Operability Study of a Grain Processing and Handling Facility

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ABSTRACT

An operability study has been performed to identify the latent risks in a grain processing and handling facility. The methodology which had been devised to examine the design and operation safety of chemical plants is applied here to the operation of grain processing and handling facilities. The study presents the results of analyzing the bucket elevator subsystem of a grain elevator for the purpose of identifying potentially dangerous conditions. Possible causes and consequences of component failures or improper operating conditions in the bucket elevator subsystem are systematically identified and corrective actions that are required to improve the safety of the subsystem are presented.

INTRODUCTION

The United States is a principal supplier of grain in the world market, and since production and export of grain are continually rising, the role of grain processing and handling facilities is becoming increasingly important in the United States. Therefore, the series of severe grain elevator explosions that occurred during the months of December 1977 and January 1978 aroused much public concern about the safety and security of operating grain elevators. Since then much effort has been made to identify the causes of dust explosions and to develop preventive measures, but explosions still continue to occur.

In this work the principle of the operability study (Lawley, 1974; 1976; Chemical Industry Safety, 1977; National Grain and Feed Association, 1979) which examines qualitatively the safety of a system, is elucidated. The method is applied to grain processing and handling facilities.

PRINCIPLE

The operability study was originally developed to examine the safety of chemical plants in the design stage (Lawley, 1974); however, the study is also effective for inspecting the safety of an existing plant. There is no reason to believe that it is not applicable to systems similar to chemical plants, e.g., grain elevators.

In an operability study, a series of questions is generated in an orderly but creative manner by a team of design and operations personnel. The team takes the position that a problem—be it in design or operations—can arise only when there is a deviation from the design or operating intentions, e.g., the failure of a leg belt in a grain elevator to move when it should. The operability study, therefore, is a method that examines the safety of a proposed design or existing plant by systematically identifying every conceivable process deviation. The study is carried out by applying a carefully chosen checklist of guidewords to each integral part of the system; Table 1 lists such guidewords. The use of guidewords ferments unrestricted thought to detect all conceivable process abnormalities.

TABLE 1. A LIST OF GUIDE WORDS

Guide words	Meanings	Comments
NONE	The complete negative of these intentions	No part of the intentions is achieved but nothing else happens
MORE OF LESS OF	Quantitative increases or decreases	These refer to quantities & properties such as flow rates and temperatures as well as activities like 'Heat' and 'React'
AS WELL AS	A qualitative increase	All the design and operating intentions are achieved together with some additional activity
PART OF	A qualitative decrease	Only some of the intentions are achieved; some are not
REVERSE	The logical opposite of the intention	This is mostly applicable to activities, for example reverse flow or chemical reaction
OTHER THAN	Complete substitution	No part of the original intention is achieved. Something quite different happens

Consider a process deviation such as the failure of a leg belt to move. The operability study team attempts to identify all causes, such as electrical failure of the head drive motor, mechanical failure of the head drive assembly, slippage between the leg belt and head pulley, etc., and all its consequential effects on the system, including failure of the bucket elevator to left grain, plugging in the boot, friction between the leg belt and head pulley leading to overheating, etc., and all its consequential effects on the system, including failure of the bucket elevator to lift grain, plugging in the boot, friction between the leg belt and head pulley leading to overheading etc. The procedure enables the team to unearth latent problems in the system. The procedure enables the team to unearth latent problems in the system. The principles, on which problem identification is based, are summarized in Fig. 1.

Actions required to eliminate the causes or to prevent consequences are usually decided on the basis of past experience. For a major risk subsystem, however, a quantitative examination must be carried out.

PROCEDURE

The preparative work, details of the procedure, and organization of findings of an operability study for an

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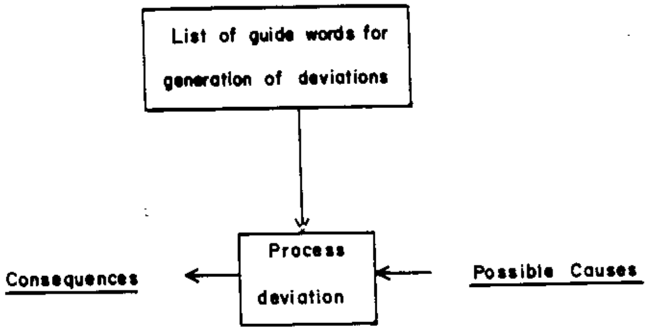

Fig. 1—Operability study for identifying potential problems in a system.

existing system are explained in this section.

