PDHonline Course G514 (3 PDH)

Human Factors in Forensic Analysis of Accidents

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Discussion Areas

- History of Human Factors and Ergonomics
- Basics of Human Factors
- Application of Human Factors to Design, Manufacturing, Assembly
- Human Factors in Cause Analysis
- Examples of Human Factors in Forensic Engineering Analysis
- Human Factors Mistake

A Very Brief History of Human Factors and Ergonomics

- Modern Human Factors and Ergonomics has its roots in the aviation and aviation psychology.
- In particular, HF&E was originally focused on human interaction and the design of controls and displays in aircraft, as well as the effects of flight on the pilot.
- During World War II, advances in complex machinery, weaponry, and manufacturing productivity stretched the limits of human capability. Machinery, weaponry, and manufacturing had to design for HF&E as the human being became the limiting factor in productivity or tasks.
- Continued modern advances in consumer products, machinery, weaponry, manufacturing, computers, and the workplace necessitated the design for HF&E.
- Today, HF&E is critical to a consumer product's success.

A Very Brief History of Human Factors and Ergonomics (cont.)

- Today, HF&E is critical to a worker's success at multiple, repetitive, or complex task.
- Today, HF&E can be critical to a human's overall mental well being with regards to products, tasks, and etc.
- HF&E is defined by the Human Factors Ergonomics Society as: "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance."
- For more information and resources, take the time to visit HFES's website at: https://www.hfes.org
- HF&E includes psychology, engineering, biomechanics, industrial design, and physiology

Human Factors – The Five Senses

- In Forensic Engineering Analysis of Human Factors, often times the big focus are on the five senses:

- **Sight** – Line of sight, Lighting, What did a witness see. Was an assembly process within sight or was it a blind assembly.

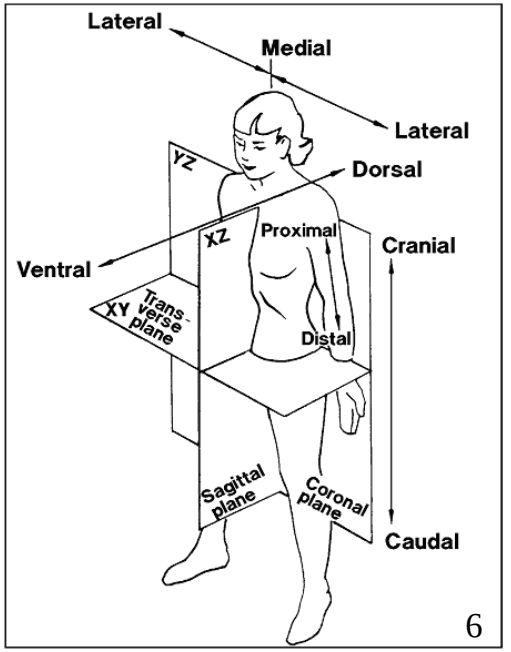
- **Hearing** – Audible warnings, alarms, sirens, bells. What could a witness hear? What did they hear?
- **Smell** – Where there any odd odors such as chemicals, fuels, smoke, or etc., during or prior to an accident.

- **Touch** – Sensations of temperature (hot/cold), wind blowing, slipperiness of flooring, contact with objects, or fit with regards to tooling.

- **Taste** – Not as commonly used in Forensics, but sometimes extreme odors of smell can produce a taste in a witnesses mouth.

Human Factors - Physiology

- Height and weight – Extreme ends of high or low height or weight can be a factor in accidents or outcomes of accidents.
- Please review the NASA anthropometry measurements (see http://msis.jsc.nasa.gov/sections/section03.htm)
- In addition; physiology considerations may include: age, physical conditioning, handicap or physical limitations, pre-existing medical conditions



Human Factors – Psychology

- Generally in Forensic Engineering, we are typically not considering the mental health or state in the cause analysis.
- However, witness statements, deposition testimony, or testimony may be affected by mental health issues, or the mental state of a witness. Mental health or mental state may be a factor in how much credence can be placed on a witness when attempting to discern conflicting witness testimony.
- Generally in Forensic Engineering, the psychology of human behavior can help explain certain behaviors that may be contrary to human logic.

Human Factors – Background, Knowledge, and Experience

- Every person has a different background, body of knowledge, and experience.
- Differing background, knowledge, and experience can produce a different human response to a stimuli, or a different human response to a device, a task, or a problem.
- Generally, the engineer attempts to control the persons behavior via engineering controls or administrative controls.

