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COMMISSION OF THE EUROPEAN COMMUNITIES

MODEL OF A STRATEGY FOR EUROPE'S ENERGY SUPPLY BASED ON METHANE AS THE PRIME ENERGY CARRIER

by

C. MARCHETTI, C. RINALDINI and A. SCHNEIDERS

1974

Joint Nuclear Research Centre
Ispra Establishment - Italy

Paper presented at the
First International Congress on Technology Assessment
The Hague, The Netherlands
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D.G. XIII - C.I.D.
29, rue Aldringen
Luxembourg
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entered the picture. For its intrinsic merits it tends to substitute oil in fixed installations, the degree of substitution depending essentially from its availability. In the case of the Community, proved gas reserves are equivalent to five years total oil consumption as the present rate. New processes of oil reforming developed in Britain, U.S., and Japan, have recently reached the commercial stage. These open the possibility of transforming essentially crude oil into methane with high energy efficiency (around 95 %) and costs comparable to oil refining. The great potential of these processes is shown by the implications of the new strategy for the European energy supply system discussed in this paper. In this, strategy methane is considered the prime energy carrier capable of covering a large fraction of the oil market (e.g. 70 %). This methane should come essentially from the reforming of crude oil. The benefits of this strategy are the following: 1) chemical pollution due to fuel is essentially eliminated for the fraction covered methane. 2) Problems linked to road transportation of fuels are greatly alleviated. 3) Gas fields in the Community can be used as strategic reserves with the capacity to face an interruption of the imported oil supply for five to ten years. The cost of this strategy is evaluated in terms of fractional cost of the yearly oil consumption. A possible time scale for its application is given.

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ABSTRACT

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Note :

The opinions expressed in this paper are the author's and are not meant to reflect those of the Commission of the European Communities.

Introduction:

This paper presents an analysis of the second order consequences of the introduction of Substitute Natural Gas (SNG) processes (Ref. 1) using oil as the feedstock, whose development started in Great Britain about 20 years ago and are now ready for industrial application.

SNG plants are a kind of reforming refinery in which oil fractions, and even crude oil itself, are in a sense "burned" in steam according to the overall reaction:

$$4n \left[- CH_2 -\right] + 2n \ H_2O \rightarrow 3n \ CH_4 + nCO_2$$

The symbol $\left[- CH_2 -\right]$ is used to represent the building block of an aliphatic molecule, without implying that only aliphatic molecules can be used. The reaction is slightly exothermic.
Alternative processes (Ref. 2) are based on straight hydrogenation, hydrogen being produced in the usual way by steam-reforming part of the feedstock.

A very important feature of these SNG plants is that in capital and operating costs and efficiency they are comparable to a present day refinery producing the usual mix of oil products, if desulphurization is included.

The energy picture in Europe

A mere 20 years ago the question of energy-supply problems in Europe simply did not arise. Recoverable coal reserves were sufficient for at least 200 years and only a small fraction of energy requirements was covered by oil imported from the very abundant reserves in the Middle East.
But the decline of the coalmining industry, the intrinsic advantages of fluid fuels, and the "cheap oil" policy of the oil companies have since brought about a profound change.

In the present pattern of Europe's energy supply, and in the most authoritative forecasts, petroleum is the main source of energy (Table I) (Ref. 3).
More than 95% of this petroleum is imported: the European Community's dependence on a highly unstable and politically volatile market, is great today and will increase in the future.
For structural and economic reasons coal consumption is not expected to increase and nuclear energy, if confined to the production of electricity, will be unable to cover more than a small fraction of the energy market in the short term (by 1985 about 4% of the energy delivered to the consumer is expected to come from nuclear plants).

Natural gas entered the picture fairly recently. Owing to its intrinsic merits it tends to replace oil in stationary applications, the degree of substitution depending chiefly on its availability.
The elasticity of a system in accepting natural gas is shown by Fig. 1 which shows the increase in gas consumption in the Netherlands following the discovery of the Groningen gas fields. It shows that, where gas is available, it soon comes to supply virtually all stationary installations.

Oil and gas reserves in Europe are given in Table II (Ref. 4). Although Europe clearly cannot rely for its energy supply on these sources alone, proven gas reserves are equivalent to about five years' total oil consumption at the present rate.

