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DRY CLEANING OF SUGARCANE - A REVIEW

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Abstract

In the light of increasing public pressure to minimise environmental pollution, green cane harvesting will probably soon become the norm worldwide. The effects of delivering and crushing green cane, which contains all of the associated extraneous matter, on the cost of production and the quality of sugar are well known. In consequence of these effects the different options for dry cleaning the cane are being considered. A description of the dry cleaning hardware that has been reported in the literature is presented as well as a suggested scheme for a dry cleaning plant situated at a sugar factory.

Introduction

The effect of extraneous matter on the cost of production of sugar has been a regular topic of investigation. Its importance is reflected in the large number of papers dealing with the subject (Birkett, 1942; Cargill, 1976; Fogliata *et al.*, 1977; Scott *et al.*, 1978; Lionnet, 1981; Pillay, 1988; and Ivin and Doyle, 1989). The traditional method of reducing the extraneous matter of cane, namely burning, is becoming unacceptable because of the environmental consequences. Dry cleaning is a means of removal of a significant proportion of this material before the cane is shredded, thus avoiding the negative effects it has on sugar processing. Dry cleaning also provides the potential to supply large quantities of energy-rich fibre which can be used directly at a sugar factory for activities such as off-crop refining, the generation of electricity or the manufacture of by-products. An in-depth economic analysis is essential before large scale adoption of dry-cleaning. This paper is an attempt to summarise information on the subject and it will, hopefully, provide a useful starting point for such an analysis.

Extraneous matter in delivered cane

By extraneous matter is understood any material that is delivered to a sugar factory as part of the cane but which does not materially contribute to increasing the amount of sugar produced or has the tendency to lower the purity of the mixed juice. Included in this classification are: cane tops, dry and green leaves, weeds, water, soil, rocks and tramp iron. Some authors have used the word "trash" as a collective term for all extraneous matter. In South Africa trash is synonymous with dry leaves associated with cane stalks. To avoid confusion, extraneous matter will be used as the all inclusive collective term, and individual components will be referred to by their specific names such as tops, leaves, sand etc.

The quantity of extraneous matter as a percentage of clean stalks depends on the cane variety, on the harvesting method and on the weather conditions at harvest. Legendre and Irvine (1973) report that when hand cutting, stripping and loading were practised in Louisiana prior to 1942 the amounts of extraneous matter rarely exceeded 4%. By 1947, when mechanical harvesting had become predominant, the trash levels had nearly doubled. In a South African study using NCo 376 cane (approximately 800 tons in mass) de Beer *et al.* (1989) found that unburnt, untopped cane contained 22,2% tops and leaves whereas burnt, topped cane of the same variety contained only 3,2%. Clayton and Roberts (1971) state that in Florida the trash content of cane just before harvest is approximately 30%. The quantities of sand and rocks in the cane can vary depending on soil conditions, harvesting and loading methods, and weather conditions at harvest.

Cane cleaning methods

The simplest, and probably most effective, method of reducing the unwanted material in delivered cane is burning either before, or soon after, harvesting. This method has been used worldwide for many years. However, the environmental pollution from the smoke and airborne particles is receiving increasing public resistance. Moreover, there is evidence (Lionnet, 1994) that cane that has been burnt will deteriorate far more rapidly than unburnt cane. Smith *et al.* (1984) argue that green cane harvesting may be a more lucrative practice than burning. Experiments showed that 5-7% more recoverable sugar was available in matched samples of green versus burnt cane. The effect of burning on soil fertility, wind erosion susceptibility and accelerated moisture depletion, as well as the destruction of sucrose in the burnt cane plant and the elimination of energy-rich biomass are relevant factors.

In many Brazilian and Louisiana factories cane is washed with water to remove the relatively large quantities of soil that accompany cane after mechanical harvesting. It has been estimated (Clarke, 1991) that 1-2% of the sucrose in the cane is lost as a result of washing. The Biological Oxygen Demand (BOD) load on the environment is 1 kg BOD per ton of cane washed. A mill crushing 300 tons cane per hour requires 1100 m3 fresh water per hour. This method of cleaning is clearly impractical for South Africa.