Human Factors – Situational Awareness

- In academics or employee training or child rearing, situational awareness can illustrated by the difference between hearing and listening.
- Human beings are generally not “on” all the time.
- Studies have shown that a persons level of attention and attention span naturally changes throughout the day. Attention can be effected by sleep, legal and illegal drug use, alcohol use, and even snacks or regular meals.
- Situational awareness can be affected by Background, Education, and Experience, especially if a person is new to a task or function, or doesn’t recognize or understand the situation in which they are in.

Human Factors – Human Perception Reaction Time

- Human Reaction time is often quoted at somewhere between 0.15 to 0.30 for very simple tests.
- Take a break and try the following Human Benchmark tests and review the overall results: http://www.humanbenchmark.com/
- Unfortunately, it is not correct to assume a constant Human Perception Reaction time for all tasks.
- An oft studied Human Perception Reaction time field is driver response in accidents.

Human Factors – Human Perception Reaction Time (cont.)

- In Motor Vehicle Accident Reconstruction and Cause Analysis, Mr. Limpert analyzed driver response in accidents with the following conclusions:
- There are automatic (i.e. reflex, shifting gears) and nonautomatic reactions, with nonautomatic reactions taking more time.
- Elements of driver reaction are: perception time, judgment time, reaction initiation time, and reaction execution time.
- For braking under ideal driving conditions, braking maneuvers required a range of 1 to 1.5 seconds.
- Studies with car-pedestrian nighttime accidents showed that HPR may range as high as 3 seconds.

Human Factors – Human Perception Reaction Time (cont.)

- To expand upon Mr. Limpert's conclusions, Human Reaction time is not constant.
- Human Perception Reaction Time is dependent additionally on the:
  - Task
  - Task Difficulty (Manual and/or Mental)
  - Number of Inputs/Stimuli that have to be processed
  - Number of Decisions that need to be made to accomplish a reaction
  - System delay after reaction execution
- Example: What if the humanbenchmark exercise on pg. 10 required the correct solving of a math problem?

HF& E in Design

- In product design, generally a product is designed for the physiology of the maximum number of possible users.
- A product may be targeted to a subset of the entire population by geography, climate, country, language group, gender, or specialized use group.
- The form, fit, and function of the product meet the need or demand of the intended target audience, while also be designed for the ability to be supplied at an economical value.
- A generic and inherent requirement is safety.

HF& E in Design

- Typically HF&E may be incorporated into the design via policy, procedure, or engineering consensus standards for the product or device.
- Example: Treadmills have to conform to ASTM F2115-12.
- ASTM F2115-12 prescribes requirements for things like roller guards, minimum foot rail width, a non-slip moving surface, min width and length of surface, and etc.; all of which contain requirements essentially based HF&E.

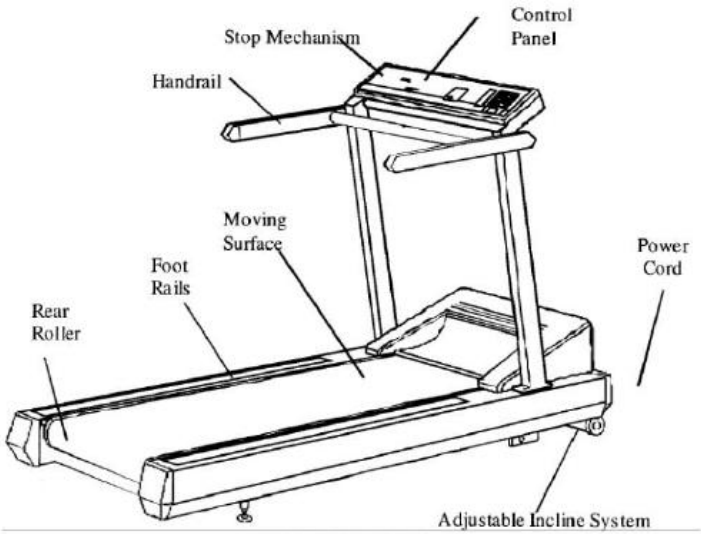


FIG. 1 Treadmill Terminology

HF& E in Design – FMECA/FMEA

- HF&E may be incorporated in design as a part of a Failure Mode Effects and Criticality Analysis (FMECA), or FMEA.
- For a detailed explanation of FMECA, please click on the following link: http://armypubs.army.mil/eng/DR_pubs/DR_a/pdf/tm5_698_4.pdf
- For a brief explanation of FMECA, please click on the following Link:
- http://www.weibull.com/hotwire/issue46/relbasics46.htm
- HF&E would typically be added a section or separate items of risk or failure modes, and then be assigned an effect and criticality.

