

Survey of lime kiln operation and ringing problems

Efstathios Notidis and Honghi Tran

ABSTRACT: *A survey of operating conditions and ringing experience of 134 kilns in Canada, the United States, Finland, and Sweden showed that ringing is responsible for 20% of all kiln downtime. No single variable was found to have a definite correlation with ringing. It appears, however, that older kilns and kilns that alternately burn either oil or natural gas tend to have more ringing problems than kilns that burn oil or natural gas alone.*

KEYWORDS: *Canada, combustion, design, economics, Finland, formation, gas, lime kilns, noncondensibles, operations, rings, surveys, Sweden, USA, variables.*

Ring formation in lime kilns can be costly due to costs associated with ring removal, purchase of fresh lime, and mechanical damage to the kiln. Experience of ringing differs from mill to mill because of the varying operating conditions of individual kilns. Some kilns that burn high-sulfur-containing noncondensable gases (NCG) from recovery processes reported ringing problems (1, 2), while others have burned NCG for years with no ringing problems.

This survey was conducted as part of the research program, "Mechanisms of Ring Formation in Lime Kilns," undertaken at the University of Toronto. The objective was to assess, through a questionnaire, the current status of kiln operations and ringing

problems. The questionnaire addressed kiln design and operating variables that may lead to ringing problems, NCG combustion, and the economic impact of ringing.

The questionnaire was distributed in the period between June 1990 and March 1991 to mills in Canada, the United States, Finland, and Sweden, with the assistance of the Canadian Pulp and Paper Association Alkaline Pulping Committee, the TAPPI Alkaline Pulping Committee, Rainer Backman of Åbo Akademi in Finland, and Per Ulmgren of the Swedish Pulp and Paper Research Institute.

A total of 134 responses from 106 mills were received: 17 from Canada, 75 from the United States, 23 from Sweden, and 19 from Finland. Each

response represents one kiln. The information from the responses was organized, sorted, and analyzed using conventional database and spreadsheet programs.

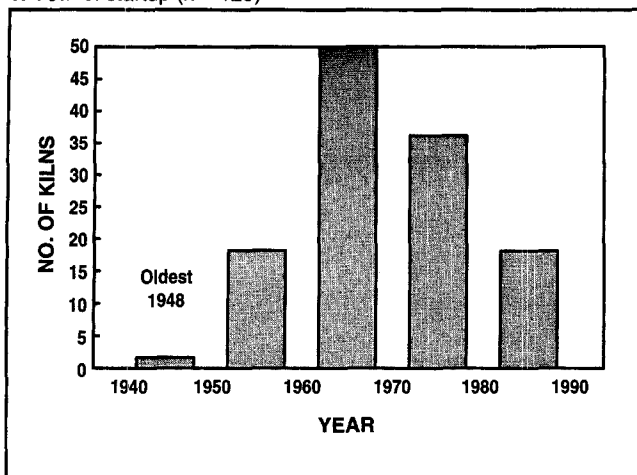
Design parameters

As shown in **Fig. 1**, the majority of kilns were built in the 1960s and 1970s. Forty-three of 133 kilns were manufactured by Fuller/Traylor, with Allis Chalmers and F. L. Smidth constructing 28 each, and Ahlström 26. The kiln volume is a function of designed production capacity (**Fig. 2**). The most common kiln dimensions were a diameter of about 3.2 m (10.4 ft) and a length of 90 m (270 ft), and a designed production capacity of about 190 metric tons of CaO per day, ranging from 30 metric tons to over 500 metric tons of CaO per day. Kiln slope has no correlation with the kiln capacity, and varies from 1.5% to 5%.

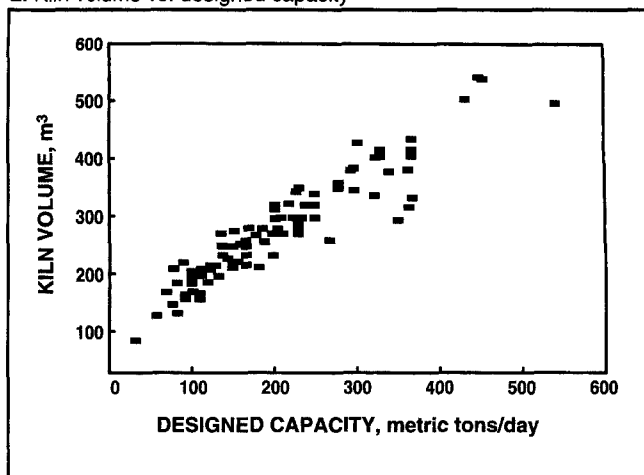
Seventy-one of 133 kilns were fitted with product coolers. Thirty-five of 105 kilns use Garland chains, while 29 use high-density chains. The balance use either a combination or low-density chains. Double-brick refractory lining is used in two thirds of the kilns, while single-brick lining is used in the other third. The majority of the kilns (79%) are fed with lime mud from a single precoat filter, while 19% have two precoat filters in parallel and 2% have three filters in parallel. One-half of precoat filters were manufactured by Dorr-Oliver. The other half were divided among Goslin, Ahlström, and Hedemora.

