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PRILLING OR GRANULATION OF UREA

Some comparative criteria of recently developed granulation technologies and improved airprilling

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We have compared the three recent 'newcomers' among shaping technologies with airprilling because by far the greater part of world urea production is prilled and because of the criticism prilling has been receiving from advocates of granulation such as:
<u>PRILLS ARE TOO SMALL AND TOO WEAK; PRILLING CAUSES AIR POLLUTION AND IS MORE EXPENSIVE THAN GRANULATION.</u>

Fluidized bed granulation	: Nederlandse Stikstofmaatschappij	(NSM)
Spouted bed granulation	: Mitsui Toatsu	(MT)
Falling curtain granulation	: Tennessee Valley Authority	(TVA)
Air prilling	: Stamicarbon	

It should be recognized that it is virtually impossible to generate a set of only a few reliable characteristics that clearly, precisely and uniformly distinguishes between the various shaping technologies under all circumstances: a trade-off between a large number of variables must always be made. The purpose of this paper is to at least identify a number of criteria which are of importance for appreciating the differences between the shaping technologies discussed here. In preparing this paper we have made use of published information but also of know-how with respect to urea technology, prilling and granulation available within our parent company DSM and UKF, the fertilizer division of DSM, as well as within the Stamicarbon organisation.

More particularly, we shall discuss the following subjects:

1. TYPICAL PROCESS INFORMATION.
2. PRODUCT CHARACTERISTICS.
3. SOME IMPORTANT ASPECTS OF SHAPING.
4. INTEGRATION OF THE SHAPING FACILITIES WITH THE UREA PLANT.
5. OPERATION, MAINTENANCE, ONSTREAM TIME AND FLEXIBILITY.
6. INVESTMENTS AND PRODUCTION COSTS.
7. SUMMARY OF OBSERVATIONS AND COMPARISON.

1. TYPICAL PROCESS INFORMATION

1.1. Recycle system;
1.2. Formation of particles of desired size;
1.2.1. NSM granulation;
1.2.2. MT granulation;
1.2.3. TVA granulation;
1.2.4. Stamicarbon prilling.

1.1. RECYCLE SYSTEM (See figure 0)

Contrary to prilling, where solid material is made by direct solidification of molten urea droplets, the size of which almost equals the required final product size, all granulation processes function by solidifying successive layers of solution or melt onto the surface of particles which are separately fed into the granulator and are made to grow during their passage through the granulator by continual spraying. Because growth is not uniform the granulate stream from the granulator is split into 3 fractions by screening:

1. oversize material, which is normally crushed to seed material and recycled to the granulator;
2. final product;
3. undersize material which re-enters the granulator as 'recycle' and contributes to cooling.

This requires a recycle system, which is usually not required for prilling. Such system consists of coolers, screens, bucketelevators, conveyors, crushers; hoppers, dustabatement systems, metering devices etc. For the same unit capacity, product grade, layout, recycle ratio - the recycle ratio is expressed in kg of product recycled to the granulator per kg of final product or per kg urea in the feedstock- and quality of installed equipment it may be safely assumed that the investment, utility, operating and maintenance costs and on-stream time of this part of the plant are independent of the granulation technology which is involved.

When more than one product size is required the recycle system should be designed for two conditions:

. smallest particle size, because in that case the recycle ratio is maximum;

. largest particle size, because more air will be required for the fluid bed cooler, increasing the dimensions of air blowers, exhausters and the dust abatement systems, also the solids loop (screens, crushers, etc) must be adapted.

1.2. FORMATION OF PARTICLES OF DESIRED SIZE

In all granulation processes the granules are formed in a granulator, the granules are discharged to the recycle system and oversize product and seed material re-enter the granulator.

1.2.1. NSM granulation See figure 1

In a rectangular granulator, granules are fluidized with air which is distributed through a perforated plate.

Urea solution of 95-96 wt % concentration is atomized in air-assisted spray nozzles and is sprayed onto the fluidized particles, which subsequently grow by accretion with simultaneous water evaporation. In this way, part of the released heat is removed. The bed dimensions are determined by heat balance considerations, humidity conditions, fluidization and dust carryover criteria and by the spray density. A plant designed for a certain urea concentration (e.g. 95 wt %) will have an output that is very much determined by the actual urea concentration.

Urea conc. % by weight	94	95	96	97	98	99	100
Plant output %	120	100	80	72	65	60	55

1.2.2. MT granulation See figure 2

The rectangular granulator is provided with cones attached to a perforated plate for distribution of air to fluidize the granules and to make granules move from one cone to the next. Each cone is provided with a spray nozzle for urea melt (99.0-99.7 wt %) with a spray capacity of some 200-300 MTD. Separate spouting air enters the cones causing an orderly cyclic movement of particles, which grow by layering. Capacity increase is possible with a multicone arrangement. Because no water is evaporated, more air is required for the granulator at the same recycle ratio.

1.2.3. TVA granulation See figure 3

In a rotating drum provided with special internals, falling curtains of granules are formed on which a urea melt (99.0-99.7 % concentration) is continuously sprayed during the passage of the granules through the granulator. The granules are cooled with air and by evaporation of a fine water mist sprayed into the air with separate nozzles while passing co-currently through the drum.

Growth takes place by layering. Internals (pans) shorten the fall of the granules, so preventing breakage with simultaneous dust formation, and also provide a large open area in the drum in which the water spray nozzles are installed. Special attention is given to humidity control to prevent the granules absorbing moisture, which is made possible by separately controlling the water flow.

Emphasis is also placed on proper seed preparation and the dosing of dust-free seed on a granule-to-granule basis.

1.2.4. Stamicarbon prilling See figure 3A

A urea melt of 99.7 % concentration is distributed in the top of a cylindrical, usually concrete, tower by a rotating bucket. The urea melt droplets solidify and cool during their free fall in direct contact with ambient air.

The prills are collected and transported in the base of the tower by a rake to a conveyor belt and by this belt to the storage. It is also possible to delete the rake by installing a conical bottom in the tower, and it is possible to reduce the towerheight by installing an additional product cooler.

In recent years, Stamicarbon has patented a process by which small seed particles are brought into the tower to prevent 'undercooling' of the droplets, so increasing the mechanical strength of the prills. The mechanical strength is also increased by adding some formaldehyde or similar material, at the same time improving the storage characteristics of the product with respect to caking. By a special construction in the tower it is possible to separate the air from the tower in two streams, respectively with a higher and a lower dust concentration. This makes it possible, when necessary, to remove dust only from one air stream instead of cleaning the total air amount.

The absolute amount of dust from the tower is extremely low (1-1.5 kg/MT of product), and a further reduction of that amount should only be effected if required by environmental legislation.
For that situation DSM has tested and compared two wet-type dust recovery systems on a pilot plant scale, with the following results: See table 1

Table 1

PILOT PLANT DATA OF DUST ABATEMENT

	System A	System B
Collection efficiency	80 %	90 %
Power consumption, kWh/1000 m^3 air	0.6	0.8
Dust emission, kg/MT urea	0.2-0.3	0.1-0.15

Because the cleaning costs are proportional to the air volume, and the air volume is related to the tower height, optimization is necessary for each particular situation.

Prior to dust recovery, the dust content in air from granulationplants is abou
20-50 times higher than in air from prilling towers.
Recovery of that dust is always necessary and probably also economically justified.

Dustemission after the dust recovery system are said to be respectively for NSM, MT and TVA are 0.10-0.15, 0.2 and 0.10-0.15 kg/mt urea.

<u>In Table 2</u> information on consumption of additives and utilities of shaping facilities only, based on 0.10-0.15 kg dust/MT urea as dustemission, is given

<u>Table 2</u>	<u>NSM</u>	<u>MT</u>	<u>TVA</u>	<u>Stac-Prillin</u>
Additives such as formaldehyde kg/MT urea	For granulation and storage reasons 5	For storage reasons 1*(estimated)	For storage reasons 0.5	For storage reasons 2
Power consumption kWh/MT urea	35	31	18	10
LP steam consumption kg/MT urea	40	10	10	10

* We have been recently informed that apart from ureasoft, a product developed by M.T. and TEC - up to 6 kgs formaldehyde are used in M.T.'s New Zealand plant to improve the storage properties of the ureagranules and to reduce dust formation.

2. PRODUCT CHARACTERISTICS

2.1. Particle size distribution, a market criterion.
2.2. Biuret content, another market criterion.
2.3. Shipping, handling and storage properties.

2.1. PARTICLE SIZE DISTRIBUTION, A MARKET CRITERION (See Table 3)

We have distinguished between 5 different urea grades by average diameter and product size range depending upon the application of the product. Table 3 indicates by which shaping technology these grades (preferably) can be produced.

Table 3

Technologies versus urea grades

Urea grades	Average size, mm	Size range, mm	Granulation			Prilling
			Fluidized bed	Spouted bed	Falling curtain	
1. Feed grade	0.6	0.2-1.0	-	-	-	x
2. Agricultural grade (standard)	1.7	0.8-2.6	-	-	-	x
3. Agricultural grade (coarse)	2.2-2.5	1.0-3.4	x	x	x	x
4. Forestry grade	5	3-6.5	x	x	x	-
5. Super-granules	15	10-20	-	-	x?	-

Table 3 illustrates that coarse agricultural grade can be produced by all four shaping technologies. Feed grade and standard agricultural grade are preferably made by prilling, feed grade can be made by prilling only and standard agricultural grade product can be made by granulation only at the cost of a high recycle ratio, preferably this product should be prilled.
Forestry grade and supergranules can only be made by granulation and as far as we know TVA only has produced supergranules. During said production probably additional seeds were formed, limiting the plant output considerably and making it necessary to increase the recycle ratio to over 3.1. We fear that semilar problems will occur during fluid bed granulation.
Supergranules have been produced with the pan, however at recycle ratio's of over 7:1.

Ad 1. Feedgrade is used for cattle feed, a rather limited market exists.

Ad 2. Standard agricultural grade still finds the widest application of urea as a fertilizer. It is also used as technical grade urea with additional demands on purity such as colour, turbidity, Ph-reactivity etc. and is used for urea formaldehyde resins and glues.

Ad 3. Coarse agricultural grade was made to meet bulk blenders' requirements with respect to particle size matching with other blending materials such as DAP and KCl. In the USA this size is dictated by DAP, having an average size of 2.25 mm (see table 4). As can be observed in the Table, prills 'B' and granules 'C' match the full product size range of DAP and KCl better than granules 'D' and 'e' do and much better than prills 'A' do.

Ad 4. Forestry grade is used for aerial application, a very limited market exists.

Ad 5. Super granules. The demand for this product and possibly of forestry grade product may increase since it has been found (IFDC) that one supergranule placed deep between four rice plants is usually more effective than the best split urea application in improving the rice yields from wetland.

Yields similar to those obtained with the best split urea can be achieved with 10 -30 % less urea. Similar results might be obtained with broad-cast sulphur coated urea (S.C.U.). To reduce production costs of S.C.U. it might be attractive to use particles larger than prills, such as forestry grade as a base material.

Deep placement calls for applicators, which exist already, also for prills. Mechanisation in rice-agriculture possibly is another necessity to enable deep placement. Recent investigations indicate that no significant difference exists between rice yields from wetland when ureaprills, urea forrestry grade granules or urea supergranules are deepplaced with an injector. NSM reports that in some field tests with granular forrestry grade urea higher yields and better N-efficiencies were obtained than with urea prills at a nitrogen gift of 45-0 kg N/ha. The urea was broadcasted, partly incorporated and split application was practized. More research is strongly recommanded.

Table 4

TYPICAL GRANULOMETRY FOR BULK BLEND FERTILIZERS

	Percentage retained on screens with opening of:					Average diameter, mm
	4 mm	2.86 mm	2.03 mm	1.43 mm	1.02 mm	
DAP (typical)	1	36	49	14	-	2.25
KCl (typical)	4	33	42	17	2	2.22
Urea prills (A)	1	4	44	46	6	1.72
Urea prills (B)	1	42	52	4	2	2.33
Urea granules (C)	1	38	57	4	1	2.31
Urea granules (D)	-	8	52	39	2	2.15
Urea granules (E) *	-	0.3	99.5	0.2	-	2.45

* Note the very narrow size distribution, which is typical of TVA.

(A) Typical of the sixties and seventies

(B) Special design of the eighties, suitable for bulk blend market

(C) Typical of cold spherodizer process in the seventies

(D) Made by NSM granulation

(E) Made by TVA granulation.

