

Neutral sulfite-anthraquinone pulping for linerboard: a lower temperature and mild alkalinity approach

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ABSTRACT *A laboratory study of neutral sulfite-anthraquinone (NSAQ) pulping for linerboard has been conducted under lower temperature and milder alkaline conditions than usual. The wood furnish included eastern Canadian softwood and softwood-hardwood mixtures. Preliminary test results showed that NSAQ pulping at 165°C would be sufficient to produce a satisfactory linerboard-grade pulp. At a pulping time of 50 min, the process would provide a 20% higher pulping yield than the usual kraft process. The NSAQ pulp strengths were comparable to strengths of the kraft pulps.*

KEYWORDS:

Anthraquinone
Linerboard
Pulping
Sulfite pulping

The beneficial effects of anthraquinone monosulfonate on the alkaline treatment of cellulosic materials was first reported by Bach and Fiehn (1) in 1972. Subsequently, Holton (2) and Nomura (3) separately discovered that 9,10-anthraquinone (AQ) was effective in enhancing kraft and soda pulping of wood. The specific benefits include higher pulp yield, lowered alkali charge, and/or reduced cooking time. Today, several kraft and soda pulp mills throughout the world are using AQ-type additives routinely to obtain higher mill productivity. The most common forms of additives used are anthraquinone dispersions and soluble sodium salt of dihydro-dihydroxy-anthracene (DDA).

The effect of AQ and its analogs on sulfite pulping was first reported by Virkola and coworkers (4) in 1979. Apparently, the effect of AQ on sulfite pulping was considerably greater than that on either kraft and soda pulping. For example, with the use of AQ, alkaline sulfite pulping could be

achieved within practical pulping time and temperature.

The use of the AQ-catalyzed sulfite pulping method for the production of linerboard has been reported by various researchers in Canada and elsewhere (4-11). In particular, linerboard pulp of comparable quality could be produced by the ASAQ or the NSAQ method at a higher yield than by the kraft technique.* For example, a 70%-yield ASAQ linerboard is comparable in quality to a 55% yield kraft linerboard (7). Indeed, several successful mill-scale trials have been conducted during the past 2 years in the United States and Canada (7).

There is an unusual opportunity for small sulfite mills to consider AQ-catalyzed sulfite pulping. Improved pulps of higher yield could be made with little modification to existing process equipment. Most published studies pertain only to pulping experiments at relatively high temperatures (>175°C) and pressures. Operation at high temperature is a means of reducing pulping time to a duration closer to that of the kraft mode of operation. Unfortunately, most sulfite digesters are not designed for pulping at such temperatures and pressures.

There is little or no information

available on alkaline sulfite pulping at 165°C or lower. At 165°C, the saturated water pressure is only 88 psig (12). Such a pressure value is practicable for many older sulfite digesters.

The principal objective of this study was to determine the basic properties of sulfite-AQ linerboard pulp made under mildly alkaline conditions at 165°C.

Results and discussion

Pulping rate

The maximum temperature used in both NSAQ and kraft pulping was set at 165°C to provide operation within the maximum working pressure (<90 psig) of actual digesters in many older sulfite pulp mills. Faster pulping rates could be attained with higher maximum temperatures.

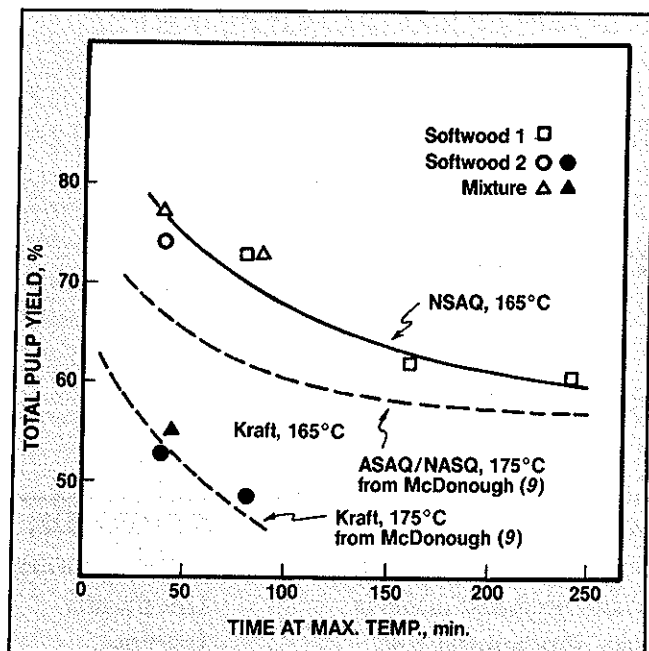
As shown in Fig. 1, NSAQ pulping yield was substantially higher than kraft pulping yield. McDonough and Paulson (9) and Isotalo (6) had recently reported similar findings in a study on ASAQ and NSAQ pulping at 175°C (linerboard).