HF& E in Design – HF Design Matrix

- When HF&E has revealed itself to be a big driver in the design of a product, a separate design requirement may be required as a part of the design review process.
- The HF&E design process may be codified into engineering standard work, process, policy, or procedures, and often times appear to be like a checklist, matrix, or logic flow chart.
- Example from: http://helix.gatech.edu/Classes/Me4182/2002S3/webs/teamJMH/Paper.htm

	WEIGHT	Standard Handtruck	Tri-Wheel Design	Roving Design	Moveable Track	Bicycle-Tire Design	Sliding-Rod Design
Functional Performance							
Can carry load on ground	10	+	-	+	+	+	+
Can move load downstairs smoothly	7	-	+	-	+	+	-
Can move load upstairs smoothly	7	-	+	+	+	+	+
Can carry heavy load	5	+	+	+	+	+	+
Ability to carry wide load	7	+	+	+	+	-	+
Ability to turn corners	5	+	-	+	+	-	+
Reduction in load/efficiency	10	-	-	+	+	+	+
Human Factors							
Safety	10	+	+	+	+	-	+
Easy to Use	7	-	+	+	+	+	+
Set-up	5	+	+	+	+	+	+
Manufacturing							
Inexpensive	7	+	+	+	+	+	+
Ease of production	9	+	-	+	+	+	+
Simple design	7	+	-	+	+	+	+
Rating		556	460	580	534	514	606
ABSOLUTE RATING		0.92	0.76	0.96	0.88	0.85	1.00

HF& E in Design – Sales and Marketing

- HF&E design requirements may also be driven by sales and marketing need. <groan by the engineers>
- In a product line that has many competitors, HF&E may be the competitive or differentiating factor on which product survives or leads in the market.
- The best design from an engineering utility, performance, or technology standpoint doesn't always "win".
- There is probably no better example than the cell phone or smart phone market.

HF&E in Manufacturing or Workplace

- HF&E in manufacturing and workplace is not only about the ergonomics and comfort in the workplace.
- HF&E has to be concerned about repetitive motion and maximum human effort and capability.
- HF&E also has to consider the hazards and exposures of workers to the environment and conditions in which they have to work.
- Tools, standards, and guidelines have been created to guide the engineer when designing for the manufacturing or workplace environments.

HF&E in Manufacturing or Workplace

- The NIOSH Lifting index provides a simple way for engineers designing workplace tasks to calculate and evaluate the proposed tasks.
- Please click on the following link and review pages 1-34:
- http://www.cdc.gov/niosh/docs/94-110/pdfs/94-110.pdf
- Furthermore, many of the HF&E manufacturing and workplace issues are at the heart of what has been codified under OSHA.
- Please click on the following link and review the table of contents for 1910 General Industry standards, and 1926 Construction Industry standards.
- https://www.osha.gov/law-regs.html

