# Effective measures for preventing auto combustion in bagasse stacks

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**ABSTRACT**

Shortage of forest based fibrous raw materials and the availability of sugar cane bagasse in substantial quantity at one source - sugar mill - have made bagasse the most viable alternate source for pulp and paper making. Utilisation of bagasse for paper making is known even 150 years ago. The low bulk density of bagasse makes it necessary to store it in baled/pile form. Despite the substantial technical developments, one of the main reasons for failure of many mills based on bagasse is the lack of satisfactory method for preserving during non-crushing season, which results in huge losses due to deterioration and hazards of the fire during storage. When stored for prolonged periods, bagasse deteriorates due to the action of micro organisms. The residual sugar content of bagasse, vast surface exposed to atmosphere, humidity, and ambient temperature facilitate growth and multiplication of micro organisms. Various biochemical reactions which take place during storage are highly exothermic and increase the temperature of stack in course of time, leading to fire hazards A case study of techniques developed at Seshasayee Paper and Boards Limited to measure and monitor the temperature rise in bagasse stacks is presented in this article. Modifications and improvements carried out based on our experience to avoid auto combustion, when higher temperatures are registered, are explained. Suggestions for further improvements in this direction are also included

## INTRODUCTION

Dwindling forest resources has casued acute shortage of conventional raw materials for pulp and paper making. Bagasse, a residue left over after extraction of juice from sugar cane (Sacharrum officinarum) is a highly potential, renewable raw material resource for this industry. It has the advantage of being readily available at central places, namely sugar mills, which are easily accessible. Further, the development of tech nology for making different grades of pulps and a number of varieties of paper from this raw material as well as incentives being given by Government of India by way of central exise relief have given an impetus for using bagasse for pulp and paper making extensively.

The Production of bagasse, which constitutes almost thirty percent of the cane crushed, is seasonal stretching over a period of seven to eight month, depending upon the availability of sugar cane, whereas the pulp and paper industry is engaged in production operations throughout the year. Therefore, it is imperative to store bagasse and make it available to the pulp and paper industry, during off season. In view of the bulky nature of this material, it has become necessary to transform it in to consolidated bales for economy in transportation and conserving the storage area.

The bagasse bales, transported from the Sugar mill, before and after depithing, are stacked in the paper mill premises to a reasonable height of eight to ten meters with an easy access for stacking and destac-

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king as per the requirements. The storing of bagasse brings in a host of problems with respect to degradation in the physical strength, blackening of the surface and spontaneous combustion.

The article presented here deals with various exothermic biochemical reactions which result in auto combustion and the effective measures taken by Seshasayee Paper and Board Limited to avoid the fire accidents.

## METHODS OF STORING BAGASSE

The following methods of storing bagasse are being practised in various countries as on date.

2.1 I Bale storage methods

- 2.1.1 Celotex method
- 2.1.2 Thibodaux method
- 2.1.3 The Taiwan method
- 2.1.4 Large bale storage method

2.2 II Wet bulk storage methods

- 2.2.1. The Ritter process
- 2 2.2 The International Paper Co Process
- 2.2.3 Cusi process

2.3 III Moist bulk storage

- 2.3.1 Valentine method

2.4 IV Moist bulk storage after compaction

2.5 V Dry storage methods

- 2.5.1 The Tablopan method—Venezuela
- 2.5 2 The standard building products method-Jamaica

Normally, in moist bulk and wet bulk storage methods the possibility of fire accidents does not exist due to circulation of liquids and keeping the temperature low. Therefore, Scope of this article is restricted to baled bagasse storage and prevention of fire accidents. A brief description of bale storage methods is given below.

### Bale storage methods :

### Celotex method

The procedure involves baling of bagasse with 50percent moisture to optimum size and stacking it in a definite optimum pattern. Outside of the stack is treated with boric acid and covered with ashphalt-coated sheet metal. The bagasse is allowed dry at a controlled rate to prevent over heating and excessive build up of acetic acid produced by fermentation.

