X Distribution of Accidents That Occurred in All Units of Coal Fired Thermal Power Plant by Using HFACS Technique

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Necessary measures should be taken to ensure that the energy is uninterrupted in coal-fired thermal power plants. For this reason, in the study, 100 accident reports that occurred in 13 units between 2016-2019 at the X coal-fired power plant were analyzed. The causal factors of these accidents were analyzed statistically and classified using the human factor analysis and classification system (HFACS) method. As a result of the study, the accidents that occurred in 13 units were analyzed according to the HFACS category in the tables and it was concluded that most of them were caused by inadequate management.

Keywords: Human Factors Analysis and Classification System (HFACS), occupational accidents, coal thermal power plant
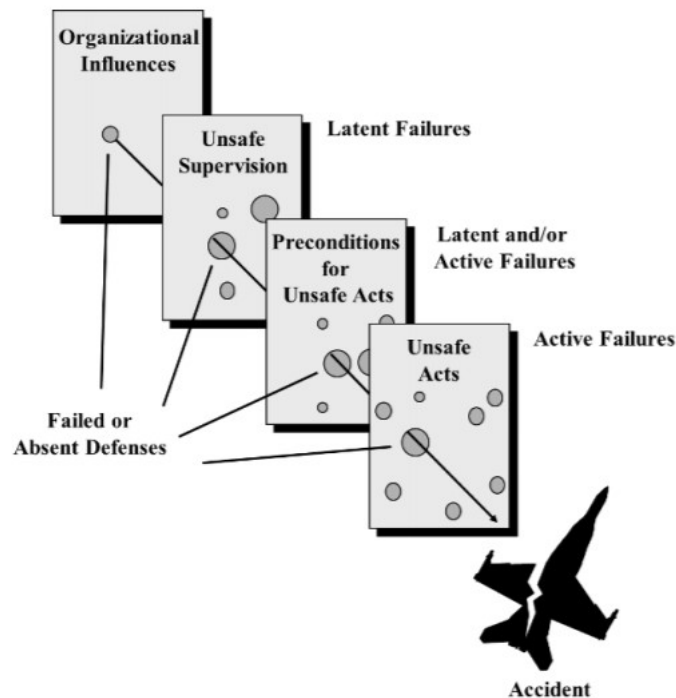
INTRODUCTION

Human error is seen as an inappropriate or unacceptable human decision or action that reduces efficiency, security, and system performance. When the accidents that ocur and the sectors they occur are examined, it is difficult to find out what caused this situation if the accidents are caused by the human factor. In accident analysis, if the cause of the accident is not a mechanical failure, the analysis to be performed will be intuitive. However, advanced tests are sufficient to detect mechanical faults. There is the HFACS Method used to create the accident database for the detection of human error in the accidents that occur. The HFACS Method was developed by Shappell and Wiegmann. HFACS is derived from Reason's Swiss Cheese Model. HFACS is a very useful method used in aviation, maritime, health and many other sectors. In the study, the accidents that occurred in the coal-fired thermal power plant were examined. The causes of the accidents were determined using the HFACS method and an accident database was tried to be created.

Swiss Cheese Model

It is an approach recommended by Reason (1990) that draws particular attention to the occurrence of human error. Reason (1990) explains that accidents can be examined up to four levels of failure. These are Unsafe actions, Prerequisites for unsafe actions are Unsafe control and Organizational effects. The system is similar to the Swiss cheese slice, as shown in the Fig. 1. Cheese represents barriers and protects against failure. Holes also show remaining errors. When holes and errors are lined up at every level in the system,

the system is prone to an accident. The Swiss Cheese Model shows the reasons for the occurrence of errors. The model explains that this is a series of events, not necessarily an event that caused an error. Briefly, The Swiss Cheese Model shows the reasons behind why errors occur. It explains that it is not necessarily one event that leads to an error, but a series of events. Errors in an institution are considered losses; the role of risk management is to prevent losses from occurring. However, this model was not sufficient to identify and classify the actual and latent causes in a systematic method. In order to satisfy this need, the HFACS framework was generated.