Natural gas as a fuel

Natural gas is a premium fuel for stationary installations, as is shown by its rapid and wide acceptance by the consumer whenever it is available. Availability actually seems to be the only limit to its widespread use.

The advantages of methane as a fuel are the following:

1) It is the least polluting of hydrocarbons, because it contains no sulphur and burns cleanly (Table 3) (Ref. 5).

2) It needs simple burners, and furnaces can operate unattended for long periods.

3) Distribution is via underground pipes which are fixed and unobtrusive, while the oil is distributed chiefly by road tankers, greatly contributing to traffic congestion.

4) Distribution costs for large quantities tend to show an advantage for methane.

5) No stocks are needed at the consumer site.

Methane can also be used to fuel vehicles. In Italy about 50 000 cars run on it (chiefly for tax reasons) carried in heavy steel cylinders. The use of fibre-wound plastic containers would be a great improvement.

Buses and trucks using LNG (Liquefied Natural Gas) are in experimental service in Italy, Switzerland and Germany (Ref. 6). Advances in low-temperature insulation have made losses due to boil-off quite negligible (e.g., $<1\%$ per day).

The point is, however, that a perfectly usable, if not perfect, technology exists for running cars on natural gas. It may become compulsory to use natural gas in towns as an anti-pollution measure, as has been proposed for the Los Angeles area.

SNG Plants

Plants to produce SNG from an oil feedstock, (mainly naphtha fractions) were originally developed by the British Gas Council (Ref. 1) and are now licensed around the world. Fig. 2 (Ref. 7) gives the simplified flowsheet for an SNG plant using a naphtha feedstock. Note that a desulphurization step is part of the process. As market evolved, the British Gas Council extended the scope of its SNG processes to use all petroleum fractions as feedstock, and even straight crude.

Table 4 gives an economic comparison of these plants in relation to the feedstock used (Ref. 8). It will be observed that the saving due to the use of cheaper feedstocks tends to be balanced by higher capital costs and lower conversion efficiency.
Two comments must be made in this table, a) it is too schematic in that if, say, 10% of the heaviest fractions of the crude are used for other purposes (e.g. firing a power station) efficiency and economics would be greatly improved and b) processes handling crude are in an early stage of technological development.

It is important to observe that :

1) the capital cost of an oil-SNG plant and a refinery of similar capacity are in the same ball park;

2) efficiency, defined as the ratio between the calorific values of products and feedstock of an oil SNG plant and a refinery is very similar;

3) SNG comes out sulphur-free; this is facilitated by the complete breakdown of the feedstock molecule.

Efficiency and capital cost at present look less good for the heavy fractions, with a break-point at a boiling point of 300°C [see Fig. 5] (Ref. 8), above which capital costs increase by a factor of almost three, and energy losses almost double. This is chiefly due to the primitive state of SNG technology for this grade of feedstock, which explains why the date used herein relate more particularly to naphtha reforming.

Distribution costs of Natural Gas versus Oil products

It is not easy to assess the distribution costs of gas and oil on a really comparable basis owing to the inevitable variations involved, the variable "mix" of oil products, and geographical factors.
The ideal situation for our purposes is to compare the cost of distrib ution from a refinery serving a given area, assuming that it either:

a) produces the usual mix of oil products; or

b) produces only SNG

Distribution costs estimated with the aid of oil and gas companies (Ref. 9) for a typical European situation are given in Table V. They are clearly of the same order, with natural gas having the advantage when consumption is increasing, because the distribution networks are designed with substantial overcapacity.

SNG as the main fuel

The foregoing data led us to consider the possibility of using SNG in the place of oil products, with SNG plants gradually replacing refineries and the gas transport and distribution network progressively extended. Our analysis is a first-order approximation aiming at evaluating the capital costs and the relaxation time of the system.

On the basis of the data in Table I, refinery capacity in Europe is expected to increase by 5% per year for the next ten years. The life time of equipment, excluding the infrastructure and general facilities, has been conservatively estimated at about 10 years. On these assumptions, and if SNG plants are built as part of the natural replacement and extension of refinery capacity, a major fraction of the energy supply can be provided in the form of SNG within a few years (Table VI).