### Thibodaux method

In this method, a complete mechanical handling system is used for stacking bagasse bales. Most of this system is automated. In addition to saving labour costs, the mechanical handling has resulted in lower losses and better stacking in the field.

### The Taiwan method

Taiwan sugar corporation and the Taiwan Pulp and Paper Corporation developed a method for baling, handling and storage of bagasses. In this method, small bales of 25 kg to 30 kg at 40 to 45 per cent moisture are made. These are stacked efficiently using a bucket type stacker. Although this method requires a tremendous amount of labour, it is not expensive in areas where labour costs are low.

### Large bale storage method

In order to reduce handling and transportation costs to a minimum, bagasse is moist depithed at the sugar mills and compressed into very large bales, weighing 800 kg (400 kg moisture free basis). These are mechanically loaded on trailers and transported to the pulp mill. This method of baling and handling results in very low handling and transportation costs for the distances involved.

## DETERIORATION OF BAGASSE DURING STORAGE

The loss due to deterioration of dry bagasse in storage is high. Bagasse is bio - degradable. After sugar extraction , the residual sugar in bagasse is responsible for microbial growth. The population of fungal, bacterial and actinomycete spores increases. The conditions of bagasse are favourable for the moulds, yeasts and bacteria to multiply and distribute uniformly throughout the mass of material. The residual sugars and other soluble nutrients and moisture (nearly 50 per cent), the openness of its structure, its high exposed surface, the warm climate and other factors allow a very fast growth of microbial life. Thus, it serves as a most fertile substram for the proliferation of fungi bacteria and other micro organisms.

## BIOCHEMICAL REACTIONS

The chemical reactions involved in bagasse storage and the corresponding heat generation are given in Table 1. The molecular weight and heats of combustions of the

TABLE. 1.

CHEMICAL REACTIONS AND HEAT GENERATION

| | Reaction | HEAT GENERATION CAL / GR MOL OF SUCROSE |
|---|---|---|
| 1. | $C_{12}H_{22}O_{11}$ + $H_2O$ → $2(C_6H_{12}O_6)$ + <br>SUCROSE GLUCOSE & FRUCTOSE | 8.32 |
| 2. | $2(C_6H_{12}O_6)$ → $4(C_2H_5OH)$ + $4CO_2$ + <br>GLUCOSE & FRUCTOSE ETHANOL | 33.16 |
| 3. | $C_{12}H_{22}O_{11}$ + $12O_2$ → $12(CO_2)$ + $11(H_2O)$ + <br>SUCROSE | 1348.2 |
| 4. | $2(C_6H_{12}O_6)$ + $6O_2$ → $6CO_2$ + $6H_2O$ + <br>GLUCOSE & FRUCTOSE | 1339.88 |
| 5. | $2(C_6H_{12}O_6)$ → $4(CH_3CH(OH)COOH)$ + <br>GLUCOSE &, FRUCTOSE LACTIC ACID | 32.68 |
| 6. | $4(C_2H_5OH)$ + $4O_2$ → $4(CH_3COOH)$ + $4H_2O$ + <br>ETHANOL ACETIC ACID | 470.64 |

TABLE 2.

MOLECULAR WEIGHTS AND HEAT OF COMBUSTION OF PRODUCTS

| COMPOUND | FORMULA | MOLECULAR WEIGHT | HEAT OF COMBUSTION CAL / GR MOL | K CAL / KG |
|---|---|---|---|---|
| SUCROSE | $C_{12}H_{22}O_{11}$ | 342.3 | 1348.2 | 3939 |
| GLUCOSE & FRUCTOSE | $C_6H_{12}O_6$ | 180.16 | 669.94 | 3719 |
| ETHANOL | $C_2H_5OH$ | 46.07 | 326.68 | 70.91 |
| ACETIC ACID | $CH_3COOH$ | 60.05 | 209.02 | 3481 |
| LACTIC ACID | $CH_3CH(OH)COOH$ | 90.08 | 326.8 | 3628 |
| PURE CELLULOSE | $(C_6H_{10}O_5)$ N | | | 4600 |

products are given in Table 2. All the reactions given in Table 1, take place at once. The rate of each reaction is influenced by various factors.