FIGURE 1
THE "SWISS CHEESE" MODEL OF HUMAN ERROR CAUTIONS

Human Factors Analysis and Classification Systems (HFACS)

    The human factor analysis and classification system (HFACS) was introduced in 2000 by Shappell and Wiegmann, and Reason (1990) is a method derived from the Swiss Cheese Model. It is the most widely used and reliable method to examine and classify the causal factors of accidents and incidents in various industries such as medicine, construction, marine, mining industry, oil, aviation, railway. The result of previous researches in the different industry fields appears that HFACS is a reliable retrospective tool to analysis the extensive accident investigation reports, identifying where and which errors a reliable retrospective tool to analysis the extensive accident investigation reports, identifying where and which errors and adverse events are underlying organizational system. The human factor analysis and classification system is a model designed to find the root causes of human errors. HFACS has defined the human factor at four levels, namely Unsafe Acts, Preconditions for Unsafe Acts, Unsafe Supervision and Organization Influences. Within these four levels, there are many subcategories that further explain the contributing human factor. The HFACS framework is shown in Fig. 2

FIGURE 2
HFACS FRAMEWORK, EACH UPPER LEVEL WOULD AFFECT DOWNWARD LEVEL,
PROPOSED BY WIEGMANN AND SHAPPEL
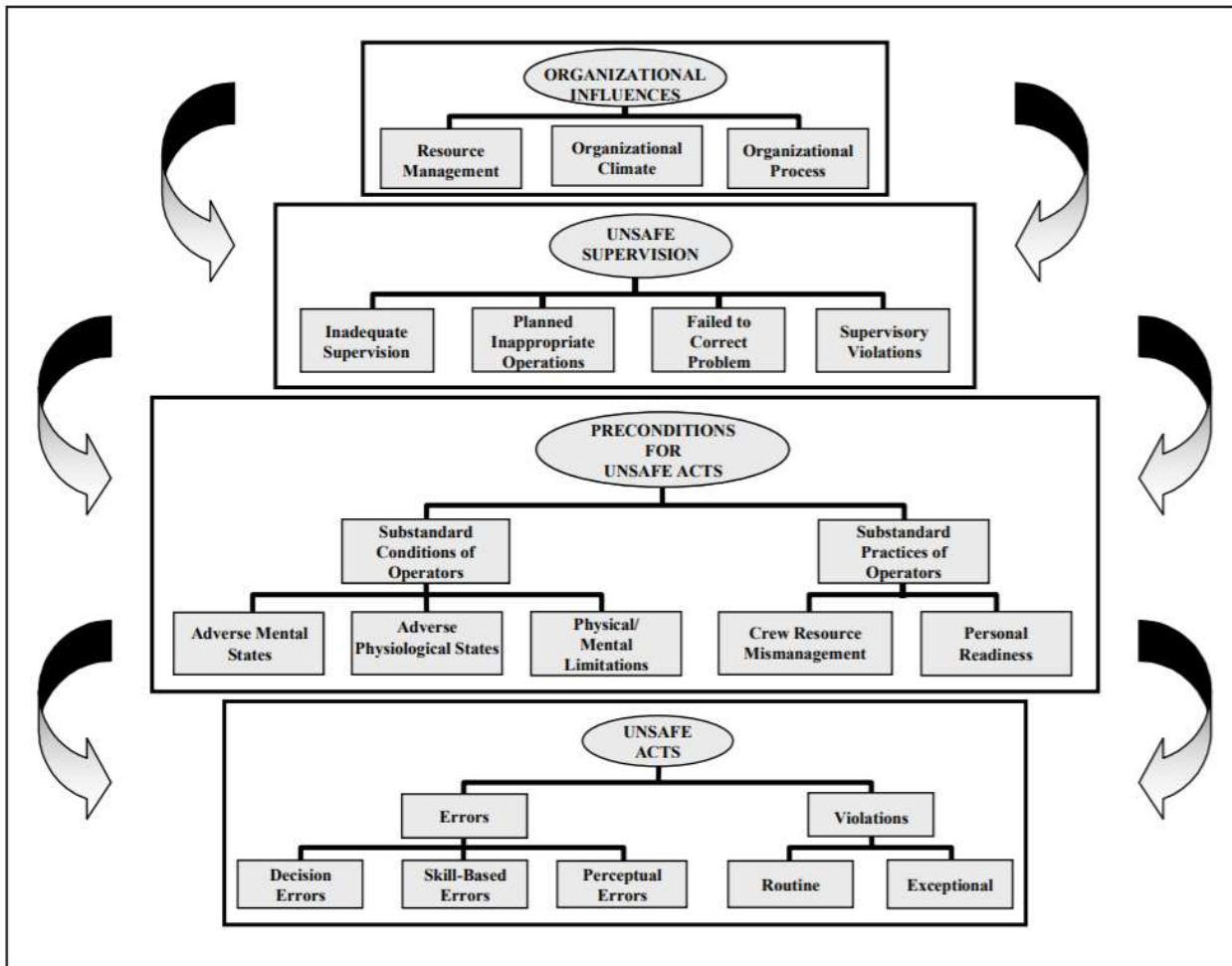
HFACS examines human error at four levels. Each higher level affects the next downward level in HFACS framework.