The authors work at The Pulp and Paper Centre and the Department of Chemical Engineering and Applied Chemistry at the University of Toronto, Toronto, ON, Canada.

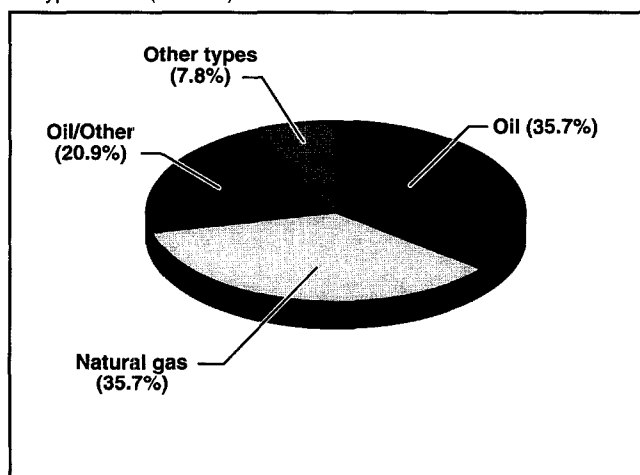
1. Year of startup ($n = 123$)



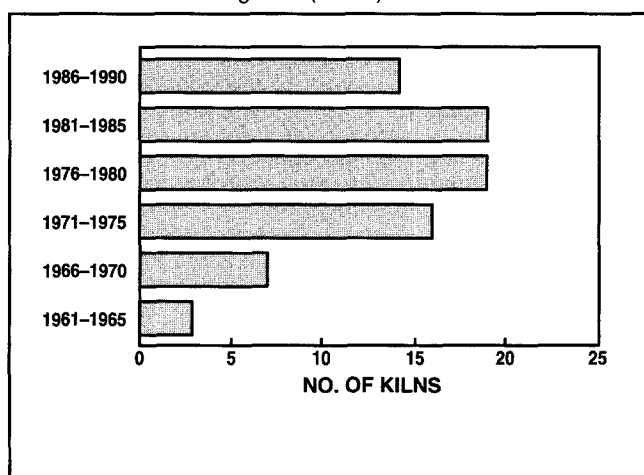
2. Kiln volume vs. designed capacity



3. Type of fuel ($n = 129$)



4. Year since first burning NCG ($n = 79$)



Operating parameters

Most kilns are operated at $\pm 10\%$ of their designed capacity; however, four kilns operated at over 150% of designed capacity.

Fuel

Most kilns burn either oil or natural gas (36% each), while the balance alternate between oil, gas, and some other fuel depending on cost and availability (Fig. 3). Two thirds of all kilns surveyed are burning noncondensable gases. This practice first started in the 1960s but became commonplace in the early 1970s (Fig. 4). Of these kilns, 61% percent introduce NCG through the fuel burner, while most of the rest introduce NCG through a separate

burner. Most mills burn NCG in the kiln "as is." Only one quarter of the kilns burn NCG that have been either scrubbed or diluted. Both methods of pretreatment are equally common.

Temperatures

Figure 5 shows kiln operating temperatures at various locations. The average temperature at the feed end is about 220°C (430°F), the same as that in the dust chamber. The average temperatures at the chain section, kiln front end, and at the point of lime product discharge are 450°C (830°F), 1020°C (1870°F), and 650°C (1200°F), respectively. Most kilns operate their primary air at ambient temperature, and their secondary air at slightly higher

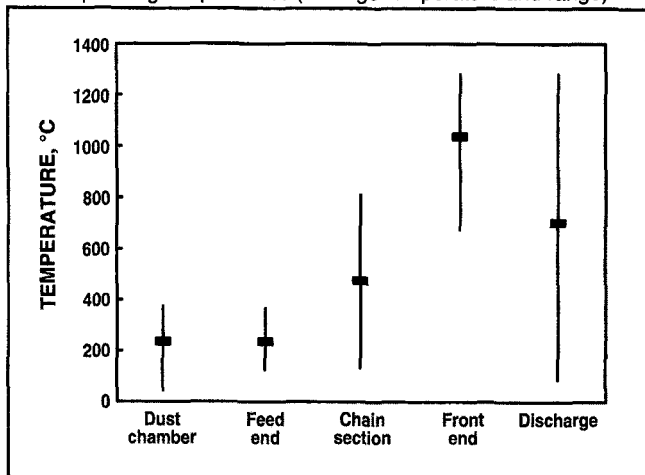
temperature, depending on whether or not they are equipped with satellite coolers.

Figures 6 and 7 respectively show the breakdown of temperature at the kiln feed end and front end. The most common operating range for the feed-end temperature is about 260°C (500°F), while the front-end range is around 1100°C (2010°F). The much wider variation in front-end temperature compared to the feed end is expected because of the difficulty in temperature measurement at the front end of the kiln.