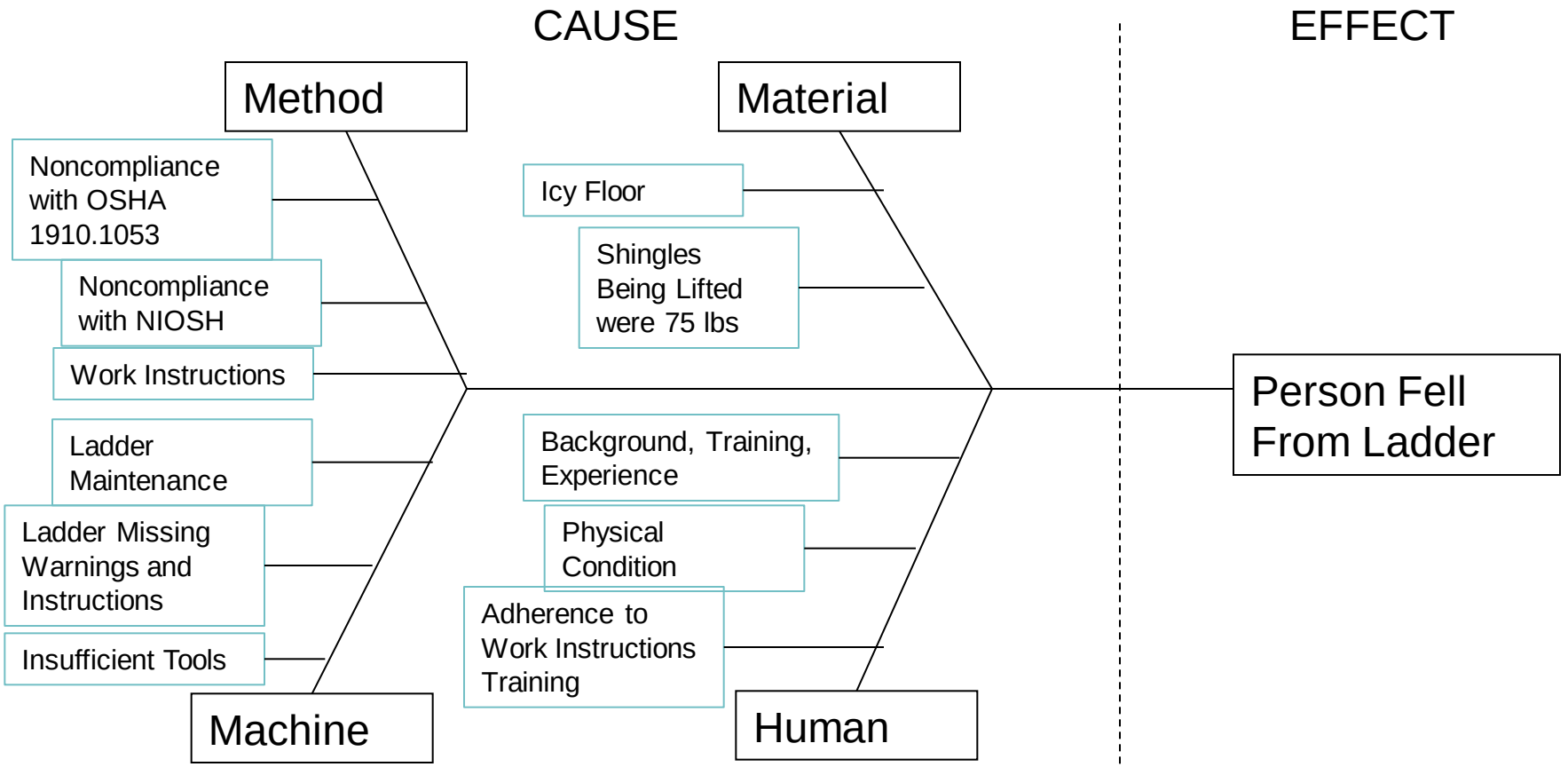
HF&E in Manufacturing or Workplace

- In Manufacturing Engineering, HF&E may appear again in FMECA/FMEA of the flow lines and manufacturing processes being designed, or a part of the ME's work processes, policies, and procedures.
- For example, a flow line aisle width or a manufacturing work station size may have minimum requirements to meet means of egress or emergency escape requirements per the fire code or OSHA.
- HF&E may also appear again during Task or Job Hazard Analysis, or Task Design Analysis.
- See the following link: https://www.osha.gov/Publications/osha3071.pdf
- See the following link:

  http://www.usability.gov/how-to-and-tools/methods/task-analysis.html

HF&E in Forensic Cause Analysis

- In the Root Cause Analysis Tree, HF&E usually appears in the Human or Methods portion of the tree.



Sample Fishbone Diagram

Scientific Method

- Forensic Engineers adhere to the Scientific Method when attempting to determine the cause of accidents.
- NFPA 921, Guide for Fire and Explosion Investigators proposes the following method:
- Recognize The Need – Determine cause of incident.
- Define The Problem – What caused the incident.
- Collect Data – scene and evidence inspection, photos, reports, destructive evidence examination/testing, and etc.
- Analyze Data
- Develop a Hypothesis
- Test Hypothesis
- Select Final Hypothesis – Final Cause determination
- HF&E may not be a primary cause, but could a cause or an aggravating factor in the cause of an accident.

Engineering Hierarchy in Safety

- We briefly mentioned Engineering Controls and Administrative Controls earlier.
- Engineering Controls are the controls engineered into a product or process that attempts to eliminate or minimize the hazard to a user or person proximate to the product or process.
- Example of an Engineering Control would be an interlocked fixed machine guard. If the guard is removed or opened, the machine is designed so that it can not cycle or function.
- In the Hierarchy of Safety, Engineering Controls are superior to Administrative Controls.

Engineering Hierarchy in Safety (cont.)

