15th Americas Conference on Wind Engineering
May 19-22, 2025 — St. Louis, MO
Center for Hazard Mitigation & Community Resilience
Missouri University of Science and Technology
2025 ACWE

Wind vulnerability of industrial facilities equipment

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KEYWORDS: Wind Vulnerability, Refinery, Risk Model, Equipment Classification.

ABSTRACT

Background and Significance

The authors, with the support of the Wind Hazard and Infrastructure Performance Center (WHIP-C), are developing wind vulnerability models for large industrial facilities, such as refinery plants. This research presents numerous challenges, as these facilities are spread over vast areas that can exhibit significant variations in wind speeds, surface friction, topography, and other factors. Moreover, the infrastructure components of these facilities can vary greatly, including power stations, pipe racks, tanks, warehouses, cranes, towers, and more.

This research is important for establishing a future standard methodology for determining vulnerabilities in refineries and industrial facilities. We believe it could become a tool that reduces subjectivity in defining vulnerability, which is currently approached in a variety of inconsistent ways. Standardizing the methodology for wind vulnerability models is essential for enabling fairer comparisons in the future and drawing conclusions with reduced bias.

Methodology

The authors propose decomposing a refinery into several subsystems corresponding to its different equipment. for which conventional risk models can be applied: one site, one hazard, one vulnerability. These models will then be combined (though not necessarily added) based on the intercorrelations between the subsystems. In this so-called "LEGO" approach, typical vulnerability equipment can be plugged in and interconnected, much like LEGO blocks, to produce an aggregated wind vulnerability model for the entire system.

The primary focus of this research lies in the development of wind vulnerability matrices and curves for refinery equipment and structures, which serve to quantify and assess the susceptibility to wind-induced damage. The columns of a vulnerability matrix are probability density functions (pdf) of damage conditional on different hazard intensity intervals (each column represents a different intensity interval). The vulnerability curve plots the expected damage for each column pdf as a function of hazard intensity. Vulnerability matrices and curves are commonly used to estimate potential economic losses by correlating hazard intensity with a specific loss metric.

The most vulnerable equipment, and therefore the focus of our study, are the tanks and pipe-racks, The study starts with detailed taxonomies of tanks and pipe-racks within refineries, which translate into the characterization of different classes for each type of equipment. The taxonomies also inform the nomenclature that identifies each class of equipment for which we define a vulnerability model. By characterizing all equipment into different classes based on their corresponding taxonomies and having established the vulnerabilities of each equipment class, we will achieve a comprehensive understanding of the vulnerability of the equipment in the refinery.

A refinery Process Flow Diagram (PFD) is an essential documentation for its operation. The PFD illustrates all the processes, each of which involves one or more equipment, and each equipment has its own taxonomy, and for which we have already defined vulnerability based on their type and class. What is particularly interesting is that it also shows the interconnections between these processes. This allows us to define a workflow, understanding the equipment involved and the vulnerabilities associated with each equipment, as well as the overall vulnerability of each process flow within the refinery. By weighting and interconnecting the vulnerabilities of each flow, we can determine the overall vulnerability of the refinery.

Major Findings and Implications

A typical refinery PFD from Occupational Safety and Health Administration (OSHA), helped to identify and map 48 key processes, their relationships, and 71 unique product flows. within a typical refinery configuration. Furthermore, we categorized and tagged all processes according to equipment type, as shown in Figure 1, and initiated the classification of equipment into distinct categories.

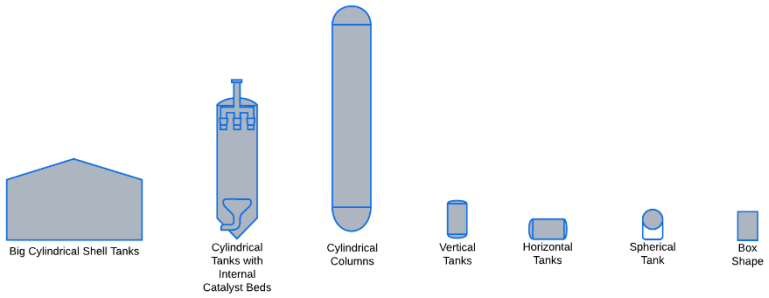

Figure 1: Tank classification

We shall present vulnerability curves, primarily for these different classes of tanks. By developing and comparing these curves, we provide a framework for evaluating the wind vulnerability of tanks, which are critical equipment in refinery and industrial operations.

This is a work in progress. The goal is to develop a framework to characterize and assess the wind vulnerability of a refinery plant. Several key preliminary results will be presented at the conference, including the definition of the crude oil process flows, the characterization of the equipment involved including its wind vulnerability, and an analysis of the limitations inherent in the wind vulnerability model.