Level-1 Unsafe acts of operators: This level is where the majority of causes of accidents are focused. Such causes can be classified into the two basic categories of errors and violation. While errors involve unintentional unsafe acts, violations involve unsafe acts that employees of thermal power plant has performed on its own initiative. In other words, errors can be described as "legal" unsafe acts that lead to involuntary bad results. The HFACS model refers to three kinds of errors. These are; decision errors, perceptual errors, skill-based errors. Violations are divided into two groups; routine and exceptional violations.

Level-2 Preconditions for unsafe acts: This level tackles the hidden failures within the causal sequence of events as well as more obvious active failures. It also identifies the context of substandard conditions of operators and the substandard practices they adopt. It is argued that unsafe acts can cause about 80% of accidents but focusing only on unsafe acts resembles focusing on the illness rather than the underlying cause. Therefore, researchers should first try to find out what caused the unsafe act. The preconditions for unsafe acts are examined under two headings; the substandard practices of operators and the substandard conditions of operators.

Level-3 Unsafe supervision: This level traces the causal chain of events producing unsafe acts up to the front-line supervisors. According to Reason's Swiss Cheese Model, this error group, which is located in the 3rd class of the HFACS framework, consists of errors and violations made by management. Unsafe supervision is examined under four main headings. These are; inadequate supervision, planned inappropriate operations, failure to correct a known problem and supervisory violations.

Level-4 Organizational influences: This level involves the hardest to get of these latent failures, fallible decisions of upper levels of management, which directly affect supervisory practices, as well as the conditions and actions of front-line operators. Organizational influences are the most overlooked errors in analysis. Errors in this level directly affect unsafe supervision and indirectly affect unsafe acts. The HFACS model refers to three types of organizational influences; resource management, organizational climate and organizational process.

METHODOLOGY

Data Sources

This study is based on the analysis of accidents that occurred in X Coal Fired Thermal Power Plant between 2016 and 2019. Accidents will be classified according to the HFACS method and an accident database will be occurred.

Analysis of the Data

100 serious accidents occurred between 2016 and 2019 at the X coal fired thermal power plant. These accidents have occurred due to falling from height, fracture, falling object, fire, chemical contact etc. Accidents mostly occurred in the boiler operating unit of the system. The number of accidents and their percentages in the system are shown in the Table 1 below. According to Table 1, the highest accident percentage occurred in the boiler operating unit with 20%. The lowest accident percentage belongs to the turbine maintenance unit.

