ADN is more than particles and formulations – it is a part of future missile propellants

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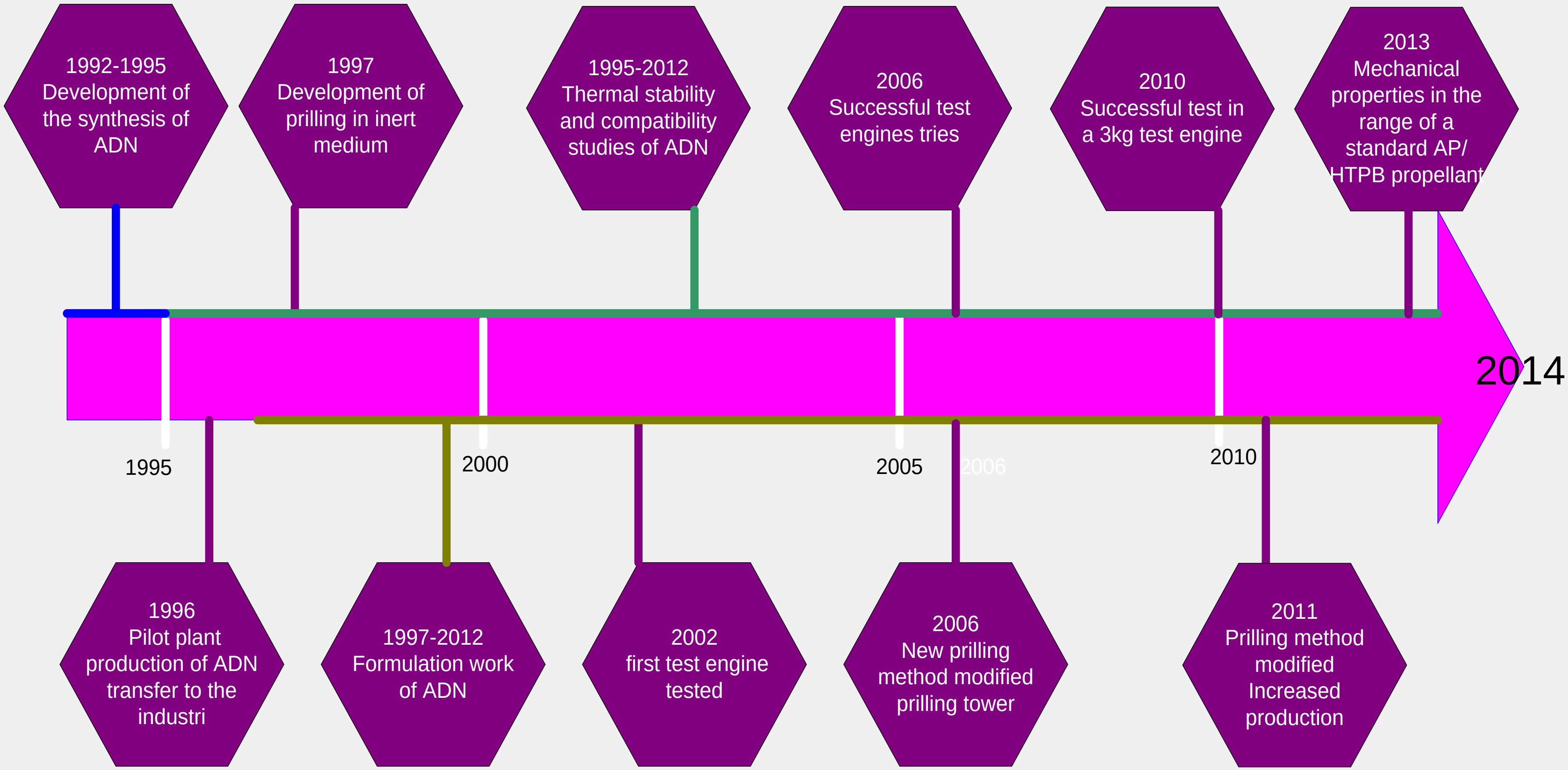
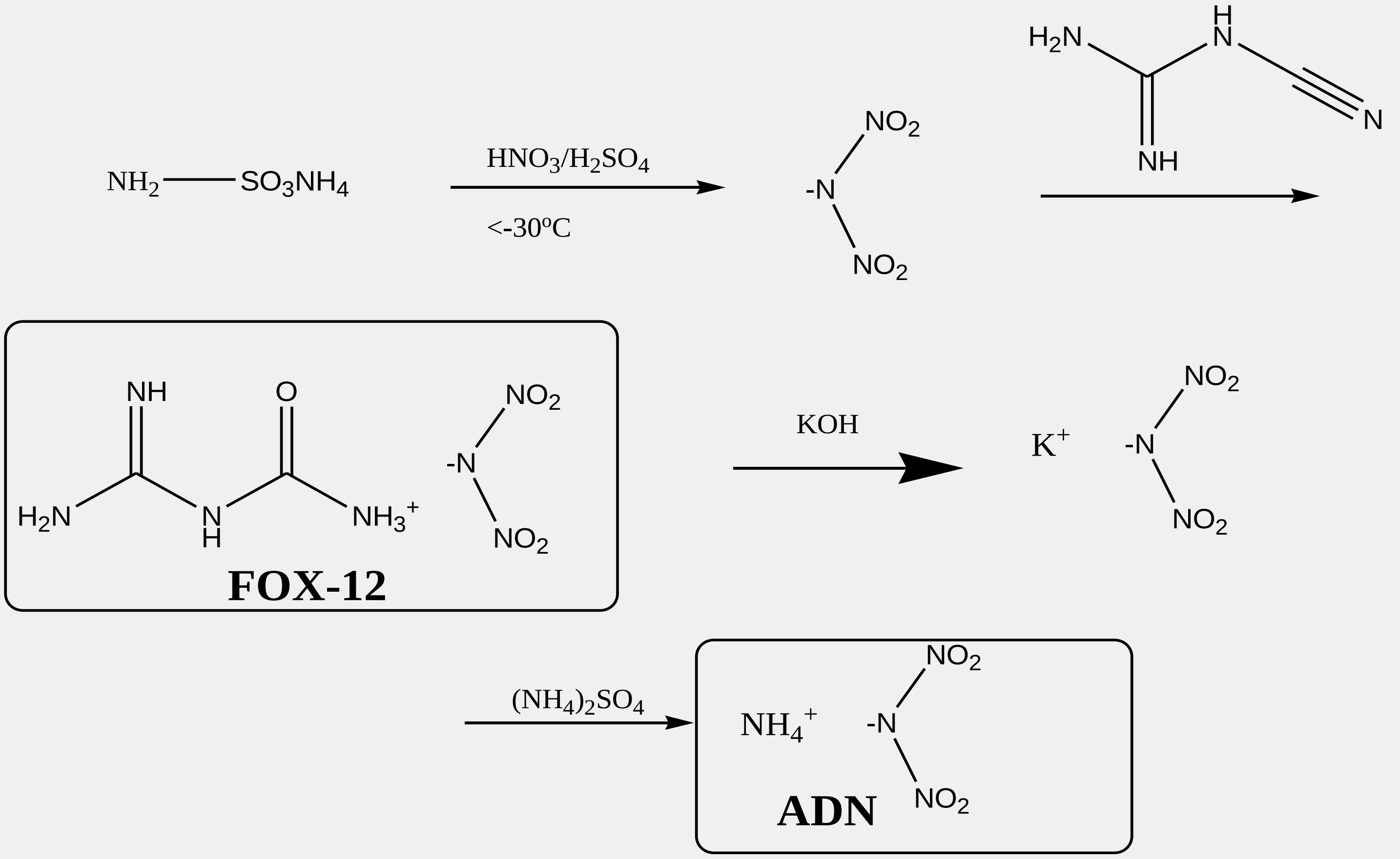
ADN Development at FOI