2.2. BIURET CONTENT, ANOTHER MARKET CRITERION

We can distinguish between products with:

a. a low biuret content (0.25-0.4 %), used for foliar application (e.g. citrus), which is achieved by crystallization at higher utility costs and about 15 % higher installed costs as compared with the evaporation process.

b. a standard biuret content (0.8-1.4 %) used for all other fertilizer applications and obtained by the evaporation process;

c. a high biuret content (> 1.4 %) used for non-fertilizer purposes, such as technical grade urea, melamine and cattle feed.

We have calculated the standard biuret content of the final product for an integrated plant (see Table 5). Of course, also low-biuret products can be made by all shaping technologies. We expect that the lowest biuret content (max. 0.25 %) will be achieved by prilling.

2.3. SHIPPING, HANDLING AND STORAGE PROPERTIES

In Table 5 we have summarized the main product characteristics which are relevant for shipping, handling and storage properties.

Caking (agglomeration or lumping) may occur during storage in bulk or bags and can be measured as a percentage of 'light' 'medium' or 'heavy' lumps in a test over an extended period of time. Caking is caused by the formation of crystal bonds between particles and can be minimized by:

- product characteristics such as a low water content of the final product, high crushing strength, minimum contact area between the particles (e.g. large, round, smooth particles);
- low storage temperatures (max. 60 °C);
- humidity conditions during storage; the optimum situation exists when the particles cannot absorb or evaporate water from or to the surrounding air.

The caking tendency of re-stored, aged product is usually considerably less than that of fresh, stored product.

Table 5

PRODUCT CHARACTERISTICS

		NSM granules	Mitsui Toatsu granules	TVA granules	Stamicarbon prills
1. Crushing strength (2.4 mm)	kg	(F) 3	(E) 1.25	(C) 3.0 (D) 3.3	(A) 1.0 (B) 1.2
2. Impact strength	%	(F) 75-100	(E) ?	(C) 95-100 (D) 95-100	(A) 30-60 (B) 75-90 1)
3. Abrasion resistance	%	< 1.0 3)	?	< 0.5 2)	?
4. Bulk density (poured)	kg/m^3	< 700-720	± 740	740-770	720-740
5. Sphericity	%	75-90	?	85-95	80-95
Water in final product	% wt	≤ 0.25	≤ 0.2	0.05-0.1	0.2
Formaldehyde in final product	% wt	0.5	?	0.05-0.1	0.2
Biuret in final product	% wt	0.75	0.85	0.85	0.8

1) with seeding
2) without formaldehyde
3) with formaldehyde

Product	A	B	C	D	E	F
Formaldehyde content % wt	0	0.2	0	0.05	0	0.55
Water content % wt	0.3	0.2	< 0.1	<0.1	0.2	0.25

re 1. The crushing strength indicates at which static load a particle fractures. It is almost proportional to D_d^2 (D_d= particle diameter), and is in this paper expressed in kg force. The crushing strength can also be expressed in bar, which makes it independent of D_d. We have found that a crushing strength of about 20-25 bar (or 0.9-1.2 kg force for D_d = 2.4 mm) is sufficiently high to prevent degradation of the particles (to dust) during storag
A low water content of the feedstock, a low final product moisture content and a high formaldehyde content are favourable for a high crushing strength; e.g. each 0.1 % of formaldehyde increases the crushing strength by approximately 3 bar.

re 2. The impact strength provides information about the resistance of particles to the dynamic forces as occur during handling and transportation and is therefore more important than the crushing strength. In Table 5 we can see that prills made by the 'seeding' process have an impact strength which equals the impact strength of granules and is almost twice as high as that of prills made by the original, non-seeding prilling process.

re 3. Abrasion resistance is measured by a TVA test, and according to NSM is improved when formaldehyde is present in the product; for TVA products the abrasion resistance is almost equal with and without formaldehyde.

re 4. 'Poured' bulk density is usually 3-4 % lower than 'tapped' bulk density. It is an important criterion in sizing bags, storage bins and transport vehicles and in shiploading. The process conditions during shaping (e.g. water content of the feedstock), the particle size distribution (smaller particles may fill the voids between larger particles) and the sphericity all affect the bulk density of a particular product.

re 5. The sphericity and surface roughness are important also in connection with the angle of repose, which should be minimum 25° to prevent unbalancing of a ship when not fully loaded.

3. SOME IMPORTANT ASPECTS OF SHAPING

3.1. Heat removal by air, water evaporation and 'cold' recycle per 1000 kg of final product

3.2. Air requirement in kg per 1000 kg of final product.

3.3. Permissible humidity to avoid moisture absorption by the granules.

3.4. Required water evaporation when the urea concentration of the feed is below 99.7 %.

3.5. Minimum required fluidization velocities.

3.1. HEAT REMOVAL BY AIR, WATER EVAPORATION AND COLD RECYCLE PER 1000 KG OF FINAL PRODUCT

As an overall result during shaping, a urea solution or melt of temperature t solidifies into solid particles of specified dimensions and a final temperature t_2, during which process heat is released (Q_1).

In Figure 4 the enthalpy difference between a urea melt at a temperature of t °C and a final product temperature of t_2 °C can be found.

In Figure 5 we have plotted Q_1 vs t_2, whereby Q_1, is calculated from the enthalpy difference of figure 4, assuming that t = 140 °C and that a watercontent up to 5 % has a negligible influence on the enthalpy difference.

Q_1 equals the amount of heat which has to be removed by:

1. Air in the granulate cooler (heat amount = Q_2)
2. Cold recyle in the granulator (heat amount = Q_4)

Both Q_2 and Q_4 are determined by $\Delta t = t_1 - t_2$ (t_1 is the temperature at which the granulate enters the cooler and t_2 is the final product temperature) and by the recycle ratio R.

3. Water evaporation (heat amount = Q_5)
4. Air in the granulator (heat amount = Q_6)

For granulation $Q_6 = Q_1 - Q_5 - Q_2 - Q_4$; for prilling $Q_6 = Q_1$

Knowing the water evaporation in kgs/1000 kgs final product and R we can easily find Q_2 and Q_4 in this figure.

Use of figure 5			kcal/1000 kg final product
* t_2 = 60 °C	Q_1	=	85,000
1. t_1 = 110 °C; Δt = 50 °C; R = 0.5	Q_2	=	30,000
2. t_1 = 110 °C; Δt = 50 °C; R = 0.5	$Q_2 + Q_4$	=	40,000
3. t_2 = 60 °C; waterevaporation = 45 kg/ t.urea	$Q_1 + Q_5$	=	56,000
4. $Q_6 = Q_1 - Q_5 - Q_2 - Q_4$	Q_6	=	16,000

3.2. AIR REQUIREMENT IN KG PER 1000 KG OF FINAL PRODUCT

The air requirements of the cooler and the granulator are proportional to Q_2 and Q_6 respectively, and further depend on the temperature rise of the air, which in degrees C is approximately as follows:

Fluid bed coolers: $t_2 - t_g + (t_1 - t_2)\ 0.25$
NSM granulator : $t_1 - (t_g + 15)$
TVA granulator : $(t_1 - 15) - t_g$
MT granulator : $t_1 - (t_g + 5)$
Prilling tower : $t_{g2} - t_g$

t_g = ambient air temp.
t_1 = granulate bed temp.
t_2 = final product temp.
t_{g2} = air temp. at tower exit (60-80 °C)

In figure 6 we can find the air requirement in kgs/1000 kgs of final product for the fluid bed cooler, the granulator and the prilling tower as a function of the heat to be removed (Q_2, Q_6 and $Q_6 = Q_1$ respectively) and as the function of the rise in temperature of the air.

Calculating the temperature rise of the air with the above formulae for t_1 = 100 °C, t_2 = 50 °C; tg = 25 °C and tg_2 = 80 °C and using figure 5 and 6 for conditions as given in Table 6 the air requirements can be found in this Table.

Table 6

AIR REQUIREMENT IN KG/1000 KG OF FINAL PRODUCT

	Granulation			Stamicarbon
	NSM	MT	TVA	Prilling
Water evaporation, kg	50	0	50	0
Recycle ratio	0.5	1.0	0.5	0
Air requirement of fluidized bed cooler	3350	4400	3350	0
Air requirement of granulator	1350	1750	1350	0
Air requirement of gran. spray nozzles	500	0	0	0
Air requirement of prilling tower	-	-	-	6700
Total	5200	6150	4700	6700

The low air requirements for TVA and NSM granulators are caused by the water evaporation in the granulator.

NSM uses additional air for its urea nozzles, which does not contribute to heat removal. Air used for the waterspray nozzles of TVA contributes to heat removal. Though the air amount for prilling is highest, it is not necessarily much higher than the total air requirement of granulation as is sometimes suggested.

Lower recycle ratios usually (when Δt air granulator $>$ Δt air cooler) reduce the total air requirement; at the same time, however, the air requirement of the granulator is increased, which is not attractive because dust recovery from granulator exhaust air is more difficult than from cooler air.

A higher granulate temperature reduces the air requirement of the granulator considerably, though the total air requirement is reduced only moderately. Granulate temperatures above 110 °C are not recommended. (See Table 7).

Table 7

AIR REQUIREMENT IN KG/MT UREA VERSUS GRANULATE TEMPERATURE

				Conditions	
t_1,°C	granulator	cooler	total	tg	25 °C
90	2100	2850	4950	t_2	50 °C
100	1350	3350	4700	R	0.5
110	750	3850	4600	W	50 kg (water evaporation per 1000 kg of final product)

3.3. PERMISSIBLE HUMIDITY TO AVOID MOISTURE ABSORPTION BY THE GRANULES

Figure 7 represents the threshold value temperature relation for urea: when the relative humidity of the surrounding air equals the threshold value, water cannot be transferred to or from the particles.

Example: For 50 °C, the threshold value is 0.63 and the corresponding critical moisture content of air is 0.055 kg H_2O/kg dry air, which means that water can be absorbed only if the air humidity $>$ 0.055 kg H_2O/kg dry air.

In Table 8 the influence of process variables on the ultimate humidity conditions in the granulator is given for ambient air of 25 °C saturated with water vapour. Figures 5 and 6 have been used for calculating the air requirement of the granulator.

Table 8

HUMIDITY-RELATED PROCESS VARIABLES

	Granulate temp. t_1	Recycle temp. t_2	Water evaporation kg/MT final product	Recycle ratio R	Ultimate humidit $x = \frac{\text{kg } H_2O}{\text{kg dry air}}$
'Base case'	100	50	50	0.5	0.057
Case 'A'	90/110	50	50	0.5	0.044/0.087
Case 'B'	100	40/60	50	0.5	0.070/0.052
Case 'C'	100	50	55/60	0.5	0.068/0.085
			65/70		0.114/0.160
Case 'D'	100	50	50	0.25/0.75	0.045/0.108

The ultimate humidity x is always below the critical humidity content at temp. t_1 and, therefore, no moisture can be absorbed. When, however, R and/or the water evaporation rate increase, x will rapidly approach the critical moisture content at the threshold value.

Most critical is the granulator area in which 'cold' recycle is first contacted with ambient air. TVA in that case sprays relatively more urea melt and less or no water in the front end of the drum, so causing both the product and the air temperature to increase quickly without increasing the moisture content of the air. In other parts of the drum these temperatures are controlled by the amount of water which is sprayed into the drum. When water must be evaporated from a urea solution, the air humidity will start to increase simultaneously with the increase of the 'cold' recycle temperature, which may make it necessary to preheat the air.

3.4. REQUIRED WATER EVAPORATION WHEN THE UREA CONCENTRATION OF THE FEED IS BELOW 99.7 %

Water evaporates from the surface of the granules and from the droplets as they travel to the granules.

. The required time to evaporate water from the surface

$$T_W = C.\frac{D2}{\Delta P}$$

where D is the initial diameter of the granule, and ΔP the log mean water vapour pressure difference. It is also proportional with the amount of water to be evaporated and it is about 10 times higher for a recycle ratio of 0.25 vs. 1.0.

For evaporation of 10-50 kgs water/1000 kg feedstock at a granule surface temperature of 100 °C, from granules ranging in size between 1-5 mm and at a recycle ratio of 0-25 to 1.0, $T_{W_{min.}}$ is some seconds and $T_{W_{max}}$ is a couple of minutes.