Some micro organisms hydrolize sucrose to six membered sugars (Glucose and Fructose) as per reaction 1.

The same organism oxidises and splits the invert sugars (glucose and fructose) already present in the fresh baggasse into alcohol and carbondioxide and contribute most to the initial acceleration of the proliferation of micro organisms. This also contributes to generation of heat (reaction 2).

In each of the reactions given in Table 1, only a fraction of the energy liberated is utilised for the propogation of micro organisms life, such as biosynthesis and assimilation, while major part appears in the form of heat.

The increase of temperature inhibits the growth of saccharomyces. Other types of organisms start developing in favourable conditions, for example, lactgobacilli may proliferate at a temperature of about 50 degree centigrade and produce lactic acid (reaction 5). However, unless the environment is at a low pH, other harmful thermophilic organisms may also develop.

In the presence of atmospheric oxygen, the dissimilation processes are accelerated more heat is released. These processes may oxidize completely glucose and fructose to $CO_2$, rather than to ethanol and $CO_2$ (reaction 4).

In general, the predominant biochemical reactions are the splitting of sugars into ethanol and $CO_2$ and in the presence of atmospheric oxygen, some degree of oxidation of sugars to $H_2O$ and $CO_2$ and of ethanol to acetic acid (reaction 6).

If the temperature does not exceed 26 degree centigrade and if oxygen is available the processes become increasingly oxidative as the availablity of sugar decreases.

If the temperature is allowed to increase, other microbial strains develop and various side reactions start taking place, involving not only soluble sugar, but also some of the polysaccharides that are the constituents of fibre. For optimum conservation of the cellulosic content of bagasse, it is necessary that the biochemical reactions are selective in the sense that only soluble organic matter is involved.

## TEMPERATURE DEVELOPMENT IN BAGASSE

A typical temperature curve of stored bagasse is shown in Figure 1. According to this, the temperature increases from 30 degree centigrade during one day to a first maximum of 48 degree centigrade. The temperature time profile for a bagasse pile of industrial dimensions is shown in Figure 2. The figure shows two distinct temperature periods, the first lasting approximately eight days at the beginning of which the temperature steadily increases from ambient to a maximum of about 40 degree centigrade and the second temperature period in which the temperature increases to a new maximum of 60 degree centigrade remaining at the level for a few days and then slowly decreasing. The temperature time profile depends upon the size of the pile, ambient temperature, wind conditions, sugar and nutrient content of bagasse.

