Was Murphy Wrong?
Thoughts on the Application of Murphy's Law to the Operation and Design of Chemical Plants

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Abstract

We've all heard of Murphy's Law. It has been stated in various forms, generally something like "If something can go wrong, it will go wrong, and at the worst possible time." We often quote Murphy's Law, often in a light-hearted or joking context. But, do we really believe it? What effect does our belief in Murphy's Law have on how we actually operate and design chemical plants? Is our application of Murphy's Law appropriate? How should we be using Murphy's Law?

Introduction

There are many statements of Murphy's Law, and also a large assortment of corollaries, commentaries, postulates and other variations of Murphy's Law. A search of the Internet with any search engine will reveal hundreds of hits, a large percentage of which appear to be related to computers and software. From my own experience with computers and software, this is certainly not surprising! Some common statements of Murphy's Law include:

- If anything can go wrong, it will.
- If something goes wrong, it will at the worst possible time.
- If there are two or more ways to do something, and one of those ways can result in a catastrophe, then someone will do it.
- If anything just cannot go wrong, it will anyway.
- The probability of anything happening is in inverse ratio to its desirability.
- Nature always sides with the hidden flaw.

And then there is O'Toole's Commentary on Murphy's Law: Murphy was an optimist.

Murphy's Law has become a part of the English language – nearly everybody understands what we mean when we refer to Murphy. We frequently quote

Murphy's Law and its variations, often in a joking manner, when something goes wrong. But, was there really a Murphy, did he really state this law, and what did he have in mind? Does the universe really operate in accordance with Murphy's Law? Do we really believe in Murphy's Law, and does it have any impact on how we behave? What relevance does Murphy's Law, or a belief in Murphy's Law, have to the operation and design of chemical manufacturing facilities?

History of Murphy's Law

Yes, there really was a Murphy (Bear, 1978). Captain Edward A. Murphy was an engineer working on United States Air Force Project MX981 at Edwards Air Force Base, California in 1949. This project was designed to determine how much sudden deceleration a person can stand in a crash. In the testing program, volunteers were strapped in a rocket propelled sled, and their condition was monitored by a group of transducers in a harness as the sled was rapidly halted. Following one test, it was found that no data was recorded because all of the transducers had been wired incorrectly. Captain Murphy cursed the responsible technician, saying "If there is any way to do it wrong, he'll find it." A few days later Air Force doctor John Paul Stapp, working on the project, attributed the test program's good safety record to a firm belief in Murphy's Law at a press conference. Murphy's Law was picked up by the press, and has been a part of the language ever since.

Actually, as Matthews (1997) notes, Murphy had just restated something which had been observed for many years:

> *The best laid schemes o' mice an' men*
> *Gang aft agley.*
> – Robert Burns, 1786

> *I had never had a piece of toast*
> *Particularly long and wide*
> *But fell upon the sanded floor*
> *And always on the buttered side.*
> – James Payn (Victorian satirist), 1884

Does the World Follow Murphy's Law?

So, is Murphy's Law true? While we often quote its many variations, most of us would admit that it is not really "true" if asked. We would admit that our "belief" in Murphy's Law is a result of selective memory. We easily remember the times that things go wrong, but all of the times that things go as expected are readily forgotten. The world behaved in the way we expected (and wanted) it to behave, and that is not memorable.

Actually, it turns out that, in some cases, Murphy's Law can be shown to be correct in some situations. In an interesting article, Robert A. J. Matthews has identified cases in which the universe really is "against us" (Matthews, 1997). Some of these are a result of people's poor understanding of the laws of probability, and others represent true physical behavior of systems. For example:

- X If all lines in the supermarket are assumed to move at the same average rate, with random variation in the time to serve each customer, there is only a 1/3 chance that the line you are standing in will be faster than the one on either side of you. And, if you can see 10 lines, there is only a 1/10 chance that yours will be the fastest. So, most of the time, you will observe other lines moving faster than yours.
- X Start with a drawer containing 10 pairs of socks, and randomly lose socks. A probabilistic analysis reveals that, by the time you have lost half of your socks, it is four times more likely that you will have a drawer full of odd socks, rather than five complete pairs. And, the most likely outcome is two complete pairs and six odd socks.
- X Matthews analyzes Payn's observation that the toast always lands butter-side down, and determines that this is indeed the expected outcome. The weight of the thin layer of butter is not significant, nor are aerodynamic effects. The toast lands butter side down because the torque induced by gravity as the toast falls results in a rotation rate that causes the butter side to be down when the toast is dropped from the height of a typical table. All of this can be related to basic physical constants of the universe, which determine everything from the rotation rate of the toast to the maximum reasonable size for a mammal living in the earth's gravitational field (and therefore establishing the typical height of a table). Matthews' conclusion: the toast lands on the butter side because the universe is designed that way!

So, we can conclude that, for at least some cases, Murphy's Law does correctly predict the most likely outcome. But, these cases are really the exception.

Consequences of Failures and Errors

Most of the things we attribute to Murphy really do represent selective memory of bad experiences or events in which a failure or mistake has occurred. But, what is the usual outcome of failures and errors? In many cases, there is no bad outcome. The universe is really a very benign and forgiving place, and allows us to get away with errors and failures most of the time. If this were not the case, it is unlikely that any of us would have survived childhood. We can all remember dumb things that we did as children, and most of us survived those mistakes. If Murphy was really right, and the worst possible outcome occurred, most of us would not be here.

Consider some examples of failures in every day life, in high risk systems, and in the operation of chemical plants:

- X Many years ago, on the way to work, I ran through a stop sign at a fairly busy intersection at about 40 miles per hour. I don't know why – I know the intersection well, and pass through it twice a day, every working day. But, on this particular day my mind was somewhere else, and I did not stop. According to Murphy, I should have been hit by a passing gasoline truck at about 60 miles per hour and killed in a large fireball. In fact, there was no traffic coming, there wasn't even a policeman watching the intersection, and the only consequence was that I got to work a few seconds earlier.
- X On August 23, 1962, a United States Air Force Strategic Air Command (SAC) B-52 bomber armed with nuclear weapons got lost due to a navigational error while on a routine airborne alert route over the Arctic Ocean. The bomber flew over 1,300 miles on a course which would have taken it into the air space of the Soviet Union. About 300 miles from Soviet airspace, ground control detected the error and ordered an immediate change of course. There is no indication that the Soviet air defense systems detected the B-52 in this incident. It is frightening to think of the potential consequences had this error occurred a few months later, in October 1962, during the Cuban missile crisis. The SAC was still using the airborne alert route, which its review subsequently categorized as "high risk," through the first ten days of the missile crisis (Sagan, 1993).
- X A reactant was incorrectly charged to a batch reactor, and the result was an unanticipated runaway reaction. The engineers and chemists working on the process were unaware that the reaction could occur. Note that this occurred before HAZOP was commonly used – the reaction should have been identified from the HAZOP deviation "MORE REACTANT". In a world ruled by Murphy, the reactor would have blown up. In the real world, the emergency relief system on the reactor was large enough for the incorrect charge which actually occurred, even though it had not been designed for the unknown reaction.
- X Because of confusing control system displays, an operator moved a group of remote control valves on Reactor Train A, thinking he was operating the corresponding valves on the identical Reactor Train B. With some operations in this equipment, this error could have resulted in a serious incident. In fact, when it was done, a batch was in a vacuum distillation step, and the consequence was a purge of the batch to the reactor overhead, and no release of chemicals (Hendershot and Keeports, 1999).
- X A flammable solvent leaked from a pressurized reactor into a building and caused a explosive mixture in the building. Murphy would predict that the cloud would find an ignition source and there would be a large, catastrophic explosion, but, in this case there was no ignition and the cloud dispersed.

The often forgiving nature of the world has an adverse impact on people's perception of risk – we begin to expect the world to *always* behave that way. Each of our individual experience with the world is limited, and serious incidents really are relatively rare events. Most of the time, we will get away with at risk behaviors. At an AIChE short course on statistical design of experiments, one of the principles discussed by the instructor, Dr. Stuart Hunter, was "Rare events do happen, but not to me" (Hunter, 1970). That principle may be appropriate for interpreting the results of a group of experiments, but it is not a good rule for determining what is safe behavior. Our expectations for frequency of injuries and chemical incidents are very high – we expect them to be extremely rare. Just because we get away with a certain behavior many times does not mean that the behavior is acceptable. Each of us, as an individual, has too small a data set of experience to reach a meaningful conclusion on this issue based on our own individual experience. If the unsafe behavior persists, eventually the rare event (an incident or injury) will occur to somebody, and perhaps to me.

