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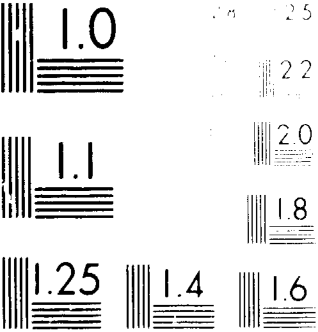
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IMPROVEMENT OF BUILDING MATERIALS MANUFACTURE

DP/CPR/80/010

CHINA

Technical report: The cement industry and possibilities for the application of automatic control

Prepared for the Government of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Michael Zographos,
expert in automatic control of cement plants

United Nations Industrial Development Organization
Vienna

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Explanatory notes

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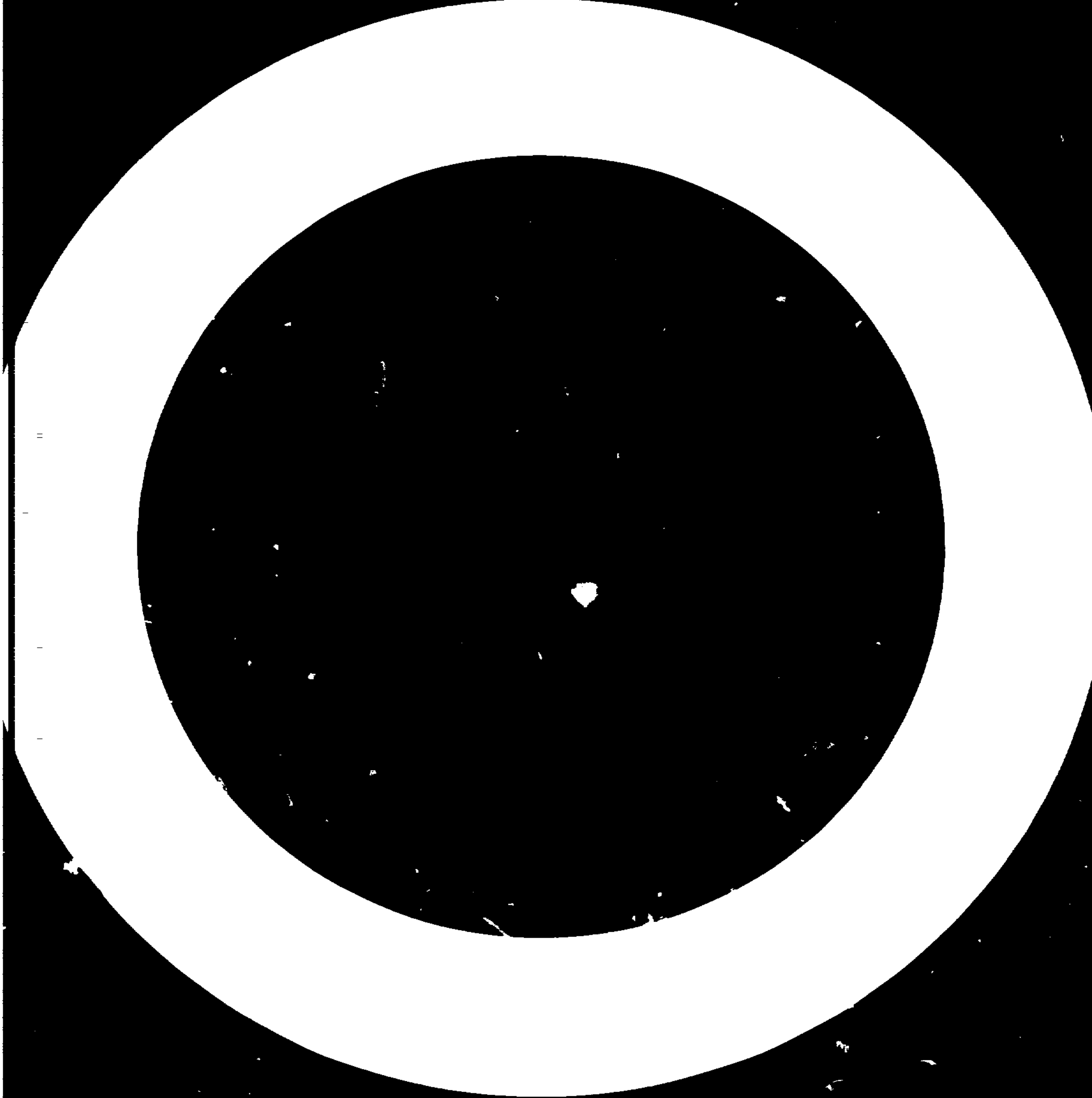
ABSTRACT

As part of the United Nations Development Programme (UNDP) project "Improvement of building materials manufacture" (DP/CPR/80/010), an expert was sent by the United Nations Industrial Development Organization (UNIDO), the executing agency, to the Research Institute of Building Materials at Guanzhuang, China, to advise on technical and administrative aspects of automatic control in the State cement industry. The mission was carried out from 5 to 28 August 1981.