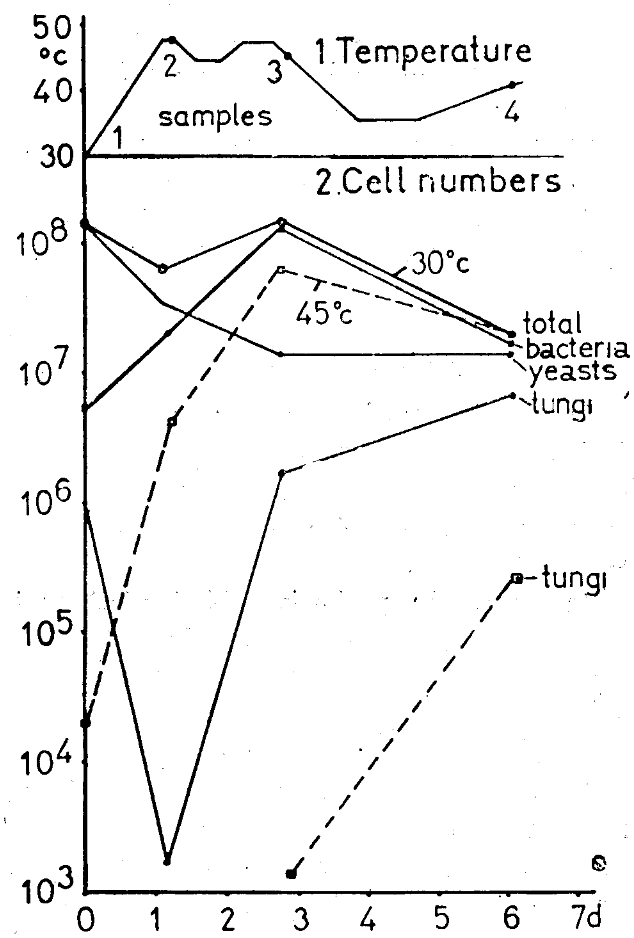



FIG.1. TEMPERATURE CURVE AND CELL NUMBERS

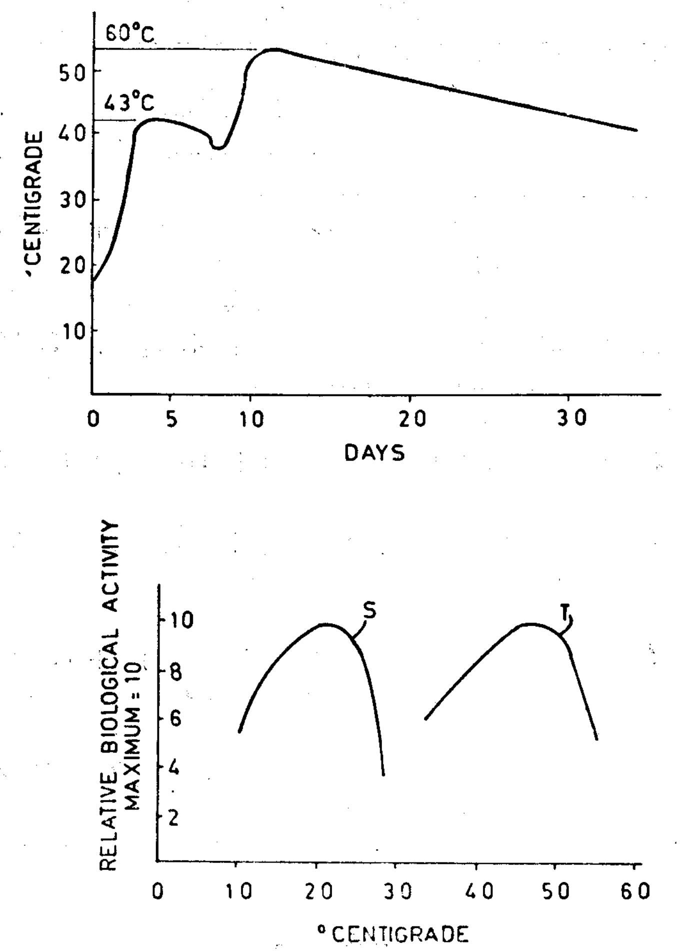



FIG.2. TEMPARATURE AND TIME PROFILE OF BAGASSE PILE

## LOSSES DURING STACKING

Inspite of dense consolidation, some of the bagasse bales, while loading and unloading in to the trailers and trucks to transport the materials from sugar mill to the paper mill, crumble and generate loose bagasse.

When loading, unloading and stacking is done manually, this loss can be kept under control only by strict supervision on the methods of handling. The loose bagasse generated while stacking also contributes to the problem of filling the air gaps, which are deliberately kept for good ventilation to kept the temperature inside the stack low. While building stacks, a clear pattern is maintained as per the various methods developed scientifically. Seshasayee Paper and Boards started stacking bagasse from the adjacent sugar mill from the season of 1984-85. In the initial period, the stacks were made in the size of 600 to 800 tonnes of BD bagasse and to a height of 12 to 15 metres.

## FIRE ACCIDENTS AND CONTROL MEASURE

First fire accident took place in March 1987 in a stack consisting of approximately 650 tonnes of BD bagasse. The cause for the fire accident could not be immediately established as the source of fire could have been external. Within a close proximity of one and a half months, another fire accident took place involving two bagasse stacks.

The second fire accident has led to modification in spacing the stacks, by maintaining some minimum safe distance between the stacks to avoid spreading of the fire at the time of fire accident.

The loose bagasse spilled in between the stacks was found to be working as fire propagating media from one stack to the other. Strict measures were taken to keep the area between stacks free from loose material to reduce the loss in case of an accident.

