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Towards The Independence of The Propellant Industry for Munitions and Rocket

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Kata kunci:

Industri propelan, Nitroselulosa, Nitrogliserin, Propelan Basis Tunggal, Propelan Basis Ganda

ABSTRAK

Indonesia belum mampu menghasilkan propelan yang merupakan komponen penting sistem pertahanan negara. Ketergantungan jangka panjang pada impor untuk amunisi dan komponen roket dapat membahayakan kesiapan operasional TNI. Isu dan kelemahan tersebut rentan terhadap tekanan politik dan kurang memiliki kesiapan faktor independensi dan deterrence dikarenakan mempengaruhi kebanggaan nasional terhadap pertahanan negara, pemasangan pabrik propelan tidak boleh ditunda. Nitroselulosa, bahan baku utama selulosa dan nitrogliserin, yang bahan baku utamanya adalah gliserin, digunakan sebagai bahan baku utama dalam produksi propelan. Industri dalam negeri telah menghasilkan dua bahan baku utama tersebut.

***Keyword*:**

Industrial Propellant, Nitrocellulose, Nitroglycerin, Single Base, Double Base Propellant

ABSTRACT

Indonesia has not yet been able to generate propellants, which are crucial components of the country's defense system. Long-term reliance on imports for ammunition and rocket components can compromise the TNI's operational readiness. These issues and weaknesses include being susceptible to political pressure and having less independence and deterrence factor readiness. Because it affects national pride in national defense, the installation of a propellant factory should not be postponed. Nitrocellulose, the primary raw material of cellulose and nitroglycerin, whose primary raw material is glycerine, is used as the primary raw material in the production of propellants. Domestic industries have generated the two primary raw materials.

1. INTRODUCTION

It is crucial to have the ability to make items in order to advance technological capabilities. The presence of rich natural resources (raw materials) does not translate into assets that can be possessed without evolving technological capabilities [1]–[3]. Natural resources, meantime, have become increasingly useful materials thanks to the advancement of science and technology, particularly in the fields of security and defense [4]–[6]. The following diagram illustrates the potential for the propellant and explosives industry. The propellant is a propulsion material used in light, medium, and heavy munitions as well as for rocket filling [7]–[10]. The majority of the raw ingredients may be purchased/have been produced domestically as shown in Figure 1.

Propellants can be divided according to the general raw material, namely (a) single base propellant (nitrocellulose) used in pistol munitions, (b) double base propellant (nitrocellulose & nitroglycerine) used in small and large caliber munitions and in rockets, (c) triple base propellant (nitrocellulose, nitroglycerin & nitroguanidine) used in large caliber munitions and howitzers, The integrated propellant plant consists of (a) ball powder plant, (d) nitroglycerine plant, (c) nitroglycerine powder plant, (d) nitrocellulose plant,

(e) plant rocket propellant. The discussion in this paper is limited to the process of making Nitroglycerin, Nitrocellulose, and Double Base Propellant.

2. MATERIAL AND METHOD

2.1 Materials

To determine the extent to which the quantity and quality of propellant raw materials have been carried out surveys and data collection of industries that have produced materials related to the process of making nitrocellulose and nitroglycerin. The following data sources of raw materials as shown in Table 1.