Assuming that SNG plants are built on the same sites as existing refineries (certainly not an optimum assumption), the large-bore pipeline network will increase during those years by about 2 000 km/year. In view of the rapid extension of the gas distribution network in in recent years (Fig. 3), pipeline production and laying capacity is not expected to be overstretched.
Thus, within the limits of our approximation, the gradual replacement of an oil/oil products distribution system by an oil/SNG distribution system can be done at substantially nil differential cost.

We have not included here the cost of conversion, e.g. burners, at the consumer's end because from previous experience with natural gas we assume that the consumer reaps a number of marginal benefits which compensate for the expense of the substitution, e.g., simpler equipment, dispensing with preheating of the fuel and with storage tanks and stocks, automatic delivery and, for the small consumer, substantially higher efficency (~+ 30%).

An energy supply strategy based on natural gas and SNG

The fact that 95% of our oil is at present imported, shows how great the European Community's dependence upon the Middle East is, and it will increase in the future with the ever-growing demand for oil. The threat of a sudden interruption of supplies is a real possibility and if it materialized, it would be very dangerous to the Community. Moreover, the threat can be successfully used to push up the price of oil. The recent increases in crude oil prices showed how this works in practice.

True, Europe now has mandatory oil stock piles of two to three months' requirements. These stocks are tactically important as they provide cover against a strike by the oil carriers, for example, or similar short term occurences. It can easily be demonstrated however, that they have no strategic importance, because they have been paid for and therefore no harm can be inflicted on the exporting countries by using them. (These countries will actually benefit from the holding of large oil stock piles by the Community, since they can invest the proceeds, and because no effective measures, with the possible exception of war, could be taken within such a short time).

In our opinion a really important element in a strong bargaining position vis-à-vis the exporting countries would be instead Europe's ability to withdraw from the oil market for a substantial period, e.g. five to ten years.

As a means of acquiring this ability we suggest a strategy based on the following measures:

a) Compulsory construction of SNG plants instead of oil refineries to provide new and replacement capacity.

b) Use of European gas fields as strategic reserves. The rate of depletion should be rapidly cut to zero, with proper compensation for the owners.

c) Construction of an emergency trunkline system linking these gas fields to the gas transport network, with sufficient capacity to offset the shutdown of all SNG plants.
As regards the possible rates of offtake from gas fields, very high rate can be attained by gradually refilling depleted gas fields and artificial reserves, e.g. "bubbles" in aquifers.

The cost of the strategy

a) as emerged from the foregoing discussion, the differential cost of producing and distributing the SNG substituted for oil products can be considered zero. So that no cost should be charged to the strategy on that score.

With reference to point a, b and c above:

b) if the gas reserves are "frozen" as strategic reserves, a scheme has to be devised to compensate their owners and keep up the level of exploration. A very straight-forward, unsophisticated form of compensation would be for the community to buy the gas at the rate at which it would have been extracted, e.g., 3% per year of the proven recoverable reserves. We estimate that compensation on this basis would amount to some \$2 . 10^9/year. The money is not really lost but, in a sense, frozen, since it will be recovered when the gas is finally used.

c) a possible emergency system is illustrated in Fig. 4. The estimated cost is around \$8 . 10^9 (Table VII). The system is not optimized.

Table VIII shows the total net cost of the strategy assuming it to be operative for 20 years, under the conditions set out in the table. As a rule of thumb this cost related to oil consumption is equivalent to an increase of about \$0.3/barrel, which is certainly not negligible but should be compared with the recent increases of more than \$ 1/barrel. In other words, if the only result of the strategy were to prevent a single increase of \$0.3/barrel in the price of oil, it would pay for itself.

Possible Refinements of the Basic Strategy

Since the most conservative boundary conditions were used, improved versions of the strategy can be devised. For example, Norwegian and Russian gas, LNG imports, the conversion of coal to liquid and gaseous fuels, not to mention new gas discoveries in Europe and real optimization of the layout and operation of the gas grid, are beneficial factors, in that they reduce the cost of implementing the strategy and extend the period during which the Community can withdraw from the market.

- The importance of Norwegian and Russian gas is obvious, and some details are given in Fig. 5.
- LNG imports make SNG plants unnecessary for the relevant market

share, although the specific capital cost differs little between the two. An LNG tanker fleet would be a valuable asset, however, if the strategy were to cover all oil importing countries (OPIC).