Dry cleaning options

The term "dry cleaning" refers to the use of mechanical equipment to reduce the extraneous matter in cane by techniques other than burning or washing. There can be little doubt that, if sugar is the main product from cane and if green cane harvesting is the only option, then some form of dry cleaning is highly desirable, if not imperative. The potential benefits of dry cleaning are:

- cost savings in terms of reduced wear and maintenance
- increased factory capacity due to reduced quantities of extraneous matter
- reduced energy consumption for the same amount of sugar produced
- lower losses of sugar in filter cake, bagasse and molasses
- easier factory operation due to lower viscosity of syrups and molasses
- improved sugar quality
- supply of large quantities of biomass that can be used for other industrial operations.

The drawbacks of introducing dry cleaning are:

- additional equipment is required which needs additional capital, labour and maintenance and consumes energy
- a certain percentage of sucrose-rich cane is likely to be wasted
- adequate provision for the disposal or utilisation of the dry cleaning by- and waste products needs to be made.
- a modified system of cane payment would have to be implemented for South African factories.

The options for dry cleaning, in the author's opinion, are:

(a) Where sugar is the main product of the factory and there is no need for additional energy for subsidiary operations then dry-cleaning should be done as close to the point of harvest as possible so as to minimise transport costs. If left in the fields the separated soil, tops and leaves usually have a benefit by diminishing erosion and conserving moisture. Once transported to the mill these components are only a nuisance.

(b) If a sugar factory requires moderate amounts of additional energy this can be supplied by the relatively dry leaves. Lucht (1992) showed that energy equivalent to 1,6 tons coal can be supplied by the leaves of 100 tons cane. In this case it would be advantageous to leave the relatively bulky, moist tops in the fields and to separate the leaves from the stalks prior to crushing. Removal of rocks and soil could be achieved in the same operation.

(c) Where a major by-product operation requires maximum supply of fibre it is advantageous to harvest and transport the whole cane plant to the factory. Bernhardt and Wienese (1994) have shown that all parts of the cane plant yield an acceptable quality fibre for paper pulp production. In order to minimise the adverse effects of trash on sugar production it is recommended that separation of the rocks, soil, tops and leaves still be done prior to crushing. Excess bagasse and the fibre from tops and leaves can be recombined after sugar extraction.

Some experimental and pilot plant dry cleaning equipment

Rock and tramp iron removal devices

McElhoe and Lewis (1974) studied the separation of rocks from cane by altering their trajectories through a stream of high velocity air directed at right angles to the direction of fall. The less dense cane stalks are deflected more by the air stream than the heavier rocks and a splitter plate suitably positioned effects the separation. By making provision for a third compartment the light cane leaves can also be separated from the stalks. A pilot plant that could de-stone 100-140 tons field cane per hour was built. A diagrammatic representation is shown in Figure 1 (adapted from McElhoe and Lewis, 1974). Cane loaded onto a gathering conveyor is combed out by a carding drum from where it falls onto a feed conveyor which launches the cane, rocks and leaves into a falling trajectory. Tests showed that the cross-flow airstream should be directed as close to the top of this trajectory as possible for maximum separation.

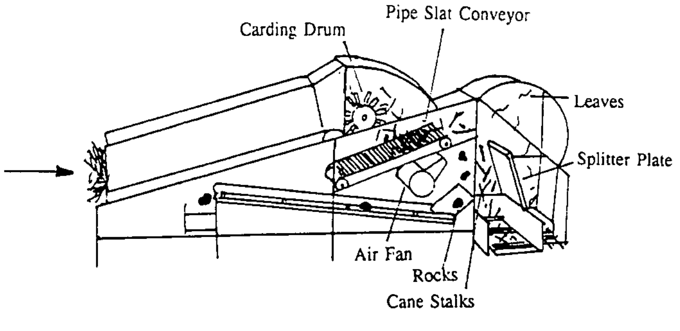

FIGURE 1 Diagrammatic representation of pneumatic rock removal pilot plant.

