# Hazard Identification and Risk Assessment for the Use of Booster Fans in Underground Coal Mines

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# Outline

- Introduction
- Booster Fans in U/G Coal Mines
- Hazard Identification and Risk Assessment
- Risk Assessment Tools
- Conclusions

# Introduction

**Booster Fan**

- An underground fan installed in a main airway and sized to handle the quantity of air needed in a section
- Installed in a permanent bulkhead and equipped with a set of airlock doors and fan monitors
- Can be used to create safer work conditions and allow the extraction of minerals from greater depths.

# Merits and Demerits of Booster Fan

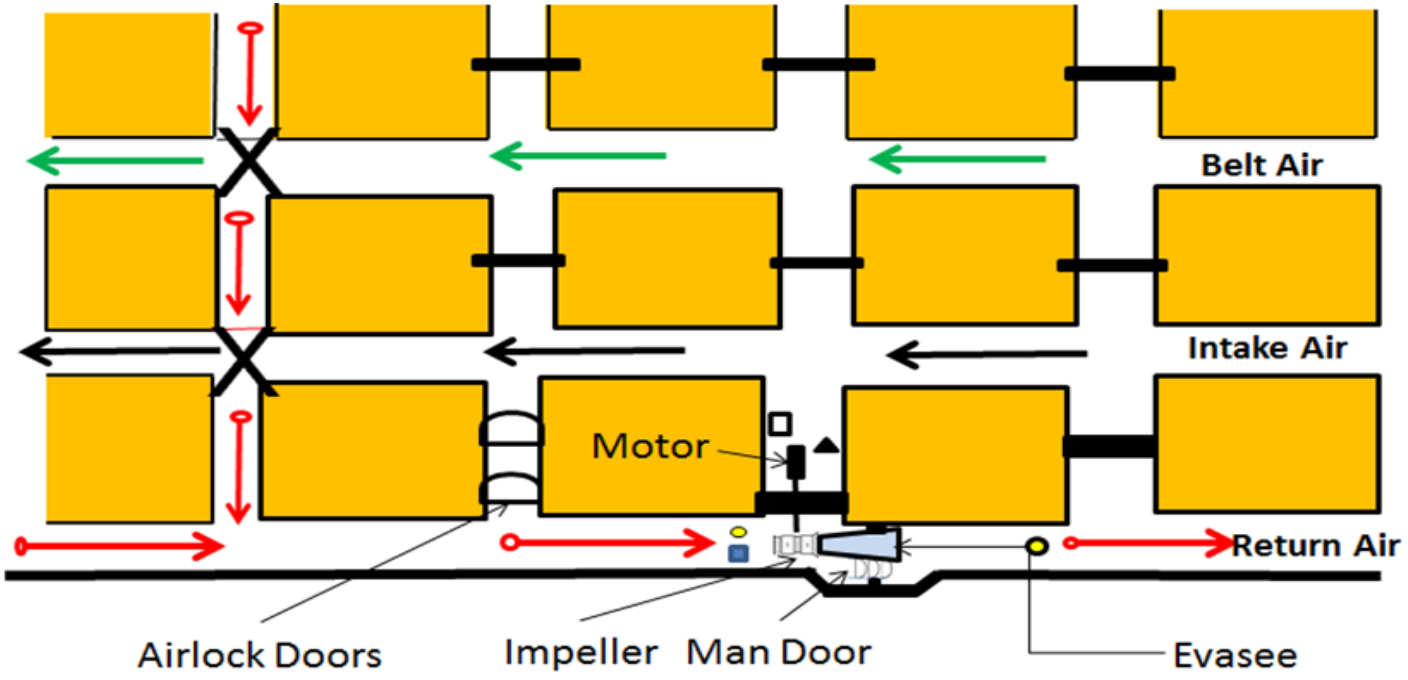
**Merits**

- Reduces main fan pressure
- Reduces air leakages
- Reduces ventilation cost.

**Demerits**

- Increases possibility of uncontrolled recirculation
- Increases propensity of fire
- Increases build-up of contaminants.