- If coal could be converted to liquid fuel at competitive prices, to even part of the Community's /100 000 million tons of coal reserves, it would also be of obvious importance.

- The relative location of gas fields and SNG plants is plainly an important factor in the total cost of the gas grid. A less obvious point is that, via the emergency trunklines, the gas fields can be used as a back-up or for daily and seasonal peak-lopping. The SNG plants could then operate continuously at full capacity and without reserves. The resulting savings on capital and operating costs should be deducted from the cost of the emergency grid.

- Dividing Europe in blocks of consumption and natural gas reserves, we find a fairly good match between them except for the southern block, which therefore requires very long large-bore emergency lines coming down from the north. These could be greatly reduced in size if they were used to beef up the local emergency reserves by slowly replenishing totally or partially depleted local gas fields, or even to feed man-made reservoirs, e.g. in aquifers. This would also facilitate high rates of gas supply to the emergency network.

Conclusions

This analysis, although based on a first-order approximation shows clearly that SNG technology can offer the same advantages as natural gas: low pollution, unobtrusive distribution, and simplicity in use; and can do so with marginal cost differentials over the existing system. It also shows that SNG can rapidly attain substantial penetration of the energy market by taking advantage of the rapid obsolescence turnover of refinery plant and of the expansion of the market itself.

An incidental bonus of an SNG-based strategy is that it provides a technically feasible way of acquiring a much-needed bargaining strength vis-à-vis the oil exporting countries.
The implementation of such a strategy should do much to calm the hysteria stemming from a sence of powerlessness that now characterizes the attitudes of the oil-importing countries, and the oil-exporting countries would certainly benefit, in the long term; if the former-so strong in so many ways-feel reasonably secure. Besides, the authors realize that, for the actual implementation of this SNG-based strategy, an unrealistically high degree of political coordination is necessary.

TABLE 1

Primary Energy Consumption in the Community : Units M Tce

Solid fuel		Liquid fuel	Natural Gas	Primary Electricity *	Total
1960	476 (64%)	214 (29%)	13 (2%)	39 (5%)	742
1965	453 (48%)	423 (45%)	22 (2%)	40 (4%)	938
1970	368 (31%)	653 (56%)	88 (7.5%)	55 (4.7%)	1 164
1975	292 (19.6%)	905 (61%)	203 (13.6%)	88 (6%)	1 488
1980	267 (14%)	1165 (62%)	296 (16%)	163 (8.6%)	1 891
1985	246 (10%)	1459 (61%)	381 (16%)	292 (12.5%)	2 378

* Primary electricity is expressed in the tons of coal equivalent which would be necessary to generate it in conventional thermal power plants.

TABLE 2

Natural Gas Reserves and Oil Reserves of the European Community in 1972

	Gas (10^9 m^3)			Oil (10^6t)
	Confirmed	Estimated	Total	Confirmed
Netherlands	1990	342	2332	37.3
United Kingdom	700	300	1000	686.9
W. Germany	202	72	274	81.6
Italy	180		180	32.9
France	215	85	300	12.8
Denmark		50	50	33.3
	3287	849	4136 (=4550 Mtce)	885(=1248 Mtce)

TABLE 3

Pollutants from oil- and gas-fired equipment

(Kg per ton of fuel)

	Fuel Oil	Natural Gas
Sulphur oxides (as SO_2)	30	-
Nitrogen oxides (as NO_2)	13.5	6.9
Organic acids (as CH_3COOH)	13.5	1.3
Aldehydes (as HCHO)	1.3	1.0
Other organics	4.6	1.4

TABLE 4

SNG Production Cost Factors for Various Feedstocks, mills/Nm^3 - Gas Capacity 7.10^6 Nm^3/day

Feedstock	Naphtha	Kerosine/ Light Gas Oil	Med/Heavy Gas Oil	Crude
Utilities, Catalyst, etc.	1	1.1	1.3	1.5
Labor and related overhead	0.4	0.4	0.6	1.0
Capital charges	4.4	7.4	10.8	13.3
Total non-feedstock cost	5.8	8.9	12.7	15.8
Thermal Efficiency, %	91	90	84	79
Investment $ 10^6	70	70	105	130

TABLE 5

Natural gas transport and distribution cost in a typical situation

Transport cost (from the harbour to the city gates)

	Natural gas (by pipeline)	Oil (by pipeline)	Oil (by tank car)
For an average distance of 300 km($/Tcal)	380	200	600

Distribution cost (from the city gates)

Use	Natural gas	Heating Oil	
		($/Tcal)	$/t
Residential	2100	1500	15
Commercial	1350	1500	15
Industrial	200	120 - 500	1.2 - 5

TABLE 6

Energy consumption in Europe in 1982 under three different circumstances.