The expert delivered a series of lectures to engineers from cement plants and relevant institutes covering classical and modern control theory; the use of state space in mathematical modelling; and the application of automation in dry-process cement plants for the control of mill and kiln operation. He also visited plants to collect information first-hand on the cement industry.

The cement industry in China is in need of modernization and must progress through the necessary steps, from manual to the ultimate in automatic control and supervision, if it is to increase productivity, lower energy consumption and maintain high standards of quality. It must further restructure the management of the plants.

This modernization programme must be carefully planned with the aid of the cement institutes. The Research Institute at Guanzhuang, which specializes in the design of automatic control units and energy-saving kiln arrangements, could be expanded to carry out research in fundamental control theory and develop control strategies. Further, it could investigate the use of low calorific value fuels and poor raw materials. In order to be able to carry out the necessary research, however, the Institute must modernize its own laboratories by purchasing new, essential equipment.



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INTRODUCTION

The cement industry in China dates back to 1889 when the first shaft kiln was constructed at the Tan Jen cement plant. In 1906, the first rotary kiln became operational, with an annual output of 40,000 tons. When the People's Republic of China was founded, in 1949, national output was some 660,000 tons per annum, and it has been growing ever since. Concomitant with the development of medium- and large-scale State controlled plants, determined efforts were made to promote vertical small-scale plants, and in 1958 these latter alone had a total output of 270,000 tons. In 1965, 234 small plants produced some 5.3 million tons, and in 1980 3,400 of them produced 55 million tons. In 1980, a total of 49 medium- and large-scale plants also produced 25 million tons, bringing the total national output to just over 80 million tons; the corresponding national demand was in excess of 100 million tons.

The industry is aware that it faces a number of serious problems, starting with the scarcity of high-quality limestone, high energy consumption per ton of clinker, and the need to increase production and efficiency. Of the total number of rotary kilns in operation in 1981, 63 percent were of the wet-process type; only a small number of kilns used the more energy-efficient cyclone preheaters. Only two rotary preheater kilns employing precalciner burners were in full production. A new preheater precalciner rotary kiln had been completed at the Xin Jiang Cement Plant and was undergoing tests.

The Government, in order to reduce energy consumption, raise production and ensure high quality, has decided to modernize the industry by: introducing dry-process kilns with cyclone preheaters; lowering the heat load from the present value of over 1,000 kcal/kg (4,000 kJ/kg) of clinker to the European level of around 750 kcal/kg (3,000 kJ/kg); and automating various stages in the production cycle. In August 1980, the Government requested UNIDO assistance in achieving the above aims, within the framework of a development programme centred on the building materials industry (DP/CPR/80/010). One of the objectives of this particular project, as formulated by UNIDO representatives and their counterparts from the Ministry of Building Materials was to provide an expert to advise on technical and administrative aspects of automatic control.

The expert arrived in Beijing on 5 August 1981 and remained in China for 23 days. He was attached to the Research Institute of Building Materials (referred to throughout this report as the "Institute") in Guanzhuang, East Suburb, Beijing.

During the expert's initial discussions with his counterparts, it became apparent that the original purposes of the Institute would not be fully covered by the project objective as formulated. A series of lectures was seen to be necessary in order to provide the Institute with:

(a) Information on the cement industry in the developed countries, including the extent of and trends in automation; measuring devices; and energy-saving systems;

(b) Guidance in research work on automating the industry;

(c) Advice on conducting or developing research in the fundamental theory of control and on establishing automation research laboratories in accordance with the chemistry used in the cement industry;

(d) An evaluation of the possibility of establishing, under the guidance of the Institute, a Centre to investigate and test methods for measurement and automation in the industry.

It was subsequently decided to modify the expert's job description, with the result that he divided his time between visiting plants to collect information on the industry and lecturing at the Institute and in plants on the application of automation. In the course of the lectures, the expert provided examples of mathematical modelling techniques and the development of a computer program for the direct digital control (DDC) of a rotary kiln. Apart from the lectures, no other formal training was provided. It is the belief of the expert that with the revision of the job description, the objectives of the Institute as well as the wishes of the Government were met.

RECOMMENDATIONS

The following recommendations, which refer (A) to the cement industry and (B) to the Institute are based on discussions held at the Institute and at the two plants visited as well as on the assumption that the latter were largely representative of dry-process cement plants throughout China.

A. The cement industry

1. Plant modernization should start with the application of remote control and mechanization/automation in the operation of kiln and mill systems, in preparation for the ultimate application of DDC.

2. The application of automatic control in turn should start with the proportioning of raw materials in the raw mill. (This presupposes the utilization of dry-process plants, which are more energy-efficient.)

3. The grinding process should be improved by introducing an automated pre-blending system to provide the mill with material of similar grain distribution, regardless of raw material quality.

4. The application of automatic control to rotary kilns should follow any developments that might take place in the prehomogenization and grinding processes, since kiln control is facilitated by the supply of homogeneous raw meal.