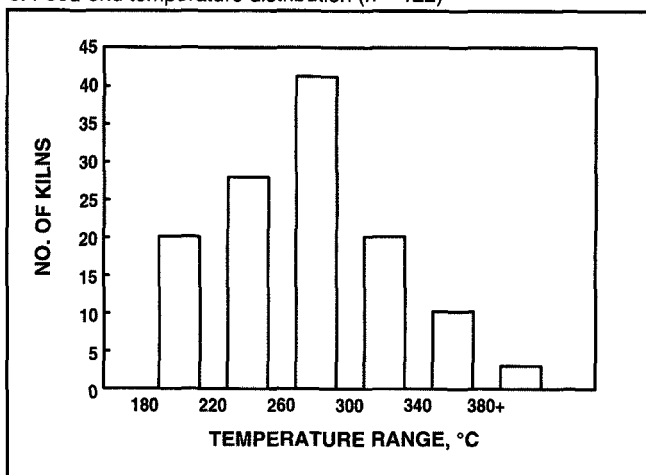
Lime mud

The solids content of mud fed to the kiln averages about 70 wt%, varying between 67 wt% and 73 wt%. The so-

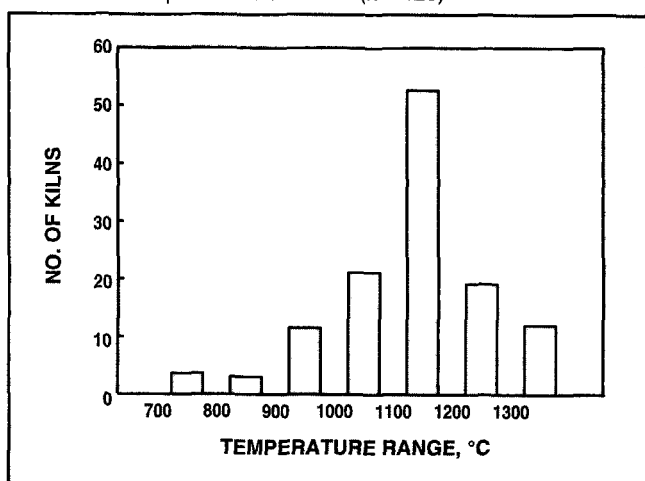
5. Kiln operating temperatures (average temperature and range)



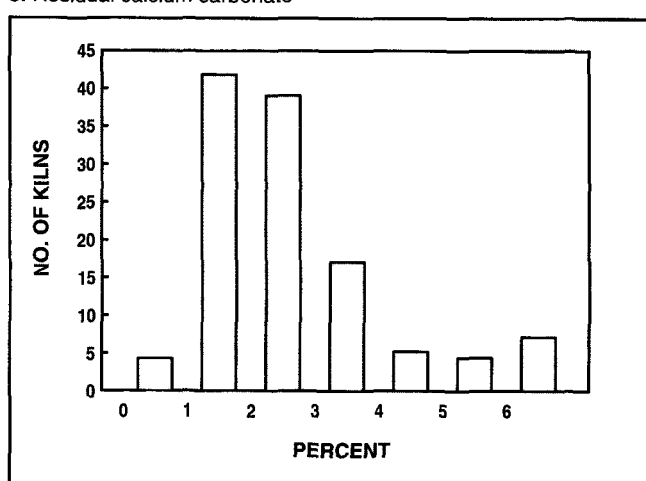
6. Feed-end temperature distribution (n = 122)



7. Front-end temperature distribution (n = 123)



8. Residual calcium carbonate



dium content of the mud averages about 2 wt% Na_2O on dry solids before the precoat filter (mud to filter) and about 0.5 wt% Na_2O on dry solids after the precoat filter (mud to kiln).

The chemical composition of lime mud provided by 61 respondents showed that lime mud consists of about 90–95 wt% CaCO_3 and 5 wt% of impurities or inert matter. Among the impurities, sodium, magnesium, sulfur, and phosphorus have the highest concentrations expressed as oxides, followed by silicon, aluminum, potassium, and iron. Only 25 respondents provided information on ring deposit composition. The limited data showed that ring deposits have a similar composition to lime mud, with a lower CaCO_3 content and a higher sulfur or CaSO_4 content.

Lime and liquor properties

Most kilns produce good lime. The residual CaCO_3 in the product lime varies between 1% and 3% (Fig. 8). The lime availability averages about 90%, varying between 75% and 95% (Fig. 9).

The white liquor sulfidity in Canadian and U.S. mills averages about 29% on active alkali, ranging from 18% to 39%. It is significantly lower than that in Scandinavian mills, where the average sulfidity is 34%. The average active alkali in white liquor is also lower in North American mills, 100 g/L Na_2O , compared with 121 g/L Na_2O in Scandinavian mills. The white liquor causticity in North American and Scandinavian mills was the same, averaging about 80%.