(10^6 tce)

CASE I		CASE II		CASE III	
Solid fuel	258	Solid fuel	258	Solid fuel	258
Oil	1275	Oil	271	Oil (North Sea)	200
		SNG from oil	1004		
Nat. Gas	327	Nat. Gas	327	Nat. Gas	1040
Prim. El.	206	Prim. El.	206	Prim. El.	206
	2066		2066		1704

Case I - Normal conditions. Derived from Table 1

Case II - Oil-refineries begin to be replaced by SNG plants in 1975 under the assumptions set out in the test.

Case III - As in Case II, but oit imports are cut off, starting from 1 January 1982 and energy consumption is reduced by 20%.
Oil from the Community-controlled zones of the North Sea will be used entirely for transport.

TABLE 7

Additional trunkline network needed in emergency condition (end 1980)

	Pipeline Length (100 km)	Additional capacity (Gcal/sec)	Cost of the additional line (10^9 $)
Groningen-Amsterdam	1.8	158	2.1
Amsterdam-Rotterdam	0.68	120	0.58
Rotterdam-Köln	2.40	36	0.62
Köln-Frankfurt	1.83	25	0.32
Frankfurt-Karlsruhe	1.52	18	0.21
Karlsruhe-Stuttgart	0.76	19	0.10
Stuttgart-München	2.20	18	0.30
Rotterdam-Antwerpen	0.87	54	0.34
Antwerpen-Charleroi	1.08	24	0.18
Charleroi-Lille	1	32	0.23
Lille-Paris	3	18	0.37
North Sea-London	2.9	25	0.51
North Sea-Liverpool	3.6	37	0.96
North Sea-Danemark	3	7	0.15
Cortemaggiore-Firenze	1.5	6	0.56
Firenze-Napoli	4.8	6	0.19
Total			7.71

The capital cost of the pipelines, of laying them and of pumping stations was estimated by the optimization procedure described in Ref. 10. However no scale effect has been taken into account for flows over 10 Gcal/sec (corresponding to a maximum pipe diameter of about 1.7 meters).

TABLE 8

Cost of the strategy over 20 years

Cost of the strategy ($\$10^9$)				Cost of an equivalent oil stock pile ($\$10^9$)			
Total discounted cost (1)		Annual cost (2)		Stock pile equivalent to the gas reserves (4)		Stock pile equivalent to a year's consumption (1980) (5)	
		Constant rate	Rate proportional to consumption in 1980.	Discounted	Annual	Capital	Interest (8%)
Freezing the reserves :	11.4						
Emergency trunk lines :	14.3						
Total	25.7	2.75	1.93	53.5	5.7	16.3	1.3

1. The total cost of the strategy is the sum of:
   - the economic penalty due to the deferred use of 3%/year of European gas reserves;
   - the cost of an emergency trunkline network designed to meet European needs in 1980 and expanded at the rate of 5%/year to caterfor the annual increase in consumption. These costs are discounted at 10%/year to the first year in which the strategy is in operation (1980). The value of the gas was worked out from a cost of $20/ton for oil, as suggested in Ref. 11.
2. The total costs are converted into a constant annual rate or an annual rate proportional to oil consumption (assumed to increase by 5%/year).
3. As a comparison, the cost of an oil stock pile was calculated in two cases. Only the cost of the stockpiled oil ($20/ton) was included and not the cost of the storage tanks; the latter will be about the same as the former, doubling the total cost.
4. Total discounted cost and constant annual cost of an oil stockpile with the same energy content as Europe's gas reserves.
5. The capital cost and the interest on it, for an oil stockpile equivalent to the annual consumption in 1980.