- Administrative Controls are controls established external to the product or process that attempts to minimize the hazard to users or persons proximate to the product or process.
- Administrative Controls comes in a variety of forms such as standard work practices, policies, procedures, laws, industry consensus standards, instructions, warnings, manuals, and training.
- An Example of an Administrative Control would be Driver's Education, or a company's Lock Out/Tag Out Program, or a warning sign by an abandoned quarry that says, "No Swimming."

HF&E and Forensic Analysis

- Often forensic analysis of accidents involve an attempt at determining, proving, or disproving negligence or liability.
- HF&E can come into play especially when trying to determine what a witness knew prior to, and during the accident.
- HF&E can come into play when determining the adequateness of engineering controls.
- HF&E can come into play when determining whether or not a person received enough administrative controls to prevent the accident.

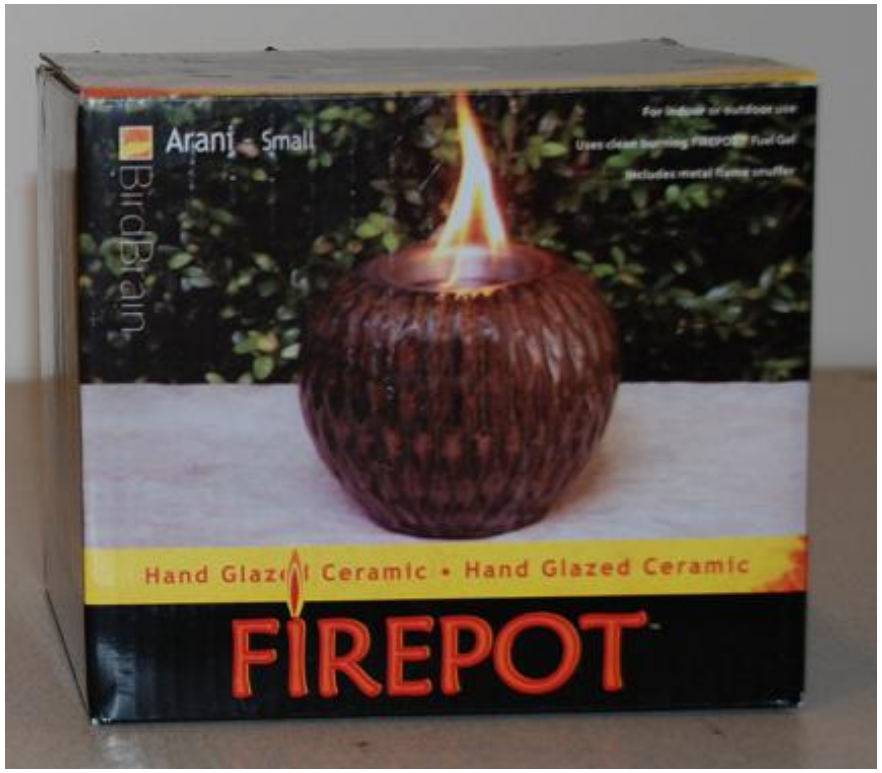
Examples of HF&E and Forensic Analysis of Accidents

