The Rotary Cement Kiln

Second Edition

by

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Preface

Often regarded as the heart of the plant, the kiln constitutes clearly the most important step in the process of cement manufacturing. It represents the largest single capital investment and consumes the major portion of the energy requirements in the plant. Regardless how much effort and attention is being given to the preparation of the kiln feed, the fact remains that the feed has to be properly burned in the kiln so that a good quality product can be sold to the customer. Because of its importance, the kiln burning operation deserves special attention and kiln operators should be properly trained. The old simple saying still holds true: "When the kiln discharges clinker, the company has a fighting chance to make some profits, but when no clinker is produced, no money can be made."

The rotary kiln requires specialized knowledge and experience on the part of the operator so he can successfully perform his job. Thus, with its complex instrumentation and multiple reactions, the kiln poses a significant challenge to the kiln operator. It is obvious that the kiln operator occupies one of the key positions in the production crew.

The Rotary Cement Kiln is the first handbook of its kind to deal not only with the theoretical aspect, but also with the actual control functions of kiln operation. First published in 1972, the original edition of this book dealt primarily with wet- and long dry-process kilns. Since that time, the cement industry has undergone a radical change brought about by the energy crisis of the mid-seventies. More fuel and labor efficient kilns were built to keep pace with the rapid advances in cement manufacturing technology. Capital that was sufficient twenty years ago to buy a complete new cement plant today will barely be enough to buy a kiln. But, the new modern preheater and precalciner kilns of today, outperform and outproduce the older wet and dry kilns by a wide margin. Most of these are also fully automatic, controlled by computers and the noisy, dusty burnerfloor of the past has been replaced by remote, air-conditioned control rooms. There is no question that these technological advances have benefited the kiln operator for they have made his job easier and more pleasurable. On the other hand, there is no doubt that the operator's responsibility has greatly increased because most are responsible not only for kiln operation but for the control of the raw and finished grinding departments too. It is the author's hope that this revised edition will be as well accepted in the cement industry as the first book. We have expanded each chapter to make this a more complete and up-to-date training and reference book not only for kiln operators but for supervisors and management staff as well. Most important, we have added extensive discussions for preheater and precalciner operations.

The author discusses the theoretical fundamentals, including basic cement chemistry, composition of the kiln feed, heat balances and heat transfer, combustion, flames, fuels, and the air circuitry in a rotary kiln.

Step-by-step descriptions of the control functions for the operation of a rotary kiln are extensively discussed. The described burning procedures and techniques have been tested over many years on kilns of various dimensions, and experience has proven them to be entirely successful. So much so that computer control programs have been recently written and successfully placed in operation that were based on the 27 basic kiln control conditions first introduced by the author in our first book. Adopted for hundreds of kilns worldwide, they are the foundation for stable and economical operations.

The appendix includes a section with conversion tables, definitions of common terms relating to rotary kilns, and a suggested outline for a training program for new operators.

Many thanks to Joseph J. Waddell who coauthored the first edition with me.

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Part I

Kiln Systems and Theory

1.

History

Vertical furnaces and simple forms of shaft kilns were used for burning lime well over 2,000 years ago. History tells us that the Romans used a vertical furnace in which to burn a pozzolanic lime. Near Riverside, California are the remains of underground furnaces (Fig. 1.1) in which the early Mexican settlers burned limestone to make lime during the first part of the 19th century. In later times so-called bottle and shaft kilns were employed. Vertical kilns of the type shown in Fig. 1.2 were constructed in Southern California about the turn of the century.

Early development of the rotary kiln probably started about 1877 in England, but Frederick Ransome is usually credited with the first successful rotary kiln, which he patented in England in 1885. Although the first Ransome kilns were a major breakthrough in the cement industry at that time, many years passed before a successfully operating rotary kiln was put into production. It was mainly the pioneer work of American engineers a few years after Ransome's discovery that brought the concept of the rotary kiln out of its infancy. The first economical rotary kiln in America, developed by Hurry and Seaman of the Atlas Cement Company, went into production in 1895.