# Booster Fan Installation Details



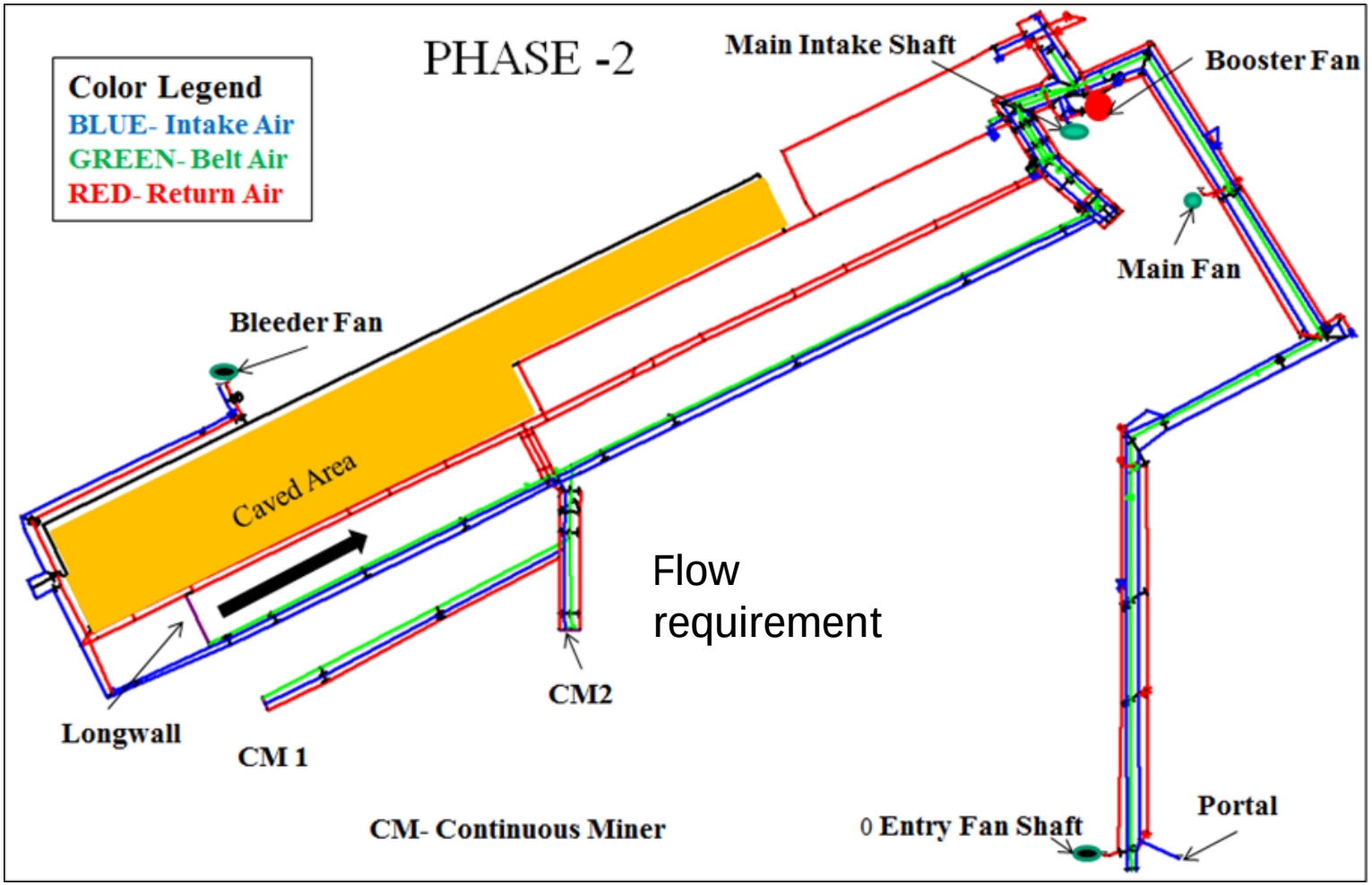
# Custom Built Centrifugal Fan

# Booster Fans in U/G Coal Mines

## Sample Coal Mine

- Ventilated by exhaust system of ventilation
- Has one long-wall section and two continuous miner sections
- Has one main surface fan
- Has one main intake and two smaller intake airways
- Has a good scope for the use of booster fan.

# Mine Ventilation Network




Mine Ventilation Network

# Mine Ventilation Network

**Requirement of Air**

| | |
|---|---|
| C M Section 1: | 33.0 $m^3/s$ |
| CM Section 2: | 21.0 $m^3/s$ |
| Longwall Face : | 47.0 $m^3/s$ |
| Bleeder System: | 21.0$m^3/s$ |
| Sealed Area: | 66.0 $m^3/s$ |

188 $m^3/s$

**Statement of the Problem**

- Mine needs efficient and safe ventilation system to fulfill the requirements of air at the different sections of a mine while considering leakages

- It requires either single fan system or two fans system to fulfill the requirements of air.