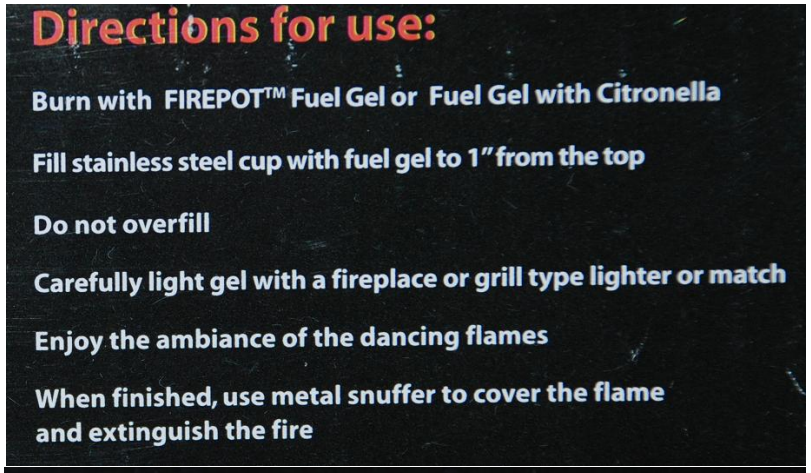
Example 1: FirePot Investigation

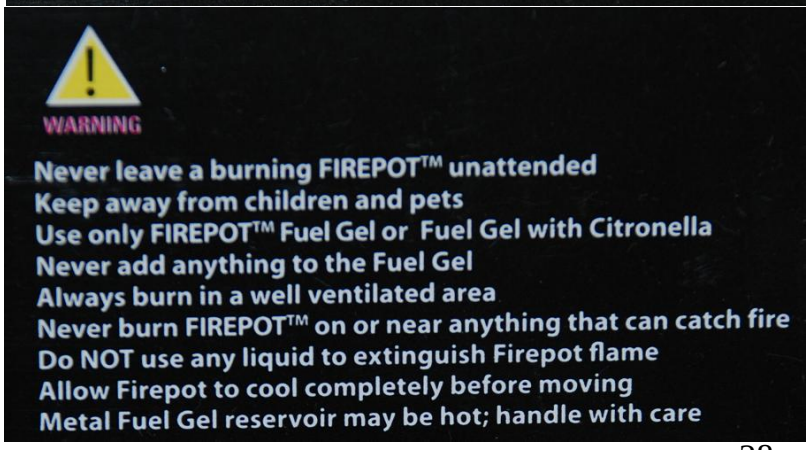
- In 2010, we were contacted about a case in which a female minor was burnt.
- An adult was filling a product called a FirePot with fuel gel when the incident occurred.
- Subsequently the case was closed and the product was recalled.
- Please review the following CPSC Recall:
- http://www.cpsc.gov/en/Recalls/2012/Bird-Brain-Recalls-Pourable-Gel-Fuel-Due-to-Burn-and-Flash-Fire-Hazards/#remedy

Example 1: FirePot Investigation (cont.)

- The following are photos of the packaging for the FirePot as well as warnings and instructions:







Example 1: FirePot Investigation (cont.)

- So what is the problem?
- This is a photo of the product actually lit as compared to other similar engineering art:

FirePot - Lit

Citronella Lamp

Citronella Tiki Torch

Example 1: FirePot Investigation (cont.)

- The fuel gel for this device burned so cleanly that a reasonable person could not see if the device was still lit.
- During use and upon burning out, the area around the device smelled like alcohol fuel gel, so there was no way to tell by smell whether or not the device was still lit.
- The device can maintain a small flame, so feeling the device for heat may not tell a person whether the device was still lit.
- Upon attempting to refuel the device, fire can actually travel back up to the fuel container and cause a little explosion.
- This is a prime example of where the administrative controls (warnings and instructions), and the engineering controls (snuffer) could not adequately control the hazard given the human factors limitations.

Example 2: Motor Vehicle Accident Reconstruction

- Many times in MVA, witnesses are asked, “Did you see the other vehicle prior to the collision?”
- The common response is, “I didn’t see the other vehicle.”
- Driving is a complex function in which humans are processing a lot of visual information and making many split second decisions.
- A typical example are the photos on the next slide taken on the same highway heading from Connecticut through New York.
- Time is near daylight.
- Weather is clear.
- **Exercise:** Turn to the next slide, look at the photo for 2 seconds, then proceed to the next slide and look at the photo for 2 seconds and the proceed to the questions on slide on page 26.

Example 2: Motor Vehicle Accident Reconstruction Exercise

Example 2: Motor Vehicle Accident Reconstruction Exercise

Example 2: Motor Vehicle Accident Reconstruction Exercise

First Photo Questions:

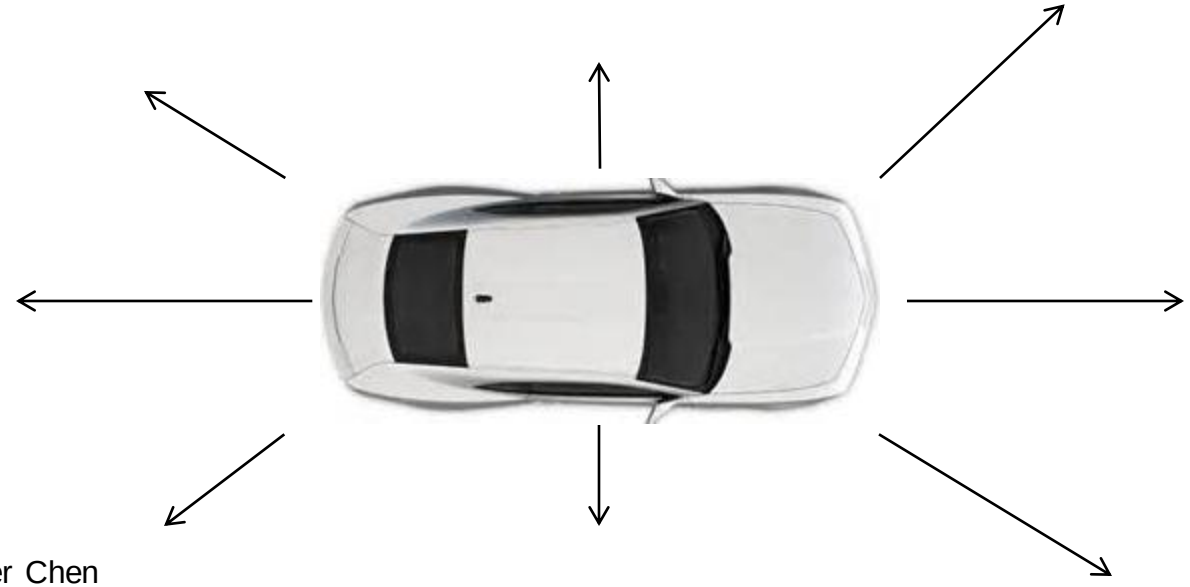
- How many cars were in front of you in the first photo?
- How many lanes were there in the opposite direction?
- Which lane were you in?

