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ENERGY MANAGEMENT IN A WET PROCESS CEMENT PLANT

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ABSTRACT

Cement manufacture is one of the most energy intensive industries in the Philippines. This paper discusses the overall approach undertaken by Bacnotan Consolidated Industries Cement Plant in reducing its fuel consumption from a level of 1700 kcal/kg of clinker to the current level of 1450 kcal/kg. This approach was an application of systems analysis wherein a problem such as high fuel consumption is treated as a result of faults in a system where man, machines, materials and processes interact. This is in contrast to the common approach of putting the blame entirely on the machines or on the materials, failing to see that for a problem such as this, one is dealing with a system. Fishbone analysis was used to identify the various faults and corrective actions were then planned and undertaken. Plant energy management organization, audit procedures as well as the system improvements which lead to improved fuel consumption are likewise discussed in the paper.

BCI CEMENT PLANT PROCESS, MATERIALS AND EQUIPMENT

BCI utilizes the so called wet process of cement manufacture. The process flow sheet is shown in Figure 1. The main raw materials are limestone, silica and pyrite. Each material is fed into a jaw crusher and a hammer mill and then conveyed to a storage bin. Samples of each raw material are analyzed to determine the proper proportions which will result in the desired characteristics of the product. From the storage area the materials are fed into a ball mill where these are mixed with water and ground to a fine size (80% passing thru 175 mesh). The slurry is stored in blending tanks from which calculated amounts are discharged to a large basin. The large capacity of this continuously agitated basin helps to maintain a stable quality of the slurry for the day's production. From this basin the slurry is pumped into a dryer called a calcinator. The main element of the calcinator is a rotating cylindrical grate holding numerous hollow metal cylinders called filling bodies. Figure 2 shows a cross section of the calcinator. The filling bodies serve as thermal flywheels absorbing heat from the hot kiln gases and transfering it to the incoming slurry. This result in the formation of millimeter size partially dried nodules. The nodules are discharged into a rotary kiln where a series of chemical reactions convert these into granular clinkers. The kiln is a refractory lined steel cylinder that is installed with a slight inclination and is rotated slowly.