# Solutions to the Problem

## Simulation Results

| Fan Duty | Pressure (Pa) | Quantity ($m^3/s$) | Air Power (kW) | Total Air Power (kW) |
|---|---|---|---|---|
| 1. Single Fan System | | | | |
| Main Fan Only | 5758 | 470 | 2693 | **2693** |
| 2. Two Fan System | | | | |
| Main Fan | 4045 | 433 | 1747 | **2571** |
| Booster Fan | 3063 | 270 | 824 | |

# Installation and Commissioning

- Requires bypass drift, or widening of existing drifts, and installation of airlock doors
- Needs enough space to house the fan assembly, man doors, and condition monitoring components
- Needs manufacturer involvement during fan installation.

**Evaluation Standards**

| | |
|---|---|
| Vibration (alarm): | 5.5 mm/s |
| Bearing- Motor temperature: | 85 ºC |
| Fan duty: | 5% of designed values |

# Hazards Identification

A hazard is anything that has potential to cause harm to miners or damage to property

Inventory of Hazards:

- Electrical: fan, monitoring malfunction
- Mechanical: moving parts
- Chemical: fires, spontaneous combustion
- Pressure: stuck in airlock door.

# Hazards Identification

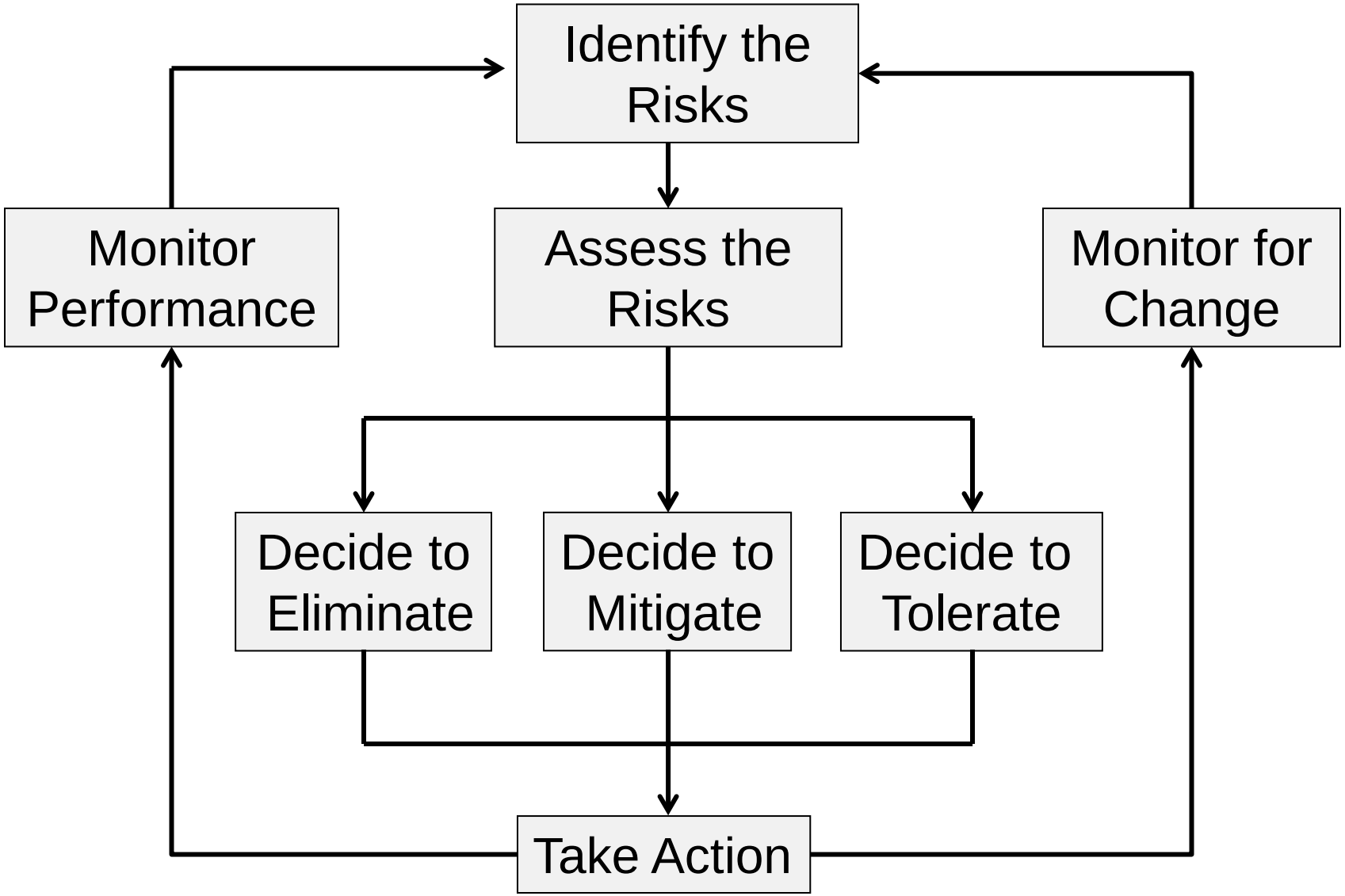
Unwanted Events:

- Power failure to mine
- Erroneous monitoring of read-outs
- Equipment failure
- Fires and explosions
- Recirculation of air contaminants

# Risk Assessment

- Risk is a product of likelihood of occurrence and consequences of undesired event
- Risk Analysis is the process by which risks are identified, examined and their magnitudes are determined
- Risk Assessment is the process by which the outcome of risk analysis is compared to its risk acceptance criteria

# Principles of Risk Assessment



# Risk Matrix

## Categories of harm severity

Catastrophic:  Multiple deaths
Critical:  One death or multiple severe injuries
Moderate: One to three severe injuries
Minor:  One severe injury or multiple minor injuries
Insignificant:  One minor injury

## Categories of harm probability

Most Certain:  Occurs once or twice a year
Likely:  Occurs less than once in year or may recur once in 5 years
Possible:  Has occurred or may recur in 10 years
Unlikely:  May occur in 20 years
Rare:  Has never happened

# Risk Matrix

| Likelihood | 1 Insignificant | 2 Minor | 3 Moderate | 4 Major | 5 Catastrophic |
|---|---|---|---|---|---|
| | Risk Rating | | | | |
| 5. Most Certain | 5 | 10 | 15 | 20 | 25 |
| 4. Likely | 4 | 8 | 12 | 16 | 20 |
| 3. Possible | 3 | 6 | 9 | 12 | 15 |
| 2. Unlikely | 2 | 4 | 6 | 8 | 10 |
| 1. Rare | 1 | 2 | 3 | 4 | 5 |

| **Risk Rating** | Legends | Guidelines for Risk matrix |
|---|---|---|
| 15 to 25 | (Ex): Extreme | Eliminate or avoid and implement action plan |
| 9 to 12 | (H): High | Proactively manage |
| 4 to 8 | (M): Medium | Actively manage |
| 1 to 3 | (L): Low | Monitor and manage |

# Risk Assessment Tools

1. Job Safety Analysis
2. Bow Tie Analysis
3. Workplace Risk Assessment and Control
4. Failure Mode Effect Analysis
5. Fault Tree Analysis
6. Event Tree Analysis
7. Hazards and Operability Studies

# Workplace Risks Assessment and Control (WRAC)

1. A broad-brush risk ranking approach
2. Breaks down the mining process with potential hazard
3. Involves a flow chart with potential hazard identification
4. Accomplished with the use of JSA and SOPs
5. Identifies potential unwanted events
6. Includes the likelihood and consequences of each stage
7. Includes controls and recommended measures

# WRAC (Design Stage)

| Steps in process | Unwanted Events | Current Control Measures | L | C | R | Recommended Measures |
|---|---|---|---|---|---|---|
| Oversizing and poor location of booster Fan | Recirculation and fire | Use VnetPc software to size and site the fan | 2 | 4 | 8 | Check for recirculation before implement the design |
| Failure to design good monitoring system | Undetected fire and recirculation | Manual sampling of air | 3 | 4 | 12 | Follow the good practice as adopted in other country |
| Failure to good design airlock doors and bulkhead | Recirculation , fails to open airlock door | Airlock doors and bulkhead tested for its stability | 2 | 4 | 8 | Follow the good practice as adopted in other country |

# WRAC (Installation & Commissioning)

| Steps in Process | Unwanted Events | Current Control Measures | L | C | R | Recommended Measures |
|---|---|---|---|---|---|---|
| Failure to measure temperature and vibrations | Recirculation, fire, damage to foundation | Fan monitoring system | 2 | 4 | 8 | Manual check and maintenance |
| Misalignment of fan shafts | Excessive vibration of fan parts | Follow manufacturers specifications | 3 | 3 | 9 | Alignment must be tested manually |
| Testing of Fan | People caught in between moving parts | Barriers and screens around the Fan | 1 | 5 | 5 | Safety screen, good illumination |
| Failure to follow SOP's | Fan not running well | Training | 2 | 4 | 8 | Refresher training |