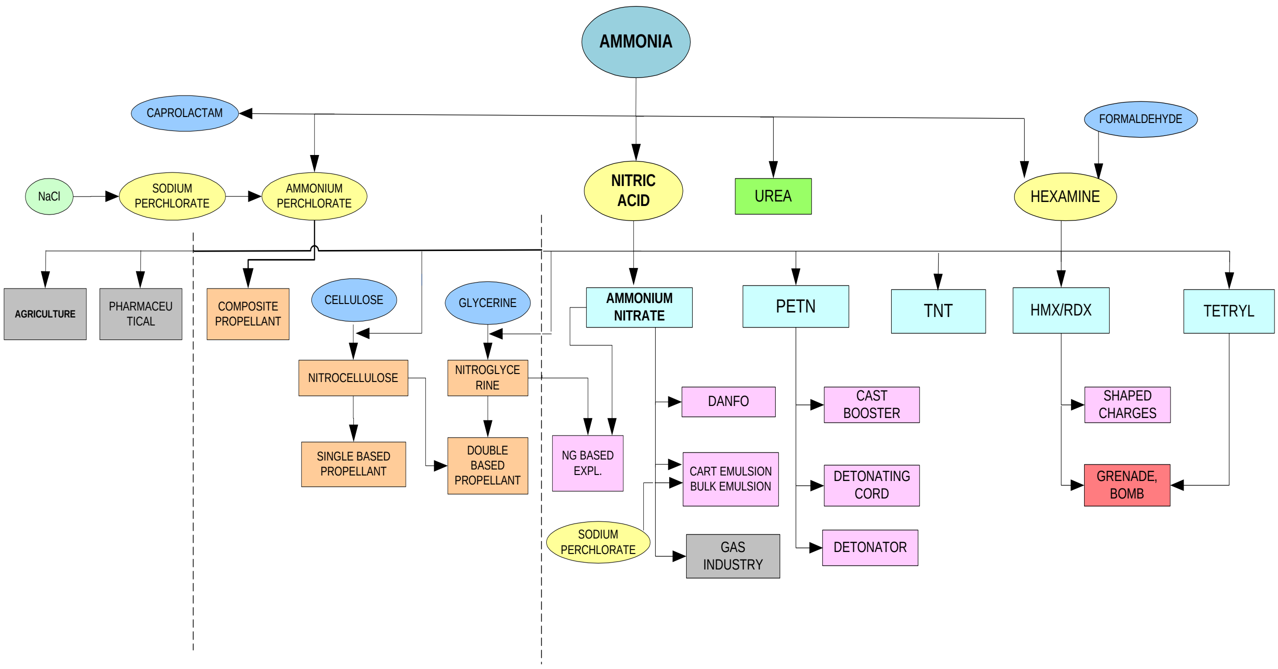


Figure 1. Diagram illustrates the potential for the propellant and explosives industry

: the raw materials are already produced and available domestically.

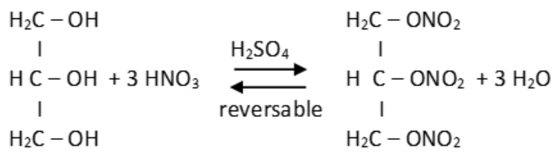
Table 1. Propellant Raw Material Source

No	Factory Name	Types of Products	Production Capacity/Year	Location
1	PT. Inti Cellulose Utama Indonesia	Cellulose, 99.99%	2.700 tons	Banten, Leces Probolinggo, Mojokerto, Padalarang, Blabak.
2	PT. Aribhawana Utama	Glycerin	20.000 tons	Medan
	PT. Budi Aneka Cemerlang		1.500 tons	Tangerang
	PT. Cisadane Raya Chem		25.500 tons	Tangerang
	PT. Para Sawita		5.400 tons	Medan
	PT. Sayap Mas Utama		3.000 tons	Bekasi
	PT. Sumi Asih		9.000 tons	Bekasi

No	Factory Name	Types of Products	Production Capacity/Year	Location
	PT. Wing Surya		4.000 tons	Gresik
3	Pabrik Asam Sulfat	Sulfuric Acid		Jakarta
4	Pabrik Asam Nitrat	Nitric Acid		Jakarta, Surabaya, Cikampek
5	Pupuk Kaltim I & II	Ammonia (NH_3)	330.000 Tons	Kalimantan Timur
6	Aceh Fertilizer	Ammonia (NH_3)	330.000 Tons	Aceh
7	PT. Pupuk kujang	Ammonia (NH_3)	330.000 Tons	Cikampek
8	Pupuk Sriwijaya	Ammonia (NH_3)	927.200Tons	Palembang
9	Industrial Gases	Oxygen (O_2)	4.802.476 M3	Jakarta
10	PT. Nila Alam	Oxygen (O_2)	829.080 M3	Jakarta

2.2 Nitroglycerin (NG) Manufacturing Process

Nitroglycerin is made from the reaction of glycerin with nitric acid with a sulfuric acid catalyst. The reaction is as follows :



Due to the significant risk and potential hazards of this research, extreme vigilance is essential. This is due to Nitroglycerin's nature, which is extremely sensitive, poisonous, and explosive and will decompose into:

$$4\ C_3H_5N_3O_9 \rightarrow\ 12\ CO_2 +\ 6N_2\ + 10\ H_2O + Heat$$

Nitroglycerin based on a chemical reaction is produced by reacting glycerin (glycerol) with nitric acid. However, there are several kinds of processes for making nitroglycerin.