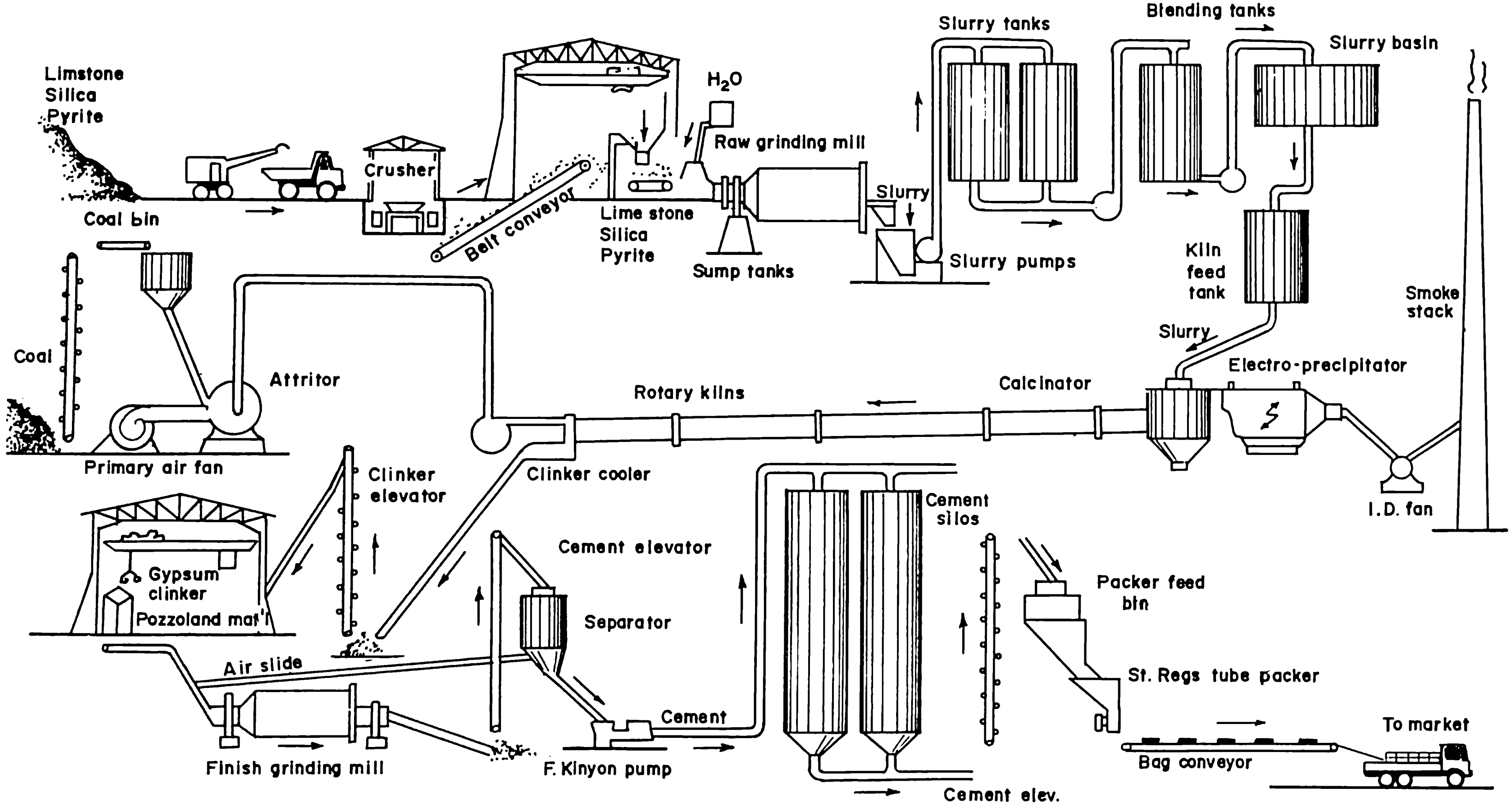

Figure 1 BCI Cement Flow Sheet

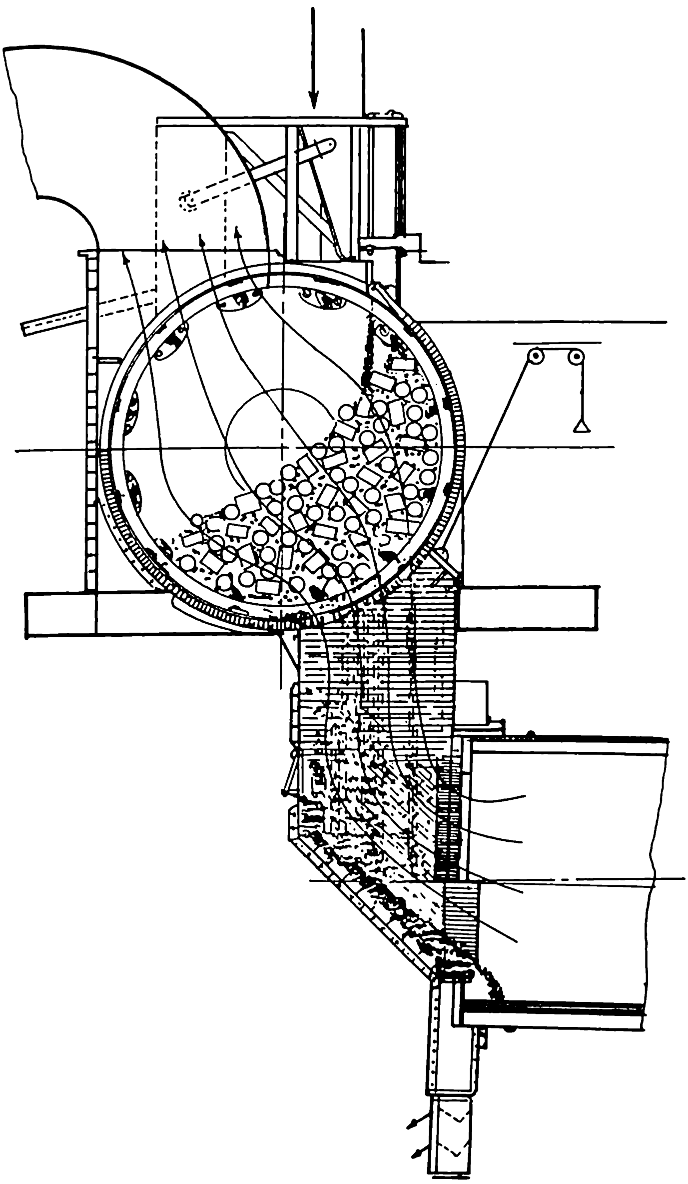

Figure 2 Cross section of the Calcinator-slurry Dryer

Turbulence is thus induced as the materials gravitate downwards. BCI Cement has three rotary kilns, a 10 ft diameter by 247 ft long kiln and two 3 m diameter by 56 long kilns. Heat to sustain the chemical reactions is supplied by the combustion of pulverized coal and air at the other end of the kiln. The clinkers are discharged into another heat recovery equipment called the clinker cooler. The main element of the cooler is a moving grate. Here air for combustion is pre-heated by recovering the sensible heat from the bed of clinkers. The clinkers leaving the cooler are temporarily stored prior to crushing in a roll crusher and final grinding in a ball mill. The ball mill is also fed with measured amounts of additives like gypsum and pozzolan. The final product which is cement is pneumatically conveyed from the mill to a silo for storage prior to the final step which is the packing of the cement into 40 kg bags.

BCI CEMENT PLANT ENERGY PROFILE

BCI Cement Plant has three rotary kilns all of which are capable of firing either coal or bunker oil. Rubber tires and dried wood are used during pre-heating. The heat rate, also called specific energy consumption, of the kilns is measured in terms of the ratio of the total kilocalories of fuel fired to the total quantity of clinker produced. The plant heat rate for the previous semesters are shown in Figure 3. At present, due to the efforts undertaken at improving the efficiency of the kilns, the heat rate is 1450 kcal/kg of clinker. The plant is currently targeting a heat rate of 1400 kcal/kg of clinker.

The electrical energy consumption profile of the plant is shown in Figure 4. For purposes of auditing the electrical energy consumption, the plant is equipped with meters for the following sections: Crusher, Raw Mill, Kiln, Finish Mill, Packhouse and Productive services. The following table lists the main equipment under each section.

Section	Main Equipment
Crusher	Jaw Crusher, Hammer Mill, Belt, Conveyor, Crane
Raw Mill	Ball Mill, Slurry Pumps, Slurry Tank Agitators, Overhead Cranes
Kiln	Rotary Kiln, Coal Atitor, Combustion Air Blowers, Calcinator, Clinker Cooler, Induced Draft Fan, Dust, Conveyor, lectrostatic Precipitator
Finish Mill	Roll Crusher, Ball Mill, Air Separator, Kinyon Pump

As shown by Figure 4, the Raw Mill, Kiln and Finish Mill sections are the major consumers of electricity. For the year 1989, the average specific electrical energy consumption was 4.55 kwhr per bag of clinker.