Planning

The operability study of a system is usually accomplished by using diagrams that exhibit the function of the system. In the case of a grain processing and handling facility, diagrams depicting the structures and electric circuits of a bucket elevator and the conveyor system are needed in addition to the diagram that outlines the entire facility. For an existing system, these diagrams are not always available. The diagrams must them be prepared based on existing plans, personal observation, measurement, and the operating manuals and equipment catalogues.

For the study team to perform effectively, its members must be carefully selected. For an existing plant, it would include the study leader, who is a person well-trained in the technqiue of operability study, the design engineer (if available), the operations manager, and the maintenance engineer (if available). The leader's main responsbilities are to ensure that the full study procedure is followed and that every point, as it arises, is discussed and questioned to the correct level or detail.

Execution

An operability study involves the following steps.

Step 1: Outline the functions of the entire system in very broad terms at the beginning of the first study meeting. (This outline ensures that the team has an adequate background knowledge of the process and of the function of each subsystem within the total area.)

Step 2: Determine subsystems that have high risks.

Step 3: Select a subsystem and explain in detail its functions.

Step 4: Apply a list of guidewords to the subsystem. (The guidewords are listed in Table 1; the method for using them is illustrated in Fig. 2.) As the relations between the causes and consequences of each process deviation are brought to light, the need for action should be evaluated immediately by the team.

Step 5: Examine whether all selected subsystems have been considered. If not, return to step 3.

This five-step procedure is displayed in Fig. 3.

Organization of Findings

In general, one should consider the actions required both for eliminating probable causes and for preventing the possible consequences of the deviation. In the case of performing an operability study for an existing system, however, the emphasis should be on the examination of actions required for eliminating probable causes rather than actions required for preventing possible consequences from occurring.

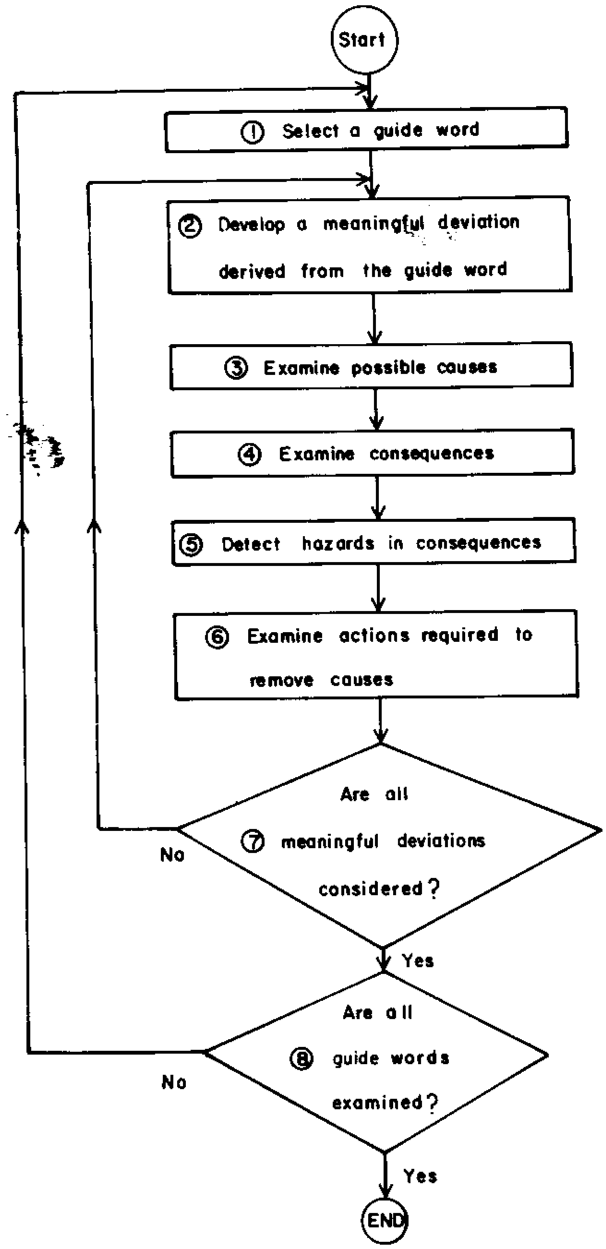

Fig. 2—Sequence for using the guide words.