. The amount of water evaporation from a droplet is proportional with $\frac{P}{D^2}$ and with the available contact time between the droplet and the surrounding air, which for the same initial nozzle velocity increases with the distance over which the droplet travels.

This distance is easier to define and probably longer for TVA than it is for NSM. For evaporation of 10-20 kgs water/1000 kgs feedstock we calculated that the required droplet size is about 40 um (NSM) and 200 um (TVA).

. For NSM the largest amount of water evaporates from the granule surface, for TVA the majority of the water evaporates from the droplet surface.

3.5. MINIMUM REQUIRED FLUIDIZATION VELOCITIES

Fluidized bed equipment requires a minimum fluidization velocity v_g min. which depends on the granule diameter D and is usually designed for 1.3 to 1.5 v_g mi
In Figure 8 both the minimum and design fluidization velocities for urea particles are plotted.

Annex 1 might be of interest, because it illustrates how to use the information which has been supplied in this Chapter, when applied to a fluid bed granulator. It appears from the required LMTD (10) necessary for heattransfer and from the calculated residence time of the granules in the bed (12), available for waterevaporation from the granulesurface, that most probably the bed height is primarily determined by the required water evaporation; in this case the bed height should be at least 0.5 m (see chapter 3.4).
The maximum granulation capacity should not exceed 4000 kg/hm^2 bed area and the actual air velocity should at least be equal to the design fluidization velocity.

Annex 2
Illustrates the use of figure 9 for calculating a fluid bed cooler for urea. 'f' will approach 1 when both Vg and/or g decrease and/or when the bed height h increases. For larger particles and the same bed height 'f' will decrease. When 'f' increases Gg' decreases and the required bed area per 1000 kg final product decreases as well, which means that the bed dimenions can be smaller for the same capacity.

4. INTEGRATION OF THE SHAPING FACILITY WITH THE UREA PLANT

Table 9

UTILITIES VERSUS DESIGN DATA

Alternative:	Base	1	2	3	4	5	6	7
Design data:								
1. Feedstock conc. wt %	99.7	99.7	99.7	99.0	99.0	99.0	95.0	95.0
2. dust recycle %	nil	2	4	0.5	2	4	nil	4
Utilities/MT urea:								
steam 25 bar, 250 °C	base	+4	+6	-28	-26	-24	-37	-34
steam (export), 4 bar	base	-38	-80	+82	+42	-	+219	+141
cooling water (28 °C), m^3	base	+2	+4	-6	-4	-2	-15	-11

The urea plant will deliver urea feedstock of 95-99.7 % concentration to the shaping facility. It will receive urea dust, in an amount expressed as a percentage of the production capacity (as a 40 % urea solution), from the shaping facilities.

We have studied the effect of varying the feedstock concentration and dust recycle on the utility consumptions and the installed equipment costs of our total recycle CO_2 stripping process provided with evaporation and a waste water treatment in which both the urea content and the ammonia content of the aqueous effluent are reduced to 50 ppm. A further reduction to 10 ppm is possible.

In Table 9 differences in utility consumption of 7 alternatives are given versus a base case + or - refers to a higher (respectively lower) utility consumption or export of 4 bar steam of the urea plant only, caused by the integration with a shaping facility.

The base case is integration of the urea plant with prilling: alternatives 2, 3 and 7 are integration of the urea plant with the Mitsui Toatsu (assumed), the TVA and the NSM process respectively.
In alternatives 6 and 7 the feedstock will contain about 0.3 % ammonia, which will contaminate the exhaust air from the granulation plant. This content can be reduced at the expense of additional equipment and utility costs in the urea plant. The use of lean (ammonia-containing) urea plant process condensate for scrubbing in the wet dust recovery systems of the shaping facility - though attractive for the waste water treatment of the urea plant - is not recommended because it will cause air pollution.
The intermediate storage capacity in the urea plant for 75 % urea solution should be approximately four times larger in the case of granulation than in the case of prilling, in order to cope with temporary interruptions of the production caused by equipment failures in the granulation plant.

5. OPERATION, MAINTENANCE, ONSTREAM TIME AND FLEXIBILITY

Prilling is undoubtedly the simplest process:

1. When a 99.7 % urea melt is delivered to the tower, operation can start immediately at full load; for granulation this may take some hours.
2. The prilling bucket needs visual inspection for its cleanliness only once a shift. This may also take place with a television monitor in the control room. In a granulation plant it is necessary to control parameters such as the recycle ratios, seed production and metering, feedstock concentrations, water sprayed into the granulator, capacity variations, granule size changes, etc.
3. The absence of most of the mechanical equipment makes for easier prilling operation, lower maintenance costs and hundred percent onstream time. Prilling will never interrupt or limit the output of the urea plant. (According to NSM, the onstream time for its granulation plant under normal operating and maintenance conditions is 345 days (95 %) per year).
4. All shaping processes accept capacity variations; for prilling the capacity may be varied between 60 and 125 % without changing the operating parameters of the tower. This is more complicated for granulation.

6. INVESTMENTS AND PRODUCTION COSTS

The four different shaping technologies are compared on the basis of integration with the STAMICARBON total recycle CO_2-stripping urea process. The urea plant is provided with an evaporation unit to make products with a standard biuret content and with a waste water treatment unit to reduce both the urea content and the ammonia content of the aqueous effluent to 50 ppm. The ambient air temperature is 25 °C and the final product temperature is 50 °C.

6.1. INVESTMENTS

The investment costs for the granulation processes are based on a dust emission of 0.1-0.15 kg urea per tonne final product of coarse agricultural grade.

Detailed information on the TVA process enabled us to estimate the investment required for the granulation unit. Because the three granulation processes operate at approximately the same recycle ratio, the differences in investment will only be marginal.

These investment costs were corrected for changes of investments in the urea plant caused by the integration of the plant with one of the granulation processes, taking the urea plant design based on integration with prilling as a reference.

In figure 10 the investements for granulation have been plotted versus the unit capacity as a band rather than as a single line to allow for the above corrections, for moderate investment differences in the granulation section itself and for differences in licensing policies.

For prilling four different curves were drawn to indicate the effect of product size and the presence of dust abatement equipment on the investments.

1. Coarse agricultural grade and dust emission of 1 - 1.5 kg/MT urea
2. " " " " " " 0.1 - 0.15 kg/MT urea
3. Standard agricultural grade and dust emission of 1 - 1.5 kg/MT urea
4. " " " " " " 0.1 - 0.15 kg/MT urea

Alternatives 2) and 4) are provided with dustabatement equipment; in all 4 alternatives a seeding installation and a rake in the tower base are included.

All investment figures are based on W. European conditions, and converted into US dollars at an exchange rate of US dollar = 2.80 Dutch Florins.

The investment costs for all prilling process alternatives are lower than those for the granulation processes. An additional advantage of prilling might be the construction of concrete prilling towers at low cost by local labour, without the need for foreign currency, which might be attractive in many countries.

6.2. PRODUCTION COSTS (see Table 10)

For a depreciation over 10 years at 10 % interest, differences in fixed production costs between granulation and prilling (base) can be calculated from Figure 10.

For granulation we took the average band value at an assumed on stream time of 330 days per year at design capacity of the integrated plant. For prilling we took curve 2 for coarse agricultural grade product including dust abatement equipment and also an on stream time of 330 days per year at design capacity nothwithstanding these integrated plants have proven to operate more than 345 days per year above design capacity.

Data from Table 2 and 9 were used to calculate variable production cost differences between granulation and prilling (base), using unit prices of US ¢ 6 per kWh, US ¢ 1.75 per kg steam (25 bar and 250 °C), US ¢ 1.2 per kg steam (4 bar, export), US ¢ 1.5 per m^3 of cooling water, US ¢ 40 per kg of formaldehyde and US ¢ 14 per kg of ammonia (see chapter 4).

Table 10

Differences in fixed and variable production costs in US ¢ per metric ton urea

	Plant capacity MTD	NSM	MT	TVA	Prilling alternative 2
Fixed costs:	500	+128	+128	+128	base
	1000	+126	+126	+126	base
	1500	+121	+121	+121	base
Variable costs:					
kWh		+150	+126	+48	base
Steam 25 bar, 250 °C		-60	+11	-49	base
Steam 4 bar		-133	+96	-98	base
Cooling water		-16	+6	-9	base
Formaldehyde		+120	-40	-60	base
Ammonia		+42	0	0	base
Total		+103	+199	-168	base
Total production costs:	500	+231	+327	-40	base
	1000	+229	+325	-42	base
	1500	+224	+320	-47	base

\+ or - indicate higher (respectively lower) costs for granulation compared to prilling (base).

Note: When more export steam is made available, its value will reduce the total variable costs.

The differences in fixed production costs between the three granulation processes and prilling are almost the same, being US $ 1.25, in favour of prilling.

The differences in variable production costs depend very much on the unit prices; the consumption figures being very accurate. For other unit prices than we used, table 10 can be adjusted. We know that the unit price for low pressure (export) steam can vary considerably from one plantsite to another.

When the unit price of this stream is negligible, the urea plant design usuall will be adjusted to prevent the export of steam. When this does not occur, the variable production costs for both NSM and TVA will be increased with some US $ 1 - and these costs for MT will be decreased with some US $ 1.-. Differences in consumption of power and formaldehyde distinguishes one granulation process from the other and all granulation processes from prilling.

7. SUMMARY OF OBSERVATIONS AND COMPARISONS

1. It is not sensible, if not impossible, to use granulation technologies for feed grade and standard agricultural grade and prilling for forestry grade and supergranules.
Coarse agricultural grade can be made with each of the four technologies.
TVA has made supergranules with an average size of 15 mm.

2. Operational and maintenance costs are lowest and the on stream time is highest with prilling.
As far as water evaporation is concerned, operation of the granulator will be increasingly complex for MT, TVA, and NSM, respectively; for the recycle system no substantial differences are expected.

3. Most commercial experience has been obtained with prilling; 150 towers up to 2100 MTD and expected max. unitsize practically unlimited; NSM has operated its own 800 MTD commercial unit for several years, has licensed and under construction 7000 MTD and the expected max. unit size is > 1750 MTD; MT started a 470 MTD unit in New Zealand in September 1982, not all problems have been solved yet, expected max. unit size unknown; TVA operates its 300 MTD demonstration plant since June 1983, expected max. unit size 1200-1500 MTD. Both MT and TVA have less large scale commercial experience.

4. Costs of operation and maintenance, on streamtime and flexibility are more favourable for prilling than for granulation.

5. Biuret content of the final product is not a selection criterion, neither are impact strength and sphericity or formaldehyde and water content of the final product. Formaldehyde however is an important cost factor.
It is our experience that a crushing strength of 20-25 bar is sufficient and this is met by all four technologies.
The bulk density ranges from 700-770 kg/m^3 and could be a selection criterion.

6. Investments for granulation plants are substantially higher than for prilling plants.

7. The total production costs per MT prilled urea are approximately US $ 2 to 3 lower than per MT granulated urea for NSM and MT and almost equal for TVA. This is both caused by the difference in investment and variable costs. The variable costs depend on an accurate calculation of the consumption figures and on unit prices for energy and other materials. Other unit prices may change the results considerably. Comparing the total production costs, makes it possible to rank the four shaping technologies for this criterion.

In general, we conclude that prilling is not at all as bad as advocates of granulation want us to believe. Prilling requires the lowest investments and yields product at the lowest cost price with a max. onstream time and the lowest maintenance and operating costs.
It has found the broadest acceptance in the world.
Earlier reported drawbacks, such as a high air pollution, a too small average product diameter and a too low mechanical strength do not (longer) apply to our prilling process.
We recognize that prilling has its limitation with respect to the maximum prill size, but in our opinion the potential user should realize that the production of a particle size larger than the maximum possible, by installing a granulation plant, will increase his production costs. When a selection has to be made between available granulation technologies, the potential customer should also recognize that the costs of integration with the urea process are of importance for both the consumption figures, especially of steam, and the investment costs of the urea plant.