Kappa number

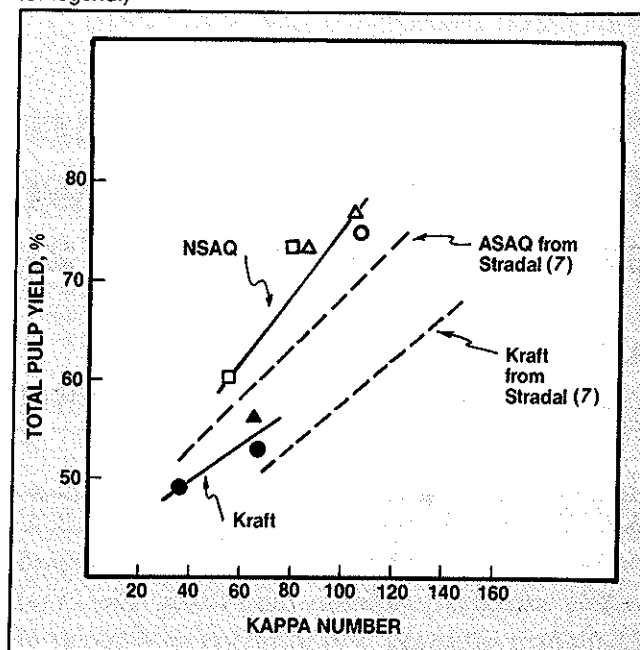
Figure 2 shows that for a given kappa

*The term "sulfite-AQ" is used generically here. In practice, alkaline sulfite-anthraquinone (ASAQ) refers to pulping under strongly alkaline conditions (with a starting pH of >12, for instance). Neutral sulfite-anthraquinone (NSAQ) denotes pulping under mildly alkaline conditions (with a starting pH of 10-12).

1. NSAQ and kraft pulp yields



2. Relationship between pulp yield and kappa number (See Fig. 1 for legend.)



number, the total pulp yield is higher for NSAQ pulp than for kraft pulp. There was no appreciable difference in the relationship of kappa number vs. yield for the two furnishes (100% softwood, and 80% softwood and 20% hardwood).

Refining energy

The energy of revolutions made in a PFI mill was used as a relative measure of refining energy. All NSAQ pulps required less energy for refining to any specific freeness than the kraft pulps (Fig. 3). Stradal *et al.* (7, 8) have previously reported similar decreases in refining energy requirements. At a similar pulp yield range for either NSAQ or kraft pulp, samples containing 20% hardwood were tested to need significantly less refining energy than samples containing no hardwood.

Physical strengths

Burst strength and stiffness are the two most important parameters characterizing the physical strengths of linerboard. Tear, tensile, and stretch strengths are not crucial properties for linerboard.

Burst strength

Higher yield NSAQ pulp has a burst strength equal to that of typical kraft pulp (Fig. 4). A similar yield advantage at a given burst strength has been noted by others (5-9). For example, at a burst index of 8 kPa·m²/g, NSAQ pulp of 72% yield is comparable to

kraft pulp at 57% yield. In terms of wood cost alone, this yield advantage is substantial. At \$80 (Canadian)/o.d. metric ton of wood, the economic advantage could be about \$32 (Canadian)/a.d. metric ton of pulp.

As shown in Fig. 5, NSAQ pulp has a higher burst strength than kraft pulp. McDonough and Paulson (9) have previously reported similar findings for southern pine.

Stiffness

This strength parameter is indicative of the ability of the linerboard component of the corrugated board to withstand edgewise compression. Typically, the ring crush test is used to determine stiffness. As shown in Fig. 6, the NSAQ pulp of higher yield is equal to the kraft pulp of lower yield in stiffness.

Tear strength

NSAQ pulp is known to have a slightly lower tear strength than kraft pulp, and Fig. 7 shows that the higher yield NSAQ does indeed have lower tear strength. This tear strength is not for a linerboard-grade pulp of high quality.

