U. BERAR, eng.
V. IONESCU

A Manufacturing Program for the Irrigation Spray Pipes Industry

The authors try to establish an optimal structure for the irrigation spray pipes manufacturing, related to the raw materials or to the investments minimization.

Portable irrigation spray pipes are nowadays steel or aluminium pipes, as a rule. In some countries, on account of objective economic and historical reasons, these pipes are made of steel only, as in the Federal Republic of Germany or in the German Democratic Republic, while in France, in the United Kingdom, in Italy, in Israel, in the U.S.S.R. and in Romania irrigation pipes made of various aluminium alloys are used.

During the past fifteen years synthetic pipes, namely polyvynil chloride pipes, have been used and there is an increasing tendency towards the use of polyethylene and polypropylene pipes [1].

Each of the above-mentioned materials exhibits a number of qualities and shortcomings, which have lead to the need of selecting the most adequate material, or the most adequate range of pipes made of various materials, based on a series of technical or economic criteria. Metallic pipes have a longer life than the synthetic ones, at the expense of weight, and consequently they raise transportation problems and require increased investment costs. From the hydraulic point of view, aluminium pipes, having large bores, exhibit higher frictional load losses than the plastic pipes. Frictional losses finally result in an increased electric power consumption and the need for additional pumping equipment.

In computing the comparative capacity of various possible solutions, the "carried on wheels" type of pipes — at present being experimented at the Research Institute for Land and Pedologic Improvements (I.C.I.F.P.) — have also been considered, namely those equipped with polyethylene and polypropylene pipes.

The technical economic characteristics of various pipes and of the two inner diameters mostly used in actual practice, which have been taken into account for the elaboration of the mathematical model, are as follows:

(a) Ten years durability; this is a limit imposed not only by the current discount period, but also by moral wear. We do not at present dispose of sufficient available data for a definition of what is to be understood under the concept of a portable material durability, if the said material is used under open field conditions (i.e. it is exposed to variable climatic conditions).

b) Load losses become a problem when they exceed 6 cu. m./100 m., as for a 250-metre branch, nearly an atmosphere is accumulated (for an initial flow rate of 10 l./sec.). This restriction is generally affecting small bore pipes, with large pressure losses, this being in fact their sole shortcoming.

(c) The trampling sensitivity refers to the resistance shown by various pipes on the occasion of the very common accident of being driven over by vehicles. Bearing in mind their situation of being laid underground and of being subjected to frequent handling and storing operations, it was considered that it might be helpful to include this aspect too in the computation. In this case, the comparability is referring to the aluminium pipes quality. The lower resistance exhibited by branch sections "on wheels" is induced by their relatively more elaborate assemblage which, in case of an accident, requires repairs.

(d) The transportation time refers to shifting these pipes from one position to another, the workers being required to walk on a wet ground. In this case, the metallic — or PVC — pipe rigidity and their low weight are the most valuable qualities. The restriction value has taken into account a mean value approximating that of an aluminium, or polyethylene, pipe.

(e) Decreasing the consumption of metal, in general, (aluminium + iron + + steel) and of aluminium in particular, is one of the major purposes set up by the economic plan. It may be noticed that for polyethylene pipes, a comparatively low quantity of aluminium is required (in view of manufacturing the coupling). The restriction value was chosen so as to fall between the values of aluminium pipes and those of the "on wheels" pipes. If the restriction is more rigourous, the system cannot be solved.

(f) The number of workers needed for 250 m. of pipe (the length of a branch). The objective is established around the mean value corresponding to manually shiftable pipes.

(g) The investment cost for pipes (lei/m) is the main objective aimed at by the designer and the user, because it has a very special effect on the works profitability. The value objective is the mean of the various material values. As in other cases, for a more rigorous condition — i.e. 30 lei/m — the system cannot be solved.

(h) The weight restriction is closely related to pipes handling conditions on the site, their storing conditions, etc.