Synthesis and production of crude ADN

ADN Synthesis – Eurenco Bofors



ADN versus FOX-12

FOX-12

- Ingredient in IM grenades
- Ingredient in Gun propellant
- Air-bags in Cars

ADN

- Ingredient in Solid propellant
- Ingredient in Liquid mono propellant

Price will fall with increased demand for either FOX-12, ADN or both

ADN production

- ADN produced by EURENCO Bofors
  - High purity (+99 %)
  - High thermal stability → no stabilizer needed
  - Needle shaped particles

  - FOI have developed a new synthesis method that will lower the production costs further
  - The synthesis method will be implemented forthcoming year

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Estimated future price for crude ADN

The estimated production price for crude ADN in the 40 ton scale will be about

35 $ per lbs.

The estimated production price for crude ADN in the 400 ton scale will be about

33 $ per lbs.

ADN Particles

Particle Processing

- Which sizes of ADN prills is needed?
- The standard Sizes in formulations of AP prills is 200µm and 20µm
- In our investigation of ADN/GAP formulation we saw no difference in burn rate between the different sizes

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Prilling and crystallisation metods of ADN

- Prilling in inert medium
- Standard prilling tower
- American version of prill tower
- Cool crystallisation
- FOI modified prill tower

Prilling in inert medium

Pros

- Prilling is rather fast

Cons

- Crystallization is reactor size dependent
- Prilling in mediums like, DOA, DOS, HTPB, Paraffin etc.
- Medium washed away create waste of solvents
- Product not pure enough recrystallize during storage

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Standard prilling tower

Pros

- High production
- Low cost

Cons

- High investment cost
- High tower
- Risk for static electricity

American version of prilling tower

Pros

- Narrow particle size distribution

Cons

- Costly recrystallization necessary
- Process safety risk (high temperature)

Cold crystallization

Pros

- Cheap production
- Narrow size distribution

Cons

- Difficult to develop a working method
- Biggest by-product ammonium nitrate disturbs the crystal growth
- Small crystals 20-40 µm

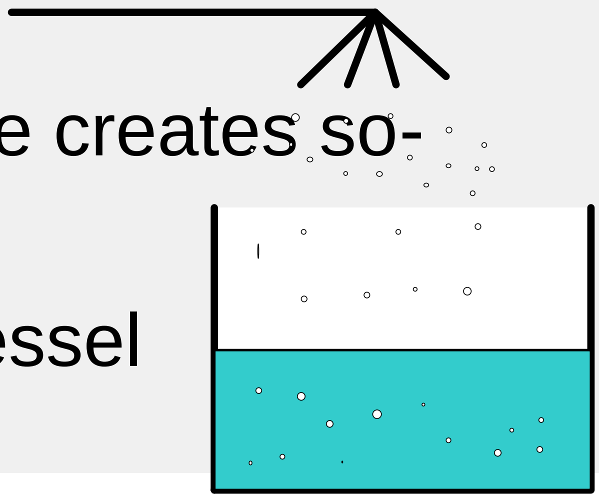
FOI modified prill tower

Pros

- Fast melting
- If ADN is ignited in the process only partial damage to the equipment

Cons

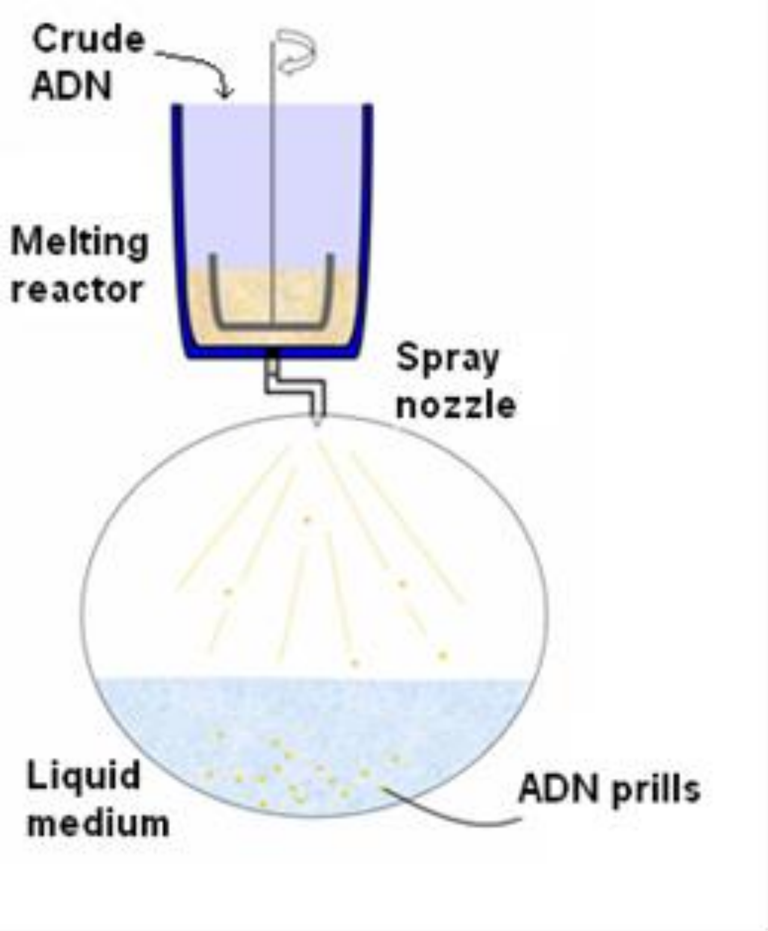
- Spraying of an liquid throw a orifice creates so-called “waterfall electricity”
- A inert medium in the collection vessel



Former Spray prilling method at FOI

250g Crude ADN

- is melted within 15 minutes
- Sprayed in 1 minutes
- Dried for 12 minutes
- Mixed with 0.5% fumed silica to prevent caking