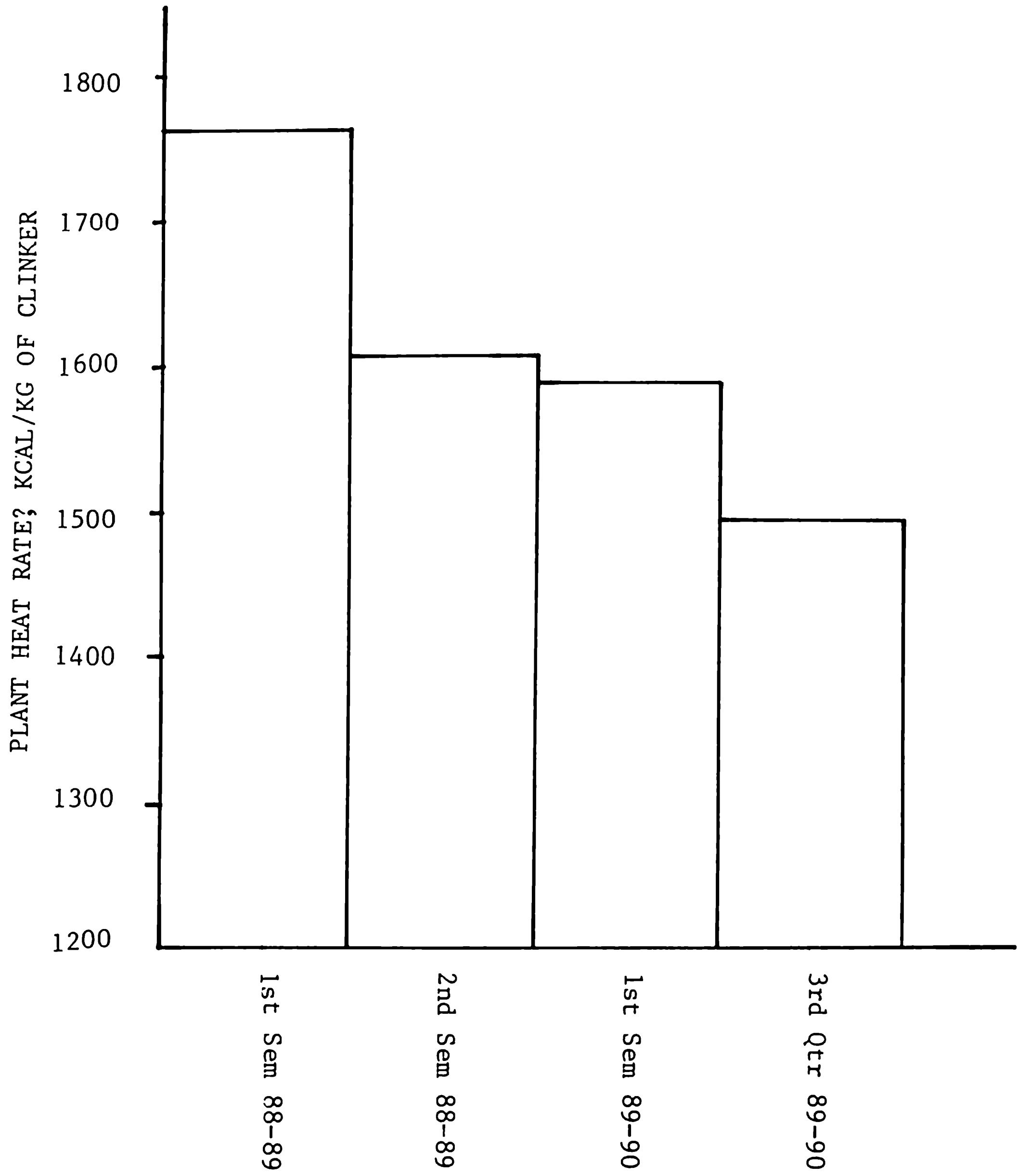

Figure 3 Plant Heat Rate for Previous Audit Periods

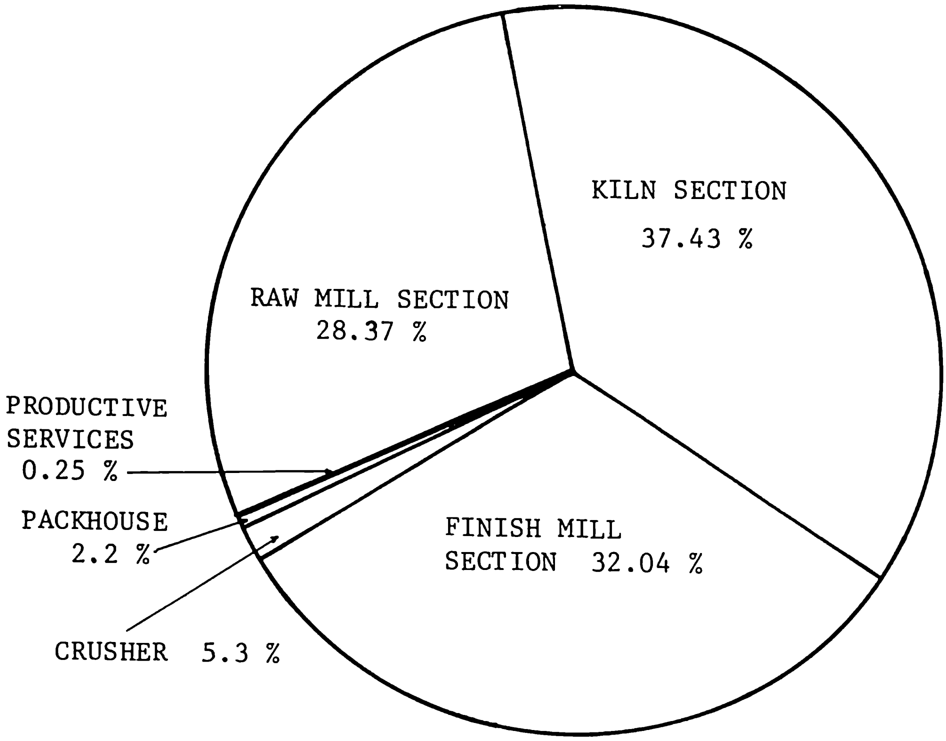

Figure 4 BCI Cement Electrical Energy Consumption Profile

BCI CEMENT PLANT ENERGY MANAGEMENT ORGANIZATION

Energy management at BCI is organized in accordance with the six major tasks required in implementing a successful energy management program: supervision, analysis, planning, implementation, monitoring and reporting. These are shown in Figure 5. At BCI, the energy manager is the plant manager. One of the innovations introduced by the current manager is the concept of the work improvement team (WIT). Each division in the plant has its own WIT, composed of the Division Chief and the foremen. The team is tasked with analyzing among other problems, the causes of low productivity and low efficiency in their work area and formulating the possible action steps to .counteract such causes. The WIT's were taught the concept of system analysis to facilite the accomplishment of their assigned task. The output of each WIT is a set of specific objectives and the programs to attain their objectives. These are then presented to the Department Head and the Plant Manager. The advantage of having WITS's is that involvement in energy management is maximized; ideas for efficiency improvement emanate not just from the energy manager but from the direct users of energy as well.

The analysis of efficiency problems on a plant wide level is done as part of the regular plant management staff meetings where the group act as one WIT. The staff includes not only the department and division heads of the Production and Engineering Department but also those of the Finance and Administration Departments. During the staff meetings plans for efficiency improvement are concretized, responsibilities are assigned to specific persons or group of persons and timetables are set. The energy monitoring and reporting tasks and the persons responsible for these are discussed separately in the next section.

BCI CEMENT PLANT ENERGY MONITORING AND REPORTING PROCEDURES

The monitoring of the plant heat rate is done on a daily basis by the plant's energy officer. Data for the heat rate are obtained from the totalized readings of the coal weigh belt feeders which reflect the total coal consumption and from the results of the material mass balances. The latter determines the amount of clinker by measuring the consumption of slurry and subtracting the moisture, ignition and dust losses. Bulletin boards at strategic locations in the plant display the day's heat rate, the heat rate for the period from the first day of the month to the current date (called to date heat rate), the target heat rate for the month, together with the daily, to date and target volumes of clinker and cement produced. During plant management staff meetings the plant's energy efficiency performance for the week is reported by the person in charge of the kiln operations who at BCI is the Mill Engineer. Staff meetings that fall at the end of the month conduct a review of the performance for the month. Every semester, the plant's energy efficiency performance for the past six month period and the efficiency targets for the next six month period are reported to the company's top management by the Plant Manager during a so called budget conference. Accountability at different levels is thus enforced.

USE OF THE SYSTEMS APPROACH

As mentioned proviously, two innovations introduced to the plant by the current plant manager are the Work Improvement Teams and the use of the systems approach by these teams

