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**In 1982, the name of the International Superphosphate Manufacturers' Associations (ISMA) was changed to International Fertilizer Industry Association (IFA).*

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COMPARISON BETWEEN BULK AND PALLET STORAGE IN A NEW STRAIGHT AND COMPOUND FERTILIZER PLANT

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1. Preliminary considerations

Whenever bulk and pallet systems are compared, there are often opinions based on particular criteria or experiences which can never result in a clear understanding of the problem.

Introducing this paper, we want to leave out particular cases and stick to general results with concrete applications.

It has been possible to establish a systematic method which led to a general analysis. We took as a basis the costs and we considered details only for the cost items which differed from one system to another. For instance we took account of the cost of labour since it was different but not of laboratory expenses which do not depend on the system adopted.

We considered the following cost items :

- Characteristic amortization of each system
- Characteristic maintenance of each system
- Labour
- Fuel and lubricants
- Electricity

and we omitted

- Common amortization to both systems
- Common maintenance to both systems
- General expenses
- Expenses to be apportioned
- Miscellaneous
- Laboratory costs
- Other less important items without any influence on the final cost results, as maintenance products, etc...

We called :

$$y = \text{total cost}$$
$$y_1 = \text{characteristic amortization cost}$$
$$y_2 = \text{characteristic actual cost}$$
$$y_3 = \text{costs common to both systems}$$

so that :

$$y = y_1 + y_2 + y_3$$

and we based our analysis on the formulae :

$$y - y_3 = y_1 + y_2$$

The final formulae are given as an appendix. In the following text we shall only give formulae, define parameters, represent them graphically and interpret results.

2. Parameters

Some of the parameters involved in the formulae, although they change costs according to the importance they have ; however, have the same importance irrespective of the design of the projected plant ; for instance, the cost of a pay-loader. However, others determine the structure of the plant, necessarily dependent on the market, such as : number and range of products, annual output and method of delivery.

Finally, other parameters depend on economic factors such as the number and size of production and bagging plants.

We believe that the logical development of a new project is : first to know the basic parameters and the amounts to be produced, the number of products and the market demand ; then to look for the best way of reaching the objectives by combining the technical means available and selecting the most economical ones, considering the actual prices or, if necessary, the future ones.

The objectives and prices usually depend on external conditions and we can only act by deciding the means to reach these objectives.

Although we only defined general formulae, in which all parameters are independent (see appendix), for the final presentation of the paper we fixed price parameters which have not been updated. The parameters which determine the means available to reach the objectives were also fixed but we have achieved the analysis and studies which we considered appropriate in each case and which can also be examined in the appendix.

In this way, we could establish that, in the plant, we would need more than one production unit since the variety of products would necessarily be wide and important ; further, since the total production considered for satisfactory results can reach 600,000 t/year, we believe that the output of each unit should be around 500 t/d.

The same applies to conditioning units which we fixed at 30 t/hr for bulk and 60 t/hr for pallets. A more detailed appraisal of this decision can be found in the appendix.

Two parameters in this group were considered more specifically, i.e. the minimum number of days of continuous production of the same product in the case of bulk and the number of days when the product should be stored before bagging and palletization with the conclusion that, because of their influence on the cost, in particular the number of days of continuous production, the smallest number of days should be adopted; provided we can guarantee the products obtained are of a good average quality, we estimate that this number is seven.

The parameters which define the production objectives : number of products and importance of the seasonal sales variations, were left completely variable so as to study their effect on costs.

We have omitted other cost factors which affect the total cost such as manufacturing costs, but we have studied the effects of the cost of storage.

3. Storage capacity

To analyse the characteristic amortization, we must know the investments and, thus, the storage capacity needed. This was studied in appendices 1, 2 and 3 for bulk and in appendix 5 for pallets, so that we arrived at the following formulae :

Bulk system :

$$\text{for } X < \frac{C.d.n.}{2.r.} \qquad A = C.d.n.$$

$$\text{for } X < \frac{C.d.n.}{2.r.} \qquad A = r.X + \frac{1}{2} + C.d.n.$$

(See the list of signs used at the end of the text).

Considering C = 500 t/d for the average capacity of each plant and 7 days minimum continuous production of one product, in fig.1 the variation of storage capacity was given for the bulk system.

$$X < 1,750 \frac{n}{r} \; ; \qquad A = 3,500\, n$$

$$X < 1,750 \frac{n}{r} \; ; \qquad A = r.X + 1,750\, n$$

in which we see that, when deliveries are not seasonal (r = 0), for each product we need 3,500 t storage capacity, and, as fertilizer season " intensity" grows (r increasing) the necessary storage capacity increases in relation to the change in the value of "r".

In appendix 1 the seasonal intensity aspect was analysed.

The value $X = \frac{C.d.n.}{2.r}$ gives the point where the amount to be stored for the foreseeable seasons exceeds the amount necessary to ensure continuous production.

As can be seen, parameters n and r have a decisive influence on the storage capacity and, hence on investments and costs. The following equations give the storage requirement of a pallet system as compared to a bulk system.

For bulk storage : $A_G = \frac{d'.X}{100}$

For pallet storage : $A_p = r.X - \frac{2}{3} . \frac{d'.X}{100}$

in which d' is the number of days when the product must mature before bagging (d' = 7 d) :

$$A_G = 0.07.\, X \; ; \; A_p = (r - 0.0466) \; ; \; X$$

which, as can be seen, is not related to the number of products.

4. Amortizations

The share of characteristic amortization is given by the following formulae :

Bulk system :

$X < 1,750 \frac{n}{r}$; $y_1 = \frac{1}{X}$ (n. 110,560.32 - 1,930.5) + r.66.632 + 6.66632

$X > 1,750 \frac{n}{r}$; $y_1 = \frac{1}{X}$ (n. 57,713.82 - 1,930.5) + r.96.8192 - 6.6632

Pallet system :

$$y_1 = - \frac{1,930.5}{X} \times r. \; 126.267 + 8.3547$$

These formulae are represented by parabola asymptotic to the y_1 y axis in which r = 66.632 + 6.6632 ; r = 96.8192 + 6.6632 and r = 126.267 + 8.35 respectively.

The graphical representation is illustrated in figure 2 which shows that the higher the "r" value the more expensive the corresponding amortization for the pallet system as compared to the bulk system. However, for a given "r" value, the characteristic amortization of the pallet system varies less unfavourably than for the bulk system when the number of products made increases.

The intersection points of the parabola for the pallet system and the series of parabola for the bulk system are those of equal characteristic amortization cost. They can be obtained analytically by making cost values equal. As we want them to intersect each other always in the area corresponding to $X < 1,750 \frac{n}{r}$ the equation which limits the zone where one system or the other is suitable is (when referring only to characteristic amortization).

$$r = 0.411 + \frac{12,665.87 - n. \; 4,607.7384}{X}$$

which, when represented on the X, r plane of figure 3, gives a parabola for each n value. The area above each parabola is that of higher costs of amortization for pallets and the area underneath each curve a higher cost for bulk systems. The parabola itself represents the line of similar amortization costs for each system.