The pilot plant, which had a height of 10,4 m and a length of 22,8 m, used a conveyor 2,44 m wide. The blowers required 82 kW of power and delivered 26,4 m3/s air with a nozzle outlet velocity of 58 m/s. The nozzle spanned the full width of the conveyor and contained vanes to ensure even airflow throughout its width. The plant removed 96% of the large rocks (13-46 cm) and 98,5% of the smaller rocks. Measured cane losses were 0,55%. The pneumatic separation system also separated 70% of the fibrous trash when unburnt cane was used. Approximately 3% of the incoming cane fell short of the splitter plate but most of this cane was retrieved by a salvager which used an inclined roll with a spiral ridge to divert large rocks and three rotating "pocket" rolls that collected the smaller stones and sand.

A de-stoning system employed before a cane billeter is shown in Figure 2 (adapted from Rivalland, 1988). This system utilises a gap between two adjacent rolls through which stones tend to fall whereas the interlocking cane stalks normally straddle this gap.

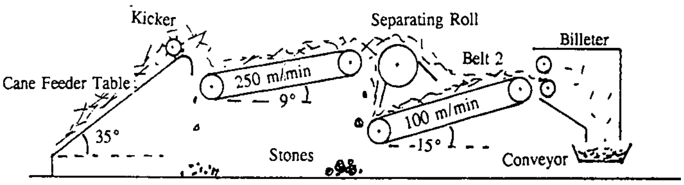

FIGURE 2 Rock removal system utilising gap between adjacent rolls.

Another reportedly effective stone separation system, also described by Rivalland (1988) utilises an inclined plate effecting a reversal of cane flow to separate stones by the higher inertia of the denser stones. This is illustrated in Figure 3.

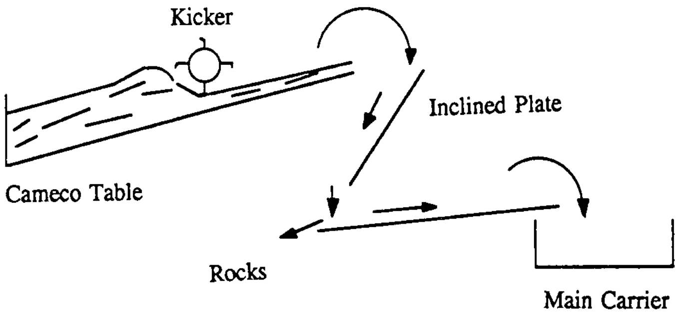

FIGURE 3 Rock removal system using deflector plate to effect reversal of cane flow.

The Cuban dry cleaning plant installed at the Savanna factory in Reunion uses a "kicker" unit instead of a blower to separate rocks and cane, illustrated in Figure 4 (from Rivalland, 1988).

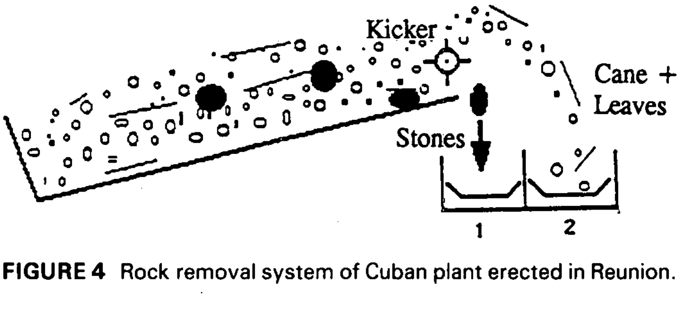

FIGURE 4 Rock removal system of Cuban plant erected in Reunion.

The new Komati mill uses a tyned drum of large diameter positioned near the base of an inclined feeder table to "comb" out rocks from the cane. The cane is carried over the drum by the tynes whereas most of the rocks fall between the tynes without passing over the drum. A diagram of the system, which is adapted from Anon.(1993), is shown in Figure 5.

