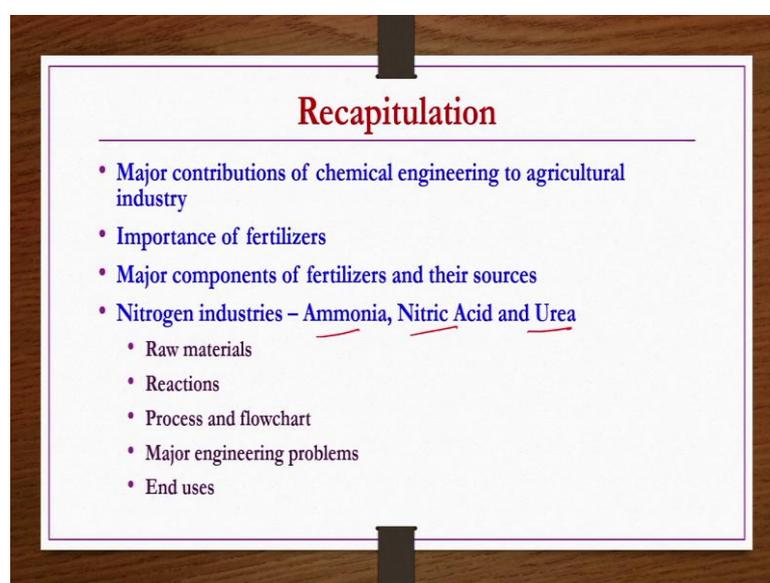


**Inorganic Chemical Technology**  
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**Lecture - 17**  
**Nitrogen Industries - Ammonium Nitrate**

Welcome to the MOOCs course Inorganic Chemical Technology, the title of today's lecture is Nitrogen Industries, Ammonium Nitrate. We will have a kind of recapitulation of what we have discussed in last few lectures.

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We started with discussions on major contributions of chemical engineering to agricultural industry. So, then we realized that fertilizers and pesticides are the areas in which the contribution of chemical engineering is very huge. Indeed, fertilizers and pesticides can be manufactured only by the chemical engineers. Not only that one, we also realized that several unit processes and unit operations associated with the food processing and preservation technologies are also handled by the chemical engineers.

So, having known this much of contribution, important contribution of chemical industries or chemical engineering professional to agriculture industry, we started our discussions on fertilizers. So, we started our discussion with nitrogen fertilizers, but before going into the nitrogen fertilizers directly, we started discussions on importance of

fertilizers. Especially towards the growth of the plants and then seed formations and then fruits and fruits formation etcetera all those kind of things, those we have discussed.

Then we have discussed what are the components of fertilizers and their sources, then, we started nitrogen industries or nitrogen fertilizer industries where we discussed manufacturing of ammonia, nitric acid and urea. Under the manufacturing of individual of these three components, what we have seen, their respective raw materials, their reactions, process and flowchart, major engineering problems and end uses etcetera. We have seen for each of these three components.

(Refer Slide Time: 02:25)



**Ammonium Nitrate ( $\text{NH}_4\text{NO}_3$ )**

- **Pertinent properties:**
  - Mol. Wt.: 80.05
  - Melting point: 170°C
  - Boiling point: decomposes at 200°C or higher
  - Solubility: soluble in water (900 g/l at 20°C), alcohol and  $\text{NH}_3$
- **Grades:**
  - C.P.: White hygroscopic crystals or granules
  - Fertilizer: 93 – 95% (containing 33% N)
- It is explosive when mixed with combustible materials or exposed to high temperatures

So, today we are going to discuss another nitrogen fertilizer that is ammonium nitrate ok. We start with pertinent properties, molecular weight is 80.05, melting point is 170 degree centigrade, boiling point it decomposes if you heat it 200 degree centigrade or beyond that one ok. Solubility, it is soluble in water, alcohol and ammonia as well; for example, in water, 90 grams of ammonium nitrate is soluble in 1 liter of water at 20 degree centigrades.

Then coming to the grades, different grades are available; technical grade is white hygroscopic crystals or granules, fertilizer grade 93 to 95 percent ammonium nitrate fertilizers which contain 33 percent of nitrogen. It is very explosive when mixed with combustible materials or exposed to high temperature. So, actually not only as fertilizer, this component is also used as a kind of explosive component as well. For explosions

also it is used; so, one has to be very careful not only during the manufacturing of ammonium nitrate, but also during the storage as well as the utilization point of view as well.

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**Consumption pattern:**

- Heavy demand for it in mixed fertilizers due increased use of N as agricultural fertilizer
- Small fraction is also used directly as fertilizer in India
- This is because nitrate nitrogen is inferior to ammonical nitrogen, particularly in rice paddies
- Also converted to nitrolime or nitrochalk (calcium ammonium nitrate) and ammonium sulfate nitrate

**End uses**

	(in USA)	(in India)
• Fertilizer	85%	> 90% (in mixed chemical fertilizer production)
• Explosives	12%	
• Miscellaneous chemicals	03%	

- Until world war II, it was mainly used as an explosive
- It still accounts for more than 75% of all explosives
- Presently major use is as fertilizer because of its high nitrogen content (33.5% N)

So, consumption pattern if you see, heavy demand for it in mixed fertilizers is there due to increased use of N as agricultural fertilizer. This is this actually we have been seeing in last 2 to 3 class that you know high nutrient and high nitrogen fertilizers are the demand of agricultural industry. So, many manufacturer are preparing manufacturing nitrogen or mixed chemical nitrogen fertilizers where N is in higher proportions right; so, that is what we have seen.