Tensile breaking length

Figure 8 shows that NSAQ pulp has substantially higher tensile strength than kraft pulp. McDonough and others (5-9) have reported similar findings in studies of pulping at higher temperatures with other wood species. Figure 9 shows that the profile for burst vs.

tensile strength is essentially identical for NSAQ and kraft pulps.

Commercial implementation

In view of such favorable test results with the sulfite-anthraquinone approach in general, why has the process not been implemented commercially already in North America? There are still several obstacles in the route to commercial practice.

New mill construction

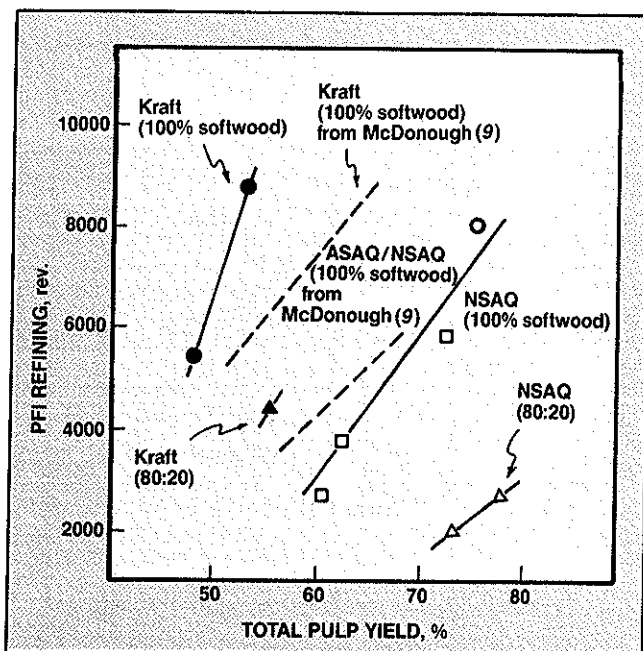
There have been virtually no new linerboard mills constructed in North America during the last five years. Because of the diminishing wood resource base, few new linerboard mills will be constructed over the next five years. Therefore, the sulfite-AQ approach has had no competitive opportunity.

Manufacturing operation

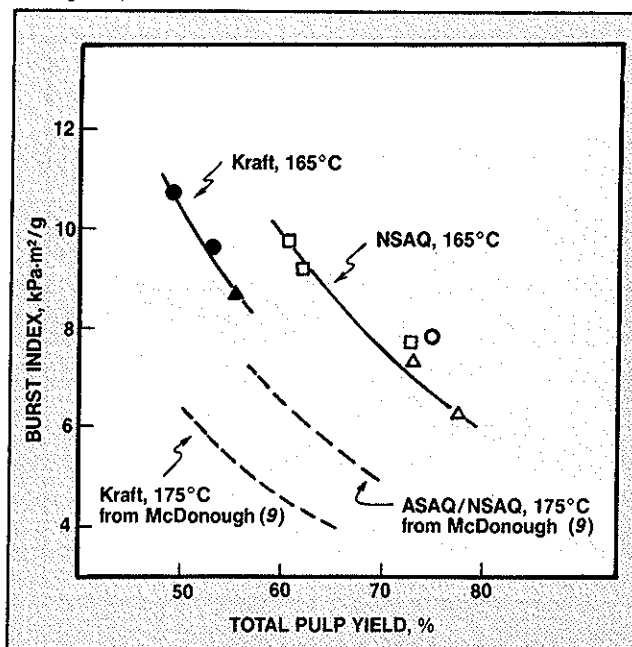
Several commercial trials of linerboard production have been made in Canada and elsewhere (7, 10, 11) during the past few years. For example, CIP Inc. has evaluated sulfite-AQ linerboard pulp through to the manufacture of the corrugated containers (7). The trial was considered to be generally successful.