1. **Schmid-Meissner** *continuous process*
2. **Nitro Nobel** *injector proses*
3. **Biazzi** *continuous process*

2.2.1 Schmid-Meissner

Schmid-Meissner was the first process in the manufacture of nitroglycerin. The process includes nitration, separation, and purification of nitrogen by neutralization and washing. The nitrator is in the form of a stirred tank, equipped with vertical cooling pipes. As a cooling medium, brine is used which enters at a temperature of -5°C. The mixed acid enters from the bottom of the nitrator and glycerin enters from the top while the result exits by overflowing to the separator (stainless steel). The nitrator temperature is maintained at not more than 18 °C and atmospheric pressure. The separated nitroglycerin is mixed with a hot mixing solution, in the form of soda and ammonia and then emulsified with air. The separation of nitroglycerin and residual acid is based on the formation of two layers and differences in density. The remaining acid with a lower density is in the upper layer and nitroglycerin in the lower layer. The remaining acid coming out of the separator will be recovered, while the nitroglycerin is washed in a tower or washing column containing baffles. In the washing column, the mixture is emulsified using cold water and injecting compressed air. The emulsion flows from the top of the column to the intermediate separator, then flows to the bottom of the washing column II. The emulsion flows from the top of the washing column II to the separator II, then the liquid flows again. to washing column III and separator III until the desired stability has been achieved (Vuono, 1984).

2.2.2 Nitro nobel

The apparatus in this process is an injector which is used to mix glycerol with pre-cooled nitration acid. The flow of acid through the injector will create a vacuum so that the glycerin will be drawn in. The mixing of these two substances is very fast and will form an emulsion. Glycerin is sucked into the injector at a temperature of 48 ^{o}C and immediately reacts with acid. The reaction takes place at a temperature of 45-50 ^{o}C. The emulsion obtained is immediately cooled to 15 ^{o}C and then exits by gravity to the centrifuge, where nitroglycerin will be separated from the waste acid, then the used acid can be recycled or denitrified. The mixture containing nitroglycerin was emulsified with a water jet to form a non-explosive mixture, then neutralized with Na_2CO_3, and washed. The stabilized nitroglycerin is passed through the injector to form a non-explosive water emulsion for safe storage.

2.2.3 Biazzi

Biazzi continuous is the newest process in the production of nitroglycerin. The equipment consists of a nitrator, separator, and stirred washer. Some of the appliance units are made of stainless steel, to prevent nitroglycerin build-up. The process includes nitration, separation, and purification of nitroglycerin by washing. The nitritor is a small cylindrical vessel equipped with a stainless steel vessel with a cooling coil, where brine at a temperature of (-2) – (-5) ^{o}C is circulated during nitration to maintain the reaction at 15^{o}C and atmospheric pressure (1 atm). Then the nitrator product enters separator I to separate nitroglycerin from residual acid based on specific gravity and solubility, then the remaining acid is neutralized with a 2% sodium carbonate solution. In the washing tank the nitroglycerin is emulsified with water and washed to dissolve the neutralized salts, then flowed to separator II to separate the salts from the neutralization with nitroglycerin until the stability standard (safety factor) was reached. Furthermore, the nitroglycerin produced is stored in a storage tank (Kirk and Othmer, 1996), the complete process diagram is shown in Figure 2.