So, but here in India especially this ammonium nitrate is not used directly as a fertilizer mostly. Rather it is used as intermediate to prepare many other chemicals in addition to the mixed fertilizers ok. Let us say ammonium sulphate, etcetera, those kind of you know nitro lime, etcetera, these kind of mixed fertilizers if you wanted to produce, then this ammonium nitrate is used much more in India.

Though it can be directly used as a kind of a fertilizer, but; however, in Indian soil use of ammonium nitrate directly it causes you know it is having too high leaching rate in Indian soils. That is the reason Indian soils, we do not use ammonium nitrate directly as fertilizer, rather we use it for the preparation of mixed chemical fertilizers like you know

phosphate, sulphates, etcetera. Those kind of fertilizers those we are going to discuss anyway, for that purpose it is majorly used.

Because of such reasons in addition to the increased use of N as agricultural fertilizer the demand for ammonium nitrate is also increasing. It is also used in small fraction as fertilizer in India, but very rarely very very less negligible ok. This is because nitrate nitrogen is inferior to ammonium nitrogen, especially particularly in rice paddies what you need? You do not need you know superior nitrogen content through the nitrogen fertilizer.

You need inferior content smaller contents are required; so, that that is the reason nitrate nitrogens are in general used in rice paddies. It is also converted to chemicals like nitrolime which is also known as nitrochalk right. Nitrochalk chemical name is nothing, but calcium ammonium nitrate and then it is also used for the production of ammonium sulphate nitrate. These are all nothing, but you know mixed chemical fertilizers.

If you see the end uses in India more than 90 percent is used as fertilizer, but in mixed chemical fertilizer production, not directly as a fertilizer. Ammonium nitrate directly itself is not used as a fertilizer in chemical industries, very small amount is only very small fraction is only used. But majority of it more than 90 percent of ammonium nitrate produced in India is used for a mixed chemical fertilizer production ok, something like ammonium sulphate nitrate calcium ammonium nitrate etcetera.

But; however, if you see in USA 80 percent is used as a fertilizer, 12 percent it is used as a explosive something like you know for mining purpose sometimes you need to do some explosions; so, it is also used as a explosives. And then up to 12 percent it is used as a explosives in United States of America, miscellaneous chemicals production remaining 3 percent is used ok.

Ah In fact, until World War II, it was mainly used as explosive only, even today also whatever explosives are available out of its 75 out of its 75 percent of that one is coming from this ammonium nitrate only right. However, these days it is primarily used as a fertilizer because of a demand for high nitrogen content. Ammonium nitrate in general it is having 33, 33.5 percentage nitrogen right. You know NPK fertilizers we understand that how much total N percentage is there, what is the available P<sub>2</sub>O<sub>5</sub> and then what is the available K<sub>2</sub>O etcetera these are the things we have seen.

So, how much N is there in a fertilizer that is you know important that is the important factor ok. Not only that one though it is not used as a kind of ah direct fertilizers in India sometimes you need to make a balance. Urea is a better option for nitrogen fertilizers in general as we have discussed in previous lecture.

However, 100 percent urea you cannot use, sometimes you need to make a balance. So, the remaining balance of nitrogen fertilizers whatever are there may be fulfilled by the other fertilizers other nitrogen fertilizers and one of them is ammonium nitrate.

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**Production of  $\text{NH}_4\text{NO}_3$**

- All existing plants are based on reaction of nitric acid and ammonia
- However, producing it in different solid form (as pellets, crystals or flakes) is the primary variation amongst various plants
- Chemical reaction:  $\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$  ;  $\Delta H = -20.6 \text{ kcal}$
- Raw materials:
  - 57 – 60%  $\text{HNO}_3$  (i.e., nitric acid produced directly from oxidation – absorption tower)
  - Ammonia in liquid form
  - Clay (diatomaceous earth, kieselguhr) for coating on end-products to avoid explosions
- Quantitative requirements:
  - (a). Basis: 1 ton of  $\text{NH}_4\text{NO}_3$  (98% yield)
    - Ammonia 0.22 ton ✓
    - 60%  $\text{HNO}_3$  1.38 ton ✓
  - (b) Plant capacities: 100 – 500 tons/day

Now, production of ammonium nitrate, production of ammonium nitrate is done by one simple method by reacting ammonia and then nitric acid. When you react the ammonia and nitric acid then you will get ammonium nitrates and then almost all plants are based on this reaction only right. So; obviously, from one plant to the other plant there may be some differences; those differences are primarily coming if you produce this ammonium nitrate in solid form right.

If you wanted to produce as a pellet; so, the after the reaction whatever the steps are there; so, how are you doing that is one option. And then if you wanted to have a crystals; so, then how are you doing that process how are you implementing in the plant. Flakes if you wanted to have ammonium nitrate flakes, even the reaction itself is different.

For example if you wanted to produce pellets crystals etcetera, then liquid phase reaction is required; if you wanted to produce ammonium nitrate flakes, then the reaction has to be gaseous or vapor phase reaction has to be take place. So, then; so, then for this case you know first from the first point itself is the different route though the reaction is same.

For these two forms let us say pellets and crystals the reaction starting point is same, but after forming that ammonium nitrate solution 75 percent usually you get after the reaction that from that point how are you processing that may be differing from one plant to the other plant. So, this is the only possible variation from one plant to the other plant producing this ammonium nitrate.