Second Photo Question

- How many trucks were there in front of you?
- How many cars were in front of you?
- What were all the cars and trucks colors?
- How many lanes were there in the opposite direction?

Example 2: Motor Vehicle Accident Reconstruction (cont.)

- It is not common or practical for drivers to attempt to memorize details of all the vehicles or vehicle speeds around them.
- Drivers are attempting to manage speed and direction to maintain clearances in 8 directions.
- Driving is a very dynamic situation in which the number cars, conditions, visibility, traffic patterns, and traffic control devices are constantly changing.



Example 2: Motor Vehicle Accident Reconstruction (cont.)

So remember in MVA reconstruction:

- "I did not see the other vehicle" doesn't mean a person is visually or cognitively impaired, or inattentive.
- "I did not see the other vehicle" could mean "I perceived and noticed no threats to my vehicle."
- "There was no cars in front of me" could mean "There were no cars within my perceived minimum safe following distance."
- "They came out of nowhere" could mean "They were outside of my physical line of sight given road topography and driving conditions."

Example 3: Human Response to Fire

- In 2009, I was contacted about an incident in which a person perished in a residential fire. According to fire reports, the roommate discovered the fire and alerted the person to the fire. However, instead of exiting right away, the person attempted to retrieve and put on his boots. Subsequently, the person became overcome with smoke, fire, or lack of oxygen.
- Please click on the following link for another example:
- http://youtu.be/U8VPS3UMl-s

Example 3: Human Response to Fire (cont.)

•From: http://wgntv.com/2014/09/08/vigil-to-be-held-for-4-children-killed-in-house-fire/

"Four children were killed in a house fire on Chicago South Side Monday morning.

The four siblings were trapped and died in the bedroom of their apartment. Two were found huddled in a closet that had no door. Two were found on a bed – an older sibling on top of the younger one as if there for protection.

The 911 call came in about 3:40 a.m. but fire officials tell WGN the fire may have been smoldering even longer because it was a torch by the time they arrived.

It started in an apartment on the second floor where no one was home and it spread quickly down the hallway and the back stairs to the third floor where the children, their mother and her boyfriend were sleeping.

Fire officials believe the boyfriend opened the door to the hallway. The flames were so intense that they pushed them back most likely into a corner of the living room where they had about ten seconds to decide whether to jump or not.

Shamaya Coleman broke her arms and legs in the jump. Her boyfriend, Nate Johnson, because he opened the door, inhaled flames and smoke that scorched his throat and lungs. He was transferred to Loyola University Medical Center's burn unit and is in critical condition."

Example 3: Human Response to Fire (cont.)

- From the previous examples, despite perhaps years upon years of training (school fire drills, public service announcements, and etc.) people may act contrary to what would largely be considered to be logical or expected.
- People stay when they should go. People go when they should stay and help others.
- The human psychological factors that affect response to a fire can include: immaturity (in the case of children), love, maternal or paternal instinct, a sense of duty, an unfounded expectation of invulnerability, and in the case of most people, lack of experience.