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We mention in particular the Institute of Gas Technology, Chicago.

10) "Transport of Natural Gas and Hydrogen in Pipelines" by G. Beghi, J. Dejace, G. Grassi, C. Massaro, Euratom Internal Report, not available.

11) "Natural Gas for Industry and Electric Power Plants in the Netherlands" by G.W. Bruggeline, Symposium on the Problems Relevant to Natural Gas Markets in Europe, Barcelona, 23-29 Oct. 1970.

Addendum and Corrigendum to EUR 5140 e

Corrigendum:

On page 7, second paragraph, 2^{nd} line:
Read Fig. 1 instead of Fig. 5

Addendum :

See following figures :

Figure captions:

Fig. 1 (ref. Page 7)
Capital costs of oil gasification plants (from ref. 8)

Fig. 2 (ref. Page 6)
Flow sheet of oil gasification plant

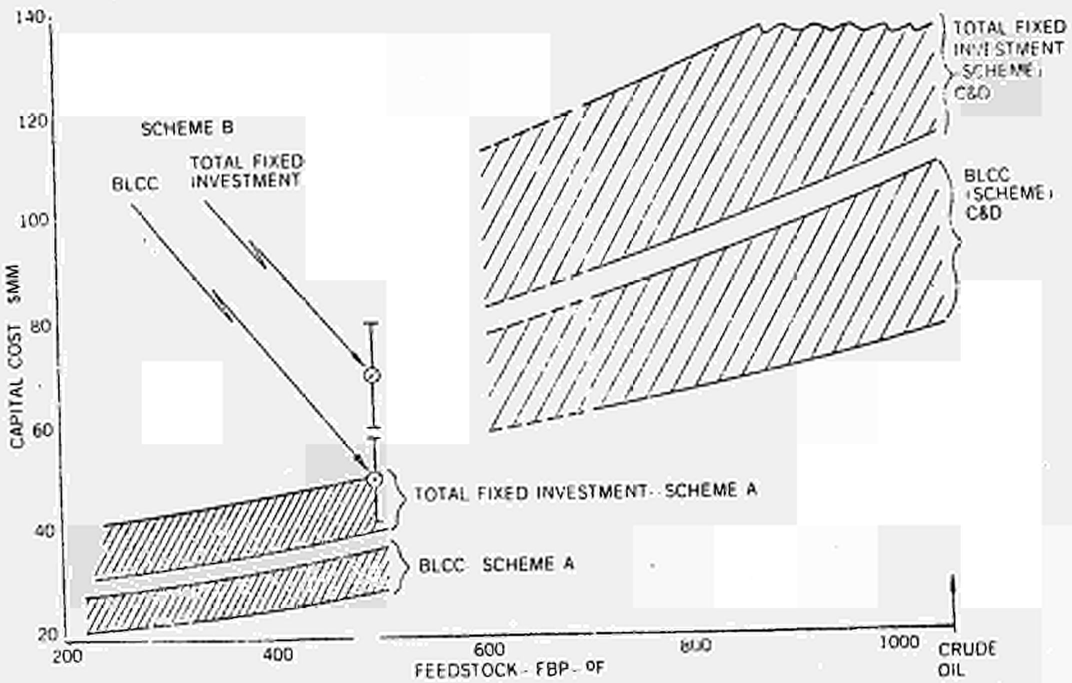
Fig. 3 (ref. Page 8)
Development of gas pipe line network in the European Community

Fig. 4 (ref. Page 11)
Transport and emergency network in Europe

Fig. 5 (ref. Page 11)
Graph showing the duration of European gas reserves under different assumptions concerning imports and new discoveries.

Figure 1

Capital costs of oil gasification plants (250 million std. cu. ft. / day).