TABLE 1
UNITS WHERE THE ACCIDENTS OCCURED AND ACCIDENT PERCENTAGES

Boiler Maintenance	7 %
Boiler Operation	20 %
Turbine Maintenance	3 %
Mill Maintenance	8 %
Electrical Maintenance	4 %
Flue Gas Treatment	4 %
Coal Taking and Preparation Department	11 %
Ash slag Processing Unit	7 %
Turbine Operation	4 %
External Facilities Mechanical Maintenance	11 %
Flue Gas Operation	5 %
Electrical Operation	5 %
Construction Maintenance	11 %

In order to classify the factors underlying 100 boilers in the X coal fired thermal power plant, 558 categories have been assigned to each of the four HFACS categories. The obtained statistics are analyzed and shown separately in the tables. The 100 accidents that occurred in the coal-fired thermal power plant are shown by HFACS codes as belonging to separate units in Table 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14.

TABLE 2
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE BOILER MAINTENANCE UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	9	21
Routine Violations	7	17
Inadequate Supervision	6	14
Adverse Mental States	3	7
Crew Resource Mismanagement	3	7
Supervisory Violations	4	10
Skill-based Errors	1	2
Physical Environment	2	5
Planned Inappropriate Operations	1	2
Decision Errors	2	5
Failure to Correct a Known Problem	1	2
Personal Readiness	2	5
Adverse Physiological States	1	2

TABLE 3
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE BOILER OPERATION UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	12	13
Routine Violations	7	7
Inadequate Supervision	17	18
Adverse Mental States	17	18
Crew Resource Mismanagement	2	2
Supervisory Violations	11	11
Skill-based Errors	5	5
Physical Environment	7	7
Planned Inappropriate Operations	2	2
Decision Errors	11	11
Personal Readiness	1	1
Adverse Physiological States	2	2
Physical/ Mental Limitations	1	1
Resource Management	1	1

TABLE 4
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE TURBIN MAINTENANCE UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	1	6
Routine Violations	2	11
Inadequate Supervision	2	11
Adverse Mental States	2	11
Crew Resource Mismanagement	1	6
Supervisory Violations	1	6
Skill-based Errors	2	11
Physical Environment	1	6
Planned Inappropriate Operations	1	6
Decision Errors	1	6
Resource Management	1	6
Unexpected/ Exceptional Violations	2	11
Failure to Correct a Known Problem	1	6

TABLE 5
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE MILL MAINTENANCE UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	4	9
Routine Violations	6	13
Inadequate Supervision	8	17
Adverse Mental States	4	9
Crew Resource Mismanagement	1	2
Supervisory Violations	5	11
Skill-based Errors	1	2
Physical Environment	3	7
Planned Inappropriate Operations	1	2
Decision Errors	4	9
Resource Management	1	2
Unexpected/ Exceptional Violations	3	7
Technology Environment	3	7
Perceptual Errors	1	2
Physical/ Mental Limitations	1	2

TABLE 6
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE ELECTRICAL MAINTENANCE UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	2	9
Routine Violations	5	22
Inadequate Supervision	3	13
Adverse Mental States	1	4
Supervisory Violations	4	17
Skill-based Errors	2	9
Decision Errors	3	13
Resource Management	1	4
Failure to Correct a Known Problem	1	4

TABLE 7
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE FLUE GAS TREATMENT UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	2	9
Routine Violations	4	17
Inadequate Supervision	6	26
Adverse Mental States	4	17
Decision Errors	4	17
Planned Inappropriate Operations	1	4
Physical Environment	1	4
Crew Resource Mismanagement	1	4

TABLE 8
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE COAL TAKING AND PREPERATION UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	9	13
Routine Violations	7	10
Inadequate Supervision	10	15
Adverse Mental States	3	4
Decision Errors	3	4
Planned Inappropriate Operations	1	1
Physical Environment	5	7
Crew Resource Mismanagement	3	4
Adverse Physiological States	3	4
Skill Based Errors	5	7
Technology Environment	4	6
Supervisory Violations	8	12
Perceptual Errors	1	1
Resource Management	3	4
Failure to Correct a Known Problem	1	1
Organizational Climate	1	1