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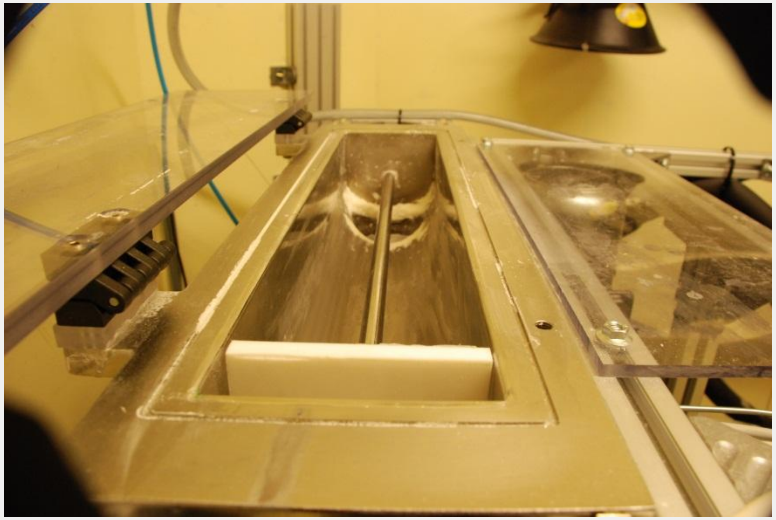
Spray prilling at FOI using the former method

- Particle density: 1.775 g/cm^3
- Tap density: 1.11 g/cm^3
- Melting point: ~ 93°C

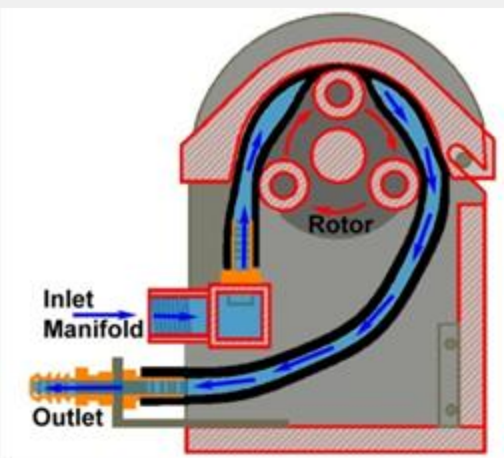
Feeding and Melting od ADN

Batch size: 2500 g

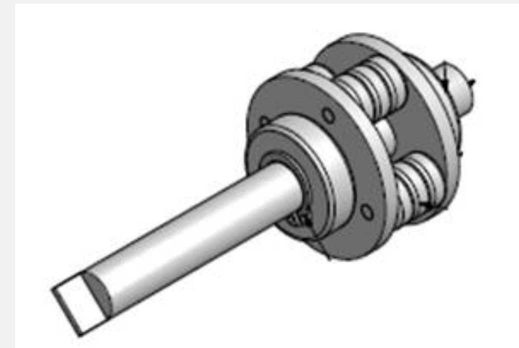
- Crude ADN sticky and fed slowly
- Melt time: 7 min
- No degradation is found

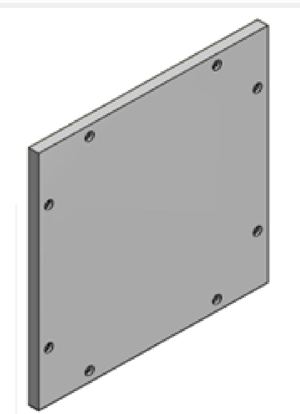


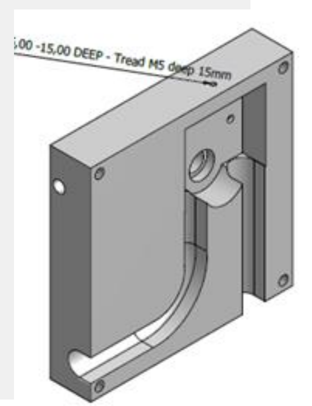
Pumping melt ADN



- Peristaltic pump Speed controls the liquid
- To prevent ADN from solidifying in the feeding line the pump house was heat traced







Spraying

- Inert medium is sprayed on the sides
- Nitrogen is fed to the twin fluid nozzle
- Feeding lines are heat traced
- Spraying 3 min (200µm)

Drying and Control

Drying is carried out in a fluidized bed dryer

- Drying 12 min

- Operation control dived up in
    - Melting
    - Spraying
    - Drying
    - Cleaning loop

