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# Frame for Comprehensive Fire Risk Management

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**Abstract:** ***Risk is the potential for realization of unwanted, adverse consequences to human life, health, property, or the environment. Estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event, given that it has occurred. The project emphasize on the Fire Risk management in industries using the method FRAME. FRAME or the Fire Risk Assessment Method for Engineers was developed as a tool to help a fire protection engineer to define a sufficient and cost effective fire safety concept for new or existing buildings. The project was carried out in a leading public sector cattle feed manufacturing company. The major accidents reported in the industries are due to Fire. The industry needs a permanent solution for the conditions inside the raw material warehouse that could result in a fire accident. Thus the Fire Risk inside the warehouse is assessed using FRAME. According to FRAME, for the existing Risk value, Preventive measures have to be taken for risk reduction. The solution found out for the problem is the application of Thermal infrared cameras.***

**Keywords:** Fire Risk, FRAME, Heat detection, Thermal infrared cameras

## 1. Introduction

The project is carried out in a leading public sector company in India setup in 1995. The design of the plant is based on European Standards. Only dumping of raw materials and stacking of finished feed is manual while the other processes are fully automated and controlled from the plant control room. Raw materials are stored in the raw material warehouse, grains like jower, and maize, sunflower extraction are stored in the silo and molasses is stored in the molasses tank. The major accidents reported in the industries are due to Fire. The first one was in the year 2001 which resulted in a loss of almost 60 Lakhs of Rupees. The maize stored in the silos caught fire. The reason for the fire was the heat generated within the silos. The base of the silo was earlier flat shaped and that resulted in the stagnancy of the stored raw materials. This issue was then solved by changing the shape from flat bottom to a cone shape.

The second accident was inside the Raw material warehouse. Charring occurred in the maize stacks stored inside the raw material warehouse. This then developed in to fire but was controlled before it becomes a major issue. This happens mainly due to the stagnancy of the stacks at the bottom, the moisture content in the stacks and the presence of oil after processing.

***Scope of the Study***

The industry needs a permanent solution for the conditions inside the raw material warehouse that could result in a fire accident. Thus the Risk level inside the Warehouse has to be studied initially then if necessary, corrective measures have to be taken.

## 2. FRAME

There are plenty of standards that define how to design fire protection systems. However, only a few methods exist to define how much fire protection a building would need to be reasonably protected. Building codes have such requirements, but these are mostly meant to assure a safe escape or rescue for the occupants, but not to salvage the building, nor to protect its content or the activities in it.

"FRAME" was developed as a tool to help a fire protection engineer to define a sufficient and cost effective fire safety concept for new or existing buildings. Unlike building codes that are mostly meant to assure a safe escape or rescue for the occupants, "FRAME" also aims at protecting the building, its content and the activities in it. This method can easily be used to evaluate fire risks in existing situations.

Three calculations are made for each situation: The first for the building and its content (property), the second for the occupants, and the third for the business or activities that take place in the building. These three calculations are necessary because the “worst case” is probably different for the buildings, persons or activities, as well as there can be differences in the effectiveness of the protection. A well maintained and active online support by the experienced professionals helps in utilizing the method for Risk Management.

*The definitions and basic formulas for the various factors in the method are:*

***A. Building and content:***

The Fire Risk R is defined as the quotient of the Potential Risk P by the Acceptable Risk Level A
and the Protection Level D
$R = P / (A * D)$
The Potential Risk P is defined as the product of the fire load factor q, the spread factor i, the area factor g, the level factor e, the venting factor v, and the access factor z.
$P = q * i * g * e * v * z$
The Acceptable Risk Level A is defined as the maximum value 1.6 minus the activation factor a, the evacuation time factor t, and the value factor c.
$A = 1.6 - a - t - c$
The Protection Level D is defined as the product of the water supply factor W, the normal protection factor N, the special protection factor S and the fire resistance factor F.
$D = W * N * S * F$

***B. Occupants:***

The Fire Risk R1 is defined as the quotient of the Potential Risk P1 by the Acceptable Risk Level A1 and the Protection Level D1

$R1 = P1/(A1 * D1)$

The Potential Risk P1 is defined as the product of the fire load factor q, the spread factor i, the level factor e, the venting factor v, and the access factor z.