The bagasse storage yard was well equipped with fire hydrants to enable effective fire fighting with minimum loss of time.

During these accidents, it was observed that the air gaps kept for ventilation were working as access channels for the air for combustion of the interiors of the bagasse stacks. Dismantling of some portions of stacks which had not caught fire, use of high pressure water for extinguishing the fire, etc. proved effective to contain the fire and prevent spreading. Front end loaders were found to be of considerable help in such situations to deal with loose bagasse and to create the gaps for arresting the fire.

It was observed that simmering heat and hence smoke were internally present in the stacks, for nearly two to three days after extinguishing fire and continuous quenching with water. This requires a greater vigil in the areas to avoid recurrence and re-eruption of fire.

## PREVENTIVE MEASURES

In view of these two accidents, intensive exercises were made to come up with a viable method of protecting the stacks without catching fire because of spontaneous combustion. An innovative idea which has occured is to measure the development of temperature at the centre of the stack using a sensing probe with a portable thermometer. The specifications of the probes fixed are given in table 3. This temperature measurement was initially started two times in a day and extended to six times a day.

It was easy to lay the probes in the stacks that were being built as the probe could be placed at a hight of one meter while building the stack. In the case of existing stacks, a different technique had to be used for inserting the probes of. GI pipes of 1 to 1 1/2" dia were hammered to reach the central portion and the temperature probe was pushed through the GI pipes without disturbing the stack structure. The measured temperatures were in the range of 45 to 60 degree centigrade, depending upon the various reasons explained in Para 5.0.

### TABLE 3 SPECIFICATION OF PROBE

| | |
|---|---|
| ELEMENT | : Pt 100 Ohms at O Degree C |
| STANDARD | : DIN 43760 |
| NO. OF ELEMENTS | : SIMPLEX |
| INSERT SHEATH | : SS 9.5 MM ID x 100 MM Lg |
| EXTENSION LEAD | : 3 Core PVC insulated 10 Mtrs long |
| END CONNECTION | : Special threaded type adaptor |

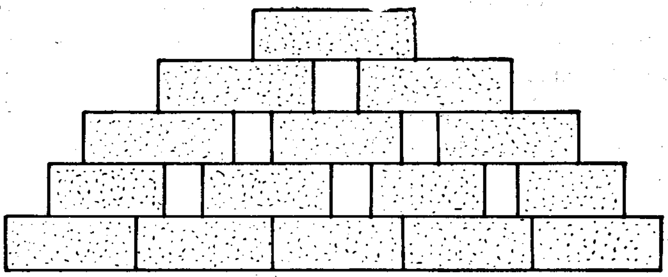


FIG. 3. BAGASSE STACK.

