The Application of Simulation Techniques to Enhance Nitroglycerin Production Efficiency: A Case Study of the Military Explosive Factory in Nakhon Sawan Province

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Abstract

This study's goals were to enhance nitroglycerin manufacturing efficiency through simulation, recover nitroglycerin from the storage facility, and enhance nitroglycerine recovery and purge systems. It was found that the problem was nitroglycerin reflux. Therefore, the researcher created three alternatives to solve the problem. The system of Nitroglycerine Recovery and Purge was then simulated using the FlexSim program, and each alternative was tested. The results demonstrate that the alternative system-led Nitroglycerine Recovery and Nitroglycerine Purge System collaborate to produce Nitroglycerine, which is more efficient than other alternatives and can reduce production time. It can also improve the recovery of nitroglycerin. It also serves as a guideline for developing a real-world system and modeling it for training staff without wasting chemical raw materials or fuel energy.

Keywords
Efficiency Increase, Nitroglycerine recovery and purge system, production Improvement, simulation

1. Introduction

Explosives, which can be categorized into low explosives and high explosives, are any one or more types of substances that, when exposed to a sufficient amount of heat or mechanical force, will instantly decompose, creating heat and large quantities of pressurized gas that will destroy everything nearby (Boonsin Kulsiripruek 2021).

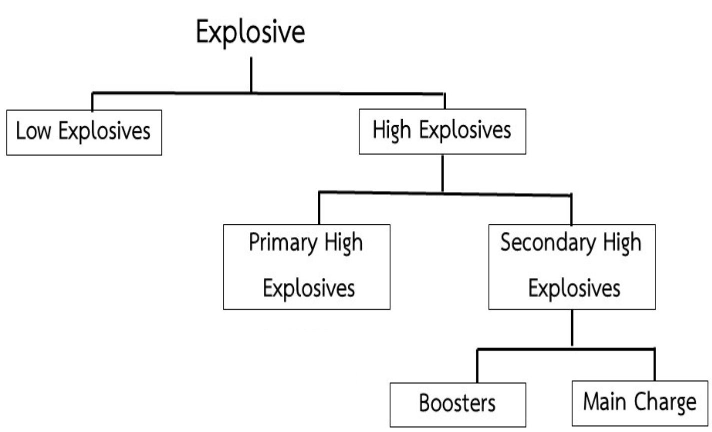

Figure 1. Category of Explosive (Military Explosive Factory Propellant Handbook 2021)

Nitroglycerine, abbreviated NG, is an explosive liquid energy substance (Boonsin Kulsiripruek 2021) It was first discovered in 1846 when Ascanio Sobrero, an Italian chemist, mixed glycerin with a mixture of nitric and sulfuric acids. It is highly explosive when subjected to vibration. Then Alfred Bernhard Nobel discovered a means to slow down the detonation of explosions by mixing nitroglycerin with an inactive sorbent like powdered silica, atomic manganese, or absorbing cotton fibers. It is also known as gunpowder, diatomaceous earth, and atomic earth in some locations. Nitroglycerin is a colorless liquid in its natural state. It is a chemical compound between "nitrogen" and "glycerin." Dynamite is a very explosive type. However, because it is safe to move, it is used in a variety of contexts. It is often used in various industries, such as mining, building tunnels and canals, and making war weapons.

Nitroglycerin is derived from the nitration of glycerin. In this procedure, concentrated nitric acid and sulfuric acid are gently mixed with glycerin. The approximate composition is 40% nitric acid and 50% sulfuric acid. The glycerin must be about room temperature because when glycerin is mixed, it causes an exothermic reaction that generates very high heat. This can be solved by slowly mixing the substances. After a few minutes of mixing, immerse the container in ice to prevent an exothermic reaction. Overheating can lead to nitric acid decomposition or an explosion. The temperature of the substance should be 30 °C.