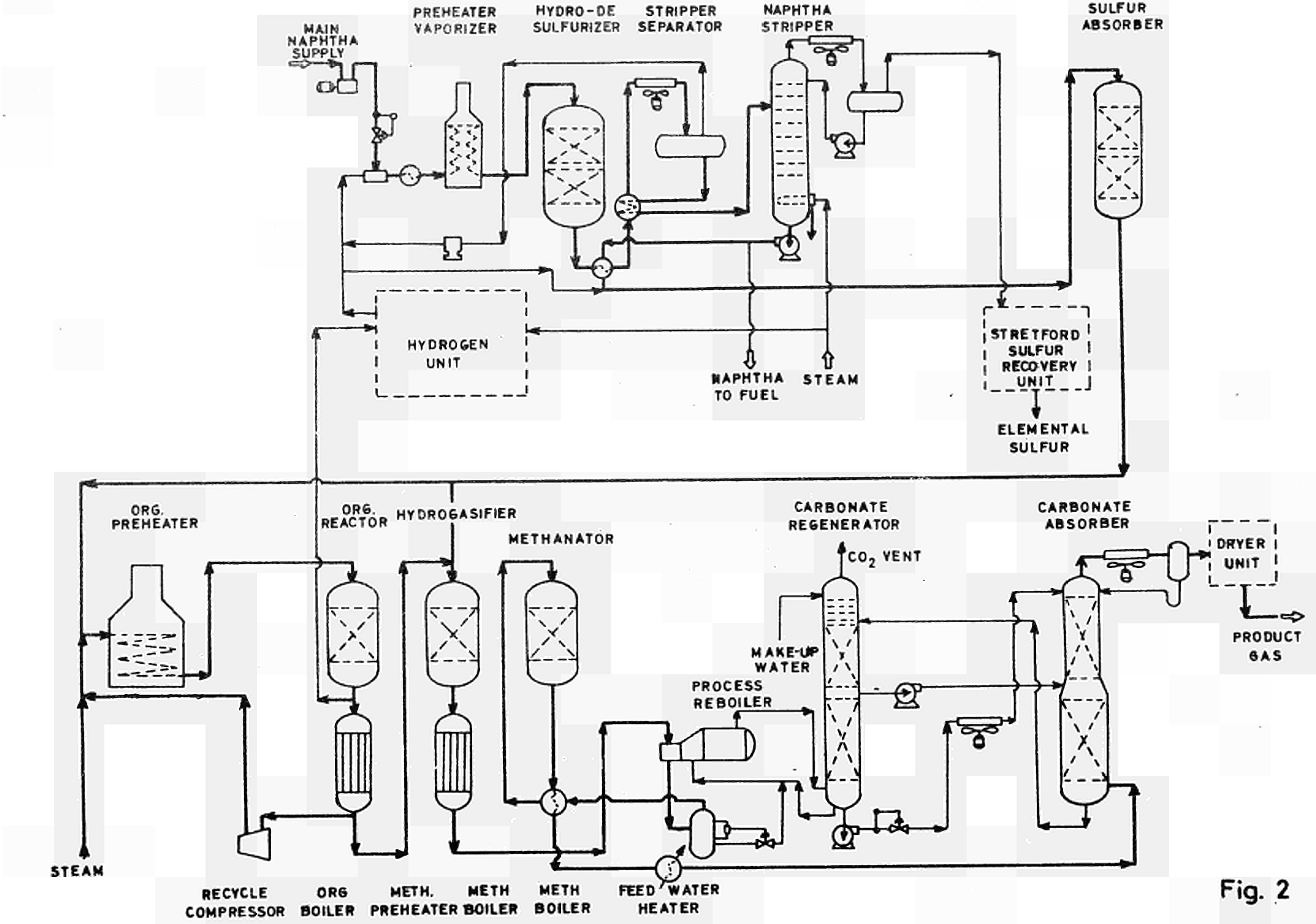

MAIN NAPHTHA SUPPLY
PREHEATER VAPORIZER
HYDRO-DE SULFURIZER
STRIPPER SEPARATOR
NAPHTHA STRIPPER
SULFUR ABSORBER
HYDROGEN UNIT
NAPHTHA TO FUEL
STEAM
STRETFORD SULFUR RECOVERY UNIT
ELEMENTAL SULFUR
ORG. PREHEATER
ORG. REACTOR
HYDROGASIFIER
METHANATOR
CARBONATE REGENERATOR
CO_2 VENT
CARBONATE ABSORBER
DRYER UNIT
PRODUCT GAS
MAKE-UP WATER
PROCESS REBOILER
STEAM
RECYCLE COMPRESSOR
ORG BOILER
METH. PREHEATER
METH BOILER
METH BOILER
FEED WATER HEATER

