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Exploring Ways to Enhance Fire Safety in Paper Mills by Innovative Strategies

Abstract:

Any paper professional would agree that most of the paper mills have made good arrangements for fire safety in their plants. Mills are not only following the rules and regulations but are making their efforts to keep the mill environment safe. This is obvious, considering the fire accidents we hear about almost twice or thrice a year.

As discussed with many mill owners, whenever they hear about any such accident, the first action is to review own safety arrangements to pinpoint and highlight any weak point, so that suitable arrangements may be made in time. Still, accidents do take place.

This paper discusses the possible actions which may be considered to further safeguard our mills.

Keywords: *Paper Mill, Fire, Safety, Hazard, Accident, Wastepaper*

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Introduction

Have you ever reviewed fire safety arrangements in your facility as an independent professional? Well, experts' audit is something different, and you must have got it done already, and implemented all the recommendations and suggestions. Now, you also must do it yourself.

First, have a round in your plant; go back you your office and grab a sheet of paper. Note down the value of inventory of goods (raw material, intermediate products, finished paper, boiler fuel etc. as well as the plant and machinery), which might be at risk. To secure this, you have already installed safety arrangements, which are being inspected by your concerned team members as per protocols. Now think about a fair amount of additional money (hypothetically) you'd like to invest to make arrangements a little stronger- you may want to have more extinguishers, more hydrant valves, branch pipes, monitors or have a separate godown for some of the items. Well, this time, the decision is totally yours- as for the external auditors everything was in line.

Being the owner, director, CEO or general manager, please do this exercise in your plant independently; and if you can identify some more possibilities, please do go ahead, without wasting time. But if you are still not able to find any place to add something else, you can be pretty sure that you have done enough. Having done that, get ready for the question- "are you sure no fire accident will take place with such arrangements in place?"

The Common Approach

The general approach being followed towards fire safety, so far, is confined towards these major targets-

- Handling and storing the flammable material safely,
- Keeping all fire-fighting equipment operative,
- Training workforce about use of fire hydrants, extinguishers etc.

Be it fuel, petrol or paper, cloth or chemical, furniture or livestock, the basic approach remains the same. Most of our focus is on how quickly and efficiently we can stop fire once it has initiated. On the other hand, how to stop the initiation of fire itself, there are just a few guidelines-

- Avoid having electrical connections or wires in fire prone area.
- Ban use of cigarettes, bidi and matchbox, lighter etc. in fire prone areas.

Not only this, but there are also several standards and codes which may be useful for anyone concerned with fire safety. Please do spend some time having a look at standards for other segments (like cotton, libraries etc.) as these may also give some additional input. Some of these standards are-

- IS 4645-2024 Storage of Paper & Board (Code of Practice)
- IS 14489: 2018 (Reaffirmed 2023) Occupational Health and Safety Audit — Code of Practice

- IS 3079: 1990 (Reaffirmed 2000) Code of Practice for Fire Safety of Industrial Buildings: Cotton Textile Mills
- IS 11460-1985 (reaffirmed 2010) Code of Practice for Fire Safety of Libraries and Archives
- IS 1642-2013 Fire Safety of Buildings (General): Details of Construction-Code of Practice
- IS 1646-2015 Fire Safety of Buildings (General): Electrical Installations-Code of Practice
- IS 2190-2024 Selection, Installation and Maintenance of First Aid Fire Extinguishers- Portable and Mobile- Code of Practice
- IS 14689-1999 (Reaffirmed 2020) Code of Practice for Fire Safety in Industrial Buildings (Printing & Publishing Industry)

Not only this, but there are also detailed recommendations on size and layout of storage yards and godowns are available for fire-fighting purposes. Usually, the change in climatic conditions or change in properties of material stored to reduce fire propagation is considered as out of field of fire-fighting experts.

Paper is Different

However, paper being a little different material compared to various other flammable materials, needs to be handled and stored in a more scientific way. Only the calorific value, stoichiometric combustion air requirement, adiabatic flame temperature etc. cannot be used to describe the flammability of paper. Prolonged atmospheric conditions, quality of paper, physical nature of paper, physical condition of paper all play a significant role regarding the ease of difficulty of a lot of paper to catch fire.

