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DISTRICT HEATING IN BRESCIA

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0. Introduction

There are, by now, hundreds of cities in Europe and in the world using district heating.

Besides, I have accepted the invitation of Euratom as we think that our experience presents some interesting aspects; moreover it allows we think useful consideration on the development of the integrated management of energy in Italy.

District heating in Italy is anything but widespread. Practically, up to now, Brescia is the only city provided with a system of this type.

With the present lecture we intend to give information from a general point of view on the reason why in Italy the situation is so lacking, on the reasons which have driven Brescia's Municipal Authority to adopt this type of policy and, finally, on the characteristics of the achieved plants, and on the results of management.

1.1. The organisation of public services in the cities of Italy

I shall briefly summarise, for those who are not acquainted, the situation of the energetics public services in Italy.

For the production, transport and distribution of the electric energy ENEL (Electric Energy Authority) has been in charge since 1962, i.e. since the priva=

te electric enterprises were nationalized. By the nationalization the Electric Energy Municipal Authorities were excluded, that is the production and/or distribution enterprises created by the municipality to satisfy the town demands through their own organisation. There are about sixty of such enterprises and concern large cities such as Milan, Turin, middle sized cities such as Brescia, Verona, Trieste, etc. up to town of only 10.000 inhabitants.

Power stations and transport mains are obviously interconnected with those of ENEL. Electric energy selling prices are unified over the whole national territory.

For the production, import and transport of the natural gas the SNAM (National Society of Natural Gas) is in charge. It is one society of the ENI (Hidrocarbons National Authority) group which is entrusted with the managing of all oil products. The distribution in the town centres, instead, is carried out directly by the Municipalities through the gas Municipal Authorities,or private interprises.

Up to now, the Municipality in Italy using natural gas are about 1,300: about 200 of these are managed by Municipal Authorities; a few towns have indipendent plants for the production of technical gas.

The tariffes are calculated on the effective costs' basis. The large heterogeneity of the Italian climate involves huge differences of the yearly consumption per user and consequently differences in costs, and therefore in tariffes, from town to town.

Instead, the gas supply cost from SNAM to single towns is unified; such cost is of a binomial type; that is a fixed monthly cost proportional to the maximum hourly flow plus a unitary price per cubic meter. Actually the monthly fixed price is about of 1,823 Lit. per cubic meter per hour of flow.

The variable price is about of 47,23 Lit/cm. The average cost varies consequently from 55 to 62 Lit/cm according to the year utilization of the networks.
The other public services not energetics, in particular the water supply, public transport, street cleansing and refuse collection are now nearly everywhere directly administered by the Local Board.
The municipalized authorities therefore are the principal operative instruments of the local administrations for the management of the public services.
They have their own management, own budget, own equipment, own organization.
Some towns have created more Municipal Authorities, one for each service; others instead have preferred to group homogeneous services. So, for instance, Enterprises for the water and gas supply are very common. Few are the towns which have only Municipal Authority in charge of all public services: the most complete in this sense is that of Brescia, where the A.S.M. runs all public town services: electricity, water, natural gas, public transport, street cleansing and refuse collection, street lighting, traffic ligts, touristic promotional activities and, more recently, the distric heating.
In the national field there is in Italy no Ministry of Energy or Power Authority

1.2. The District Heating in Italy

In Italy the only example of district heating is that of Brescia. No other town has, up to now, concretely realised such plants. Why is Italy so behind in respect of all other central European Countries? This is a very important question which has not yet received a satisfactory answer.

Certainly the climate has its influence, but this is not a satisfactory reason. Infact, in the "Val Padana" (Po river Valley) the cold is nearly as intense as that for instance, of Zagabria, Munich and Paris, Cities which possess large urban heating plants.

Neither can the lack of funds, be given as a good reason. Indeed the coldest Italian Region is Piemonte, which is also one of the richiest and most industrially developed. Althogh it is true that the local government suffers from cronic lack of money and therefore undertakes with difficulties projects in not essential fields (sewers, schools, public lighting, etc.).

Certainly even the uncooperation of which we have already spoken, among the national Authorities (above all ENEL and ENI) has had its negative influence.

Even this consideration is not fully convincing. It is infact obvious that in case of pressure from local communities, the Government would have probably seen about modifying the statutes and the aims of those Boards.

In my opinion the basic reason for such delay is attributed to the too recent and too rapid development of single family or building heating plants. Let me explain better. Up to the last world war, practically, in Italy there was no building heating plants except in the middle and high class families. The large majority of them used solid fuel (coal, lignite and wood) burnt in stoves or fires situated in those rooms which were more used. Bedrooms, for instance , were almost everywhere left cold. After the war,when the reconstruction of towns started after the bombing disasters, liquid fuel boilers started to appear on the market. After the discovery of natural gas in the Val Padana, gas distribution networks, and single family boilers had a large development.

In other words we had passed directly from the uncomfortable and not very practical wood stoves to the more modern, clean and easy to manage systems in private flats or buildings. The fuel price was then very low, and the comfort very high. People welcomed this transformation as a decisive quality bound into the progressive rise of the standard of living, without paying attention to any other type of plant, or more advanced technologies. It looked as we had reached the optimal solution, never to be modified.

Another consideration: urban district heating in Europe has taken its first step and developed in countries rich in coal. The transport of this fuel infact is very expensive, difficult, and hard to burn well with high efficiency in little plants. It has been therefore fairly easy thinking of building large stations near the coal mines, run with industrial principles, and to transport, instead of coal, hot water.

Only afterwards combined heating-energy were developed.

In Italy there is hardly any good coal. It is therefore justified that central heating system of the urban type were not carried out before the energetics crisis which has upset the terms of the problem. The subsequent arrival of gas-oil and natural gas in large quantities, besides favouring the tendency to the individual solution of the heating problem, killed every interest in district heating, which,exactly in those years had a slight start(for instance: the plants "Comasina" in Milan).

The concept of energetic saving and of integrated policy of energy was practically unknown by the Italian citizen before October 1973. The same applies for ecology and problems of atmospheric pollution. The latter was in fact considered the price to pay for progress.
The "Kipur war" rudely awoke public opinion in particular with the shortage of gas-oil during the winter of 1973/1974. Too late though! As a matter of fact, together with the increase in price of petrol, there exploded the economic crisis from which, up to date, Italy has not yet emerged.

Public opinion, starting from that more qualified, had matured in the convinction of the necessity to follow a very different way: the integrated management of the energy. Nevertheless, financial difficulties prevented the greater number of the local communities from taking concrete projects in this direction.
In conclusion we think that only now the mentality of integrated management of the energy, well behind other European country, is finally making headway in Italy, although with many difficulties and doubts.

1.3. Situation of the City of Brescia

In this depressing picture, the city of Brescia is an exception for a series of happy circumstances. To better clarify the reasons of this different situation it might be worthwhile to give some information on the city and on its public services policy.
Brescia is the second important city in Lombardy after Milan. It is situated 100 km from Milan on the road to Verona and Venice between to lakes of Iseo and Garda. It has 220.000 inhabitants (it reaches 300.000 with its hinterland). The economic activity is evenly

subdivided between agriculture and industry with quite a lot of interest in tourism.

The metallurgical and mechanical industry have in particular very old traditions and they are actually occupying the first places not only in the national field but also in the Europe. The average income per capita is rather high; much higher than the national average, and one of the first in the whole country.

Figure 1 shows the energetics supply and consumption according to the different sources. Brescia has an active and dynamic population with a risky undertaking spirit. Also very emphasized is the policy of the municipalization of public services, which started in the first years of this century electric energy and water supply. Little by little other services joined the last of these being the district heating. For this policy the way of a unique organism has been chosen: as I have already said: the Azienda Servizi Municipalizzati.

The organization of the A.S.M. is unitary. Only one remote control station allows the administration of all primary plants of the different services (electricity, gas, water sistem) constantly optimizing the production, transport and distribution through an automatic computer "on line".

One single office, at the service of the users, gives them, above all, the settlement of any problem connected with the above mentioned services.

ENERGETICS BALANCE OF THE CITY BRESCIA

AS IT SHOULD HAVE BEEN IF DISTRICT HEATING COMPLETED

(in Tcal = milliard Kcalorie) YEAR 1972

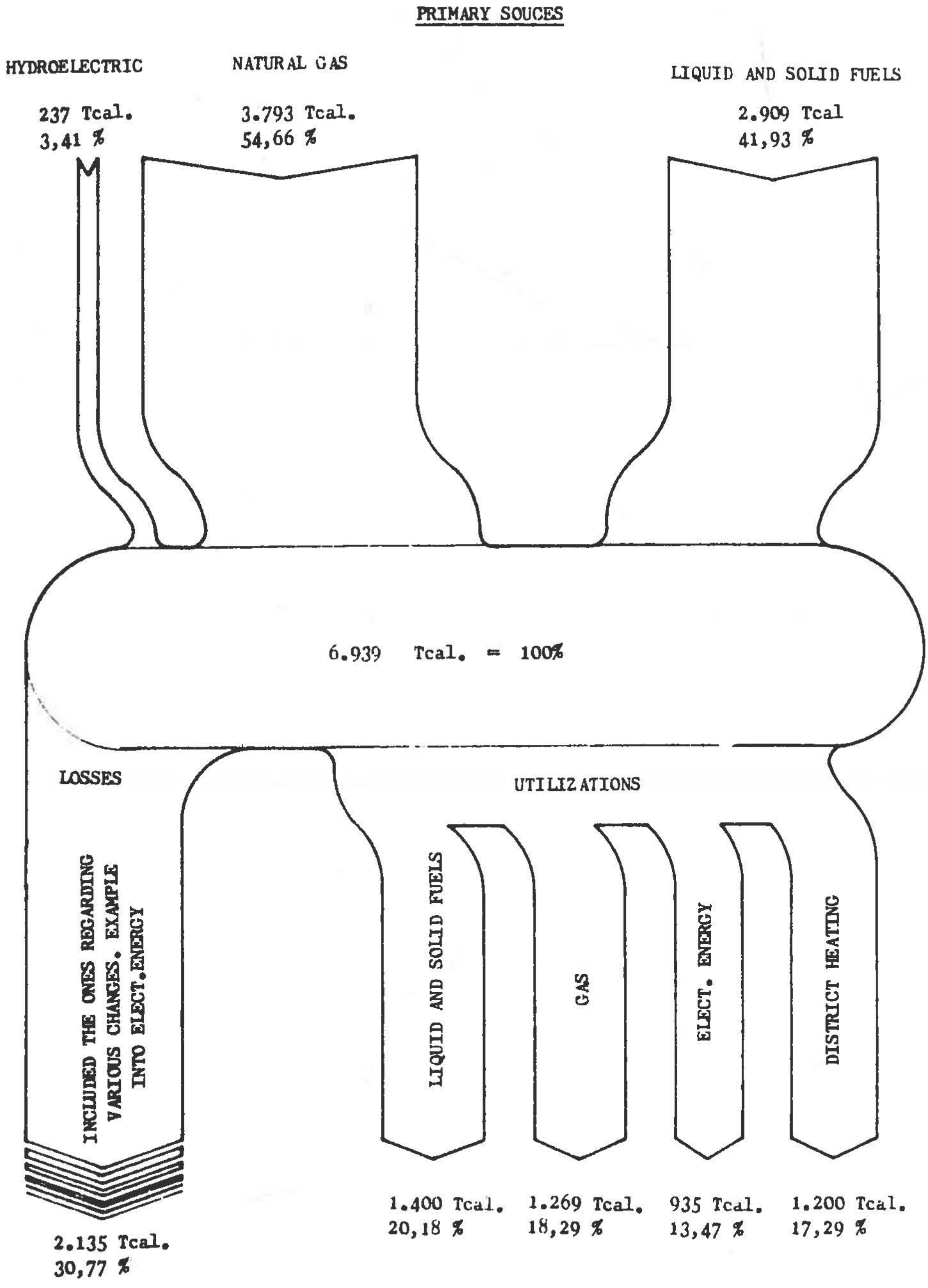

FIG. 1

A unique administration, general management and programming system have allowed to mature among the managing staff and middle collaborators, inter-energetics and more in general inter-services mentality with a unique view with a concrete possibility of coordination. This is in my opinion a very important fact for better understanding of the situation.

In conclusion I think it is possible to resume the basic motivations which have permitted the city of Brescia to realize the district heating:

a) Brescia is a city large enough to allow initiatives of industrial character, but small enough to be able to control its development;

b) it is inserted in an industrial and social context very accentuated, which accepts, indeed stimulates any avantguarde initiative;

c) the population has for sixty years acquired the mentality of self-governing administration of the public services;

d) the A.S.M. has acquired as well, the open mentality of an inter-energetical policy; it is equipted with technicians, plants, appropriate experience and technologies; for this reason it has full trust of the citizens.

Objectively these conditions did not happen in other Italian cities.

Let us now give a brief description of the most important plants of the Azienda:

- electric energy

figures 2,3 and 4*show the power and energy trend furnished by the A.S.M. network to the direct users.

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* Editor's Note: Author did not submit a Fig. 4.

