Accidents as an Unwanted Energy Transfer[1]

by

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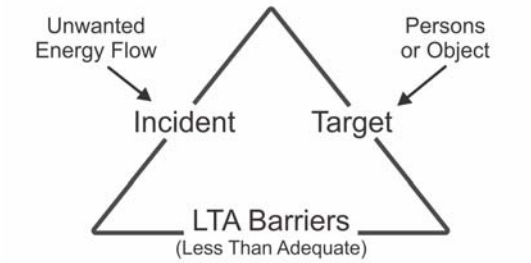
Accidents can be thought of in terms of an unwanted energy transfer from a source to the target. Stephenson (1991, p.147) "*defines an **incident** as an unwanted flow of energy. An **accident** is defined as occurring when this unwanted flow of energy, in the absence of adequate barriers, strikes targets in the energy path and injures people and/or damages property (Figure 1).*" The concept of preventing unwanted energy transfers to the target is a key component in barrier analysis, MORT, and accident prevention.



Source: DOD reported in Stephenson, J., (1991). System Safety 2000 - A Practical Guide for Planning, Managing, and Conducting System Safety Programs. New York, New York: Van Nostrand Reinhold. p.148.

Figure 1: Accident Triangle

Barrier analysis is a conceptual cornerstone of the accident process in MORT (Management Oversight and Risk Tree) developed by Johnson, (1973), and updated by and Tross and Nertney (1995) and Kingston (2009). It is a stand-alone analysis. The four components in barrier analysis are embodied in Stephenson's (1991) definition and include the elements of an unwanted energy flow, a target, Less-Than-Adequate (LTA) barriers, and multiple causes. The four components are considered causal being both necessary and sufficient for an accident to occur (Kingston 2009, Copi 1964). Barrier analysis was developed and used by large agencies such as the Army Corps of Engineers, Department of Energy, Department of Defense, the Atomic Energy Commission and NASA.

The two operative terms are the "source" and "unwanted." Both wanted and unwanted energy flows originate from a source. Much of living involves wanted energy transfers. A camper boils water on a gas stove for a cup of coffee or dinner. An energy transfer occurs between the burning gas and the pot of water. A whitewater kayaker surfs a wave. Surfing the wave is a form of kinetic energy transfer. Digesting the dinner cooked on the gas stove is an energy transfer where the food is converted to sugar and other nutrients by the body.

An energy flow is "unwanted" when the transferred energy flow results in injury, damage, or loss. As noted, the barriers are less-than-adequate. If the camper accidently knocks over the pot of boiling water, the boiling water creates an unwanted energy flow that can harm the target (e.g. thermal). Surfing the wave is fun, but the wave can capsize the kayaker and lead to an unwanted energy transfer (e.g. kinetic, thermal). The consumed food could be tainted resulting in indigestion, diarrhea, or other illnesses (e.g. toxic pathogenic).

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[1] This is the written proposal accepted for the 2020 Research Symposium at the virtual AORE Conference. The formal present is the video titled "**Accidents as an Unwanted Energy Transfer**." The video parallels closely this proposal.

Often used in the literature is the term "hazard" or "danger" rather than "source" (Kauffman and Moiseichik 2013, Meyer and Williamson 2008, Priest and Baillie 1987, and Reason 1990, 2008). Obviously, hazards and dangers can create potential unwanted energy transfers. However, the previous examples with the stove, surfer, and food demonstrate that the same source can create both wanted and unwanted energy transfers. Unfortunately, focusing on hazards and dangers can potentially ignore energy flows that are normally wanted but that can also result in unwanted energy flows.

In Figure 2, Stephenson (1991) lists typical sources of energy flows. In the outdoor area, flammable materials, kinetic, thermal and toxic pathogenic energy flows would most likely be found. Stephenson incorporates the energy flow concept into the Energy Trace and Barrier Analysis (ETBA) process. His worksheet is not much different than other tools that were derived from the original MORT materials (Oakley 2003, Kingston 2009, and Kauffman and Moiseichik 2013). They all seek to place barriers between the unwanted energy flows and the target.

Figure 2. Types of Energy Flows

Acoustical radiation	Kinetic-rotational
Corrosive	Mass, gravity, height
Electrical	Nuclear
Electromagnetic and particulate radiation	Pressure-volume/K-constant-distance
Explosive pyrophoric	Thermal (except radiant)
Flammable materials	Thermal radiation
Kinetic-linear	Toxic pathogenic

Source: Stephenson, J, (1991 p.149)

Hadden (1973) listed ten steps for reducing energy transfer from the source to the target (Figure 3). The steps relate to the creation of barriers. Figure 3 lists these steps and uses the previous stove, kayak surfing, and digestion examples. Trost and Nertney (1995) classified barriers by **type** (e.g. equipment design, physical barriers, warning devices, procedures and protocols, knowledge and skill, culture and attitude, and supervision), **location** (e.g. barrier on source or target, separation through time and space), and **function** (e.g. prevention, control and minimization). These barriers are quite similar to the underlying factors identified by Kauffman and Moiseichik (2013) and suggest some consistency in barrier classifications.

Figure 3. Hadden's 10 Steps for Reducing Energy Transfer

1. **Prevent the marshaling** (do not produce or manufacture the energy) (e.g. have a cold dinner; skip surfing the wave; don't use suspect food, etc.)
2. **Reduce the amount** (e.g. choose a smaller wave to surf; test the food before eating it)
3. **Prevent the release of the energy** (e.g. create a stove and pot that can't topple)
4. **Modify the rate of release** (e.g. choosing a smaller wave slows down reaction time; choose a stove with lower BTU output, etc.)
5. **Separate in space or time** (e.g. keep people out of the kitchen when operating the stove, etc.)
6. **Interpose material barrier** (e.g. place a board between the stove and cook; wearing shorts is prohibited in the kitchen, etc.)
7. **Modify shock-concentration surfaces** (e.g. choose a friendly wave to surf, etc.)
8. **Strengthen the target** (e.g. wear a life jacket, increase knowledge and skill, etc.)
9. **Limit the damage** (e.g. choose a wave with a safe washout; sample the food first, etc.)
10. **Rehabilitate persons and objects** (e.g. kitchen protocols, increasing kayaking knowledge and skills, etc.)

Source: Hadden (1973)

Conclusion

Returning to Stephenson's (1991) definition of an incident and accident, unwanted energy flows are a key component in the accident process. Barrier analysis is simply the process of placing barriers that unfortunately are less-than-adequate between the source of the unwanted energy flow and the target. Understanding and identifying potential unwanted energy flows is key to understanding accidents and the accident process.

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