5. Costs

Appendix B also gives the <u>characteristic actual costs</u> according to the equations :

In the bulk system :

$$X \quad 1.750 \, \frac{n}{r} \; ; \; y_2 = \frac{1}{X} \, (n. \, 45,127.79 - 603) + r.225,7632 + 22.5761$$

$$X \quad 1.750 \, \frac{n}{r} \; ; \; y_2 = \frac{1}{X} \, (n. \, 23,519.14 - 643.5) + r.238.11 + 22.5761$$

In the pallet system :

$$y_2 = \frac{427,356.6}{X} + r. \, 132.3398 + 34.7733$$

As in the case of amortization, the formulae were represented on figure 4, also giving a series of parabola for each "r" value.

Contrary to what happened in the case of amortization, it appears that the actual characteristic cost of the pallet system decreases as compared to that of the bulk system when the "r" value increases and then becomes more favourable when the number of products increases.

We have seen therefore :

For a higher number of products, the amortization cost is <u>less unfavourable</u> for the pallet system than for the bulk system and the actual costs are more favourable for pallets. This occurs for specific "r" values. When "r" increases, e.g.when fertilizer seasons become intensive, the pallet system is also <u>favourable</u> from an actual cost system viewpoint and <u>less favourable</u> from an amortization viewpoint.

This is quite logical if one understands that the number of products has no great influence, in the bulk system, but that the intensity of seasonal selling has an influence in both systems of storage.

6. Total costs

The addition $y_1 + y_2$ (characteristic amortization costs + characteristic actual costs) results in the total characteristic cost with the following formulae :

Bulk system :

$$X < 1{,}750\ \frac{n}{r}\ ;\quad y-y_3 = \frac{1}{X}(n.155{,}688.11-2{,}533.5) + r.292.3952 + 29.2393$$

$$X > 1{,}750\ \frac{n}{r}\ ;\quad y-y_3 = \frac{1}{X}(n.81{,}232.96 - 2{,}574) + r.334.9292 + 29.2393$$

Pallet system :

$$y-y_3 = \frac{425{,}426}{X} + r.258.6068 + 43.128$$

which, as usual, are represented on table 5 which are series of parabola for each "r" value and very more favourably in the case of pallets when "r" increases.

It is worth stressing the influence of the parameters "n" and "r". While the number of products keeps things equal in the comparison with the pallet system, "r" changes substantially the relative position of the parabola of characteristic costs for the pallet system as compared to the bulk system, from a clearly unfavourable position when r = 0.1 to a lower cost than in the bulk system when r = 0.2.

It can be seen that while "r" influences the cost difference proportional to the value of "r", the number of products produces a steady variation of the difference for each "n" value".

An example should clarify the above statements. Let us consider the case of a factory producing 300,000 t/year. The difference in costs between the two systems will be given by the general formulae :

$$X < 1{,}750\ \frac{n}{r}\ ;\ \Delta(y-y_3) = \frac{1}{X}(n.155{,}688.11 - 427{,}959.5) + r.33{,}7884 - 13.888$$

$$X > 1{,}750\ \frac{n}{r}\ ;\ \Delta(y-y_3) = \frac{1}{X}(n.81{,}232.96 - 428{,}000) + r.76.3223 - 13.8887$$

If X is given the number 300 000 :

$$X < 1{,}750\ \frac{n}{r}\ ;\ \Delta(y-y_3) = (n.0.51896 - 15.3152) + r.33.7884$$

$$X > 1{,}750\ \frac{n}{r}\ ;\ \Delta(y-y_3) = (n.0.27 - 15.3153) + r.76.3224$$

The plane representation $[\Delta(y-y_3),\ r]$ gives series of parallel straight lines whose values at origin is (n.0.51896 - 15.3182) or (n.0.27 - 15.3153) respectively, the slope being 33.7884 or 76.3224.

This is represented in figure 6 which shows clearly that the influence of "r" is much higher than of "n".

Considering that the logical range of variation of the "n" value lies between 1 and 20 and that the seasonal feature of fertilizer sales since it is a fertilizer market, is between 10 % and 20 % of total annual deliveries, e.g. $0.1 < r < 0.2$, it appears, when looking at figure 5, that cost differences are not very large.

7. Equal cost curves

In such a way a graph can be drawn (figure n° 7) giving <u>curves of equal cost</u> for pallets and bulk just by making the respective formulae of the resulting characteristic cost equal, which gives the formulae :

$$\text{For } X < 1{,}750 \frac{n}{r} \; ; \; r = 0.411 + \frac{12{,}665.87 - n.\ 4607.7384}{X}$$

$$\text{For } X < 1{,}750 \frac{n}{r} \; ; \; r = 0.1819 + \frac{5{,}607.79 - \; ; \; 1{,}064.3396}{X}$$

and which, on a graph limits the areas where one system is favourable or the other.

Thus, on the abscissae are the "X" values or the annual production of the factory and, on the ordinates, increasing "r" values or the intensity of delivery seasons and, for each "n" value, the number of products made by the factory, we shall have a curve above which the pallet system has the lower cost and below which the bulk system has the lower cost.

Let us consider the way to use that graph with an example which could also serve to show how circumstances can vary.

Assuming a factory with an initial production of 170,000 t/y which produced only five products (21 % A.S., 20.5 % A.N., 26 % A.N., 7-12-7 and 10-10-10) and with a seasonal variation of deliveries of 15.7 %, by putting point ($X = 170\ 000$, $r = 0.157$) in the plane and looking for the curve corresponding to the five products, ($n = 5$), we find that the point is below the curve, in an area where the bulk system is less costly.

At present, this plant makes 18 products with an annual output of 400,000 t and a seasonal variation of 18.6 %. By introducing in the plane point ($X = 400.000$ $r = 0.186$) and by comparing with the curve $n = 18$, we can see that the point is located above the curve, which indicates that the pallet system is preferable from an economic viewpoint.

8. Investments

Since cost differences are not very large, for financial reasons, the system might be chosen on the basis of investments but, after thorough investigation, it appears that differences in initial investments are not very large either. Indeed, appendix 8 gives formulae showing investments, which should be deducted, resulting in the difference between one system and the other. If coefficients are calculated on a peseta basis, the formulae are :

For $r < 1{,}750 \frac{n}{r}$; $\Delta I = + 188.955.r - 2.525.n + 29.1376$

For $r > 1{,}750 \frac{n}{r}$; $\Delta I = + 16.764.r - 1.325.n + 29.1376$

Figure 8 shows indeed that, considering the state of the fertilizer market, a large number of products is needed("n" between 10 and 20).

Considering that the output of each production unit was 500 t/d the figures apply to an "X" value equal to or higher than 150,000 t/y.