Conventionally, findings from an operability study have been arranged in tables that contain deviations, their probably causes, consequences from the deviations, and actions required to eliminate or prevent them. In this paper, the findings are presented in a diagrammatic format in order to improve presentation of the relationship among a deviation, its probable causes, and its conceivable consequences, and to exhibit every action required for eliminating each cause. Referring to Fig. 8, an arrow on the right of a rectangle displaying a possible cause (e.g., BEL-a) is associated with an arrow on the left rectangle displaying the actions required for eliminating it (e.g., BEL-a).

DESCRIPTION OF THE SYSTEM

Fig. 4 exhibits the schematic of a grain elevator that contains two main sections, namely, the storage bins and the workhouse. A storage bin is usually built in the form

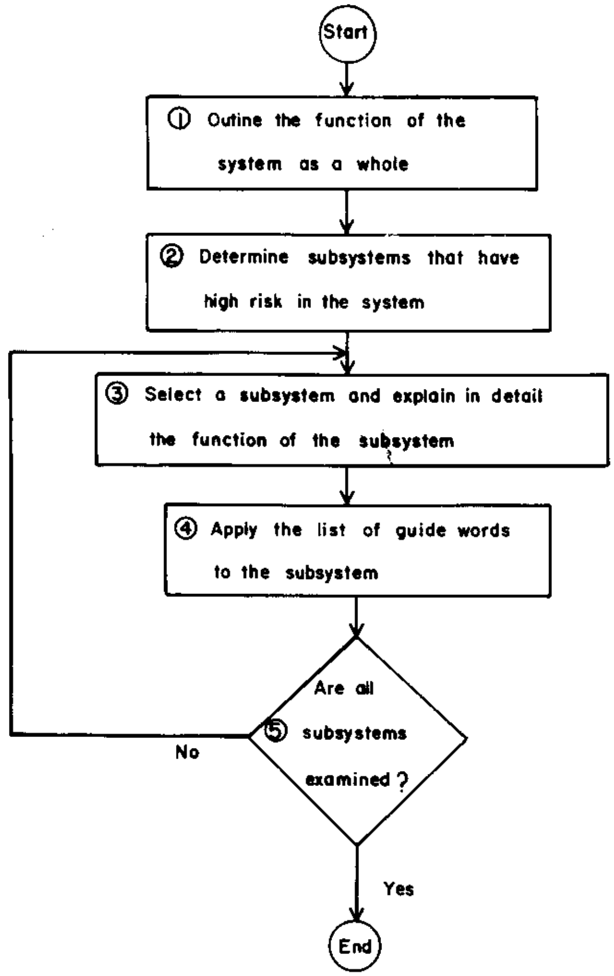

Fig. 3—Procedure for an operability study.

of a hollow cylindrical tower. The workhouse contains several levels where equipment for receiving, elevating, weighing, cleaning, and distributing grain are located. It also contains additional bins for holding, shipping, and mixing grain.

Incoming grain may arrive by truck, rail, or barge. In Fig. 4, the grain is unloaded from freight cars to receiving pits and is carried from the receiving pits to the boot spout by the conveyor system. The grain is fed from the boot spout to the boot, and then lifted from it to the garner. It is then moved from the garner to the scale bin where it is weighed.

The grain is fed from the scale bin to the upper conveyor system and is carried on the upper conveyor belt to a designated storage bin. The grain is poured into the bin through a moveable tripper for storage.

In shipping, the grain is discharged by gravity through a spout onto a loadout belt or conveyor. The grain is lifted again to the top of the elevator, from which it is moved to a designated workhouse bin. The grain is discharged from the bin into a freight car, barge, or ship.

It is known that the following subsystems have high malfunction risks (Schmidt, 1978):

1. Bucket elevator
2. Conveyor system from the receiving pit to the boot spout.
3. Upper conveyor system
4. Lower conveyor system
5. Dust collecting system

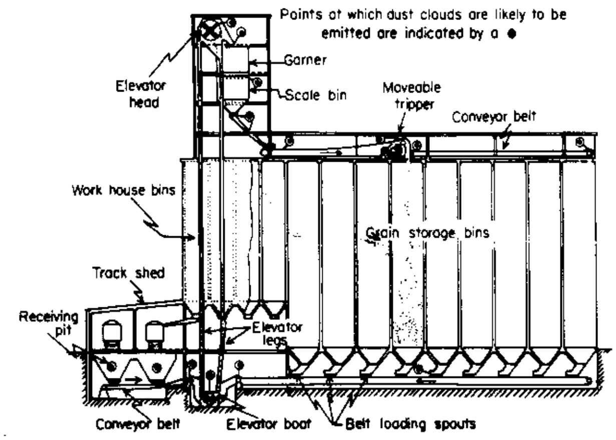

Fig. 4—Schematic of a typical grain elevator.