Basically, like cotton, wood etc., paper also absorbs moisture from atmosphere, if the relative humidity is high. This makes these three- paper, cotton and wood fall into a special category. However, due to stiffness of paper compared to cotton, the bulk volume of paper trims is usually much higher compared to a roll of paper, log of wood or heap of cotton/cloth. That is why paper needs to be looked at with reference to its intrinsic properties especially for fire prevention purposes.

The Physical Nature of Paper/Waste Paper

Let us have a look at the following sets of images-

Image 1 & 2: Wooden log and shavings

area of 40,000-50,000 m2/ton. Consider a reel having 1 meter diameter and 1 meter face length- the area shall be around 4.71 m2, and for approximate weight of around 600 kg, the specific surface area can be calculated as 7.85 m2/

Image 3 & 4: Paper roll and paper cuttings

One would agree that wooden shavings can easily catch fire, while the log (fig. 1) will be difficult to catch fire in the first instance. Similarly, have a look at Images 3 & 4.

Exactly the same case exists here. If you have a single burning matchstick, a lot of paper cuttings can be put to fire easily. But that would not be the case with the roll of paper.

In fact, compared to a specific surface area of typically 10-20m2/ton for a solid reel (image 3), the paper cuttings/trimmings (image 4), have specific surface ton. For smaller reels, it would be somewhat higher. On the other hand, for a 50gsm paper sheet, each 50 grams mean 2 SqM. Of surface, which can also be calculated as 40,000 m2/ton. Definitely, this results in easier spreading of fire. This also highlights the fact that the physical nature of the material is extremely important to consider while planning about fire safety.

Propagation of Fire

The above examples illustrate how the shape of material is an important aspect while evaluating the risk of fire spreading in the initial phase. One must also bear in mind that if the heavy solid materials like wooden log or paper reel catch fire the fire is not easily stoppable. To understand and explain this further, a model[1] has been made as shown in figure 5.

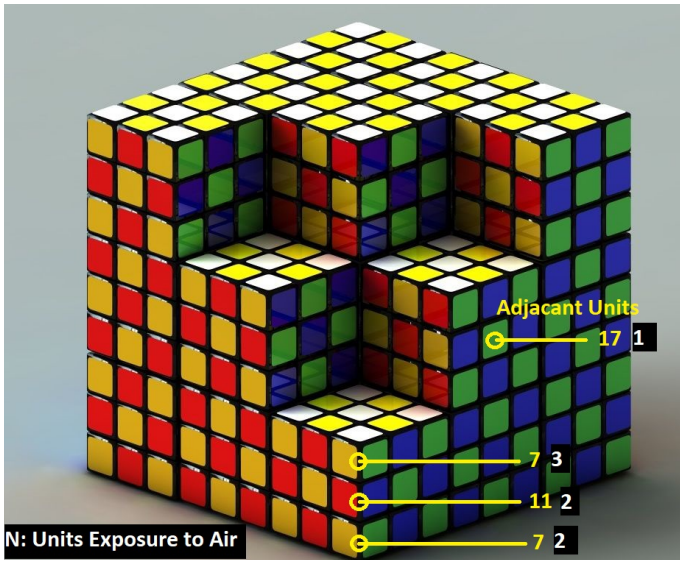


Image 5: A model of fire sensitive combustion prone block.
(The topmost marked block can get heat from one of its side, which can be dissipated to 17 adjacent units, thus making it difficult to catch fire. While the block two level above it can receive heat from 3 sides, the heat from which can be dissipated to nearby 7 blocks, thus making it more prone to catch fire.)

Any material can be considered as a three-dimensional structure of different small units (blocks) or cells. First of all, fire initiates at a particular unit. Upon its incineration, the heat generated is dissipated to its adjacent units. In case there are more adjacent units like in the one shown in figure (17 adjacent units), the heat is dissipated to 17 units, and hence, propagation of fire will not be that easy. The generated heat will be divided to this 1 unit, so each unit will get relatively less heat. Compared to it, some other cells like those having 7 adjacent units; all the heat generated shall be dissipated to only 7 units, thus putting them under more risk of fire propagation.