9. Technical advantages

Since differences are not very large either from investment or from cost viewpoint, the selection of one system would largely be based on the technical advantages specific to each concrete case and there the pallet system has a favourable position. Here are a few advantages of this system :

1. - A better use of the storage area without any need to reserve space for each product

2. - A better use of the bagging plants either at a given moment (daily variations) or for a season (seasonal variations).

3. - A better use of labour for the same reason as above

4. - Deliveries are more reliable for the following reasons :

   a) Bagging plant breakdowns do not affect deliveries

   b) At a given moment, almost instantly, a number of loading points could be available, irrespective of the number of bagging plants.

c) The complicated control system of vehicles in relation to the product to be loaded is not necessary.

d) There is no difference in the waiting time for different products which, in the case of the bulk system are loaded at different points.

e) Vehicles loading different products need not have two or three collection times.

5. - The risk of mixing different formulations is avoided since each formulation is bagged continuously.

6. - For the same reason, possible errors when feeding the bagging plant with a given product are avoided.

7. - It is possible to control production precisely since each batch is weighed before bagging without any mixture with the previous batch of the same product.

However, the bulk system has the advantage that, as products are checked at the time of delivery, less time is necessary for conditioning and there is a lesser risk of caking so that the customer gets higher quality products.

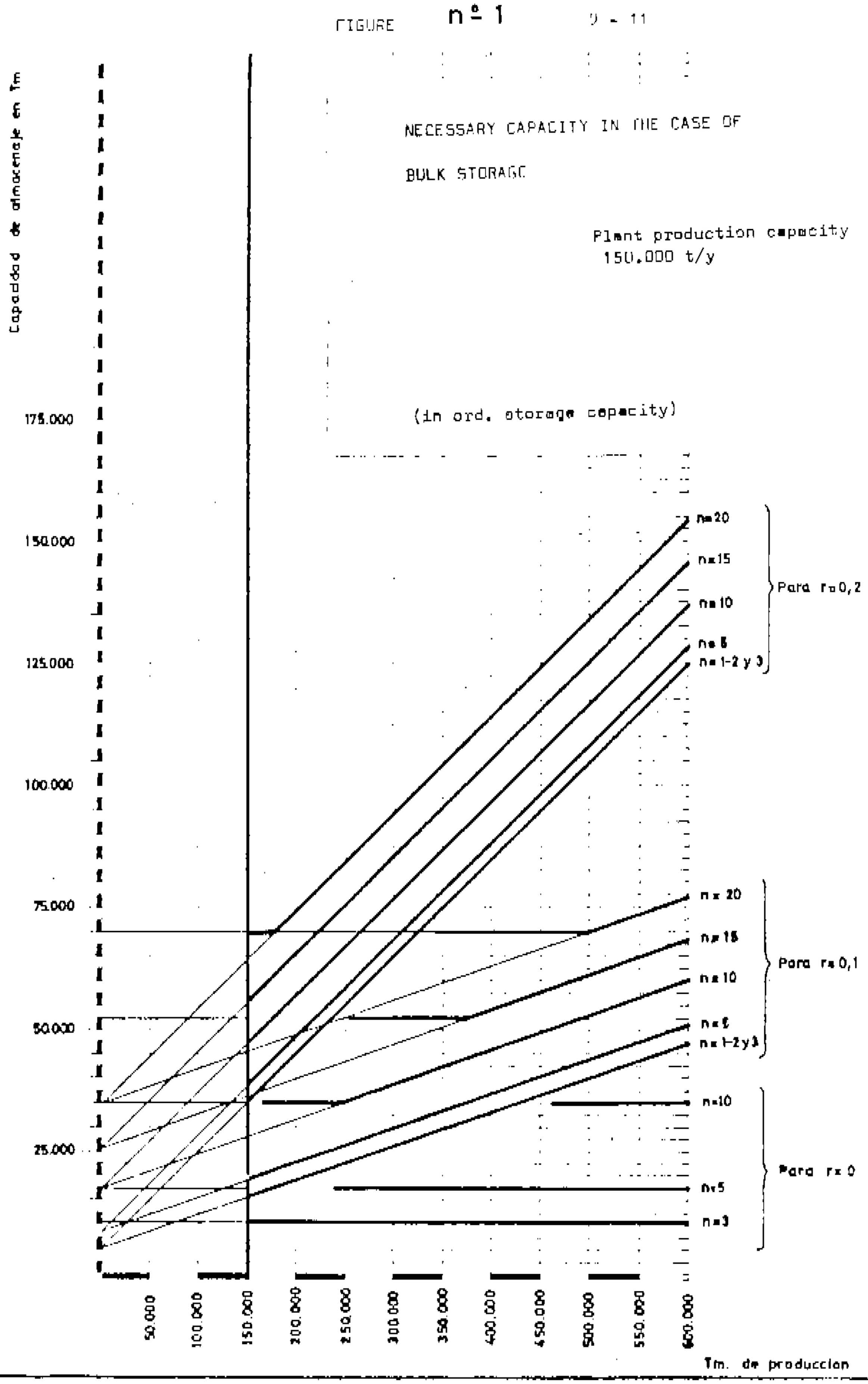


FIGURE n° 1 9 - 11
NECESSARY CAPACITY IN THE CASE OF
BULK STORAGE
Plant production capacity
150.000 t/y
(in ord. storage capacity)
Capacidad de almacenaje en Tm
175.000
150.000
125.000
100.000
75.000
50.000
25.000
n=20
n=15
n=10
n=5
n=1-2 y 3
Para r=0,2
n=20
n=15
n=10
n=5
n=1-2 y 3
Para r=0,1
n=10
n=5
n=3
Para r=0
50.000
100.000
150.000
200.000
250.000
300.000
350.000
400.000
450.000
500.000
550.000
600.000
Tm. de produccion