A.S.M. ELECTRIC ENERGY

Max power output measured in High
voltage for direct consumers in
BRESCIA

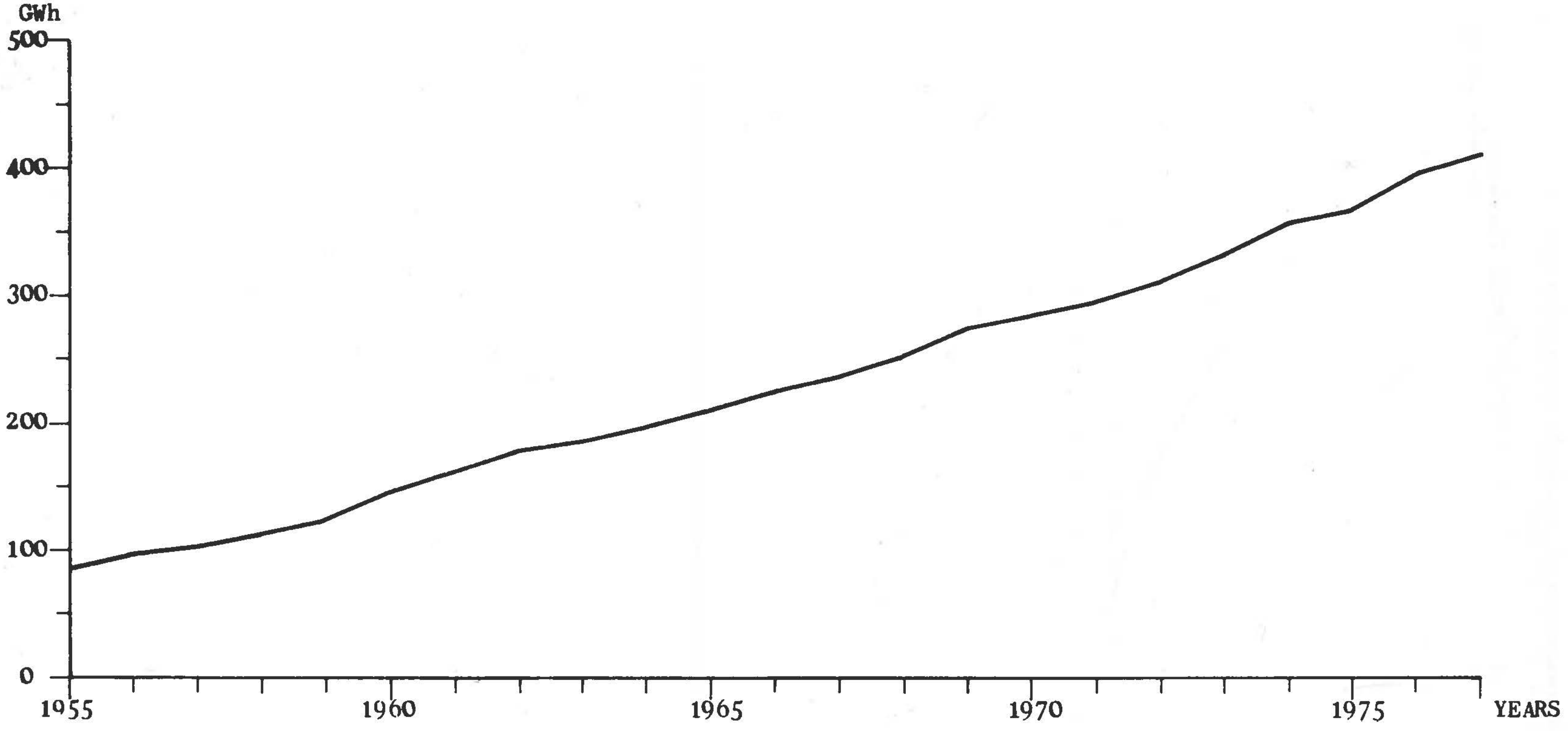
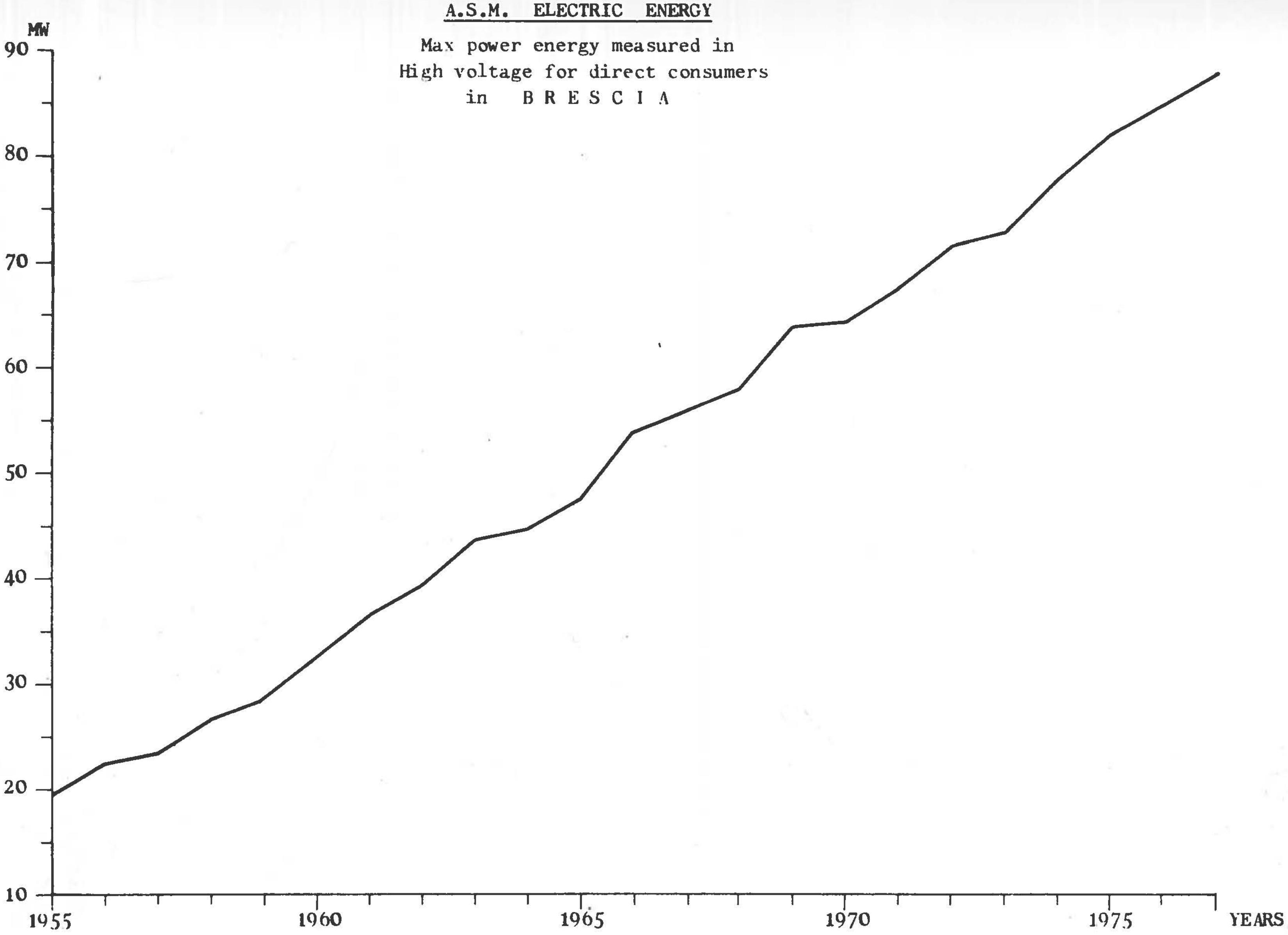


FIG. 2



A.S.M. ELECTRIC ENERGY

Max power energy measured in High voltage for direct consumers in BRESCIA

FIG. 3

The strength of the production is set up by the thermoelectric power plants of Cassano (110 MW in joint ownership with the Municipal Electric Enterprise of Milan) and of Mincio (80 MW in joint ownership with the Municipal Enterprise of Verona). I have to underline the fact that it consists of plants built and run in cooperation between two municipalities. This is the result of another aspect of the policy adopted: certain big investments have to be realized by joining the forces of more communities which have similar problems.

The potential of these two power plants, already decide, and the starting of the turbo-group of the new combined plant, which shall be spoken about later, will cover the requirements of the citizens for the next twenty years.

The picture is completed with some small hydroelectric plants.

As before mentioned the management of these plants is in cooperation with ENEL and the network are interconnected with the same.

Before speaking of district heating, another considerations about of <u>gas</u>.

The gas distribution in Brescia started in 1953. Before, since 1910, the production was realized through the gasifaction of coal.

Since 1973 the increase rate of the consumption had remained constantly on a rather high value; in the last three years we had a very huge increase in conseguence of the low cost of natural gas in respect of gas-oil (see fig.5 and 6).

A.S.M. - GAS SUPPLY FOR DIRECT USERS OF BRESCIA

(Excluded: losses and district heating)

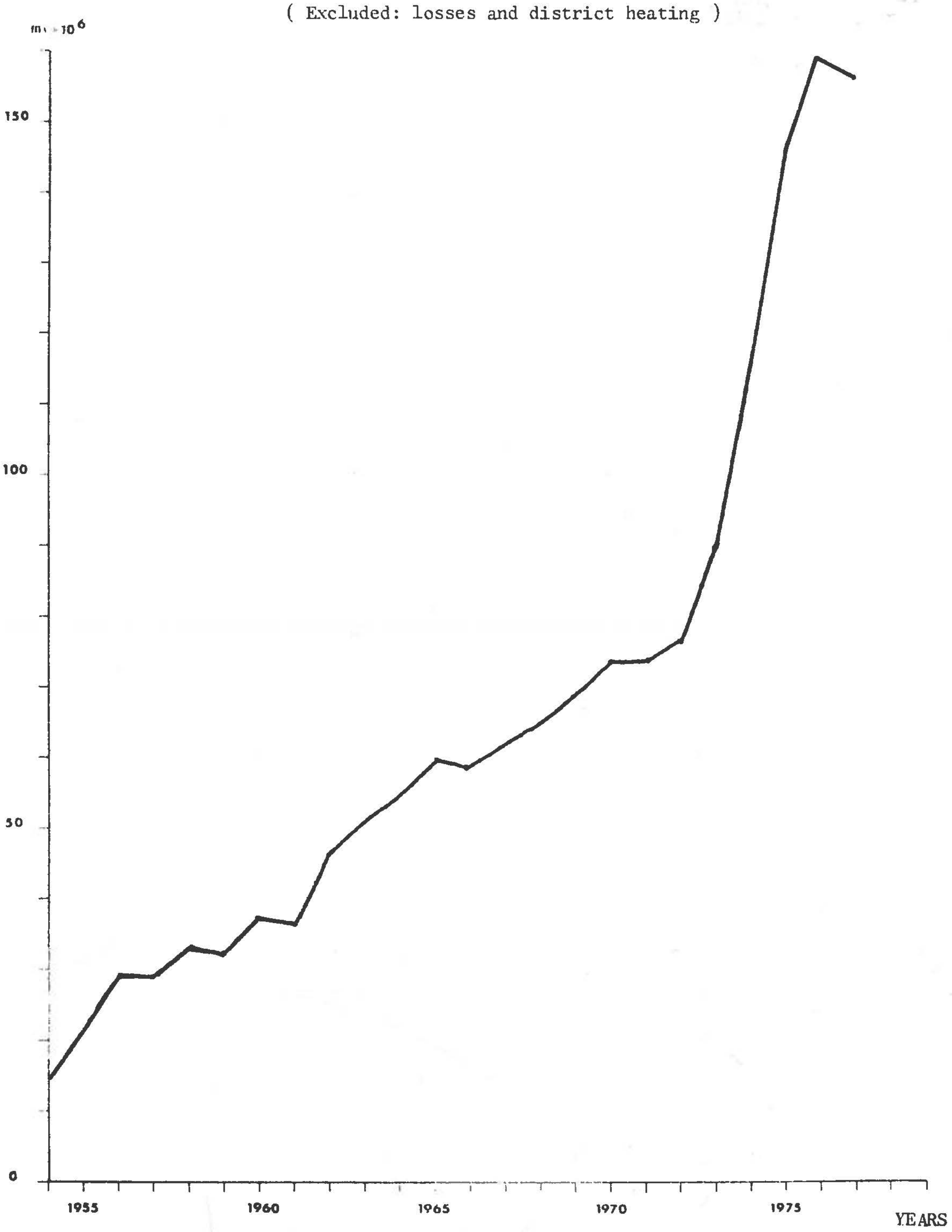


FIG. 5

A.S.M. METHANE GAS NETWORK DURING THE 25 YEARS SERVICE

	Hourly flow engaged with SNAM Mcm/h	High pressure network Km	Low pressure network Km	Decompressions stations n°	Yearly output million Nmc	Max flow Nmc/h	Max daily output Nmc
1953	---	30,0	130,0	13	4,7	3.500	40.000
1963	15.380	46,8	224,0	18	51,7	23.134	385.000
1972	27.500	62,9	358,9	30	76,9	33.810	575.000
1973	31.061	73,1	370.7	30	89,2	37.412	686.000
1974	44.000	83,4	381,0	32	122,1	45.006	823.171
1975	46.000	91,9	391,0	34	155,4	57.623	1.104.848
1976	46.500	104,5	408,7	35	174,0	63.500	1.206.005
1977	49.500	105,4	413,6	37	175,8	58.450	1.151.391

FIG. 6

In occasion of the start of the district heating it has been studied the subdivision of zones of influence between gas and district heating and the belts to be supplied with each of the two services. The peripherical zones with low building density and less population density, besides most of the historical centres, are reserved for gas.

I think it is necessary to linger for a moment over the type of policy adopted for the gas sector. As I mentioned before, the gas is bought by the SNAM on a binomial tariff. Being the consumption very variable whether during the day hours (see fig.7) or during the year (see fig. 8 and 9) it becomes necessary to find some instruments to use the plants better, so as to render less discontinuous the flow from the gas pipelines. This objective has been up to now achieded through pressure stocking plants (20 bar) filled during the night and emptied during the day hours of highest requirements and with the integration during the 10 - 15 most cold winter days with propane mixed with air, so as to render it interchangeable, from the combustion point of view, with natural gas (see fig. 10).

1.4. The District Heating in Brescia

Let's take now a brief look at the situation in the year 1970. The problems to be solved inside the Azienda were above all the following:

1. it was felt necessary to be able to rely on an electric production of tactical type for pick load and for the reserve, very near to the consumption baricentre, that is near the town;
2. it was needed, to develope the policy of improvement of the diagram of gas supply. Being in fact increased the gas consumption purely concentrated during the winter months, the bad use of the networks