Dust recycle

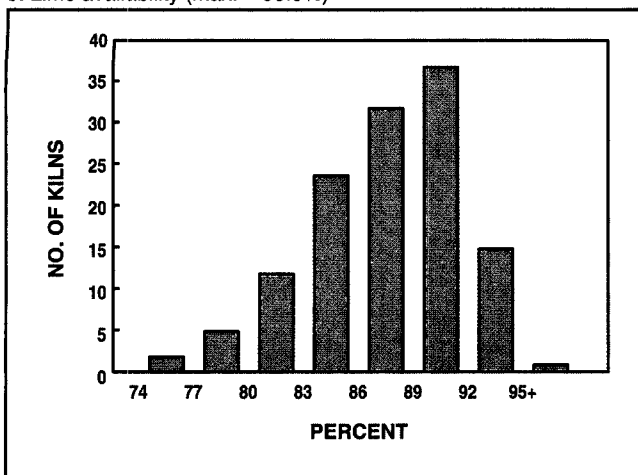
Most of the kilns recycle between 5% and 15% of the feed mud as dust (Fig. 10). The most common method of dust capture is the use of scrubbers, which accounts for 69%, followed by precipitators (22%) and cyclones (9%). The majority (81%) of kilns recycle the dust via the precoat filter, while the rest either return the dust directly to the kiln or use a combination of both practices.

Ringing experience

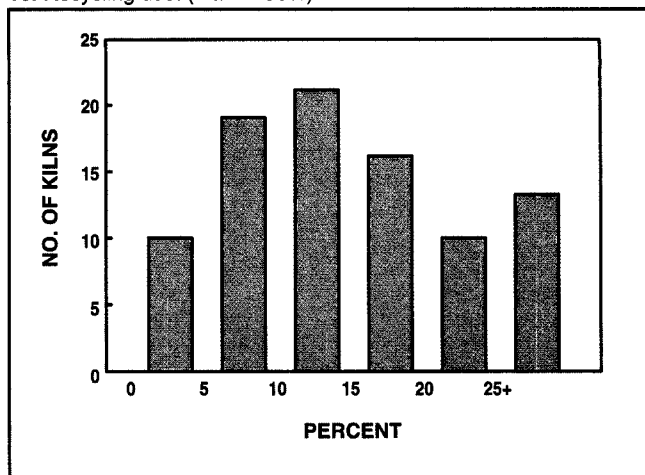
Location of rings

There are typically three types of rings, which occur at different locations in lime kilns (3). Mud rings occur just

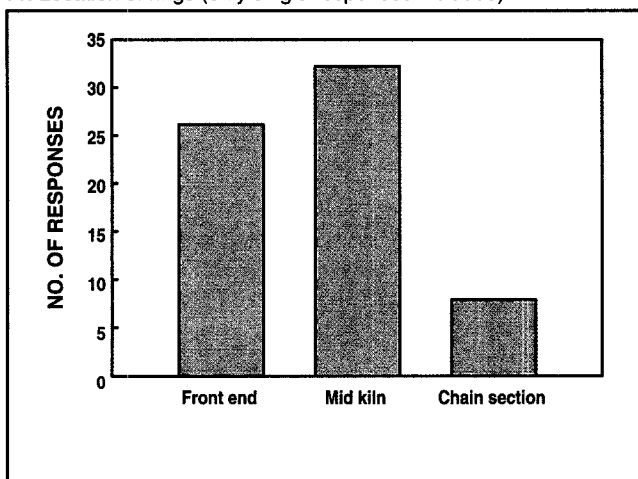
9. Lime availability (max. = 95.5%)



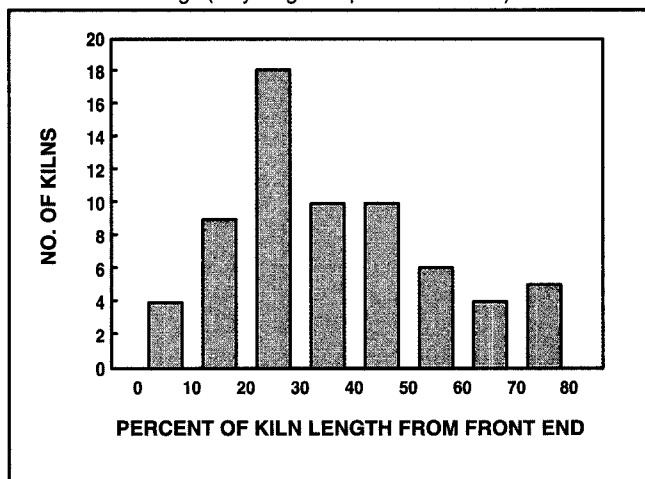
10. Recycling dust (max. = 50%)



11. Location of rings (only single responses included)



12. Location of rings (only single responses included)



after the chain section. Mid-kiln rings usually occur in the middle of the kiln, starting at a location near the beginning of the calcination zone and ending at about 20 meters (60 feet) from the front end. Front-end rings are located close to the burner.