The "nitroglycerine recovery and purge system" refers to the process of taking nitroglycerine from the final nitroglycerine trap building into the recovery process to be stored in the storage building and nitroglycerine weighing into the production process again without wasting raw materials (Nobel Explosives Company Limited 1993). Another function of the Nitroglycerine Recovery and Purge system is to flush contaminants from nitroglycerine. If the heat test value is lower when detected, this process will remove the contaminant sodium carbonate solution stained from nitroglycerin, resulting in pure preserved nitroglycerin. When checking the heat test value of nitroglycerin again, it will be found that the heat test value is higher than the safety criteria.

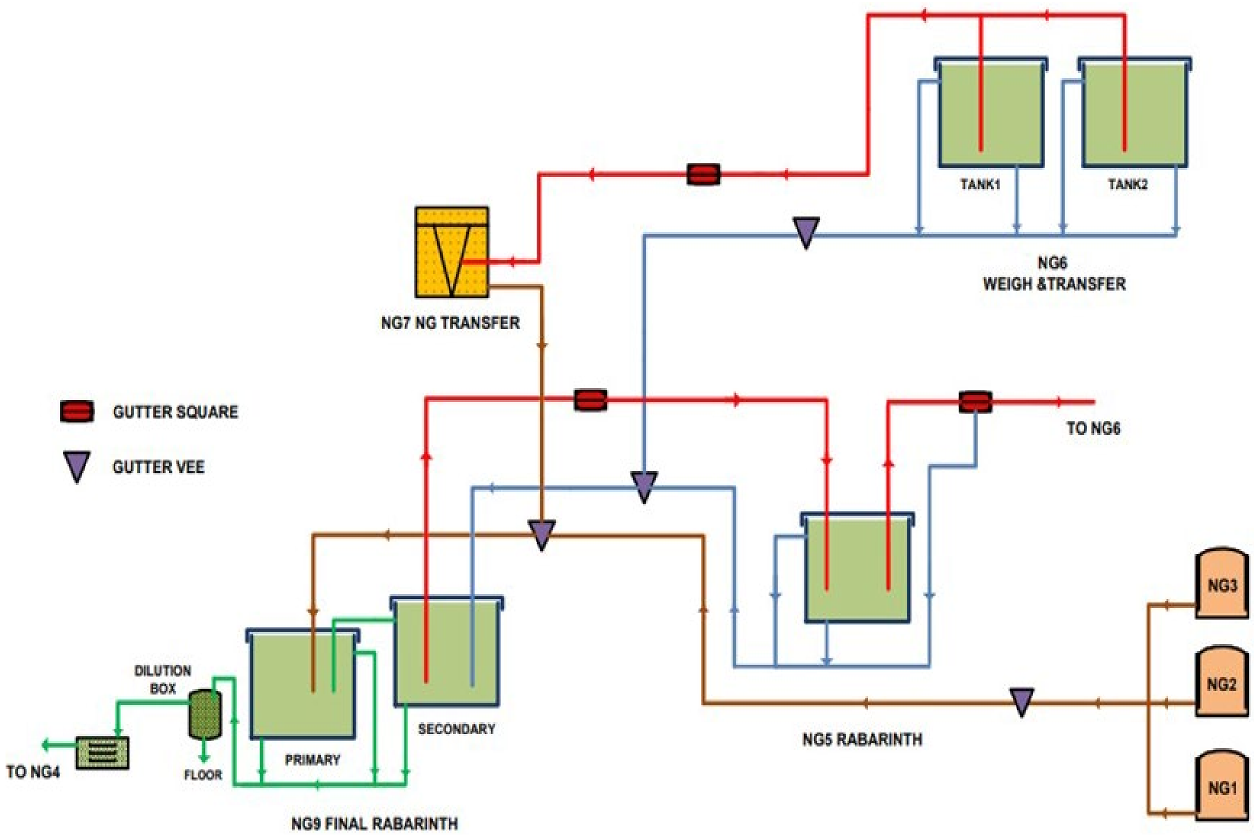

Figure 2. The Structure of Nitroglycerine Recovery and Purge System
(Nobel's Explosives Company Limited. Hazard Studies, 1993)

Simulation is the process of designing a model of the real system and then experimenting with the model to learn the behavior of the system or to evaluate the results from the use of various strategies under the specified requirements. Kelton et al. (2003) stated that computer simulation is a group of techniques for simulating actual events or the behavior of various systems on a computer by applying computer programs to analyze the workflow and perform a variety of activities. The data is collected and analyzed to find the correct form in the computer program for future improvement. The simulation is divided into two main parts: modeling and analytical modeling. Consequently, it is found that the simulation's methodology depends on the model and how it is applied. The model must be able to help in understanding the real working system in order to describe the behavior and improve the performance of the real system (Thongprasert 2001). With the advancement in computer technology, simulations have been used to solve a variety of problems, such as warehouse management, process scheduling, production systems, queuing systems, etc.

