**Power Plant Design using Allam Cycle CCS**
(Technical Report)

**Tesoro Anacortes Refinery Explosion: Who Should Be Held Accountable?**
(STS Research Paper)

An Undergraduate Thesis Portfolio

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# Socio-Technical Synthesis: Allam Cycle CCS and the Tesoro Anacortes Incident

My technical work and STS research are linked in that they both consider the role of process safety in the chemicals industry. My technical work incorporates thorough hazard analyses and highlights health and safety considerations to ensure that a new Allam cycle based natural gas power plant can be implemented in a cost-effective and safe manner. My STS research differs from my technical work by considering how moral responsibility for major chemical accidents can be systematically derived from root-cause analysis, specifically for the Tesoro Anacortes refinery explosion of 2010. Overall, both projects consider the importance of having excellent process safety programs in order to protect workers, the community, and the environment from chemical process hazards.

The Allam cycle is a revolutionary new method of producing electricity from fuels with near perfect sequestration of carbon emissions. Because only natural gas and pure oxygen are fed to the process, highly pure $CO_2$ is produced as a combustion product that can be drawn off from the process without energy intensive $CO_2$ separation. Consequently, the Allam cycle produces no carbon emissions and can deliver electricity at competitive prices – this feasibility has already been proven at a 50 MWe pilot plant in La Porte, TX, with development of a larger scale Allam cycle plant currently in the works. Due to high purchased oxygen prices, my technical work concluded that a large scale 600 MWe Allam cycle plant is uneconomical when an on-site air separation unit is not employed. This provides the important insight that in the current energy

market, the Allam cycle must be paired with other profitable technologies like air separation to achieve economic feasibility.

My STS research project builds upon standard root-cause analysis in an attempt to systematically assign responsibility for the Tesoro Anacortes refinery explosion. On April 2nd, 2010, a heat exchanger catastrophically ruptured near the refinery's Naphtha Hydrotreater Unit due to a phenomenon known as high temperature hydrogen attack (HTHA), killing 7 Tesoro employees. I argue that The American Petroleum Institute (API) should be held morally accountable for the Tesoro Anacortes refinery incident over Tesoro because only they satisfy all responsibility criteria postulated by Van de Poel, which are wrong-doing, causal contribution, foreseeability, and freedom of action. By characterizing the Anacortes network using Actor-Network Theory and then applying the responsibility criteria to both groups systematically, I was able to argue that with all other criteria being satisfied, Tesoro does not satisfy the foreseeability criteria while the API does.

Developing these projects together was valuable because it allowed me to observe two often neglected aspects of process safety – the role of inherently safer design and the assignment of moral responsibility for process safety incidents. Curricular discussions about process safety incidents often focus too narrowly on root cause analysis. My technical work gave me a better understanding of how social conditions and simple mistakes in plant design might lead to the root causes instrumental in the Anacortes refinery explosion. The tragic consequences of the Anacortes refinery explosion discussed in my STS research demonstrated a sobering reminder of what is on the line in engineering design and that those who do not properly address process safety hazards can and will be held morally responsible. In turn, this motivated me to deeply consider the process safety hazards relating to my technical work and to focus on inherently safe

power plant design. Overall, working on my technical and STS research projects simultaneously allowed me to achieve a more holistic understanding of process safety.

## Table of Contents