Bucket Elevator

Fig. 5 shows a typical bucket elevator. It consists of a continuous belt on pulleys called a leg belt, with buckets attached to it. The grain enters the boot at the bottom and is elevated by rotating the head pulley. Normally, the leg belt is moved at a constant speed and the volume of grain lifted to the garner is adjusted by the receiving pit gates and the belt loading spout gates. The boot shaft take-up is adjusted to maintain proper leg belt tension. Fig. 6 displays the electric circuit of the head drive system. An ammeter plays an important role in detecting an overload of the bucket elevator.

Conveyor system

The schematic of a conveyor system for transporting grain from the receiving pits to the boot spout is shown in Fig. 7. The head and tail pulleys, troughing, and return

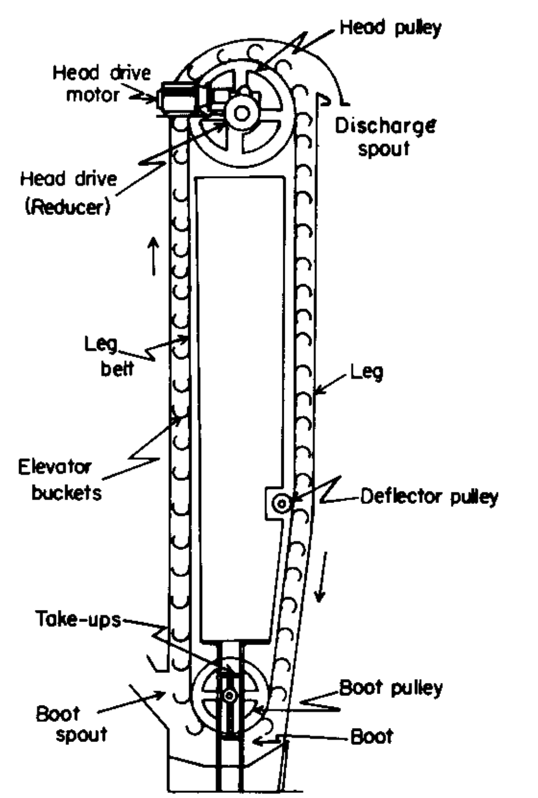

Fig. 5—Bucket elevator section of a typical grain handling facility.

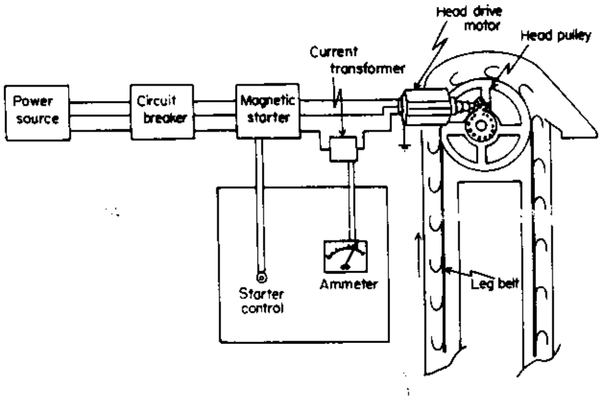

Fig. 6—Electric circuit diagram of head drive system.

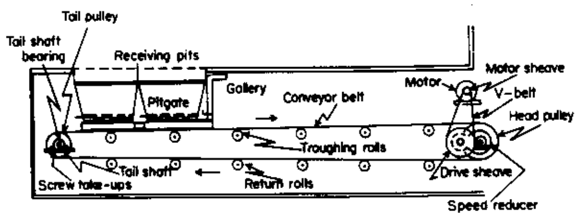

Fig. 7—Conveyor system for transporting grain from the receiving pit to the boot spout.

rolls are installed to maintain smooth movement of the conveyor belt. The screw take-ups that set up the tail shaft bearing are adjusted to maintain proper conveyor belt tension. The volume of grain fed from the receiving pits to the conveyor belt is controlled by the pit gates. It is important to adequately control the pit gates to prevent overfeeding grain onto the conveyor belt, which causes plugging of the boot.

A conveyor system is installed in the gallery that carries the grain to the storage bins. A dust system may be installed in the galley to collect dust generated there.