In this survey, respondents were asked to identify the types of rings occurring in their kilns and to sketch the exact location where rings were usually observed. As shown in Fig. 11, most respondents have qualitatively identified their rings as being "front-end" and "mid-kiln." However, when the actual ring positions were plotted using the data provided by each mill, it became clear that rings have been observed everywhere in the kiln, although they formed most frequently

between 10% and 30% of the kiln length away from the front end (Fig. 12). This suggests that many mills confuse front-end rings with mid-kiln rings.

Frequency

Ringing is reported to be responsible for about 20% of all kiln downtime, including scheduled shutdowns. The magnitude of the problem may be considerably bigger than the number indicated. Over 90% of the respondents have experienced ringing in the past, while more than 80% have had a ringing problem within the last two years. Those kilns undergoing between one and three shutdowns annually, tend to do so due to ringing. Interestingly, for

mills that have more frequent kiln shutdowns, ringing does not appear to be the primary cause. Frequent kiln downtime and possibly concomitant cleaning presumably prevent ring accumulation (Fig. 13).

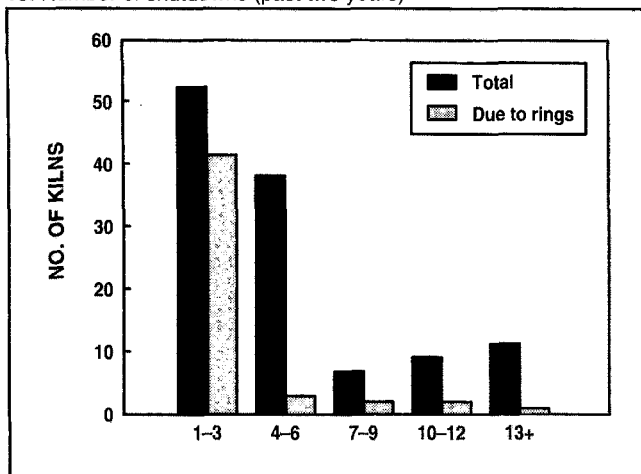
Ring removal methods

Figure 14 lists the ring removal methods most often used by the 112 respondents who have experienced ringing problems. Many mills use more than one method to remove kiln rings.

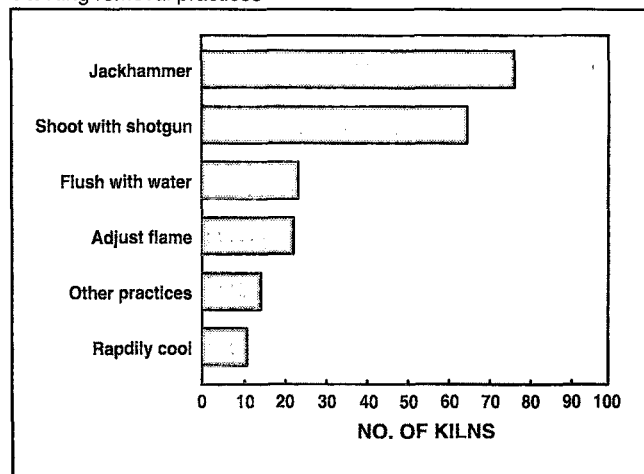
Costs

The costs associated with a ringing shutdown can be substantial. Most mills spend less than US\$ 10,000 for a ringing shutdown. Many mills spend

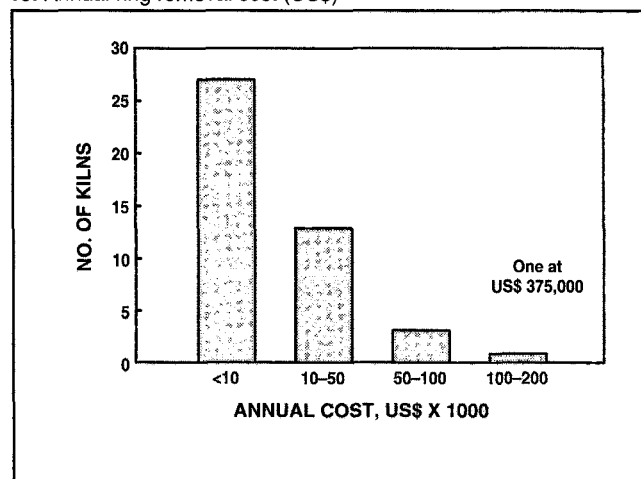
13. Number of shutdowns (past two years)