Similarly, we can see that the bottom most marked unit has availability of oxygen from two sides, while to top highlighted unit has relatively less oxygen available (one side only) for combustion. This obviously justifies the need to make our storage increasingly compact and small. If we can stop or at least reduce air supply to the exposed sheet, it would be an additional advantage.

Not only this, but this model also helps understanding how a focused approach can be implemented to minimize risk of initiation of fire.

The Calorific Value

The reported calorific value of paper is around 3000 kcal/kg. Well, there might be some minor deviations depending on paper quality, type of raw material used, ash content etc., but that would not make a big impact. Still, we have already observed the impact of physical shape on fire initiation properties of paper.

But can we do something to reduce the calorific value of paper? Will it make any significant impact?

When paper is kept at low humidity level for longer duration, its moisture content decreases, and it becomes easier for paper to catch fire. That is why, in humid summer, there are relatively less chances of such accidents. Paper is a little hydrophilic. If paper is kept at 10% moisture, the calorific value decreases from 3000 kcal/kg to say 2640 kcal/kg (the moisture also needs some energy to get evaporated). Furthermore, spraying water would also drop-down

temperature slightly. However, this change in calorific value (3000 to 2640) does not seem significant enough to make fire mishaps too frequent during dry weather.

But are we missing something?

Looking Beyond Calorific Value

It is said that to initiate ignition of paper, the temperature of it must go above 200 ºC. Consider a sample of dry paper kept at 40 ºC. Let us take the specific heat of it as 0.25kcal/kg. To raise temperature of 1kg of this by 160 ºC, we need just 40 kcal of energy, as shown below-

Ambient Temperature:	=	40 ºC
Temperature for ignition:	=	200 ºC
Specific Heat of Paper:	=	0.25 Kcal/kg
Heat required for increasing temperature for 1 kg of-		
Dry paper: 1 x 0.25 x (200-40)	=	40.0 kcal
But, if this paper contains 10% moisture, then		
For paper: 0.9 x 0.25 x (200-40)	=	36.0 kcal
For water: 0.1 x 1.00 x (200-40)	=	16.0 kcal
Latent Heat of Water: 540 X 0.1	=	54.0 kcal
Total:		**106 kcal**

That means while burning 1 kg dry paper you need to supply 40 kcal, while for paper having 10% moisture, you need 106 kcal of energy. Interestingly, at 20% moisture, this figure reaches 282 kcal energy. This shows the significance of ensuring a minimum safe moisture limit for paper.

The Climate

Most of the fire mishaps are usually told to occur during summers. But, if we analyze data carefully, we can find that humidity plays a much bigger role in fire mishaps compared to temperature. The recipe for fire disaster starts with dry paper, dry weather, and something else to initiate the process.

Initiation of Fire

The fire can initiate when a small part of paper catches fire due to any external event. First, an initiation of fire has to be taken place. How? Most paper mill workers and others associated with paper understand well the importance of fire safety, and hence negligence must not be the primary cause. In most of the open storage areas, one can be pretty sure about absence of an electric spark. We are, here, not ignoring these two causes, but trying to explore some other possibilities.

Now, we can see that when the atmosphere is dry, paper becomes dry and adjacent air is also dry, this makes a dangerous combination. In case of wind blowing, a spark may take place by itself; or it may appear for any other unpredictable reason.

Static Electricity

In fact, static electricity can be strong enough to start combustion at any place. Due to low humidity, air becomes good insulator and restricts the balancing of charge by slow rearrangement of electrons. Many papermakers have noticed that the complaints of static charge often appear more during dry weather only.

The Spark Trial:

Please do have a look at the spark created by a simple kitchen lighter. The spark is strong enough to start flame on the gas burner. But can it initiate flame on paper? In fact, several trials made on paper yielded to no result. However, the experiment was once repeated during dry weather, with old newspaper in place of copy paper used earlier. This time, of course after some efforts, the paper started burning. That indicated that dry paper, under dry climate can catch fire just by a small spark.

Similarly, concentrating sun rays using a magnifying glass can be used to burn paper. Many of us have done this experiment in our childhood. Such situations, though rarely, may appear by the reflection from windowpanes etc.

