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Incident prevention tools–incident investigations and pre-job safety analyses

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ABSTRACT

Careful and thorough incident investigations and pre-job safety analyses completed by knowledgeable and competent individuals can significantly reduce workplace incidents. Working parties must act together to make these safety tools effective. To get the staff units to work together in a co-ordinated manner, they must be shown the value of their work in preventing accidents. Examples of actual accidents investigated during the author's 18 years as a mine inspector in Saskatchewan are discussed within the context of pre-job safety analyses. The causes of the accidents are explored with close reference to how pre-job safety analyses could have prevented their occurrence.

1. Introduction

Risk increases when the probability of an incident occurring increases or the severity of injury increases. In this paper, two general tools are outlined to prevent accidents from occurring and reduce their severity. Such tools are incident investigation analysis, and pre-job safety analysis. The working parties of management, supervision and workers must manage analyses so that incident frequency and injury severity are reduced. The combined expertise and point of view of these employee units will make the work process safer. It is essential that the working parties work together in a co-ordinated manner so that they all see the value in conducting these investigations and pre-job safety analyses.

Actual Incidents that were investigated during the author's 18 years as a Mines Inspector in Saskatchewan, Canada are presented. They demonstrate how pre-job safety analysis could have prevented these incidents from occurring.

2. Accident prevention

Incidents occur at mine sites, which may or may not have significant consequences. These incidents may not have caused injury; minor incidents can be caveats for more severe incidents, where a worker may be injured.

Frank Bird analysed the general results of more than 1,000,000 incidents, as is shown in Fig. 1 [1]. As is revealed in the model, incidents where there is no visible injury or damage occur more frequently than incidents where a serious injury has occurred. Lessons can be learned from all these incidents.

The lessons learned can provide control to the workplace so that similar incidents do not occur, which could possibly give rise to more severe consequences. These controls can be learned through incident investigations. Alternatively, the work environment can be controlled through pre-job safety analysis so that the possibility of incidents occurring is diminished.

2.1. Incident investigation

When an incident occurs, a team should be formed to investigate the reason for its occurrence, and to establish controls to prevent recurrence. The team should comprise of at least one management representative and at least one worker representative. The team should examine the site where the incident occurred, conduct interviews about the incident, and collect physical evidence. Such physical evidence could include physical objects that could possibly be used for verification, photographs, and videos. The aim of this is to reconstruct the incident, find causes, and determine controls to prevent recurrence. After reconstructing the incident, a back analysis would seek to learn the reasons the incident occurred. This would include reasons that are

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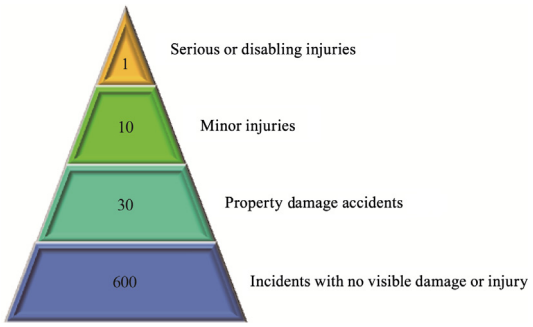

Fig. 1. Bird's pyramid model [1].

physical, procedural, and associated with the work environment. This is summarized in the causes which are:

(1) Direct causes: what prompted the incident.
(2) Indirect causes: what events transpired to contribute to the direct cause of the incident.
(3) Root causes: what practice or knowledge would have prevented the incident from occurring.

After the causes are found, controls must be observed to prevent recurrence. This would include considering what actions would prevent these causes from developing again. This would involve implementing one or more of a multitude of actions within the physical environment including how workers interact with the physical environment, procedures, and training.

2.2. Pre-job safety analysis

Ideally, unexpected incidents do not occur in the workplace. The probability of these incidents occurring can be reduced by providing workers with tools to ensure they assess their work environment: the work environs, the equipment used, the weather, their work colleagues, their training, and work procedures. Management must provide workers with these tools.

Management must provide an ordinarily safe work environment, the staff and time to provide training to the workers, the procedures to provide means to complete their tasks, and supervision to provide guidance to the work before and while it is being conducted. Workers must also work with their colleagues to ensure that they are not endangered and are working safely for themselves and others. These workplace elements which influence worker safety are depicted in Fig. 2.