FIGURE nº 2 9 - 12

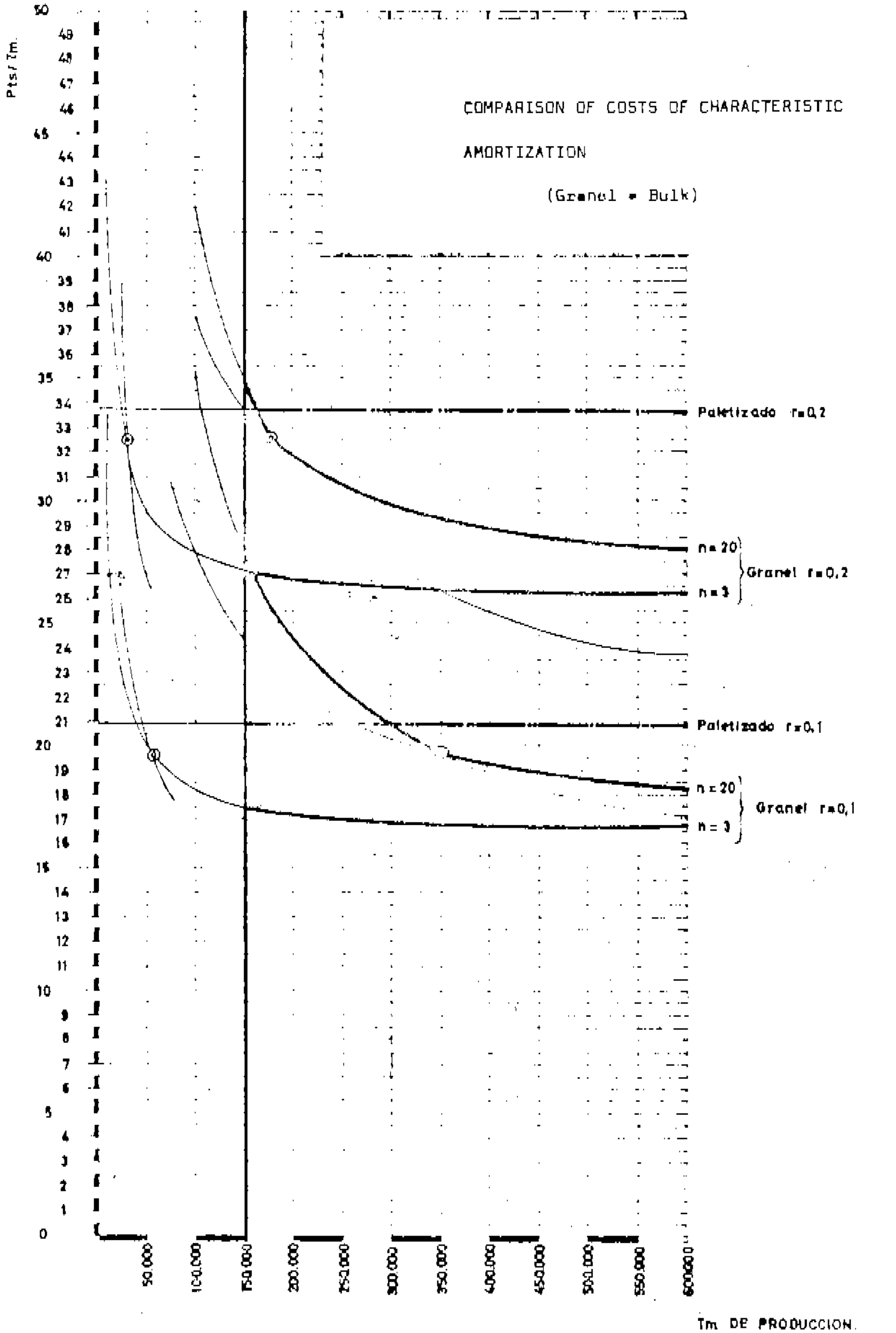


FIGURE I nº 3

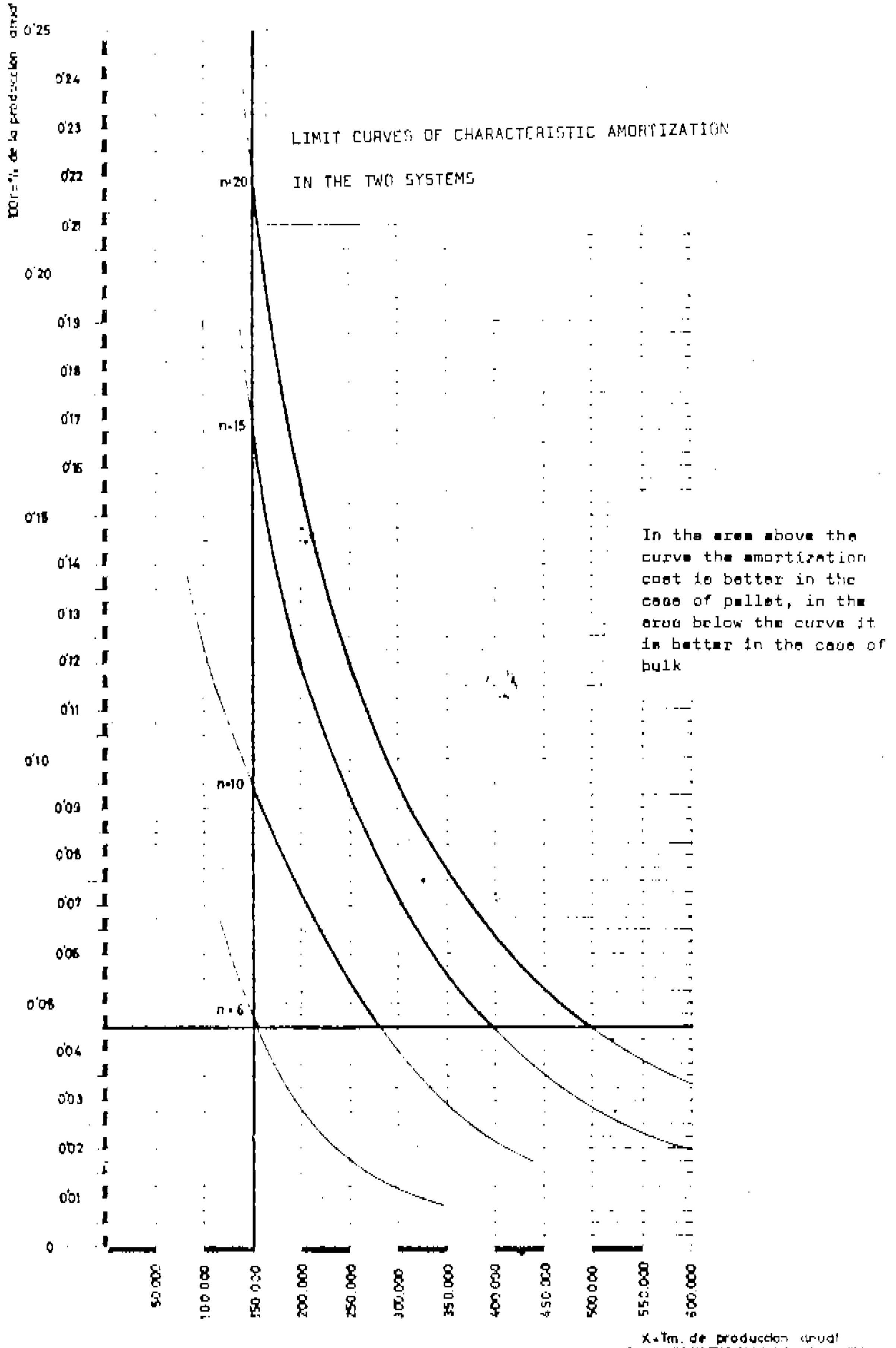

LIMIT CURVES OF CHARACTERISTIC AMORTIZATION
IN THE TWO SYSTEMS
In the area above the curve the amortization cost is better in the case of pallet, in the area below the curve it is better in the case of bulk
n=20
n=15
n=10
n=6
0'25
0'24
0'23
0'22
0'21
0'20
0'19
0'18
0'17
0'16
0'15
0'14
0'13
0'12
0'11
0'10
0'09
0'08
0'07
0'06
0'05
0'04
0'03
0'02
0'01
0
50.000
100.000
150.000
200.000
250.000
300.000
350.000
400.000
450.000
500.000
550.000
600.000
X=Tm. de produccion anual