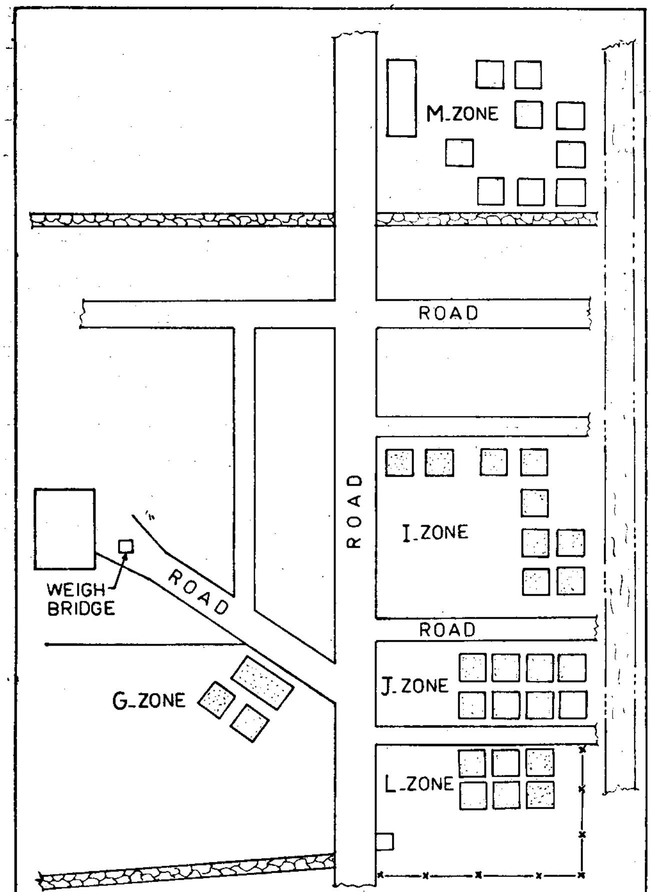



FIG.4. BAGASSE YARD LAYOUT

During subsequent monitoring, the temperature in some stacks registered 100 degree centigrade. In such cases immediate action was taken to quench with water or destack the material for supply to the pulp mill. This technique had worked effectively.

Wetting of bagasse stacks that show the tendency for an increase in temperature is being practised. This wetting of the stacks not only brings down the temperature but also increases the bagasse in summer season. This has the disadvantage of blackening the top surface of bagasse stacks which is not desirable for making bleached pulps. For periodical wetting of stacks in summer months, to keep the temperatures under control, sprinklers and fire hoses were used.

## IMPROVEMENTS IN THE SYSTEM

The Placement of temperature measurement probes inside the GI pipe line required modification and improvement to avoid pilferage in the yard. The design of the Probes after modification are shown in Figure 5.

It has been observed that some of the probes as well as pipes got damaged during the destacking operation requiring replacement.

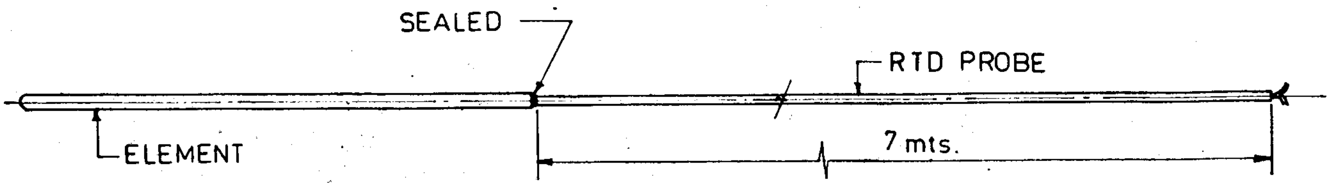
Heavy corrosion was observed on the GI pipes due to the acidic conditions prevailing in the stacks. An alternative and economical meterial of construction is being experimented for serving the purpose of this cover pipe for temperature probes.

### Reducing the size of the stacks

Reduction of size of stacks has brought down the formation and generation of loose bagasse as the hight could be kept within the easily accessible range. Initially, these stacks were tried with 250 BD tonnes material from October 88. In various trials carried out, 150 tonnes of BD bagasse per stack was found to be optimum. From February 1989, stacks were built with a quantity of 150 BD tonnes material per stack. This has also given a scope fore better ventilation and and reduction in temperature which will help in avoiding auto ignition.

### Experimental stacking 1

In continued efforts to improve the system, an experimental stack was made with a BD weight of 60 tonnes without air gaps to monitor the temperatures. Probes were inserted from all the four sides of the stack. This was with an intention of cutting out the air to avoid spontaneous combustion which was otherwise available through the ventilation ports. The temperatures inside the stack varied widely and no definite conclusion could be drawn for safe storage. Hence, the practice of stacking with proper air gaps for ventilation is continued.




RTD PROBE.

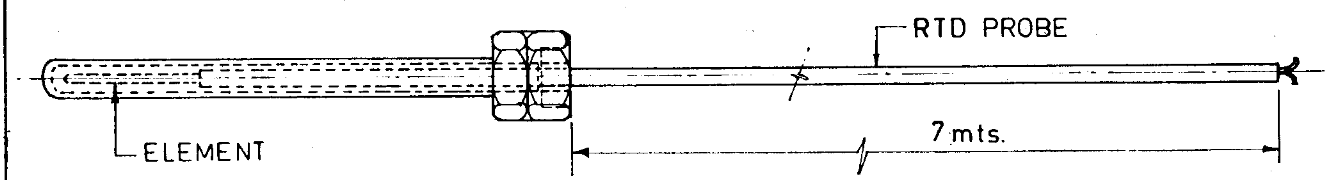



FIG.5. RTD PROBE (MODIFIED).