A tool exists to assist workers in conducting their work safely: pre-job safety analysis. Pre-job safety analysis may be conducted

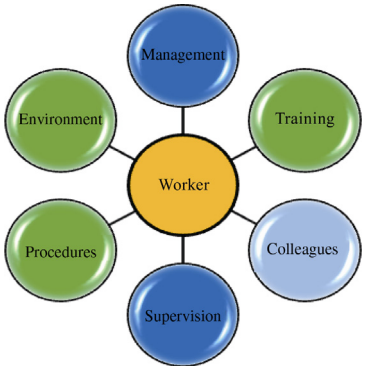

Fig. 2. Workplace elements influencing worker safety.

individually or as a group. Unsafe conditions noted before and while work is being conducted should be eliminated before work begins [2]. The work should therefore not begin until controls are installed so that the unsafe condition or work process noted no longer pose a risk. Workers have a right to refuse work that they believe will endanger themselves or others.

Two pre-job safety analysis systems will be discussed: Neil George 5-point safety system, and field level risk assessments.

2.2.1. Neil George 5-point safety system

A pre-job safety analysis system was developed for the Ontario mining industry by Neil George in 1942. At the beginning of each shift, the worker, in this case a miner, must evaluate for health and safety risks at his worksite by using the five point safety system [3]. This system must be analyzed by the miner in the area where the work is to be conducted. As the name suggests, miners must consider five points before beginning to work.

Five-point safety systems are general and do not have specifics, and can therefore be used at different workplaces. The Neil George five-point safety system is a straightforward and structured means for miners to assess their workplace, equipment, and work procedures. Mine workplaces are dynamic and continually changing. To complete the five point safety system, it is often necessary to complete checklists and refer to maintenance log books to ensure they are current.

The five-point safety system encourages independent thinking and real time engagement, because the miners must check their workplace, equipment, and required workplace procedures and continue to do so throughout the shift. Columns for successive tasks to which the miners are assigned during their shift are oftentimes present. Miners often carry a card with the five points noted down for them to consider. There is space on many of the cards for miners to note down suggestions to improve safety.

Five-point safety directives are as follows:

(1) Check the entrance to the place of work. The worker-miner must check his/her surroundings as he/she makes entry to the workplace. This includes travelling from the dry to the work place, and going between workplaces.
(2) Are working place and equipment in good order? The miner must check the working place and equipment to ensure they are safe. Checking the working place and equipment may require examining specific checklists. If there are records detailing when a qualified professional last inspected the working place or equipment, the miner must check to ensure that the records are current.
(3) Are people working safely? The miner and fellow miners must wear the required personal protective equipment (PPE). Is everyone following safe work procedure? The miner must ensure that the correct procedures are being followed by the crew or a risk assessment that is being completed if warranted.
(4) Do an act of safety. The miner should note an act of safety accomplished by himself/herself. While conducting any job, an instance will present itself where a safe act is required to do the job safely or prevent a hazard from presenting itself. It is a constant reminder for miners to think about safety.
(5) Can, and will, miners continue to work properly? The miner must keep safe work in mind. Before beginning the task, the miner must consider what is necessary to complete the job safely in terms of personal protective equipment, materials, equipment, and procedures or risk assessment as the job progresses. The miner must check to see if all that is required to do the job safely can be accessed. If something new becomes known during work and the means to do the

job safely is not immediately available, the miner must consider what action is needed to be done to ensure that all workers remain safe.

2.2.2. Field level risk assessment (FLRA)

A system used on many construction sites involves teams of workers who work together as colleagues to evaluate for health and safety risks at the workplace. This system is called the field level risk assessment (FLRA) [4]. Instances when this would be necessary include before beginning work, when a new worker joins the crew, when work procedures change due to site conditions, when new equipment is introduced, and when the activities of others in the area may pose a risk.

Some forms or checklists may be used in conjunction with the FLRA such as hot work permits, confined space entry, ground disturbance checklists, working at heights checklists, critical lift checklists, and mobile lift equipment checklists. These lists aim to assess and effectively control risks

FLRA directives are as follows.