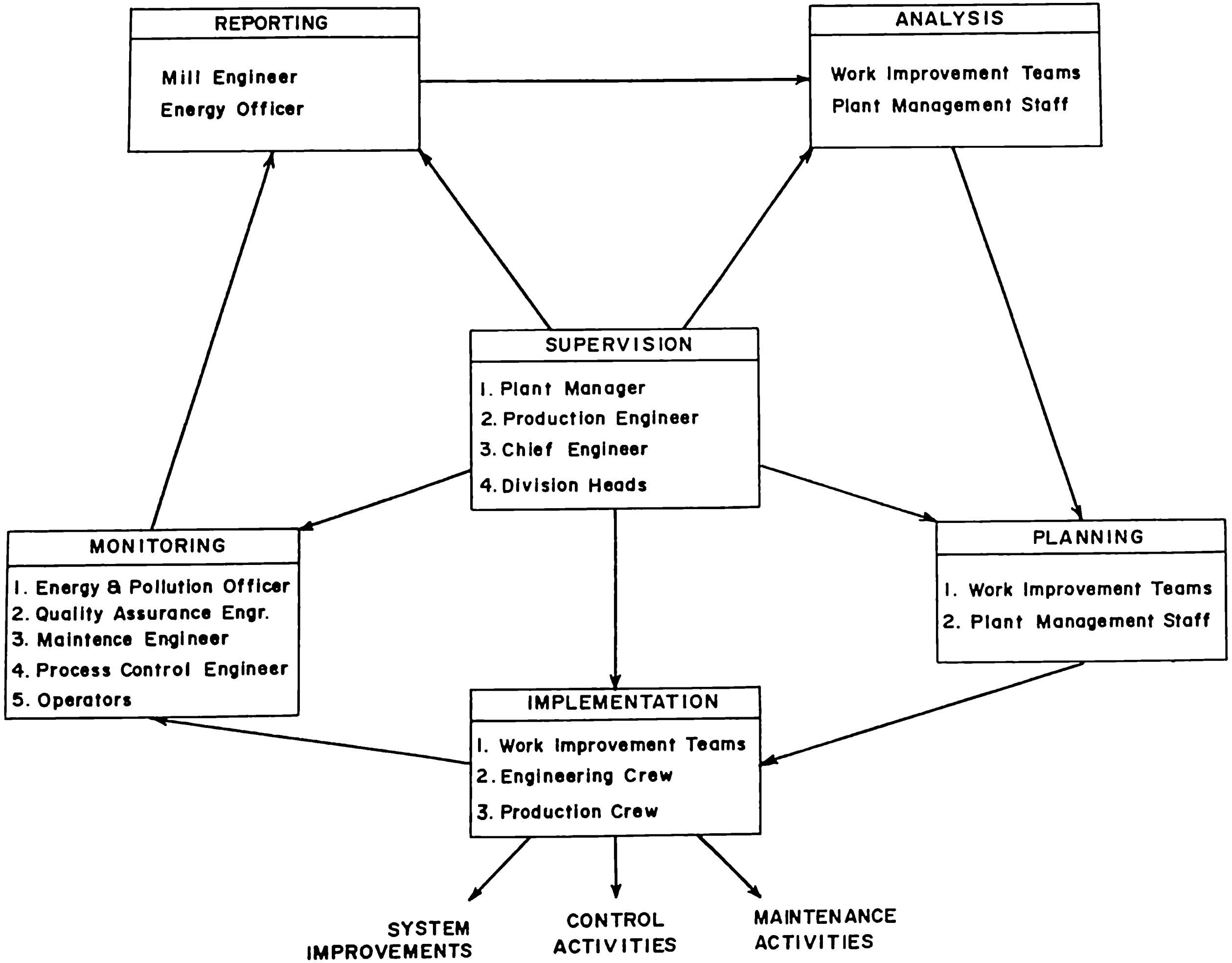

Figure 5 BCI Cement Energy Management Organization

in solving the problem of poor fuel efficiency. In the systems approach, a problem is seen as the result of faults in a system and for a system such as BCI Cement Plant, this system consists of not just the various pieces of plant equipment but also the materials entering and leaving the equipment, the processes for which these machines are used, and most important, the man component or the persons involved in the operation, and maintenance of the machines, the monitoring and control of the materials and processes, and the supervision of personnel. Thus the first task of the Work Improvement Team was to define their system. This required determining the system components and establishing the interactions between the system components. To illustrate this concept, consider the system shown on Figure 6. The main components of this system (as in most of the systems dealt with by the WIT's) are man, machines, materials and process. Note that the man component sits above the other three and this is because the man component exercises control over the other three components. There are several interactions present in this system. The man - process interaction is accomplished via the instruments which let the operators know of how the process is going by displaying the process variables. The man - machine-process interactions are the control activities that manipulate the machines to ensure that process variables are within the desired limits and that the correct product quality is attained. Man - machine interactions consist of equipment condition monitoring activities and the various corrective and preventive maintenance activities. Man - material interaction is by way of the analysis of the raw materials, slurry, kiln gases, clinkers and cement and the consequent adjustments made on the materials, and/or on the process, and/or on the machines to attain the desired material characteristics.

Next to the analysis of the system is the step of defining (or redefining) the system objectives. At BCI, the general objectives were laid out by the plant manager from which specific objectives were drawn by the WIT's.

The aim of the systems approach is the improvement of the current system to accomplish the system objectives. However one cannot do this without first identifying what are needed to be improved. With the system approach one focuses not only on faults within the individual system components but also faults in the interactions between these components to arrive at a complete analysis of the problem.

On Figures 7 to 12 are shown the various system faults that have been identified to be the causes of high heat rate. The major causes are presented in Figure 7 and these are: unstable kiln operation, high slurry moisture, high kiln exit gas temperature, inadequate heat recovery of clinker sensible heat, low kiln capacity utilization, overburning underburning of clinker, poor combustion efficiency and poor burnability of the raw mix. Each of these causes were analyzed further to determine the man, machine, materials and process related faults as well as the interaction faults that contributed to the above causes. The results are shown in Figures 8 to 12.

After having determined what were needed to be improved in order to meet the objective of reducing the heat rate, the next task was the planning of system improvement projects. The next section discusses the specific system improvements which as of this writing had been done or being implemented at BCI.