5. Management should be reorganized in order to raise production and cut costs.

6. On the basis of the forecasted increase in demand for each province, the Ministry of Building Materials should set long-term production targets for the plants. This would allow each plant to plan its schedule well ahead and to decide between modifying existing units or installing new ones.

7. Young engineers and technicians employed in cement plants should be trained in the operation, maintenance and supervision of technologically advanced equipment.

8. Some advanced equipment and technological know-how should be imported in order to speed up modernization of the plants.

B. The Institute at Guanzhuang

1. The Cement Division should be restructured to expand its research programme in fundamental control theory, instrumentation, energy-efficient systems and the use of fuels of low calorific value.

2. To help the Division prepare its research programme, the services of one foreign specialist in each of the following field should be requested, on a long-term basis: organization of research departments; management; control theory; and computer software.

3. The Division should purchase some new equipment to enable it to carry out its research plan.

4. To broaden their outlook, selected engineers from the Institute and the industry should make short visits to plants in other countries employing technologically advanced equipment. Those selected should speak the relevant foreign language.

5. Young university graduates should be encouraged to carry out post-graduate research on cement technology in foreign universities having the relevant facilities.

I. MAIN DUTIES AND ACTIVITIES OF THE EXPERT

As mentioned in the Introduction, the main duties of the expert were two-fold: delivering lectures and visiting cement plants.

Lectures

The lectures were attended by 25 cement technology specialists from the Institute, the cement plants at Liu Li he and Huaxin, and the Research Institute of Cement at Hefei.

The lecture programme included a brief review of the classical and modern control theories, illustrating the difference in approach between the two (time-domain analysis of modern control theory as opposed to frequency-domain analysis of classical theory). Emphasis was placed on the use of state space and space variables for the representation of systems. In addition, the application of mathematical models and their derivation was examined as a means of enhancing understanding of the system under investigation. For example, the model of a differential pressure-measuring device was derived and the necessity for a number of linearization assumptions in the derivation of the model was pointed out. The assumptions simplify the model without reducing its accuracy and make it readily available for analysis.

The use of optimization methods (on- and off-line) and sensitivity analysis in the study of systems were also covered, in order to complete the review on modern control theory, and an example of off-line optimization was considered. The theoretical part of the lectures was completed with the examination of the question of the structure of a system, and the choice between applying feed-back and feed-forward for its control.

With regard to the question of applied control theory in industry, the expert dealt with the subject of automation in the industry, ranging from its introduction (primarily with the use of remote control) to the eventual employment of computers for DDC. The difference was stressed between the automatic control of processes and the substitution of a number of routine actions by machines, defined as "mechanization" but known widely as "automation". Both automatic control and mechanization have applications in a cement plant, but the main emphasis of the lectures was on the use of automatic control in the blending-grinding process in mills and in the burning process in rotary kilns.

As the control of raw material proportioning in the raw mill was a question of primary importance to the Institute engineers, it was examined in great detail, starting with an extended description of the necessary hardware for the sampling, transportation and chemical analysis of the raw materials. The modern method of chemical analysis used X-ray fluorescence, which has the advantage of providing quick results for up to 28 different elements in a sample. Sampling, transportation, and preparation and loading of the sample on the X-ray analyser are usually fully mechanized ("automated"), while the control action which adjusts the feed rate of the raw materials is carried out using a digital computer. The chemical analysis of the sample is fed to the digital processor, the program works out the necessary moduli (alumina and iron) and the lime saturation factor (LSF) on the basis of this analysis, compares their values with those desired, which have been set previously by the production or chemical engineers of the plant, takes into consideration previous samples and the time-lag in the system, and eventually works out the new value of the set point of the raw material feeders.

Strategy for automatic control of raw materials proportioning is one of the two major problems in Chinese cement technology currently undergoing thorough examination at the Institute. Accurate proportion control at the grinding process yields homogeneous raw meal and is of utmost importance for the production of high-quality clinker - in addition to the fact that the production of homogeneous raw meal is a necessary condition for the smooth running of rotary kilns. Efforts at the Institute are directed towards developing the appropriate digital software for automatic control of raw meal quality. The expert provided advice on the development of a program; however, no actual program was availab.e since these are developed by the manufacturers to match their own hardware and represent an investment which they expect to recover.

The application of automatic control to rotary kilns is the other major problem confronting the Institute in its attempt to modernize the industry, minimize energy consumption and guarantee quality. This subject was examined in detail, control strategies for the rotary kiln and the cooler being considered separately. The difficulty of developing mathematical models for the burning process was recognized and, during discussions, the experience gained using an experimental mathematical model for the DDC of a wet-process kiln in Hefei Province was considered. The DDC of a kiln applying the theory of "fuzzy logic" is currently being considered. Using fuzzy logic in a process computer, it is possible to simulate the actions of a kiln operator who controls the kiln through a series of qualitative statements. This use was demonstrated by an extended graphical example and by listing the rules for controlling the fuel rate of a kiln by measuring the oxygen content of the exhaust gases and the rate of change of the drive torque. Finally at the request of the engineers from the plant at Huaxin, a computer program for the DDC of a kiln was developed (see annex).