RESULTS AND DISCUSSION

In this section the results of an operability study of the elevator are presented and discussed. The conveyor system that carries grain from the receiving pits to the boot is quite similar to the bucket elevator; hence, the conclusions presented here can be applied to it as well.

Fig. 8 displays the results of applying the guideword "NONE" to the speed of the leg belt, which is an important state variable of the bucket elevator. Possible causes for the deviation, e.g., failure of the leg belt to move, are the electrical failure of the head drive motor, mechanical failure of the head drive assembly (failure of the head drive motor, head drive, or head drive shaft bearings), slippage between the leg belt and head pulley, and overloading of the leg. In other words, if the leg belt fails to move, possible consequences are various difficulties involving the bucket elevator, e.g., failure of the bucket elevator to lift grain, plugging in the boot, and overflow of grain from the boot spout onto the floor.

To illustrate how a probably cause can be prevented from occurring, the electrical failure of the head drive motor is examined. The actions to be taken are to inspect periodically the head drive motor, magnetic starter, circuit breaker, and electric circuit wire, and to repair or replace whatever appears worn or may malfunction. Although Fig. 8 exhibits actions required for eliminating

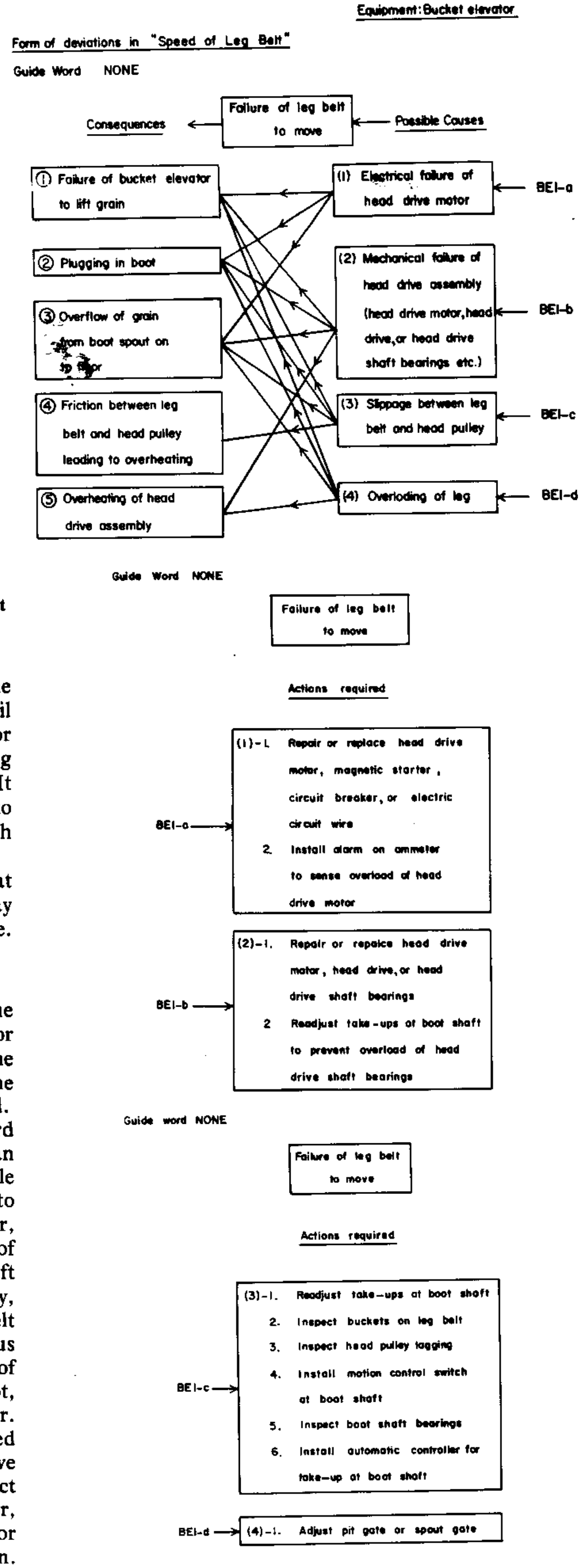

Fig. 8 -Results for the bucket elevator—failure of the leg belt to move.