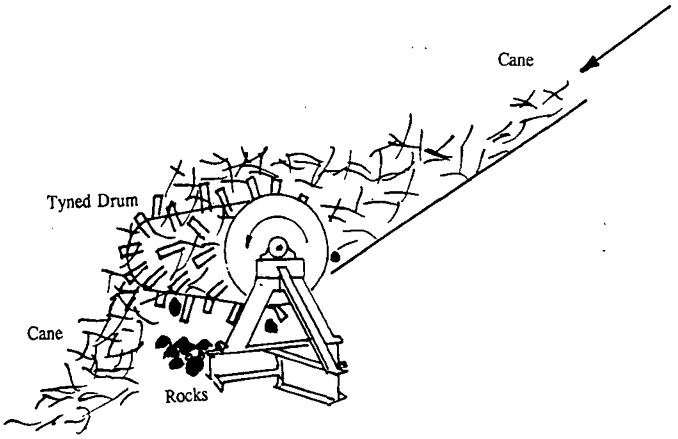

FIGURE 5 Large diameter tyned drum rock removal system installed at Komati mill.

Sand and small stones

The pilot plant described by McElhoe and Lewis (1972) used a feed conveyor consisting of pipe slats mounted on two chains which ran over sets of rubber tyres. A 16 mm gap between the pipes was very effective in allowing a large proportion of the sand and small pebbles to be separated from the cane before the pneumatic rock removal blowers. Figure 6 (from McElhoe and Lewis, 1972) shows the construction of the pipe slat conveyor.

At Sezela sugar factory, where bagasse is used for furfural production, sand is removed by tumbling the bagasse in perforated drums.

In Taiwan (Thompson, 1992), where green cane is harvested mechanically and delivered to the factory as billeted cane, removal of sand is effected at the sugar factory before the main cane carrier by using a grid of longitudinal 40 mm round steel bars inclined at 40° to the horizontal. A double grid system removes approximately 30% of the sand and leaves. Another system uses a rotating drum, inclined at 23°, whose walls are constructed of 6 mm stainless steel round bars separated by a 12 mm clearance and running parallel to the axis of rotation. Removal of about 35% of the extraneous matter by the rotating drum has been measured. A system of intermeshing, rotating stainless steel discs (16 mm thick) of round or square shape and 440 mm diameter, separated by 26 mm gaps, is also used to convey cane from the off-loading conveyor to the main carrier at a decline of 20°. The speed of rotation is 35 rpm. This is reported to remove 40% of the extraneous matter.

Sand will also be removed by the pneumatic system of McElhoe and Lewis (1972) and through the action of cleaning rolls and stripping fingers described below.

Tops and leaves

A variety of mechanisms has been investigated for the removal of tops and leaves. Loose leaves can be removed pneumatically using high velocity air. Pneumatic separation efficiency depends on the quantity and velocity of the air used. Chopping cane into smaller sections enhances the trash removal efficiency. Cochran and Clayton (1968) found that an overall trash removal of 77% was achieved when the length of the chopped pieces was 150 mm while for 380 mm pieces the removal efficiency was 73% and for 600 mm pieces only 59%. An air velocity of 25 m/s blown through 150 mm long cane pieces was sufficient to remove 98% of the loose leaf trash. Pneumatic separation is, of course, ineffective on green immature stalk because its density is close to that of mature stalk. Thus tops which have had most of their leaves removed as a result of billeting cannot be separated by pneumatic means. The amount of leaf trash can vary significantly for different cane varieties, or different cultivation conditions such as weather, soil, irrigation or natural rainfall.

Most mechanical harvesters have an adjustable "average" topper which will cut off and separate the immature tops at a preset height. If these toppers are set to minimise the loss