Plants

Xin Jiang Autonomous District cement plant

There are 50 cement plants in the Xin Jiang Autonomous District, 3 of which are situated in the city of Urumchi. One of the plants visited - the Xin Jiang plant - is located 7 km south-west of the city centre, and is the only one in Urumchi having rotary kilns. It began its operation in 1958 with two long dry-process rotary kilns and an annual production of 145,000 tons. In 1966 the diameter of the kilns was enlarged at the burning end from 2.4 to 3.0 m (length - 60 m) and production was raised to 200,000 tons per year. A third dry-process kiln (length - 45 m; diameter - 3 m), utilizing a 4-stage cyclone preheater with a precalciner burner, is undergoing tests and will soon go into full production with a designed capacity of 600 tons per day. The kiln was designed and installed jointly by the plant engineers and their counterparts in the Cement Division of the Institute; in fact, the preheater-precalciner design was tested at the pilot plant of the Institute.

All kilns, as well as the precalciner burner, are coal-fired and use fuel with calorific value of 6,000 kcal/kg (24,000 kJ/kg). The electrical energy is supplied from the national grid at 35 kV, but power is also produced locally from a 1,500 kW steam turbine-alternator by passing the kiln exhaust gases through a heat exchanger. A 3,000 kW turbine-alternator is now planned to go on-load with the operation of the third kiln, utilizing once again the exhaust kiln gases. This will improve the thermal load of the rotary kiln and will provide virtually all the necessary power for the plant, since the total installed capacity is about 4,500 kW.

With the exception of black shale, which is obtained from the surrounding mountains, the raw materials are transported by rail: limestone - 45 km; gypsum - 118 km; iron ore - 700 km. Thus, transport accounts for about 20 percent of the cost of cement, with fuel and electrical energy consumption accounting for another 35 percent. Coal is transported by road from a distance of 30 km.

The raw meal is controlled manually. A sample is obtained every half-hour and analysed in the plant laboratory. If the need arises, the disc feeders of the raw materials are adjusted manually by the shift operators. The two original kilns are manually controlled. The third one has five local control loops built-in which supervise (a) the motor torque, (b) raw meal feed rate, (c) fuel feed rate, (d) CO_2 and O_2 exhaust gas content, and (e) the speed of the cooler grate.

The question of dust control is currently of major importance. The preheater kiln has its own electrostatic precipatator (the only one in the factory) which, however, could not be stabilized at its optimum voltage. This problem was discussed at length. The electronic control system was examined, as well as the dimensions of and power supplied to the precipitator, and it was concluded that a probable reason for the instability was the high temperature of the exhaust gases. The attempts of the engineers in charge were therefore directed towards lowering the temperature and raising the relative humidity of the gases.

The plant currently produces six types of cement, of which four are oil-well types for the demands of the region. About half of the production is dispatched in sacks to destinations up to 1,500 km distant while the remainder goes in bulk. The district's rail network being limited, trucks are the main means of transport. A fairly adequate road system exists, but there is room for improvement.

Demand in the Xin Jiang district exceeds production. In 1980, production was about 200,000 tons short of demand. In 1981, demand is forecast at 1.3 million tons, while anticipated production is around 900,000 tons. The new rotary kiln will go some way towards relieving this shortage, and in the Xin Jiang plant plans are already in hand to enlarge the diameter of the original kilns.

With regard to effecting immediate improvements in the plant, the expert was of the opinion that it is of the utmost importance to install an instrument for measuring the CO content in the flow of exhaust gases in the new preheater-precalciner kiln - prior to their treatment by the electrostatic precipitator - primarily as a safeguard against a possible explosion and secondly as an indicator of the completeness of combustion. Moreover, installing an optical pyrometer at the output end of the kiln would provide useful information about the burning process and later assist with the possible application of DDC.

Considering the long-term modernization schedule for the plant, by order of priorities, it would be advisable to start with mechanizing the feeders of the raw mills, which at present are manually controlled. Next, the application of automatic control to raw material proportioning could be considered, using a process computer coupled to a device for quick analysis of the raw meal content. With respect to the kiln on the basis of the experience gained with the analog controls, DDC could be applied, using a separate process computer.

As a general observation, the number of persons employed in the plant is in excess of the number that would be found in a plant having the same annual production in Europe or the United States. This may be partly explained by examining the administration tree (below) of the plant. The plant has its own large repair and construction workshops, design and construction departments, and planning, co-ordination and technology departments. Nevertheless, 150 persons in the kiln department and 130 in both the raw and cement mill departments must be considered a large number for the staff of these units. On the whole, however, the Xin Jiang plant gives the impression of being well-run.