Annex 1 Case study for fluid bed granulator

Basis bed temperature t_1 = 100 °C, recycle temperature t_2 = 50 °C, ambient air temperature t_g = 25 °C
Recycle ratio R = 0.5, water evaporation rate = 50 kgs/1000 kgs final product, average granule diameter d = 2,5 mm

1 Calculate heat removal (Q_6) in kcal/1000 kgs final product, use fig. 5 — 19.000

2. Calculate air requirement (N) in kg/1000 kgs final product, use Q_6 and fig. 6 — 1.350

3. Calculate design fluidiz. air quantity (N') in kg/h.m² bed area — 5.100
$N' = V_g$ design.3600 ρ_g air V_g design = 1.5 m/s from fig.8
ρ_g air at 100 °C, 1 bar = 0.947 kg/m³

4. Granulation capacity in kg/h.m² bed area = $\frac{N'}{N}$ x 1000 — 3.800

5. Product mass flow kg/h.m² bed area = (R+1) granulation capacity — 5.700

6. Heat removal (Q') in kcal/h.m² bed area = $\frac{\text{granulation cap.}Q6}{1000}$ — 72.200

7. Heat transfer coefficient U_b in kcal/h.°C.m³ bed volume — 42.000
$U_b = \alpha . S = \alpha . 6 \frac{\epsilon}{d}$ α measured: 35 kcal/h.C.m² gran. surface
S spec. gran. surface m²/m³
ϵ bedporosity m³/m³ = 0.5

8.	Bed height h_b in m.	h_b	0.1	0.5	1.0
9.	$U_b' = U_b . h_b$ in kcal/h.°C m² bed area		4200	21000	42000
10.	Required temperature difference in °C = $\frac{Q'}{U_b'}$				
	calc. LMTD	°C	17.2	3.4	1.72
11.	Bed weight kg/m² bed area = $h_b . \epsilon . 1200$		60	300	600
12.	Residence time of granules per m². bed area = $\frac{\text{bed weight}.3600}{\text{product mass flow}}$	sec.	38	189	379

Annex 2 Case study for fluid bed cooler

Basis: As for annex 1. In addition however the bed height = 0.1 m, C_s is the specific heat of the product in Kcal/kg °C = 0.415 (being an average value between C_s = 0.434 at 110 °C and C_s = 0.39 at 50 °C), C_g is the specific heat of the air in kcal/kg °C = 0.24, G_g is the massflow of air in kg/h, G_s is the massflow of product in kg/h.