FIGURE 1 nº 4

9 - 14

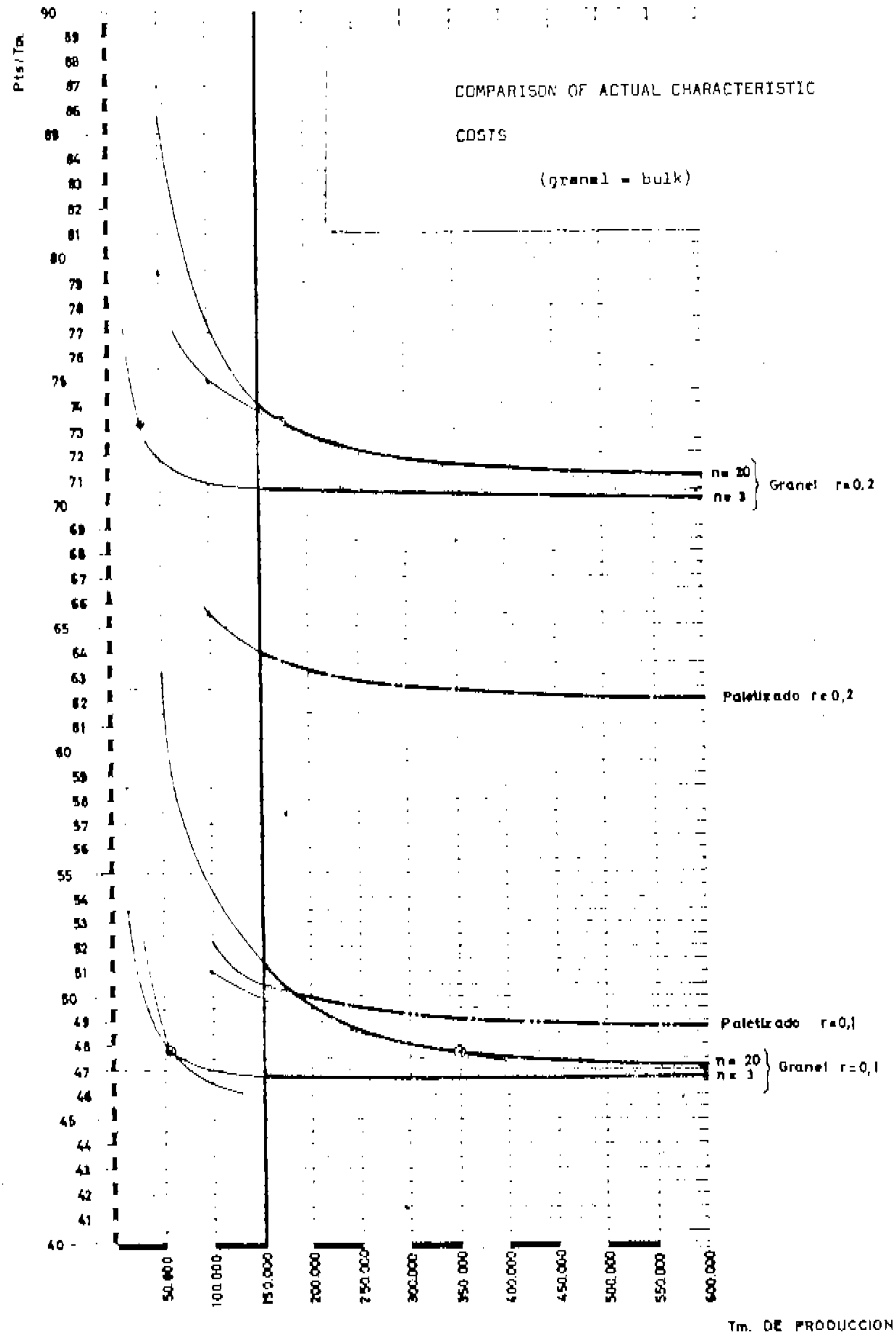


FIGURE n° 5 9 - 15

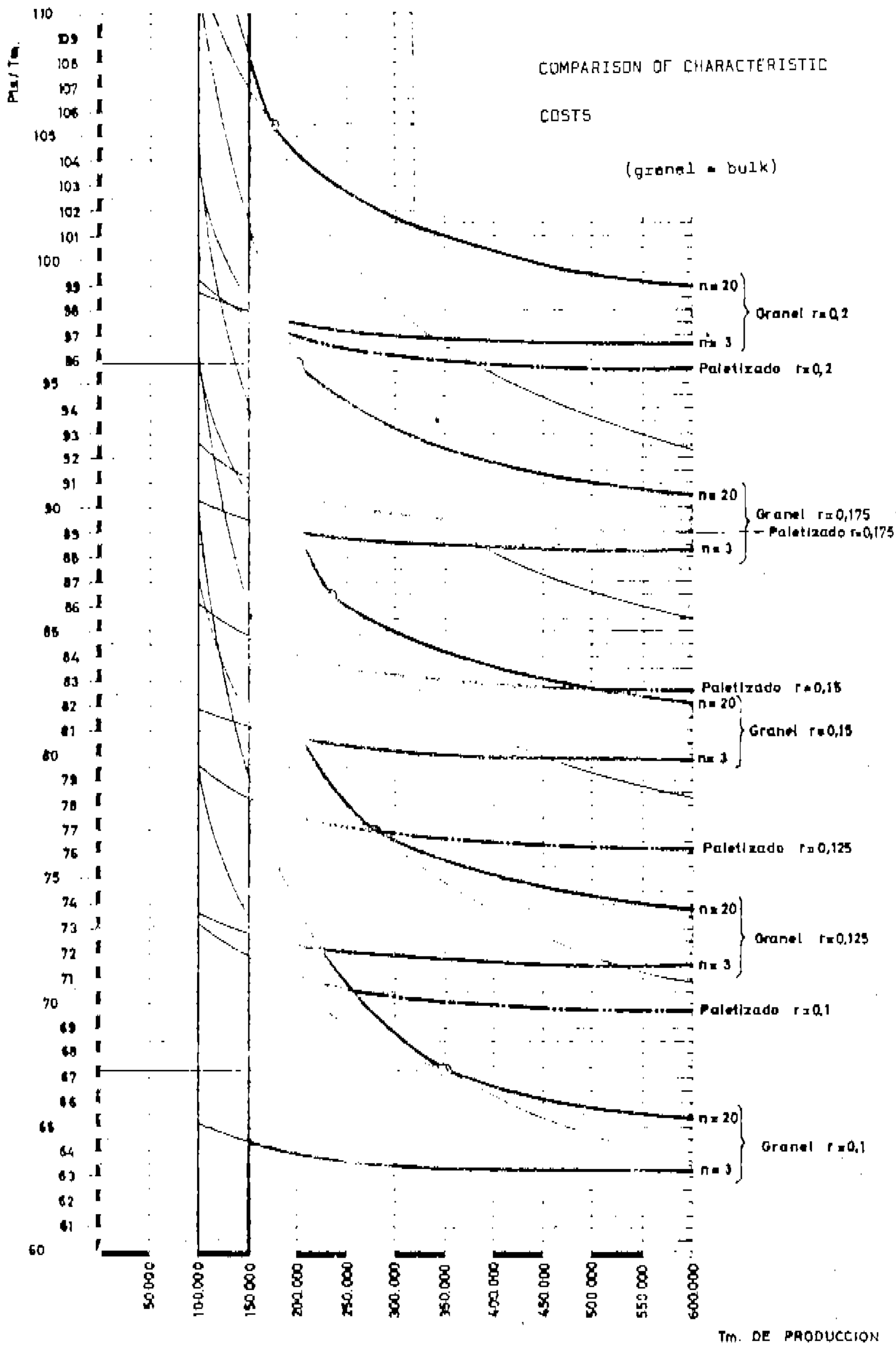


FIGURE nº 6 9 – 16

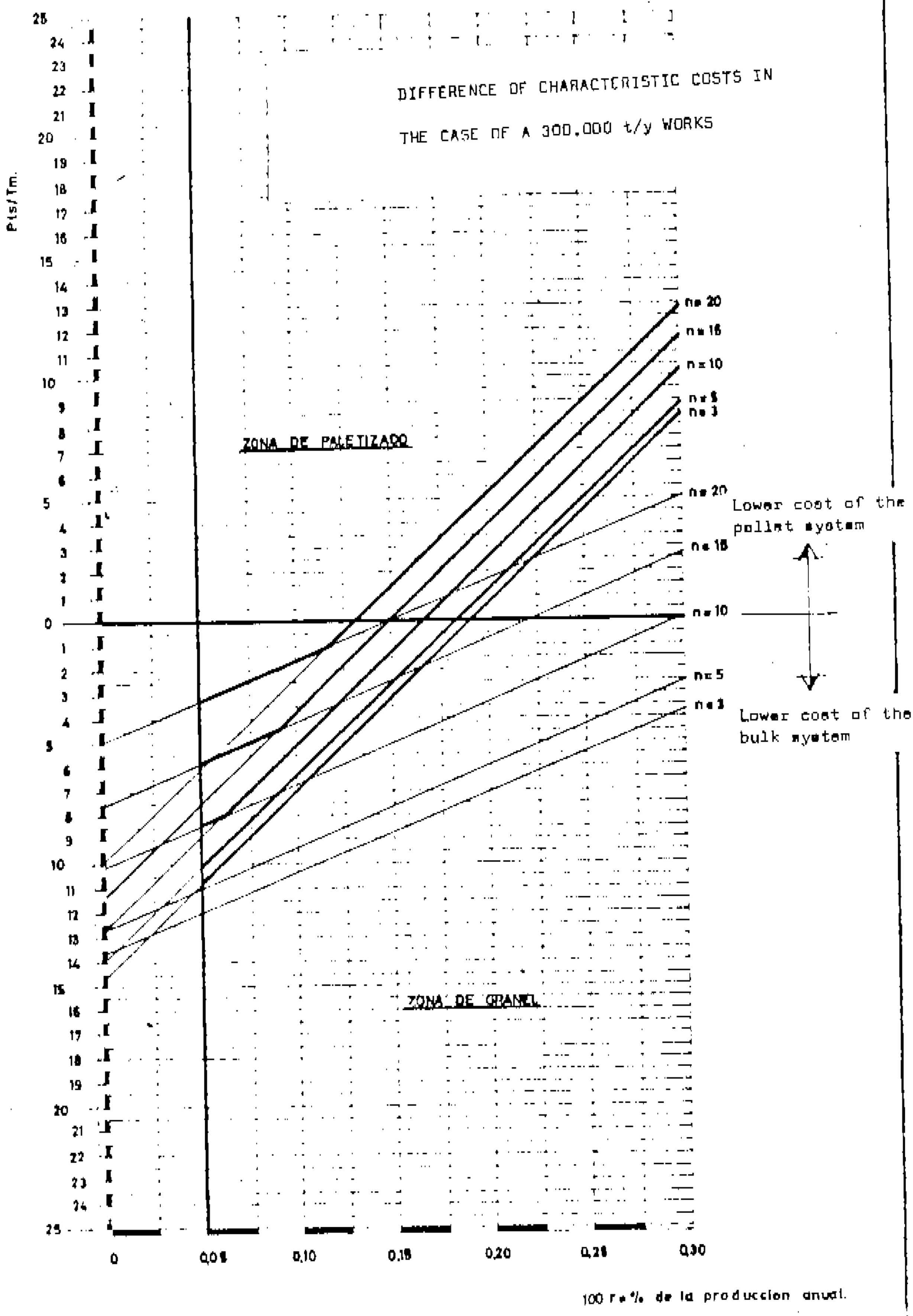


FIGURE nº 7

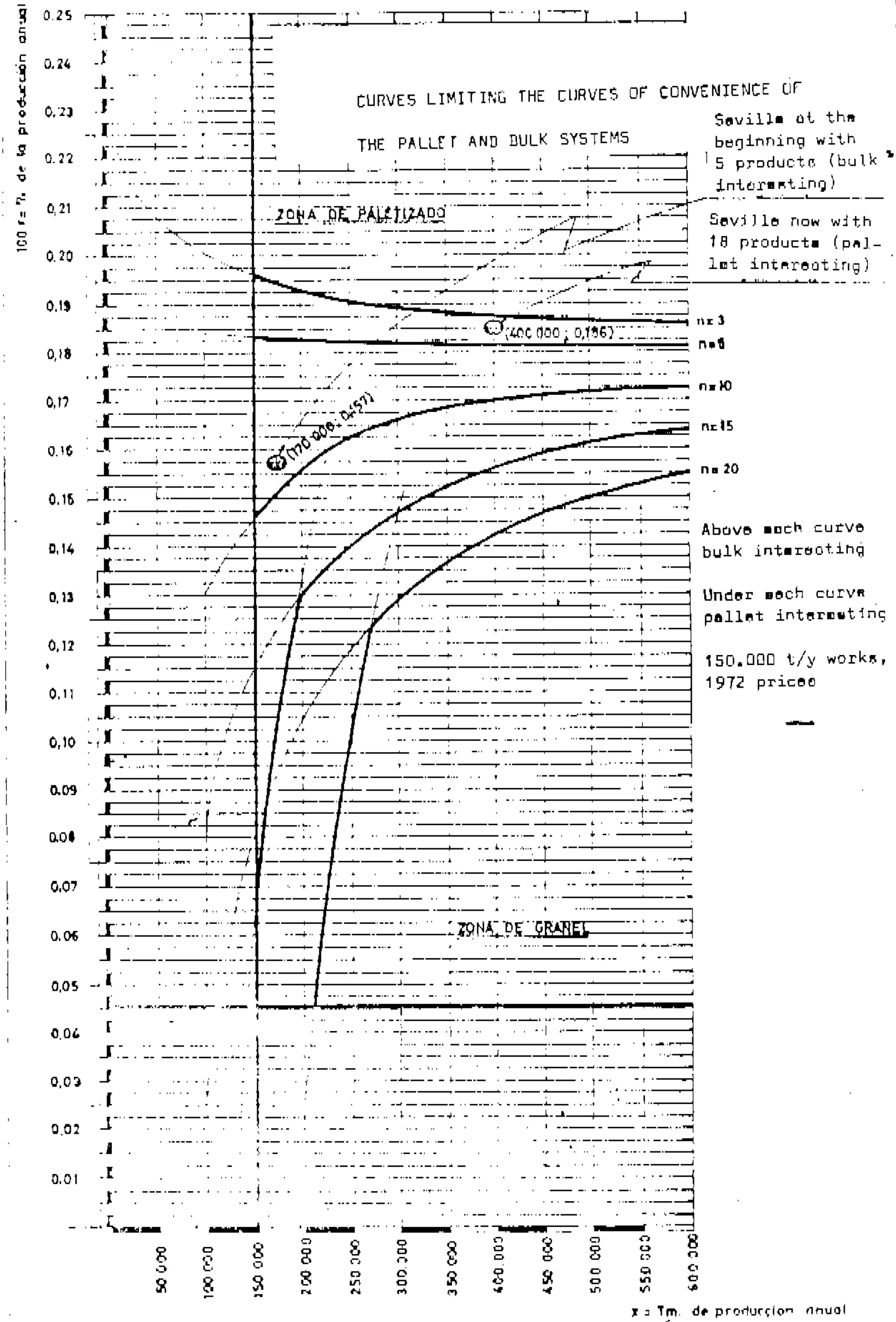
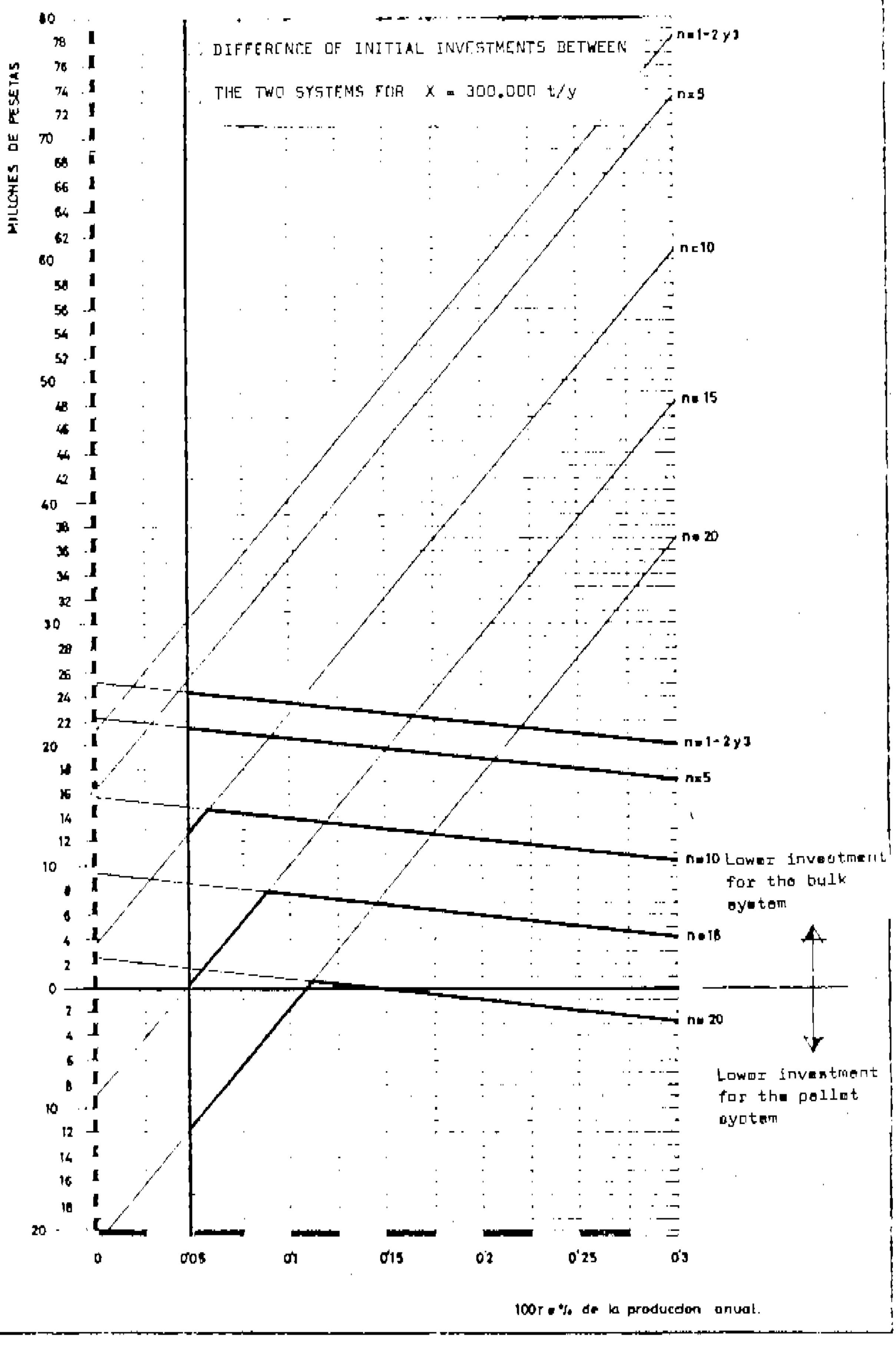

CURVES LIMITING THE CURVES OF CONVENIENCE OF
THE PALLET AND BULK SYSTEMS
Seville at the beginning with 5 products (bulk interesting)
Seville now with 18 products (pallet interesting)
ZONA DE PALETIZADO
ZONA DE GRANEL
(400 000 ; 0,186)
(170 000 ; 0,157)
n = 3
n = 6
n = 10
n = 15
n = 20
Above each curve bulk interesting
Under each curve pallet interesting
150.000 t/y works, 1972 prices
100 r = % de la producción anual
x = Tm. de producción anual

FIGURE nº 8


DIFFERENCE OF INITIAL INVESTMENTS BETWEEN
THE TWO SYSTEMS FOR X = 300.000 t/y
MILLONES DE PESETAS
n=1-2 y 3
n=5
n=10
n=15
n=20
n=1-2 y 3
n=5
n=10
n=15
n=20
Lower investment for the bulk system
Lower investment for the pellet system
0
0'05
0'1
0'15
0'2
0'25
0'3
100 r = % de la produccion anual.

