Open-Ended Problems: A Future Chemical Engineering Education Approach. J. Patrick Abulencia and Louis Theodore.

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Term Projects (4): Health and Hazard Risk Assessment

Term Project 32.1

Nuclear Waste Management

As with many other types of waste disposal, radioactive waste disposal is no longer a function of technical feasibility but also a question of social or political acceptability. The present placement of facilities for the permanent disposal of municipal solid waste, hazardous chemical waste, and nuclear wastes alike has become an increasingly large part of waste management. Today, a large percentage of the money required to build a radioactive waste facility will be spent on the siting and licensing of the facility [1].

Nuclear or radioactive waste can be loosely defined as something that is no longer useful and that contains radioactive isotopes in varying concentration and forms. Radioactive waste is then further broken down into categories that describe waste by activity, by generation process, by molecular weight, and by volume [1].

Radioactive isotopes emit energy as they decay to more stable elements. The energy is emitted in various forms, including alpha particles, beta particles, neutrons, and gamma rays. The amount of energy that a particular radioactive isotope emits, the time frame over which it emits that energy, and the type of contact with humans, all help determine the hazard it poses to the environment. The major categories of radioactive waste that exist are high-level waste (HLW), low-level waste (LLW), transuranic waste (TRU), uranium mine and mill tailings, mixed wastes, and natural occurring radioactive materials (NORMs) [1,2].

The physical form of the waste is a critical factor in determining the probability that the waste will remain isolated from the biosphere. Many treatment processes can be employed to reduce the volume or increase the stability of waste that must ultimately be permanently disposed. Landfill fees for radioactive waste is assessed largely on the volume of the waste to be disposed. Current trends in the rising cost of waste disposal have led to the generators' implementing one or a number of waste minimization techniques.

You have been hired to develop an improved method of either treatment or disposal of nuclear waste, or both. Factors to be included in your analysis are:

1. Political concerns
2. Societal concerns
3. Economics
4. Environmental Concerns
5. Health and hazard risks [3]

Term Project 32.2

An Improved Risk Management Program

Developed under the *Clean Air Act's* (CAA's) Section 112(r), the *Risk Management Program* (RMP) rule (40 CFR Part 68) is designed to reduce the risk of accidental releases of acutely toxic, flammable, and explosive substances. A list of the regulated substances (138 chemicals) along with their threshold quantities is provided in the Code of Federal Regulations at 40 CFR 68.130.

In the RMP rule, EPA requires a *Risk Management Plan* that summarizes how a facility is to comply with EPA's RMP requirements. It details methods and results of hazard assessment, accident prevention, and emergency response programs instituted at the facility. The hazard assessment shows the area surrounding the facility and the population potentially affected by accidental releases.

EPA requirements include a three-tiered approach for affected facilities. A facility is affected if a process manufactures, processes, uses, stores, or otherwise handles any of the listed chemicals at or above the threshold quantities. The EPA approach is summarized in Table 32.1. For example, EPA defined Program 1 facilities as those processes that have not had an accidental release with offsite consequences in the five year prior to the submission date of the RMP and have no public receptors within the distance to a specified toxic or flammable endpoint associated with a worst-case release scenario. Program 1 facilities have to develop and submit a RMP and complete a registration that includes all processes that have a regulated substance present in more than a threshold quantity. They also have to: analyze the worst-case release scenario for the process or processes; document that the nearest public receptor is beyond the distance to a toxic or flammable endpoint; complete a five-year accident history for the process or processes; ensure that response actions are coordinated with local emergency planning and response agencies; and, certify that the source's worst-case release would not reach the nearest public receptors. Program 2 applies to facilities that are not Program 1 or Program 3 facilities. Program 2 facilities have to develop and submit the RMP as required for Program 1 facilities plus: develop and implement a management system; conduct a hazard assessment; implement certain prevention steps; develop and implement an emergency response program; and, submit data on prevention program elements for Program 2 processes. Program 3 applies to processes in Standard Industrial Classification (SIC) codes 2611 (pulp mills), 2812 (chloralkali), 2819 (industrial inorganics), 2821 (plastics and resins), 2865 (cyclic crudes), 2869 (industrial organics), 2873 (nitrogen fertilizers), 2879 (agricultural chemicals), and 2911 (petroleum refineries). These facilities belong to industrial categories identified by EPA as historically accounting for most industrial accidents resulting in off-site risk. Program 3 *also* (and this is important) applies to all processes subject to the OSHA Process Safety Management (PSM) standard (29 CFR 1910.119). Program 3 facilities have to develop and submit the RMP as required for Program 1 facilities plus: develop and implement a management system; conduct a hazard assessment; implement prevention requirements; develop and implement an emergency response program; and provide data on prevention program elements for the Program 3 processes [4].

As a recently assigned intern (to the health and hazard risk assessment group) at Region II EPA headquarters in New York City, NY, you have been requested by your immediate supervisor to develop an improved RMP for the Agency.

Comment: There are many State agencies that have developed RMPs (or the equivalent) that may be valuable in completing this project.

Table 32.1 RMP Approach [1]

Program	Description
1	Facilities submit RMP; complete registration of processes; analyze worst-case release scenarios; complete 5-year accident history; coordinate with local emergency planning and response agencies; and, certify that the source's worse-case release would not reach the nearest public receptors.
2	Facilities submit RMP; complete registration of processes; develop and implement a management system; conduct a hazard assessment; implement certain prevention steps; develop and implement an emergency response program; and, submit data on prevention program elements.
3	Facilities submit RMP; complete registration of processes; develop and implement a management system; conduct a hazard assessment; implement prevention requirements; develop and implement an emergency response program; and, provide data on prevention program elements.