# WRAC (Operation Stage)

| Steps in Process | Unwanted Events | Current Control Measures | L | C | R | Recommended Measures |
|---|---|---|---|---|---|---|
| Mechanical Electrical Fault | Failure of interlocking | Main and booster fans in same circuit | 2 | 3 | 6 | Independent power source for booster fan |
| Chemical | Fire | Good house keeping | 3 | 5 | 15 | Good monitoring, firefighting equipment must be in place |
| Chemical | Buildup of mine gases | Through flow ventilation | 3 | 5 | 15 | Construction quality control of vent. devices |
| Chemical | Spontaneous combustion | Shotcreting of the roof, floor and sides of roadways | 2 | 4 | 8 | Booster fan located in overlying or underlying strata |
| Chemical | Dust buildup on blades | Water spraying during cutting and crushing | 1 | 5 | 5 | Scheduled Maintenance of diesel units (250 hrs) |

# Interpretation of Outcomes of WRAC

- All the inventory of hazards are identified during design installation and operation stage
- Major hazards would be controlled by recommended control measures
- Fire and recirculation are major hazards and need special attention to prevent them.
- Interlocking between main and booster fan must be tested and maintained in order

# Failure Mode Effect Analysis (FMEA)

- Applicable to potential failure of subsystems
- Failure modes of individual items are determined
- Effect on other items and system are recognized
- Risk rank of failure item are determined
- Criticality is calculated (severity X probability)
- Control measures are prioritized based on criticality
- Bottom-up evaluation technique
- Qualitative and quantitative techniques

# FMEA of A Sample Problem

| Failure Mode (Electrical) | Effect on | | L | C | R | Controls |
|---|---|---|---|---|---|---|
| | Other | System | | | | |
| 1. Failure of monitoring devices | a) Undetected environmental conditions | Undetected spontaneous heating and fire | 3 | 5 | 15 | Redundant sensors recalibration maintenance |
| | b) Undetected vibration and temperature of motor bearings | Overheating of motor source of ignition | 3 | 4 | 12 | Provide un-interrupted power supply |
| 2. Failure of power to mine site | Main, booster and bleeder fans are stopped | Whole ventilation system is collapsed | 3 | 5 | 15 | Generator set with standby fan |

**L- Likelihood C- Consequences R- Criticality or Risk rank**

# FMEA of A Sample Problems

| Failure Mode (Mechanical) | Effect on | | L | C | R | Controls |
|---|---|---|---|---|---|---|
| | Other | System | | | | |
| 1. Failure of main fan | Main fan is stopped | Ventilation is deteriorated | 2 | 5 | 10 | Stop booster fan and down-stream equipment |
| 2. Failure of booster Fan | Booster fan is stopped | Ventilation is deteriorated | 2 | 4 | 8 | Open airlock doors, stop downstream equipment |
| 3. Failure of airlock doors | Flow of air is stopped | Ventilation is short-circuited | 2 | 4 | 8 | Stop downside equipment<br><br>Guide miners to refuge chamber |

# Interpretation of FMEA Outcome

- Failure of power to the mine site is an extreme risk
- Failure of the monitoring system is a high risk
- Failure of the main fan is a high risk
- Failure of the booster fan is manageable
- Failure of and airlock door is manageable;  however, it can induce recirculation of air contaminants

# Conclusions

- Risk Assessment is an integral part of booster fan operation in underground coal mines in others part of world
- Fire and flow recirculation are two major hazards associated with the operation of booster fans
- RA reduces the impact of undesired events, if known early
- Risk matrix information prioritizes the risks
- FMEA is used to analyze risks of system components
- WRAC is used to analyze risks by JSA and SOP
- RA is used during design, installation & operation stages

# Future Work

- Fault Tree Analysis will be applied to hazards identified in the case study to determine main contributing factors
- Attempts will be made to collect field data associated with main and booster fan to quantify the risk
- The outcomes produced by WRAC and FMEA will be refined by applying a revised risk matrix
- Major hazards and risks associated with the operation of booster fans will be summarized and used to develop an operation protocol

***Thank You***


Questions?

# Booster Fan Installation Details