Noting hazards to which workers are exposed. As work is being conducted, it is necessary to question what hazards are present to them and the surrounding workers.

(1) Assess the risk. Note and assess the probability of the hazard causing an adverse outcome and the possible severity.
(2) Control those risks. Note the means to control the risk by noting the hazards, the means to control the hazards, who will control them, and who will check if the controls are adequate.
(3) Follow up. At this point, follow-up is required after the job is completed. This would include reactivating controls that were suspended to conduct the work and notifying any personnel with interest of the work being completed.

3. Working parties

Incident investigations and pre-job safety analyses are most effective when all workplace parties work together as a cohesive team for safety. The four workplace parties are: management, supervision, workers, and assessors. These parties work together to keep the workplace safe, see Fig. 3.

3.1. Management

Management must be involved to maximize the effectiveness of incident investigations and pre-job safety analyses [5]. They are involved in incident investigations to ensure that those conducting it have access to the information they need and have access to required expertise. Management is required to utilize the controls recommended by the investigation team or put in place another that is as or even more effective, unless it can be shown there is a gross disproportion between the benefit to health and safety, and the costs.

Management also decides which pre-job safety analysis system to use. It must ensure all workers are trained in its use. Records are kept of investigations and pre-job safety analysis outcomes. They can then compare incidents that have occurred regarding the points noted in pre-job safety analyses. In addition, the pre-job safety analyses completed by workers should be explored to see if there are any trends in unsafe conditions. Management must respond to observations noted by workers. Feedback provided by management as to how well the pre-job safety analysis was conducted can be a powerful incentive to supervisors and workers to reinforce the importance of pre-job safety analysis. This would keep supervision and workers positively engaged in the health and safety process.

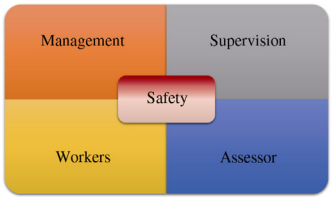

Fig. 3. Cohesive unit for safety.

3.2. Supervision

Supervision may be part of the incident investigation team. Even if they are not, supervisors must ensure that the investigation team has access to the means of finding information crucial for the investigation. Supervisors must ensure the controls agreed on by management and the investigation team are implemented.

All pre-job safety analyses should be checked while the work shift is ongoing to see whether they have been completed adequately. Supervisors should coach and mentor the workers completing them to ensure they are filled adequately. Feedback provided by supervisors for well conducted pre-job safety analyses can be a powerful incentive to workers to reinforce the importance of pre-job safety analyses.

3.3. Workers

Workers on the investigation team are there to prevent incidents from repeating. They must examine each incident in as much depth as necessary to find what they need; this may require consulting experts. When management and the investigation team have reached a conclusion as to what controls are necessary to prevent similar incidents from occurring, workers must cooperate to ensure that these new controls are implemented.

Workers are required to focus on pre-job safety analyses before beginning work. Management has given them a tool and requires them to use it to make their workplace safe. Effective supervision teaches workers how to use the tool to help them identify unsafe situations. The pre-job safety analysis is completed by checking the worksite, equipment, and applicable work procedures. Any observations of the workplace, equipment, and work process are jotted down. Any safety improvement suggestions should also be noted.

To use the pre-job safety analysis tool effectively, workers must be thoughtful and not simply ticking boxes. If they are unsure about how to do a task, they should get the required training [6]. Management may disseminate the data accrued from past pre-job safety analyses if it is applicable to other workplaces. This data may be used effectively to support subsequent pre-job safety analyses.

3.4. Assessor

An assessor should examine incident investigations and pre-job safety analyses. This assessor can see if there are any trends when reviewing the records that management is responsible to keep, see if there are any links to incidents that were not noted, and pass on any suggestions made by the workers completing the pre-job safety analysis.

4. Co-ordinated manner

All staff at a workplace want to be safe; not to suffer any illnesses or any injuries while they are at work. To ensure that working parties are united as to how to work towards this goal, defining their roles makes them realize what they must do to make the workplace safer. The staff must prioritize health and safety to ensure the investigation and safety tools are used appropriately–they must make it happen.