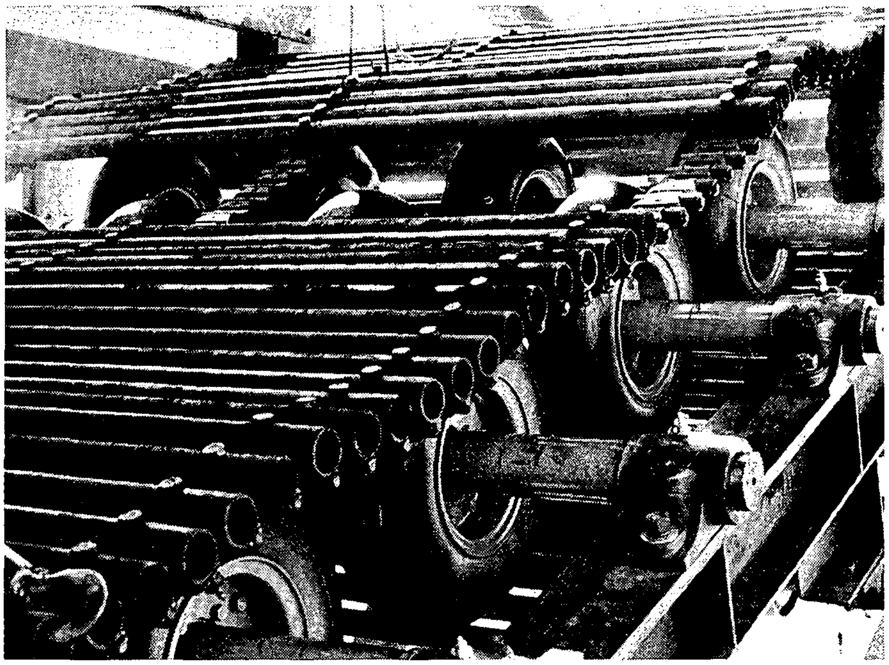

FIGURE 6 Pipe slat conveyor system used to remove sand and small stones.

of mature stalks then a certain proportion of cane will still have sections of tops. A device that can remove these is called a selective topper. Most selective toppers engage the leaves associated with the top. This results in the remainder of the stalk being pulled into the topping device. The structural weakness at the junction of the mature and immature portions of the cane stalk causes the top to snap off from the rigid cane. Corn husking rolls which consist of one spirally fluted steel roll running on a rubber roll have been tried (Cochran and Clayton, 1968). They were effective in breaking off the immature tops from mature cane stalks, but a cane loss of 4% was measured. The rolls were also effective in detaching and separating most of the dry leaves.

Other roll types that were investigated for trash removal and selective topping included pairs of steel rolls of which one had a spiral band and the other was a plain roll. The most effective clearance between the spiral band and the mating flat surface was 0-1 mm. A spiral band height of 6 mm was found to be more effective than one 2,5 mm high (Ramp, 1965). Hydraulic drives made rapid reversal of rotation possible when excessive amounts of trash had wrapped around the rolls.

An improvement on spiral rolls were pairs of hexagonal or square rolls. One roll in each pair was driven by an hydraulic drive while the other roll was geared to the first roll in such a way that a ridge from the one roll always coincided with a flat portion on the other, as shown in Figure 7 (from Cochran and Clayton, 1968). Clearances of 0-1,3 mm were recommended.

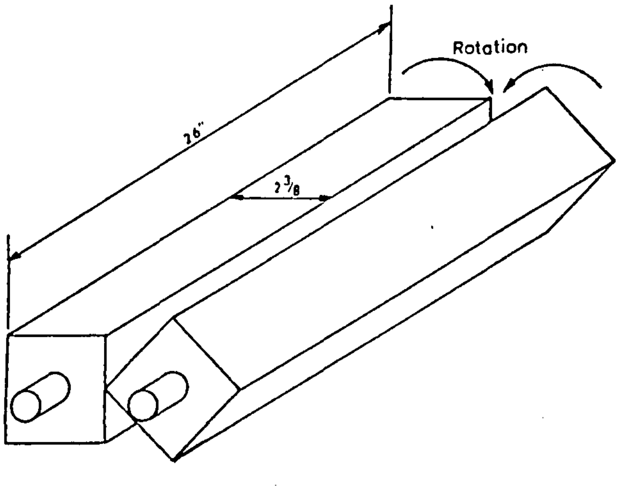

FIGURE 7 Relative position of the two square rolls used for selective topping and leaf detrashing.

Rolls with machined edges tended to perform better than those made from stock material. Typical cross-sectional dimensions that were found effective were 60 mm sides for the square rolls and 125 mm between parallel sides for hexagonal rolls. The most effective rotational speed was 400-700 rpm (Cochran and Clayton, 1968). At these speeds no wrapping of leaf trash round the rolls occurred. The rolls appeared to be slightly more effective when the direction of cane feed was parallel to the axes of the rolls. Square rolls were found to perform slightly better than the hexagonal rolls and an overall removal of 78% of the trash was measured when chopped cane was cleaned. The polygon shape of the rolls produces a kicking and tumbling action which enhances contact of trash with the rolls. The loss of mature cane in these tests was reported as negligible.