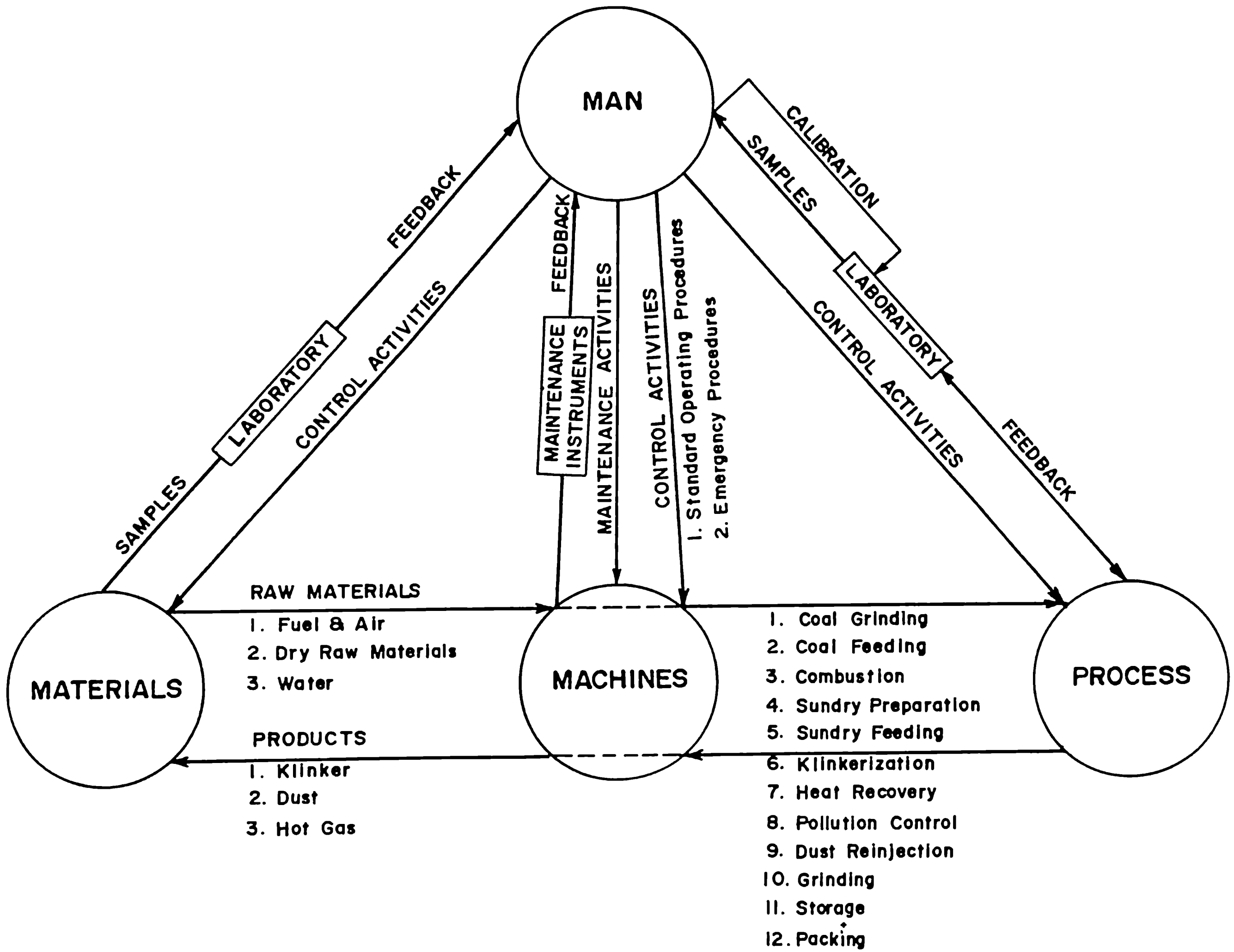

Figure 6 BCI Cement — Plant Level System

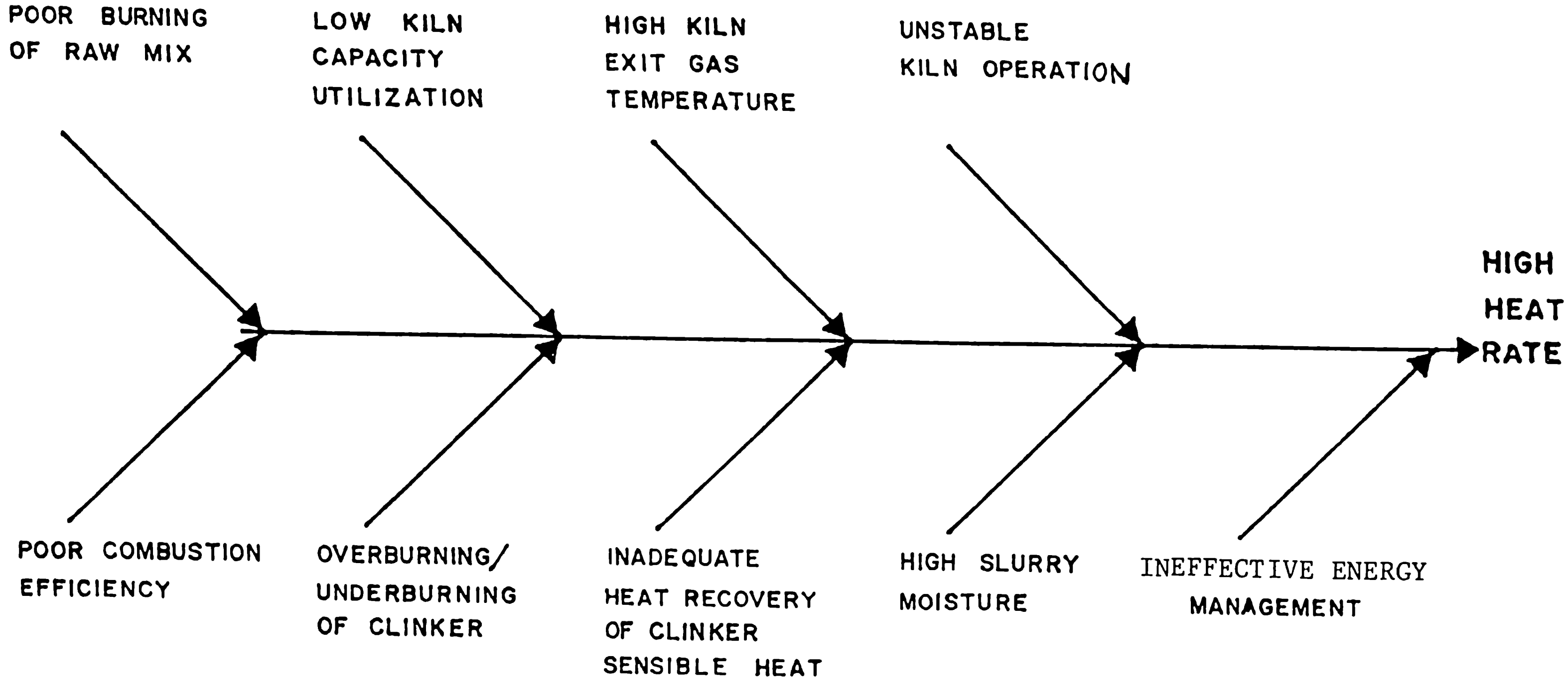

Figure 7 General Fishbone Diagram for the High Heat Rate Problem

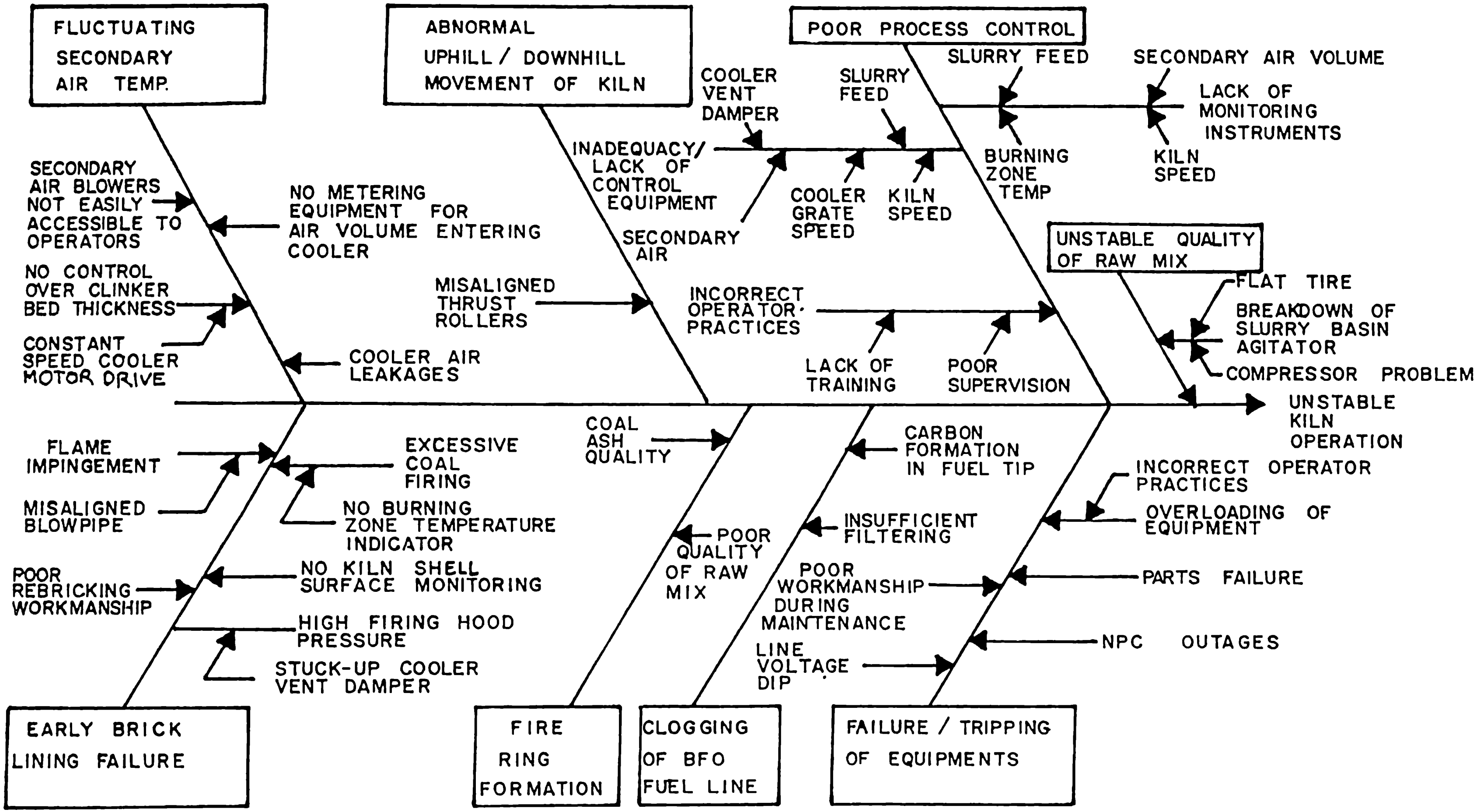

Figure 8 System Faults Leading to Unstable Kiln Operation

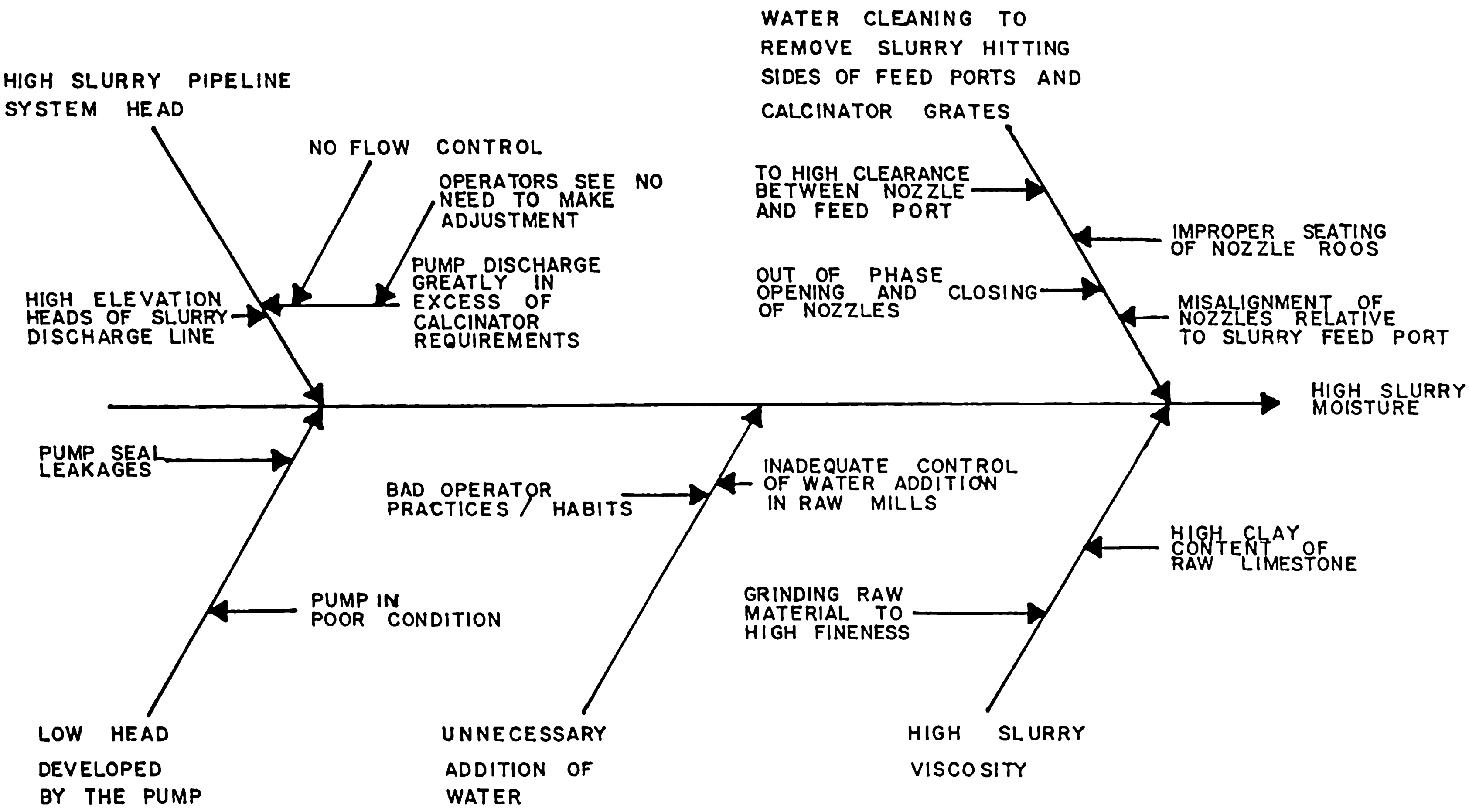

Figure 9 System Faults Leading to High Slurry Moisture

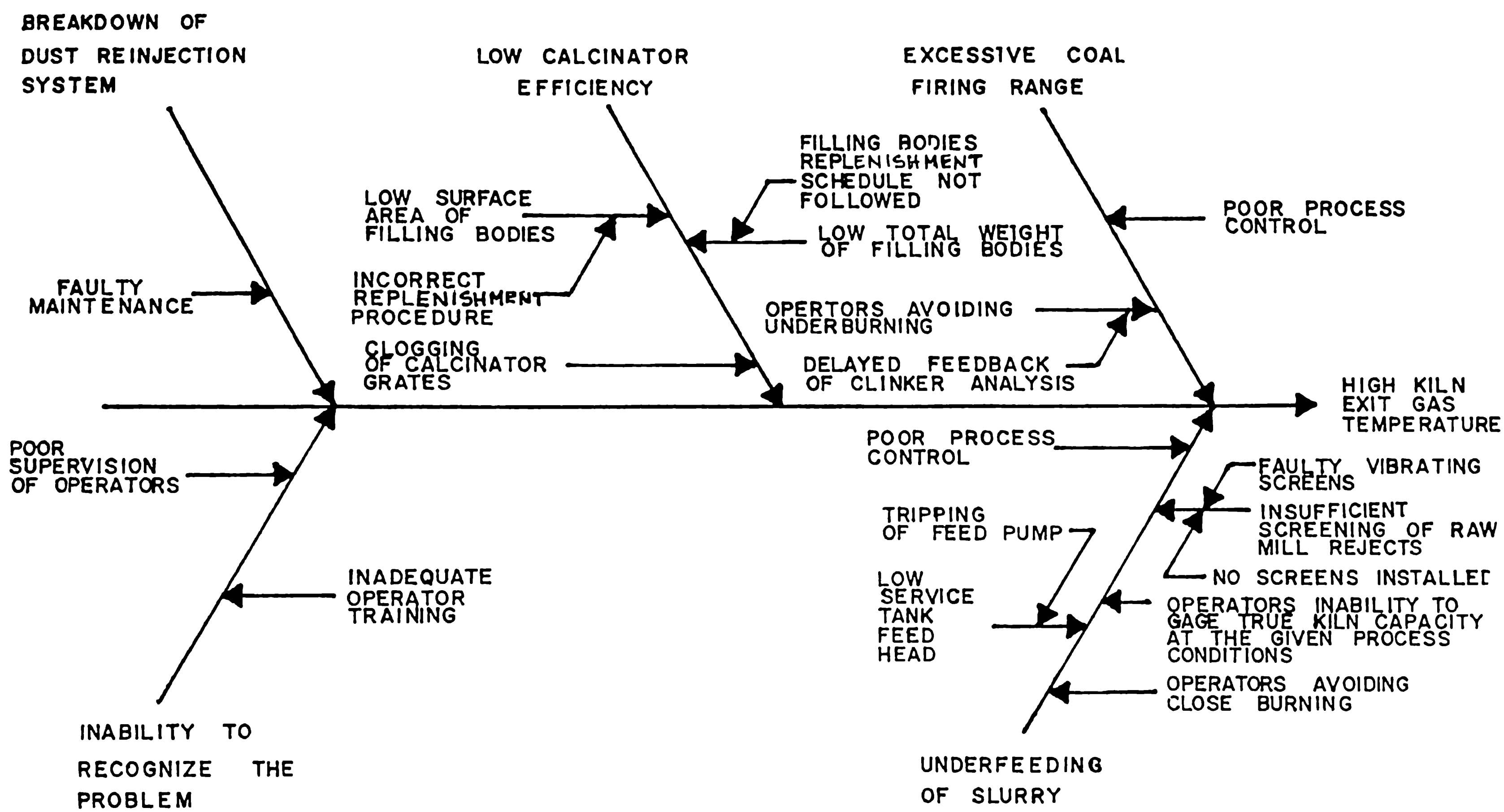

Figure 10 System Faults Leading to High Exit Gas Temperature

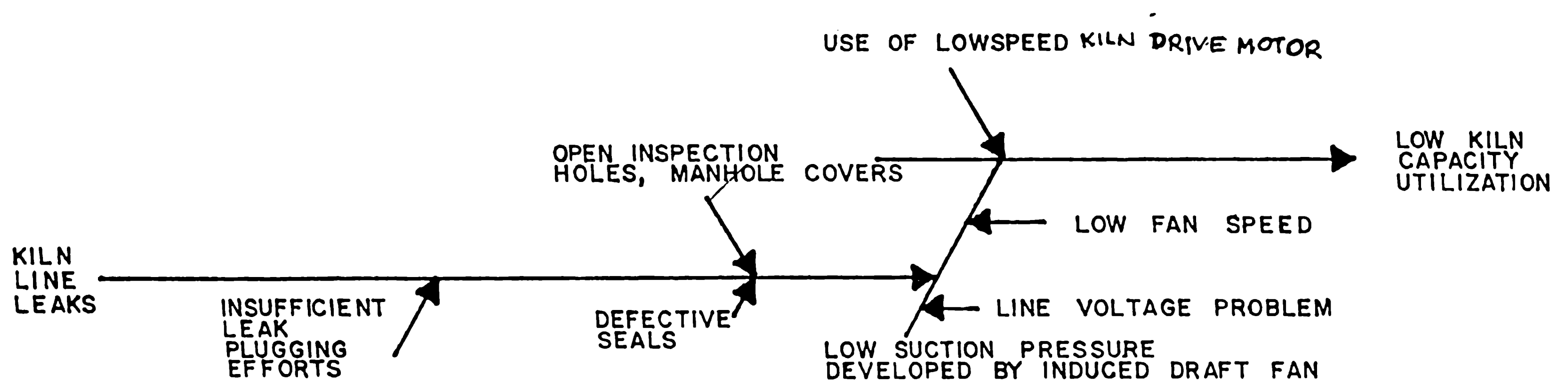

Figure 11a) System Faults Leading to Low Kiln Capacity Utilization