$P1 = q * i * e * v * z$

The Acceptable Risk Level A1 is defined as the maximum value 1.6 minus the activation factor a, the evacuation time factor t, and the environment factor r.

$A1 = 1.6 - a - t - r$

The Protection Level D1 is defined as the product of the normal protection factor N and the escape factor U.

$D1 = N * U$

***C. Activities:***

The Fire Risk R2 is defined as the quotient of the Potential Risk P2 by the Acceptable Risk Level A2 and the Protection Level D2

$R2 = P2 / ( A2 * D2)$

The Potential Risk P2 is defined as the products of the spread factor i, the area factor g, the level factor e, the venting factor v, and the access factor z.

$P2 = i * g * e * v * z$

The Acceptable Risk Level A2 is defined as the maximum value 1.6 minus the activation factor a, the value factor c, the dependency factor d.

$A2 = 1.6 - a - c - d$

The Protection Level D2 is defined as the product of the water supply factor W, the normal protection factor N, the special protection factor S and the salvage factor Y.

$D2 = W * N * S * Y$

## 3. Fire Risk

***A. The Potential Risk***

P (Property) = 9.515
P (Occupants) = 4.227
P (Activities) = 5.99

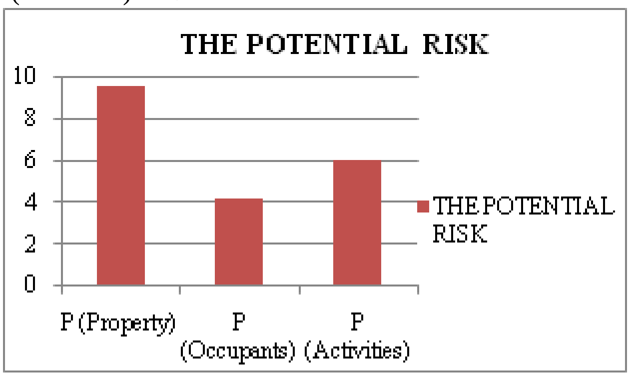


**Figure 1:** The Potential Risk

***B. The Acceptable Risk***

A (Property) = 0.9552
A (Occupants) = 0.552 (Corrected to D = 1.25)
A (Activities) = 0.9