A Simple Solution: Misting

Having understood the climate, it seems logical to explore ways to increase humidity in the areas near paper storage. Fine mist is a possible solution for the same. Spraying very fine mist around storage areas can be explored as a possible solution.

Many mills use water spray over the wastepaper in summer season. However, most paper professionals fear degradation in paper quality due to repeatedly wetting and drying of paper. Mills using white grades of raw materials, especially with the ground wood grades, find the brightness reductions while the kraft based mills observe reduction in strength of paper due to frequent water spraying on wastepaper stock.

In such situations, misting can be done around the storage areas, like roads etc. Misting can reduce temperature to a significant extent, and the relative humidity increases to a certain extent.

Using a Firewall

Can we have something to protect our systems from fire mishaps? Paper does not catch fire by itself like bagasse. Some sparks, some flames, some hot waves must hit it to initiate fire. The idea here is to explore a barrier for paper to protect it from fire.

For the same, an experiment was performed. As we have already seen that a paper with high moisture is difficult to catch fire. So, if we are able to have wet paper, that remains wet for long duration, it may be used as a protection layer- like a firewall.

Firewall

For the same, a sheet of filter paper (225 gsm) was put in a polythene bag, with some water poured in it. This way, we have wet paper, and if the bag is sealed, the moisture remains within the bag. It was decided to try it as a firewall for paper.

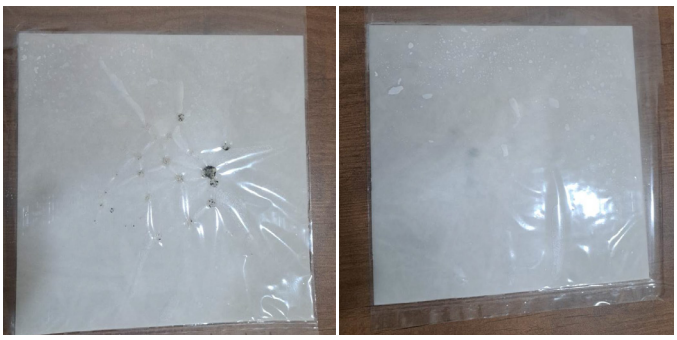
A test setup was prepared by having a metal ring of around 150mm diameter and 40mm height. A plain paper (MG Poster paper, 40 gsm) was spread horizontally over it. An empty ball pen refill was burnt, and molten burning plastic was allowed to drop on paper sheet from a height of approx. 300mm (Image 6).

Image 6: Test setup for paper and firewall

The paper caught fire easily, despite the situation when relative humidity was very high >84%, and the used paper sheet was moist (kept in open for 24 hours). The images of paper from top and bottom sides have been shown in Images 7 & 8.

Images 7 & 8: Paper got burnt in experiment (top and bottom sides)

Next, the same experiment was repeated with the wet filter paper packed in polythene bag. A minor flame started after a lot of effort but got extinguished almost immediately by itself. The images of developed firewall prototypes from top and bottom sides have been shown in Images 9 & 10.



Images 9 & 10: Impact of fire on firewall (top and bottom sides)

The proposed firewall concept gives a direction to think forward and to find out ways to replicate this on a pilot plant scale and then to a full-scale level before it is commercially used at different places. Research institutions and potential suppliers of such fire prevention systems may explore ways for it.

Conclusion

As already discussed, we need to pay maximum attention to avoid the initiation of fire. For the same, improved focus on the first two sections of the image is a must, while our focus often revolves around the third and fourth. In fact, the first point itself- "No Fire: No action is needed" needs a serious review. Use of water misting directly at wastepaper or nearby roads and other open areas also can help a lot. In closed areas like finished paper godown, artificial means of humidity management might be explored. Similarly, by using a 'firewall', we can prevent any spark or heat from attacking paper and wastepaper.

With the two proposed different approaches, we need to initiate research activities so that undesirable losses from fire accidents can be prevented.

Let's also initiate working together towards a –no fire accident- goal for paper industry.

Reference

1.D K Singhal, "Safe Storage of Paper & Waste Paper and its Handling for Accident Free Operation:, IPPTA 35(3):92-94(2023)