As expected, some operating problems have been encountered within the pulp mills, as well as in the box plants. The technical problems are not considered insurmountable. For exam-

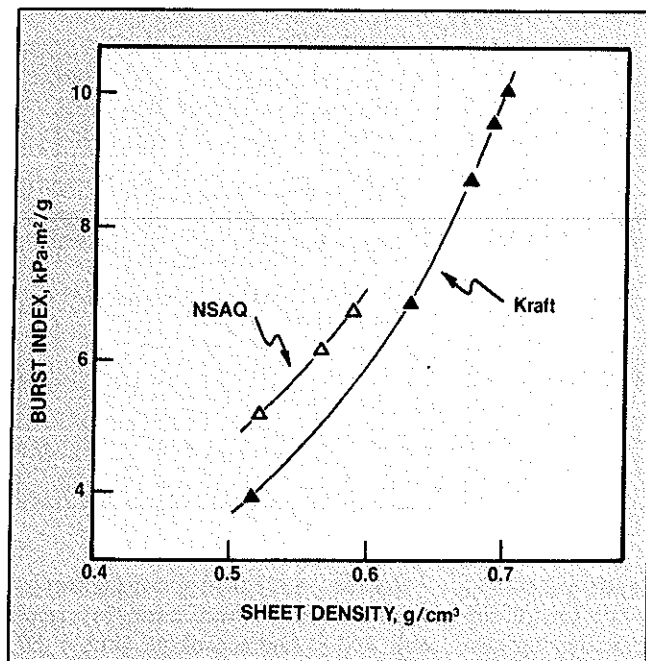
3. PFI refining (to 500 mL CSF) of NSAQ and kraft pulps



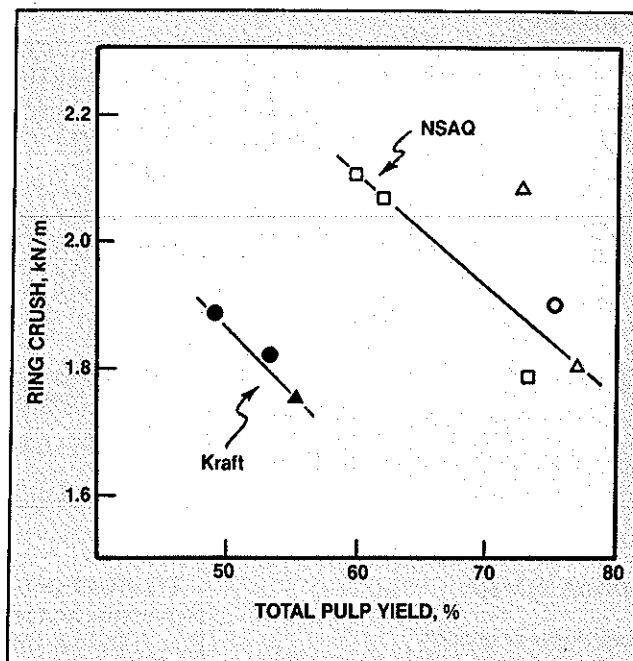
4. Relationship between burst strength and pulp yield (See Fig. 1 for legend.)



5. Burst strength as a function of sheet density (80% softwood and 20% hardwood)



6. Relationship between ring crush strength and pulp yield (See Fig. 1 for legend.)



ple, surface roughness as related to high shive content has been reported in the use of sulfite-AQ pulp for top linerboard (10). Improved refining practice would be used as a means to overcome this problem. In general, because of the "newness" of this type of linerboard, the box manufacturers would have to acquire the necessary operating experience before full-scale commercial practice could be achieved.

Chemical recovery operation

Although a kraft mill can be readily

converted to a sulfite-AQ mill, certain important changes to the chemical recovery system would be required.

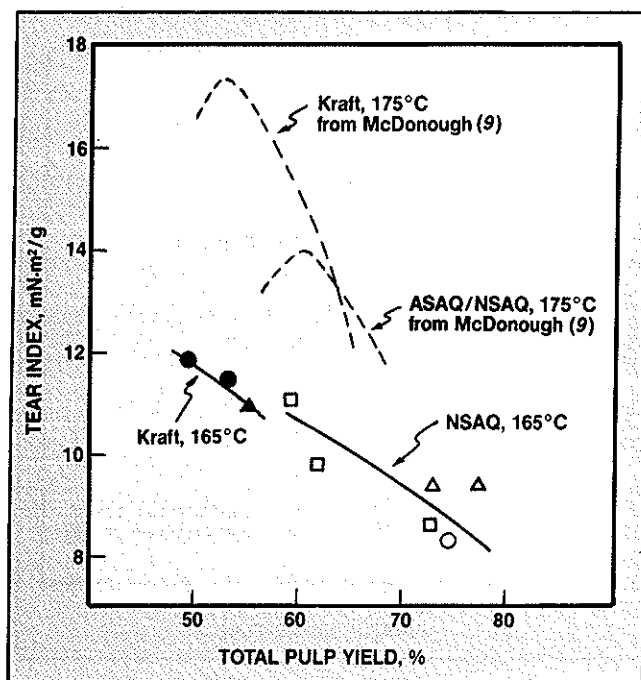
Recovery furnace

The recovery furnace would need to be refurbished with parts of improved metallurgy to accommodate the burning of the sulfite-AQ liquor, which has a higher sulfidity. Contrary to certain industry belief, a sulfite recovery furnace is not necessarily more "dangerous" to operate than a kraft furnace. Sulfite recovery furnaces generally