Human Factors Mistake or Error

Human Factors Mistake

- We are all human and we all make mistakes.
- Human Factors Error or Human Factors Mistakes has been studied extensively.
- Non-inclusively, the following list identifies many of the major causes of Human Factors Mistakes:
  - Fatigue
  - Performance Pressure
  - Over tasking or Multi tasking
  - Inattentiveness
  - Distraction
  - Willful Disregard for rules/procedures
  - Unfamiliarity of rules/procedures
  - Situational Unawareness or Unfamiliarity
  - Inadequate Supervision
  - Improper Supervision or Direction
  - Panic
  - Miscommunication or Lack of Communication
  - Confusion
  - Pre-established Bad Habit
  - Improper Extrapolation or Interpolation
  - Mismatch between capability and task
  - Lack of Confidence
  - Overconfidence
  - Habituation to Alert Stimuli
  - Underestimation of Task Difficulty or Hazards
  - Non-ideal work conditions

Human Factors Mistake Example 1

- In 2009, I was asked to take a propane sample for a house explosion in the midwest.
- The claim at the time was that an insufficient amount of mercaptan (odorant) was put into the propane that was delivered to the home.
- It was believed that the homeowner did not smell a propane leak prior to the explosion.
- The explosion blew out the back half of the house.

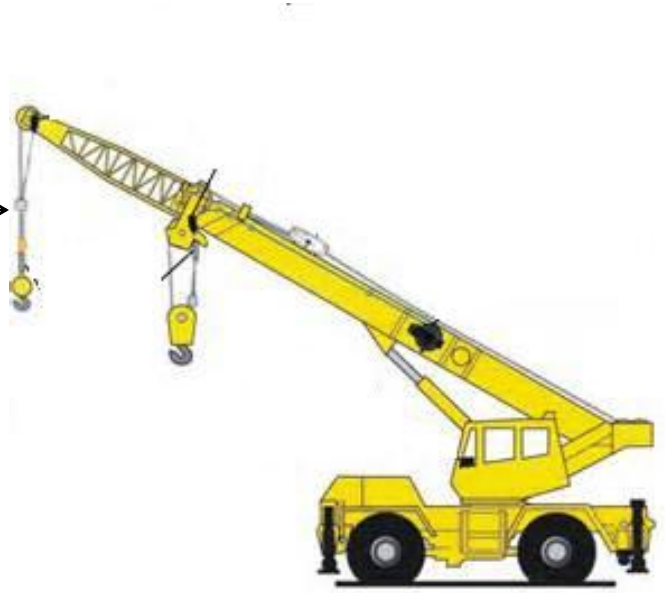
Human Factors Mistake Example 1

- It was discovered during the inspection, that the homeowner was in the propane business and had installed flexible propane lines for his own home as well as many other homes in the area.
- Due to years upon years of exposure to the odorant, it was believed that this homeowner had become habituated to the smell, and could not detect the leak at his home based on the smell.
- The sample came back from the lab demonstrating adequate amounts of Mercaptan, and all attendees during the inspection could smell the odorant when propane samples were taken.

Human Factors Mistake Example 2

- In 2010, I was asked to evaluate a crane accident in which an individual fell off of a tank when the crane operator forgot to extend his line to the auxiliary headache ball.
- Upon positioning the crane's main hook for the lift, the auxiliary ball was pulled from it's line and fell. The term of art for this type of occurrence is two-blocking.
- The spotter/rigger on top of the snow covered tank slipped, tripped, and/or fell getting out of the way of the falling auxiliary ball.

Auxiliary Ball and Hook →



Human Factors Mistake Example 1

- The operator failed to follow OSHA 1926.753(c)(1)(iv), ANSI B30.5 5-3.13, and the AEM manual with regards to avoiding two-blocking the auxiliary ball against the boom tip,
- During depositions, it was revealed that neither the operator or spotter/rigger knew of the crane industry standard hand signals. (See https://www.pinterest.com/pin/218213544415448046/)
- During depositions, both the operator and spotter/rigger testified that they met and came up with their own hand signals with regards to lifting/lowering the hook, booming out, angling up the boom, or other crane functions.
- During depositions, both the operator and spotter/rigger had different and conflicting hand signs for the crane functions.

Human Factors Mistake Conclusion

- "Human Factors Mistake or Error" is an HF&E term of art that does not automatically assign blame.
- Human Factors Mistake analysis or conclusions does not automatically mean "operator error", "blame the user", or "blame the customer."
- The Error or Mistake could be at the top of the cause analysis or tree and have root causes that go back to Methods, Machines, or Materials.
- But also in balance, Human Factors Mistake analysis or conclusions could mean "operator error", "user error", or "customer error."

Human Factors Mistake Conclusion

- CAUTION: Do not use Human Factors Mistake or Error analysis and conclusions prejudicially. Dig deeper into the root cause.
- CAUTION: There may not be enough information or evidence to make a Mistake or Error analysis or conclusion.