Administration tree, Xin Jiang Cement Plant

Plant Director

↓

Plant Vice-Director

↓

PRODUCTION MANAGEMENT

1. Co-ordinating office
2. Environment protection and accident prevention department
3. Education department
4. Planning and co-ordination department
5. Electrical services department
6. Technology department
7. Administration department (labour and wages)
8. Sales and supply
9. Design and construction department

DEPARTMENTS AND WORKSHOPS

1. Quarry department
2. Raw mill department
3. Kiln department
4. Cement mill department
5. Mechanical repairs workshop
6. Electrical and power department
7. Repair and construction team
8. Transport department (fleet of lorries)

SOCIAL SERVICES AND SUPPLIES

1. Clinic
2. Services and supplies department

Lui Li he plant

Lui Li he is situated about 45 km south or Beijing, has a good road link with the capital, and appears to be well serviced both by rail and road. The plant was established in 1939 and was equipped by the Japanese with the technology of the 1930s. Production started in 1941 and for the first ten years the plant produced a total of 100,000 tons of cement from its initial four units. The dry-process rotary kilns, which are still in operation today, are coal-fired. Plant modernization, which began in 1958, raised the output to about 500,000 tons per annum, and with the installation of a fifth rotary kiln production increased steadily so that by 1969 the total capacity (including slag cement) was 1 million tons per annum. In 1975, a sixth kiln was installed which further raised production. Currently plant capacity is 1.3 million tons per annum, of which 1 million is slag cement and the rest ordinary portland. (The last two kilns installed are of the Lepol type.)

The main limestone quarry, which is situated 15 km from the plant, has exhausted its useful deposits; the new quarry is more than 60 km away. The contents of CaO and potassium in the samples of the new quarry are 48-49 and 1.3 percent respectively. However, the clay quarry is only 3 km away from the plant. The iron modulus of the raw meal is adjusted by the addition of iron ore. Coke grit from the local coal-fired alternators is also used in the raw meal in place of clay. Gypsum is obtained from a distance of more than 60 km. Both limestone and gypsum are transported to the plant by rail.

The plant employs over 3,000 persons. Of these, 1,500 are involved in the production processes while the rest are ancillary staff engaged in primary and secondary schooling and hospital and social work in general. Of the employees involved directly in the production processes, 5 percent are engineers and technicians; 5 percent are employed at the quarries; 8 percent are administrative and clerical staff; and 82 percent are semi-skilled and unskilled workers. The large number of employees is again partly due to the fact that the plant has its own large workshops where some new equipment is manufactured and installed by the plant engineers and technicians.

In 1973, under the guidance and with the close co-operation of the Institute, efforts began at the plant to develop a system for the analysis of raw meal and the automatic adjustment of the feed rates of the clay and iron ore weight-belts. The system employs the isotope method for the analysis of samples and determines only the CaO and Fe_2O_3 percentage composition of the raw meal. Data are obtained every two minutes, fed to an analog computer, and averaged. The calculated adjustment is applied every half-hour to the "set point" of the feeders. The raw material proportioning system has been in operation since 1978 and has substantially improved the quality of the raw mill product. It is worth noting that the two Lepol rotary kilns can clock up to 300 days without stoppage, which to an extent must be due to the homogeneity of the raw meal. There is room for improvement, however: because the system is fairly limited in the sample analysis, it is not capable of coping with a large number of calculations and does not provide for system dead times or estimates of silo contents.

Again, the question of the large number of employees must be mentioned, along with the necessity to modernize the method for reclaiming raw material within the factory, to streamline and collect all control boards for at least one unit under one panel, and to improve on the instrumentation of the various units (temperature measurements for kilns etc.).

II. FINDINGS

The cement industry

Limestone quality

From the visits to the two plants, which seem to be representative of most medium- to large-scale enterprises, it became obvious that, basically, the industry is suffering from the lack of high-quality raw material in the vicinity of the plants. The plants are obliged to transport limestone or gypsum from distances of 60 km and more, even though this raises the cost of the final product and increases overall energy consumption. It is expected that in future all new plants will be situated near quarries with well proven long-term (60 years or more) reserves of high-quality raw material. Three new large-scale plants now being constructed are located close to such reserves.

High-quality limestone is becoming scarce in China: however, geological explorations and studies could lead to new sources. At the same time, research must be carried out on the exploitation of low-quality material.

Material conveying

The raw materials usually arrive at the plant by rail and are then conveyed to the stock piles by belt conveyors. They are subsequently reclaimed from the stock piles by manually operated overhead gantries. Use of these gantries, however, results in unnecessary quantities of dust being created. They also necessitate the employment of extra personnel, with resultant delays and unsteady supply. In order to raise plant productivity and cut down on this dust, the reclaiming process must be mechanized or automated, using rotary bucket-reclaiming machines or adjustable underground openings feeding a belt conveyor.

Operation of units

The operating panels of the production phase units are situated close to the units; thus, they are spread throughout the plant, and there is a minimum of remote control. As a further step towards raising plant efficiency, all control boards should be located in a single control room where the units can be supervised by experienced operators with the minimum of effort. The various drives of each unit could be interlocked for safety and energy saving.