Particle size control

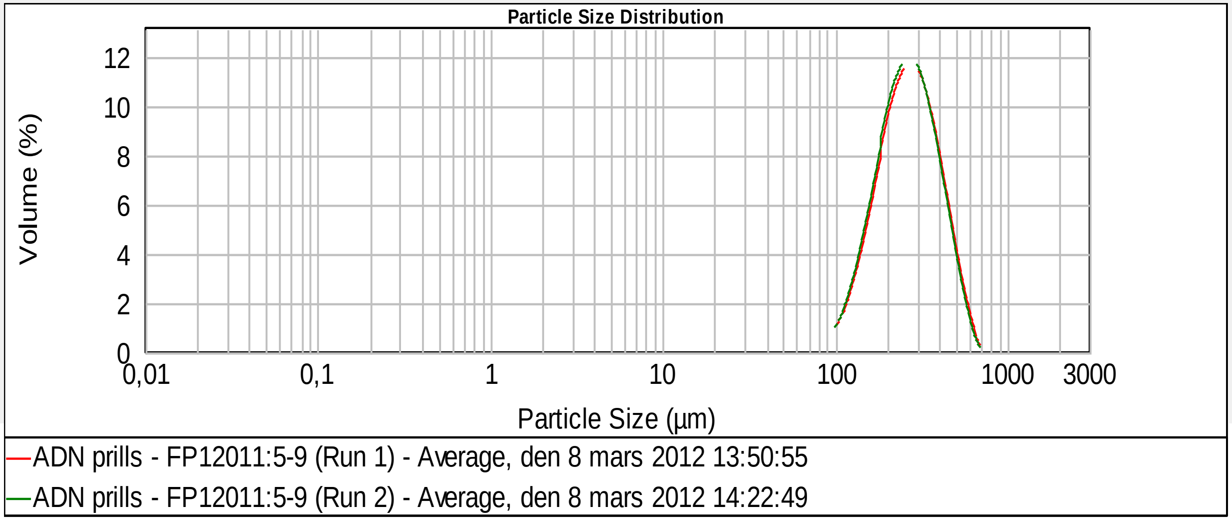
- Variations of the melt liquid flow
- Nozzle diameter
- Atomization air flow

Improvement of spray prilling process at FOI

- Average particle density: ~1.778 g/cm^3
- Average tap density: 1.03 g/cm^3
- Melting point: ~ 93°C

Size distribution

Batch	Run No.	d_{10} (µm)	d_{50} (µm)	d_{90} (µm)	Span
FP12011:5-9 (Run 1)	1	44,616	250,768	441,998	1,585
	2	27,688	238,666	428,460	1,679
	3	18,327	230,826	422,231	1,750
	Average	28,715	240,224	431,166	1,675
FP12011:5-9 (Run 2)	1	48,546	247,344	435,059	1,563
	2	30,282	237,229	422,493	1,651
	3	20,734	229,728	413,650	1,710
	Average	31,400	238,283	423,920	1,647