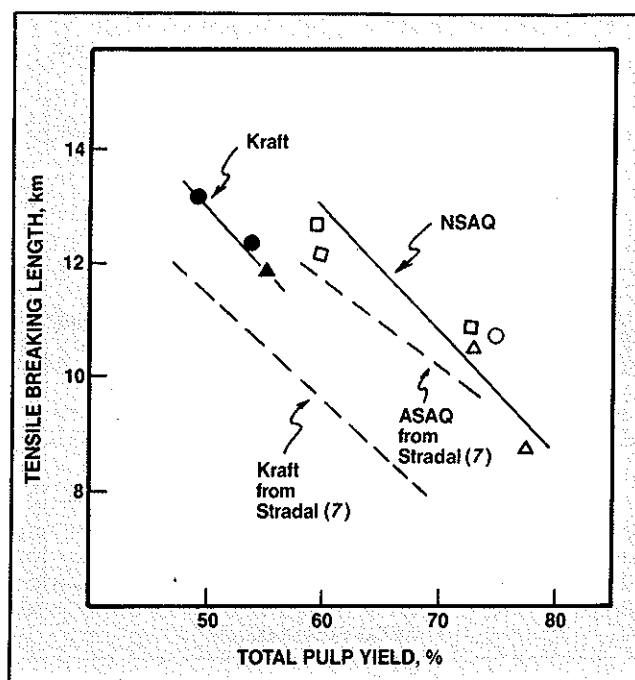
have excellent safety records (13).

The decision makers at a kraft mill could consider this refurbishing of the recovery furnace if (a) a replacement furnace is already planned or (b) a re-tubing work project is already scheduled. Outside of these situations, a kraft mill could consider the "extraordinary" refurbishment of the recovery furnace if the yield advantage of sulfite-AQ pulping should come to warrant it. The long-term benefit of lower wood cost could justify the immediate cost of a refurbished or new

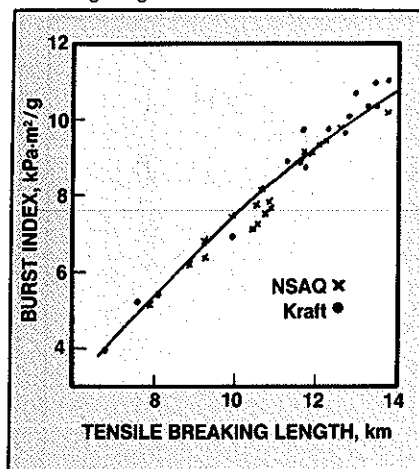
7. Tear strength of NSAQ and kraft pulp (See Fig. 1 for legend.)



8. Tensile strength of NSAQ and kraft pulp (See Fig. 1 for legend.)



9. Relationship between burst strength and breaking length



I. NSAQ pulping conditions

Liquor: wood ratio ^a	4:1
Total Na ₂ O, % on o.d. wood	18.0
Na ₂ SO ₃ , % ^b	15.3
Na ₂ CO ₃ , % ^b	2.7
THAQ addition, % on o.d. wood	0.1
Initial liquor pH	11.0
Presteam, min	10
Time to temp., min	130
Max. temp., °C	165

^aIncluding the moisture in the furnish.^bAs Na₂O on o.d. wood.

II. Kraft pulping conditions

Liquor: wood ratio ^a	4:1
Total Na ₂ O, % on o.d. wood	18.3
NaOH, % ^b	13.7
Na ₂ S, % ^b	4.6
Presteam, min	10
Time to temp., min	85
Max. temp., °C	165

^aIncluding the moisture in the furnish.^bAs Na₂O on o.d. wood.

recovery furnace.