DAILY WINTER DIAGRAM OF GAS SUPPLY
1976/1977

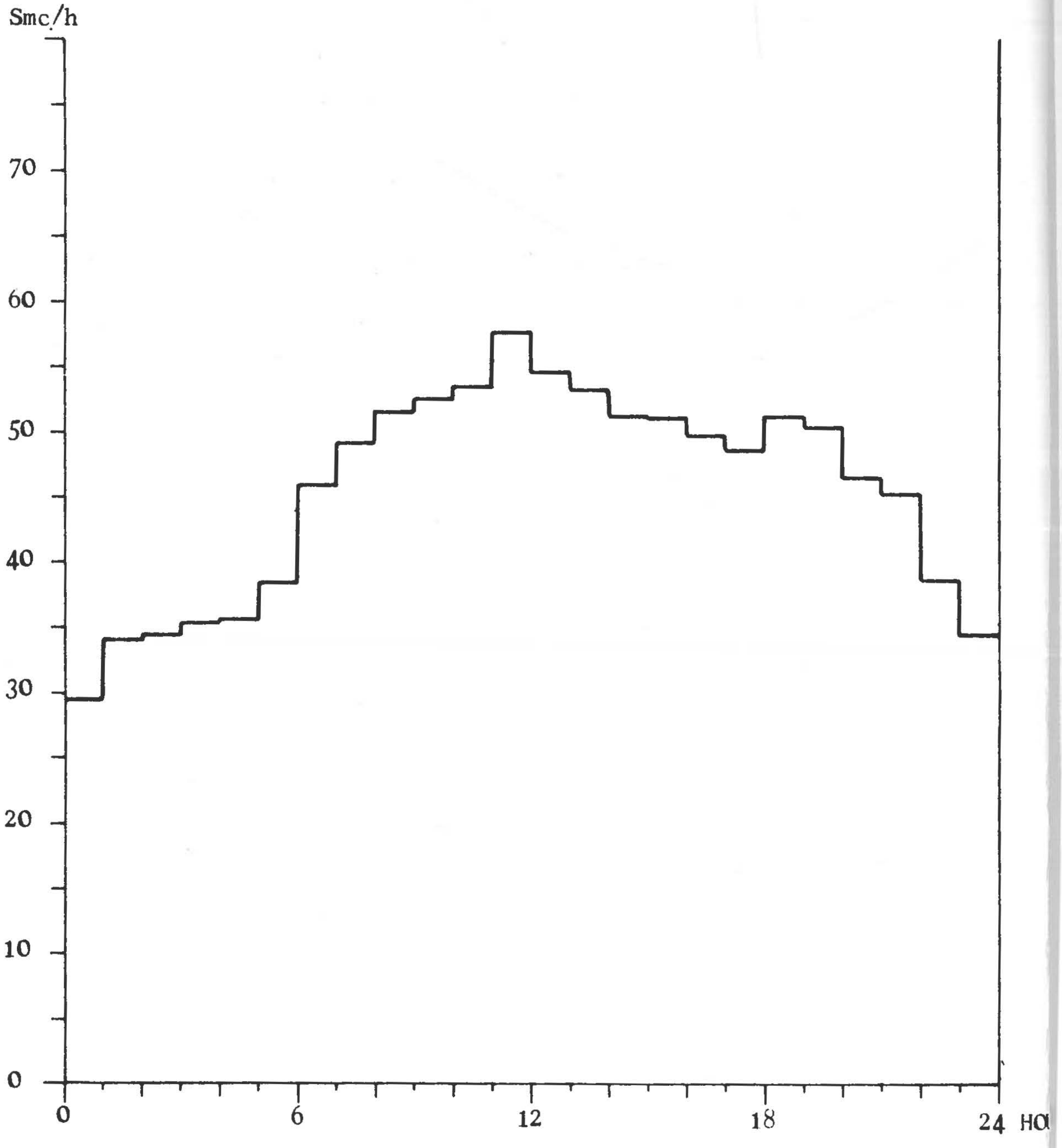


FIG. 7

DAILY GAS SUPPLY - YEAR 1977

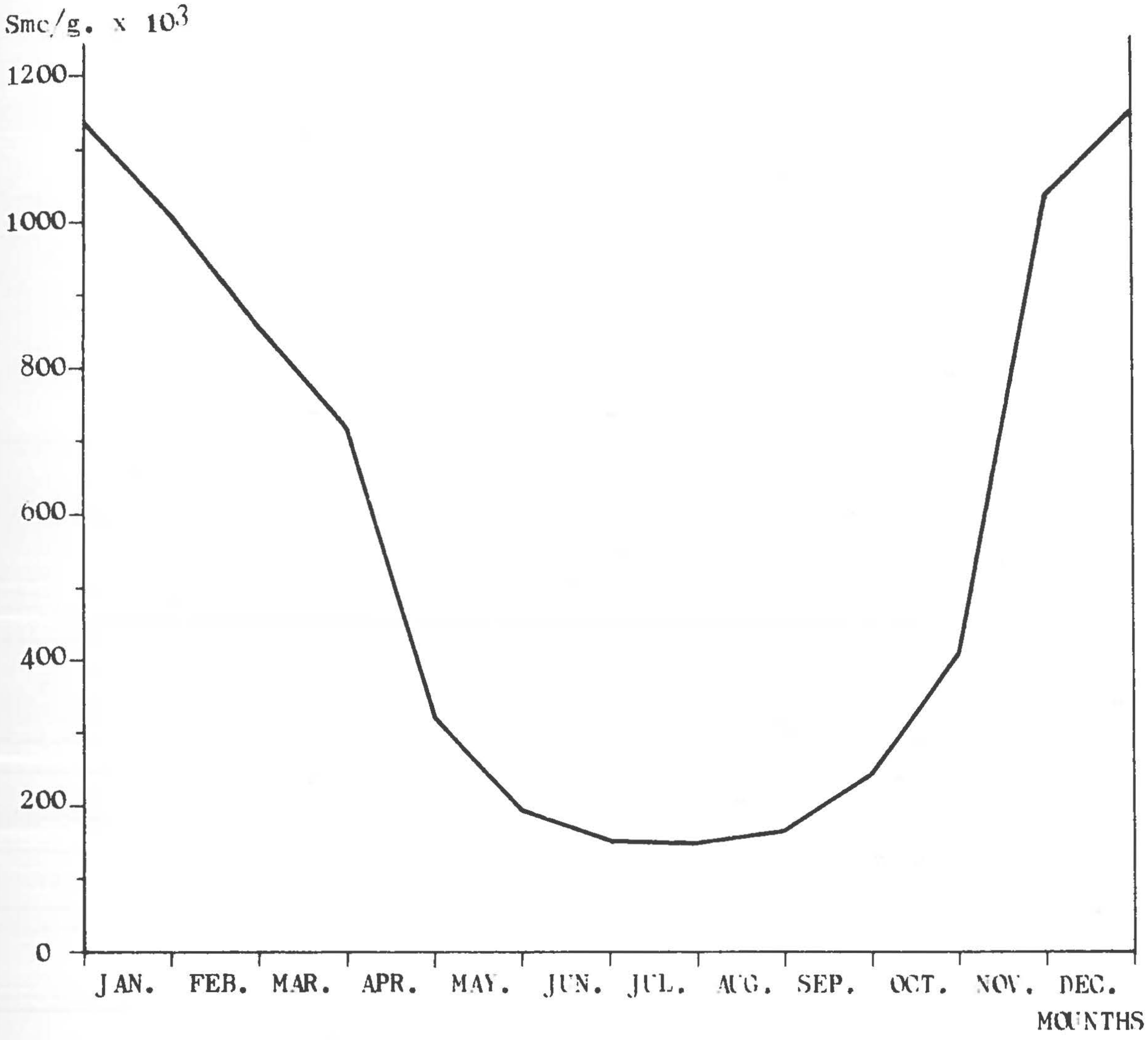


FIG. 8

DURATION DIAGRAM OF GAS SUPPLY OF 1976

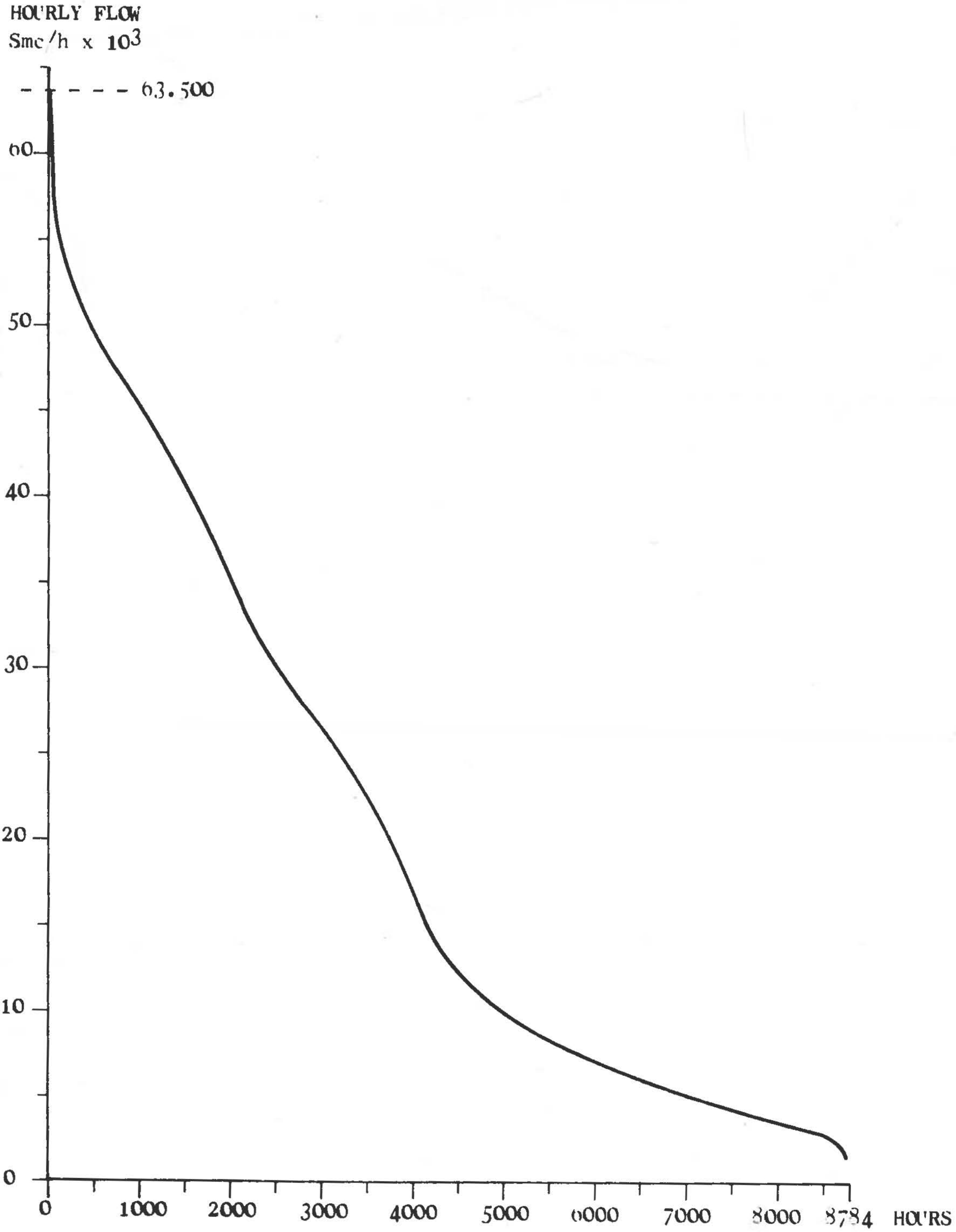
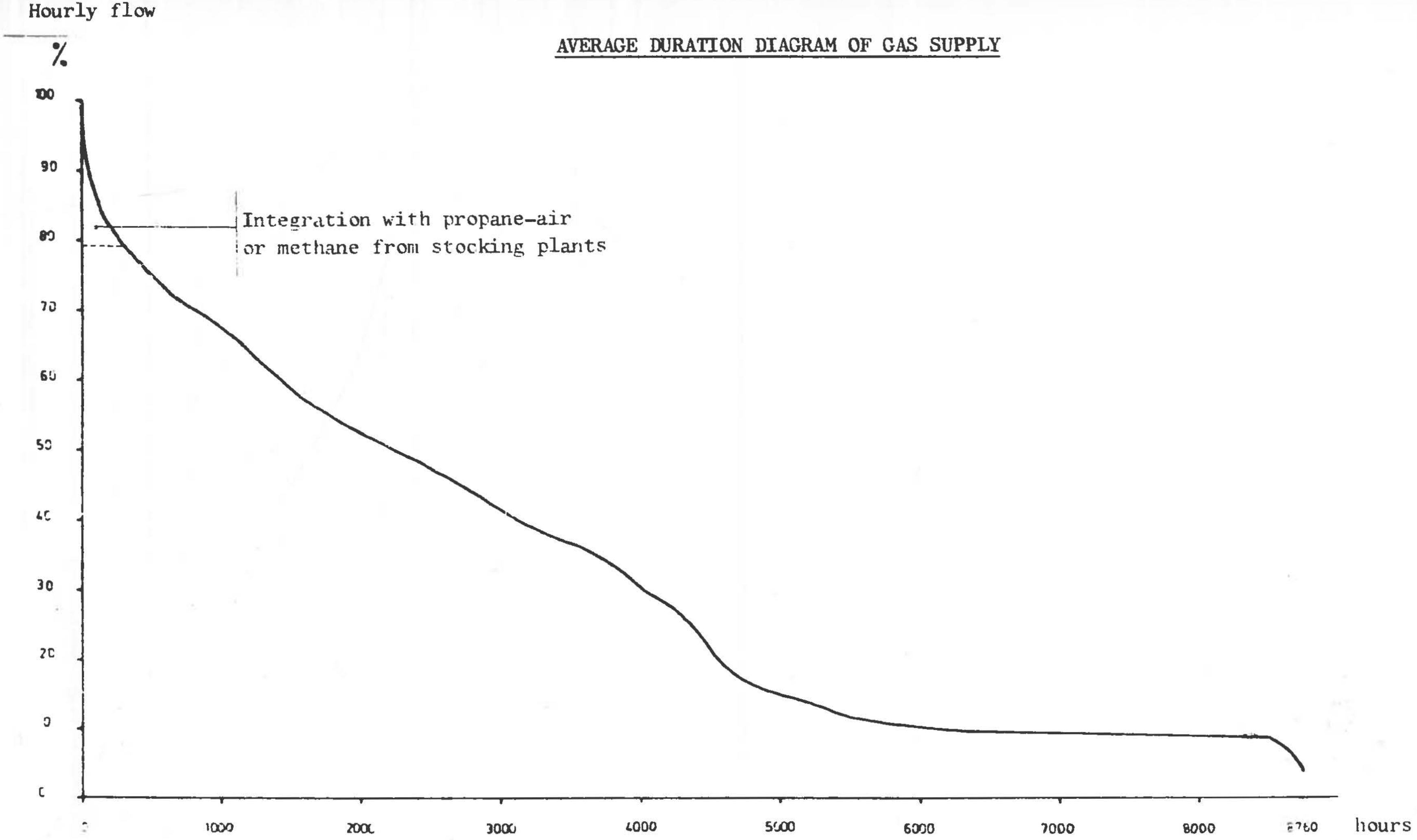


FIG. 9



AVERAGE DURATION DIAGRAM OF GAS SUPPLY

FIG. 10

was emphasized. The daily stockage and production plants were not sufficient any more;

3. we had not at that time found a rational solution for the disposal of solid urban refuse. It was thought to burn the refuse and utilize its heat ;
4. finally, the gas networks where at a saturation phase and it could have been foreseen, that in a few years it would be necessary for huge investement if the policy of methanization was to be followed.

Besides these problems of purely administrational character, other considerations of a more general interest were a burden for the final decision. Let us look now at these problems summarized:

a) ecological problem

Brescia has unfortunately a very polluted atmosphere. The large industrial development, together with the proliferation of small heating systems often burning fuel of low value and run in an unrational way, makes the quantity of SO2 in the atmosphere very high;

b) the construction of a thermoelectric power station in the borough of Brescia would have put at the disposition a huge quantity of heat, even if at low temperature;

c) the philosophy of the "finished product"

by now in the more qualified public opinion was slowly maturing the conviction that the time had come to an end when we could let the citizen choose the fuel he wanted to use for his individual heating, and that it was necessary to give the citizen the finished product for heating and hot water, with temperatures and conditions most favorable to him, reserving to the community the administration of the different fuels in an integrated outlook: the integrated energy policy.

All these motivations, put together, directed almost automatically the policy of the Azienda towards the establishment of the heating service in the context of a unitary administration of the various forms of energy.

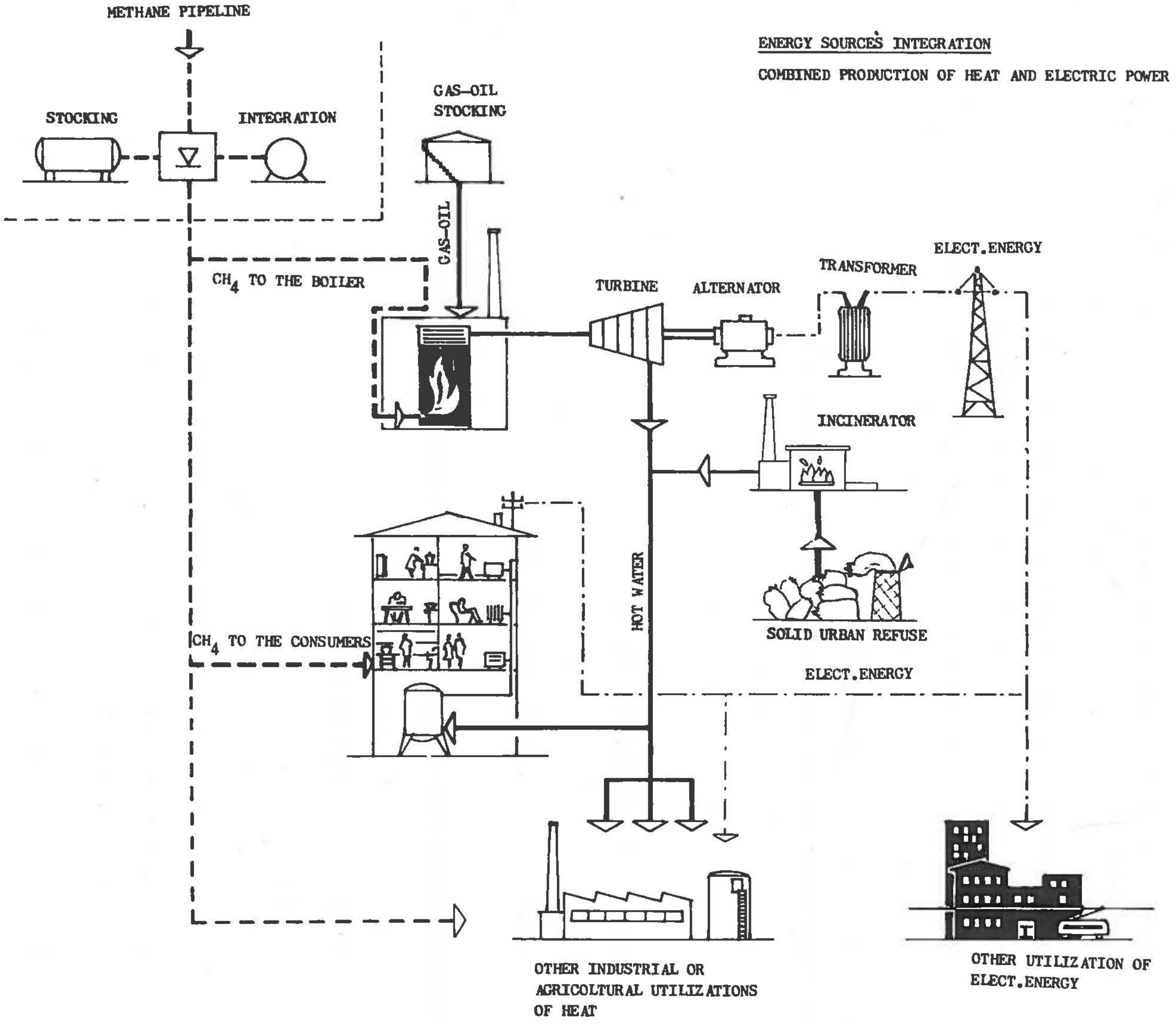
The scheme which took shape is the following (see fig 11) a thermoelectric power plant with steam turbine , built in Brescia, can be fed by gaseous fuels (natural gas) and by liquid fuels (gas-oil or heavy oil) The turbine of the back-pressure type can allow the heat extraction at low temperature for use in the urban district heating network.

Such heat can be integrated by the contribution of the solid refuse inceneration. Obviously the choice between natural gas and gas-oil his done constantly , day by day and hour by hour, in comparation to the town gas consumption; in other words the gas is marginally taken in every period of the day which never touches the maximal peak consumption; in this way the istantaneous gas flow from the SNAM methane pipeline won't be increased; increasing instead the total daily and yearly gas flow (see fig.12).

It was instead preferred to set aside, at least for the time being, the construction of an incenerator for solid urban refuse with recovery of heat, as the technology of the sector and the running costs still left great doubts especially on the technical-economical validity of such a choice.

Because of the general character of this lecture, I shall not go deep into the technical characteristics of the systems just mentioned.

I shall instead talk about other questions of more general character. About the opportunity to proceed towards an integral policy of the energy, there were no doubts even before the energetics crisis.