Shaft kilns with continuous feed are now used mainly and only for the burning of lime and minerals other than cement. Rotary kilns have replaced these shaft kilns entirely in the cement industry. Although years ago, shaft kilns showed lower thermal and power requirements than rotary kilns, the advent of the preheater and precalciner kilns with their increased output and fuel efficiency has apparently made the shaft kiln obsolete for the burning of cement clinker.

Fig. 1.1 Remains of underground furnaces that were used by early California Settlers for burning limestone to make lime. (*Riverside Division, American Cement Corp.*)

The first Ransome kilns were 45 cm (18 in.) in diameter and 4.5 m (15 ft) in length. Later, about 1900, the rotary kiln grew to 1.8 m (6 ft) in diameter by 18 m (60 ft) long which in todays terms would have to be classified as miniatures. Kiln sizes really started to explode in the 1960's when they reached dimensions up to 6.5 m (21 ft) diameter and up to 238 m (780 ft) length. With these enormous sizes and corresponding high output rates a considerable amount of new structural and control problems started to evolve. Refractory life in the kiln became uneconomically low, coolers couldn't handle that high output especially not during upset conditions, and mechanical equipment failures became weekly occurrences in many plants.

The energy crisis represented a blessing in disguise in matters of kiln design. Suddenly, fuel conservation became the number one priority item in most cement plants which led directly to increased construction of preheater kilns all over the North American continent. Although these pre-

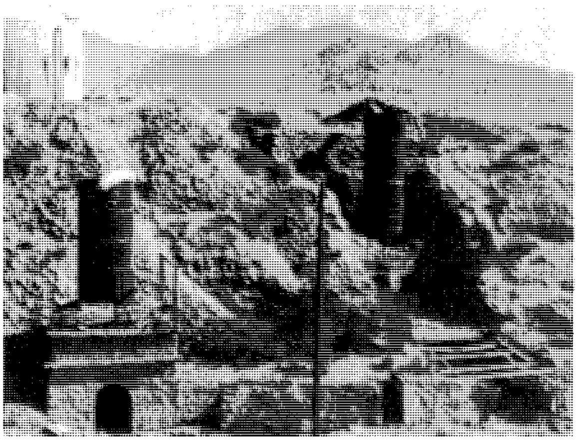

Fig. 1.2 Vertical shaft kilns were commonly in use in the latter part of the 19th century. (*Riverside Division, American Cement Corp.*)

heater kilns satisfied the need for lower fuel consumption, they didn't meet the requirements for using low-grade fuel and ever-increasing demands for higher production rates.

In an attempt to gain these higher outputs, the Japanese cement industry increased preheater kiln sizes to a point where they were back to square one, namely, these kilns again became too large; frequent mechanical problems and short brick-life became the norm just as in the times of the dry and wet monster kilns. The major breakthrough came in Europe where precalcination was successfully attempted in the late 1960's using a very low bituminous shale as a component of the kiln feed in a conventional preheater kiln. Adding combustible materials to the kiln feed, at that time, was nothing revolutionary, for the author himself, in 1957, had burned a wet kiln in Canada that contained oil shale in the slurry. The European experience, however, was the first time such an addition was successfully tried in a preheater kiln and thus paved the way for today's precalciner kiln. Precalciner kilns are the latest advance in cement manufacturing technology. They combine low thermal requirements, are able to use low-grade fossil fuels or other combustible materials, and show output rates that were considered unattainable only a few years back.

2.

Types of Rotary Kilns

Generally speaking, the clinker manufacturing processes used in rotary kilns are classified into:

Wet-Process Kilns
Semidry Kilns
Dry Kilns
Preheater Kilns
Precalciner Kilns

Each of these types are discussed here.

2.1 WET PROCESS

Into this group fall all processes in which the kiln feed enters the kiln in the form of a slurry with a moisture content of 30 to 40%. In comparison with a dry-process kiln of the same diameter, a wet-process kiln needs an additional zone (dehydration zone) to drive off the water from the kiln feed. Therefore, it must be considerably longer in order to achieve the same production rate.

To produce an equivalent amount of clinker, a wet-process kiln requires theoretically more fuel than a dry-process kiln because of the extra heat required to evaporate the water. However, in actual operation of a kiln this fundamental fact does not always hold entirely true. As one progresses in the reading of this book, the reasons for these discrepancies between theory and actual operation will become clearer and understandable.