Flexsim Simulation Software is simulation software that models the operation of a variety of systems, (Malcolm et al. 2017.) including transportation services (including a large supply chain model) and industrial production systems, in order to inform operators or other decision-makers about the efficiency and effectiveness of the operational process and recommend improvements. Once the solution is known, it can immediately improve operational problems in the simulation model without actually operating the work to reduce costs, increase efficiency, and save time.

Figure 3. Applied Simulation (FlexSim Software Products 2017)

2. Methodology

2.1 Data Collection

The researcher gathered the information from the Nobel Explosives Company Limited, a business that manages the military explosives factories, in the form of documents, manuals, plans, and factory layouts. Additionally, the data was compiled through interviews with knowledgeable individuals working in relevant contexts within Nobel Explosives Company Limited.

Figure 4. Documents, manuals, and plans of the Nitroglycerine Recovery and Purge System
(Nobel's Explosives Company Limited. Hazard Studies 1993)

2.2 Working system of Nitroglycerine Recovery and Purge

When the nitroglycerin level is below the standard, the Nitroglycerine Recovery and Purge system are used to restore nitroglycerine degradation so that the nitroglycerin is purer and within a safe range. Additionally, it is possible to use the system to pump up nitroglycerine that is released during the production of the nitration reaction as well as nitroglycerine that is released from the storage building in order to produce NG or NC paste without wasting the primary raw materials.

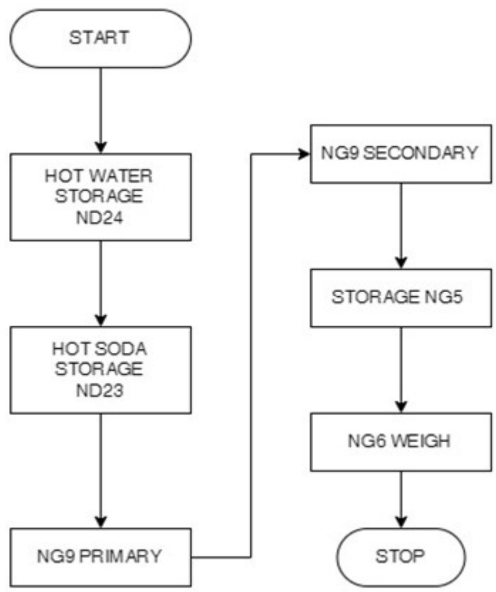

Figure 5. Flowchart of System Operation for Nitroglycerine Recovery
(Nobel's Explosives Company Limited. Hazard Studies 1993)

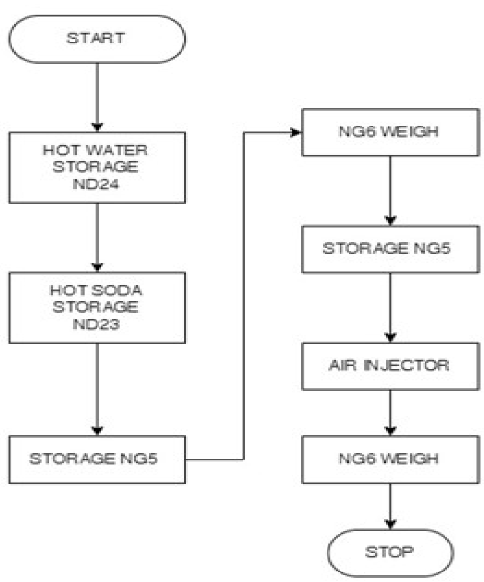

Figure 6. Flowchart of System Operation for Nitroglycerine Purge

(Nobel's Explosives Company Limited. Hazard Studies, 1993)

2.3 Examine the operation of the actual/current system.

The procedure's duration is used to determine the path that the system currently uses when using the operator, and after that, the current situation is simulated.