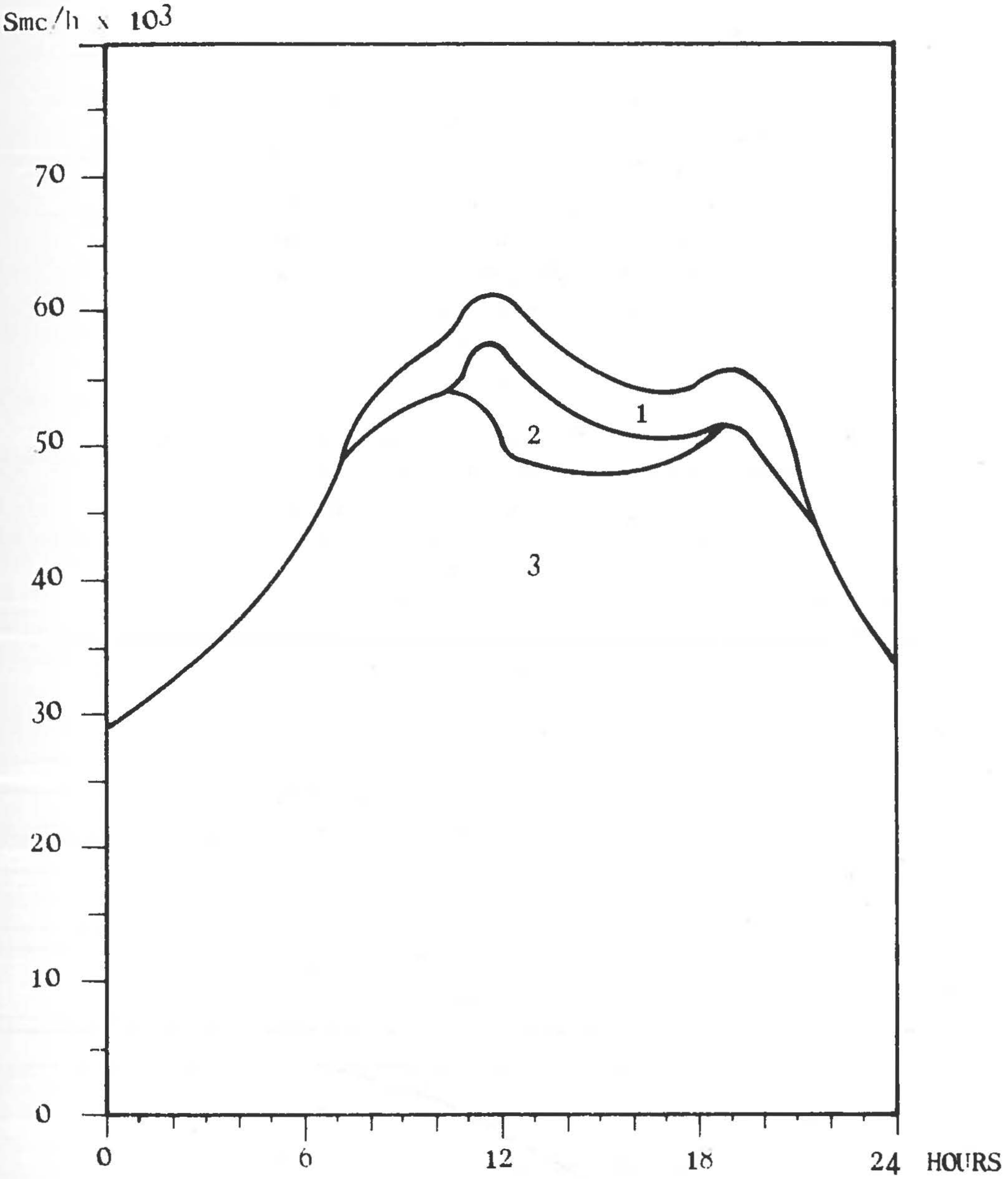


ENERGY SOURCES INTEGRATION

COMBINED PRODUCTION OF HEAT AND ELECTRIC POWER

FIG. 11

WINTER DIAGRAM OF GAS SUPPLY + DISTRICT HEATING
1976 / 1977



1) = LIQUID FUEL FOR DISTRICT HEATING
2) = AIR-PROPANE INTEGRATION (G.P.L.)
3) = GAS METHANE

FIG. 12

Important perplexities existed instead on the economical validity of these types of plants if carried out in a city like Brescia. The questions rising spontaniously were above all the following:

a) why not provide all single families with natural gas, instead of building very expensive urban district heating plants? The gas is certainly ecologically the most pure fuel; through an adeguate informative and helpful policy to the users it is possible to obtain even very satisfyng results. After all it is cheaper to transport gas than heat and in this respect the technology by now has reached a considerable degree of security;

b) the policy of the "finished product" has meaning in a binding economy (such as in the East of Europe) . In the case of a marketing economy, as the Italian one, it becomes necessary, so as to realize these objectives, a tariff-policy which renders the town dwellers indifferent whether one solution rather than another is chosen.
In other words it is necessary to study a solution so as the cost per calory of the heating shall be the same indepentently from the fuel used.
Is such a solution possible in Italy? When the liquid fuel market is completely out of the possibility of interference of the municipality and the tariff instrument of other fuels are not always in the hands of the Local Administrators?;

c) in any case, is it necessary that the city of Brescia throws itself in an adventure of this kind without the existance of a national energetics policy?
Arn't we going to risk to remain isolated?;

d) by building a district heating network is it not in fact realizing a duplicate of the gas network?

These were very important questions which required a very concrete answer. They are:

a) the district heating in Brescia can be proved economically valid only in the context of an integrated management of energy. In particular the heat has to be considered as a by-product of the electric-energy;

b) another economical element of fundamental importance is the possibility to use the feeding fuel of the power station coordinating the users' gas consumption.
As a matter of fact the advantage of this policy on the purchase cost of the gas from the SNAM in notable and it has therefore to be considered;

c) the gas is not in fact available without limit; the national reserves are after all fairly modest and, imports increase continuously (the sources of supply are actually three: Russia, Holland and - by sea - from Algeria). Future restrictions in the gas supply and increase in prices are therefore easily to be foreseen.
The gas covers actually about 13% of the total italian energetics consumptions. A large increase of such percentage is not foreseen. The specific consumption per capita in Brescia has already reached considerable values higher than that of the national average (by now we are reaching 2.000 cm /user-year against a national average of 1.000 cm /user-year).

Considerable are in Italy the pressures to increase chemical utilization of gas and to networks in the centre and south of Italy, at the present lacking in gas supplies.
It is therefore unlikely that in the future it will be possible for Brescia to dispose of larger lot of natural gas at a reasonable price;

d) as already said, the gas supply town networks are nearly saturated. Large investments might be needed in case a policy of large expansion of this fuel should be continued, with considerable increases,on the selling price;

e) it had nevertheless resulted at once clear that a policy of this type had to be based on an accurate and systematic action of marketing. It is in fatc necessary to coordinate the development of the networks and consumption, to program intervention and expenses, to gain as soon as possible new users, in respect of the realization of the plants and networks. evaluating them whether quantitatively or qualitatively in an optional way for the management of the same networks, and finally to adopt tariff system between gas and heat coordinated between them, so as to be able to practically realize the object of which we have already spoken, of the equalization of costs for calory output.

However the choice was very difficult. Too many elements not really qualified did not give absolute tranquility for the economic future of the management and the Public Authorities in Italy as elsewhere, cannot decide to spend too much on risky enterprises.
For instance a relative movement of the costs of liquid or gaseous fuel and of electric energy could at any moment upset also in a decisive way the running budget.
After many deep discussions and study, we finally decided to start.
I think now usefull to linger on the criteria adopted to verity the economical validity of the operation in the time; in other words the techniques for the audit of the returns, in a certain number of years, of invested capital.

1.5. Economical aspects of the district heating project

Every investment can be considered under the financial profile as a commitment of resources (cost)to which shall follw an aquisition of resources (return).
In monetary terms it can be considered as a cash flow initially negative to which shall follow more cash flows in a positive way.
In other words an investment can be defined as an exchange between a certain initial outlays of funds and a series of uncertain future returnes to which the running costs, uncertain as well, shall be adjoined.

Schematically, the expenditure and the financial returns can be recognised as flows of an hypothetical fund formed for the investment: hence the well known expression of "cash flow".

The difficulty to acertain immediately the remunerativeness of an investment lies, not only in the uncertainty of the expected results, but also in the different cadence of the positive or negative cash flows.

The comparison among financial flows having the same maturity is immediate an evident; while to be able to compare flows having different maturity, it is necessary to render them homogeneous.

In terms of financial mathematics if the operations are referred to a same maturity ("zero" year) it is said that they are "actualized".

The basic logic to this principle is the financial one, that is the "monetary" transformation of not homogeneous flows, hence the denomination of the "Discounted cash flow" (D.C.F.).

With this method it is possible to establish the year in which the discounted cash flow shall become positive and also the validity of the investment which shall be verified if, before the end of the physical life of the plant, the total cash flow shall show a positive sign.

In other words, with the application of this principle it is possible to determing the actualized economical result of the investment; the dyscrasia between economical and financial moment, proper of the traditional operating budget is so overcome, since all the administration (or that portion attributed to the investment) is considered as it had occured in an unique operation.

It is not therefore necessary to calculate depreciation, calculation of interest and reserve funds,but it is simply sufficient to foresee the positive or negative cash flows.

As a matter of fact an estimate is so much more difficult and uncertain when it is further ahead, but with the actualization criteria it lies in a limit proportionally inversed to its distance in time.

Supposing for instance a rate of 12%, a cash flow of 100 expected in three years time, today it is valuated 71,18 while the one expected in twenty years time is valuated 10,37.

It is therefore necessary to give particular care to the prevision of periods most near, which generally are the ones which possess elements of less uncertainty.

In valuating the profit of an investment with such a method the variabilities at stake are the following:

- amount of the investment (that is the first negative cash flow);
- amount of the following cash flow whether positive (return) or negative considering for the latter whether the capital costs or the running costs (in fact being these actualized, the classic differences of running balance between investment costs and current costs has no longer influence);
- the investment rate (if internal financial means are used, shall be necessary to assume market rate; otherwise the rate practised for borrowed capital shall be considered);
- the final residual value and the plant utilization period (salvage value).

In the specific case of the project of the district heating for Brescia, the method of D.C.F. has been used.

For each year algebraical conclusion between costs (investment and running costs) and return (heat and energy sale) has been made, with the differential result The year referred to is 1976, the interest rate 12% which corresponds to the average financial rates up to now obtained or assured to the Azienda.

As figures no. 14 and 15 shows, the cash flows present a negative sign till 1978, becomming positive in the year 1980. **(Editor's Note: Fig. 13 omitted.)**

It is to underline that the previsions of expenses and incomes have been formulated considering a constant value of the currency.

In other words it is presumed that to variations resulting from inflation in the expenses, corresponding variations proportional to the revenues, for which the result, after all, shall not change.

We think the supposition is pessimist, but is has been assumed as it involved a precautionary valuation of the investment.

As a matter of fact a relevant share of the costs shall not undergo the adjustment of the monetary devaluation; in fact capital costs bound to the amortization of the loans are not adaptable in the case on inflation.

THE PRODUCTION

2.1. - BASIC DATA FOR THE DIMENSIONING OF THE PRODUCTION PLANTS AND OF THE NETWORK

(Average values for Val Padana)

Climate conditions :

- conventional external (Min) temperature (cfr. CTI-UNI, standards) - 7°C

	EXPENSES (in mill.lire)							REVENUES (in mill.lire)				D.C.F. (in mill.lire)			
			RUNNING EXPENSES												
Years	Investements network+plant	Investements progression network+plant	Fuel	staff	El.en. for pumping and other	Fixed running expenses plant+ network (maintenance,assurance, general expenses)	Total expenses	Shares and connection income	heat sale	Electric energy sale (15 L/Kwh + 9000 L/Kw year till 1982)	total revenues	Years	Gains minus expenses	D.C.F. year "0" = 1976	D.C.F. values progression
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1972	166,2	166,2	8,05	6,3	0.4	2,7	178,65	—	5,1	—	5,1	1972	— 173,55	— 236,09	— 236.09
1973	174,3	340.5	9,11	8,2	1,2	3,0	195,81	1,5	15,0	—	16,5	1973	— 179,31	— 225,88	— 461.97
1974	953,4	1293.9	37,80	53,0	2,5	20.0	1066,70	157,6	63.6	—	221,2	1974	— 845.5	— 986.19	— 1448.16
1975	1343,6	2637,5	128,10	72,0	16,3	25,5	1585,50	319,8	356,8	—	676,6	1975	— 908,9	— 999,79	— 2447,95
1976	5748.0	8835,5	283,0	144,0	66.0	64,0	6305.0	197.5	731,2	—	928,7	1976	— 5376,3	— 5376,3	— 7824,25
1977	4442.0	12827,5	379,0	264,0	92,0	85,0	5262,0	163.0	976,6	—	1139,6	1977	— 4122.4	— 3681.0	—11505,25
1978	2569,0	15396,5	566,0	384,0	67,0	105,0	3691,0	259,0	1231,0	513	2003,0	1978	— 1688,0	— 1346.0	—12851,25
1979	1549,0	16945,5	792,0	420,0	11,0	125,0	2897,0	303,0	1594,2	1026	2923,2	1979	+ 26,2	+ 19,0	—12932,25
1980	1249.0	18194,5	1048,0	432,0	15.0	145,0	2889.0	333.0	2176,0	1251	3760,0	1980	+ 871,0	+ 554,0	—12278,25
1981	1103.0	19297,5	1306.0	444.0	19.0	166.0	3038.0	241,5	2772,5	1476	4490.0	1981	+ 1452,0	+ 824,0	—11454,25
1982	687,0	20184,5	1532,0	444,0	21,0	187,0	3071.0	216,6	3201,6	1851	5269,2	1982	+ 2198,2	+ 1114,0	—10340,25
1983	673,0	20857,5	1694,0	444,0	24,0	195,0	3030 0	215,7	3596,1	1845	5656,8	1983	+ 2626,8	+ 1188,0	— 9152,25
1984	1375,0	22232,5	1823,0	444,0	26,0	204,0	3872,0	214,8	3915,1	1950	6079,9	1984	+ 2207,9	+ 892,0	— 8260,25
1985	2967,0	25199,5	1944,0	480,0	27,0	212,0	5630,0	147,9	4177,0	2100	6424,9	1985	+ 794,9	+ 287,0	— 7973,25
1986	3767,0	28966,5	2112,0	588,0	27,0	233,0	6727,0	141,0	4366,6	2595	7102,6	1986	+ 375,6	+ 121,0	— 7852,25
1987	1657,0	30623,5	2258,0	636,0	28,0	253,0	4832,0	157,2	4553,7	3000	7710,9	1987	+ 2878,9	+ 828,0	— 7024,25
1988	917,0	31540,5	2343,0	672,0	28,0	274,0	4234,0	151,2	4751,9	3075	7978,1	1988	+ 3744,1	+ 961,0	— 6063,25
1989	765,0	32305,5	2420,0	672,0	29,0	294,0	4180,0	130,5	4938,6	3135	8204,1	1989	+ 4024,1	+ 922,0	— 5141,25
1990	379,0	32684,5	2489,0	672,0	30,0	324,0	3894,0	115,8	5096,4	3195	8407,2	1990	+ 4513,2	+ 923,0	— 4196,25
1991	349,0	33033,5	2557,0	672,0	30,0	332,0	3960,0	110,1	5243,8	3255	8608,9	1991	+ 4648,9	+ 849,0	— 3369,25
1992	308,0	33341,5	2607,0	672,0	31,0	380,0	3998,0	75,0	5371,0	3300	8746,0	1992	+ 4748,0	+ 775,0	— 2594,25
1993	270,0	33611,5	2651,0	682,0	32,0	408,0	4043,0	72,3	5612,6	3330	9014,9	1993	+ 4971,9	+ 724,0	— 1870,25
1994	220,0	33831,5	2689,0	682,0	32,0	448,0	4071,0	58,2	5702,2	3345	9105,4	1994	+ 5034,4	+ 655,0	— 1215,25
1995	200,0	34031,5	2720,0	682,0	33,0	488,0	4125,0	50,1	5777,8	3375	9202,9	1995	+ 5079,9	+ 590,0	— 625,25
1996	170,0	34201,5	2750,0	692,0	33,0	528,0	4173,0	42,0	5846,1	3405	9293,1	1996	+ 5120,1	+ 531,0	— 94,25
1997	150,0	34351,5	2769,0	692,0	34,0	578,0	4223,0	33,6	5902,2	3420	9355,8	1997	+ 5132,8	+ 475,0	+ 380,75
1998	420,0	34771,5	2797,0	692,0	35,0	628,0	4572,0	25,2	5949,1	3450	9424,3	1998	+ 4852,3	+ 401,0	+ 781,75
1999	400,0	35171,5	2808,0	702,0	35,0	678,0	4623,0	16,8	5984,0	3450	9450,8	1999	+ 4827,8	+ 356,0	+ 1137,75
2000	90,0	35261,5	2816,0	702,0	36,0	728,0	4372,0	8,4	6008,6	3450	9467,0	2000	+ 5095,0	+ 336,0	+ 1473,75
	35 261,5	–	50 331,06	14 149,5	861,4	8 133,20	108 736,66	3 258,3	105 916,4	60 792	170 666,7		+ 61 930,04	+ 1 473,75	—