Chemical conversion

With the implementation of sulfite-AQ pulping, a specialized chemical conversion unit is required. Several notable examples of sulfite chemical conversion which have been in operation for many years in North America and offshore are Tampella, Stora, and Ebara systems. Contrary to certain popular beliefs, sulfite chemical conversion units are not unusually "dangerous" to operate. Certainly they are easily operated by ordinary North American workers. In both cases, it is a matter of good safety practice and good operator training.

The benefits of the sulfite chemical conversion unit is the shut-down of the lime kiln and the recausticizing system. A "mild-alkalinity" NSAQ approach would not require a separate recausticization system.

Conclusions

A series of NSAQ and kraft pulping tests has been completed with softwood furnishes and mixtures of softwood and hardwood. The major findings of the study are as follows.

First, high-yield linerboard pulp can be made with the NSAQ pulping process using a wood furnish containing 80% softwood and 20% hardwood.

Second, the typical operating conditions are a maximum temperature of only 165°C and a cooking time of 80 min. The total Na₂O charge is 18.0% on o.d. wood.

Third, NSAQ pulp at 72% has comparable burst strength and ring crush test value as ordinary kraft pulp at 55% yield. The higher pulp yield could provide a wood cost savings of about \$30 (Canadian)/a.d. metric ton of pulp.

Fourth, at any pulp yield, NSAQ pulp requires less refining than kraft pulp to achieve a target freeness.

The technical problems as reported from various mill-scale sulfite-AQ linerboard trials are not considered insurmountable. Some operating experience

would be required in the use of the "new" linerboard in the box plants.

Finally, for kraft mills to convert to sulfite-AQ mills, the chemical recovery system has to be reorganized. The savings in wood cost would likely be the principal reason for rapid commercialization of this technology.

Experimental procedures

Wood furnish

A softwood furnish (75% black spruce, 20% balsam fir, and 5% jack pine) and hardwood chips (100% trembling aspen) were sampled from two sawmills in the Lac St. Jean, Quebec, area. An additional sample of softwood chips was specially prepared from freshly cut black spruce logs grown in the Baie Comeau, Quebec, area. All samples of chips were screened to remove oversized (>30 mm) and thick (>7 mm) materials. The chips from the two hardwood sources were also blended to give a mixture consisting of 80% softwood and 20% hardwood.

Pulping

Pulping experiments were conducted in a two-liter bomb digester for all pulping tests. The general pulping conditions used are given in Tables I and II.

To simulate hot stock refining, free liquor was drained from cooked chips prior to refining in a Sprout-Waldron disc refiner (single pass, at 0.76-mm clearance, using hot water). The final

stock temperature was 80°C at about 3% consistency.

Testing methods

Chemical and physical testing of spent cooking liquor and pulp samples were conducted according to TAPPI methods, CPPA methods, and other established test methods. Standard 60-g/m² handsheets were used in all physical strength tests. The exception was those used for the ring crush test for which 125-g/m² handsheets were used.

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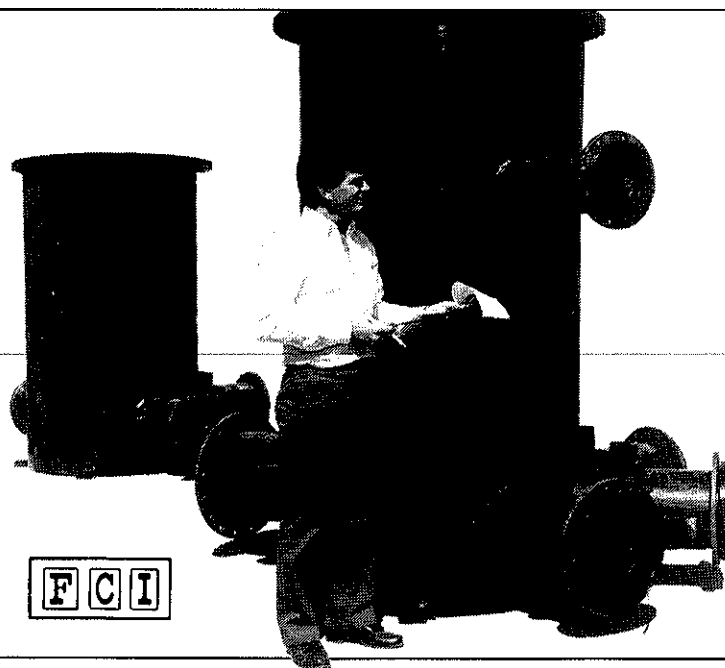
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