Table I contains the technological indexes for the above-mentioned characteristics of various portable spray pipes.

Basic data: **Table 1**

TECHNICAL ECONOMIC INDEXES FOR VARIOUS PORTABLE SPRAY PIPES

Item	Conditions	Aluminium		Steel		Polyethylene		P. V. C.		"On wheels"		Objectives	Function to be optimized
		ø 89	ø 100	ø 89	ø 100	ø 75	ø 93	ø 90	ø 100	PE 93	Al 89		
		x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}		
1.	INVESTMENTS (lei/m pipe)	40	50	60	70	30	40	26	30	70	80	$\leqslant 50$	MIN
2.	ALUMINIUM CONSUMPTION (kg/10 m pipe)	11	15	0	0	2	2	0	0	2	15	$\leqslant 12$	MIN
3.	DURABILITY (years)	12	12	16	16	6	6	3	3	4	6	$\geqslant 10$	MAX
4.	METAL CONSUMPTION (kg/10 m pipe)	12	16	30	35	2.5	2.5	1	1	25	26	$\leqslant 15$	MIN
5.	NUMBER OF WORKERS (for shifting 250 m pipe)	2	2	3	4	2	3	3	3	0.2	0.2	$\leqslant 3$	MIN
6.	FRICTIONAL PRESSURE LOSSES (m/100 m pipe)	9	2.7	3	1	5	2	6	2	2	2.7	$\leqslant 6$	MIN
7.	TRAMPLING SENSITIVITY (t.)	4	4	10	10	20	20	3	3	2	2	$\geqslant 4$	
8.	TRANSPORTATION TIME (minutes/100 m pipe)	12	16	27	32	13	18	16	20	2	1	$\leqslant 18$	
9.	WEIGHT (kg/10 m pipe)	12	16	30	35	7.5	12	16	19	35	48	$\leqslant 30$	

If we let x_i stand for the percentage of aluminium pipes (i.d. 89 and 100), steel pipes (i.d. 89 and 100), polyethylene pipes (i.d. 75 and 93), PVC-pipes (i.d. 90 and 100) and "on wheel" pipes (i.d. 93 and 89), the following system of restrictions results:

$$40x_1 + 50x_2 + 60x_3 + 70x_4 + 30x_5 + 20x_6 + 26x_7 + 30x_8 + 70x_9 + 80x_{10} \leqslant 50 \quad (1)$$

$$11x_1 + 15x_2 + \quad + 2x_5 + 2x_6 + \quad 2x_9 + 15x_{10} \leqslant 12 \quad (2)$$

$$12x_1 + 12x_2 + 16x_3 + 16x_4 + 6x_5 + 6x_6 + 3x_7 + 3x_8 + 4x_9 + 6x_{10} \geqslant 10 \quad (3)$$

$$12x_1 + 16x_2 + 30x_3 + 35x_4 + 2 \cdot 5x_5 + 2 \cdot 5x_6 + x_7 + x_8 + 25x_9 + 26x_{10} \leqslant 15 \quad (4)$$

$$2x_1 + 2x_2 + 3x_3 + 4x_4 + 2x_5 + 3x_6 + 3x_7 + 3x_8 + 0 \cdot 2x_9 + 0 \cdot 2x_{10} \leqslant 3 \quad (5)$$

$$9x_1 + 2 \cdot 7x_2 + 3x_3 + x_4 + 5x_5 + 2x_6 + 6x_7 + 2x_8 + 2x_9 + 2 \cdot 7x_{10} \leqslant 6 \quad (6)$$

$$4x_1 + 4x_2 + 10x_3 + 10x_4 + 20x_5 + 20x_6 + 3x_7 + 3x_8 + 2x_9 + 2x_{10} \geqslant 4 \quad (7)$$

$$12x_1 + 16x_2 + 27x_3 + 32x_4 + 13x_5 + 18x_6 + 16x_7 + 20x_8 + 2x_9 + x_{10} \leqslant 18 \quad (8)$$