Basic chemical reaction is reaction between ammonia and nitric acid giving rise to ammonium nitrate which is exothermic reaction, because the enthalpy of the reactants is higher than the enthalpy of the products. Now, we see raw materials basically from the reaction we can understand these two raw materials are required, one is the nitric acid; so, 57 to 60 percent pure nitric acids is sufficient.

Actually, if you remember couple of lectures back we have discussed how to produce nitric acid in which we have seen from the oxidation absorption tower of the plant, you get up to 60 percent of HNO<sub>3</sub>. If you need higher purity of HNO<sub>3</sub>, then there are purification steps those things we have discussed.

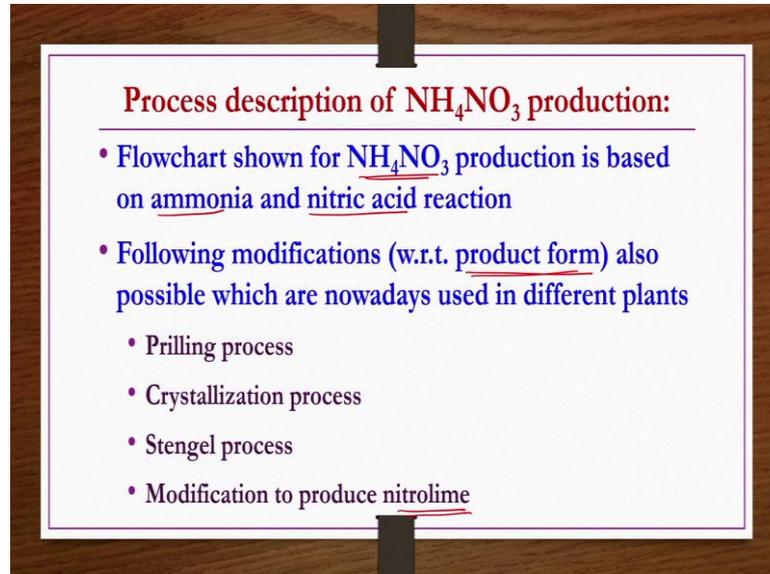
But for ammonium nitrate production whatever 57 to 60 or up to 60 percent HNO<sub>3</sub> that you get from the oxidation absorption tower of nitric acid plant is there that itself is sufficient ok, you do not need to have higher purity nitric acid.

Ammonia has to be in liquid form and then we have already seen discussed in the previous slide that it is very explosive. So, then there should be a kind of a material that can be coated to avoid the possible explosions. So, clays are in general used for coating on end products to avoid explosions; so, this is the third raw material that is required for the plant ok.

Quantitative requirements if you see, if you wanted to produce one ton of ammonium nitrate 98 percent yield; then ammonia you required 0.22 tons, 60 percent HNO<sub>3</sub> you required 1.38 tons, plant capacities vary in general 100 to 500 tons per day ok. Now, we see the process description of ammonium nitrate production right. We have seen that

ammonium nitrate production is based on the reaction between ammonia and then nitric acid right.

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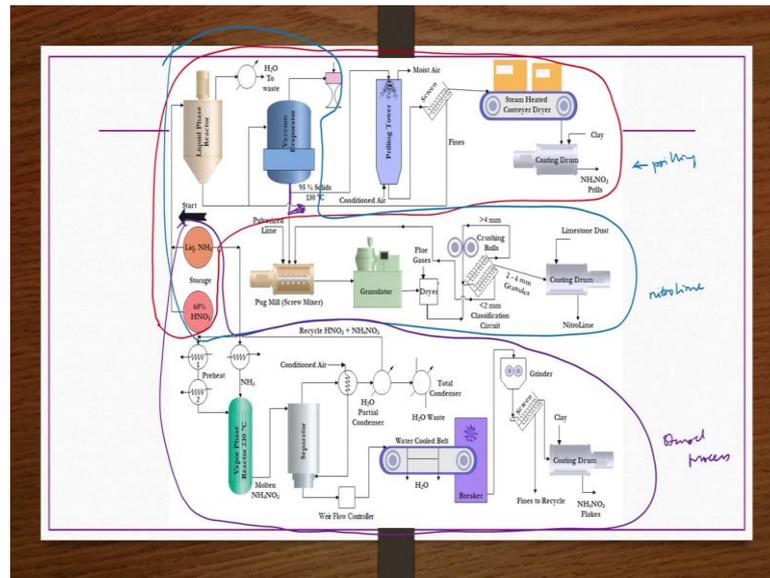
**Process description of  $\text{NH}_4\text{NO}_3$  production:**

- Flowchart shown for  $\text{NH}_4\text{NO}_3$  production is based on ammonia and nitric acid reaction
- Following modifications (w.r.t. product form) also possible which are nowadays used in different plants
  - Prilling process
  - Crystallization process
  - Stengel process
  - Modification to produce nitrolime

We have also seen few modifications are possible, especially with respect to the product form if you wanted to collect the product in a solid form ok. So, what are they like prilling process? If you wanted to get spherical pellets then prilling process you have to follow.

If you wanted to have a crystals, then crystallization process you have to follow and then if you wanted to have a flakes kind of a product then you have to follow Stengel process and then modification to produce nitrolime. If you wanted to produce nitrolime, then you have to follow the nitrolime process these are the modifications possible. So, now we see all of them through a flow chart as well as the process description we are going to discuss now.