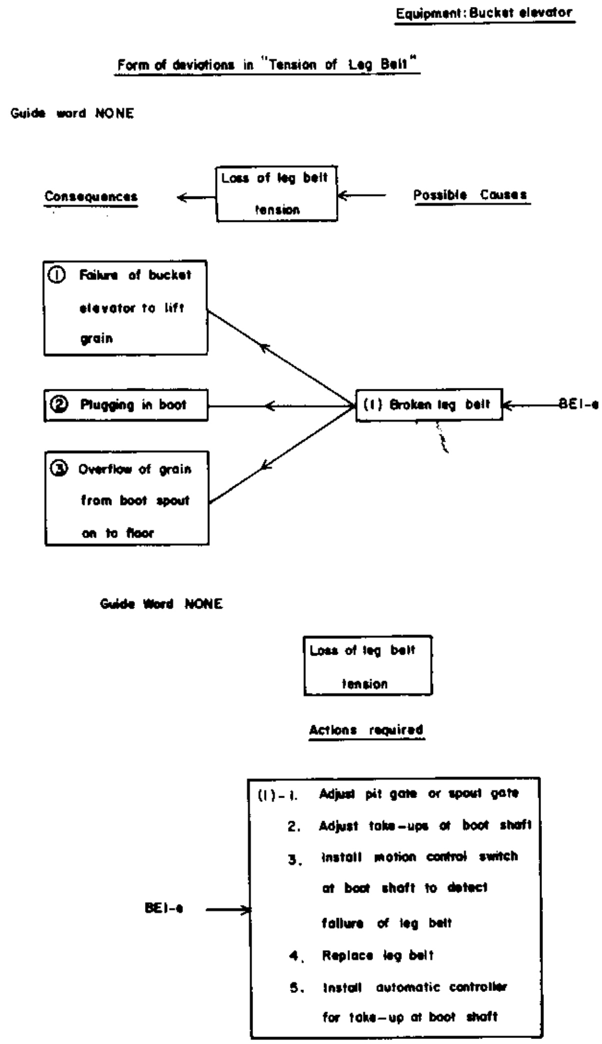

Fig. 9—Results for the bucket elevator—higher tension of the leg belt.

the probable cause, periodical inspections are omitted from the list because they are always necessary. An example of a required action is to install an alarm to the ammeter for detecting an overload of the head drive motor, which is a cause for failure. The actions required for eliminating other probably causes are similarly examined. The results of the investigation for other state variables and other guidewords are illustrated in Figs. 9 and 13.

RELATION BETWEEN OPERABILITY STUDY AND FAULT TREE ANALYSIS

Fault tree analysis is a systematic procedure used for examining a system in order to determine its component failure. To construct a useful fault tree, one must understand thoroughly the design and operating characteristics of the system. Thus, the operability study can play an important role toward the execution of a fault tree analysis by preventing an oversight in determining cause events.

CONCLUSIONS

By systematically investigating deviations from the normal operating condition of a process, an operability study can clarify the relations between the probable causes and consequences of the deviation. The