$$12x_1 + 16x_2 + 30x_3 + 35x_4 + 7 \cdot 5x_5 + 12x_6 + 16x_7 + 19x_8 + 35x_9 + 48x_{10} \leqslant 30 \quad (9)$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = 1 \quad (10)$$

$$x_i \geqslant 0, \quad i = 1, 2, \ldots, 10$$

The function objective of the program will tend to successively optimize the following objectives: minimum investments, minimum aluminium and other metals consumption, maximum durability, minimum number of workers and minimum losses.

Consequently, there will result six programs having these efficiency functions and, as restrictions, the inequations (1) — (10), except the restriction to be optimized.

The six mathematical models have been solved with the electronic computer ECONOMIST CIFA-102 and the results obtained are listed in Table II.

The analysis of these results allows the following observations:

(1) The investment minimizing condition leads to the most sound indexes — because the investment index is essential, representative and generalizing in the economic analyses, as compared to the other objectives.

(2) The combination of the investment minimizing and aluminium demand minimizing conditions leads to a suggestive and significant picture of the optimum range of portable irrigation pipes with which agriculture will soon be equipped.

(3) The PVC-pipes are not appearing, as they have been excluded from the competition.

(4) The "on wheels" polyethylene pipes appear in insignificant quantities.

(5) The "on wheels" aluminium pipes are interesting only in case the number of workers is minimized, that is in case there is an acute crisis of manpower.

(6) In all cases the small bore pipes are suitable; large bores are suitable only when friction is being minimized (insignificant).

(10) (9) (8) (7) (6) (5) (4) (3) (2) (1)

Table II

RESULTS OBTAINED *

Item	Optimized condition	Resulting percentage of pipes								Values obtained within the restriction										
		Aluminium		Steel		Polyethylene		P.V.C.		"On wheels"		Investments lei/m	Aluminium consumption kg/pipe piece	Durability, (years)	Metal consumption kg/pipe piece	Number of workers	Friction (m/100 m)	Trampling sensitivity (t.)	Transportation time, (hours/100 m)	Weight(kg/m)
		89	100	89	100	75	93	90	100	PE 93	Al 100									
												<50	<12	<10	<15	<3	<6	>4	<18	<18
1.	Investments (MIN) (lei/m pipe)	0.34	—	0.19	—	0.46	—	—	—	—	—	39.2	4.8	10	11.1	2.2	6	12.5	15.4	14.0
2.	Aluminium Consumption (MIN) (kg/10 m pipe)	0.014	—	0.40	—	0.52	—	—	—	0.057	—	44.6	1.32	10	8.1	3	4.1	14.71	18.0	18.3
3.	Durability (MAX) (years)	0.52	0.40	0.077	—	—	—	—	—	—	—	49.6	11.8	12.3	14.7	2	6	4.04	14.8	15.0
4.	Metal consumption (MIN) (kg/10 m pipe)	0.56	0.10	—	—	—	0.34	—	—	—	—	42.0	8.5	10	9.2	2.3	6	9.3	14.5	12.5
5.	Number of workers for transportation (MIN)	0.48	0.18	—	—	0.10	—	—	—	0.004	0.22	50.0	11.7	10	15.0	1.5	6	5.14	10.3	20.5
6.	Frictional hydraulic load losses (MIN) (m/100 m pipe)	0.47	—	0.13	—	0.35	—	—	0.05	—	—	50.0	8.0	10	6.0	2.5	2.2	10.2	18.0	18.0
7.	Suggested structure	20	50	30	—	40	—	—	—	—	5	38.6	7.50	10.5	6.40	2.2	4.56	4.90	16.55	36

* *Computations carried out with the CIFA-102 computer.*
The optimized value objective is given in a rectangular frame.