4.1. Staff units

The staff units at workplaces are management, supervision, and colleagues. The tools that a worker can use to make their workplace healthier and safer are provided by management. Supervision can provide the workers with support and guidance in the use of these tools. The worker also should check if their colleagues are put at risk from the worker's task, and that the colleagues are working safely. The colleagues reciprocate the favour. With the support of management and supervision, the investigation and pre-job safety analyses tools allow the workers to consider their work environment, the pertinence of procedures used, and the adequacy of their training. Their training should include how to conduct investigations and pre-job safety analyses. Fig. 4 illustrates how the worker operates with other staff units, training required, the work environment, and procedures to make their work place safer.

4.2. Prevention encouragement

Getting the three staff units, management, supervision, and workers to work together with incident investigation and pre-job safety analysis is important. This involves all three staff units working together so that they all see the benefit of recognizing the importance of accident investigation and the benefits behind pre-job safety analyses and changing their behaviour accordingly. As depicted in Fig. 5, everyone in a workplace can see the "Advantage" to having a safe work place; all workers want to go home safely [7]. It is also "do-able"; it takes time but management and supervision have to give the workers time to do their investigation and pre-job safety analyses. In terms of the "value", management and supervision respond to recommendations given in investigation and pre-job safety analysis–it provides for a safer work place. Finally, "prevalence": if everyone does the pre-job safety analysis, it will be considered important. Also, if management and supervision give support and acknowledgement, workers will realize that it is important.

Fig. 4. Workers and team collaboration.

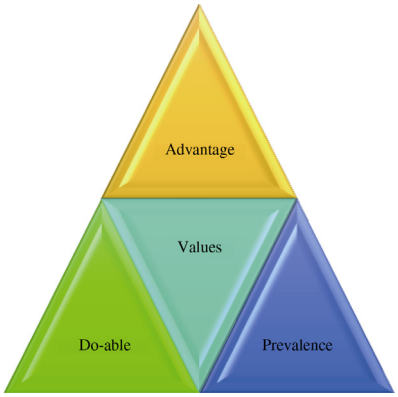

Fig. 5. Evaluation points [7].

The use of the behaviour change wheel (BCW) displayed in Fig. 6 can be summarized by considering capability-opportunity-motivation (the BCW hub) to change behaviour (COM-B) [8]. It is essential that all staff units be motivated to have incidents investigated or to conduct a constructive pre-job safety analysis. Opportunity is also important. The time and the acceptance are by all levels of staff. Finally, the "capability": does the entire staff know how to conduct incident investigations so that incidents will not be repeated with possibly more severe consequences? Does the entire staff know to perform pre-job safety analyses and learn from the findings?

The next ring in Fig. 6 describes various means of intervention strategies. There are nine intervention functions. These are all techniques that can be presented to the staff units to get them to be suitably motivated to conduct the investigation and pre-job safety analysis. The final ring in Fig. 6 demonstrates policies that one can use when delivering the intervention strategies. Two of these are legislation and regulation. There is a legislative requirement to investigate accidents. Other requirements are to inspect the workplace and any equipment being used before conducting work, and this is environmental planning. The Neil George 5-point safety system and the field level risk assessment outline this environmental planning.

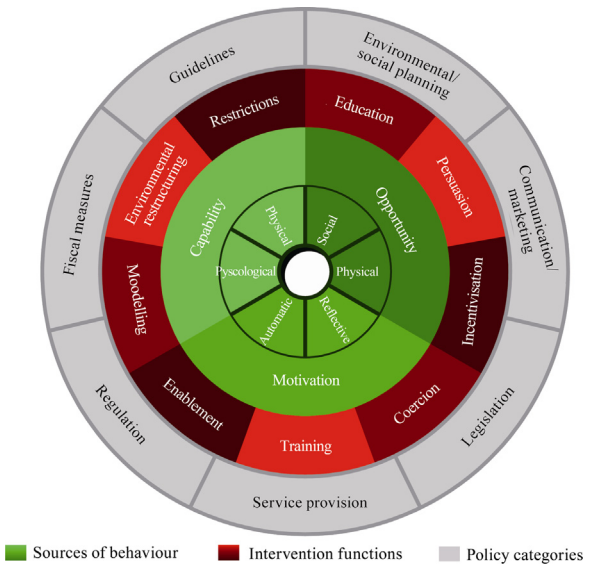

Fig. 6. Behaviour change wheel [8].