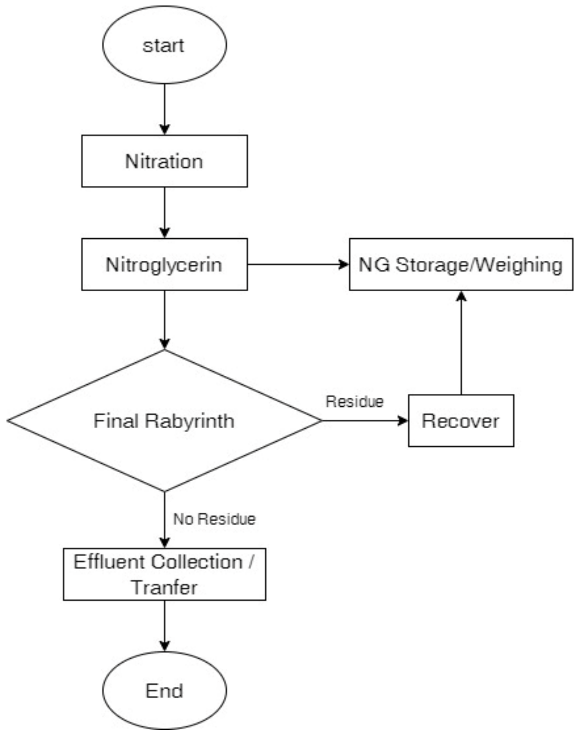

Figure 7. Flowchart of the actual/current system.
(Nobel's Explosives Company Limited. Hazard Studies, 1993)

2.3.1 Simulation of the actual/current system

The workflow was then applied to the flowchart to create a model of the current situation by designing the locations of buildings, routes, and employees, as shown in Figure 8.

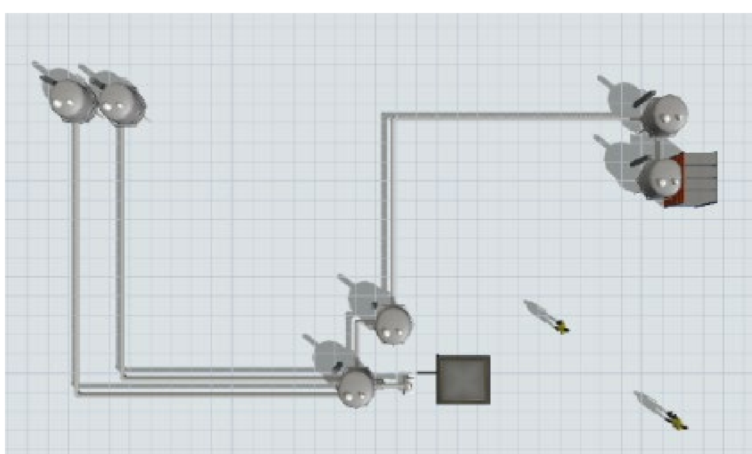

Figure 8. Simulation of the actual/current system

2.3.2 Situation analysis from the current system model

Based on the simulation of the current Nitroglycerine Recovery system by Flexsim Simulation program. until the end of the process takes a total of 3,037.38 seconds as shown in Figure 9.

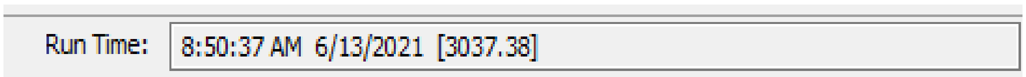

Figure 9. Total system operation time Nitroglycerine Recovery currently used

2.4 Creating alternatives

The researcher developed alternatives based on the collected data in order to enhance and improve the effectiveness of nitroglycerin production. In Figure 10, three alternatives are presented.