1. Determine V_g for d = 2.5 from figure 8 m/s 1.5

2. Calculate 'f' where $f = 1 - e - \frac{\alpha . s . h_b}{Vg . \rho g . Cg} = 1 -$ 0.898

3. Calculate $\frac{t1-tg}{t2-tg}$ 3

4. Use the left part of figure 9 to find $\frac{Gg.Cg}{G_s\ Cs}$ on the vertical axis 1.3

5. Use the right part of figure 9 to find the air requirement (Gg') on the horizontal axis, kg/1000 kg throughput 2250

6. Calculate the air requirement kg/1000 kg final product as (R+1) Gg' 3375

7. Find in figure 5 the value of Q_2 kcal/1000 kg final product 30.000

8. Calculate Δtg air (= temperature increase of the air) as follows:

$$\Delta \text{tg air} = \frac{Q2}{(R+1)\ G_g{}'.Cg}$$ °C 37

9. Calculate tg air from chapter 3.2.: tg air = t2-tg+(t1-t2)0.25 °C 37.5

10. Calculate the required bed area for 1000 kg final product/h m² 0.527

$$= \frac{(R+1)Gg'}{Vg.3600.\rho g}$$

Recyclesystem

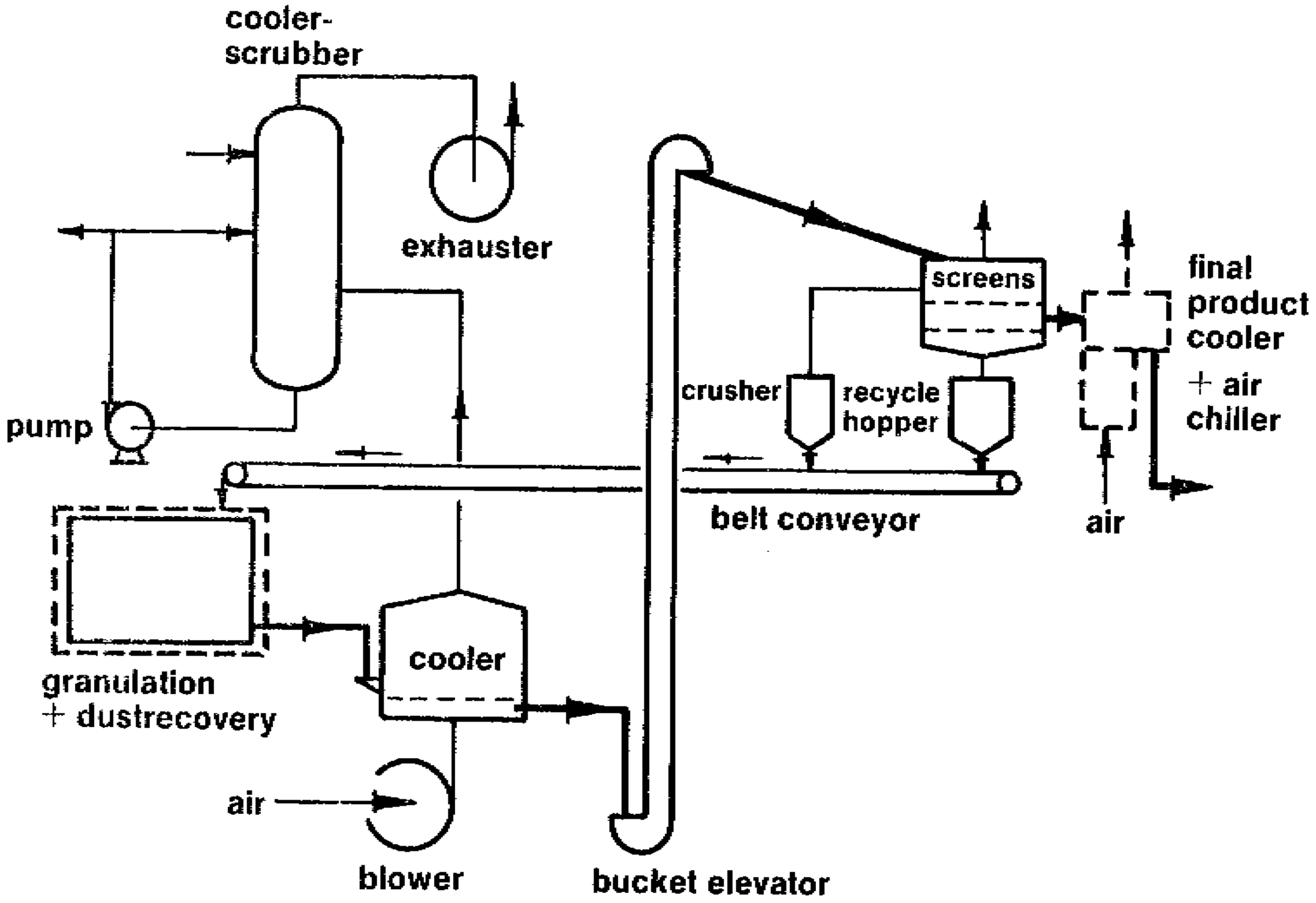


Figure 0

NSM granulator

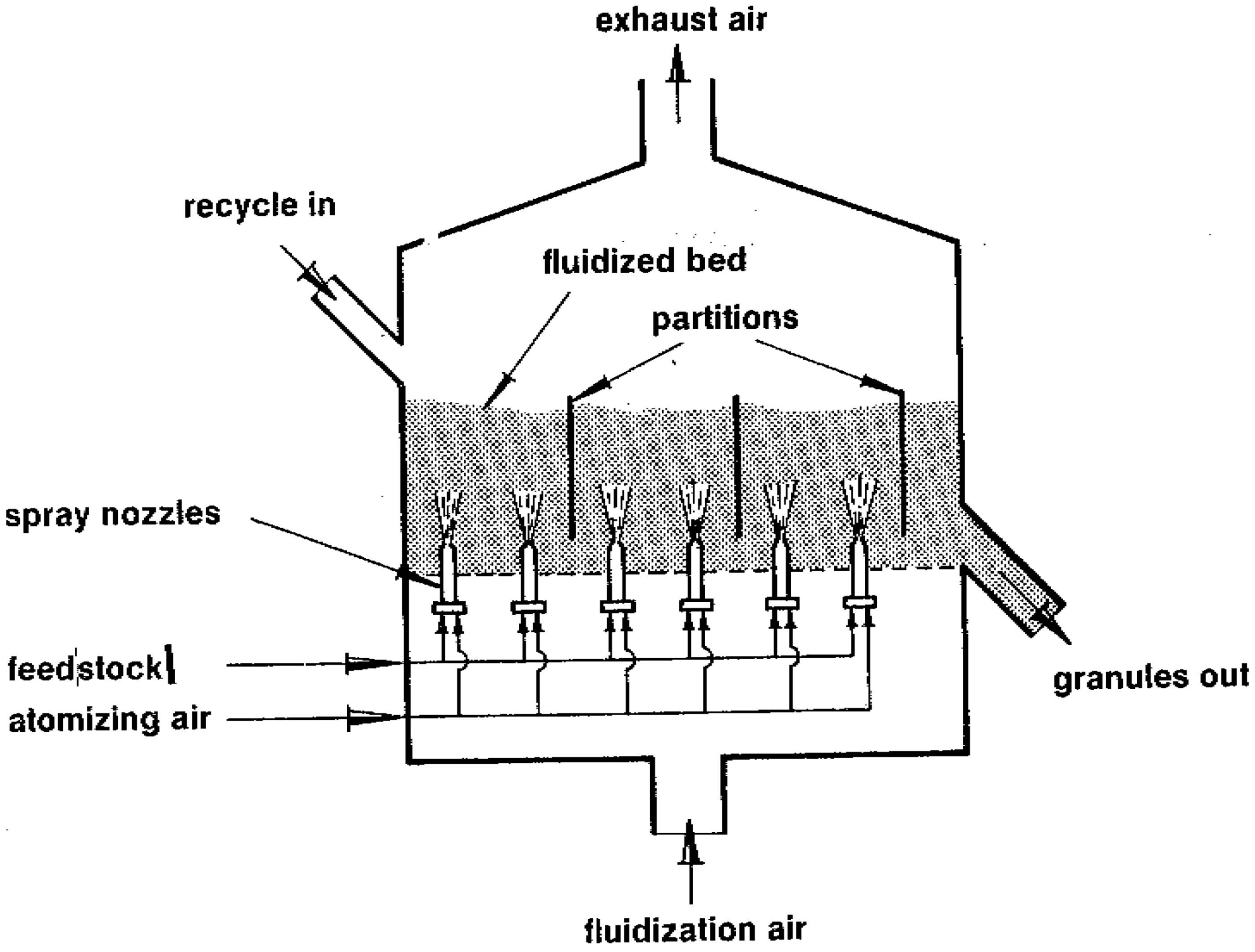
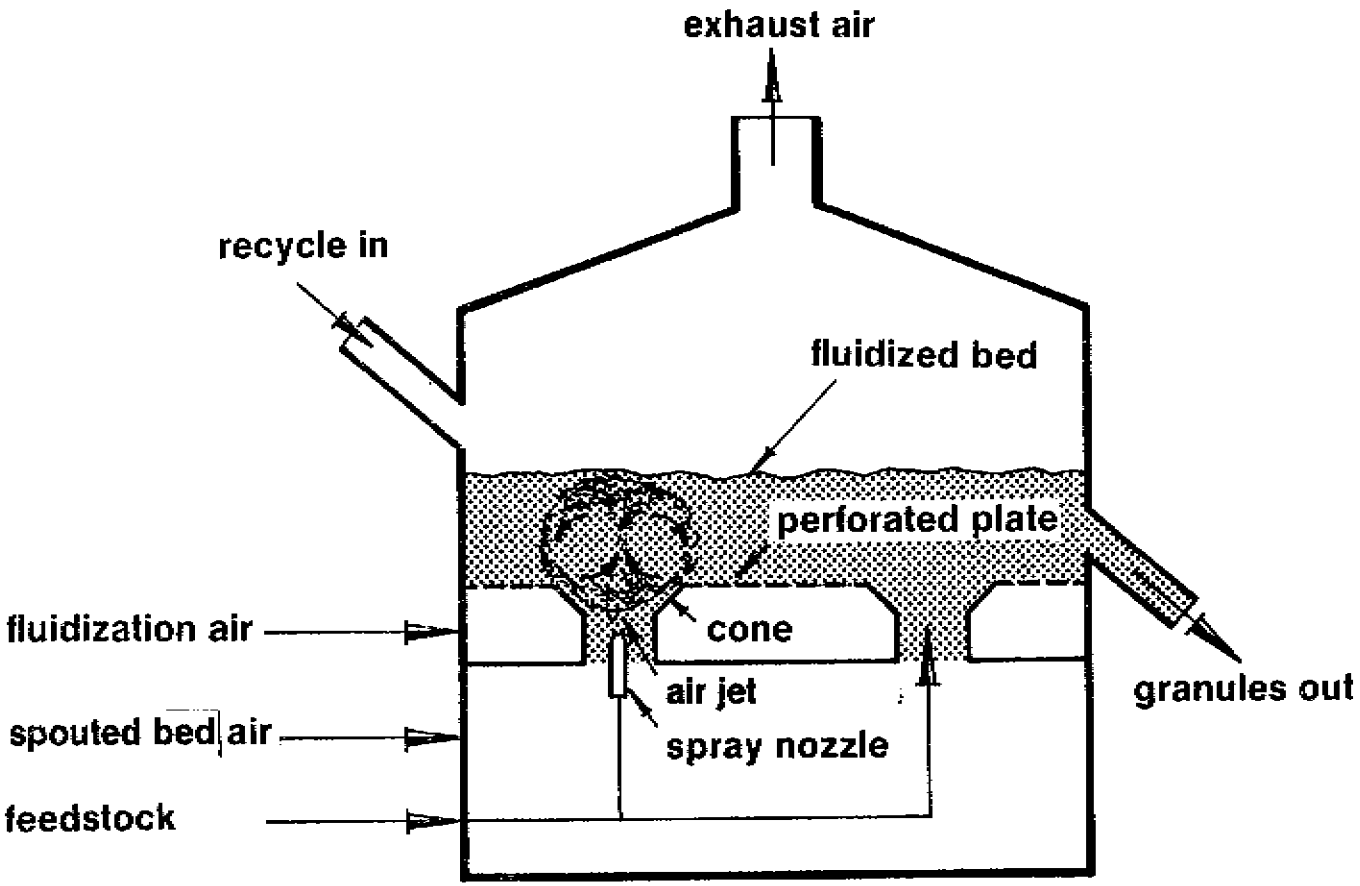
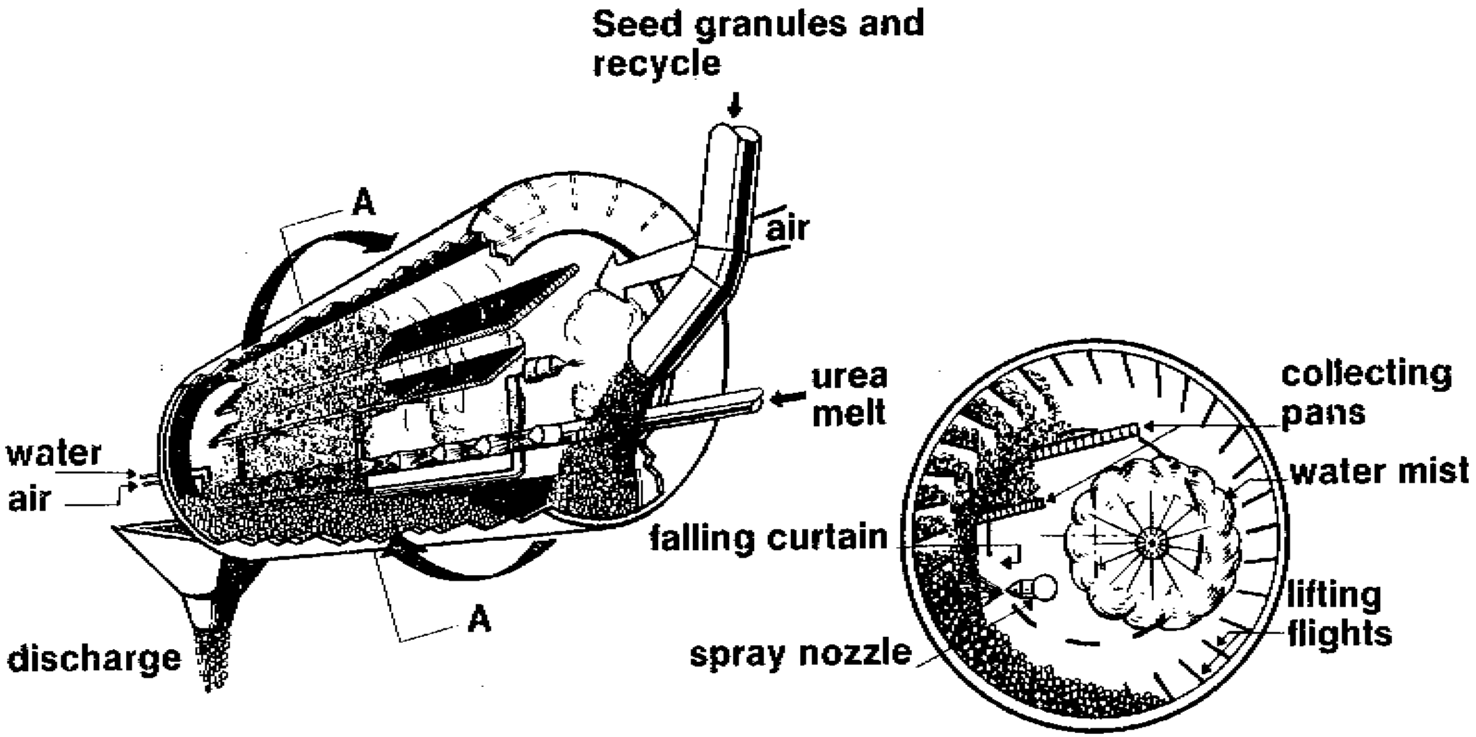