The United Kingdom's Health and Safety Executive's Health and Safety Laboratory (HSL) has produced a behaviour change model based on the COM-B. This model will more specifically understand all influences on health and safety behaviour in a work context and to provide a framework for determining appropriate interventions to encourage sustainable behaviour change.

5. Actual cases

The Neil George five-point safety system or field level risk assessments (FLRA) as applied to real life accidents.

5.1. Drill hole cleared–loaded drill hole

A surface drill operator drilled into a hole loaded with explosives causing the explosives to detonate. The operator was assigned before the shift began to clear drill holes of material that had sloughed into them by drilling from surface to an underground stope. These holes were loaded. The resulting explosion expelled the drill string from the drill hole. Workers underground in the cross-cut that was driven into the open stope where this incident took place were flattened by the explosion percussion.

If the pre-job safety analysis had been completed properly, the questions that would have been answered in this example are:

(1) Would the driller have checked for evidence of the holes being loaded?
(2) Would the underground miners have checked what work was being conducted near the stope including any surface work?

5.2. Fall protection not worn–open hole

A worker fell 20 m through a lifting well to the ground. He, along with the rest of his scaffold construction crew, was part of a team building a mill transfer tower which was 20 m above ground level. He was a junior member of the crew. He had completed a field level risk assessment for the crew by himself from ground level and the entire crew signed it off even though they were not present while it was being completed. It had been noted that fall arrest was required. This had not been noted on the FLRA at the locations where fall arrests were required. The worker was passing construction material from 20 m above ground level to the more senior members of the crew constructing the scaffold above. He was not wearing fall arrest. He had to collect some tubing from a collection area beside the lifting well. He went around the collection area to fetch tubing when he stepped into the open hole of the lifting well and fell 20 m to the ground.

If the pre-job safety analysis had been completed properly, the questions that would have been answered in this example are:

(1) What would have been revealed if the entire crew including more experienced members had done the risk assessment at the elevation where the work was carried out?
(2) Would the open hole have been noticed if they were at the workplace 20 m above ground?
(3) If noticed, would the open hole have been covered or would they have been wearing fall arrest while working around it to prevent them from falling through the hole?

5.3. Oil hose disconnected–open flame heater

Two workers inside a surface diamond drill rig were burned. While the drill was operating, a hose carrying hydraulic oil detached from a nipple and sprayed the driller and helper with the hydraulic oil. It was an extremely cold day and the inside of the drill rig was being heated with an open flamed propane heater. This open flame set the workers alight.

If the pre-job safety analysis had been completed properly, the questions that needed answering in this example are:

(1) Would the competence of the connections have been tested?
(2) Would the preventative maintenance records of the drill rig have been checked and noted as not up-to-date?
(3) Would an open-flame propane heater inside a drill rig have been identified as unsafe?

5.4. Wood cover walked on–steam weakened wood

Three workers fell 3 m into brine which was hotter than 90 °C. The tank was partially drained but there was still brine in the bottom that partially immersed them. Rakes used to mix the solution were still operating. The workers were employed by a service provider whose services were used to replace a section of wooden cover on a section of the top of a thickener tank in a mineral processing plant.

This tank was about 3 m high and 20 m in diameter. The wooden cover was comprised of planks that were supported by wooden beams that were suspended between steel beams that radiated from the centre. The steam from the hot brine weakened the wooden beam structure. In the orientation session that the workers had to attend upon arrival, they were told not to walk on top of the thickener tank.

The section that they were working on was on the side of the thickener tank away from the door. This meant that they would have to deposit the wood on the floor, pick up the wood from the floor, walk around the tank and other mineral processing machinery, and leave the wood at the door. What they did instead was carry the wood on top of the thickener tank to the side closest to the door and deposit the wood on the floor by the door.

While walking on the top of the tank, a wooden beam on which the planks were suspended failed. They fell into the tank. When it was noted that the workers were missing, the porthole on the side of the tank was removed and the workers recovered.