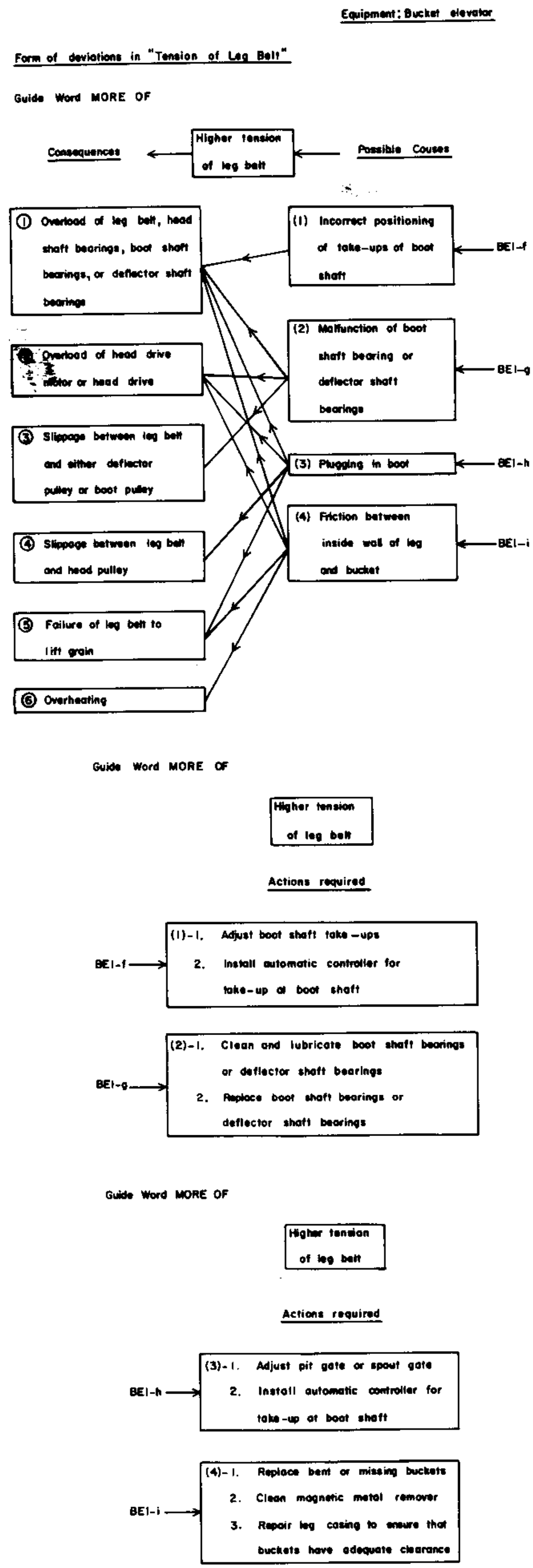

Fig. 10—Results for the bucket elevator—higher tension of the leg belt.

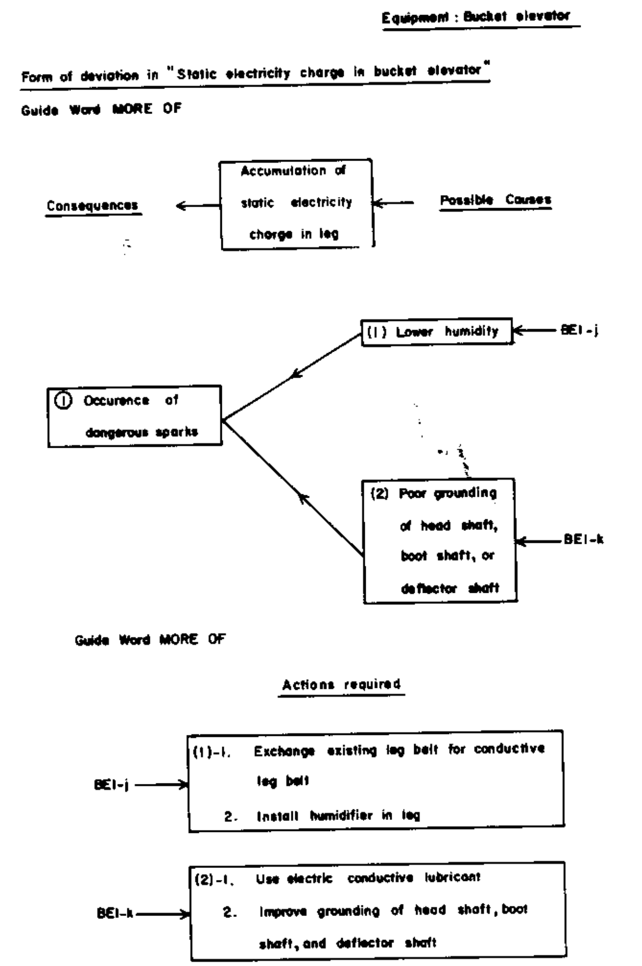

Fig. 11—Results for the bucket elevator—accumulation of static electricity charge in the leg.