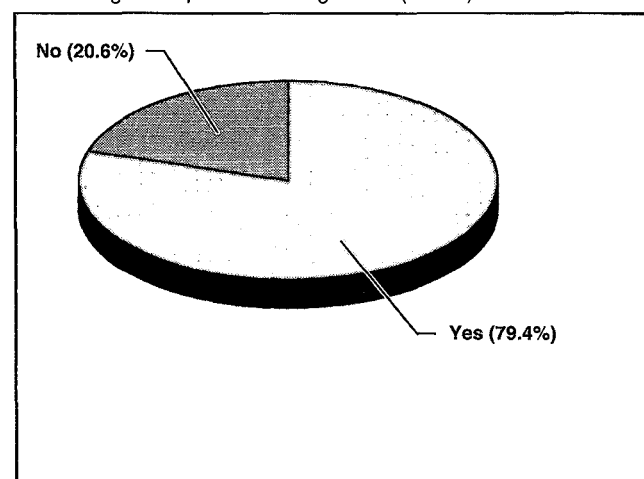
14. Ring removal practices



15. Annual ring removal cost (US\$)



16. Did rings form prior to burning NCG? (n = 63)



I. Factors believed to cause ringing in lime kilns

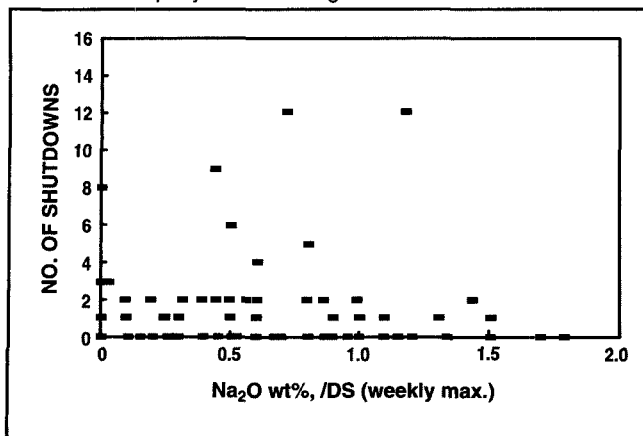
Parameters	Score (median)	Degree of importance
High soda content in mud	5	Most important
Unstable operation	3	
NCG combustion	3	
Low mud solids content	3	
Front end temperature	3	
Feed end temperature	3	
Overload	3	
Poor burners/Combustion	3	
High mud solids content	1	
High sulfur content in fuel	1	
Refractories	1	
Dams	1	
Small kiln length	?	Not sure
Small kiln diameter	?	Not sure
Lifters	?	Not sure

up to US\$ 50,000, with some as high as US\$ 130,000 (Fig. 15). The actual costs incurred by a forced kiln shutdown can be much higher than this if costs associated with disruption in mill operation are also taken into consideration.

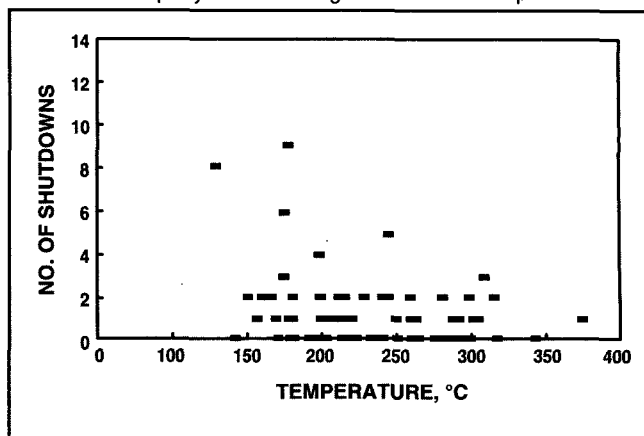
Believed causes of ringing

Respondents were asked to subjectively assign a value to various operating parameters, indicating the relative importance each parameter is believed to play in ring formation, i.e., “?” is not sure, “1” is the least important, and “5” is the most important. This subjective approach allows for the inclusion of past operating experience, which may serve to relate disparate

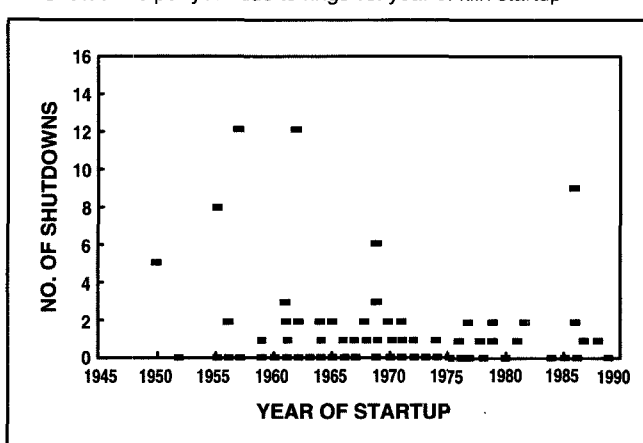
17. Shutdowns per year due to rings vs. sodium content



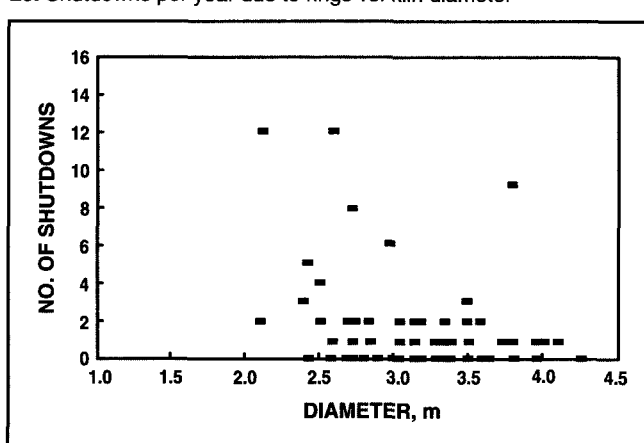
18. Shutdowns per year due to rings vs. feed-end temperature