FIG. 14

TREND OF EXPENSES, PROFITS AND

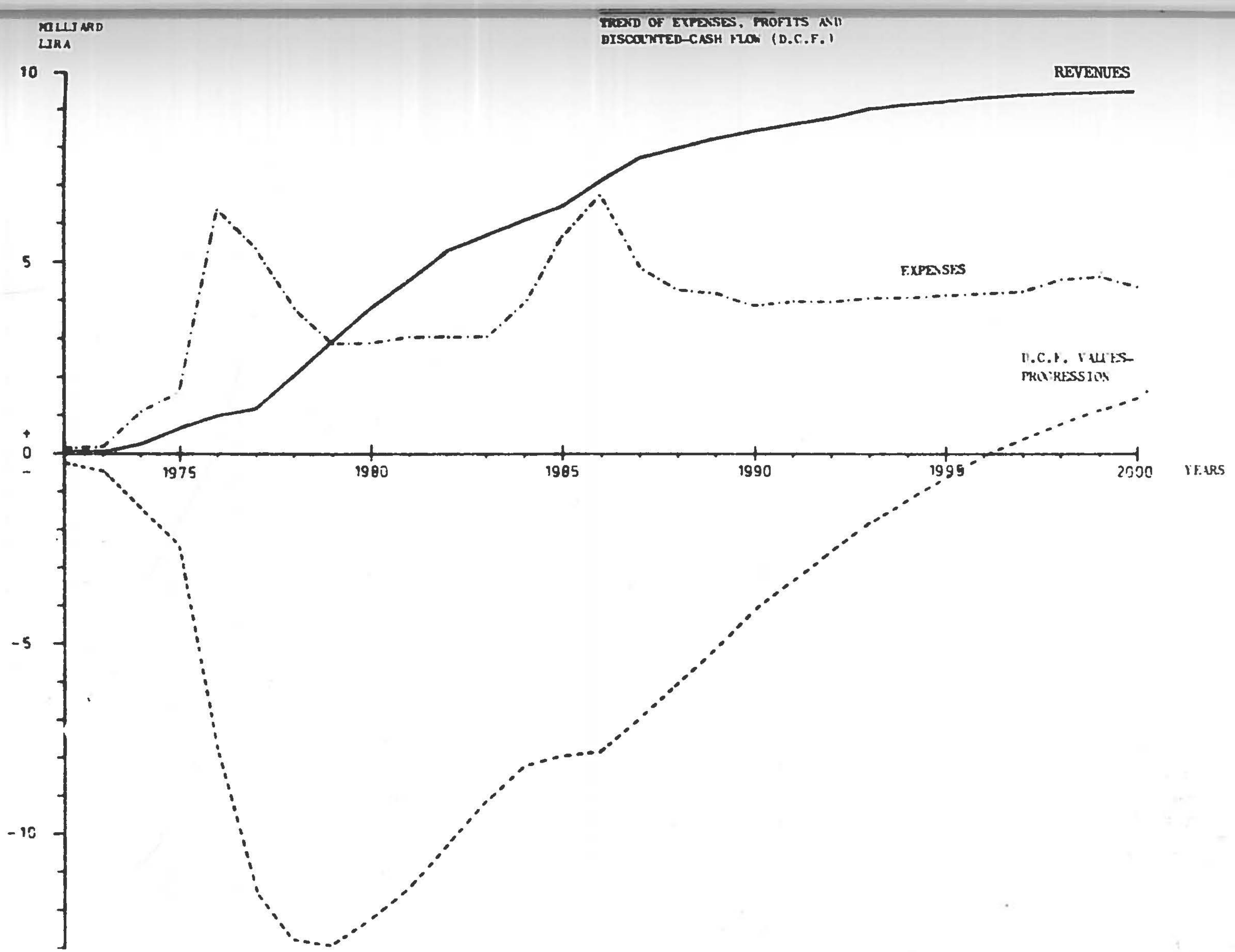

MILLIARD
LIRA
TREND OF EXPENSES, PROFITS AND
DISCOUNTED-CASH FLOW (D.C.F.)
10
5
+
0
-
-5
-10
REVENUES
EXPENSES
D.C.F. VALUES-
PROGRESSION
1975
1980
1985
1990
1995
2000
YEARS

FIG. 15

for t_i = 20°C
t_{em} = 6,073°C Q = 2544 degree/days/year
t_e = 13°C

for t_i = 19°C
t_{em} = 5,4°C Q = 2271 " " "
t_e = 12°C

That is "Q" value varies from 4,1% for each external limit temperature degree and from 7,70% for each degree of internal temperature.

- specific demand for hot water : 9 Mcal/cm.year

Average requirement

* domestic use inside houses			
- heating only	41	Mcal/cm.year	
- heating and hot water	50	"	" "
* use different from domestic	30	"	" "
general average	41,4	"	" "

The domestic use represents 70% of the total.

Choice of the areas to be supplied with heat

Areas with existing buildings having a density of more than 1,5 cm/sm (30 Gcal/h.km^2) and new areas with more than 1 cm/sm (20 Gcal/h.km^2) are economically convenient to be supplied with heat. **(Editor's Note: Fig. 2.2 referenced here deleted because of unsatisfactory reproduction quality.)**

For the development of the connected volumes for the period 1972-2000 see Fig. 2.3.

2.2. - THE HEAT PRODUCTION FOR URBAN HEATING USE

The heat can be directly produced by the fuel combustion or by the heat recovery at low temperature (degraded) extracted by a primary process of transformation in electrical or mechanical energy (combined power plant or power and heat supply station).

- external reference limit temperature (statistically the starting of the heating season happens between 12 and 15°C depending on real personal and climatic factors i.e. humidity)	
- heating period (N)	182 d/y
- external average temperature during the heating period (t_{em})	6,073°C
- daily average temperature (min)	- 10°C
- average humidity during winter period	80%
- heating period (the scattering is considerable : starting from the 5th till 25th of October; turn off from the 15th April till the 5th of May)	15 october÷16 april -

Specific heat requirement

The specific heat requirement for space heating is related to the heated gross volume (external volume from the ground to the gutter).

- specific heat capacity from 40 to 16 kcal/cm.h passing from 500 to 30.000 cm
- yearly specific demand 30 ÷ 60 Mcal/cm.year

The heating demand is measured using the degree-days/year method definite as the product of the number of the heating days in the year (N) and the difference between a stated average internal air temperature of the heated building and the arithmetic mean of the average external daily temperature (t_{em}) inferior to the reference limit temperature (t_e)

$$Q = N\,(t_i - t_{em})$$

if :

t_i = 19°C stated internal temperature in °C

t_{em} = 6,073°C the arithmetic mean of the average external temperature in °C

t_e = 13°C reference limit temperature °C

N = 182 number of heating days

for Brescia it results : Q = 2362 degree/days/year

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cm = cubic metre

sm = square metre

DEVELOPMENT OF THE CONNECTED VOLUMES FOR THE PERIOD 1972 - 2000

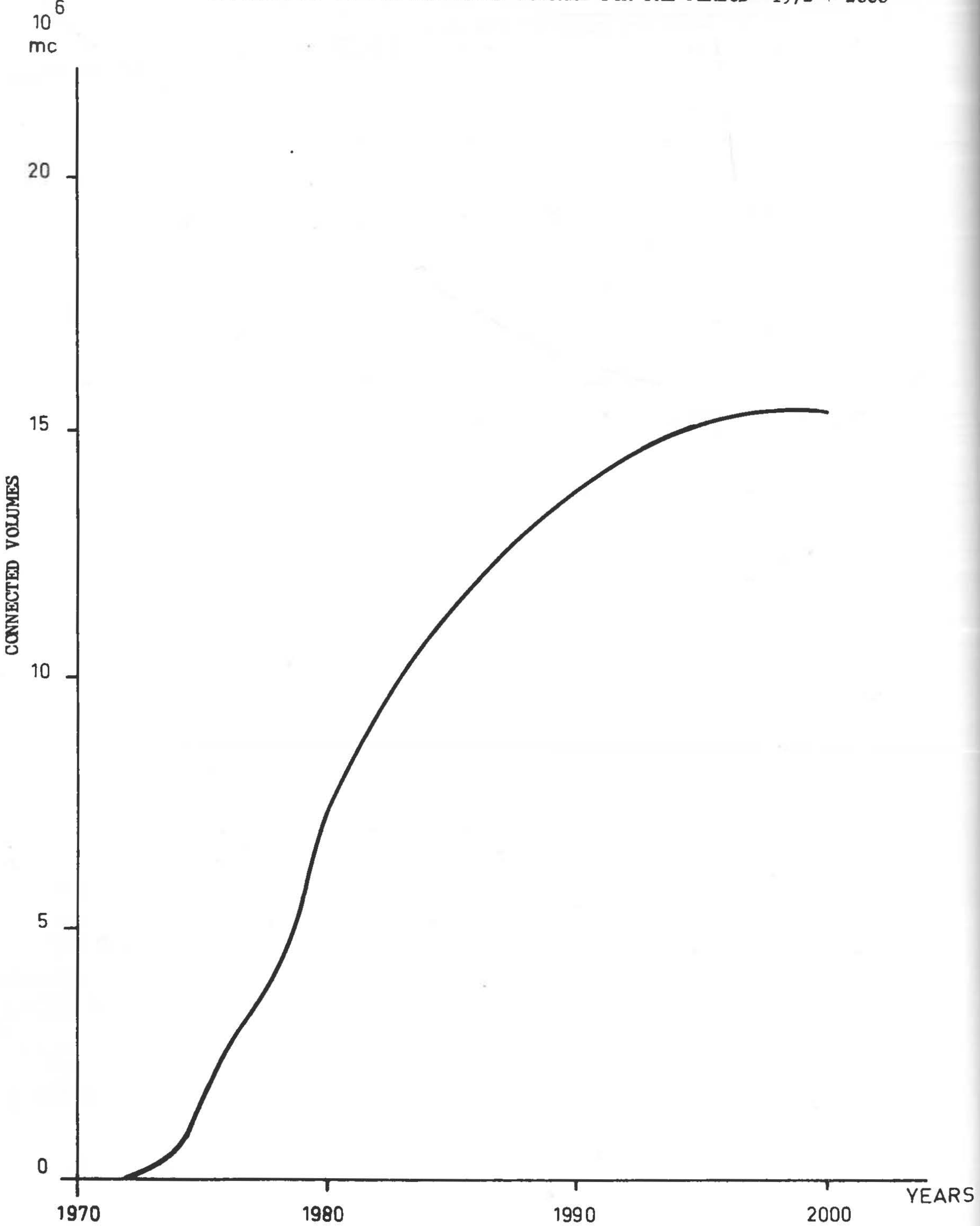


FIG. 2.3

Different combined power stations used :

- steam generator - back pressure turbine and/or controlled extration and condensing;
- gas turbine with recovery boiler from exhaust gas
- diesel engine with heat recovery from discharged gas

Fig. 2.4. - Comparison of investiment cost amongst various type of heat and power plants production

In Brescia about half of the peak load shall be produced by combined group and half by single boilers.

The heat delivered over the 50% of the peak load represents about the 15% of the yearly total heat.

Fig. 2.5. - Semplified diagram of heat required and supply temperature

Characteristics of the heat carrier

heat carrier :	super heated water
nominal pressure	- 16 bar
working pressure	- 14 bar

temperature :

supply nominal	140°C
max. working temperature	150°C
designed temperature	160°C
min. "	90°C
return - nominal	60°C
" max	70°C

The supply temperature varies with the external temperature.

The water used is demineralized and slightly additivated with trisodium phosfate and deoxidizer.

Final project of the production plant

Single boilers (in brackets the years in which the boilers shall came into service)

2 x 15	Gcal/h	(1974 - 75)	
2 x 55	"	(1975 - 1978)	pressure from 12 to 17 bar with water/steam exchanger
1 x 70	"	(1981)	

COMPARISON OF INVESTMENT COSTS AMONG VARIOUS TYPES OF HEAT AND POWER PRODUCTION PLANTS

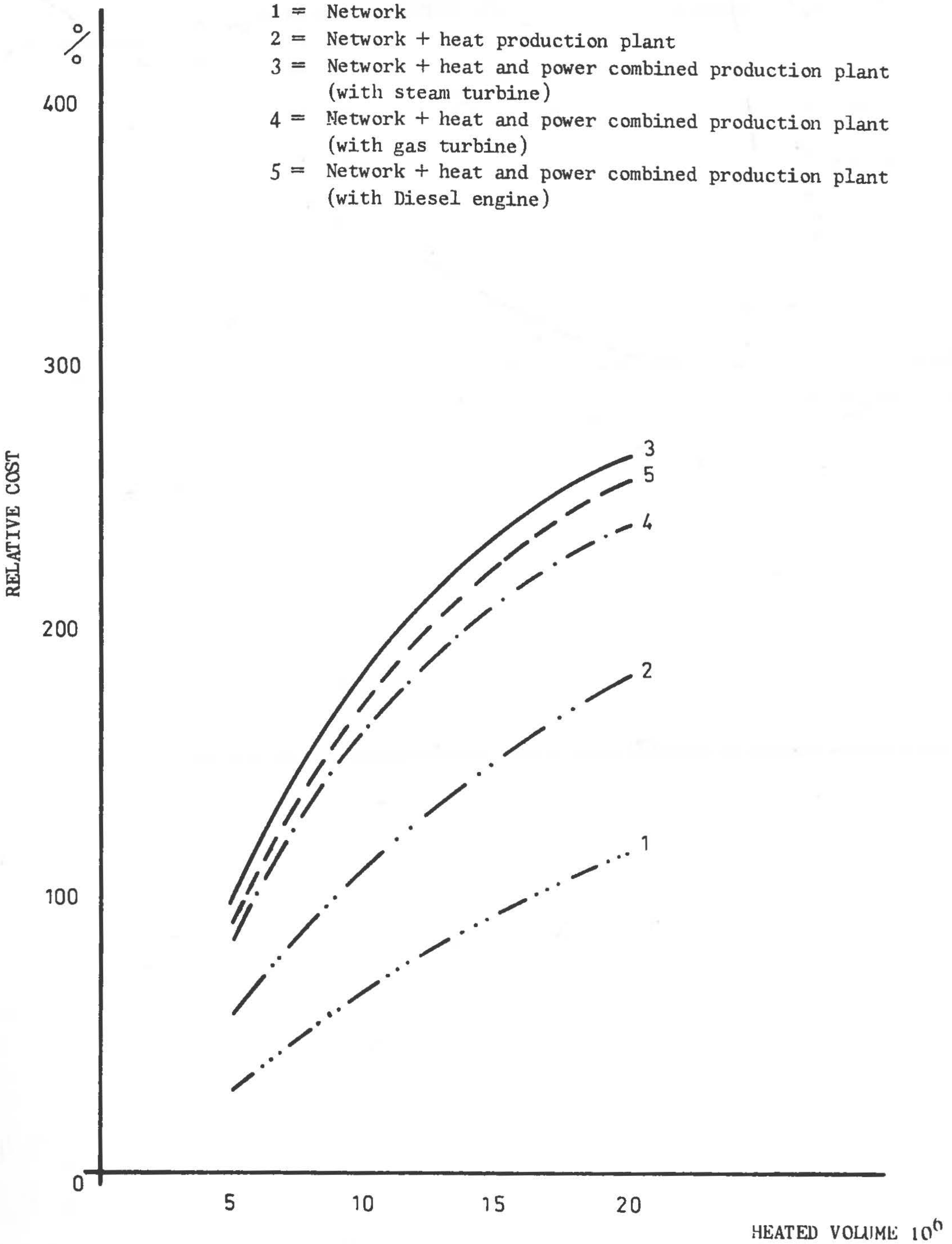
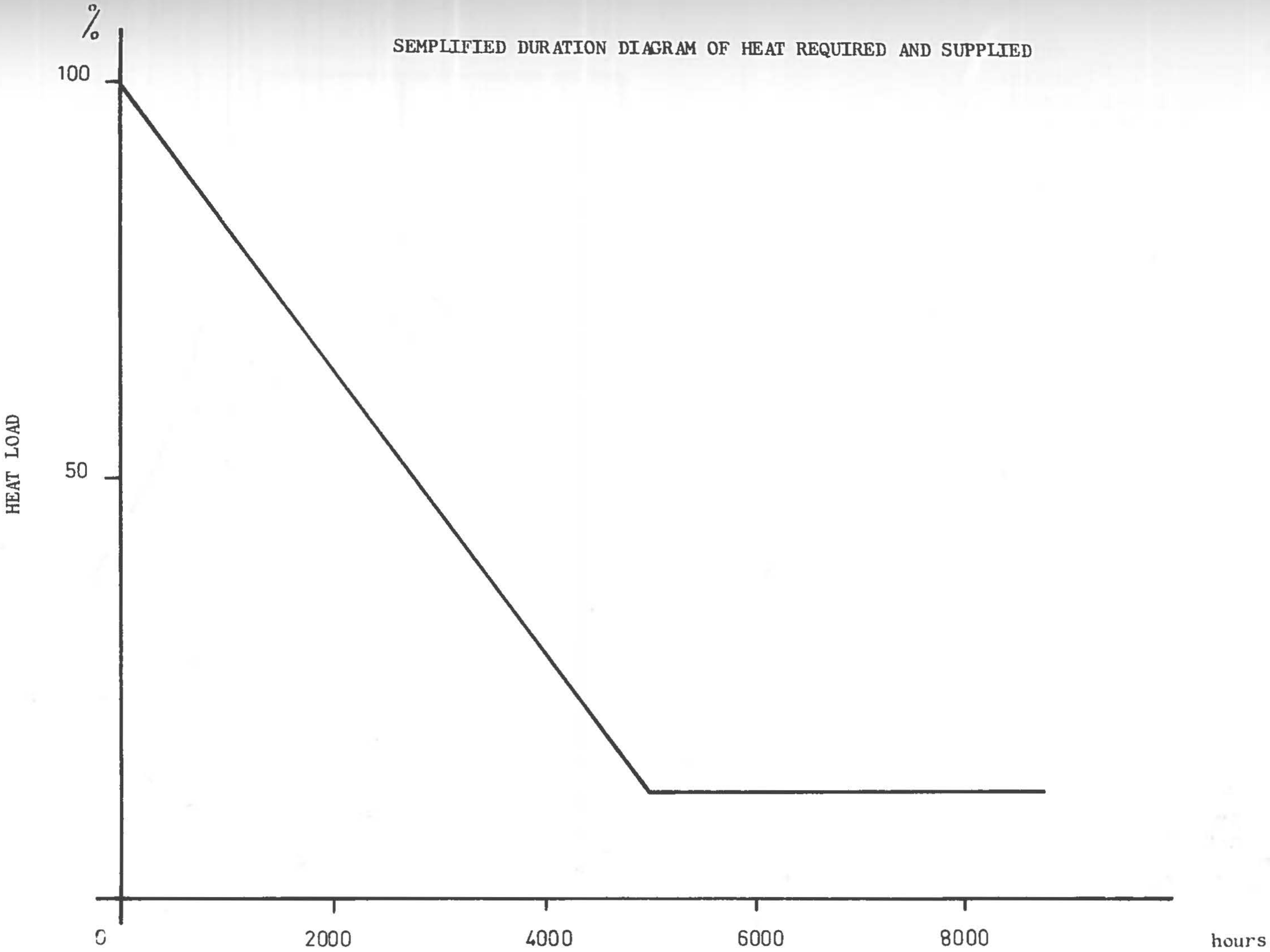