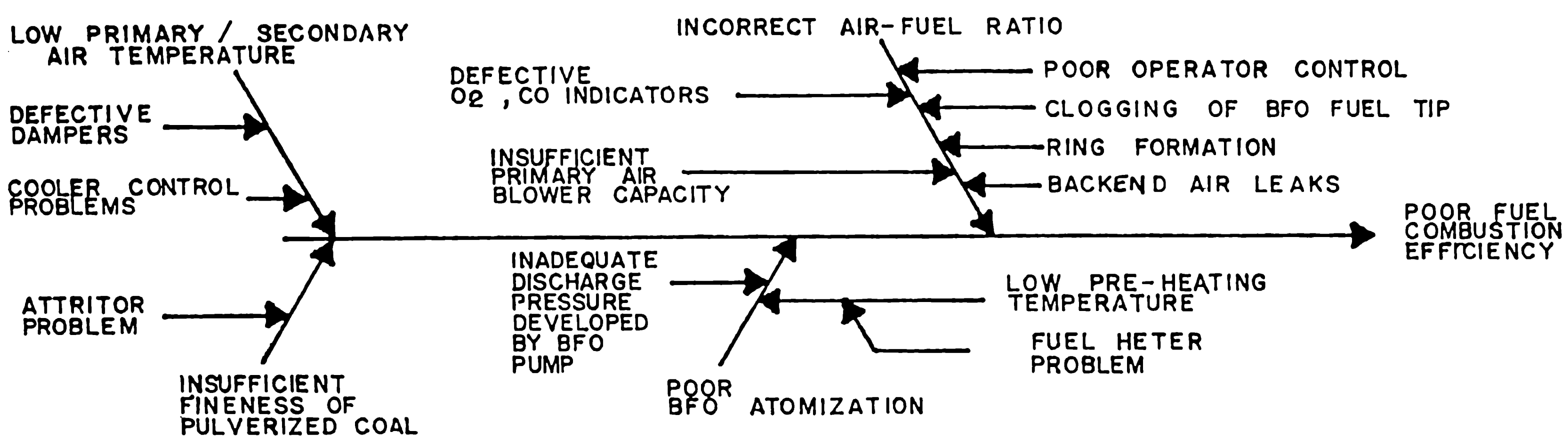

Figure 11b) System Faults Leading to Poor Combustion Efficiency

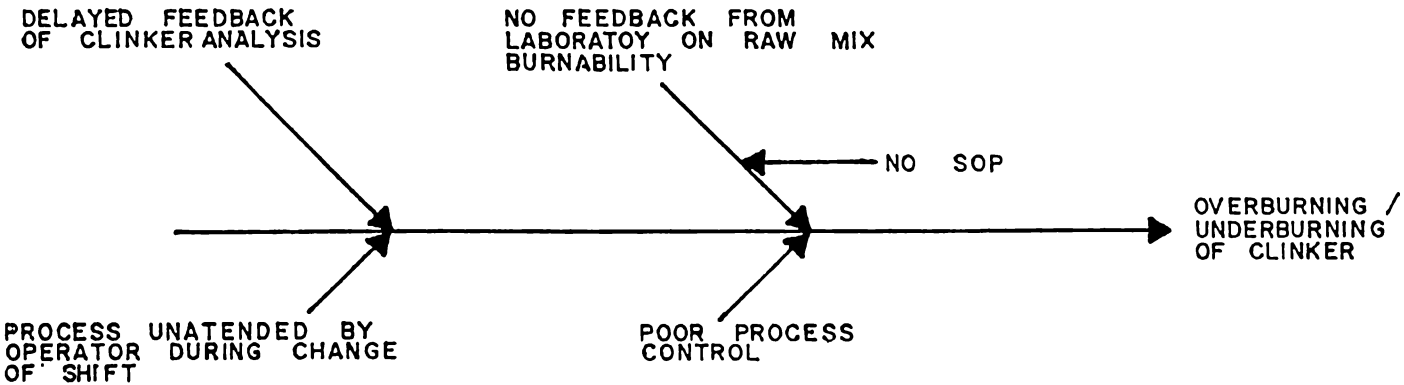

Figure 12a) System Faults Leading to Overburning / Underburning of Clinker

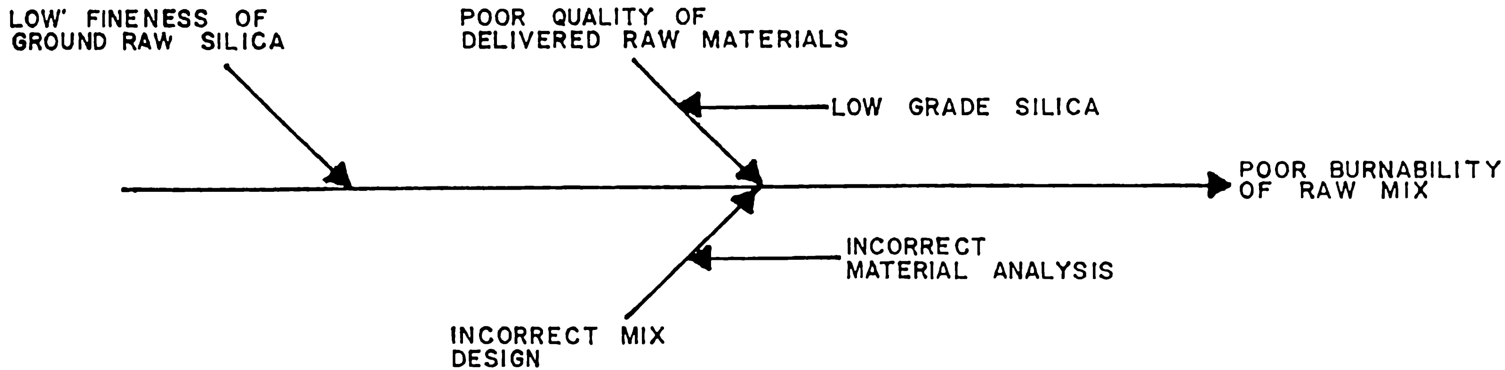

Figure 12b) System Faults Leading to Poor Burnability of Raw Mix

BCI SYSTEM IMPROVEMENTS

1. IMPROVED ENERGY MANAGEMENT

One of the major factors that helped bring about the substantial improvement in kiln efficiency was the improvement of energy management at BCI. Prior to the arrival of the current manager, energy management activities were mostly in the form of energy monitoring. The concern for efficiency in the plant was just secondary to the concern for production volume and clinker quality. Having placed plant efficiency among the top priorities, the curent plant manager assumed the post of energy manager and set in place a true energy management program which in addition to monitoring energy consumption, analyzes the causes of inefficiencies, plans system improvements, and puts into action these planned projects. Maximization of the involvement of plant personnel in this endeavor was accomplished through participation in the Work Improvement Teams.