Unfortunately, we often do reach the conclusion that a particular activity is safe based on our own past experience with no adverse outcomes. The operator goes up to the fifth floor of a process rack to take a sample and then realizes that he has forgotten his splash goggles. Not wanting to go down five floors to get the goggles, and then back up again to take the sample, he goes ahead and takes the sample carefully, and nothing goes wrong. He files that away in his memory and the next time he forgets the goggles, he takes the sample again without them. Soon that behavior extends to other safety rule violations, and other people begin to assume that they will also be OK if they don't follow the rules. Our daily experience with errors and failures will often lead us to believe that nothing bad will happen. Our behavior is showing an unconscious belief in Murphy's Law – we believe that if something can go wrong, it will. Since nothing *did* go wrong, we begin to behave as if nothing *can* go wrong, and continue the at risk behavior. Eventually, somebody will get caught and there will be an injury.

This unconscious belief in Murphy's Law is also the reason why we sometimes find safety devices not working or bypassed. I was in a supermarket and found a fire exit padlocked shut. When I told the manager, he said that the building had excellent fire protection systems, there had never been a fire, the exit was not really needed, and it was a way that unauthorized people could enter the building. He was exhibiting a belief in Murphy's Law – if the worst thing that could have happened did happen, and a fire had not occurred, a fire must not be possible and he could lock the fire escape. I suggested that something bad might occur soon – the local Fire Marshall might visit – and the next time I was in the store the lock had been removed. How many customers walked by that locked fire escape and said (or noticed) nothing before this trouble making process safety engineer made a fuss? How many people in chemical plants develop a similar acceptance of unsafe conditions or failed devices for similar reasons?

We must all work to eliminate the effects of this unconscious belief in Murphy's Law on our behavior. Maintaining good operating and safety discipline requires continual vigilance and work. We must continually look for unsafe conditions and behaviors and make sure they are eliminated. Most of the time, these unsafe conditions and behaviors will not result in an incident. This tempts us to ignore them, but, if we do, eventually Murphy will return and somebody will get hurt.

Murphy's Law - A Design Tool

When Murphy and his colleagues at Edwards Air Force Base, stated his law, they really had in mind that it is a tool for the design of devices and procedures. It is a plea for inherently safer design. When designing something, the designer must always assume that "if it can go wrong, it will," and design his device or procedure to account for errors and failures. Captain Murphy's son states the case for Murphy's Law very well in a letter to the editor of *Scientific American* following up on the Matthews (1997) article:

> "I would suggest, however, that Murphy's Law actually refers to the *certainty* of failure. It is a call for determining the likely causes of failure in advance and acting to prevent a problem before it occurs." (Murphy, 1997)

Captain Murphy believed that any failure which could occur, *eventually would* occur. As a designer, it was his responsibility to anticipate these failures, and make sure his systems were sufficiently robust to respond safely when the failures eventually did occur. For example, how could Captain Murphy have eliminated the problem of incorrectly wired transducers in the incident which prompted him to state his law? One possibility would have been to design a wiring system which could only be assembled in the correct way. If the error had been safety critical, instead of resulting in the loss of data only, perhaps this would have been done, as it has in many safety systems. For example, the design of modern polarized electrical plugs requires that they be inserted into the socket the correct way.

In the chemical industry, the Hazard and Operability Study (HAZOP) has been described as an application of Murphy's Law. HAZOP is a systematic and logical way of examining a process to identify as many failure scenarios as possible, to understand the existing safeguards, and to identify the need for additional protection. Similarly, Failure Modes and Effects Analysis (FMEA) is based on Murphy's Law. In FMEA, a specific failure mode of a device or process is assumed to occur, and the effects of that failure on the system containing the device or process are determined. In general, most chemical process hazard analysis techniques can be considered to be based on Murphy's Law.