If the pre-job safety analysis had been completed properly, the questions that needed answering in this example are:

(1) Would the working place used as a travelway on top of the tank have been checked and questioned as to its competence?
(2) Would it have been noted that they were not working safely as had been indicated in the orientation session where they were instructed not to walk on the thickener top?

5.5. Ribbon conditioner exposed–corkscrew operating

A worker fell through a hole in the grating on top of a ribbon conditioner. This ribbon conditioner was used to mix solution. During operation, the ribbon conditioner was guarded by grating. This grating in the mineral processing plant has dust piled on it. The worker was assigned to clean the grating.

The worker used a water hose to clean the grating. While he was hosing the grating off, he put weights on the hose to stop it from moving around. He used spent grinding rods as weights. He also removed a piece of grating to expose a hole into which he hosed the dust. While hosing, he slipped through the hole in the grating onto the ribbon conditioner. He pulled in one of the grinding rods which stopped the screw conveyor before he proceeded through the system.

If the pre-job safety analysis had been completed properly, the question that needed answering in this example is:

Would the worker have noted that he was close to the hole and there were tripping hazards in the area?

5.6. Ice covered water ploughed–ice opened

A worker drove a front-end loader (FEL) over a crack in the ice on ice-covered water. This was at a site cleared of snow previously for a diamond drill rig. On the sides of this site, there were windrows on the ice. These windrows were composed of the snow that was cleared.

After a site has been cleared, it is no longer insulated by snow. As such, it thickens and becomes more buoyant than the ice under the windrow. Because it is buoyant, it rises in relation to the ice in the windrow which had been weighted down with the extra snow. Once it rises, the weight makes the ice move down in relation to the ice in the windrow. Until it reaches steady-state, this movement creates cracks in the ice. Therefore, one must not cross windrows after the ice has been exposed for an hour.

The worker was assigned to clear this site with the FEL because there was more snow on it. He cleared the snow from the centre of the windrow, crossed the windrow, and deposited the snow. When crossing the windrow to return, he drove his FEL over a crack in the ice below the windrow. The FEL and he went through the crack in the ice into the cold lake water.

During the investigation, it was noted that the operator did not have any previous training about clearing snow off ice covered water. Instant messages that he shared with his brother shortly before this mishap revealed that this was a new work environment for him.

If the pre-job safety analysis had been completed properly, the questions that need answering in this example are:

(1) Would he have noted that he could not assess whether the working place was in good order because he did not have training as to how to work on ice?
(2) Would he have noted that he did not know whether he was working safety and whether he would continue to work safely because he did not have appropriate training?

5.7. Roadway foundation removed–ground gave way

A miner drove a load-haul-dump vehicle (LHD) into an open stope. He started his shift working on the construction crew. During the shift, a supervisor assigned him to work on the production crew for the rest of the shift. The job to which he was assigned was to remove ore from a stope in the lower levels of the mine with an LHD. He was performing this task but it was hot and dusty at this depth in the mine. He drove the LHD to higher levels in the mine to look for dust masks. For some reason, he drove into the upper level of the stope from which he was removing ore. This ore removal resulted in the road foundation being removed. There was a sign that prohibited passage past the point beyond which the ore was being withdrawn. This sign was on a rope that was meant to stretch across the cross-cut; the rope was not connected across the cross-cut. He drove past this point. It is thought there was a crust of rock over the stope for which the ore was being withdrawn that he successfully drove over. When he drove over this crust while returning, the ground gave way and the LHD went through this crust.

If the pre-job safety analysis had been completed properly, the questions that needed answering in this example are:

(1) Would the no-entry sign on top of the stope have been noticed even though it was not properly put up?
(2) Would the operator have been aware of the reason the sign was present?
(3) Should contact have been made with someone before driving anywhere near this stope?

6. Conclusions

In this paper, the Neil George five-point safety system and the field level risk assessment guidelines are reviewed and discussed. It is shown through actual cases that the likelihood of incidents and their severity could be reduced by conducting effective pre-job safety analyses. These two tools, when used by management, supervision and workers, will result in significant outcomes that will further lesson the likelihood of future incidents, and even if they do, they will not be as severe. The merits of using the behaviour change wheel (BCW) are also discussed. Behaviour change dialogues will outline the value in conducting practical investigations and pre-job safety analyses.

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