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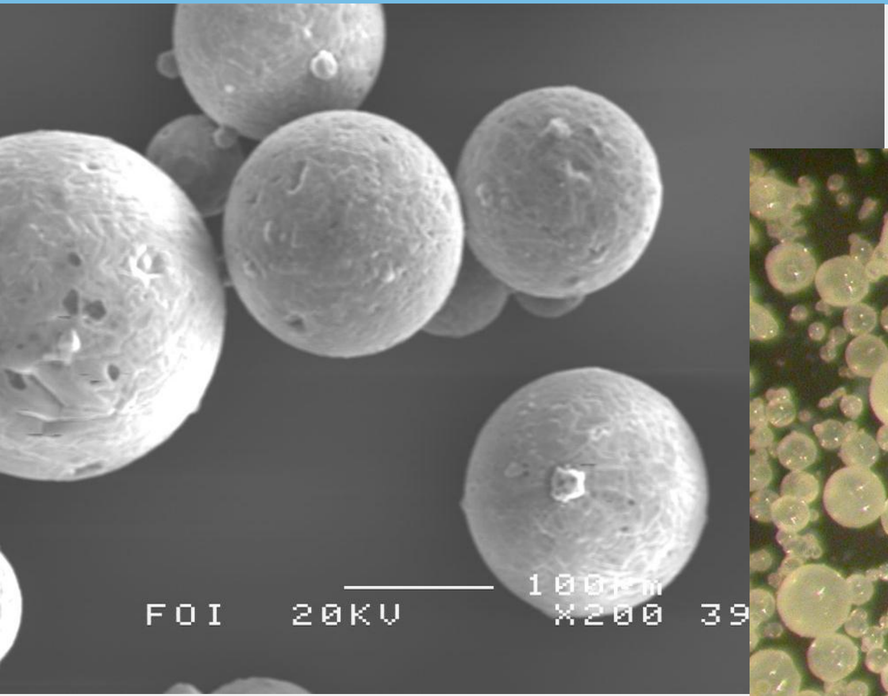
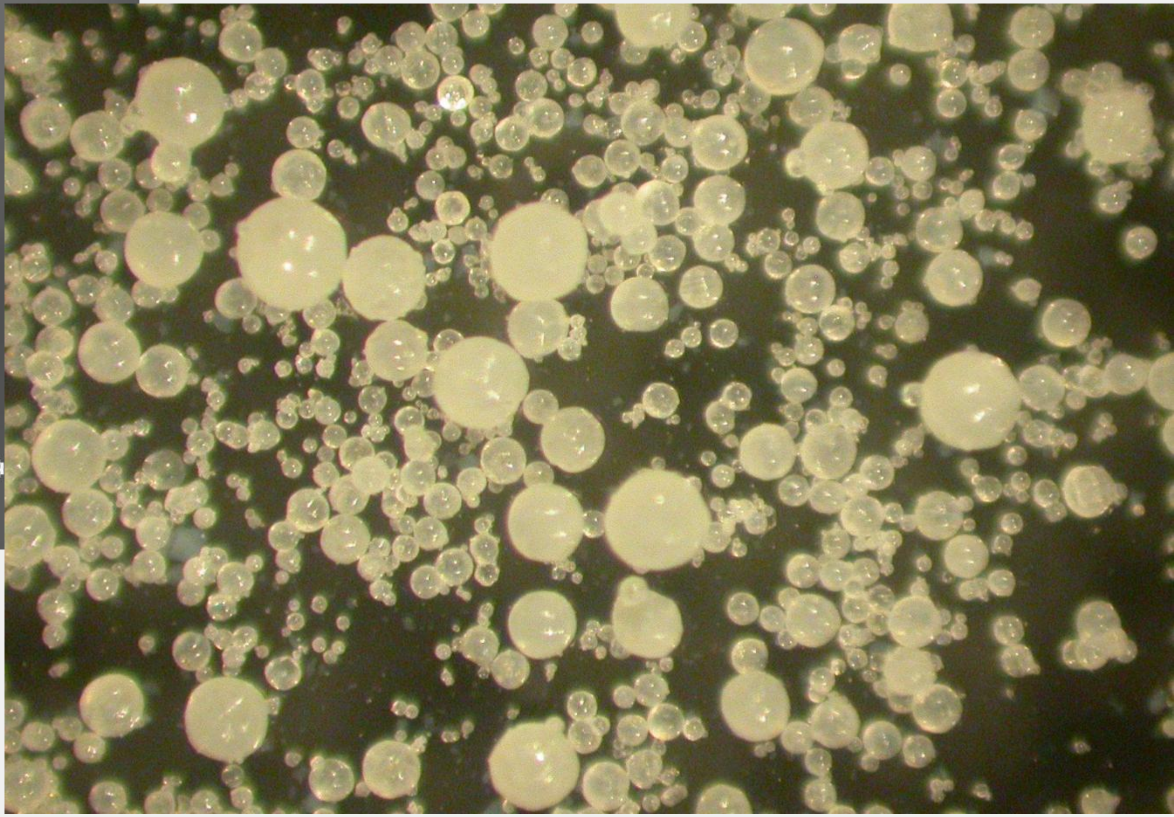
Spray prilled ADN





- ~ 200 µm
- ~ 60 µm

Estimated future price for prilled ADN

The estimated production price for prilled ADN in the 40 ton scale will be about

50 $ per lbs.

The estimated production price for prilled ADN in the 400 ton scale will be about

38 $ per lbs.