Figure 1

Mitsui Toatsu granulator



TVA granulator



Section A - A

Figure 3

Stamicarbon prilling tower

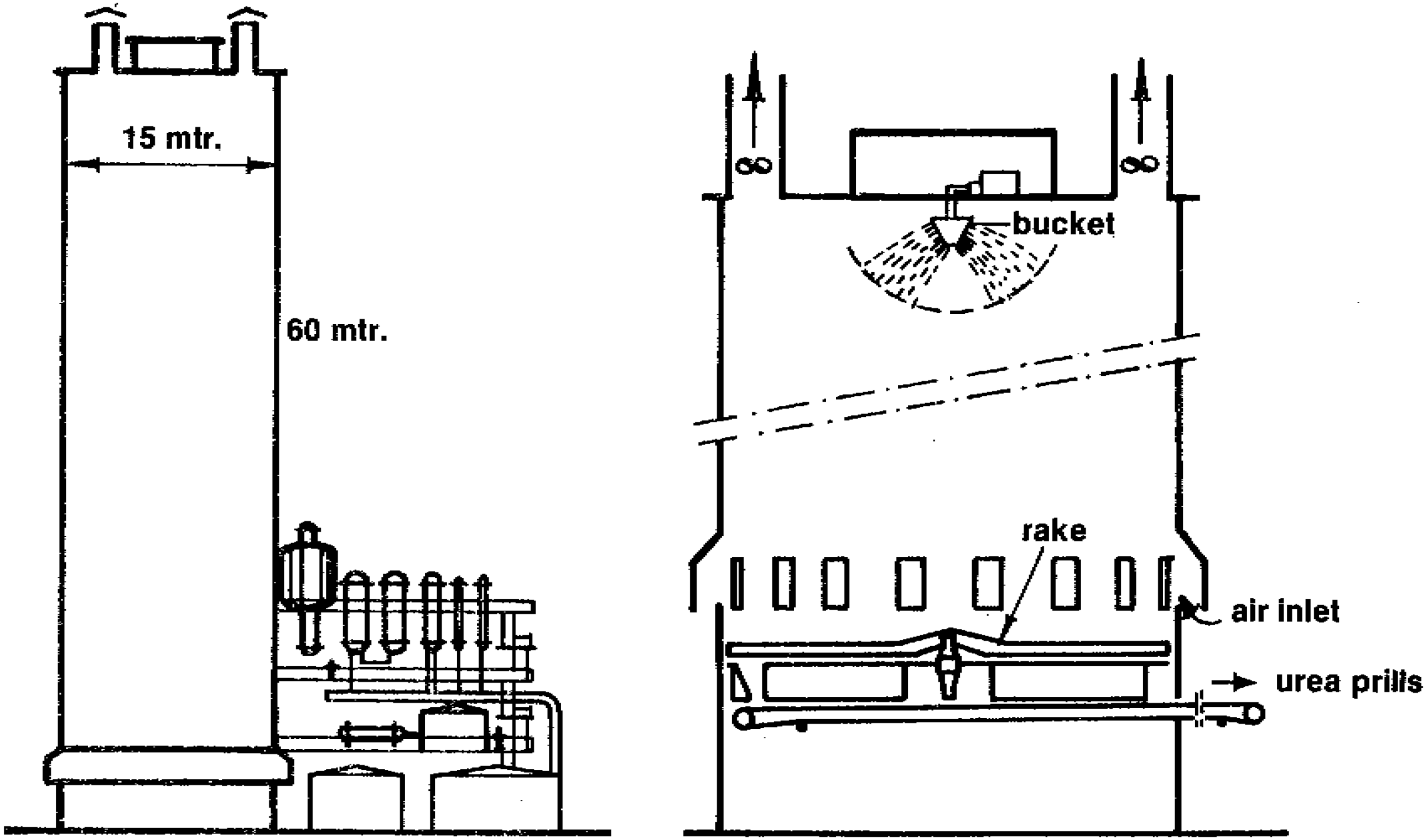


Figure 3a

Enthalphy diagram for urea

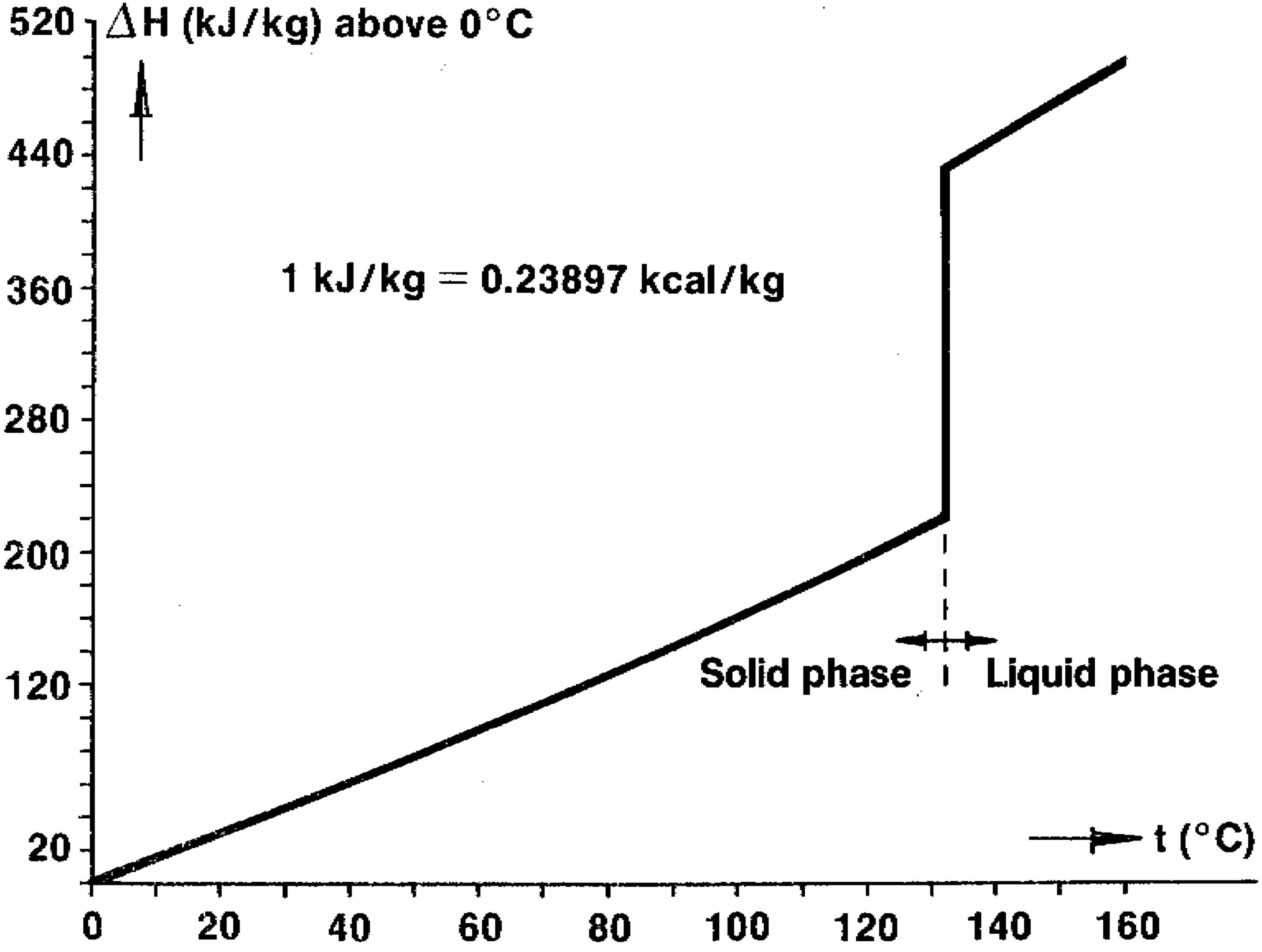
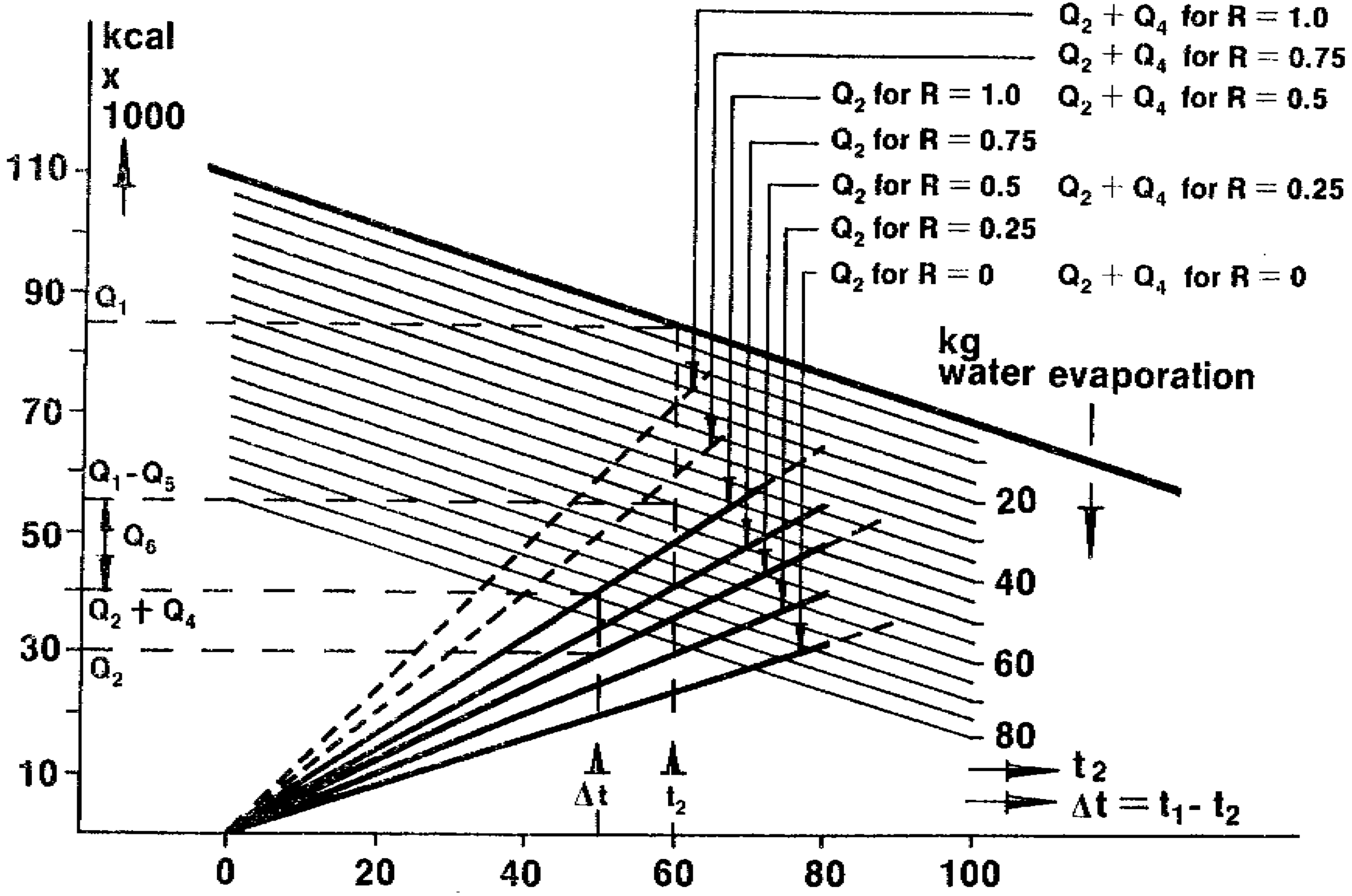