Automatic control

From the visits to the plants, and also from the discussions with the Institute engineers, it became apparent that the application of automatic control in the cement industry in China is at present very limited. Of a total of 49 medium- to large-scale plants, only four use a form of automatic control, either for the mill feed or for the operation of the kiln.

The proportioning of raw materials in the raw mill phase is applied only in the Liu Li he plant, where a system utilizes the isotope method to analyse the raw meal sample for its CaO and Fe_2O_3 content and, through an analog computer, controls automatically the feeders under the raw material silos.

At the Hunag Shi plant, in Hufei District, under the guidance of the Research Institute of Cement, DDC for a wet-process rotary kiln has been developed, using experimental mathematical models. The process computer controls (a) the fuel feed rate, (b) the kiln speed, (c) the O_2 and CO exhaust gas content, and (d) the speed of the cooler grate and secondary air supply. The results from this 650 tons/day kiln have not been very encouraging, however, and the kiln works only a few days in the year in the DDC mode, for tests. On the basis of the observations and the experience gained using the experimental model, the application of fuzzy logic in the control of the kiln is currently being considered.

As already mentioned, during the discussions that followed the lectures on kiln control, a computer program for the DDC of the kiln, utilizing the principles of fuzzy logic, was developed in co-operation with the plant engineers. The program is fairly involved as it controls simultaneously the kiln rotation speed, the position of the exhaust gas fan damper, and the fuel rate. The expert pointed out that it would be more beneficial to consider a simpler program at the initial stages of fuzzy logic application: the plant engineers and operators should have an opportunity to familiarize themselves with the new ideas.

In addition to Huang Shi, two other plants use analog control loops for the dry-process kilns: the Ben Xi plant in Liao Lin province and the plant visited in Urumchi, Xin Jiang Autonomous District.

Preheater-precalciner kilns

China already has two rotary kilns using a precalciner burner in the preheater string: the first, in the Ben Xi plant, is at present undergoing tests with a coal burner; the second is in the Shu Ping plant, Ji Lin province, and uses an oil burner. The most modern precalciner-preheater kiln is in the Xin Jiang plant. It has been designed to burn coal and is still considered experimental. The results, using both the control loops and the coal precalciner burner of this unit, have so far been extremely satisfactory, justifying and strengthening co-operation that exists between the Institute and the plant designers in developing energy-saving, high-output units.

Environmental protection

Legislation was passed recently setting upper limits for the emission of toxic wastes. The industry is applying dust-collecting systems in the grinding and burning processes; and for the filtering of hot kiln exhaust gases, prior to emission into the atmosphere, electrostatic precipitators are employed. A number of problems are being encountered with the operation of precipitators, however, due in part to the alkaline content of the meal dust, but due also to the relatively high temperature of the exhaust gases. Nevertheless, the design of the precipitators, as well as the control system for automatic high tension adjustment, seem to be of high standard.

Technical know-how

The tendency of the cement industry in China has been to avoid importing technical know-how. Instead, the industry, under the guidance of the State institutes dealing with cement technology, has followed foreign innovations through the relevant cement publications and has managed to adapt a number of these innovations to local conditions.

Currently, three new plants are under construction using technology imported from Japan and Romania. One is expected to start production in 1983, and the other two in 1984 and 1985 respectively. The design of the plants - in the order of the material flow - includes a pre-blending bed where poor-quality limestone can be enriched by clay if necessary; a roller raw mill; homogenization silos; a 4,000 ton/day preheater precalciner coal-fired rotary kiln with grate cooler and an estimated heat consumption of 850-880 kcal/kg (approx. 3,500 kJ/kg) of clinker; and a roller cement mill. The operation of the plants will be conducted through a central computer.

The foreign designers, apart from providing technical training for the plant personnel in their own plants, will provide advice and training in managerial techniques. One of the aims of the Ministry of Building Materials is to modernize industrial management.

Training

The plant manager an engineers are usually university graduates. The subjects covered in the curricula of the engineering, physics and mathematics courses indicate that the degrees awarded are the equivalent of the British or American Bachelor of Science. The lack of new graduates from which the industry suffered in the last few years has largely been overcome: there remains, however, a lack of engineers with experience in fundamental control theory, mathematical modelling and automation.

Young operators are trained at the factory for two to three years by experienced operators and follow lectures on the theoretical aspects of their fields of specialization. This complete theoretical and practical training will permit them not merely to take over the operation of existing units, but to adapt to more sophisticated control systems.

Management

The organization of cement plants in China seems rather cumbersome, leaving little scope for increased productivity (as already seen in the review of the installations at the Xin Jiang plant). In fact, it is now recognized that industry in general in China suffers from an outmoded system of management: in 1981 a high-level conference convened by the State Economic Commission on the reorganizat. ı of enterprises stressed the need to streamline industrial management. As already mentioned, both the Ministry of Building Materials and the Institute are aware of this problem: as a result, the three new cement plants under construction will have a new type of management.