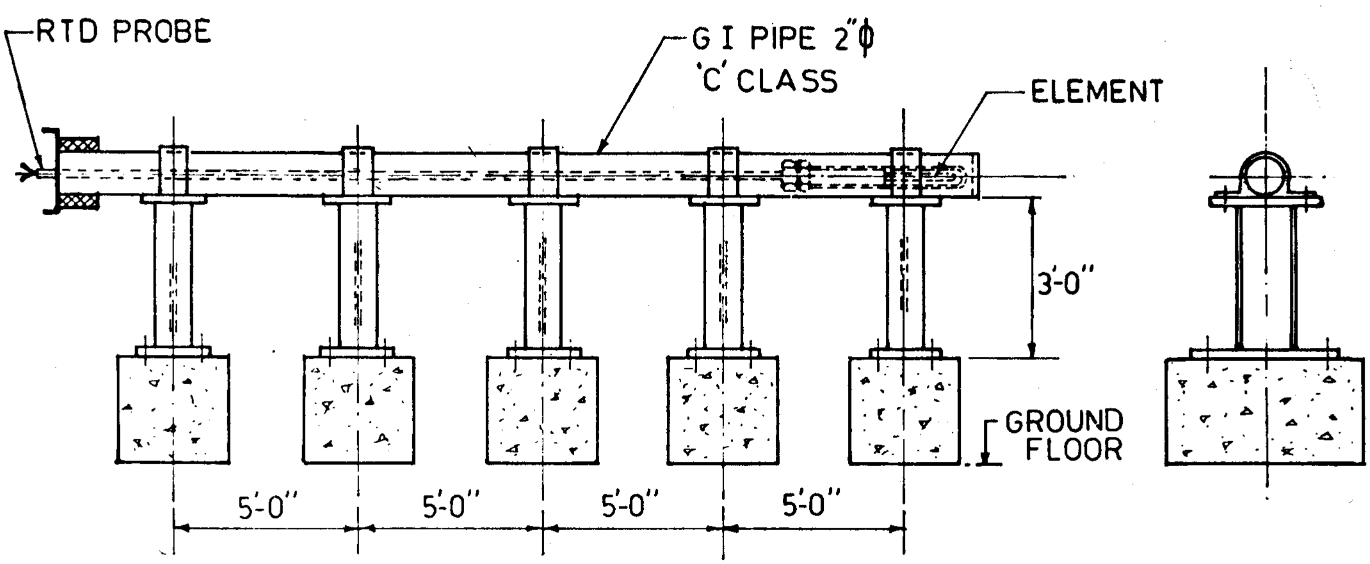



FIG.6. PERMANENT STRUCTURE FOR FIXING RTD PROBE IN BAGASSE STACKS.

Experimental stacking 2

To minimise the handling of the probes for insertion and removal while building and dismantling the bagasse stacks, an experiment is carried out to mount it on a small concrete pedestal with a cover pipe made of non-corrosive material and laying the probe permanently inside the pipe as per the details shown in Figure 6. The stack is built around the available probe. Though this method of fixing the permanent structure restricts the flexibility of building stacks at any site in the yard, this saves on the expense of replacment and repairing of probes and pipes, as well as facilitates temperature measurement at fixed places. If success is achieved, this also gives scope for automation of temperature monitoring by having a display at a centralised location, namely, control station. It is also proposed to have an alarm system for any rise in the temperature far beyond the normal levels to take measures to avoid auto combustion.

## CONCLUSION

The technique of using temperature probes for measuring and monitoring temperatures of stacks is a dependable system to predict and avoid auto combustion The control and fire preventive methods are quite effective. There is further scope for automation in this direction.

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