Inherently safer design is the most robust approach to accomplishing the goals Captain Murphy had in mind when he stated his law. In the chemical industry, this means *eliminating* hazards in the process rather than controlling them. According to Murphy, all hazard control features will ultimately fail if we wait long enough. While that risk of failure may be small, and tolerable to society, it will never be zero. Therefore, when we do a HAZOP or other process hazard study, our first question when we identify a hazard should be "Is there any practical way to *eliminate* this hazard?" Only when we are satisfied that there is no feasible way to eliminate the hazard should we begin to focus on hazard control.

Birkett (1998) describes several "Murphy incidents" in chemical laboratories which, upon closer examination, turn out to be accidents waiting to happen. For example, a graduate student was condensing boranes using liquid oxygen. When the cold finger containing the liquid oxygen broke, it created a vessel full of an explosive mixture. While you might consider this a Murphy incident, Birkett asks "what the idiot was doing bringing boranes into close proximity to liquid oxygen?" While I haven't run into anything quite this spectacular in a plant environment, I have encountered situations where a highly corrosive and water reactive material was being cooled in a vessel with coils containing cold water. While we can take many measures to ensure the integrity of the cooling coils, wouldn't it be better to identify a cooling fluid which would not react with the vessel contents in case of a leak?

Another interesting application of Murphy's Law occurs in the construction of a fault tree. I learned fault tree analysis from Dave Haasl, an engineer at Boeing who was one of the pioneers of the technique. One of Haasl's key principles for fault tree analysis was the No Miracles rule (Haasl, 1977). Haasl's No Miracles Rule states that if a failure occurs in a system which can cause it to fail into an unsafe or undesired state, and a subsequent second failure can prevent the system from moving to that unsafe or undesired state, the analyst is not allowed to take credit for the effects of the second failure in developing the logic of the fault tree. In other words, in analyzing a system we cannot take credit for the "miracle" of two simultaneous failures resulting in a safe or desirable outcome, even though it may be theoretically possible. This is also an application of Hunter's rule that "rare events do happen, but not to me". In constructing a fault tree, we assume that Murphy rules. Once a component failure occurs, we cannot take credit for subsequent rare events which might prevent system failure.

Conclusions

Murphy's Law has its place in the design of devices, processes, systems, and procedures. It forces us to assume that failures will occur, to identify and understand the consequences of those failures, and to design systems which will be tolerant of those failures. This was what Captain Murphy had in mind when he and his colleagues first stated his law. Murphy's Law is the basis of many design safety tools. It encourages the system designer to search for inherently safer systems – those which eliminate hazards entirely or minimize them sufficiently that failures cannot cause an unsafe outcome.

However, a belief, most likely unconscious, in Murphy's Law in the operation of a facility or device can lead us to believe that actions are safer than they really are. The chemical industry, and life in general, is very safe, and the world tends to be forgiving of unsafe acts. Most of the time we will get away with unsafe behavior or system failures. This may lead to complacency and an expectation that we will always get away with the behavior, or that it is not necessary to fix the failed piece of equipment because nothing bad happened while it was broken. However, our expectations for safety are high, and our personal experience is not statistically significant. Eventually we, or somebody, will get caught, and an incident will occur if the unsafe behavior persists or the unsafe failure condition is not repaired.

In conclusion, we must encourage the application of Murphy's Law in the design of systems. However, we must also work hard to ensure that we and our colleagues are always alert for unsafe conditions and behaviors, even in the absence of unsafe outcomes from those conditions and behaviors. We must be vigilant in identifying and eliminating these situations, and not fall into the trap of believing that we must be safe because no incidents have actually occurred. The best way of ensuring a safe design is to design inherently safer facilities which eliminate the hazard entirely, or reduce its magnitude sufficiently that it is not capable of doing serious harm. Again quoting Captain Murphy's son(Murphy, 1997), describing the engineers at Edwards Air Force Base:

> "They were not content to rely on probabilities for their successes. Because they knew that things left to chance would definitely fail, they went to painstaking efforts to ensure success."

We must do the same in the chemical process industries.

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