MAIN ABBREVIATIONS USED IN THAT PAPER

		Units
A =	Storage capacity, bulk	tm
A_1 =	Capacity necessary to cope with peaks of seasons	tm
A_2 =	Minimum storage capacity necessary to ensure continuous production, bulk	tm
A_g =	Storage in bulk for a production unit, in the case of pallettization	tm
A_G =	Bulk storage for a factory including "a" production units, in the case of pallettization	tm
A_p =	Storage for the pallettization system	tm
A_t =	Capacity of a bulk storage unit (two medium units), pallettization	tm
a =	Number of production units of the factory	
a' =	Number of bagging plants	
a'_1 =	Number of loading points in the case of pallettization	
C =	Average daily capacity of each production unit	tm/day
C_1 =	Output per hour of a bagging plant, bulk	tm/hour
C' =	Output per hour of a bagging plant, pallettization	tm/hour
d =	Number of days of continuous production of one product	days
d' =	Number of days of "residence" of one product in a bulk	days
n =	Number of different products	
P_1 =	Cost of building the storage place	Ptas/m^2
P_2 =	Cost per linear meter of unit partitioning	Ptas/m
P_3 =	Cost per linear meter of a belt conveyor with "tripper"	Ptas/m
P_4 =	Cost of a 30 t/h screening, filling and loading plant	Ptas/u
P_5 =	Cost of a 100/110 HP tractor shovel	Ptas/u
P_6 =	Cost of a pallet	Ptas/u
P_7 =	Cost of a 60 t/h screening, filling and pallettization plant	Ptas/u
P_8 =	Cost of a fork lift truck	Ptas/u
P_9 =	Annual cost of a filling and loading team, bulk	Ptas/team/ye
P_{10} =	Cost per hour of fuel and lubricant used by a tractor shovel	Ptas/h
P_{11} =	Price of a KWh	Ptas/KWh

			Units
P_{12}	=	Annual cost of a filling and pallettization team	Ptas/team/year
P_{13}	=	Annual cost of a delivery team, in the case of pallets	Ptas/team/year
P_{14}	=	Annual cost of a delivery supervisor, case of pallets	Ptas/year
P_{15}	=	Cost per hour of fuel and lubricants used by a fork lift truck	Ptas/hour
r	=	Proportion of annual output to be stored to cope with peak seasons	
r'	=	Proportion of annual output delivered on the day of maximum delivery	
X	=	Annual output of the factory = annual delivery	tm/year
y	=	Cost of the storage - delivery system	Ptas/tm
y_1	=	Characteristic amortization cost of investments specific of each storage - delivery system	Ptas/tm
y_2	=	Actual characteristic cost of management of each storage delivery system	Ptas/tm
y_3	=	Part of equal cost in the two systems (including amortization of equal investments ; common actual costs, costs to be split and general expenses)	Ptas/tm

Editor's Note : A number of the above abbreviations refer to indications included in the appendices. These have not been translated from Spanish and the author keeps them at the disposal of interested persons.

DISCUSSION

In Mr. SANCHEZ HERRERO's absence, Mr. RAMOS CARPIO read most of the paper.

Mr. HILL (Fisons Ltd., U.K.)

The authors are to be congratulated on the detailed mathematical analysis that they have made in their paper. The subject chosen will be of interest to many companies.

I must confess to having had some difficulty in fully understanding all the mathematics. A task made more difficult by the omission of the list of signs and appendices from my copy of the preprint.

Fisons adopted pallet storage some 10 years ago, this decision being justified by savings in capital and operating costs, and also on technical grounds. Our experience has shown that an important aspect is total pallet cost. That is, not only first cost, but pallet repair costs, pallet losses and, of course, pallet life. Perhaps the authors would like to comment further on this point.

The second question I would like to ask is : has any account been taken of price variation to encourage off season dispatch and storage by the customer ?

No explanation is given of the storage and bagging complex being considered or of the type of fertilizer being stored. I have assumed that the paper refers to a simple scheme for the storage of an easily handled product. I wonder if the authors have given any consideration to the storage of the more hygroscopic grades of fertilisers and if so whether they have taken into account the need to provide air conditioned bulk storage buildings.

I am sure there will be many production managers here today who would widely acclaim and support the suggestion of a minimum 7 days operation period for each grade. This is a luxuty which is enjoyed by few companies. In order to establish some continuity of production operation my company have pioneered what we term as "bag blending"; that is, blending two, three or four basic grades of fertiliser, or blending bases as they are called, directly into a 50 kilo bag to provide a range of NPK compounds. This ensures that each bag has the correct analysis, and the problem of segregation in bulk storage is avoided. This is another concept which supports pallet storage but it can also have other advantages in reducing the number of different grades of fertilisers to be manufactured and stored. I wonder whether the authors have looked at this aspect.

To sum up, the questions I would like answered are :

1. What account has been taken of price variation to encourage a more even off take of product over the year ?

2. Would you comment further on pallet costs ?

3. Have you given any consideration to the bulk storage of hygroscopic materials and the need of air conditioning?

4. Have you considered "bag blending" ?

Mr. RAMOS CARPIO

Answering Mr. Hill's first question we have to say for the first time that we did not take account of the price variations of the product because our study is only an analysis of the storage, bagging and dispatch costs without any consideration of the value of the product.

2. The cost of pallets is a very important factor and we have introduced the preliminary data which you can see, namely amortization and investment in the pallets as well as their maintenance cost, that is the total palletization cost. We belive that about 30% of the cost of the plant is due to the purchase of pallets.

3. We did not consider the storage of hygroscopic products nor a specially air conditioned storehouse because, for our purpose, the product has perfect storage properties.

4. The case of "bag blending" might have been considered in our study but there are additional problems of a single product bagged system.

Mr. ROLFSEN (Norsk Hydro, Norway)

We have carried out quite a lot of bulk transport in our country and I cannot say I agree with the last statement made in the paper. This mentions that bagging needs a higher quality product. Well our experience is that bulk storage and bulk transport requires a higher quality product than else because you have a greater danger or hazard of segregation. So if the material is not very high quality beforehand you will have problems and you have also quite a lot of dusting problems if the material is not quite free of dust from beforehand. I want to mention another problem which we encounter in bulk transport, that is the hazard for the vessels transporting bulk fertilizers. There is a stability problem for these vessels, and you probably know some of the vessels which have capsized and I just wanted to mention that it is a transport problem and that you should be aware of it.

Dr. KOPPER (B.A.S.F., G.F.R.)

My question is rather a comment. You made very nice cost comparisons for the producer until the product leaves the works and, on that basis and taking account of the r and n factors, you conclude that the storage and dispatch of palletized products are advantageous. However the product continues to travel to the customer and to the soil. When considering the whole system it may be that the economic advantage lies more in the bulk dispatch system.