Figure 4

Nomogram for determining heat duties per 1000 kg final product



Kg air required / 1000 kg final product vs. kcal and Δt_{air} °C

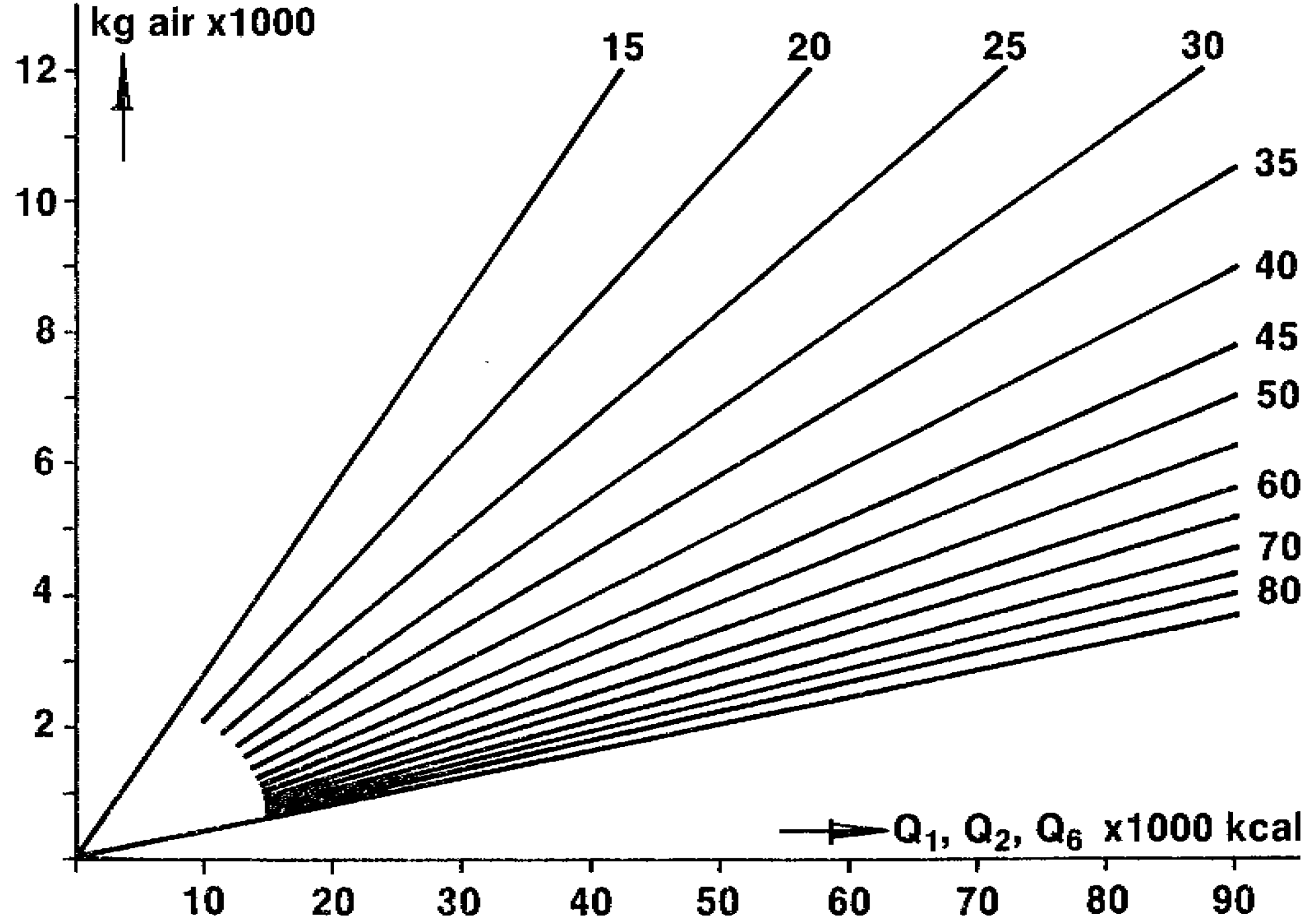


Figure 6

Threshold value of urea particles containing some water

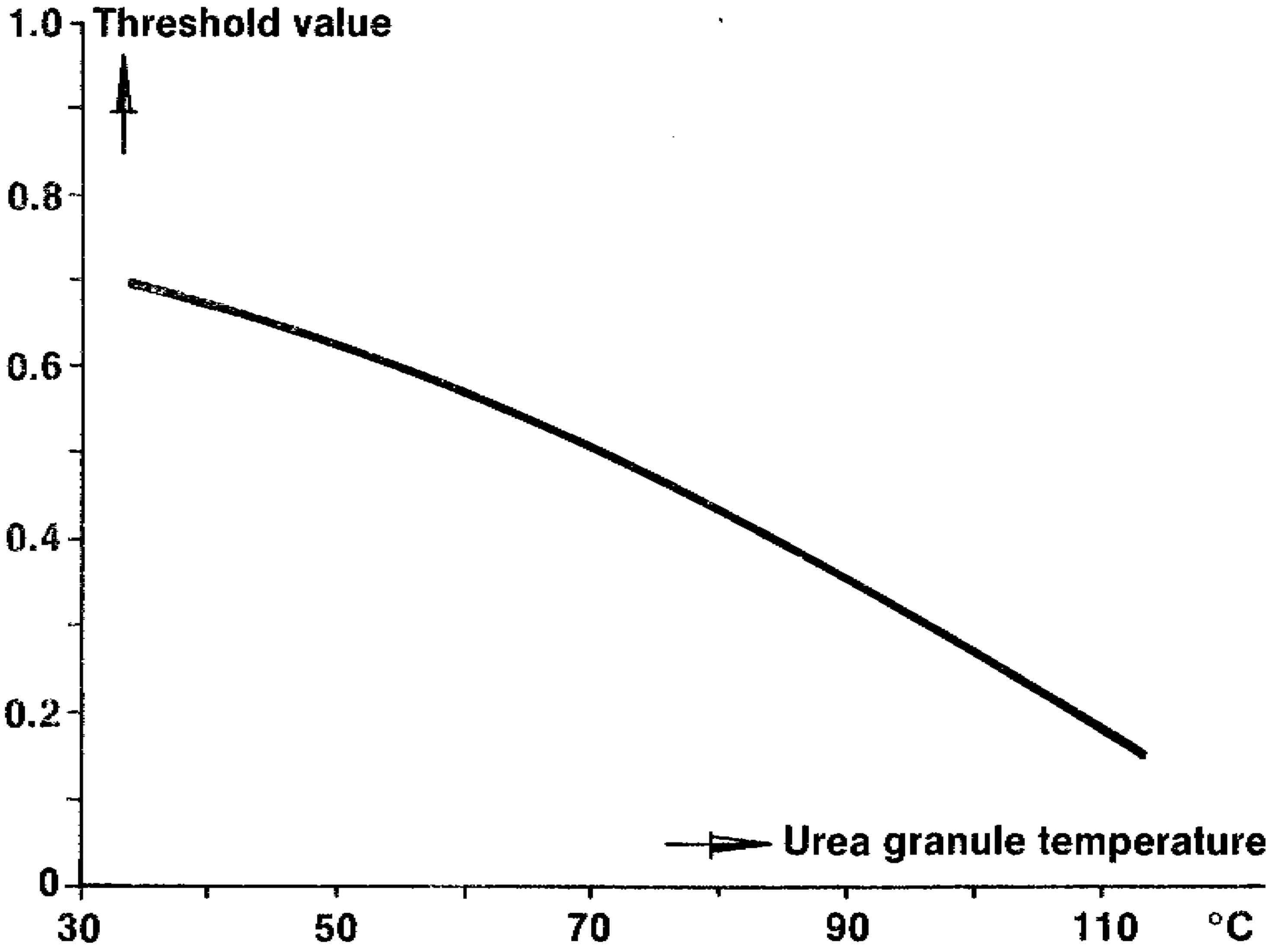


Figure 7

Fluidization velocities versus granule diameter

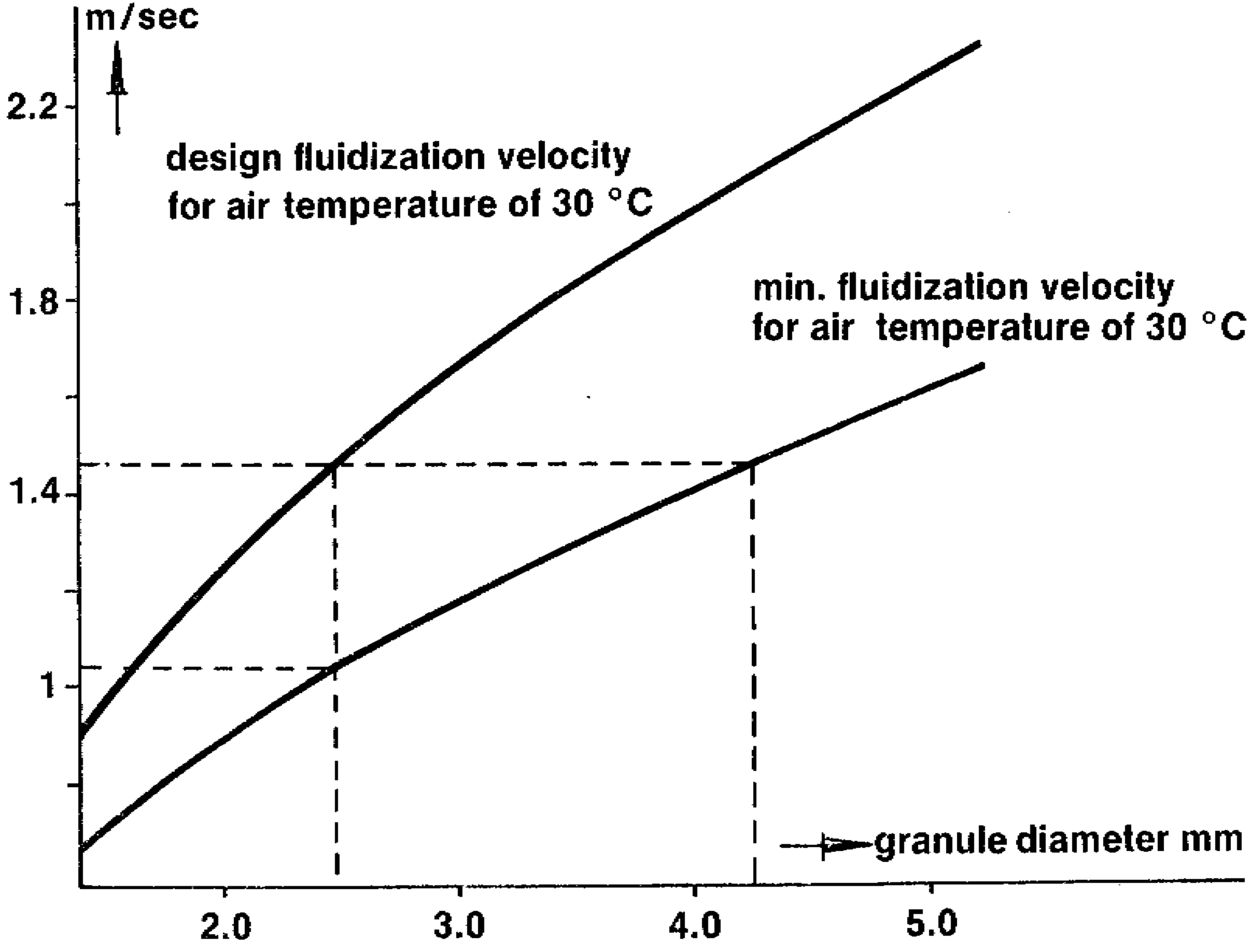


Figure 8

Air requirement of the fluidized bed cooler

kg/per 1000 kg throughput

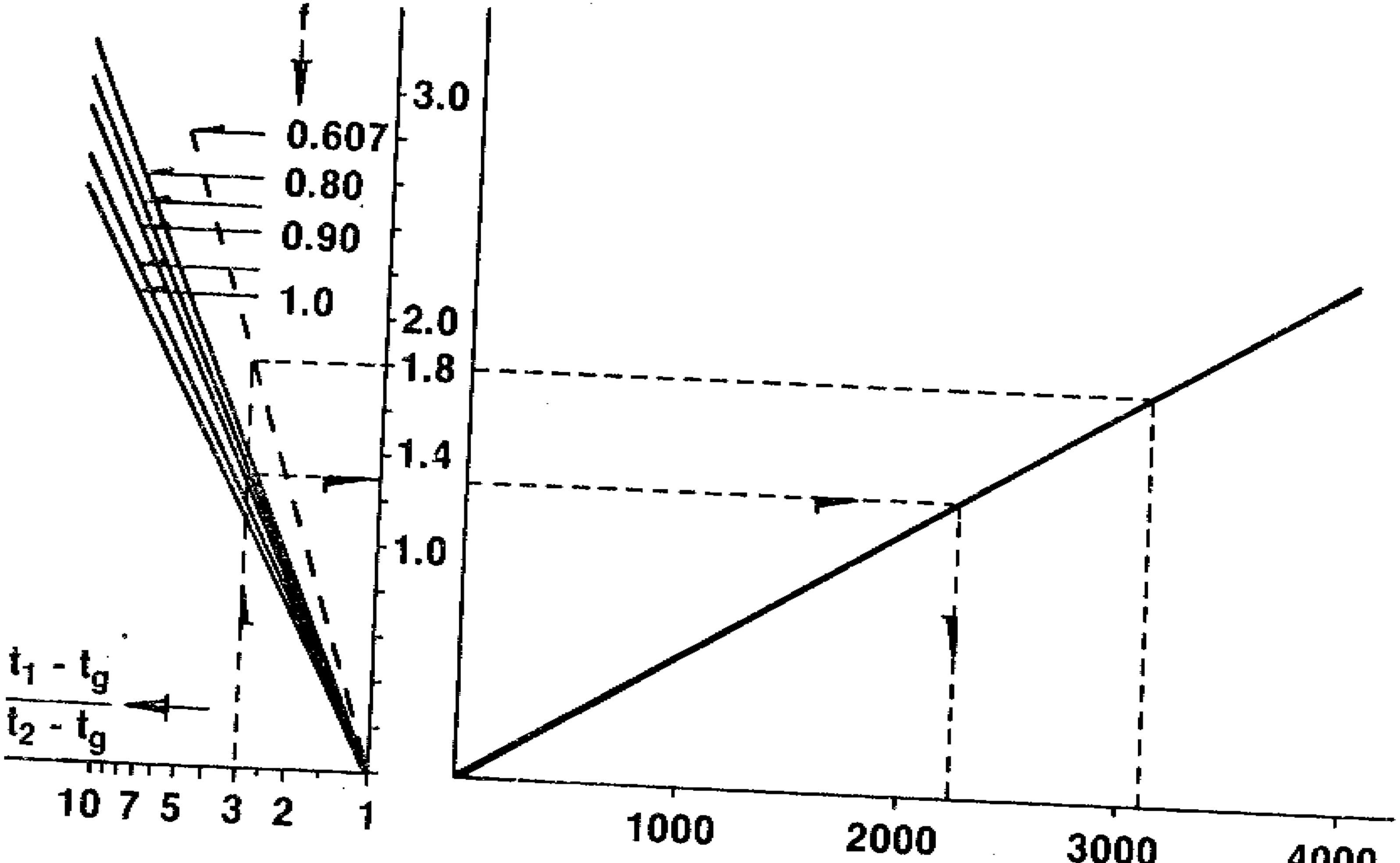


Figure 9

LEGEND FOR FIGURE 9

$$f = 1 - e^{-\frac{\alpha \,.\, s \,.\, h_b}{V_g \,.\, \rho_g \,.\, c_g}}$$ where:

α = 35 kcal/h.°C.m^2 granule surface

s = specific granule surface = $\varepsilon \frac{6\pi d^2}{\pi d^3}$ m^2/m^3

ε = bed porosity m^3/m^3

d = granule diameter m

h_b = bed height m

V_g = design fluidization velocity m/h

ρ_g = air density at 25°C kg/m^3

c_g = specific heat of air 0.24 kcal/kg°C

t_1, t_2 and t_g respectively product inlet and outlet temperature and air inlet temperature °C

G' = (R+1)G = air requirement in kg/1000 of final product

Investments for shaping processes

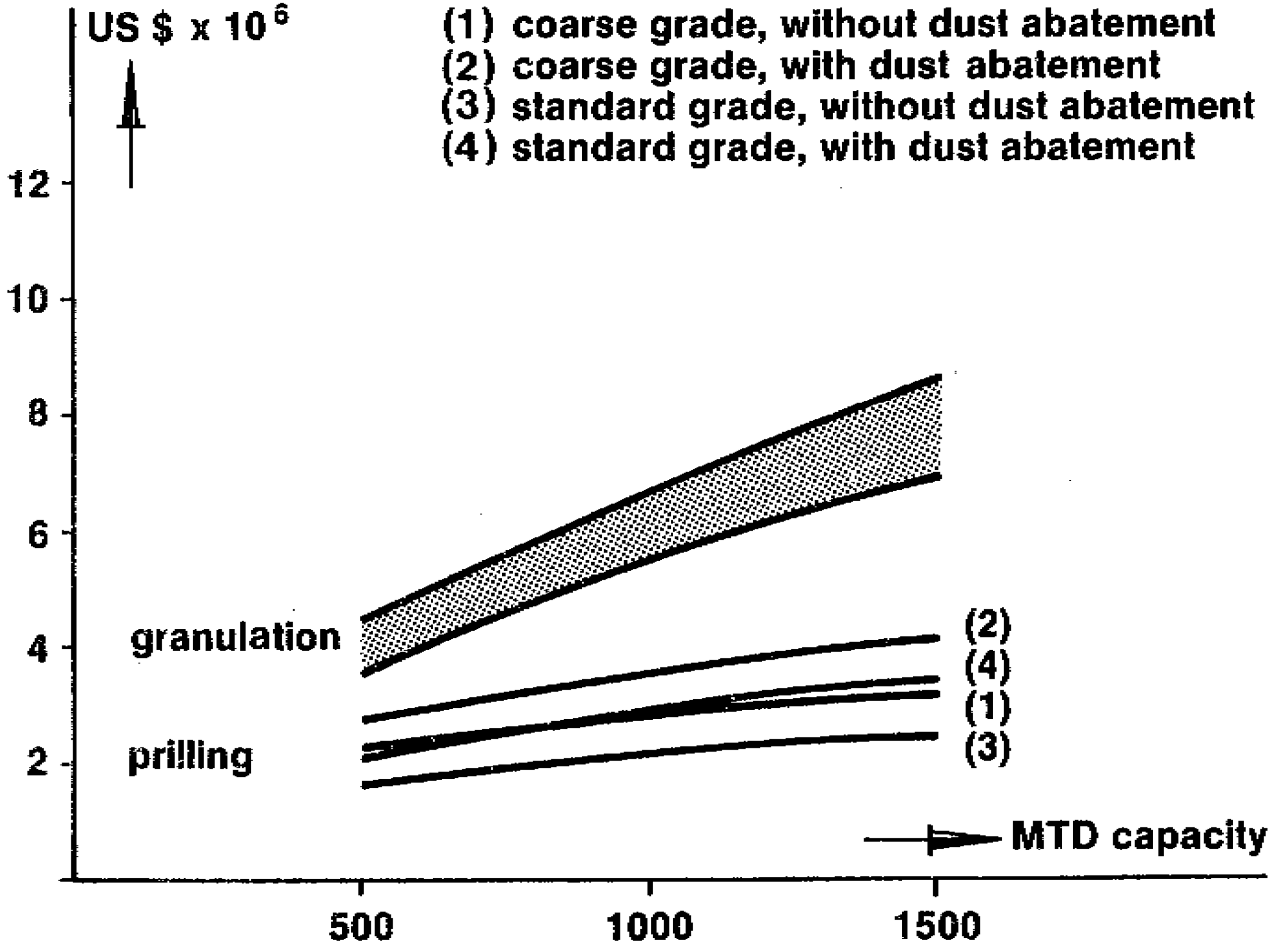


Figure 10

TA/84/10 Prilling or granulation of urea - Some comparative criteria of recently developed granulation technologies and improved air-prilling by F. Kars, Stamicarbon, Netherlands

DISCUSSION: Rapporteur N.D. WARD, Norsk Hydro Fertilizers Ltd, United Kingdom

Q - Mr. K. BELL, ICI PLC, United Kingdom

In your pilot-plant dust scrubbing trials which types of wet scrubbers did you test and which gave the highest removal efficiency?