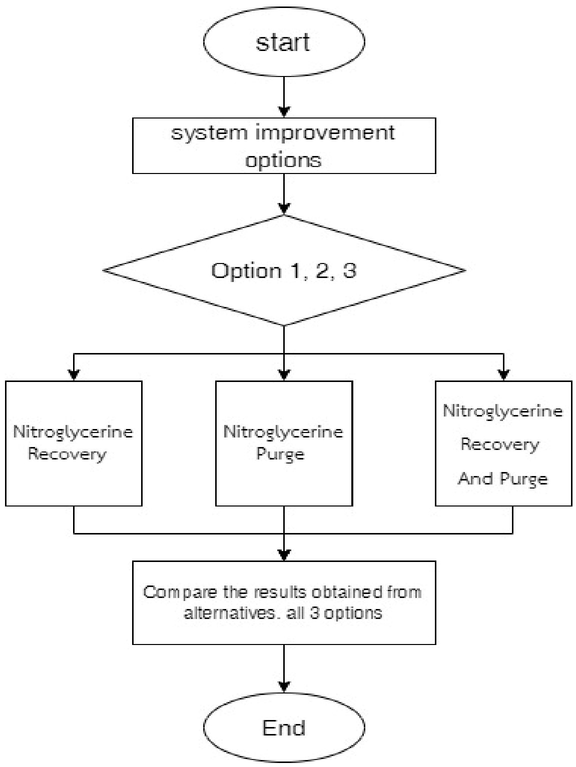

Figure 10. Alternatives for system enhancement for Nitroglycerine Recovery and Purge.

3. Simulation

3.1 Simulation model for each alternative

The three options were modeled using the Flexsim simulation software and then all three of them were compared. The simulation model shown in Figure 11 was created using an alternative Nitroglycerine Recovery System to increase the productivity of Nitroglycerine production, which takes 2040 seconds, or 34 minutes, before it is delivered to the Nitroglycerine Purge System.

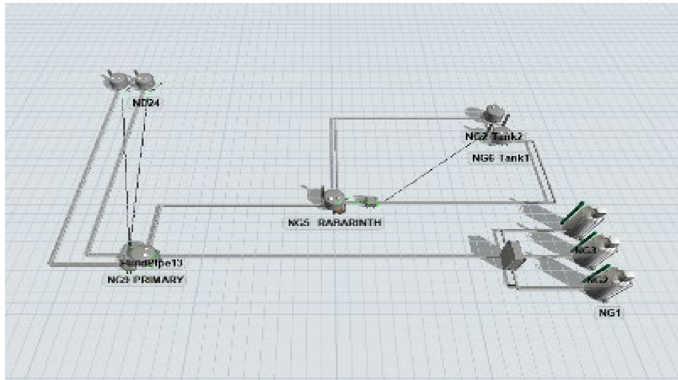

Figure 11. Simulation model of alternative in Nitroglycerine Recovery.

The simulation model shown in Figure 11. was created using an alternative Nitroglycerine Purge to increase the productivity of Nitroglycerin production, which requires 15,960 seconds, 266 minutes, or 4 hours and 26

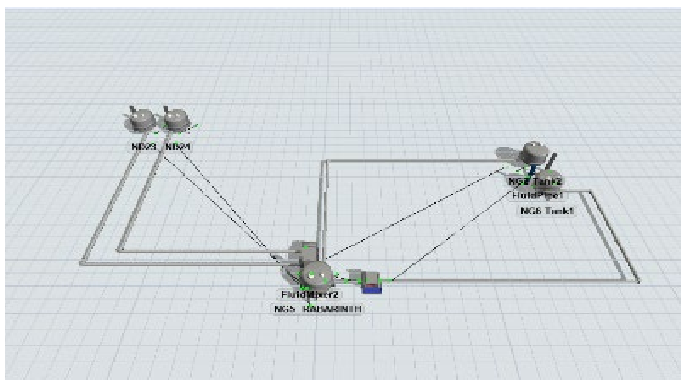

Figure 12. Simulation model of alternative in Nitroglycerine Purge.

It will take the combined amount of time required by the Nitroglycerine Recovery System and the Nitroglycerine Purge System, which is 2,040 + 15,960 = 18,000 seconds, 300 minutes, or 5 hours, to complete the process.