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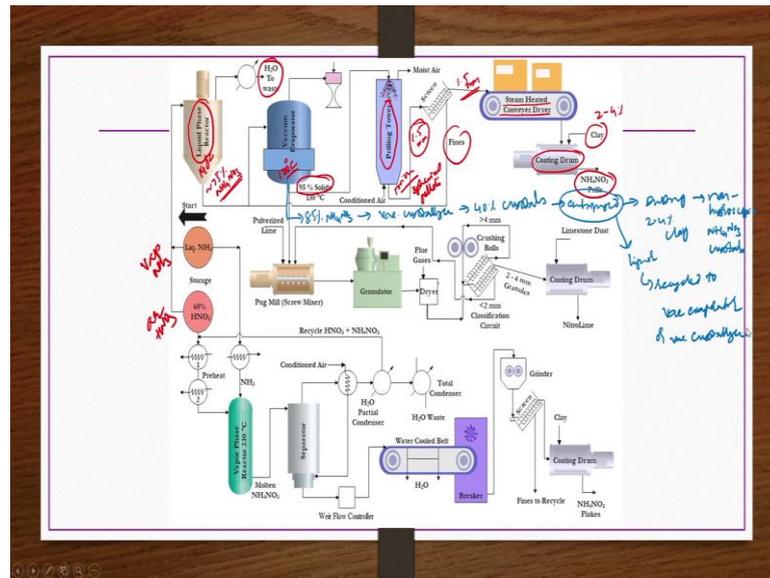


So, this is the flow chart what we can see here? It is having three processes right. So, this path whatever is there from ammonia and then nitric acid then to producing these prills as spherical crystals of ammonium nitrate this is nothing but the prilling process. And then if you follow from this reaction after this point, let us say if you take a this section; then this is a nitrolime production process, this is prilling process.

And then if you take the vapor phase reaction between nitro between ammonium vapors and then  $\text{HNO}_3$  vapors. If you do the reaction vapor phase reaction and then follow this step this process, then this is nothing but Stengel Stengel process. Crystallization process is having from this from here itself it is a simple step is there for the crystallization process that is not shown in the flow sheet.

So, all these four processes or all these four modifications that are possible in ammonium nitrate production process we are going to see one by one now ok; so, let us start discussing about the prilling process.

(Refer Slide Time: 14:59)



So, what we have aqueous phase of HNO<sub>3</sub> and then vapor phase of NH<sub>3</sub>. This you take to a liquid phase reactor right in which reaction is taking place at around 140 degree centigrade's; so, you will get approximately 75 percentage ammonium nitrate right. So, when this reaction takes place because of the heat of the reaction water boils off and then it is taken to the H<sub>2</sub>O to waste.

Because we have seen the reaction between ammonia and then nitric acid is a exothermic reaction and then because of that the heat of the reaction, during the reaction whatever the water formation is there that has been taken out boils off ok. So, 75 percent pure ammonium nitrate whatever is there that is next taken to the vacuum evaporator which is operating at approximately 130 degree centigrade; so, that you can improve the purity to 95 percent right.

So, this 95 percentage pure NH<sub>4</sub>NO<sub>3</sub> is then taken to a prilling tower where this 95 percent molten ammonium nitrate is sprayed from the top as droplets; whereas, the conditions air is allowed to pass from the bottom to the top of the prilling tower. So, what happens this ammonium nitrate solution and then air interact each other in a counter current direction.

So, that you know you can get the prills or spherical pellets from here, and then the those spherical pellets whatever are there then you pass it through a screen screening section. So, that you have the pellets approximately 1.5 mm size that is what the desired size in

general for the applications; off course, 2 to 4 mm also requires some purposes and then those things we see.

So, whatever the spherical pellets form in the prilling tower they are taken to the classifying section; so, whatever the fines are there these fines are sent back to the liquid phase reactor again right. Whatever the product of desired size let us say 1.5 mm size spherical pellets passed through steam heated conveyor dryer.

So, that you can get dry spherical pellets and those pellets are sent to coating drum where clay 2 to 4 percentage of clay is sprayed here allowed here. So, that you know ammonium nitrate prills are spherical pellets you can get; now, these are coated with clay so; obviously, it will be less explosive.

Clays are required to be coated on this pellets or whatever the flakes you get in order to avoid the explosions; so, this is the prilling process ok. Crystallization process also we can discuss here itself in the same flow sheet. So, in the crystallization process, the process is same up to whatever vacuum evaporator section is there; so, from here you may get 80 to 85 percent , 95 percent or something like that.

Let us say, you are getting something like 85 percent you know ammonium nitrate right. So, then you can take it to the vacuum crystallizer to increase the slurry with 40 percent crystals right, these will be then further centrifuged. So, that to decrease the moisture content to less than 1 percent, then these after centrifuges centrifuging what you do? You do the dusting with 2 to 4 percent clay to get a non-hygroscopic ammonium nitrate crystals, this is the crystallization process right.

While doing the centrifugation whatever the liquor is there that is recycled to either vacuum evaporator section or to vacuum crystallizer section for the makeup purpose ok. This is about prilling process as well as crystallization process 2 process we have discussed here.