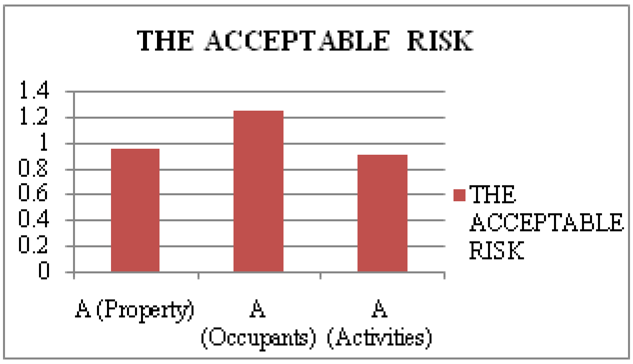


**Figure 2:** The Acceptable Risk

***C. The Protection Level***

D (Property) = 2.144
D (Occupants) = 2.785
D (Activities) = 1.8894

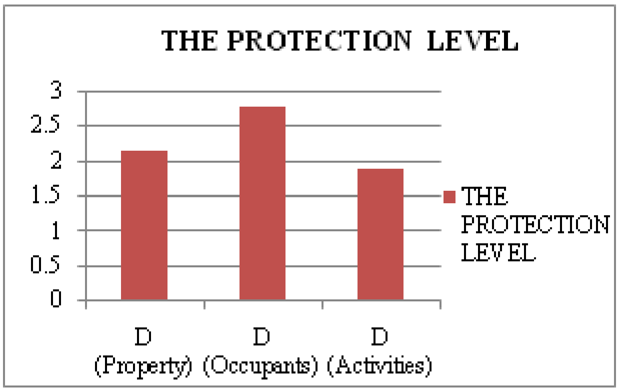


**Figure 3:** The Protection Level

***D. Fire Risk***

R (Property) = 4.646
R (Occupants) = 1.214
R (Activities) = 3.523

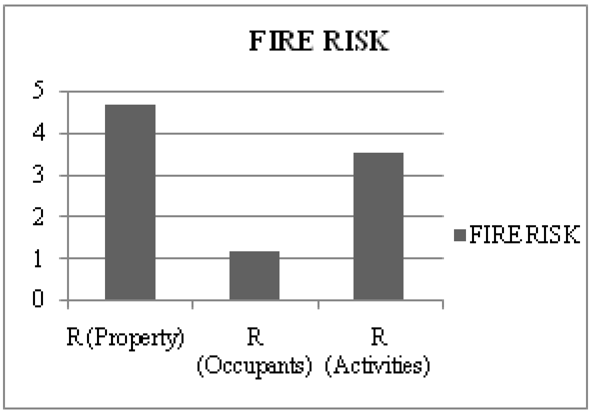


**Figure 4:** The Fire Risk

## 4. Fire Risk Reduction

- The value of R < 1.0 - Manual fire fighting system
- The value of R is between 1.0 and 1.6 - General automatic fire detection system
- The value of R is between 1.6 and 4.5 - Sprinkler protection
- The value of R > 4.5 - Preventive measures

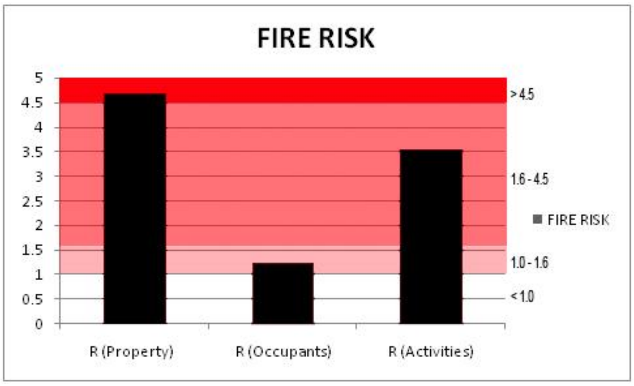


**Figure 5:** The Fire Risk (Risk Reduction)

## 5. Preventive Measures

Causes of fires on site can include:
- Arson or vandalism
- Self combustion, e.g. due to chemical oxidation, microbial decomposition
- Plant or equipment failure
- Electrical faults
- Discarded smoking materials
- Hot works, e.g. welding, cutting
- Industrial heaters
- Hot exhausts
- Damaged/exposed electrical cables

The fire triangle or combustion triangle is a simple model for understanding the necessary ingredients for most fires. The triangle illustrates the three elements a fire needs to ignite: heat, fuel, and an oxidizing agent (usually oxygen).

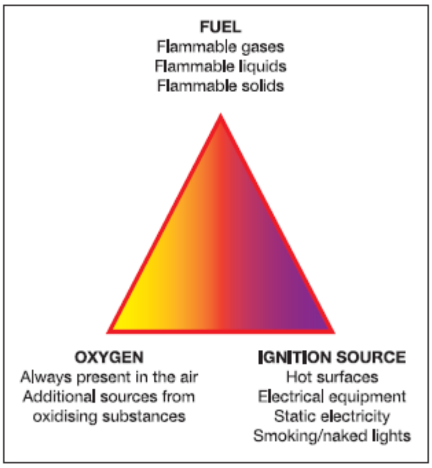


**Figure 6:** The Fire Triangle

### A. Heat

A heat source is responsible for the initial ignition of fire, and heat is also needed to maintain the fire and permit it to spread. Heat allows fire to spread by removing the moisture from nearby fuel, warming surrounding air, and preheating the fuel in its path, enabling it to travel with greater ease.

### B. Fuel

Fuel is any kind of combustible material, and is characterized by its moisture content (how wet the fuel is), size and shape, quantity, and the arrangement in which it is spread over the landscape. The moisture content determines how easily that fuel will burn.

### C. Oxygen

Air contains about 21% oxygen, and most fires require at least 16% oxygen content to burn. When fuel burns, it reacts with oxygen from the surrounding air releasing heat and generating combustion products. This process is known as oxidation. Inside the Warehouse since the activities are carried out manually, controlling of oxygen is not possible. The fuel here is the stored Raw materials itself and hence the only possible way of preventing fire in this case is controlling of Heat.