When hexagonal rolls were used to clean whole cane Roberts (1972) measured an average trash removal of 50% and a cane loss of 1%. Special arrangements had to be made to the feeder chain to ensure that the mat of cane was no more than three stalks thick so that adequate contact of the cane with the cleaning rolls was obtained. Three staggered sets of rolls were required to achieve the above mentioned degree of cleaning. The power consumption for cleaning roll systems is higher than for pneumatic systems.

Extensive experimentation was conducted on ways of stripping leaves from cane at harvesting. Rotating cylinders with different types of stripping fingers were tried. The fingers were made from spring steel, steel, chain, wire rope, rubber, teflon and fibre reinforced rubber (Ramp, 1965). Rigid elements tended to break easily, while others like wire rope and rubber suffered excessive wear. The most successful appeared to be pieces of rubber hose mounted on two pairs of cylinders. Nevertheless, feeding and conveying the cane through the stripping device was not entirely successful. The rapid wear rate and need for frequent replacement of the fingers make this method of cleaning uneconomical. Clayton and Roberts (1971) also stated that stripping fingers worked satisfactorily only for straight cane and they did not remove green trash.

Another method tried for detrashing cane used a series of rubber belts with grooves cut perpendicular to the longitudinal axis along the outer surface, as shown in Figure 8 (from Cochran and Clayton, 1968). The grooves open as the belt moves over the pulley and close as the belt travels between pulleys. As a result of this action loose leaves are picked up and separated from the cane.

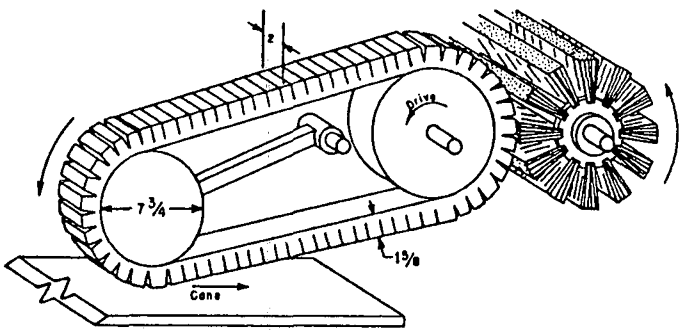

FIGURE 8 Rubber belt with transverse grooves used to remove loose leaf trash.

An overall trash removal rate of 30-40% was achieved using a set of eight such belts on chopped cane pieces 400 mm in length. The main problem with such a system is achieving adequate contact between the belt surface and cane at normal industrial conveying rates.

Suggested dry cleaning station for a sugar factory

The objective for practising dry cleaning of cane is to achieve maximum separation of extraneous matter at the minimum overall cost and with the minimum impact on the environment. Although full dry cleaning in the field would more easily satisfy the environmental impact and minimum transport cost constraints, the capital, maintenance and labour costs associated with multiple cleaning stations to serve the supply area of one sugar factory would probably make this a far more costly operation than the establishment of a single dry cleaning plant at the sugar factory. The following dry cleaning scheme is therefore proposed, as shown schematically in Figure 9.