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**Prilling process**

- Aq.  $\text{HNO}_3$  and  $\text{NH}_3$  vapors react in a stainless steel agitated reactor
- Because of reaction heat, water boils off and final  $\text{NH}_4\text{NO}_3$  salt solution is 75% at  $140^\circ\text{C}$
- This hot salt solution is pumped to vacuum evaporator to concentrate further to 95%
- From the top of 60–75m high prilling tower, hot liquor is sprayed counter-currently to conditioned air flow for solidification purpose
- Prills or spherical pellets obtained by solidification have about 1.5mm diameter
- These prills must be screened and dried before coating with clay (to avoid explosions)
- Oversized fines are re-dissolved and recycled through a neutralizing reactor
- Prilling towers are large and costly; thus for their replacement, centrifugal oil-quenching process for prill production has also been developed

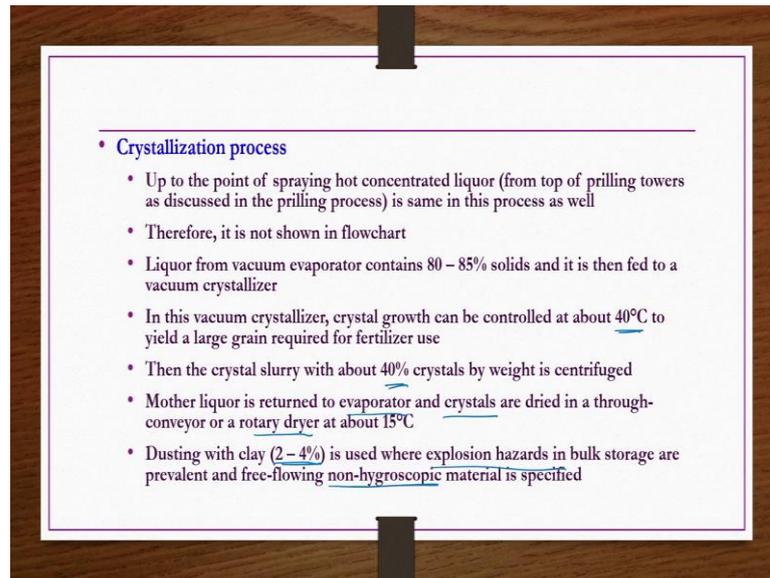
So, description wise we are going to see once again here, that is under prilling process what we have we have aqueous  $\text{HNO}_3$  and then ammonia vapors reacting in a stainless steel agitated reactor. Because of the reaction heat water boils off and final ammonium nitrate salt solution is obtained which is 75 percent pure and then it is at 140 degree centigrade.

This hot salt solution is pumped to a vacuum evaporator to concentrate further to 95 percent ammonium nitrate. And then this 95 percent ammonium nitrate this hot liquor is sprayed counter currently to conditioned air flow for solidification purpose in a prilling tower, this prilling towers are usually very tall 60 to 75 meters ok.

Prills as spherical pellets obtained by solidification have about 1.5 mm diameter, these prills must be screened and dried before coating with clay to avoid explosions. Oversized fines are re-dissolved and recycled through a neutralizing reactor. However, prilling towers are large so; obviously, they will be costly.

Thus for their replacements centrifugal oil quenching processes for prill production has also been developed. So, but the danger is that when you do the centrifugal oil quenching process no oil should be going into be in contact with the ammonium nitrate otherwise explosions may takes place ok.

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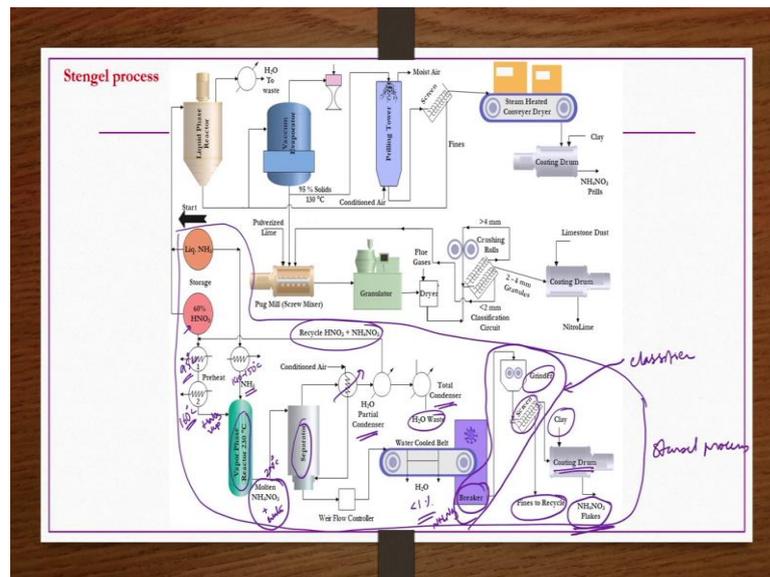


Now, the crystallization process up to the point of spraying hot concentrated liquor from top of prilling towers as discussed in the previous prilling process is same in this process as well; therefore, it is not shown in flowchart. Liquor from a vacuum evaporator contains 80 to 85 percent solids and it is then fed to a vacuum crystallizer.

In this vacuum crystallizer, crystal growth can be controlled at about 40 degree centigrade to yield a large grain required for fertilizer use. If you wanted to have the grain size 2 to 4 mm larger ones compared to the 1.5 mm spherical pellets in prilling process that you got, then you have to go for the crystallization process if you need bigger grains ok larger grains.

Then the crystal slurry with about 40 percent crystals by weight is centrifuged, mother liquor is returned to the evaporator and crystals are dried in a through conveyor or a rotary dryer at about 15 degree centigrades. Dusting with clay 2 to 4 percentage clay is used where explosion hazards in bulk storage are prevalent and free flowing non-hygroscopic material is specified. So, a clay is not only for a you know avoiding the explosion, but also it provides non-hygroscopic nature to the crystals.