2. IMPROVED KILN CAPACITY UTILIZATION

Reduced induced draft fan capacity due to air leaks in the system had been identified as the major cause of not being able to produce clinkers to the level of what the kilns are capable. By installing new "abaniko" type air seals at the feed and discharge ends of the three kilns and the all out air leak hunting campaign waged by the WIT of the Burning Division, the output of the three kilns increased from 24,000 bags per day to 27,000 bags per day. Figure 13 shows a section of the "abaniko" type of air seal. Higher capacity utilization directly results in higher kiln efficiency. Orsat analysis of samples of the kiln gas taken at the kiln feed end, electrostatic precipitator inlet and the induced draft fan inlet are done regularly to aid in pinpointing areas of air infiltration and to monitor the level of air infiltration.

3. REDUCTION OF SLURRY MOISTURE

The plant was able to accomplish a reduction of the slurry moisture from a range of 34-35 % to 32-33 % by closely regulating the addition of water at the raw mills and in the other parts of the slurry system. In addition, calcinator tenders were ordered to scrape instead of use water to clean dried up slurry in the feed ports and calcinator grates. The necessary adjustments to the nozzles and nozzle rod linkages were made to minimize the occurrence of this problem. In order to further improve the ability of the pump to handle more viscous slurry with lower moisture content, it was planned to streamline further the pipeline leading to and from the pump. In addition the excess elevation head of the slurry discharge line is to be reduced. With these improvements, it is expected that slurry moisture will be lowered further to 30 - 31 %.

4. MORE STABLE KILN OPERATION

The significant reduction of the occurrences of equipment failures was largely responsible for the improvement of the stability of kiln operation. This was accomplished through better post mortem analysis of failures conducted during staff meetings, improved maintenance work and improved procedures for the turnover of repaired equipment by the engineering crew to the production crew. A project which helped in stabilizing kiln operation was the installation of

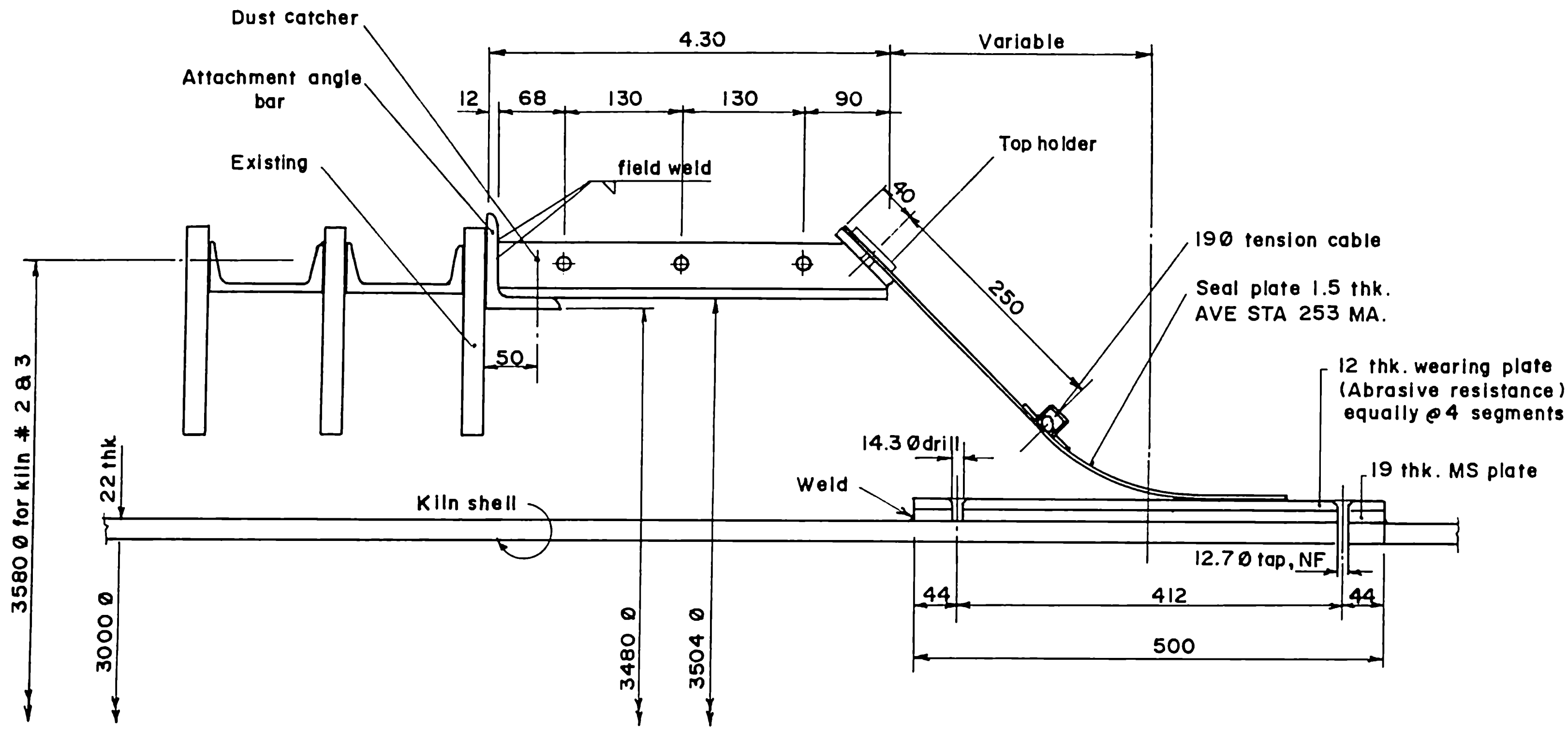

Figure 13 Feed End Kiln Air Seal

variable speed drives for the clinker coolers. This allowed the control of the thickness of the bed of clinkers on the cooler grates and attain maximum and stable secondary air temperature. More stable operation was also the result of better process control by the operators. A seminar-workshop on efficient kiln operation was conducted for all the kiln personnel wherein the participants discussed good and bad operating practices and were taught the use of instruments for process monitoring and how to correctly act under various process conditions. To prolong the life of the brick lining, the plant is now conducting the regular monitoring of the kiln shell surface temperature to identify spots with thin coating and installed new kiln shell blowers for more stable coating formation. A seminar on improved kiln rebricking techniques was also conducted by the Production engineer based on his experience gained as a trainee at Osaka Cement (Japan).

To further improve process control, the plant has embarked on a project that will install PID controllers to control the coal firing, slurry feeding and clinker heat recovery processes.

5. LOWERING OF KILN EXIT GAS TEMPERATURES

Average exit gas temperatures after the calcinator used to fall in the range of 190 to 210 C and this had been reduced to 150 - 180 C. Several efforts contributed to this and these are: 1) Regular replenishment of the calcinator filling bodies to the correct total weight and bulk volume, 2) improvement of vibrating screens and inspection of these to minimize clogging of calcinator nozzles, 3) the reduction of equipment failures in the dust reinjection system through improved maintenance work, and 4) the conduct of an operators' training seminar in efficient kiln operation. The previously mentioned project on the use of PID controllers should also helped in bringing further down this sensible heat loss.

CONCLUSIONS

The attainment of efficiency improvement rests to a large extent on good energy management which in turn requires a good energy manager and a good working energy management program that maximizes the involvement of plant personnel. An important aspect of energy management at BCI was the use of the systems approach in treating the problem of poor kiln efficiency. This allowed the plant personnel to examine not just the faults in their machines, materials or process but also to examine faults within themselves and on the way they operate, control and maintain their equipment.