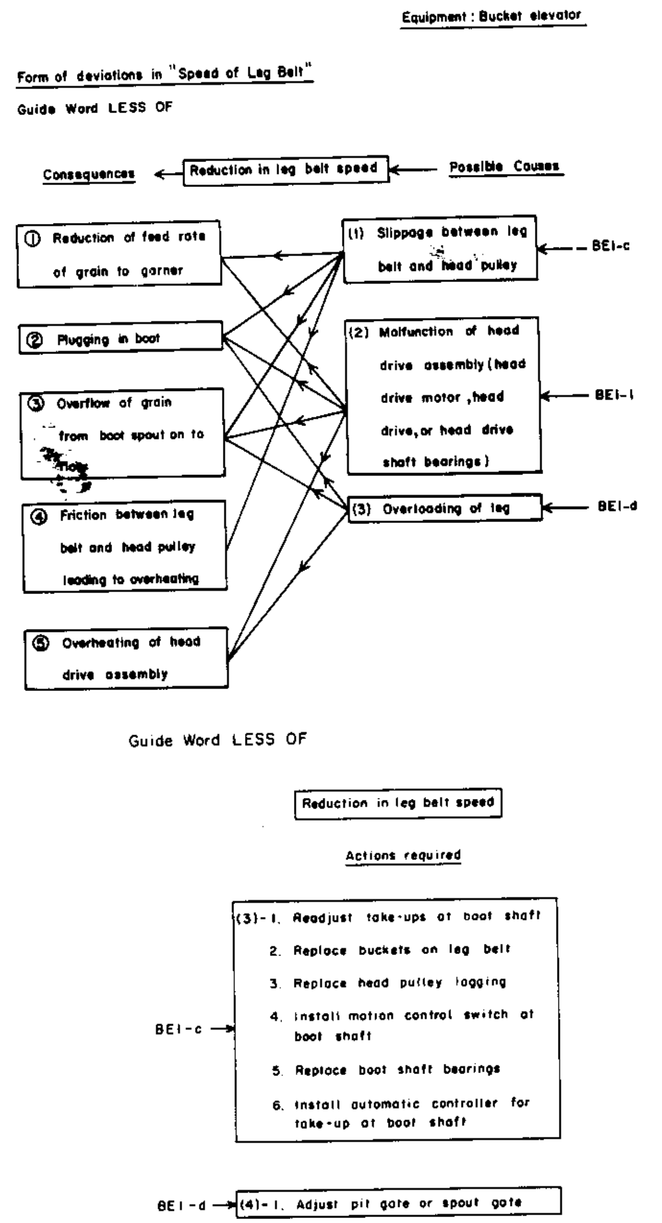

Fig. 12—Results for the bucket elevator—reduction in the leg belt speed.

operability study provides a means of systematically identifying malfunctions in the components of a system and the actions required for preventing them. Other subsystems of the grain elevator can be similarly examined.

The results of this investigation can be used:

1. For operators and maintenance workers to deepen their understanding of the importance of their actions in preventing accidents.
2. For management to improve safety and operating standards.
3. For constructing a fault tree to investigate probable causes of accidents.

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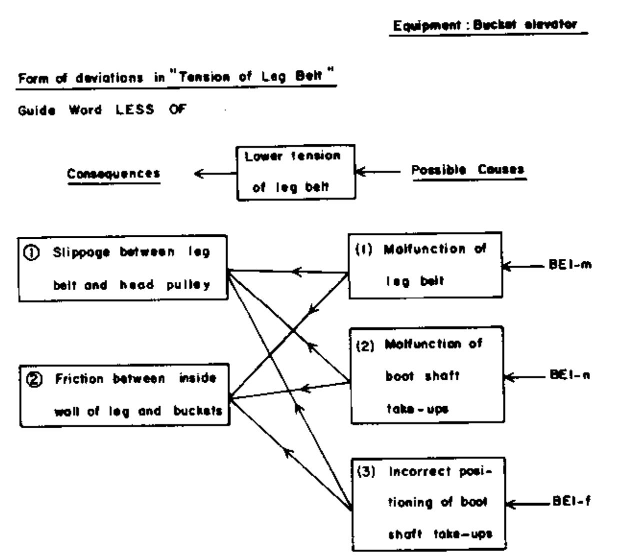

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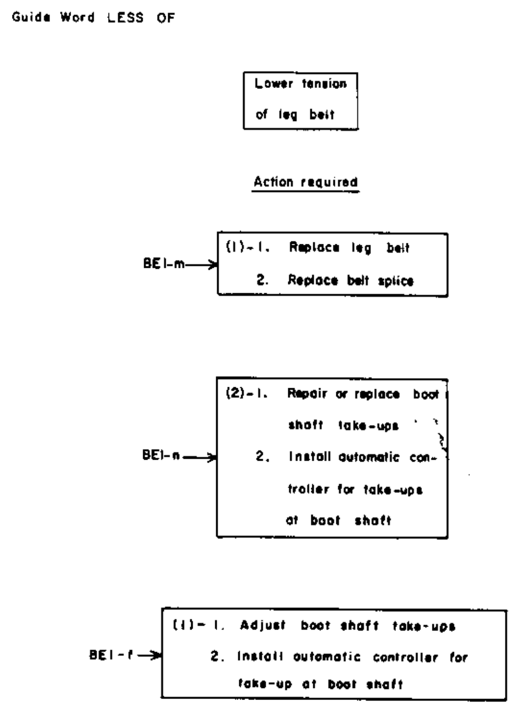

Fig. 13—Results for the bucket elevator—lower tension of the leg belt.