

$$\% \; CaCO_3 = \% \text{ total carbonate} - (\% \; MgCO_3 \times 1.186)$$

where a = ml HCl initially added

c = ml base added (phenolphtalein)

d = ml base added incl. surplus (tymolphtalein)

e = ml acid used at back-titration

Nn = Nomality of base

Nh = Nomality of acid

G = Weight of sample (0.5000 g)

42.17 = equivalent weight of $MgCO_3$

1.186 = conversion factor for $MgCO_3$ to $CaCO_3$

Complete Wet Chemical analysis

Reference is made to British Standard 4550: Part II: Methods of testing cement, Part 2. Chemical Tests.

Organization.

Excerpts from Job Descriptions recommended by IHI.

1. Technical Manager

....

b. To supervise the quarry manager, the production engineer, the laboratory Q.C. engineer, the mechanical and the electrical engineer.

....

2. Quarry Manager

....

d. To cooperate with the production engineer and the laboratory engineer to achieve the smooth production and the correct quality control of the raw material.

....

2. Production Engineer

....

b. To coordinate wuth the quarry manager for the quarry operation, the mechanical engineer and the electrical engineer for the maintenance and the operation of the power plant, and the laboratory engineer for the quality control.

....

g. To control to report all the important events to the technical manager.

....

4. Laboratory Q.C. Engineer

a. To supervise the quality control of the various products through all the processes of the plant.

b. To control that the product is as per the relevant standard specifications.

c. To control the quality of the products during processing.

d. To control the quality of the raw materials incoming from the quarries, the bought-in raw materials and fuel.

e. To supervise, direct and train his staff in order to ensure the continuous best results of quality.

B. 2-2 Supervisor, laboratory

A. Job Summary

Assume responsibility for the quality control of the raw material, raw meal, clinker and cement, fuel oil, well water and etc. by analyzing their chemical compositions and testing physical properties, in accordance with the instructions of the laboratory engineer, fundamentally day time work.

A typical organization chart for the laboratory, quarry and production is also given in the supplier's guidance book. A summary thereof is shown on the following page 3 of this Appendix.