19. Shutdowns per year due to rings vs. year of kiln startup



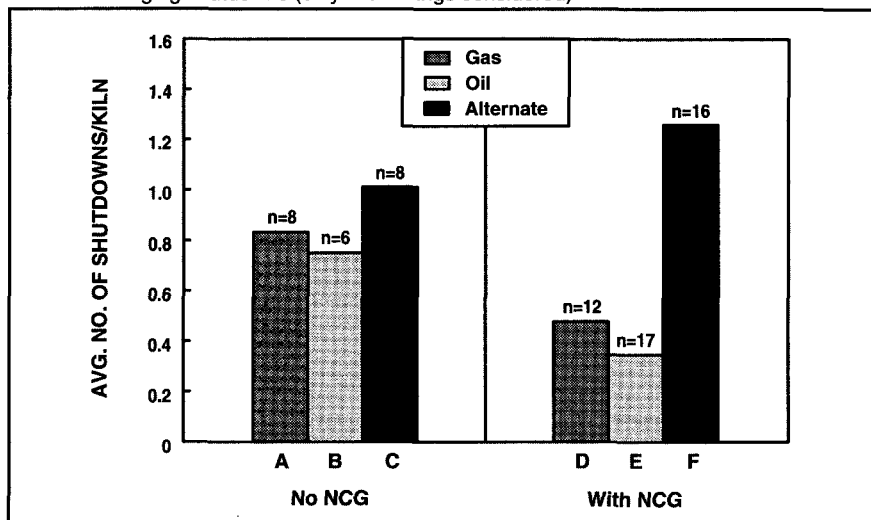
20. Shutdowns per year due to rings vs. kiln diameter



II. Kiln categories

Type	Fuel	Sulfur content
A	Gas alone	None
B	Oil alone	Some
C	Alternate between gas and oil	None/Some
D	Gas + NCG	None/Some
E	Oil + NCG	Some/High
F	Alternate between oil and gas + NCG	Some/High

21. Annual ringing shutdowns (only "front" rings considered)



parameters to the complicated, multi-variable problem of ring formation. The degree of importance of each parameter was determined based on the median of its scored values.

As summarized in **Table I**, high soda content in mud has a median score of 5, meaning that it is believed to play the most important role in the formation of rings, followed by unstable operation, the combustion of NCG, and low mud solids. Dams and refractories are not considered to be important factors.

While the responses did reflect the industry-wide belief that burning NCG plays an important role in ringing, it is interesting that nearly 80% of the respondents indicate that they already had experienced ringing problems, even before they started burning NCG (**Fig. 16**). This implies that, contrary to the general perception, burning NCG is *not* the main cause of ringing. It is not clear, however, whether or not NCG combustion has accelerated the ring formation process.

Factors affecting ring formation

The "number of ringing shutdowns per year" was used as an index to describe the ringing severity in this survey. Most parameters were found to have no correlation with ringing severity. **Figure 17**, for instance, shows no correlation between ring severity and the sodium content of the mud, which is thought to be the most important cause of ringing.

A few parameters, however, appear to have a weak correlation with ringing severity. Kilns operating with a feed-end temperature lower than 250°C (480°F) seem to experience more ringing problems (**Fig. 18**). Similarly, if a single outlying point is removed from **Fig. 19** at the year 1986, and from **Fig. 20** at the diameter of 3.8 m, the figures seem to indicate that older kilns, manufactured before 1970, and kilns with diameters smaller than 3 m (9 ft), tend to experience a greater incidence of ringing problems.

Effect of fuel

High sulfur concentration in the fuel is believed to play a role in ringing because of the presence of high sulfur, i.e., CaSO₄ content in ring deposits. Natural gas contains virtually no sulfur, while fuel oil contains about 2% sulfur. NCG contain some sulfur, although the exact amount is not known (the total reduced sulfur content in NCG is about 1–2 kg/ton of pulp).

To assess the effect of sulfur on ringing, kilns in this survey were categorized into six types, in order of increasing sulfur content (**Table II**).

Figure 21 shows the percentage of kilns burning a particular fuel, with or without NCG, and the average number of annual shutdowns due to ringing for each category. The ordinate axis represents the average number of ringing shutdowns, in each of the six kiln categories (Type A–F), i.e., the sum of the number of shutdowns due to ring formation divided by the total number of kilns burning a particular fuel. Each bar represents a kiln category as described in **Table II**. For example, the first bar from the left of the graph indicates that on average, Type A kilns (burning gas alone) experienced 0.8 shutdowns each year due to front-end ring formation (i.e., rings that formed within one third of the kiln length away from the front end).