TABLE 9
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE ASH SLAG PROCESSING UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	4	11
Routine Violations	7	19
Inadequate Supervision	7	19
Adverse Mental States	6	16
Decision Errors	4	11
Planned Inappropriate Operations	1	3
Crew Resource Mismanagement	4	11
Technology Environment	2	5
Perceptual Errors	1	3
Failure to Correct a Known Problem	1	3

TABLE 10
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE TURBINE OPERATION UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	2	10
Inadequate Supervision	4	19
Adverse Mental States	3	14
Decision Errors	1	5
Technology Environment	2	10
Failure to Correct a Known Problem	2	10
Adverse Physiological States	1	5
Physical Environment	1	5
Supervisory Violations	3	14
Organizational Climate	1	5
Resource Management	1	5

TABLE 11
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE EXTERNAL FACILITIES MECHANICAL MAINTENANCE UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	3	5
Inadequate Supervision	10	16
Adverse Mental States	5	8
Decision Errors	4	7
Technology Environment	4	7
Supervisory Violations	10	16
Organizational Climate	2	3
Resource Management	2	3
Crew Resource Mismanagement	2	3
Routine Violations	9	15
Skill Based Errors	5	8

Adverse Physiological States	1	2
Failure to Correct a Known Problem	2	3
Physical Environment	1	2
Planned Inappropriate Operations	1	2

TABLE 12
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE FLUE GAS OPERATION UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	6	29
Inadequate Supervision	2	10
Adverse Mental States	1	5
Decision Errors	2	10
Technology Environment	1	5
Supervisory Violations	3	14
Organizational Climate	1	5
Resource Management	2	10
Crew Resource Mismanagement	1	5
Routine Violations	2	10

TABLE 13
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE ELECTRICAL OPERATION UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	2	7
Inadequate Supervision	6	22
Adverse Mental States	3	11
Decision Errors	2	7
Technology Environment	2	7
Supervisory Violations	3	11
Organizational Climate	1	4
Resource Management	1	4
Crew Resource Mismanagement	1	4
Skill Based Errors	1	4
Adverse Physiological States	1	4
Failure to Correct a Known Problem	1	4
Physical Environment	1	4
Planned Inappropriate Operations	1	4
Physical/ Mental Limitations	1	4

TABLE 14
FREQUENCY AND PERCENTAGE OF ACCIDENTS OCCURING IN THE CONSTRUCTION MAINTENANCE UNIT BY HFACS CATEGORIES

HFACS CATEGORIES	FREQUENCY	% OF ALL ACCIDENTS
Organizational Process	9	13
Inadequate Supervision	16	22
Adverse Mental States	2	3
Decision Errors	6	8
Technology Environment	4	6
Supervisory Violations	5	7
Organizational Climate	2	3
Resource Management	4	6
Crew Resource Mismanagement	6	8
Skill Based Errors	2	3
Physical Environment	2	3
Physical/ Mental Limitations	1	1
Planned Inappropriate Operations	3	4
Routine Violations	10	14

RESULT AND DISCUSSION

100 accidents occurring in the thermal power plant were examined and the human factors contributing to the accidents were classified correctly. In the boiler maintenance and flue gas operation unit, accidents were investigated and classified according to the HFACS Method. It was concluded that the cause of the accidents in the Boiler Maintenance and Flue Gas Operation unit was due to the organizational process according to the HFACS Method. When examined in this direction in other units, it is seen that most of the accidents according to the HFACS category are highly caused by inadequate management.

Based on the findings presented here, when the tables are examined, it is seen that the most important factor contributing to the accidents is the insufficient management factor. Inadequate management factor indicates the primary cause of accidents that cause accidents in all kinds of operations in thermal power plants. It is undeniably important to carry out the necessary inspection and train the personnel. The data also showed that accidents were errors that can result from organizational processes, routine violations, and poor mental states. As the vast majority of accidents are due to poor management, management should implement more innovative approaches and carry out regular audits.

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