LESSON IV
ENERGY FLOW/BARRIER ANALYSIS

PURPOSE: To introduce the student to the concepts and applications of energy flow/barrier analysis.

OBJECTIVE: To acquaint the student with the following:

1. Philosophical foundation for energy flow/barrier analysis
2. Types of energy sources, barriers and targets which are considered when doing an energy flow/barrier analysis
3. Use of energy flow/barrier analysis as a "thought model" when completing a preliminary hazard analysis
4. Use of energy flow/barrier analysis in the occupational setting
5. Use of energy flow/barrier analysis in emergency response situations
6. Procedure for performing energy flow/barrier analysis
7. Advantages and limitations of energy flow/barrier analysis

SPECIAL TERMS:

1. Barrier
2. Target
3. Energy source
4. Countermeasure
5. Energy flow
6. Energy trace/barrier analysis

DESCRIPTION

Energy flow/barrier analysis (EFBA) is a system safety analysis tool used to identify hazards and determine the effectiveness of countermeasures employed or proposed to mitigate the risk induced by these hazards [1]. This tool is also known as energy trace/barrier analysis (ETBA). The energy flow/barrier method is a useful supplement to the preliminary hazard analysis discussed in Lesson III. Energy flow/barrier analysis does not employ a separate worksheet from that used for preliminary hazard analysis (PHA). Most analysts consider EFBA as a *thought process that can be used when performing a preliminary hazard analysis*. That is, a hazard (energy source) poses a risk to a target if the barriers between the energy source and the target are inadequate.

Energy sources are identified, such as electrical, mechanical, chemical, radiation, etc. Resources (targets) to be protected are identified, such as, employees, equipment, facilities, environment, quality, production capability, inventory, etc. Then the analyst assesses opportunities for undesired energy flow between the sources and targets. Barriers are countermeasures (physical or administrative) deployed against hazards caused by flows from these energy sources to targets. Examples of barriers include: barricades, blast walls, fences, lead shields, gloves, safety glasses, procedures, etc.

It is important to remember that each analytical technique discussed in this module complements (rather than supplants) the others. This is because each technique attacks the system to be analyzed differently—some are top-down, others are bottom-up. Though it has long been sought, there is no "Swiss army knife" technique that answers all questions and is suitable for all situations.

See http://www.sverdrup.com/svt for presentation slides that support this lesson.

APPLICATION

An energy flow/barrier analysis can be beneficially applied whenever assessments are needed to assure that an identified target (resource) is being safeguarded against a potential energy source that can impose harm. This assessment can be applied during the *design and development* phase but may also be applied in the *operations* phase or *concept definition* phase. This analysis can also be applied in failure investigations and when making "safe to enter" decisions during emergency response situations. Examples of its use in making "safe to enter" decisions include analysis of the state of all utilities (including steam, gas, electrical, etc.) before allowing rescue teams into a damaged building.

PROCEDURES

Procedures to perform an energy flow/barrier analysis are presented below[1]:

(1) Examine the system and identify all energy sources.

(2) Examine each potential energy flow path in the system. Consider the following for each energy flow path:

- What are the potential targets, such as personnel, facilities, equipment, productivity, mission or test objectives, environment, etc.? Remember that every energy source could have multiple flow paths and targets.

- Is the energy flow unwanted or detrimental to a target?

- Are existing barriers sufficient countermeasures to mitigate the risk to the targets?

(3) Consider the following strategies to control harmful energy flow [1]:

- Eliminate energy concentrations
- Limit quantity and/or level of energy
- Prevent the release of energy
- Modify the rate of release of energy
- Separate energy from target in time and/or space
- Isolate by imposing a barrier
- Modify target contact surface or basic structure
- Strengthen potential target
- Control improper energy input

The reiterative process used in PHA to bring the risk associated with a hazard-target combination under acceptable levels has direct parallels in EFBA. The EFBA is customarily documented using a tabular format similar to that used for the PHA. Many analysts incorporate an EFBA approach when performing a PHA, and thus view EFBA as a variant of PHA.