Energy

Basically, a cement plant demands two sources of energy - electrical and thermal, the latter in the form of solid or liquid fuels - not counting th low amounts comsumed by the diesel or petrol engines of auxiliary equipm The guarantee of continuous supply of electrical energy to a plant is its efficient operation - as indeed is the case with every heavy indus plant. The expert was left with the impression that there was no problem with regard to electrical supplies in China. It is worth noting that in some factories electrical power is generated by utilizing the hot exhaust gases from the kiln; this is an excellent example of improving the thermal load.

As China has large coal deposits, this source of fuel has been used widely for thermal energy; oil to a lesser extent. There remains, however, the problem of delivery, bearing in mind the road infrastructure. A question of current interest to the cement industry is the use of coal of low calorific value: this is to be investigated by the Research Institute at Guanzhuang, together with problems of detail, such as the metering of fuel supply in burners.

The Institute

The Research Institute at Guanzhuang was established in 1949 to carry out research and development work in the field of building materials. It has a staff of 2,000 and is divided into four divisions: the Cement Division; the Ceramic and Refractory Division; the Sheet Glass Division; and the Glass Fibre Division.

The Cement Division, which consists of eight departments, employs 330 of the total staff, 200 of which are university graduates. The Department of Automation, one of the eight, was established in the late 1950s, the emphasis of its activities being on maintenance and repairs. In the mid-1960s, the Department concentrated on developing instruments for the industry (burning zone temperature measurement, level indicator, accoustic load detectors for mills) as well as on the automatic feeding of tube mills. In the 1970s its main preocc· :ation was the use of process computers for the proportioning of raw materials and the control of rotary kilns. The isotope method for the analysis of raw materials samples was then developed, along with proportional, integral and differential (PID) controllers for weigh-feeders. A number of instruments were also designed for the control of kilns.

The present tasks of the Cement Division are to increase plant output, lower production costs, relieve manual labour, keep the emission of plant wastes within legislated limits, and keep all plant machinery in good working order. To achieve these goals, the Institute is planning to apply process computers and control the production units automatically. In order to get started on the right track, and to avoid the problems faced by technologically more advanced countries, the Division wishes to co-operate with specialists from other countries in the field of automation.

The Division further wishes to proceed with investigating the possibilities of new types of cement, according to local needs; with improving on precalciner burners; and with developing new refractory materials. In this last instance, the Division has been very succesful in developing fire bricks in its laboratories, in preparing specifications for the refractory manufacturers, and in trying them out in plants.

The Cement Division includes a large number of laboratories devoted to the geological, chemical and physical testing of raw materials and cement types. Most of the equipment, however, is old and limited in its use; it is also becoming difficult to find replacement parts. Some of the equipment currently used, with the year of manufacture, is listed below. It would be advisable to replace this equipment and to purchase new instruments. A list of the minimum equipment recommended is also given.

Current equipment in the Cement Division

1. X-ray fluoescence spectrometer (made in England, 1960)

2. X-ray diffractometer (made in England, 1961)

3. Atomic absorption spectrometer (made in the German Democratic Republic, date unknown)

4. Polarizing microscope (type Stender, 1952)

5. Universal microscope (made in the German Democratic Republic, 1962)

6. Mercury pressure porosimeter (3,000 kg/cm^2) (made in China, 1964)

7. Apparatus for absorption measurements (made at the Institute, 1965)

8. Differential thermal analyser (made in the German Democratic Republic, 1955)

9. Combined thermograph (made in China, 1969)

10. Thermo-balance (made in England, 1957)

11. Universal testing machine, type UHP35 (made in the Federal Republic of Germany, 1950)

12. Sedimentation balance (made in the Federal Republic of Germany, 1959)

13. Minicomputer, 12-bit word size, memory 8k (made in China, 1976)

14. Process computer, 16-bit word size, memory 4k (made in China, 1979)

15. Microcomputer, Cromenco system two, 8-bit word size, 64k memory (made in the United States, 1980)

16. Mass spectrometer, type MS-702 (made in England, 1967)

Recommended new (essential) equipment

1. Process computer

2. Multi-channel X-ray fluorescence analyser

3. Scanning electronic microscope with wave-length and energy-dispersive spectrometer

4. Infrared spectrometer

5. Granulometer

6. Ion probe

7. X-ray diffractometer with rotating output

8. Atomic absorption spectrometer

9. Material-testing machine with digital display (for tensile, compression and bending stress)

In addition to the above, the laboratories should be supplied with modern gas analysers and pressure, temperature and flow metres, and the related calibration instruments.

Within the grounds of the Institute, the Division has its own pilot plant, which consists of two systems: a "small" and a "large". The former has facilities for testing the grindability and burnability of various rock samples and was built in 1957. The latter is equipped with a jaw crusher, a rotary hammer crusher, a coal mill, a grinding mill and a rotary kiln capable of testing preheater and precalciner designs. The kiln instrumentation is complete with oxygen and carbon monoxide monitors, temperature measurements and a television monitor for the burning process. The Xin Jiang preheater-precalciner rotary kiln was developed in this pilot plant on the basis of a Krupp-Polysius design.