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Next is Stengel process; so, in this process what happens you have to concentrate this part of the flow sheet right. Here whatever aqueous HNO<sub>3</sub> 60 percent is there that is preheated in a preheater number 1 which is at 95 degree centigrade something approximately 90, 92, 95 degree centigrades. Then it is again preheated in a second preheater at about 160 degree centigrade.

This preheating is required because of the corrosion issues with HNO<sub>3</sub> right, because this reaction is vapor phase. Because this reaction is occurring in vapor phase for that reason also this preheating and vaporization of a HNO<sub>3</sub> is required not only the corrosion reasons ok. Whatever the ammonia is there that is passed through a heat exchanger ah to vaporize by applying the temperature of 140 to 150 degree centigrade; so, now you have ammonia vapors and then HNO<sub>3</sub> vapors.

These vapors are taken into a vapor phase reactor to react; so, then reaction takes place at around 230 degree centigrade. Then you will get a molten ammonium nitrate plus water and these are usually at 200 degree centigrade in this product. So, then what you do, this mixture of molten ammonium nitrate and water is taken to a cyclone separator to this cyclone separator conditioned air is provided.

So, that to remove the steam from the molten ammonium nitrate; so, that you can get the you know almost dry ammonium nitrate right. This condition air is applied; so, that steam can be removed either by partial condenser or total condenser as H<sub>2</sub>O. And then

whatever the almost dried or solidified ammonium nitrate is there that is collected from the bottom of the separator and then sent to a water cold belt where drying is further where further drying is done.

So, the to reduce the water content to less than 1 percent less than 0.5 to 0.6 percentage in the indeed. And then this dry ammonium nitrate whatever is there here that is taken to a classifier section where you have a breaker, grinder, and then screener this entire this section combined is known as a classifier section. So, here you required a specified sizes of a flakes; so, then you know you have to do this classification section.

So, whatever the dried ammonium nitrate is there that is broken and then grinded and then sent to the screen. Whatever the material of desired sizes are there they are sent to the coating drum where coated where coating with clay is to be done. So, that you can get ammonium nitrate flakes coated with clay to avoid explosions right.

In this process of breaking and grinding the dry ammonium nitrate, if at all you find some fines they can be recycled ok they can be recycled to the ammonium nitrate preheating section ok. So, here from this when you are removing steam using the condition air; so, it is possible that some amount of unreacted  $\text{HNO}_3$  along with the  $\text{NH}_4\text{NO}_3$  may also be going out that can be recycled back ok. This is nothing but Stengel process where you are getting  $\text{NH}_4\text{NO}_3$  flakes.

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• Stengel process

- First preheating of 60% nitric acid is done to 95°C in a stainless steel unit
- Subsequent second preheating to 160°C is done in a tantalum unit
- This preheating is essential to avoid corrosion due to high temperature nitric acid
- $\text{NH}_3$  vapor is preheated to 140 – 150°C in a single stage heat exchanger
- Vapor phase reaction between ammonia and nitric acid vapors is carried out in a packed stainless steel reactor to produce ammonium nitrate
- Then molten  $\text{NH}_4\text{NO}_3$  and water vapor at 200°C are passed through a tangential entry of a cyclone separator where air helps in removal of steam from the molten salt
- This salt is removed at bottom and solidified on a water-cooled stainless steel belt
- Finally, solids are crushed and ground to flake size and screened as per requirement
- Oversize is reground and fines are dissolved and returned to  $\text{HNO}_3$  preheater stream
- Product flakes are coated with clay, and bagged or bulk shipped

Now, the description of the same process we see, first preheating of 60 percent nitric acid is done to 95 degree centigrade in a stainless steel unit. Subsequent second preheating to 160 degree centigrades is done in a tantalum unit, these are the materials of constructions this is required if you have you know high corrosion issues. So, then you have to use this material otherwise this is sufficient.

So, at higher temperature corrosion because of hot HNO<sub>3</sub> is going to be severe. So, then you have to use a tantalum unit and then which is expensive compared to the stainless steel. This preheating is essential to avoid corrosion due to high temperature nitric acid, then ammonia vapor is preheated to 140 to 150 degree centigrade in a single stage heat exchanger.

Vapor phase reaction between ammonia and nitric acid vapors is carried out in a packed in a packed stainless steel reactor to produce ammonium nitrate. Then molten ammonium nitrate and water vapor at 200 degree centigrade are passed through a tangential entry of cyclone separator where air helps in removal of steam from the molten salt.

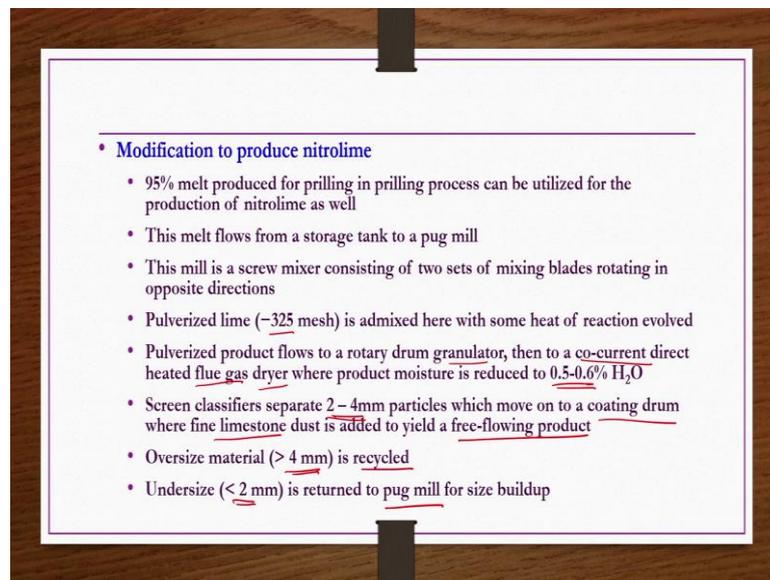
This salt which is nothing but ammonium nitrate is removed at the bottom and solidified in a water cooled stainless steel belt conveyor, on a water cooled stainless steel belt. Finally, solids are crushed and ground to flake size of required size and screened as per the requirement, oversize is reground to get the required size whatever the fines are there they are dissolved, returned to HNO<sub>3</sub> preheater stream. Product flakes are coated with clay and bagged or bulk shipped as per the requirement.