EXAMPLE

Table IV-1 lists strategies to manage harmful energy flows that focus on the energy source, the target, and the path between the source and the target. Included are physical and administrative barriers.

Table IV-1. Examples of strategies to manage harmful energy flow

Strategy	Examples
Eliminate energy concentrations	· control/limit floor loading · disconnect/remove energy source from system · remove combustibles from welding site · change to nonflammable solvent
Limit quantity and/or level of energy	· store heavy loads on ground floor · lower dam height · reduce system design voltage/operating pressure · use small(er) electrical capacitors/pressure accumulators · reduce/ control vehicle speed · monitor/limit radiation exposure · substitute less energetic chemicals
Prevent energy release	· heavy-wall pipe or vessels · interlocks · tagout - lockouts · double-walled tankers · wheel chocks
Modify rate of energy release	· flow restrictors in discharge lines · resistors in discharge circuits · fuses/circuit interrupters
Separate energy from target in time and/or space	· evacuate explosive test areas · impose explosives quantity-distance rules · install traffic signals · use yellow no-passing lines on highways · control hazardous operations remotely
Isolate by imposing a barrier	· guard rails · toe boards · hard hats · face shields · machine tool guards · dikes · grounded appliance frames/housing · safety goggles
Modify target contact surface or basic structure	· cushioned dashboard · fluted stacks · padded rocket motor test cell interior · Whipple plate meteorite shielding · breakaway highway sign supports · foamed runways
Strengthen potential target	· select superior material · substitute forged part for cast part · "harden" control room bunker · cross-brace transmission line tower
Control improper energy input	· use coded keyed electrical connectors · use match-threaded piping connectors · use back flow preventors

ADVANTAGES

The energy flow/barrier analysis provides a systematic approach to identify hazards associated with energy sources and determine whether current or planned barriers are adequate countermeasures to protect exposed targets [1].

LIMITATIONS The EFBA has the following limitations [1]:

- Even after a thorough analysis, all hazards might not be discovered. Like the PHA (Lesson III), the EFBA fails to assess risks of combined hazards or co-existing system failure modes.
- This tool also fails to identify certain classes of hazards, e.g.: asphyxia in oxygen-deficient confined spaces.
- Because of design and performance requirements, it is not always obvious that energy may be reduced or redirected. A re-examination of energy as heat, potential vs. kinetic mechanical energy, electrical, chemical, etc. may aid this thought process.

REFERENCES

1. Clemens, PL. [1993] Energy flow/barrier analysis (lecture presentation). 3rd ed. Tullahoma, TN: Sverdrup Technology, Inc. (see http://www.sverdrup.com/svt for presentation slides).

SUGGESTED READINGS

U.S. Department of Energy [1985]. Barrier analysis. Idaho Falls, ID: System Safety Development Center, EG&G Idaho, Inc. DOE 76-45/29, SSDC-29.

Haddon, W, Jr. [1973]. Energy damage and the ten countermeasure strategies. Human factors. (August).

Johnson, WG [1980]. MORT safety assurance systems. New York: Marcel Dekker, Inc.

Stephans, RA, Talso, WW, eds. [1997]. System safety analysis handbook. 2nd ed. Albuquerque, NM: New Mexico Chapter of the System Safety Society.

SAMPLE DISCUSSION AND EXAMINATION QUESTIONS

1. What is the basis for energy flow/barrier analysis (EFBA)?
2. What types of energy sources can be accommodated through EFBA?
3. What is the difference between energy flow/barrier analysis and energy trace/barrier analysis?
4. Are all barriers physical? If not, give examples of those barriers that are not physical in nature.
5. Give an example of a combination of barriers that is used to protect a target.
6. Give examples of administrative barriers.
7. What is the relationship between preliminary hazard analysis (PHA) and EFBA?
8. What type of format is used to document an EFBA?
9. How might EFBA be used to make a "safe to enter" decision after a process plant accident or in an emergency response situation?
10. Pick an industrial situation with which you are familiar and apply EFBA to assess the risk posed by an energy flow-target combination.