It would seem that the burning of NCG or increased sulfur content did not have a demonstrable effect on ring formation. However, Type C kilns, which alternately burned either oil or gas, exhibited a greater incidence of ring formation than Type A and B kilns, which burned only gas or fuel oil. This may be due to the compromises in operation and temperature fluctuations incurred by burning two different fuels. Since gas and oil burners provide different flame characteristics, the temperature profiles in kilns that burn natural gas are different from those in kilns that use oil (4). Furthermore, older kilns, especially those manufactured before 1970, seem to exhibit a greater susceptibility to ring formation.

Conclusions

This survey confirmed that ring formation in lime kilns is a persistent obstacle to the efficient operation of kraft pulp mills. Ringing accounts for 20% of all kiln downtime, with the most common region of formation occurring within 30% of the kiln length from the front end.

No apparent correlation was found between ringing and any single variable, including high sodium in lime mud and the combustion of NCG. The survey, however, suggests that the incidence and severity of ring formation are affected by a combination of factors, especially varying, nonoptimum operating conditions. This may be inferred from the fact that kilns that alternatively burn oil and natural gas consistently demonstrate more ringing problems than kilns burning either oil or natural gas. Therefore, compromises in operation and temperature fluctuations incurred by alternately burning two different fuels may not be advantageous for ringing control. ■

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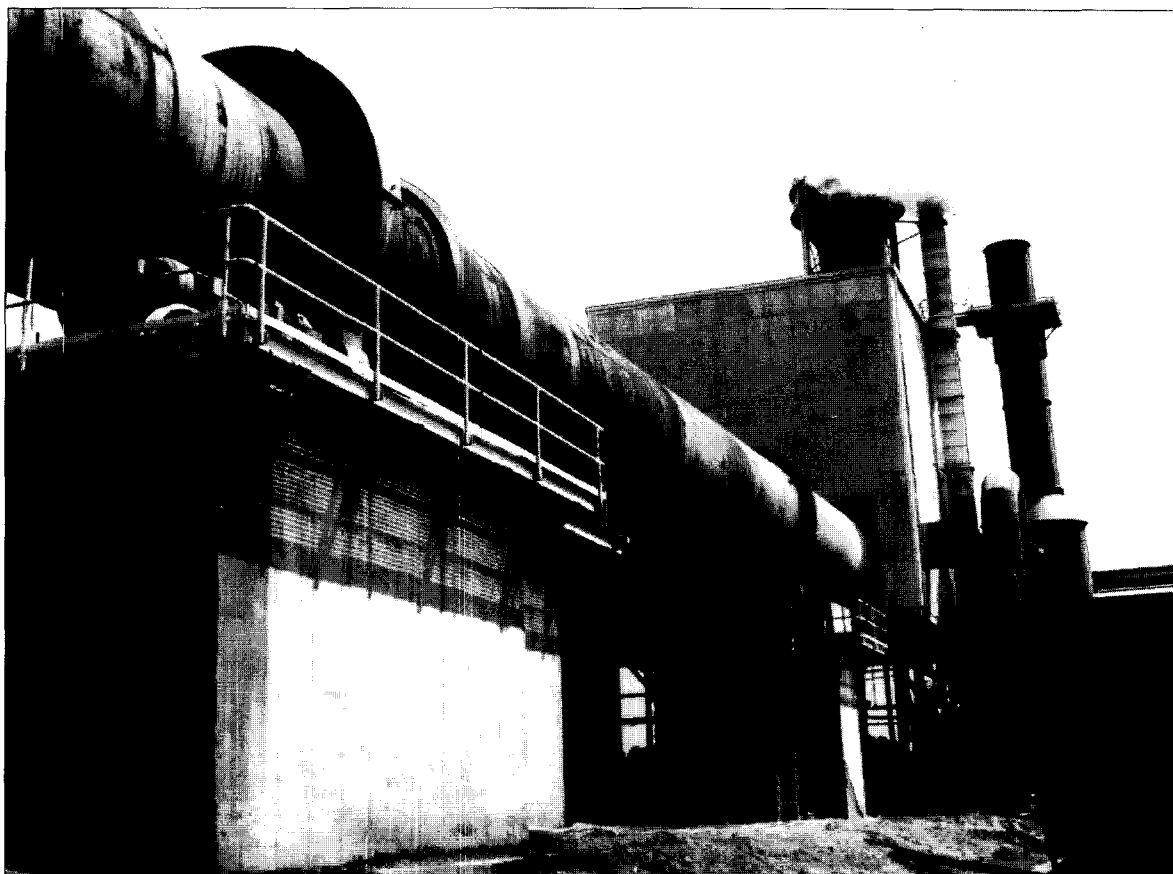
The work would not have been possible without the efforts and time provided by the individual respondents to fill out the comprehensive questionnaire. The survey is part of the research on "Mechanisms of Ring Formation in Lime Kilns," funded by Ahlström Corp., E. B. Eddy Forest Products Ltd., Georgia-Pacific Corp., International Paper Co., James River Corp., MoDo Chemetics International Corp., Potlatch Corp., Process Laboratory Corp. (Termorak Inc.), Union Camp Corp., Weyerhaeuser Co., and the Ontario government through its University Research Incentive Fund program.

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