(7) An interesting aspect: if the aluminium saving condition is necessary, 40 per cent of the pipes will be made of steel, 52 per cent of polythylene, 6.6 per cent of other materials, and only 1.4 per cent of the pipes will be made of aluminium. If we aim at saving metal in general, 66 per cent of the pipes will be of aluminium and 34 per cent of polythylene. As a conclusion, polyethylene is a desirable material.

(8) There are also some contradictory features in the table — referring to the metal and aluminium consumption — which nevertheless can be explained.

(9) It can be noticed that the last four conditions have an one-sided character. For instance: in case of a durability increase as small as 2—3 years, the metal consumption increases by 50 per cent.

CONCLUSIONS

First case. By taking into account all the factors analyzed here, we consider the following pipe manufacturing structure as being rational, according to the raw materials used:

Polyethylene	40 per cent	
Steel	30 per cent	
Aluminium	30 per cent	(out of which Ø 89 — 20 per cent; Ø 100 — 5 per cent; "on wheels" — 5 per cent).
	100 per cent	

The results obtained can be included within the specified conditions.

Second case. The manufacturing structure for different assortments of pipes in agreement with the investment minimization is suggested. In this case, the classification of materials is as follows: (1) polyethylene, (2) steel and aluminium.

The following consequences may be derived from these results:

— the need of limiting the present aluminium pipes importation;

— the development of the plastic materials manufacturing industry, in this case the polyethylene industry, and the importation of extrusion equipment;

— reorganization of research projects concerning the industrial behaviour of polyethylene and steel pipes and the improvement of their present utilization methods; and

— adequate modification of irrigation designs actually being developed.

REFERENCES

1. BOTZAN, M., *Culturi irigate*, ed. 3, Editura Agrosilvică, 1967
2. LAŞIŢA, N. and others, *Irigaţie prin aspersiune*, Editura Agrosilvică, 1967
3. *** *Faustzahlen für den Beregnungs-Praktiker*, Verlag Perrot Calw, West Germany, 1964.
4. DIEDRICH, R., *Erfahrungen über Polyetylen Rohre Kunststoffe*, Frankfurt, 1967
5. DANTZIG, B. *Linear Programming and Extensions*, Princeton University Press, New Jersey, 1963
6. KAUFFMANN, A., *Metode şi modele ale cercetării operaţionale*, Editura Ştiinţifică, Bucureşti, 1967

LA PROGRAMMATION DE LA PRODUCTION DE L'INDUSTRIE DE CONDUITES D'IRRIGATION PAR ASPERSION

Les auteurs essayent de déterminer la structure optimum de la production de conduites destinées aux irrigations par aspersion, en fonction de la matière première utilisée ou de la minimisation des investissements.

Jusqu'à ces variantes, estimées comme étant les mieux adaptées aux nécessités, d'autres variantes ont été proposées. Celles-ci optimisaient tour à tour les données suivantes: durabilité maximum, minimum d'ouvriers, etc.

En tout, 6 programmes ont été élaborés et ont trouvé une solution à l'aide d'un ordinateur ECONOMIST CIFA-102. L'analyse des résultats a permis de tirer des conclusions précieuses concernant la rationalisation de notre production de conduites avec aspersion.

ПРОГРАММИРОВАНИЕ ПРОИЗВОДСТВА ПРОМЫШЛЕННОСТИ РАЗБРЫЗГИВАЮЩИХ ТРУБ

Авторы пытаются установить оптимальную структуру производства труб для ирригации путем разбрызгивания в зависимости от используемого сырья или минимизации вложений.

Прежде чем придти к этим вариантам, считающимся наиболее соответствующими потребностям, были составлены и другие варианты, в которых последовательно были оптимизированы следующие данные: максимальная прочность, минимум рабочих и т.п.

В итоге были разработаны и решены при помощи электронновычислительной машины ECONOMIST CIFA-102 шесть программ. Из анализа результатов получены важные выводы относительно рационализации нашего производства разбрызгивающих труб.