The engineers in charge of the Cement Division hope to establish a new "Automatic Research Centre" under the supervision of their Institute. They envisage a Centre - complementary to the Tien Jien Centre, which belongs to the Design Institute of the Cement Industry and is under construction with UNDP/UNIDO funds - which would:

(a) Carry out research on cement quality;

(b) Develop instrumentation for flow-rate measurement;

(c) Develop research work in automation, including the measurement and calibration of parameters;

(d) Investigate system design;

(e) Undertake research in the fundamental theory of control.

In addition, the Cement Division proposes to pursue research on the exploitation of relatively poor raw materials and coal of low calorific value, both of which are of major importance to the industry. The difference of scope between the two institutes is apparent from the following: the Tien Jin Centre considers the design of complete plants and specializes in the selection of plant sites, according to quarry reserves, and the study of grinding and burning technologies; the control strategies, however, are developed by the Institute at Guanzhuang and passed on to the Design Institute for application in plant design.

The expert expressed reservations with respect to the establishment of a new research centre at this stage. He suggested instead that the existing Cement Division, with its staff of 200 able engineers covering all disciplines from cement technology to automation, could be profitably restructured to cope with the research objectives. To this end, it would be advisable to strengthen the Division by recruiting, on a long-term basis, highly qualified advisers in the fields of control theory, instrumentation, cement technology and management. In addition, the Institute should be supplied with up-to-date equipment and instrumentation. The possibility of UNDP/UNIDO financing the suggested restructuring should be investigated through the regular channels: Ministry of Building Materials - UNDP Resident Representative - UNDP Headquarters.

Concluding remarks

The cement industry in China needs to modernize its approach to management and hardware. It is aware of this, and, with the co-operation and guidance of the relevant cement institutes, is concentrating its efforts on raising productivity and reducing energy consumption.

To achieve these targets, however, the industry will eventually have to apply mechanization and automatic control. Moreover, it will have to reorganize the management and administration of the plants, particularly with respect to the number of employees. The design and manufacture of heavy machinery must be left to specialized manufacturers, thereby avoiding duplication of effort in the production of machinery and allowing the plants to concentrate on cement production and maintenance and repair problems.

The question of reductions in personnel may not at present be of vital importance; however, as the industry is developing, it will be somewhat unorthodox to have, in the near future, a fully automated feeding system for (say) the raw mill, while one stage upstream in the material flow the raw materials are handled manually. Automation will relieve human labour and improve working conditions.

Parallel with modernization of the plants, the education and training level of the plant employees should be upgraded to allow the operators and technicians to adapt to technologically advanced systems. The Institute is aware of the needs in this field, and since it has direct links and a good record of co-operation with the industry, it is in an ideal position to co-ordinate any assistance that might be forthcoming from the United Nations or other international organizations. The potential for the modernization of the industry and the application of the latest control methods is embodied in the able engineers of the plants and institutes. If, however, speedy modernization is the aim, the industry will have to bear the financial burden of imported technology.

In addition to automatic control for the various units, research is also required on the location of quarries yielding high-quality raw material. Specialists from other countries can provide help, if requested, with the latest techniques in conducting geological searches for limestone.

With respect to research on cement technology, the Cement Division of the Institute will continue its investigations into (a) energy-saving methods, (b) devices that metre the flow of materials in general, (c) improved systems for the proportioning of raw materials and (d) optimum loading of mills and kilns.

Finally, if the cement industry is considered as a sub-system in the broader social system, its interaction with the other sub-systems must be taken into account. Thus, there is on the one hand the question of the protection of the environment from dust and unacceptable noise leveles, and on the other hand the question of transport links between plants, suppliers and customers. A good transport infrastructure, be it road, rail or canal, is of major importance, and the present one must be examined and improved upon wherever necessary.

Annex

COMPUTER PROGRAM UTILIZING FUZZY LOGIC

Part of a computer program utilizing the principles of fuzzy logic is stated below. Changes in oxygen content, burning zone and exhaust gas temperatures are measured, processed and fed to the computer. The program controls the fuel rate, the damper of the exhaust gases fan and the rotation speed of the kiln. The following abbreviations are used:

BZT	burning zone temperature (°C)
OXY	oxygen content of exhaust gases (%)
EGT	exhaust gas temperature (°C)
DFL	change in fuel rate (ton/h)
FAN	damper opening (%)
SPD	speed of rotation (%)
ZE	zero change
HI	high increase
LO	low increase
LP	large positive change
MP	medium positive change
SP	small positive change
LN	large negative change
MN	medium negative change
SN	small negative change
OK	O.K.

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INPUT: BZT/ 1400, 1450, 1500/
INPUT: OXY/ 0.4, 1.2, 2.0/
INPUT: EGT/ 200, 225, 250/
OUTPUT: DFL/ -0.5, 0.0, 0.5/
OUTPUT: FAN/ 40, 50, 60/
OUTPUT: SPD/ 60, 70, 70/

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