FIG. 2.4



SEMPLIFIED DURATION DIAGRAM OF HEAT REQUIRED AND SUPPLIED

FIG. 2.5

The different sizes chosen shall permit the functioning under optimal conditions during the various season and loads growth.

Combined power station

two similar groups (date of entering into service in 1978 and 1986)

each of : 30 MW + 75 Gcal/h nominal

Principal characteristics

- output at continuous max load	175.000 kg/h
- nominal temperature of the superheated steam	515°C
- nominal pressure of the steam at the superheater outlet	99 ate
- net efficiency at nominal load :	
steam generator	94,2%
turbine	99,61%
generator at power factor 0,8	97,9%
auxiliary	94,61%
total efficiency	86,91%
- mechanical power at the turbine axis	30.296 kW
- electrical power at the generator terminals	29.660 "
- apparent power of the generator	39.500 kVA

Fig. 2.6 = semplified diagram of the whole power plant for the first phase (combined with 30 MW + 75 Gcal/h) simple boilers 2 x 15 + 1 x 50 Gcal/h

2.3.- REMUNERATIVENESS OF THE COMBINED PRODUCTION IN COMPARISON WITH THE SINGLE HEAT SUPPLY

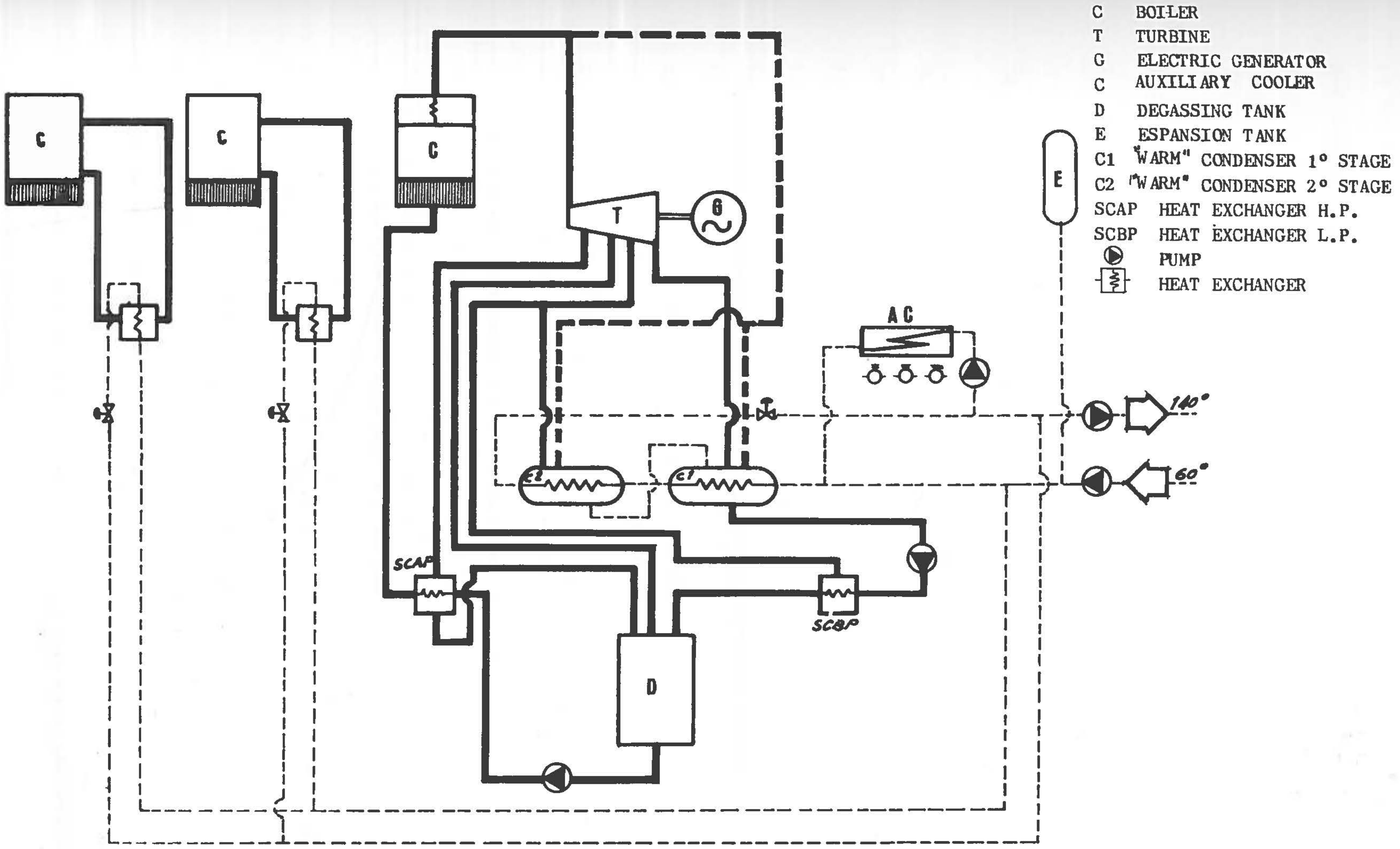
Efficiency (definitions UNIPEDE - UNICHAL)

1) power plant

$$\eta^{o} = \frac{860}{C_c} = \frac{860}{\frac{C_o}{E}} = \frac{860.E}{C_o}$$

C_o = fuel calories burnt

E = produced electricity (net or gross)



SEMPLIFED FLOW SCHEME OF THE HEAT AND POWER PLANT FOR THE FIRST STAGE
(POWER AND HEAT 30 MW AND 75 Gcal/h ONLY 2x15 + 1x55 Gcal/h)

FIG. 2.6

2) combined(or recovery) system

For the calculation of the efficiency it is not considered as consumed for the electricity production, the thermal energy contained in the extracted warm fluid for the heat supply

as the product of the efficencies of the various components or

- $\eta = \frac{860\ E}{C - \frac{Q}{\eta_c}}$ $\qquad C = \frac{860\ E}{\eta} + \frac{Q}{\eta_c}$

Where : Q = thermal energy in kcal transferred to the network, net of the internal plant utilization

η_c = boiler efficiency

The comparison is made according to the following conditions :

a) single form = the same heat quantity produced with single boilers at low pressure and the same quantity of energy produced by condensation thermoeletric plants;
this is called reference system

b) combined form = contemporary production of heat and electric in a same plant;

The comparison is made between the combined plant and the single plants or reference system, that is between a) and b)

The foundamental parameters of the combined production are :

- heat quantity contained in a burnt fuel (Gcal) = C
- "C" quantity transformed into heat (Gcal) = Q
- "C" quantity transformed into electrical energy = E
- electric factor or heat electricity combination coefficient (kWh/Gcal) $i = \frac{E}{Q}$

In the reference system for the single production, the same quantity shall be indicated with zero index. In this case C_0

is the fuel calories quantity necessary to produce with single separated plants, the same quantity of electricity E and of heat Q, as for the combined plant :

$$C_o = C_e + C_q$$

where :

C_e = represents the fuel heat consumption necessary to produce E in an ordinary thermoelectric plant

C_q = represents the fuel heat consumption necessary to produce Q in single low pressure boilers.

The combined production electricity-heat allows a saving of fuel heat measured from the difference $R = C_o - C$.
If the difference is positive, an affective benefit is obtained, if it is negative a loss.
To be able to judge the importance of the combined production it is sufficient to compare the fuel-heat R saving respectively with the fuel heat C_e necessary for the production of electricity only in a single plant, or the heat C_q produced by single boilers.
More in general and with a more rational physical meaning it is possible to relate the fuel saving to the calories which would be necessary to produce the same electricity and heat with separate plants of the reference system.

This relation is designated "r"

$$r = \frac{C_o - C}{C_o} = 1 - \frac{C}{C_o}$$

and it can be useful to compare each other the several type of combined plants with the reference system.

---

fuel heat consumption = fuel-calories

From the phisical point of view a combined plant is well distinguished by :

- the fuel-calories necessary to produce the E electricity quantity
- the fuel-calories necessary to deliver heat into the network Q
- the rate Z $= \dfrac{E}{Q}$ or electricity factor
- the rate r $= \dfrac{C_0 - C}{C_0}$ or economy index of the fuel

Two combined plants are equivalent if both index are the same. The consumption fuel-calories C_0 for the referring plants can be indicated with : $C_0 = \dfrac{Q}{\eta_c} + E \cdot C_{SE}$

where :

η_c = low pressure boiler efficency (for heat production only)

C_{Se} = specific heat consumption (kcal/kWh) necessary to produce E in a condensing power plant $C_{Se} = \dfrac{860}{\eta}$

As practical reference values are indicated :

$$\left.\begin{array}{l}\eta_c = 0{,}92\\ C_{Se} = 2.300\ \text{kcal/kWh}\end{array}\right\}\ \begin{array}{l}\text{referred to the net heat value}\\ \text{of the fuel}\end{array}$$

C_{SE} = considers the electric energy losses (about 2%) caused by the transport from a condensing power plant situated far away from a city.

The net specific consumption in H.V. at the outlet plant of 2,250 kcal/kWh rises therefore when reaching the city, where the comparison combined plant is situated, about 2,300 kcal/kWh. Here is an example, in 1974 the average specific consumption of the ENEL plants with unitary capacity more than 50 MW was of 2,347 kcal/kWh(in addition: the transmission losses above the 3%.)

DEFINITION OF REVENUES

In theory the calculation system of the profits can be simply described as follows: let us consider a combined production plant (whose parameters, likewise to the treatment of the physical aspects, are indicated without index) with a system of reference (whose parameters are indicated with o index) each of them able to supply the same electricity and heat service with the same restraints and limitations.

We shall indicate with I and Io the relative investiments referred to the year 0 and with E and E_0 the relative yearly running costs (fixed and variable).

The combined production profits or gains in comparison with the separate productions the years n considered, shall be :

$$G = I_o + \sum_1^m \frac{E_o}{(1+i)^n} - \left[I + \sum_1^m \frac{E}{(1+i)^n} \right]$$

m being the economical life period of the combined plant.

In case (as it is likely) the investments are not completly carried out in the referring zero year, the same should be used for such a year trough the usal relation $\frac{1}{(1+i)^n}$ of actualization (the method used more in general to determine the profit can be individualized in the so-called "discount cash flow" method)

(Editor's Note: Fig. 2.7 is not referenced in text and was deleted because of unsatisfactory reproduction quality)

Fig. 2.8 - Basic data of the combined group of Brescia plant (30 MW and 75 Gcal/h)

Fig. 2.9 - Fuel calories index - saved by combined production (indicative)

BASIC DATA OF THE COMBINED GROUP OF BRESCIA PLANT
(30 MW AND 75 Gcal/h)

- turbine steam inlet : pressure 95 bar, temperature 510°C
- turbine steam flow : 173 t/h

Electrical load	%	25	50	75	100
a) mechanical power on the shaft network water temperature return 60°C delivery 140°C	kW	8.224	15.576	22.896	30.296
b) electrical power generator output (same condition pt a)	kW	7.763	15.081	22.340	29.660
c) auxiliary power	kW	1.090	1.170	1.300	1.600
d) net nominal electrical power E (P_e)	kW	6.673	13.911	21.040	28.060
e) net heat output (P_q)	Gcal/h	27,901	41,811	57,167	73,768
f) net efficenty power production					
- boiler = η_c	%	92,77	93,74	94,3	94,2
- turbine = η_c	%	98,56	99,24	99,48	99,61
- generator cosfì 0,8 = η_a	%	94,4	96,82	97,57	97,9
- auxiliary = $\eta_{aux.}$	%	85,96	92,24	94,18	94,61
- total ca = η	%	74,19	83,30	86,20	86,91
g) specific consumption fuel	g/kWh	119,74	106,94	103,06	102,22
heat	kcal/kWh	1159,83	1035,18	997,61	989,48
h) fuel consumption (bunker C 9680 kcal/kg)	kg/h	3.960	6.150	8.460	11.028
i) fuel calories consumption C	Gcal/h	38,33	59,53	81,89	106,75
l) fuel-calories consumption of reference plants C_o	Gcal/h	45,67	77,44	110,53	144,72
m) saving index $r = \frac{C_o - C}{C_o}$	Gcal/h	0,161	0,231	0,259	0,262
n) fuel calories utilization (total efficency) $U = \frac{E.860.10^6+Q}{C}$		0,878	0,903	0,919	0,917
o) fuel-calories saving $R = C_o - C$		7,34	17,99	28,64	37,97
p) electric factor $Z = \frac{E}{Q}$ (net) $\frac{kWh}{Gcal}$		239	333	367	380

N.B. = Z is defined with the power values

$$Z = \frac{P_e}{P_q} \; \frac{(kW\quad)}{Gcal/h} = \frac{E}{Q} \; \frac{kWh}{Gcal}$$

FIG. 2.8

STEAM COMBINED GROUP

FUEL CALORIES INDEX SAVED BY COMBINED PRODUCTION (INDICATIVE)

$$\eta = \frac{G_o - G}{G}$$

SINGLE PLANTS FOR COMPARISON:

POWER PRODUCTION 2300 Kcal/KWh

BOILER EFFICIENCY b.p. 0,92 (HEAT PRODUCTION ONLY)

STEAM INLET CONDITION:

25 ate : 350 °C
65 ate : 470 °C
90 ate : 520 °C
120 ate : 535 °C

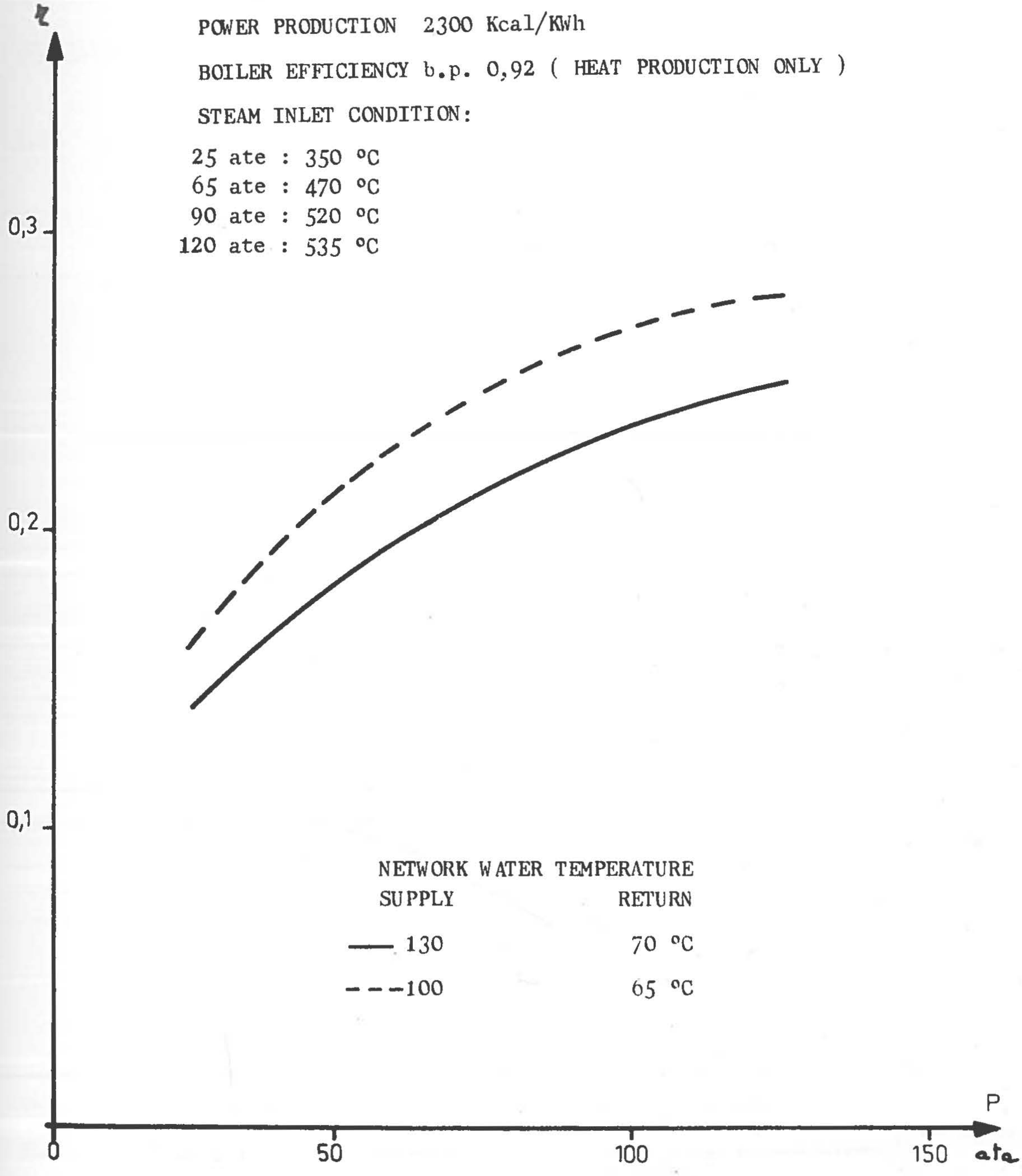


FIG. 2.9

2.4.- ADDITIONAL PARTS OF THE PRODUCTION PLANT

The pumping station : equipped with pumps at variable speed- two by two in series ; one on return intake and the other pressing on the flow; between the two pumps are the expansion vessel and the exchangers.

Four pumps of 1000 cm/h and 4 of 2000 cm/h each of head max 75 m (total in series 150 m) are in program, as well as 2 expansion vessels to compensate the network volume changes, each with a 150 cm geometrical volume to NP 16.

In the expansion vessel the min. static pressure is kept with nitrogen so as to avoid in any point of the network the vaporization (at 150°C 4 bar plus 2 bar for the level difference between the plant and the highest point of the network).

Heat accumulators and unit heaters : they are necessary to "separate" the electric and heat peak demand.
The volume of the network constitutes a stockage too.
A more general effect of "separation" is obtained through an artificial cooling of the network water with heat dispersion as well.

Primary energy supply

Primary energy comes from natural gas and/or fuel oil.
The gas comes from the local gas network station 100 m away; the fuel oil is carried by fuel truck into a 5.000 cm storage tank.

2.5.- URBAN SOLID REFUSE INCINERATION

The plant is provided for the construction of a possible urban solid refuse incinerator with heat recovery of the ordinary and combined type.

The district of Brescia (city + hinterland) has a population of more than 300.000 inhabitants with a refuse production during the summer periods of more than 250 t/d, for the heat recovery of which it is necessary that the network can distribute all the year round at least 15 Gcal/h (daily average), that means having to put into the network during the peak winter heat demand about 150 Gcal/h, that is to have more than 7 million of cm of building connected so as not to disperse heat (this is part of the 1980 program).

THE DISTRIBUTION

3.1. - Hot water distribution

The network has been planned on the base of the existing or foreseen buildings with the following principles :

- water volume with Δt = 60°C increased of 20%
- contemporaneity coefficient variable from 1, for small diameters, to 0,7 for large ones
- open net
- pressure losses : about 10 m/km
- speed increasing according to the diameter from 1 to 3 m/sec.
- viscosity according to the nominal temperature
- heat losses 9% year (at full operation)
- nominal pressure 16 bar
- proof pressure 24 bar
- ΔP min 1,5 bar
- designed temperature 160°C

The network is of a closed circuit type with two equal size pipes : one for supply and the other for return. At about half way distance there is a booster pumping station.

The pipeline is made of steel API 5L grade B or equivalent. The welginds are sample radiographed.

The pipeline is laid in :

a) reinforced concrete trench ducts without the possibility of inspection

b) in existing cavaedia

c) in steel or asbestos-cement jackets (pipe in pipe)

Pipelines are insulated in fiberglass with thickness according to the diameter

ø		50	80	100	150	200	250÷300	350÷450	500
supply	mm	50	60	60	70	80	90	100	100
return	mm	40	40	50	50	50	60	60	70

Expansions are naturally compensated or by angular or axial joints; they are calculated for a range from + 160°C to -10°C.

All the components, valves and fittings are made of steel.

Gripping rings and peak boilers, placed in appropriate points, can increase the network capacity.

Fig. 3.1. - Network scheme (North : dimensioning and verifics)

3.2. - Network development forecast; unitary costs for pipe laying

Fig. 3.2. - Network planning development

Fig. 3.3. - Planning development maps (not included in the report)

3.3. - Method of pipe laying

New districts : the laying of the pipe is programmed with all the other services (water, electricity, etc)

Existing districts : the laying of the pipe is carried out according to the development plant - Expecially in the historical centre, great problems arised because at the narrow and of other existing services which often had to be removed.

The works are normally carry out "turn Key" type.

NETWORK SCHEME

DISTRICT HEATING NETWORK SCHEME:
NORTH ZONES

Ø	DIAMETERS IN mm
Q	FLOW IN mc/h
H	PRESSURE DROP IN m H_2O
V	VELOCITY

PRESSURE DROP

A-B	78,50 m
A-C	79,30 "
A-D	81,38

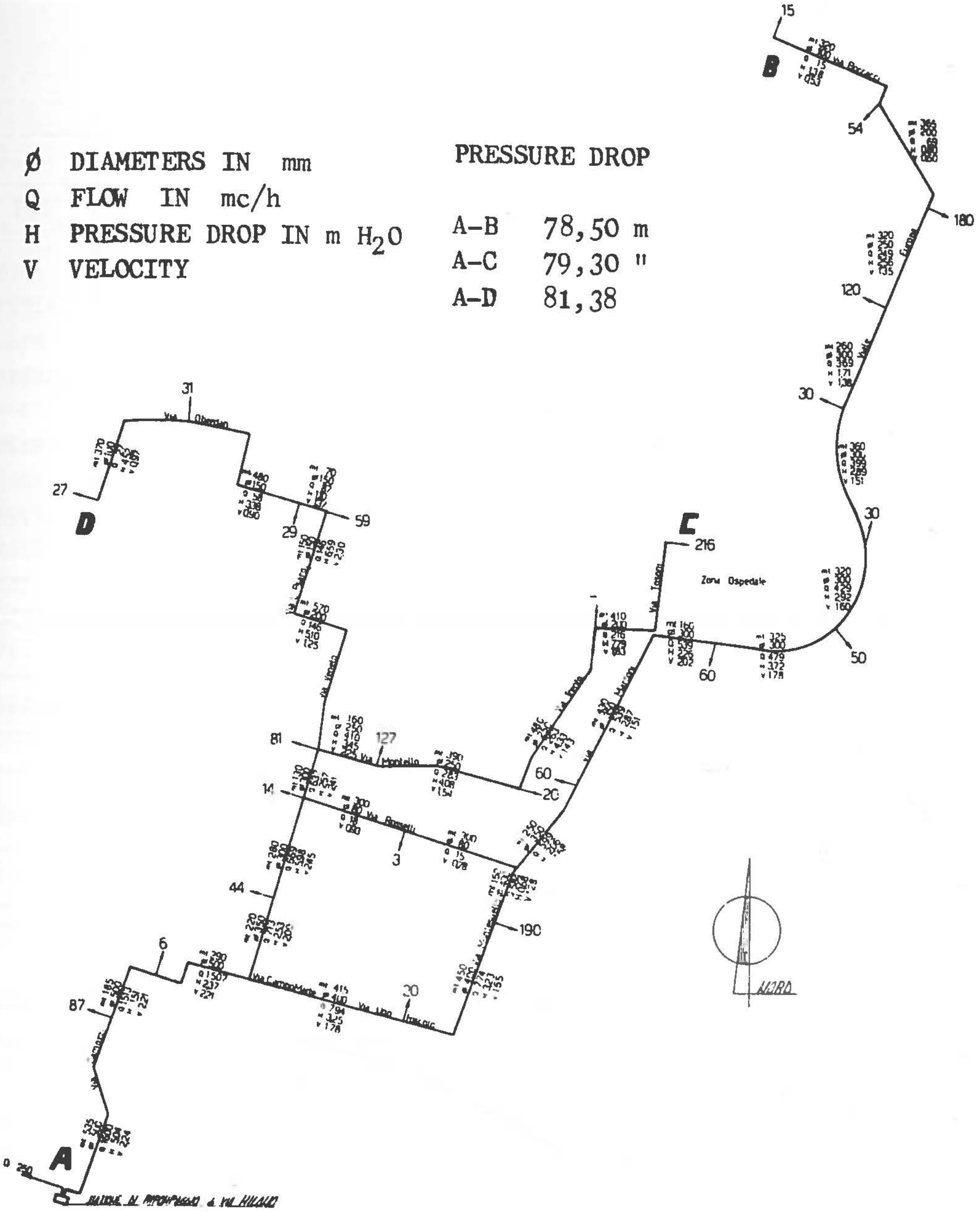


FIG. 3.1

NETWORK PLANNING DEVELOPMENT

(DOUBLE PIPES, CONNECTIONS EXCLUDET)

DIAMETER in mm	VALUE al 31.12.75	PREVISIONS						
		1976	1977	1978	1979	1980	Complet	TOT
50	50	230	180	210	260	500	1880	3310
80	687	430	1120	1870	895	540	6383	11925
100	1393	790	930	1280	1090	930	3527	9940
150	2684	940	1410	920	840	400	3751	10945
200	1916	570	350	160	1350	490	2669	7505
250	1166	1170	410	—	1240	600	3734	8320
300	—	—	160	—	—	490	1015	1665
350	921	—	2510	800	440	700	334	5705
400	526	820	539	480	—	—	—	2365
500	—	—	980	—	—	—	—	980
600	646	1690	—	—	—	—	1600	3936
700	145	—	—	—	—	—	—	145
Tot.	10.134	6.640	8.589	5.720	6.115	4.650	24.893	66.741

FIG. 3.2

Fig. 3.4. - Unitary investment costs - pipelines heat transport

Fig. 3.5. - Some **photos** of the pipelines during installation (not included)

3.4. - House connections

The distribution is of the indirect type : the heat supply to the user is done only through exchangers.

The unit consisting of the heat exchange to the user is called "substation"

Fig. 3.6. - Supply mains and secondary temperature as function of external temperature

Fig. 3.7. - Consumer's substation scheme (space heating and hot water)

The substation in new buildings are generally installed directly by building firm, while in the existing buildings provides the Municipal Enterprise.

Fig. 3.8. - Investment costs for pipes and for the whole system.

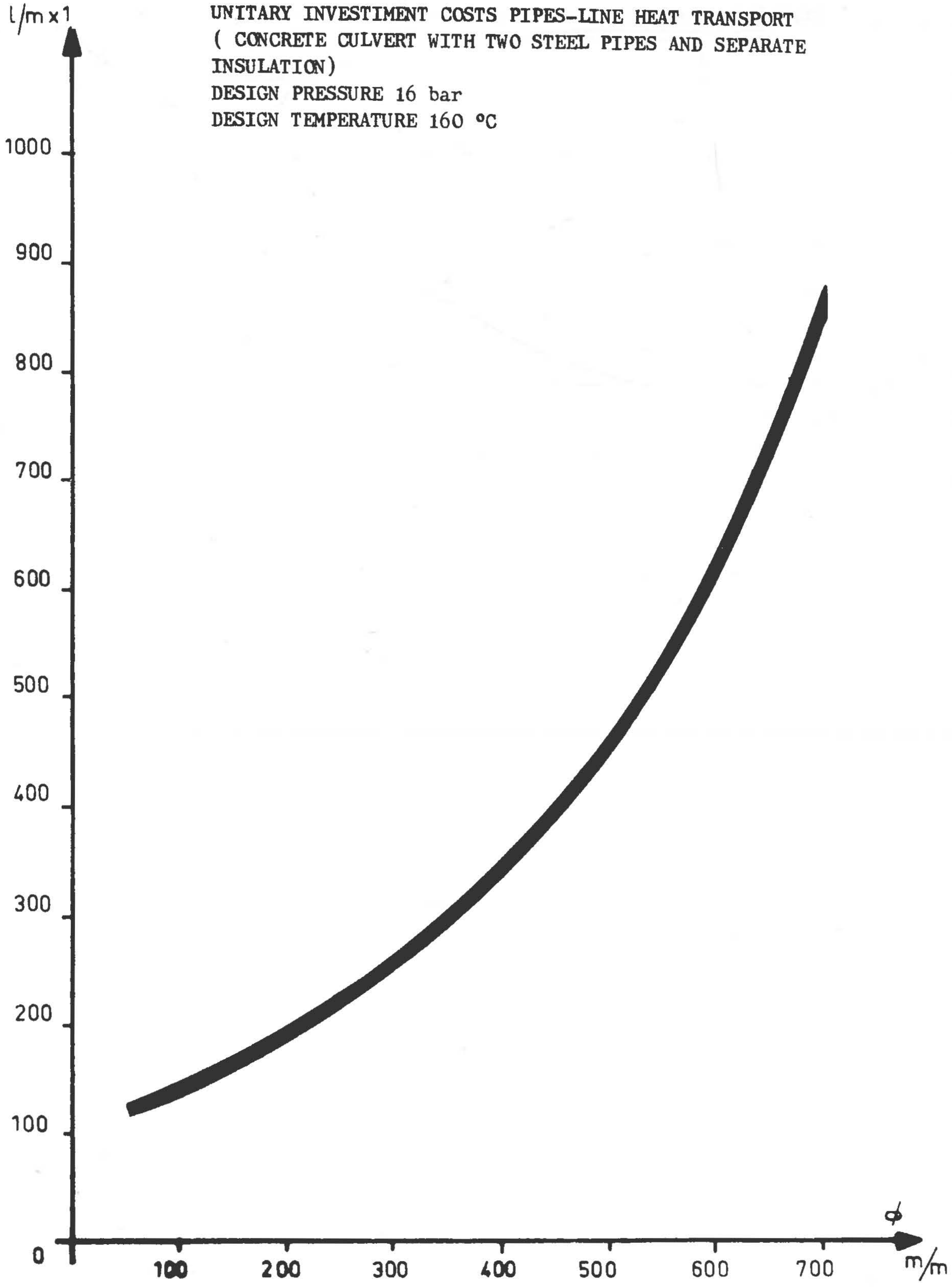
3.5. - Heat transport capacity of the heat carrier superheated water in comparison with the gas heat carrier.