So, these 2 to 4 mm granules are sent to the coating drum where limestone dust is also sprayed and then nitrolime you get it. Whatever the products or whatever the material which is having the size less than 2 mm that is taken back as a recycle to pug mill this mean this way for rebuilding the size ok.

Whatever the undersized materials are there they are sent back to the crusher; so, that further crushing take place and then size would be reduced to 2 to 4 mm again ok. So, this is the nitrolime process or modification to produce nitrolime ok.

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Now, if you see the description of this process, you have a 95 percent melt produced for prilling in prilling process can be utilized for the production of nitrolime as well, this melt flows from a storage tank to a pug mill. This mill is a screw mixer consisting of 2 sets of mixing blades rotating in opposite directions, pulverized lime having 325 mesh size is admixed here with some heat of reaction evolved.

Pulverized product flows to a rotary drum granulator then to a co-current direct heated flue gas dryer where product moisture is reduced to 0.5 to 0.6 percent of water. Screen classifiers separate 2 to 4 mm particles which moves on to a coating drum where fine limestone dust is added to yield a free flowing product.

Oversized materials having more than 4 mm size or recycled to the crusher for the further size reduction whereas, the undersize having less than 2mm are returned to the

pug mill for size build up ok. So, all 4 alternative options that are possible in ammonium nitrate plant we have discussed here right. Now, we see major engineering problems associated with the ammonium nitrate production plants.

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**Major engineering problems**

- **Corrosion**
  - Carbon steel can only be used in  $\text{NH}_3$  storage and feed system
  - Up to about  $120^\circ\text{C}$ , Type 304, extra-low carbon (ELC) stainless steel is used for aqueous or 100%  $\text{HNO}_3$
  - This material of construction (MOC) is used throughout most of the remainder of  $\text{NH}_4\text{NO}_3$  plant to avoid corrosion
  - In Stengel process, where it is necessary to preheat 60%  $\text{HNO}_3$  to  $170^\circ\text{C}$ , expensive tantalum metal is needed for heat exchanger
- **Crystallization**
  - This problem occurs in vacuum crystallization process which is oldest of four processes described
  - An Oslo-Krystal classifier is used since it provides adequate growth of seed crystals to proper size, shape and strength in a continuous manner
  - Prior to this equipment, paddle type grainer was used but only small crystals suitable for munitions specifications could be produced

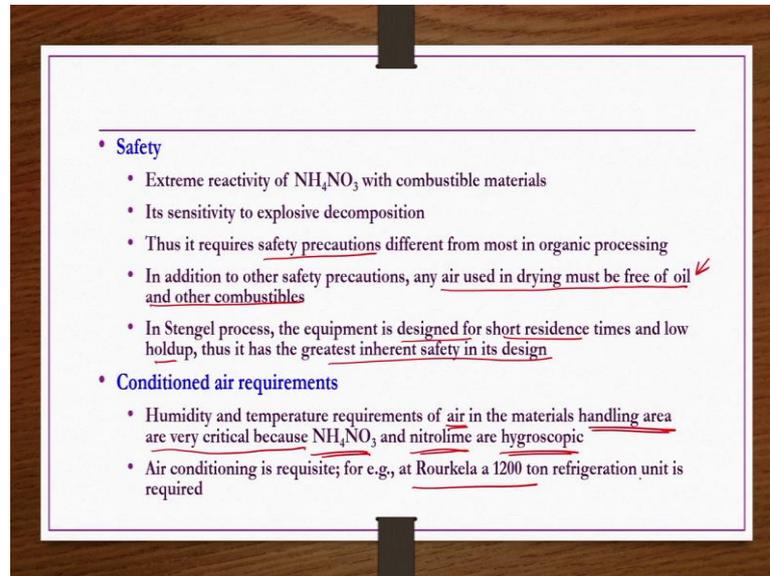
First one is the corrosion; so, carbon steel can only be used in ammonia storage and feed system because of the corrosion issues. And then up to 120 degree centigrade type 304 extra low carbon ELC stainless steel is used for aqueous or 100 percent nitric acid. This material of construction whatever ELC is there that is used throughout for most of the remainder of the ammonium nitrate plant to avoid the corrosion, these are the precautions one should take.

But; however, in Stengel process where it is necessary to preheat  $\text{HNO}_3$  to 170 degree centigrade expensive tantalum metal is needed for heat exchangers. Next is the crystallization or engineering problem associated with the crystallization. This problem occurs in vacuum crystallization process which is oldest of four processes that we have described.

