D8 A Fatal Hyperbaric Treatment Explosion Investigation Incorporating Engineering Simulations With Verification and Validation

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Learning Overview: After attending this presentation, attendees will understand some of the principles in using engineering simulations in support of forensic investigations, how to apply Verification & Validation (V&V), some of the specific strengths and pitfalls of Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD), and how a variation of an established medical device used for a different application can result in an unintended fatal hazard with attendant liability.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by demonstrating the use of engineering simulation, coupled with traditional engineering methods, to assess a catastrophic medical treatment event and demonstrate a potential low-cost mitigation. The engineering simulations not only allow for a more detailed examination of complex multi-physics events, it provides tools to clearly communicate the results to a lay audience. In forensic applications, the use of V&V methods could dictate whether simulations are admissible.

Engineering simulations have been an established tool for decades in the design of equipment, including medical devices. Investigating an equipment incident generally involves the equipment failing in some manner. Conventional calculations and simplified simulations are often sufficient for design work because the design intent is to establish a significantly safe design margin between the operating conditions and likely failure modes.[1] Failures, on the other hand, often involve non-linear or dynamic mechanisms well outside normal operating parameters. Additional knowledge and skill are needed to investigate equipment failure modes and assess the factors that led to the failure.

Engineering simulations face an additional hurdle in forensic applications. While illustrations and animations are generally treated by the courts as an extension of the expert's opinion, the static or animated images from engineering simulations are a result of intensive, complex calculations independent of the investigator.[2] This independence is a strength when properly coupled with other means, such as traditional engineering calculations, laboratory experiments, and other accepted methods of investigation. V&V provides a methodology to establish this linkage.[3,4]

The independence of simulations from the investigator is also a potential liability. Simulations can be seen as substantive evidence, not simply "illustrations." As such, they are subject to scrutiny similar to more traditional scientific tests. This means simulations could be challenged per the scientific evidence admissibility standards of the jurisdiction. The simulation's proponent must establish that the evidence is "based upon sufficient facts or data," is "the product of reliable principles and methods," and that the supporting expert witness "applied principles and methods reliably" when creating or using the simulation.[2] For these reasons, the investigator needs to not only understand the fundamental physics being modeled but also the V&V methods applied to the investigation to establish admissibility of the simulations.

This report will present a case study of a catastrophic hyperbaric treatment incident. The engineering codes and standards for medical hyperbaric systems in the United States is the American Society of Mechanical Engineers (ASME) Safety Standard for Pressure Vessels for Human Occupancy, designated PVHO-1.[5] The chamber in question, however, was for treating horses and, therefore, was excluded from the scope of the standard. A horse became agitated while in a pressurized metal chamber with an enhanced oxygen atmosphere. Key aspects of hyperbaric treatment for horses are not considered in PVHO-1. These key aspects led to the incident's cause of origin. The forensic engineer investigating the incident used FEA and CFD engineering simulation, coupled with ergonomic factors and Failure Modes and Effects Analysis (FMEA), to assess the root cause, assess liability, and develop a mitigation option.

It is recommended that investigators of equipment-related incidents learn the principles of applying engineering simulations such as FEA and CFD as well as how to determine if the simulations were properly established using V&V.

Reference(s):

1. Osage, David and James C. Sowinski. PTB-1-2014 ASME Section VIII -- Division 2 Criteria and Commentary. (2014). New York, NY: *American Society of Mechanical Engineers.*
2. Webster V., Bourn F.E. The Use of Computer-Generated Animations and Simulations at Trial. *Defense Counsel Journal.* 2016;83(4):439–459. doi:10.12690/0895-0016-83.4.439
3. Guide for Verification and Validation in Computational Solid Mechanics ASME V & V 10-2006: An American National Standard. New York, NY: *American Society of Mechanical Engineers*, 2006
4. Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer (ASME V&V20). New York, NY: *American Society of Mechanical Engineers,* 2009.
5. ASME PVHO-1 Safety Standard for Pressure Vessels for Human Occupancy. New York, NY: *American Society of Mechanical Engineers*, 2016.

Simulation, Fire, Fatal

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