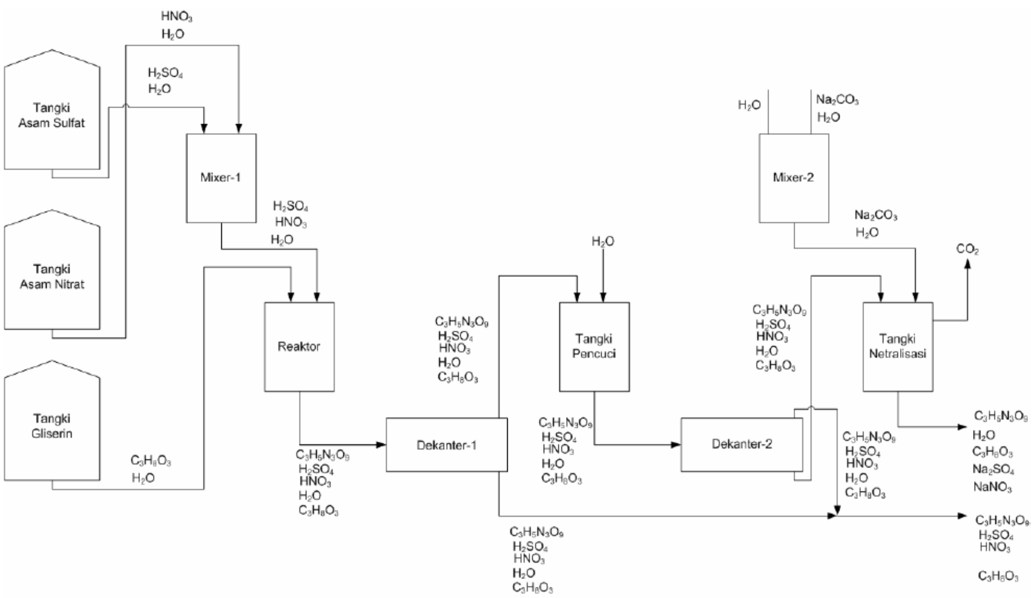


Figure 2. Nitroglycerin process production

2.3 Nitrocellulose Manufacturing Process

As the name implies, nitrocellulose is composed of cellulose compounds and nitric acid, an ester formed from the alcohol group of cellulose with nitric acid. The process of combining these two compounds is through a nitration process where there is an electrophilic substitution by nitrile ions, NO_2^+ which comes from a mixture of nitric acid and sulfuric acid with hydrogen atom groups in the cellulose.

The basis of the reaction is as follows:

$$[C_6H_7O_2(OH)_3]_n + 3HONO_2 + H_2SO_4 \rightarrow [C_6H_7O_2(ONO_2)_3]_n + 3H_2O + H_2SO_4$$

Materials and tools used:

a. Materials:
   - α - cellulose
   - Nitric Acid
   - Sulfuric acid
   - Natrium carbonate
   - Aqua Dest

b. Tool
   - Nitrator
   - Centrifugal / evaporator

Manufacturing process:

This nitration reaction takes place exothermic where heat is generated during the reaction (as opposed to endothermic, requiring heat). For this reason, cold water is needed. And the nitrator used is equipped with a cooling jacket to absorb the heat generated during the reaction. In addition, stirring in this reaction is necessary because it allows collisions between reactants to be greater in frequency so that there will be more opportunities to react. In addition, stirring serves to prevent explosions due to the unstirred part of the reactor which causes uncontrolled heat accumulation. The operating conditions for the nitration process are as follows:

Table 2. Operating conditions for the cellulose nitration process

Temperatur, ˚ C	30
Lama Reaksi, menit	25
Konversi, %	96-97

In this reaction, water is formed which directly reacts with sulfuric acid (in addition to functioning as a catalyst, it also functions to absorb water). The products of this reaction are nitrocellulose and spent acid. The results of the nitration reaction are centrifuged to separate nitrocellulose and spent acid. Spent acid that is formed is partly strengthened for reuse and partly formed by denitration and concentration of sulfuric acid. The nitrocellulose from the reaction is purified to remove residual acid by washing it twice with water and once with sodium carbonate. Then in the centrifuge separate the water with nitrocellulose. The complete process diagram is shown in Figure 3.