- Particle size 20-350µm

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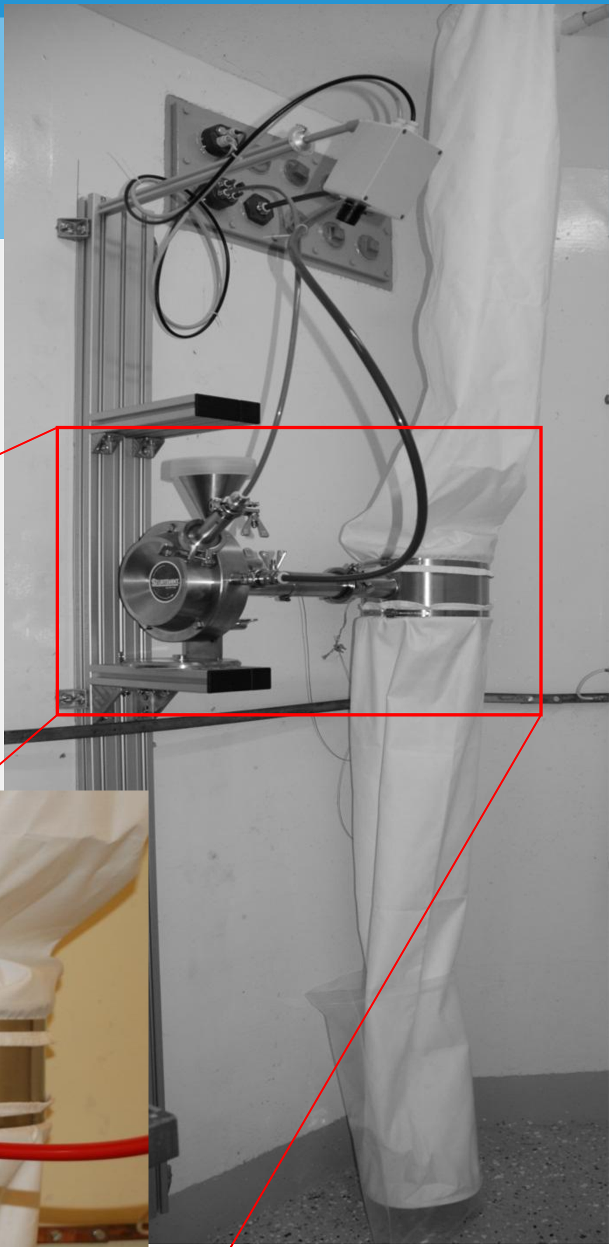
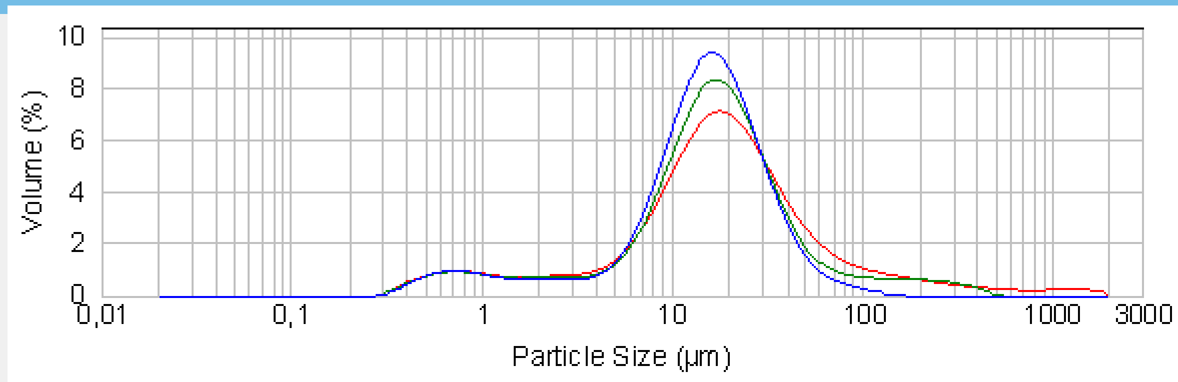
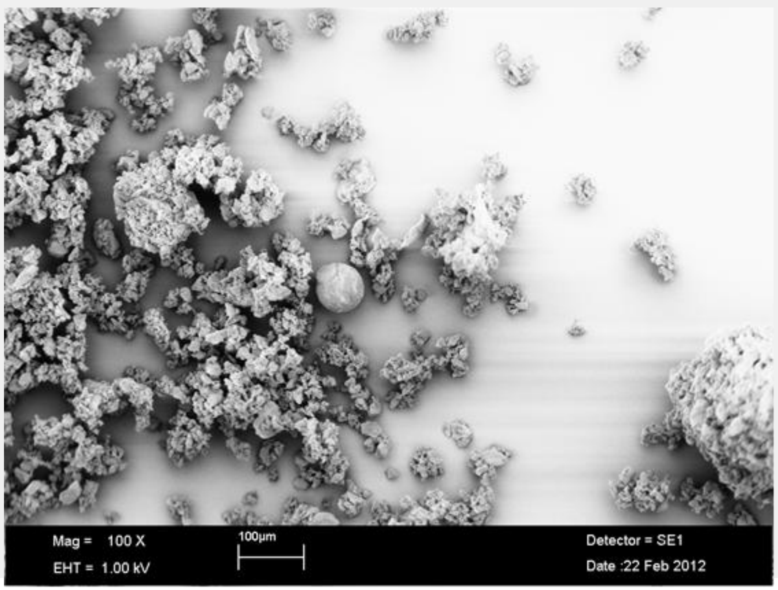
Grinding/milling

- Prilled ADN used in the air jet mill
- Different feed pressures
- 100 g takes 15 sek



Grinding/milling





- Density 1.801 g/cm^3
- Particle size 15-20µm
- Irregular in shape

Estimated future price for grinded ADN

The price for Jet milled ADN in the future has been estimated at 40 tons per year to be around

36$ per lbs.