So, Oslo-Krystal classifier is used since it provides adequate growth of seed crystals to proper size, shape, and strength in a continuous manner that is the reason it is used, it is a commercial classifier actually. Prior to this equipment paddle type grainer was used, but only small crystal suitable for munitions, specifications could be produced ok, these are the issues associated with the crystallization process.

Next is the safety, as we have already discussed ammonium nitrate is highly explosive. So, then not only during the production during the storage as well as the transportation stages also one should be careful because of explosive nature of this ammonium nitrate.

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It is extremely reactive; so, extreme reactivity of ammonium nitrate with combustible materials; so, it is sensitive to explosive decomposition. Thus it requires safety precautions different from most in other organic processes. In addition to other safety precautions, air used in drying must be free of oil and other combustibles this is what I already mentioned. If you know for drying different options are there let us say; for example, centrifugation with the oil that you are doing.

So, in that one oil should not be coming into the contact with the ammonium nitrate otherwise expressions may takes place. In Stengel process the equipment is designed for short residence times and low hold up, thus it has the greatest inherent safety in its design where you get the flakes.

Conditioned air requirement is very much essential, humidity and temperature requirements of air in the materials handling area not only during the production, but also material handling area are very critical because ammonium nitrate and nitrolime are hygroscopic ok. So, because of the required air conditioning you know at Rourkela plant 1200 ton refrigeration unit is installed.

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### Economics

- In India,  $\text{NH}_4\text{NO}_3$  has no application as a fertilizer end product because it has too high a leaching rate on soil application
- And thus it is mainly used as an intermediate in manufacture of nitrolime and ammonium sulfate nitrate
- Only captive production in an ammonia – nitric acid plant complex is competitive
- It is especially desirable if a balanced plant production – sales for urea and mixed fertilizers can be achieved
- Ammonia off-gases from once-through urea can be used to make ammonium nitrate or nitrolime
- Stengel process is considered the cheapest process for new investment money and it is also safest from a hazard standpoint

Coming to the economics, in India as I already mentioned ammonium nitrate has no application as fertilizer directly, because its leaching rate on soil is very much higher. So, that is the reason it is used for a, you know mixed chemical production or as a kind of intermediate to produce other chemicals. And thus it is mainly used as an intermediate in manufacture of nitrolime and ammonium sulfate nitrate which are mixed chemical fertilizers.

Mixed chemical fertilizers in the sense, they are not individual and there is you know sulphates also there and then calcium is also there. So, because of them these fertilizers are known as the mixed chemical fertilizers. We are going to discuss the production of mixed chemical fertilizers as well in the next week of the course.

Only captive production in an ammonia nitric acid plant complex is competitive, this process is competitive that is the reason people are following because you have several options of the material production different solid forms. And then those materials produce materials can be used as a intermediate for the production of several intermediate or chemical mixed chemical fertilizers.

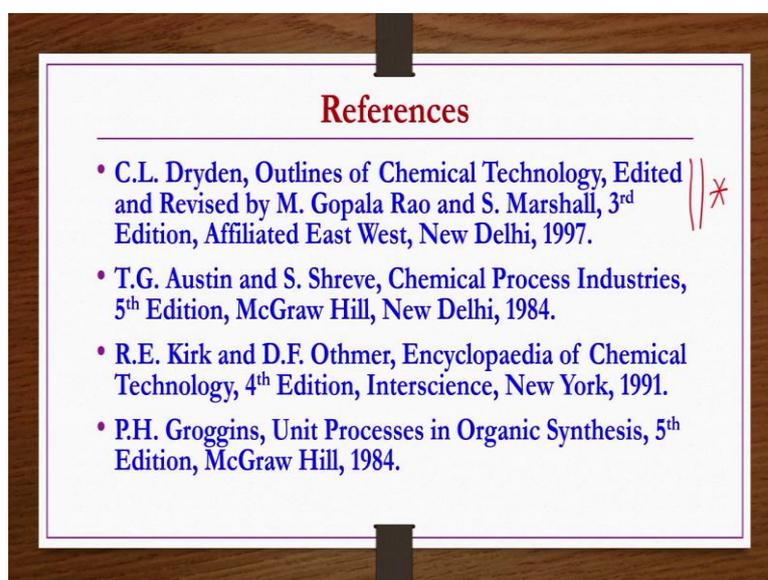
It is especially desirable if a balanced plant production sales for urea and mixed fertilizers can be achieved. As I mentioned though urea is a very good option as long as nitrogen fertilizers requirement, but; however, 100 percent you cannot have. So, then if

you wanted to maintain balanced plant production sale for urea and then mixed fertilizers you have to produce ammonium nitrate also in order to make the balance.

Otherwise, ammonium off gases from once through urea plant can be used to make ammonium nitrate or nitrolime, this we have already discussed in previous class where we were discussing about urea. So, whatever urea production plant we have seen the conversion is only 40 to 45 percent in single pass through. So, then unreacted ammonia and then CO<sub>2</sub> off gases, whatever are there you have to efficiently recycle.

So, that conversion increases or you have to use them for some other purpose; so, that economically the plant is feasible or profitable ok. So, one option is that this off gas ammonia CO<sub>2</sub> off gas may be used for you know ammonium nitrate and nitrolime production after removing the CO<sub>2</sub> from the off gases. Stengel process is considered the cheapest process for new investment money and it is also safest from a hazard standpoint ok, this we have already discussed.

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The references for this lecture references are provided here, but; however, the entire lecture is prepared from this book that is *Outlines of Chemical Technology* by C.L. Dryden edited by Gopala Rao and Marshall, 3rd edition.

Thank you.