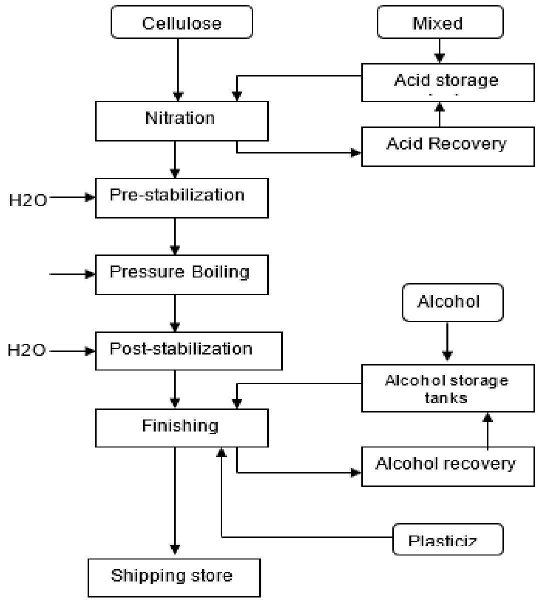


Figure 3. Nitrocellulose process production

Double Base Propellant Manufacturing Process:

The double base propellant is a mixture of nitrocellulose and nitroglycerin. Its composition is 50-60% NC and 30-49% NG.

Manufacturing Process:

Similar to the manufacture of nitrocellulose, nitroglycerin also undergoes an esterification reaction. This reaction takes place at a temperature of 30 C. This reaction is an exothermic reaction (producing heat) so that the nitrator (vessel) used is equipped with a cooling jacket. The reaction process is carried out very carefully and all mixed. After the reaction is complete, the reaction product is centrifuged then the nitroglycerin produced is washed with water and sodium carbonate (to remove residual acid) until neutral.

Materials and tools used;

a. Material:

- Nitrocellulose
- Nitroglycerin
- Stabilizer
- Organic Solvent/water

b. Tool:

- Reactor with agitator
- Printing
- Cutting machine

Manufacturing Process:

Composition of double base propellant: 50-60% NC and 30-49% NG. The manufacture of DB can be done by mixing nitroglycerin into nitrocellulose. The process can be carried out by 2 methods. The first method uses an organic solvent, and the other uses water as a solvent. For the first method of mixing nitrocellulose and nitroglycerin with a solvent and an additive (stabilizer) to form a dough (Meyer 2016; National Research Council 2016; Radford Army Ammunition Plant 2016), the mixture is then shaped into blocks by feeding it into an extrusion press and cutting machine. The result in the form of granules is screened first to remove the solvent. Dried, screened again, and then in a blender until homogeneous. The second method is to add nitroglycerin to a nitrocellulose-water suspension to form a paste (Meyer 2016; Radford Army Ammunition Plant 2016). The water is separated by evaporation on hot rollers. Then formed by extrusion and cutting.

Stages of making DB Propellant:

- Paste Preparation
  At this stage, enter the nitroglycerin solution into the nitrocellulose suspension slowly accompanied by stirring.
- Slurry Mixing
  At this stage, the paste is pumped into the lead-lines centrifuge to reduce the water to reach 18% humidity.
- Equipment
- Drying and Blending
- Finishing

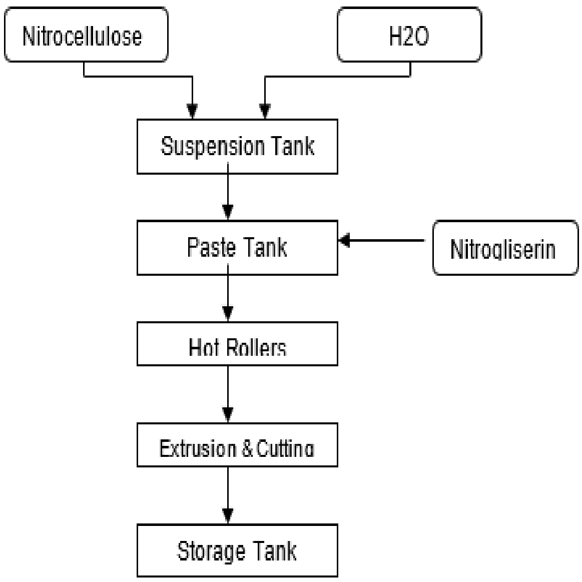


Figure 4. Process Diagram of Double Base Propellant

Table 3. Typical properties of DB propellants

Propellant (mass %)	Mass density [kg/m³]	Flame temperature [K]	Molar mass [kg/kmol]	Specific heat ratio [-]	Regression rate [mm/s]
Nitrocellulose (50-60%) Nitroglycerine (30-40%)	~ 1600	2100-3125	22-28	1.21-1.25	15-25

The complete process diagram is shown in Figure 4.