Term Project 32.3

Bridge Rail Accident: Fault and Event Tree Analysis

As noted earlier in Part II-Chapter 19, a *fault tree* is a graphical technique used to analyze complex systems. The objective is to spotlight faulty conditions that can cause a system to fail. Fault tree analysis attempts to describe how and why an accident or other undesirable events have occurred. It may also be used to describe how and why an accident or other undesirable event could take place. A fault tree analysis also finds wide application in environmental management as it applies to hazard analysis and risk assessment of process and plant systems [5].

Fault tree analysis seeks to relate the occurrence of an undesired event, the so-called *top event*, to one or more antecedent events, called *basic events*. The top event may be, and usually is, related to the basic events via certain intermediate events. A fault tree diagram exhibits the casual chain linking the basic events to the intermediate events and the latter to the top event. In this chain, the logical connection between events is indicated by so-called *logic gates*. The principal logic gates are the "AND" gate, symbolized on the fault tree by a semi-circle shape, and the "OR" gate symbolized by a square bottom/triangle top shape [6].

An *event tree* provides a diagrammatic representation of event sequences that begin with a so-called initiating event and terminate in one or more undesirable consequences. In contrast to a fault tree, which works backward from an undesirable consequence to possible causes, an event tree works forward from the initiating event to possible undesirable consequences. The initiating event may be equipment failure, human error, power failure, or some other event that has the potential for adversely affecting an ongoing process or environment.

Summarizing, a fault tree works backward from an undesirable event or ultimate consequence to the possible causes and failures. Alternatively, an event tree works forward from an initial event, or an event that has the potential for adversely affecting an ongoing process, and ends at one or more undesirable consequences.

A natural gas pipeline is attached to a combined highway/railway bridge. You have been asked to investigate the risk of a fire or explosion at the bridge. Either a rail accident or an earthquake can rupture the natural gas line. Truck accidents on the bridge will not rupture the line. After a considerable amount of effort your staff has produced the following database [7].

1. The probability of rail accident at this bridge considering traffic, maintenance, and human error is 6 x 10^{-6}/yr.
2. Pipeline rupture will occur in 60% of the rail accidents which are designated as "major".
3. The probability of an earthquake causing the pipeline to rupture is 1.5 x 10^{-8}/yr.
4. The pipeline is inerted with nitrogen for maintenance work, one percent of the time.
5. Calm wind conditions and those with a westerly component will cause ignition from a rail accident 70% of the time. The wind will cause highway traffic to be the ignition source, thirty percent of the time.

For your calculations consider all the above events to be independent [7]. Your assignment is as follows:

1. Construct a fault tree
2. Find the cut sets
3. Identify the minimum cut sets
4. Calculate the probability of an earthquake causing a natural gas fire/explosion.
5. Calculate the probability of a rail accident causing a natural gas fire/explosion.
6. Based on your results how does the likelihood of the rail accident causing the fire/explosion compare to that of the earthquake?
7. Outline what steps can be taken to reduce the probability of an "accident".

Term Project 32.4

HAZOP: Tank Car Loading Facility

A. Hazard and Operability Study (HAZOP) is a structured, systematic "what if" analysis of a process, normally carried out by a team of five to ten people with expertise in various aspects of process design, operations, and safety. Combinations of *guide words* and process elements are examined. The guide words most commonly used are:

No or not
More

Less
As well as
Part of
Reverse
Other than

For each combination, the HAZOP team determines the possibility of deviations in flow, temperature, pressure, composition, etc. The team first determines whether the deviation is physically possible in the system. Then it determines what possible combination of circumstances would cause the deviation and what the consequences would be. Finally, the team recommends action to avoid any deviation which could lead to dangerous consequences. A recorder (secretary), takes careful notes of the discussion and recommendations on each combination of guide words and process step [8]

Carry out a HAZOP analysis of the tank car loading facility illustrated below in Figure 32.1. It is used for filling cars with sulfuric acid. Pertinent data follows [9].

When a tank car is lined up and connected, the feed pump is started by the operator. The pump shuts off automatically after a predetermined amount of sulfuric acid has been pumped. A low-level switch on the tank will shut off the pump if the tank inventory is too low.

An underline in an instrument bubble (e.g., on the LALL) in the figure indicates the instrument is in the control room. Otherwise instruments are located close to the equipment. Instrumentation symbols in the figure are:

1. FAL Flow alarm-low
2. FIC Flow indicator-controller
3. HS Hand operated electrical switch
4. LAH Level alarm-high
5. LAL Level alarm-low
6. LALL Level alarm-low,low
7. LI Level indicator
8. LS Electrical switch operated by tank-level signal
9. PAH Pressure alarm, high
10. PAL Pressure alarm, low
11. PI Pressure indicator
12. TAH Temperature alarm, high
13. TAL Temperature alarm, low
14. S Signal integrator

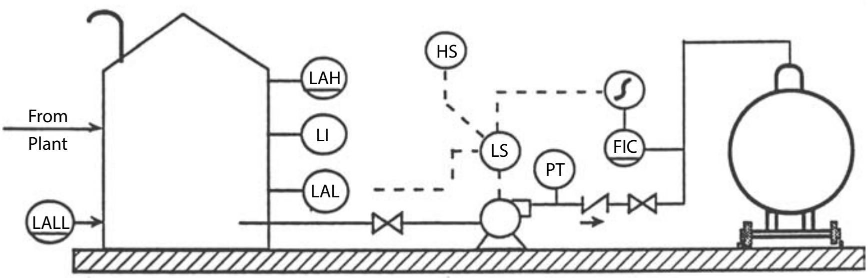

Figure 32.1 Tank car loading schematic

References

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