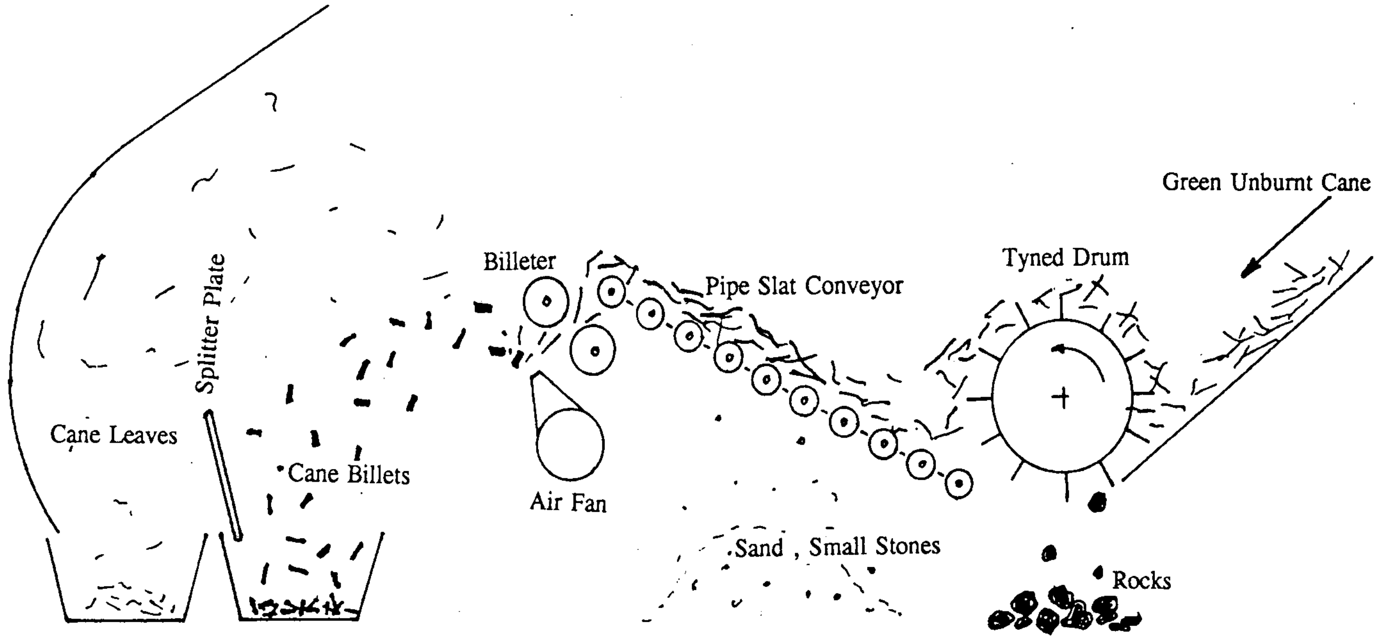

FIGURE 9 Schematic representation of proposed dry cleaning system at a sugar factory.

In order to effect significant transport savings it is suggested that average topping be practiced at harvest and that the tops be left in the field for soil and moisture conservation. According to de Beer *et al.* (1989) a 34% improvement in payload can be achieved by leaving the tops in the field in comparison to transporting the whole stalks. At the factory the main dry cleaning operations proposed are rock and tramp iron removal, sand and small stone removal, cane billeting and, finally, pneumatic separation of leaf trash from the billets. The rock removal system recommended is that used at the Komati mill because of its simplicity, robustness and relatively low energy consumption. Rock and sand removal in the field is impractical because many rocks and a significant percentage of the sand are picked up during cane loading or transloading.

For sand and small stone removal the pipe slat conveyor used by McElhoe and Lewis (1972) is suggested. A billet length of 400 mm (rather than 150 mm) is recommended for the sake of reduced wear on billeter knives and lower sucrose losses because of fewer cuts per stalk. The cleaning efficiency of 77% for 150 mm billet lengths is not significantly better than the 73% measured for 380 mm billets. It is suggested that the final pneumatic leaf trash separation step will yield sufficiently clean cane. The use of selective topping rolls, which can also remove additional leaf trash adhering to some of the billets, is not worth the extra expense in view of the stringent feeding conditions required and the rather high energy consumption, except in cases where additional fibre would be highly desirable for operations such as by-product manufacture. Provision has to be made, of course, for the acceptable disposal of the large quantities of leaf trash. It would be ideal if this trash could be used to generate saleable electricity.

Conclusions

In view of the fact that cane burning as a means of eliminating a large proportion of extraneous matter is rapidly becoming an unacceptable practice for environmental reasons, and that cane washing has similar drawbacks, a thorough investigation of dry cleaning as a viable alternative is advocated. This investigation will recognise that significant quantities of extraneous matter will have a profound effect on most items of sugar factory equipment, processing characteristics and the quality and yield of sugar. The potential economic benefits of having a ready supply of large quantities of energy-rich fibre at a point source with an industrial infrastructure will be relevant. It is hoped that the information presented will be useful in carrying out such an analysis.

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