Advantages of a wet-process kiln are:

1. feed is blended more uniformly than in the dry process
2. dust losses are usually smaller, and
3. in moist climate regions, wet processing of the raw material is more suitable than dry because of moisture already present in the blend materials.

2.2 SEMIDRY PROCESS

This member in the group of rotary kilns is also widely known under the term *Grate Process Kiln* or *Lepol Kiln*. These kilns are as efficient in matters of fuel consumption as the most modern preheater and precalciner kilns. Output rates, however, lag behind the aforementioned types of kilns. However, it is advantageous to select a Grate Process Kiln over a preheater or precalciner kiln in places where raw material moisture is so high that it cannot be economically dried by waste heat from the kiln. Lepol Kilns, because of the fact that the kiln exit gases pass through the granular feed bed, operate with much lower dust contents in the waste gases which gives these kilns a decisive advantage over other preheater kilns. Instead of granulating the kiln feed, some plants use filter press cakes to feed the kiln. In such cases, the wet-kiln feed slurry is first passed through large presses for removal of the free water and more importantly, to remove alkalies before the filter cakes are fed to the kiln.

In the grate process, pulverized dry-kiln feed is first pelletized into small nodules by means of 10-15% water addition, then the nodules are fed onto a traveling grate where they are partly calcined before they enter the rotary kiln. Heating of the nodules is effected by the exit gases from the rotary kiln, the hot gases passing through the material bed from above as they are drawn downward through the grates by means of a fan. The partly calcined material then falls down a chute into the rotary kiln where final clinkerization takes place. Because the kiln feed is already partly calcined before it enters the kiln, the rotary kiln itself is only about one-third the usual length. Fig. 2.1 is a schematic diagram of the flow of gas and material through a Lepol grate-process preheater.

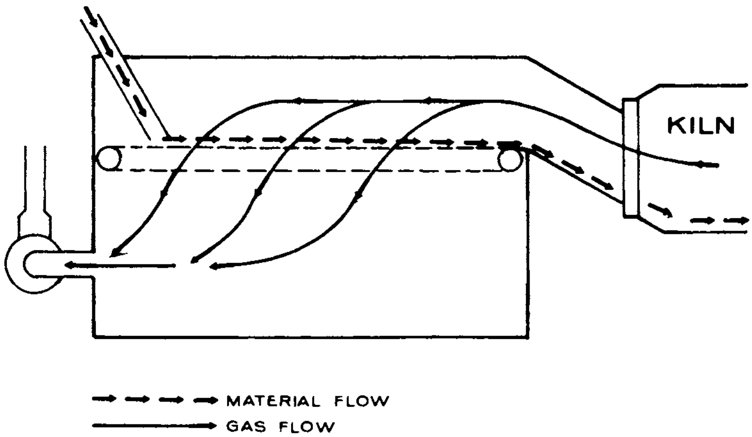

Fig. 2.1 Flow diagram of a Lepol preheater. Pelletized feed fed onto a traveling grate, is heated and partly calcined by hot kiln exit gases before it enters the kiln.

One advantage of grate-process kilns is the uniform size of clinker leaving the kiln, an aspect that is decidedly beneficial for grinding the clinker. However, there are some features not found in conventional rotary kilns that need very close attention; for example, production of the nodules and control of the thickness of the feed bed over the traveling grates. Such a kiln usually requires additional labor to attend the granulator plant.

2.3 DRY-PROCESS KILNS

As the term indicates, in this process the kiln feed enters the kiln in dry powder form. Dry-process kiln dimensions are similar to wet kilns in that they are long and typically show a length-to-diameter ratio of approximately 30:1 to 35:1. Dry-process kilns operate with a very high, back-end temperature and require watersprays at the feed end to cool the exit gases to safe levels before they enter the baghouse or precipitator. Most dry kilns are equipped with chain sections at the feed end to transfer heat, that otherwise would be lost, to the feed before the gases leave the kiln.

Fig. 2.2 shows a picture of a chain section. The gases enter the chains at a temperature of approximately 800 C (1470 F) and leave the kiln exit at a temperature of 450 C (840 F). In countercurrent flow, the material

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