Pipeline : Ø 300 mm

Superheated water ΔT = 60°C
V = 2,5 m/sec
capacity = 41 Gcal/h

Natural Gas p.c.i. = 8.200 kcal/cm
P = 220 mmHg
ΔP = 20 mmHg/km
capacity = 5,75 Gcal/h

Fig. 3.9. - Pipeline heat capacity



UNITARY INVESTIMENT COSTS PIPES-LINE HEAT TRANSPORT
(CONCRETE CULVERT WITH TWO STEEL PIPES AND SEPARATE INSULATION)
DESIGN PRESSURE 16 bar
DESIGN TEMPERATURE 160 °C

FIG. 3.4

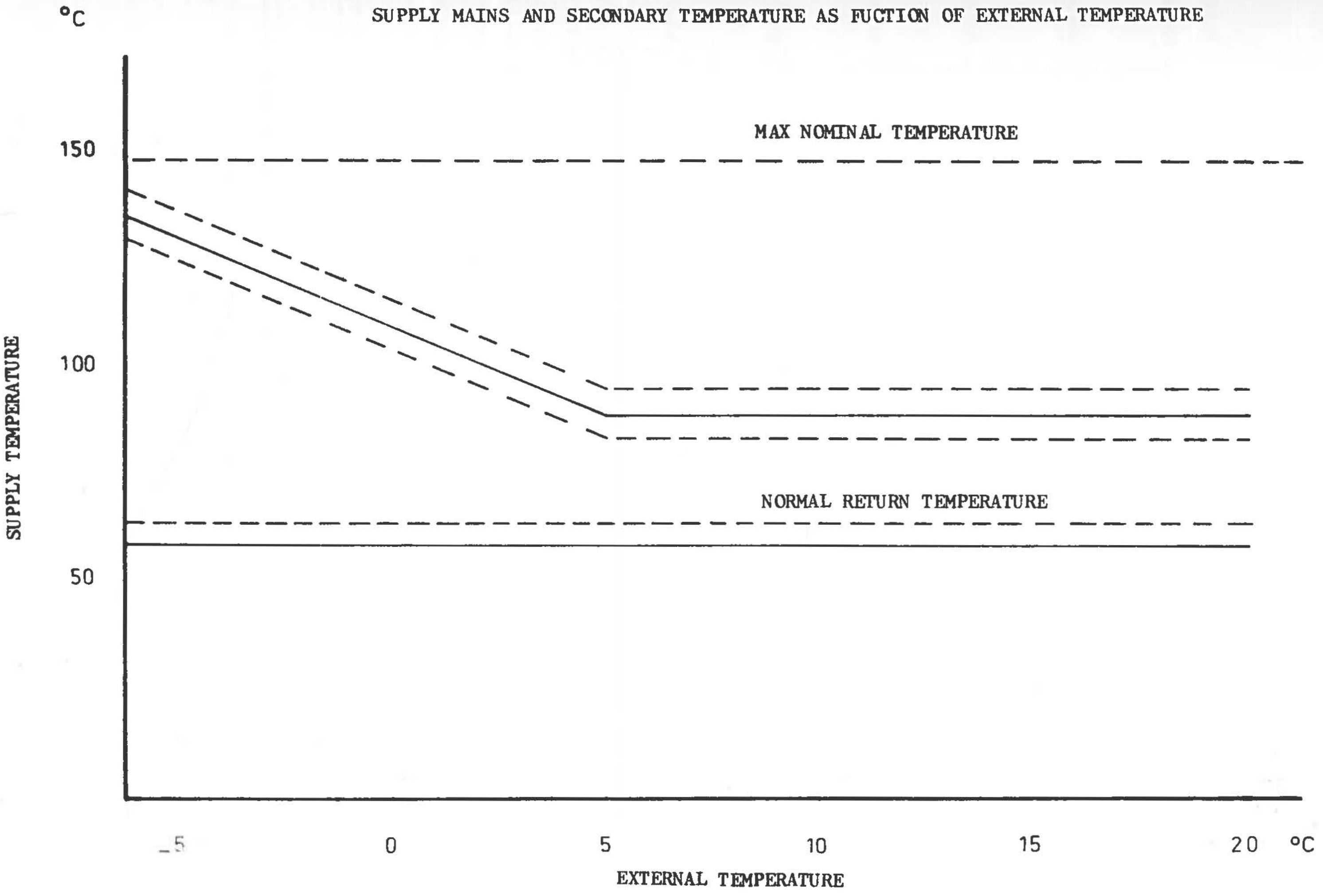
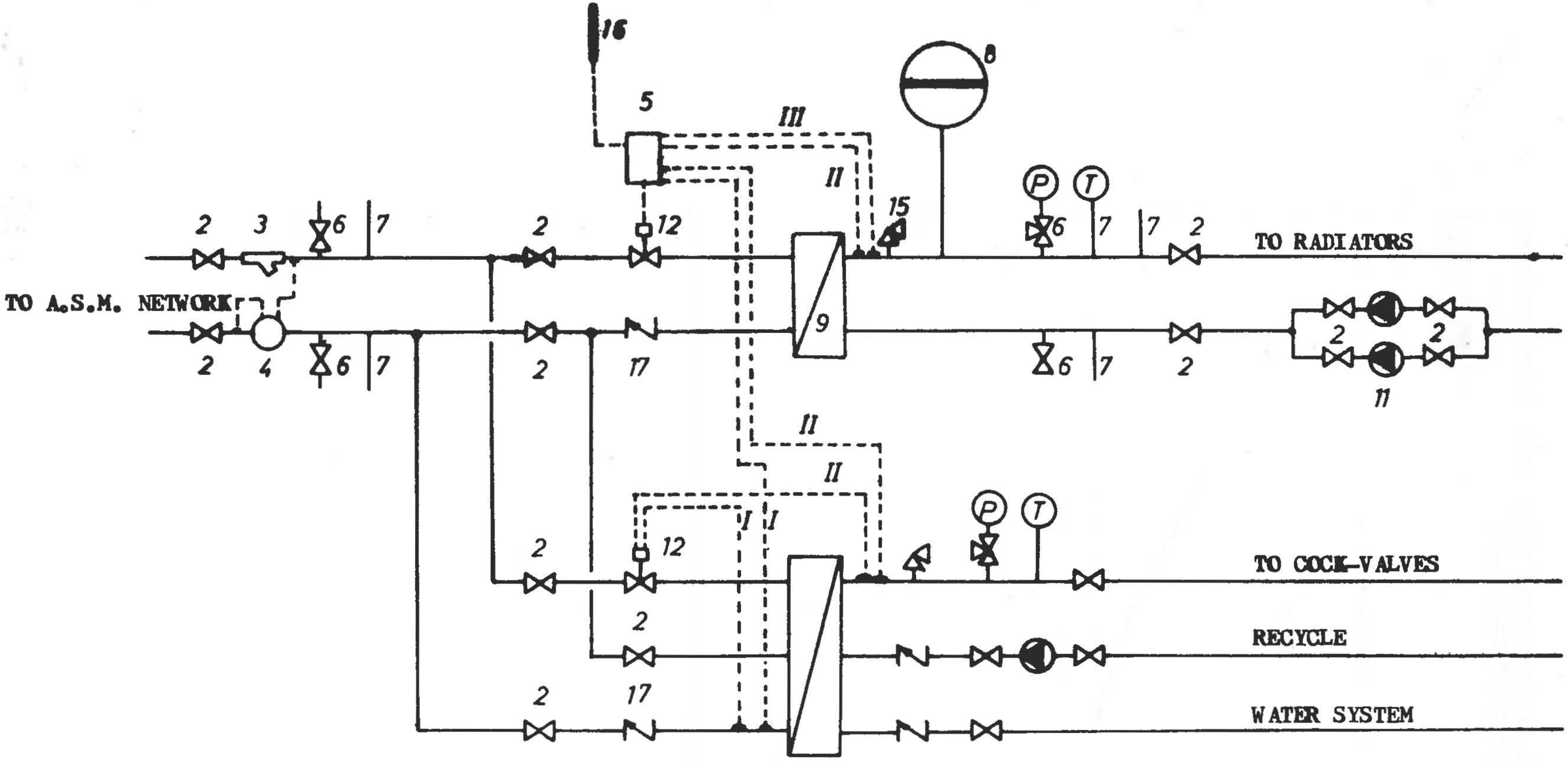

SUPPLY MAINS AND SECONDARY TEMPERATURE AS FUCTION OF EXTERNAL TEMPERATURE
°C
150
100
50
SUPPLY TEMPERATURE
MAX NOMINAL TEMPERATURE
NORMAL RETURN TEMPERATURE
-5
0
5
10
15
20
°C
EXTERNAL TEMPERATURE

FIG. 3.6



CONSUMER'S SUB-STATION SCHEME
(SPARE HEADING AND HEAT WATER)

FIG. 3.7

INVESTIMENT COSTS PIPES AND FOR THE WHOLE SISTEM

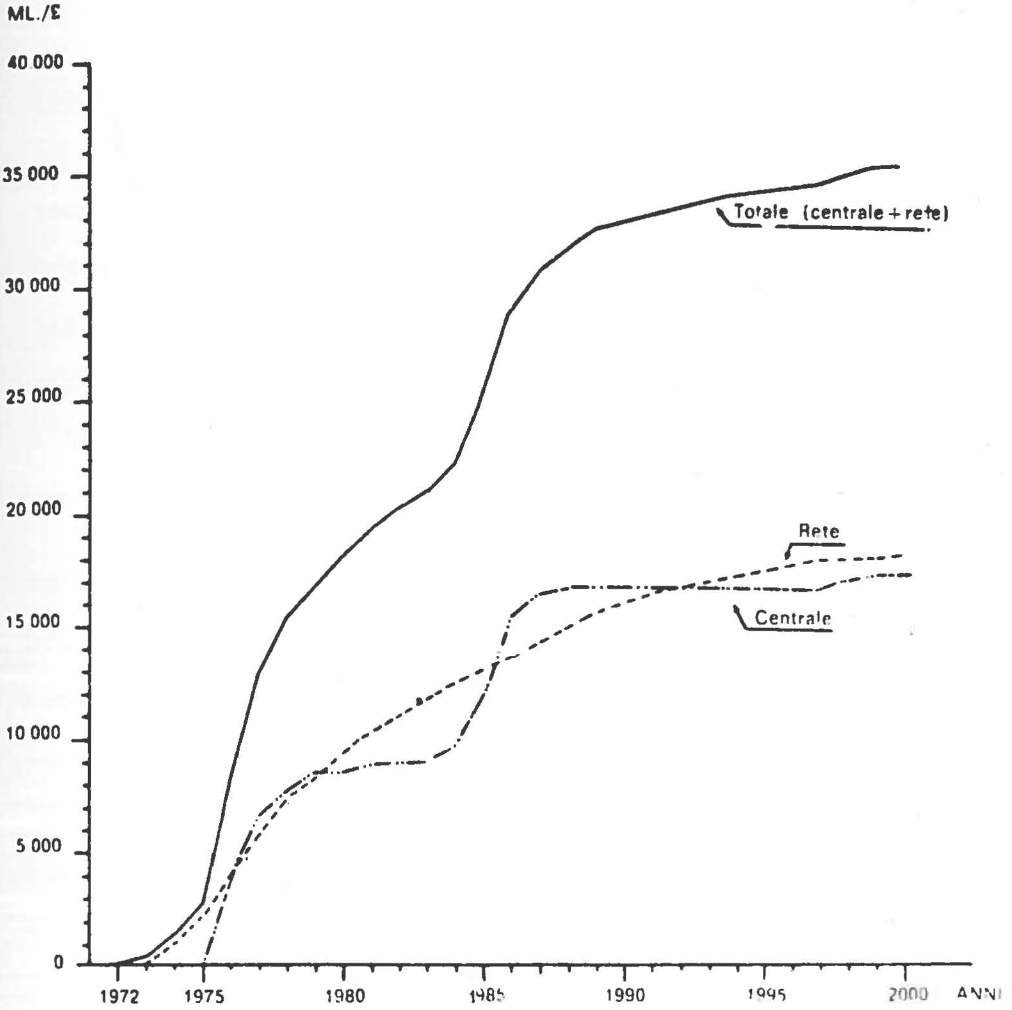


FIG. 3.8

PIPE-LINES HEAT CAPACITY

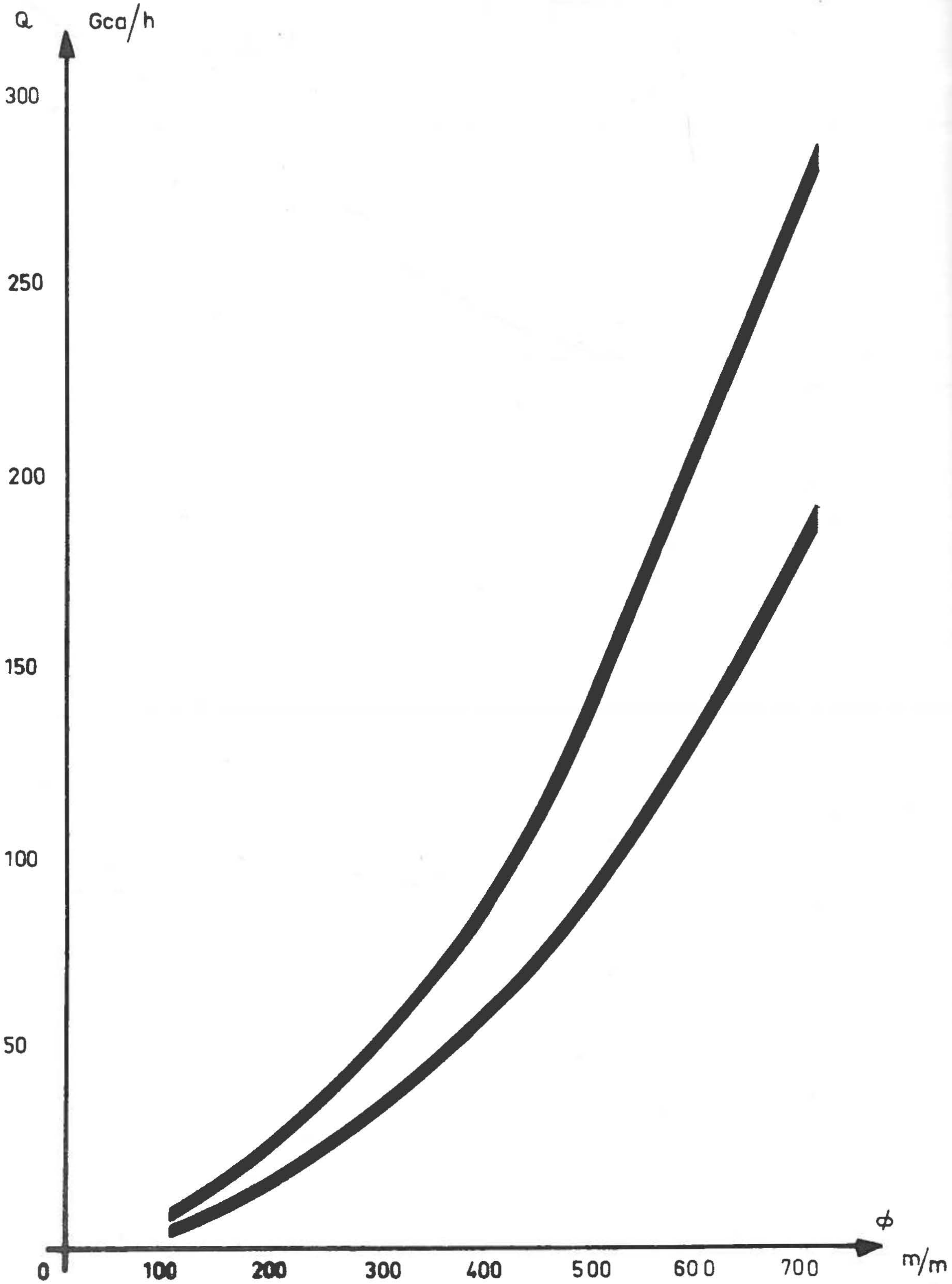


FIG. 3.9