Figure 13. shows a simulation model that was developed by applying an alternative to the Nitroglycerine Recovery System and the Nitroglycerine Purge System used in combination to enhance the productivity of Nitroglycerin synthesis, taking 16,020 seconds, 267 minutes, or 4 hours, 45 minutes.

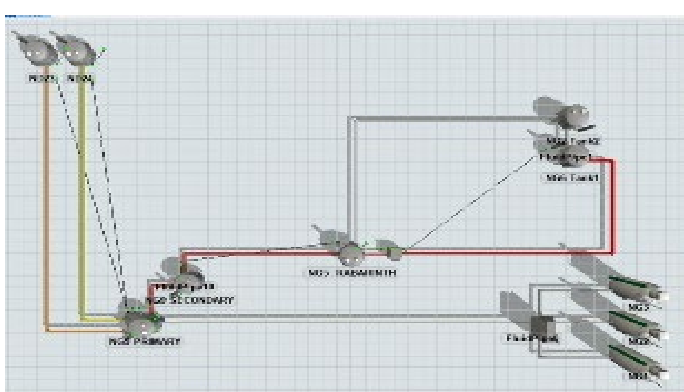

Figure 13. Simulation model of a Nitroglycerine Recovery and Purge alternative.

4. Results and Discussions

Alternative 1: Improving nitroglycerin production efficiency by developing a system for nitroglycerine recovering from simulation and using it in production without wasting the primary raw material. It takes 2,040 seconds, or 34 minutes, before it is transferred to the Nitroglycerine Purge system.

Alternative 2: Increasing efficiency in nitroglycerin production by building a system for nitroglycerine purge, resulting in the recovery process of nitroglycerin decomposition taking 15,960 seconds, or 266 minutes, or 4 hours and 26 minutes. The process duration was the combination of the Nitroglycerine Recovery System and the Nitroglycerine Purge System, which is 2,040 + 15,960 = 18,000 seconds, or 300 minutes, or 5 hours.

Alternative 3: By installing a nitroglycerin tank, valve, and pipe to link the two systems together, the Nitroglycerine Purge System is used in conjunction with the Nitroglycerine Purge System to strengthen the connection between the two systems and enable them to access one another. The simulation produced a nitroglycerin emission recovery system and a nitroglycerin decomposition recovery system capable of running continuously for 16,020 seconds, 267 minutes, or 4 hours, 45 minutes. It is also possible to work in any system.

5. Conclusions

The study's findings are based on data from layouts, manuals, and factory plans owned by Nobel Explosives Company Limited as well as on interviews with knowledgeable employees who have been given technology by the company. The development of three alternatives to improve the efficiency of nitroglycerin production was also influenced by a comparison of the work process durations between the Nitroglycerine Recovery System and the Nitroglycerine Purge. The third alternative is to apply the Nitroglycerine Recovery System and the Nitroglycerine Purge System, the regeneration process of nitroglycerin decomposition is able to work continuously. It takes 16,020 seconds, 267 minutes, or 4 hours and 45 minutes, and it can choose to run either system. It is the most suitable choice. The application of simulation techniques to increase nitroglycerin production efficiency in a case study of a military explosives factory in Nakhon Sawan Province can be a practical and effective approach to system development. Nitroglycerine Recovery and Purge can be used successfully in practice.

The technical data for this research is particular to nitroglycerin production plants, factory divisions, and military explosives factories, and only individuals working in the nitroglycerin production plant fully comprehend the working process. Those who are interested, however, can apply the concepts of the Nitroglycerine Recovery and Purge System to various operational applications. When designing a real system, it is advantageous to learn more about electrical and electronic control devices, performance display devices, and the system's control system in order to be consistent with the Nitroglycerine Recovery and Purge system and make the system more complete and safer for operators.

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Biography

Jeerasak Wisatphan received the B.Tech. (2011) in electrical technology from King Mongkut's University of Technology Thonburi, Thailand.
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His current research interest is how to use simulation techniques and industry 4.0 to develop digital twin systems for the supply chain management.