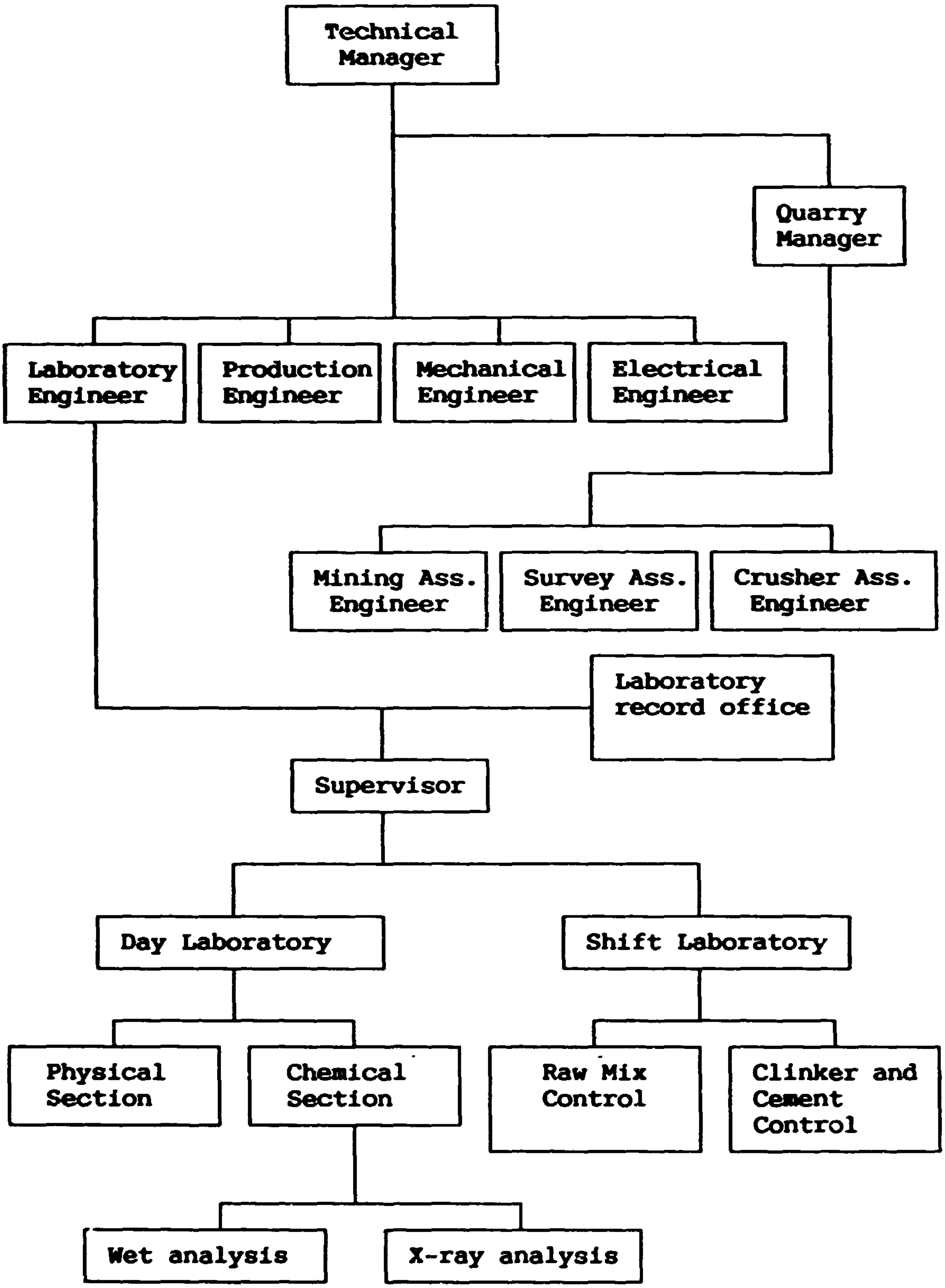
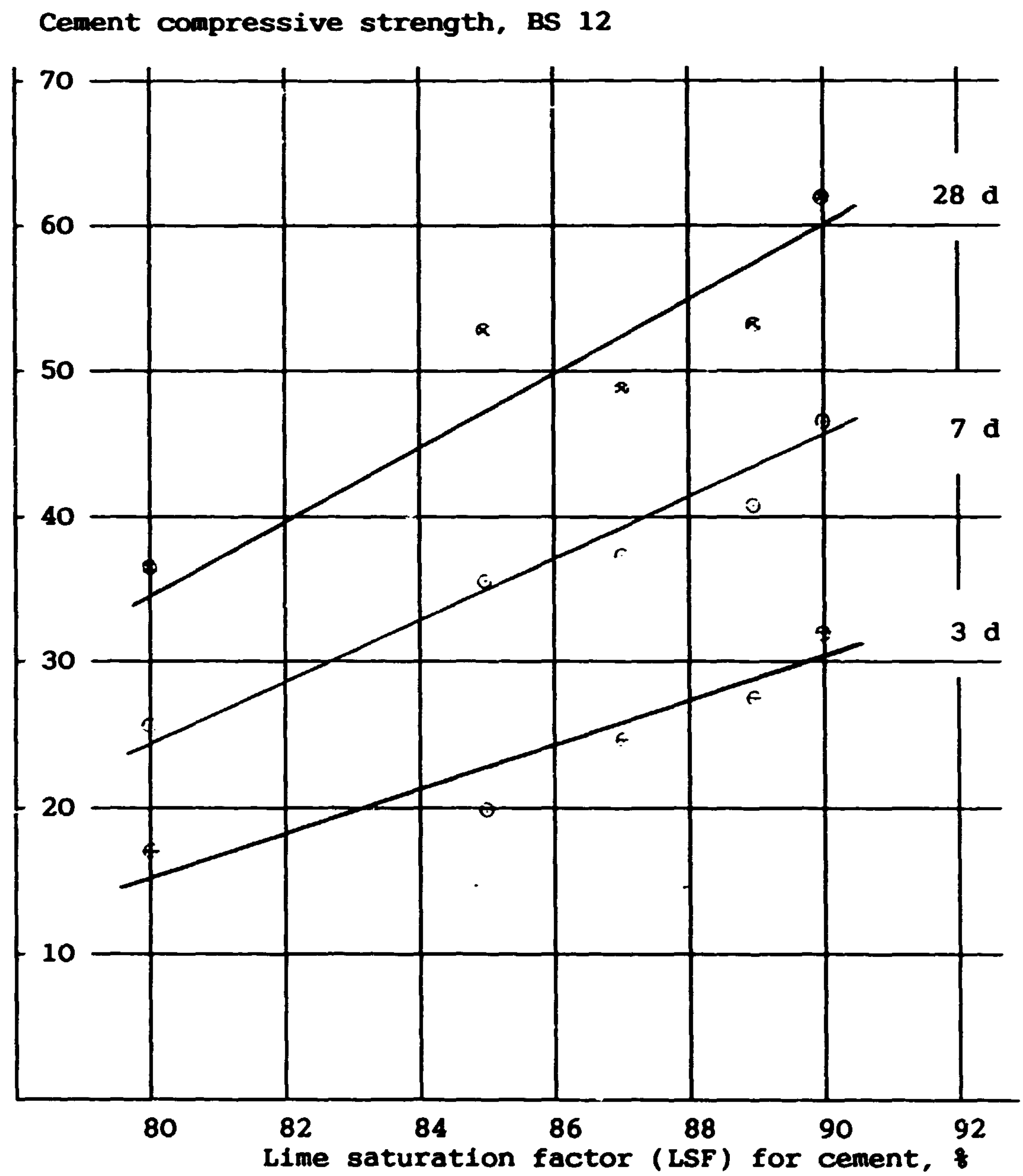

Technical Manager
Quarry Manager
Laboratory Engineer
Production Engineer
Mechanical Engineer
Electrical Engineer
Mining Ass. Engineer
Survey Ass. Engineer
Crusher Ass. Engineer
Laboratory record office
Supervisor
Day Laboratory
Shift Laboratory
Physical Section
Chemical Section
Raw Mix Control
Clinker and Cement Control
Wet analysis
X-ray analysis

Table 1.
Comparison between Chemical Composition and Cement Strength.

Month	Moduli				C3S	Blaine	Compr. strength		
	HM	SM	IM	LSF			3d	7d	28d
Dec 88	1.93	2.3	1.9	.85	36	2990	19.9	35.5	52.6
May 89	1.94	2.2	1.9	.87	41	3140	24.6	37.4	48.4
June 89	1.79	2.2	1.9	.80	22	3320	16.8	25.7	36.5
July 89	2.03	2.4	1.9	.89	48	3450	27.5	40.6	53.2
Oct 89	2.06	2.5	1.8	.90	52	3460	31.8	46.5	61.9

Comparison between Chemical Composition and Cement Strength.

Graph 1. Correlation LSF/cement strength



Comparison between Chemical Composition and Cement Strength.

Graph 2. Correlation C3S/cement strength.