## 6. Analysis Of Preventive Measures

After studies on the fire prevention techniques few of them are chosen for further feasibility study. Those few that are considered to be apt for the current scenario are:

### A. Installing HVAC System in the Warehouse:

HVAC (heating, ventilating, and air conditioning) is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. Ventilating is the process of "changing" or replacing air in any space to provide high indoor air quality which involves temperature control, oxygen replenishment, and removal of moisture, odors, smoke, heat, dust, airborne bacteria, and carbon dioxide. Ventilation removes unpleasant smells and excessive moisture, introduces outside air, keeps interior building air circulating, and prevents stagnation of the interior air.

### B. Thermal Infrared Cameras:

The energy of particles of matter in random motion is called kinetic heat (also referred to as internal or true heat). The amount of kinetic heat can be measured in kinetic temperature. The electromagnetic radiation exiting an object is called radiant exitance (M). The concentration of the amount of radiant existence emitted from an object is its radiant temperature. There is a high positive correlation between the kinetic temperature of an object and radiant temperature. Therefore, we can utilize radiometers placed some distance from the object to measure its radiant temperature which hopefully correlates well with the object's true kinetic temperature. This is the basis of thermal infrared remote sensing. The thermal cameras produce sharp thermal images with high resolutions.

### C. Linear Heat Detection Cables:

Linear Heat Detection (LHD) (also known as Linear Detection Wire or Linear Heat) is a very commonly used method of fire detection. It can detect a fire anywhere along the length of the cable, and can be of lengths in excess of a kilometer. Linear Heat Detection (LHD) cable is essentially a two-core cable terminated by an end-of-line resistor (resistance varies with application). The two cores are separated by a polymer plastic, that is designed to melt at a specific, and without which causes the two cores to short. This can be seen as a change in resistance in the wire. The linear heat detection system enables long and heavily fragmented facilities such as traffic and supply tunnels, cable routes and conveyor belts as well as large-scale buildings such as production halls, cold stores and multi-storey car parks to be monitored at all times.

## 7. Optimum Solution

In the above mentioned measures, the installation of HVAC system that could maintain the heat at a safe level is not a feasible solution when the economic factor is considered. The cost of implementation of such a system inside the large warehouse space will be very high. The linear heat detection cables are the cable lines that have to be laid around the region where the heat should be maintained. Inside the storage warehouse space the material handling is done by using forklifts and other moving automotive carriers. Hence the cables cannot be laid inside the warehouse as a safety measure. Thus the feasible solution among them is the installation of thermal cameras to detect and control the heat level inside the storage area.

Our eyes are detectors that are designed to detect visible light (or visible radiation). There are other forms of light (or radiation) that we cannot see. The human eye can only see a very small part of the electromagnetic spectrum. At one end of the spectrum we cannot see ultraviolet light, while at the other end our eyes cannot see infrared. Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum. The primary source of infrared radiation is heat or thermal radiation. Any object that has a temperature above absolute zero (-273.15 degrees Celsius or 0 Kelvin) emits radiation in the infrared region. Even objects that we think of as being very cold, such as ice cubes, emit infrared radiation. We experience infrared radiation every day. The heat that we feel from sunlight, a fire or a radiator is all infrared. Although our eyes cannot see it, the nerves in our skin can feel it as heat. The warmer the object, the more infrared radiation it emits.

## 8. Effectiveness of Thermal Imaging

Thermal imaging is a very effective technique for the existing problem inside the warehouse because of the following advantages.

### a) Prevent the fire before it starts

Thermal imaging cameras are an ideal tool for warehouse asset protection. Unlike other methods, such as CCTV monitoring and smoke detectors, thermal imaging technology can prevent a fire before it begins with its automatic temperature alarm feature, preventing expensive stock loss. It also provides an intuitive and easy to understand visual image that will allow personnel and firefighters to immediately assess the situation and recognize the problem.