A - System A: dynamic jet scrubber, developed by Stamicarbon. Use is made of a waterjet and the condensation effect of low pressure steam.

System B: Multex multiventuri dust collector, provided with polypropylene internals.

Q - Mr. S. ORMBERG, Norsk Hydro, Norway

a) Your paper gives a detailed description of all recent urea granulation processes, but not of your "special prilling design of the eighties".

Could you please describe briefly the highlights of this new prilling technique and could you also provide a list of industrial references among the 150 towers presently in operation?

b) How is the extra investment of nearly one million US$, shown in fig. 10, justified by additional equipment items?

A - a) The rotating prilling bucket design was improved to narrow the size range of the product and subsequently enabled us to increase the average prill diameter which also depends on tower height and/or the possibility to install an additional cooler. This design was incorporated in some 20-25 towers. In the mid seventies C.N.C. in Augusta (Ga), USA, requested us to design a tower for an average prill diameter of some 2.2 mm in order to meet the bulkblenders' requirements. After that Stamicarbon never received such a request, though in some prilling towers the average prill diameter is somewhat larger than it used to be in the past.

b) The difference of nearly one million US$ between a prilling system for standard grade and coarse grade product is caused by additional tower height and/or an additional product cooler.

Q - Mr. S.K. MUKHERJEE, FAI, India

What are the special features of "prilling" - <u>if any</u> - against conventional Stamicarbon "prilling process" (direct prilling) on which many commercial plants have been built and with which we are familiar?

A - In both cases direct air prilling is used, however the present rotating bucket design is improved (re my answer to Mr. Ormberg's question): up to some 0.2% formaldehyde is used, seeding is applied to prevent subcooling of the droplets, the prill capacity per m2 crossectional tower area is increased, air velocities are increased, the product temperature exit tower and/or cooler is decreased to some 50-60°C. In some plants dust abatement systems are installed.

Q - Mr. A. MARCHESI, ANIC SpA, Italy

In your paper and in your speech your clearly exposed the advantages and disadvantages of each process and a definitive choice between prills and granules cannot be made. I believe we must give the market what the market really needs and this is the question: What product do you think the market will demand in the near future?

A - The paper identifies some selection criteria and my recommendation is to use these criteria in making a choice between (Stamicarbon) prilling and granulation. However, I also strongly advise to obtain the most recent information (may be partly as guarantees) from the process licensors or from their contractors with respect to these criteria. Local conditions etc. may have an important impact on e.g. investment costs, on stream time, etc... At the end the market demand will determine the product which has to be produced in the plant and I cannot predict that market demand. As my personal opinion I expect a slowly increasing demand for coarse agricultural grade product depending upon the demand for bulkblending and recognising that, for wider spreading of the fertilizers, a large product size is more attractive. I do not expect a strong market growth for feed grade urea, foresty grade urea or super granules.

Q - Dr. B.K. BHATTACHARYA, FAI, India

The cost advantage of some $ 4 per tonne for prilled urea (vs. granulated urea). Since agronomic tests show even a 10% improvement in the efficiency of nitrogen uptake in actual field application, granulated urea might yet be the answer for the future. Has the author any comments?

A - I have collected some information on improvement of nitrogen efficiency of urea when used for wetland rice. I understand that three possibilities exist:

a. deep placement of urea
b. using a coated urea, such as sulphur coated urea (SCU)
c. using inhibitors.

A - a) Tests have been made with supergranules (e.q. IFDC) by placing one supergranule some 10 cm in the soil in between 4 rice plants, and usually the nitrogen efficiency was found to improve. Unfortunately supergranules are more expensive, labour costs for deep placement are high and to obtain farmers acceptance is a problem. Almost the same result was obtained with deep placed urea prills which are cheaper but share the other problems with supergranules. Obviously the secret is deep placement. Though applicators for deep placement of supergranules and prills have been developed, they still seem to be far from ideal.

b) With spread SCU the same nitrogen efficiency improvement was obtained. However again SCU is very expensive. It was hoped that the product costs could be reduced by coating larger granules with less sulphur, but so far only marginal improvements have been found.

c) In many laboratories work is done on inhibitors, however to the best of my knowledge so far without tremendous results. On the other hand when an attractive inhibitor is found, I expect that it can be used for every particle size.

Q - Mr. G. BRUSASCO, Fertimont SpA, Italy

Your paper concludes that prilling requires the lowest investments and yields product at the lowest operating and maintenance cost.

a. Can you explain why the latest plants have been based mainly on granulation and old prilling plants are converted to granulation?

b. Have you tested the bulk-blending behaviour of the prilled product coming out from the patented process in comparison with granular products in order to compare the segregation phenomenas?

A - a. I am only aware of one -non Stamicarbon - prilling plant in Indonesia where, because of poor product quality, a TVA pan granulator has been installed. I have also observed an increasing demand for granulation in new projects, though also prilling is still requested. I like to emphasize that I compared Stamicarbon prilling with granulation and not other prilling technologies.

b. CNC Augusta (Ga), USA sells its coarse agricultural grade product to US bulkblenders and segregation has been found neither in the blends nor during spreading in the field. As long as the average particle diameters and size ranges of the blending materials match, no segregation will occur (re table 4 and TVA studies).

Q - Mr. D. IVELL, Norsk Hydro Fertilizers Ltd, United Kingdom

Does power consumption in table 2 include dust abatement system B? If not what would be the total kWh/tonne for air prilling?

A - Power consumption figures in table 2 include dust abatement system B.

Q - Mr. E. AASUM, Norsk Hydro, Norway

a. Page 14 refers to a prilling tower air exit temperature of 80°C. Is any plant operating at this temperature level and, if not, what considerations have to be taken in design and operation?

b. What would a resulting prilling tower height be for standard agricultural grade?

c. Compared to your patent literature in table 6 you have reduced the amount of air to almost 1/3. How is this reduction obtained?

A - a. In our prilling tower design we limit ourselves to max 80°C exit air temperature and a number of towers are operating at this temperature.

b. The tower height for standard agricultural grade urea with 25°C inlet air temperature, 80°C exit air temperature and a design product temperature of 50°C is about 50 m.

c. The air requirements in table 6 are based on the above design data; it indicates that we optimized our tower design quite considerably.

Q - Mr. F. MOSTAD, Supra, Sweden

Please clarify some figures in table 10.

a. Why is the steam consumption of the TVA evaporative drum granulation process lower than the base case although it starts from a highly concentrated melt (99% - see table 9) similar to the MT spouted bed process?

b. Why is ammonia-evaporation charged to the NSM granulation process, while air drying is not required for this granulation process?

c. Has Stamicarbon established the investment figures for the granulation processes through theoretical cost evaluation or by feed back of effective construction costs?

A - a. In the base case the urea melt is concentrated to 99.7%, for TVA 99% is sufficient. For 99.7% concentration a more sophisticated vacuum system is required in the evaporation steps, which is not required for 99% concentration or lower. It should further be recognized that the data in table 10 are calculated for the integrated situation, not only taking into account feedstock concentration but also dust recycled as a solution.

b. We have not included air conditioning for NSM or others. The ammonia is present in the feedstock. Though a low concentrated feedstock (95% for NSM) reduces the steam consumption as compared to feedstock concentrations of 99% or higher, unfortunately it contains more ammonia than the more concentrated feedstocks. This ammonia is assumed to be lost and not recovered in the scrubbing systems, which can hardly be expected. At the cost of additional investments and utilities the ammonia figure can be lowered, if desired.

c. Our investment figures were estimated by DSM's Estimating Department and later correlated with the estimates made by an engineering contractor.

Q - Mr. K.L. PARKS, Agrico Chemical Company, USA

a. What about fines and lumps? Surely there must be a way to recover this material.

b. What is the influence of the "seed particles" stream on biuret formation, i.e. what is the biuret content of the product with and without "seed particles"?

c. Prilling towers have a bad reputation as dust generators. Can you give comparative results for your process vs prior prilling tower dust emissions?

d. Can the positive effects of formaldehyde, relative to caking, be ignored?

e. Were biuret values calculated or analytically determined?

f. Our experience, prior to 1975, regarding maintenance and operation (bucket plugging, wall coating, dislodged chunks of material falling to tower base, difficulty of rate change, etc...) does not coincide with the author's observations. What operational or design changes have been made to decrease these old problems?

A - a. Very seldom a screening system is installed after the tower. As in most storage sheds, usually screening is installed in the reclaiming system from the storage before shipment, where about 2% of the shipped capacity are recovered and dissolved when feasible in a urea solution before recycling to the evaporation unit.

b. Seed particles do not affect the biuret content of the product.

c. Dust emissions from our prilling towers have been measured also in the past and a figure of 1-1.5 kg/M.T. urea was also found.

d. Formaldehyde certainly has a positive effect relative to caking, and I never ignored that. The amount of formaldehyde required is however depending on the shaping technology, moisture content of final product etc... For prills 0.2% formaldehyde is sufficient.

e. Biuret formation depends upon liquid composition and exposure time at certain temperatures. Because biuret formation in granulation is considered to be negligible, we could partly calculate and determine the biuret contents taking into account for instance the dust recycle from the shaping facility.

f. As far as I know Agrico does not operate a Stamicarbon prilling tower and therefore is referring to difficulties experienced with another prilling technology. I can only discuss and comment our prilling technology.

Q - Mr. T.S. HARIHARAN, Fertil, Abu Dhabi

Locations where high ambient temperatures exist, which is suitable in: prilling or granulation?

A - Both for prilling and granulation a high ambient air temperature makes it difficult to reach a sufficiently low final product temperature unless the final product is cooled in a separate cooler with conditioned air. I have not compared the shaping technologies for high ambient air temperatures, though the paper offers the possibility to calculate air requirements for high ambient air temperatures etc... Offhand I do not anticipate that I have to change my conclusions to the contrary.

Q - Mr. T.P. HIGNETT, IFDC, USA

While you have emphasized lower cost it would be of special interest to estimate the increased value of high quality product. This may be more difficult in developing countries where there is no free market. Farmers have only the choice of using the poor quality "Standard agricultural grade" or nothing. In hot, humid climates there has been much difficulty with losses, and with fine damp, caked material that is either unusable, or difficult to spread evenly. Have the authors tried to estimate the value of the various products?

A - The paper compares product characteristics of Stamicarbon prills with granules from certain granulation technologies. I am very much aware that prills made by some other technologies are inferior to ours. We have been consulted recently by different producers on this problem, and possibly we can at least partly correct their problems. I have tried to fight the bad reputation of prills, I have tried to supply information on our prilled product, and I am certain that this product certainly cannot be considered as "poor quality" standard agricultural grade urea.

Q - Mr. E. HOLTE, Norsk Hydro, Norway

On page 8 the author states that only TVA Fallen Curtain has produced Urea Supergranules (USG).
Norsk Hydro has since 1979-80 supplied most of the USG utilized in the research and testing done both by IFDC, IRRI and FAO. The USG is produced in the NH-High Temperature pan granulation process. The recycle ratio in this process is about 3:1, not 7:1.

A - I am aware that Norsk Hydro has produced supergranulaes in their pan granulator; however, I made it clear in the beginning which processes I would compare and Norsk Hydro was not part of that list. Yes, I apologize for not having mentioned your ability to make supergranules.