3. RESULT AND DISCUSSION

If the observation and analysis of the 3 (three) processes of making nitroglycerin are carried out, it can be summarized in Table 4. From table 4. It can be concluded that the Biazzi process is a better result when compared to the others because the Biazzi process is more efficient than other processes (for the same capacity, the tool size is smaller). Compared to the Schmid-Meissner process, the Biazzi process is simpler, especially in the washing and separation units. The Biazzi process is the newest process. Domestic raw materials are sufficient to support the manufacture of Nitrocellulose (single base propellant), Nitroglycerin, and Double Base Propellant factories.

Table 4. Comparison of NG Manufacturing Process

No	Comparison	Schmid-Meissner	Nitro Nobel Injector	Biazzi Continuous
1	Raw Materials	Glycerol and nitric acid	Glycerol and nitric acid	Glycerol and nitric acid
2	Conversion	93%	90 % - 93%	95 %
3	Operational Process	1 atm, 18 ^oC	1 atm, 45-50 ^oC	1 atm, 15^oC
4	Catalyst	H_2SO_4	H_2SO_4	H_2SO_4
5	NG accumulated in system (safety factor)	Much accumulated	Much accumulated	A little accumulated

4. CONCLUSION

1. When viewed from the national demand for a single base propellant of 100 tons/year*), then the Nitrocellulose plant can be built domestically.
2. When viewed from the national demand for double base propellant of 938 tons/year*), the Nitroglycerin plant can also be built domestically, although the technology for the manufacturing process of the two raw materials still has to be purchased/licensed from abroad

REFERENCES

[1] S. Rajput and S. P. Singh, "Industry 4.0 − challenges to implement circular economy," *Benchmarking*, vol. 28, no. 5, pp. 1717–1739, 2019, doi: 10.1108/BIJ-12-2018-0430.

[2] L. A. Cisternas, J. I. Ordóñez, R. I. Jeldres, and R. Serna-Guerrero, "Toward the Implementation of Circular Economy Strategies: An Overview of the Current Situation in Mineral Processing," *Miner. Process. Extr. Metall. Rev.*, vol. 43, no. 6, pp. 775–797, 2022, doi: 10.1080/08827508.2021.1946690.

[3] K. V. Sambasivarao and S. G. Deshmukh, "Selection and implementation of advanced manufacturing technologies: Classification and literature review of issues," *Int. J. Oper. Prod. Manag.*, vol. 15, no. 10, pp. 43–62, 1995, doi: 10.1108/01443579510098310.

[4] J. Chen, S. Huang, and T. Ajaz, "Natural resources management and technological innovation under EKC framework: A glimmer of hope for sustainable environment in newly industrialized countries," *Resour. Policy*, vol. 79, no. May, p. 103016, 2022, doi: 10.1016/j.resourpol.2022.103016.

[5] A. D. Andersen, A. Marìn, and E. O. Simensen, "Innovation in natural resource-based industries: A pathway to development? Introduction to special issue," *Innov. Dev.*, vol. 8, no. 1, pp. 1–27, 2018, doi: 10.1080/2157930X.2018.1439293.

[6] S. Horn, "Digitalization and natural resources," *Radiocarbon*, vol. 9, no. I1, pp. 164–165, 2021, doi: 10.1017/s0033822200067783.

[7] H. B. Wibowo, "Current solid propellant research and development in Indonesia and its future direction," *J. Phys. Conf. Ser.*, vol. 1130, no. 1, 2018, doi: 10.1088/1742-6596/1130/1/012027.

[8] M. Ramachandran, "A review on different propellant materials for space vehicles and their characterisation," no. December, pp. 93–102, 2018.

[9] G. P. Sutton and O. Biblarz, *Rocket Propulsion Elements*, Ninth., vol. 4, no. 1. Wiley, 2017.

[10] S. L. Bragg, "Rocket engines," *Nature*, vol. 196, no. 4857, p. 912, 1962, doi: 10.1038/196912b0.