Thermal imaging cameras require neither maintenance nor any expensive and power consuming lighting to be effective. Thermal imaging cameras also generate fewer unwanted alarms, which are a common problem with CCTV cameras and smoke detectors. And as an additional advantage thermal imaging cameras from can also be used for security, detecting intruders in total darkness if necessary. Thermal imaging cameras might be slightly more expensive than CCTV cameras and smoke detectors at the initial purchase, but as they require no light whatsoever to function the maintenance costs and energy bills are kept low. This solution is also the only system that actually prevents the fire, keeping your assets safe and protecting you from costly stock loss, making it the best warehouse asset protection solution on the market today.

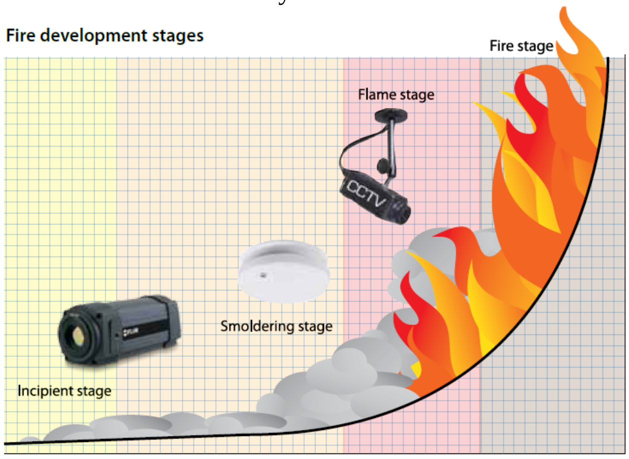


**Figure 7:** The Fire Development Stages

### b) Infrared thermometers Vs Thermal cameras

Infrared (IR) thermometers are reliable and very useful for single-spot temperature readings, but, for scanning large areas or components, it's easy to miss critical components that may be near failure and need repair.

A thermal imaging camera can scan entire motors, components, or panels at once - never missing any overheating hazards, no matter how small.

### c) Use thousands of infrared thermometers

With an infrared thermometer you are able to measure the temperature at one single spot. Thermal imaging cameras can measure temperatures on the entire image. The camera has an image resolution of 60 x 60 pixels means that it is equal to using 3,600 IR thermometers at the same time.

### d) Find problems faster and easier with accuracy.

It's easy to miss critical problems with a spot IR thermometer. A thermal imaging camera scans entire components giving you instant diagnostic insights showing the full extent of problems.

### e) "Lights-out" warehouse monitoring

Unlike visible image cameras that might be used to detect smoke, thermal imaging cameras do not require lighting to produce their images. Therefore, they support "lights out" 24/7 warehouse monitoring. Furthermore, thermal imaging cameras have another advantage: they can also see through smoke. This means that in case a fire should break out, they can be used to guide firefighters to the source of the fire and to see if there are still people in the smoke filled room. However, thermal imaging cameras can "see" hot spots well before smoke or flames appear. This makes them ideal tools for asset protection in warehouses.

### f) Multiple alarm features

Thermal imaging camera can provide a signal directly to an audible or visual alarm device but they can also be combined with a PLC or PC controller to create a monitoring system with advanced features. With FLIR's thermal imaging camera firmware, or PC-based software, these features can include:

- High, low, and average temperatures in an image
- Temperature set-point alarms
- Multiple target spots and alarms
- Delays to ignore temporary temperature increases due to forklift trucks in the area
- Temperature trend analysis to reveal problems before a set-point is reached
- Ethernet connections to a central controller
- Connecting multiple cameras to a central monitor
- Alarm messages and images via ethernet, email, or FTP

## 9. Result

The Fire risk for the Property inside the warehouse is found out to be 4.646. For the occupants the fire risk is 1.214and the same for activities is 3.523. Thus a preventive measure should be implemented and thermal cameras are the optimum feasible solution for the risk situation existing inside the storage warehouse.

## 10. Conclusion

After the fire risk estimation study inside the Company storage warehouse, it is clear that a necessary preventive measure has to be implemented for the safe operation inside the space. It is found out that the Thermal imaging cameras will be a suitable solution for the problem inside the study area. The thermal imaging can reduce the fire risk inside the warehouse for a large extent since it detects the heat rise even before the fire begins.

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