The price for Jet milled ADN in the future has been estimated at 400 tons per year to be around

34$ per lbs..

ADN – GAP Formulation

AND-GAP formulations

- ADN is incompatible with isocyanates
- A number of different curing systems have been studied.
- FOI have shown that it is possible to use isocyanates to cure ADN based formulations by
  - selecting a suitable isocyanate
  - Tuning the curing temperature
  - Tuning the amount of curing catalyst
- Bonds formed are fully compatible with ADN.

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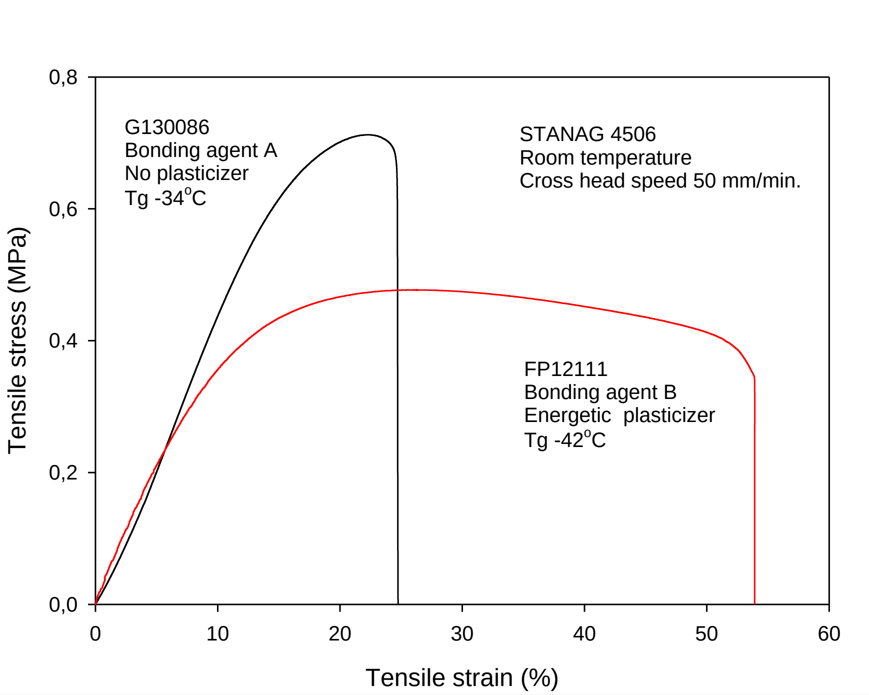
Improved mechanical properties

- Several bonding agents have been tested
- Two have been selected.
- Results from tensile testing of two ADN/GAP propellant formulations on the right side
- Formulations contains 70% ADN
- Different bonding agents were used in the formulations
- One of the formulations contained an energetic plasticizer.



Propellant	E_0 (MPa)	σ_m (MPa)	ε_m (%)	σ_r (MPa)	ε_r (%)	T_g (°C)
G130086 [b]	6.4 (0.4)	0.71 (0.01)	21 (1)	0.65 (0.02)	24 (2)	-34
FP12111 [c]	4.7 (0.2)	0.46 (0.01)	26 (1)	0.33 (0.03)	45 (7)	-42

a) Standard deviation within parenthesis.
b) 4 samples tested.
c) 5 samples tested.

Conclusions

- ADN prills are readily available in different sizes from Eurenco Bofors Sweden
- The estimated future price for ADN will provide a reasonable price estimate for a ADN propellant in a missile system
    - A ADN/GAP propellant motor in a missile system machined and finished for mounting will cost approximately 80-110$ per lbs.
- The performance for a ADN/GAP propellant is higher than for a double base propellant that means that if the performance is included in the price estimate the price for a ADN/GAP propellant is lower
- Mechanical properties of a AND/GAP propellant can meet the properties of a standard AP/HTPB Propellant

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- Taking into account the last couple of year’s technological progress concerning the development of a ADN based propellants
- The cost structure of ADN when it is produced in reasonable production scale

ADN can seriously be considered in a propellant for a future missile systems