Fig. 2

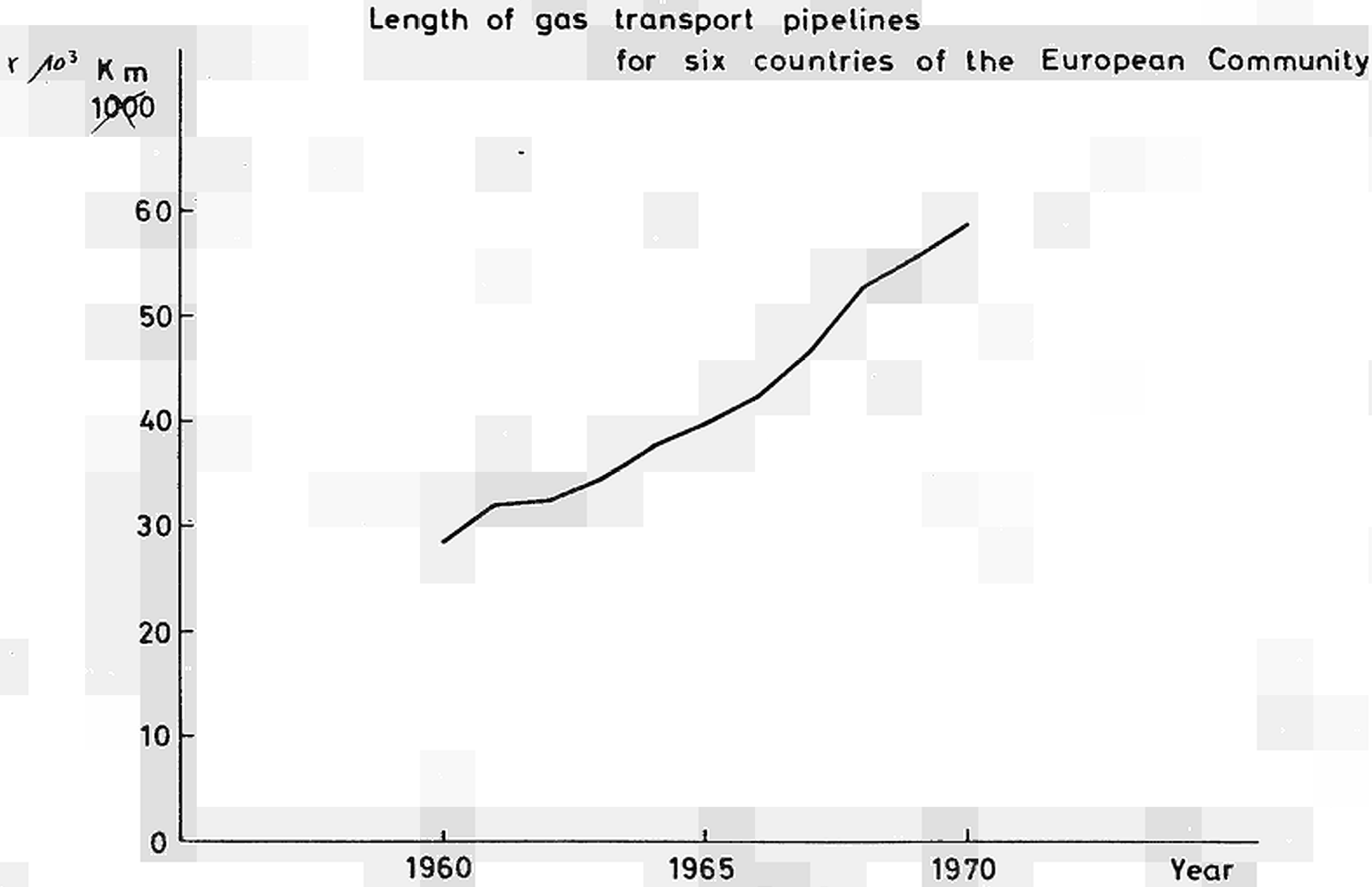

Length of gas transport pipelines
for six countries of the European Community
10^3 Km
~~1000~~
60
50
40
30
20
10
0
1960
1965
1970
Year

Fig. 3

TRUNKLINE NETWORK AND THE EMERGENCY NETWORK

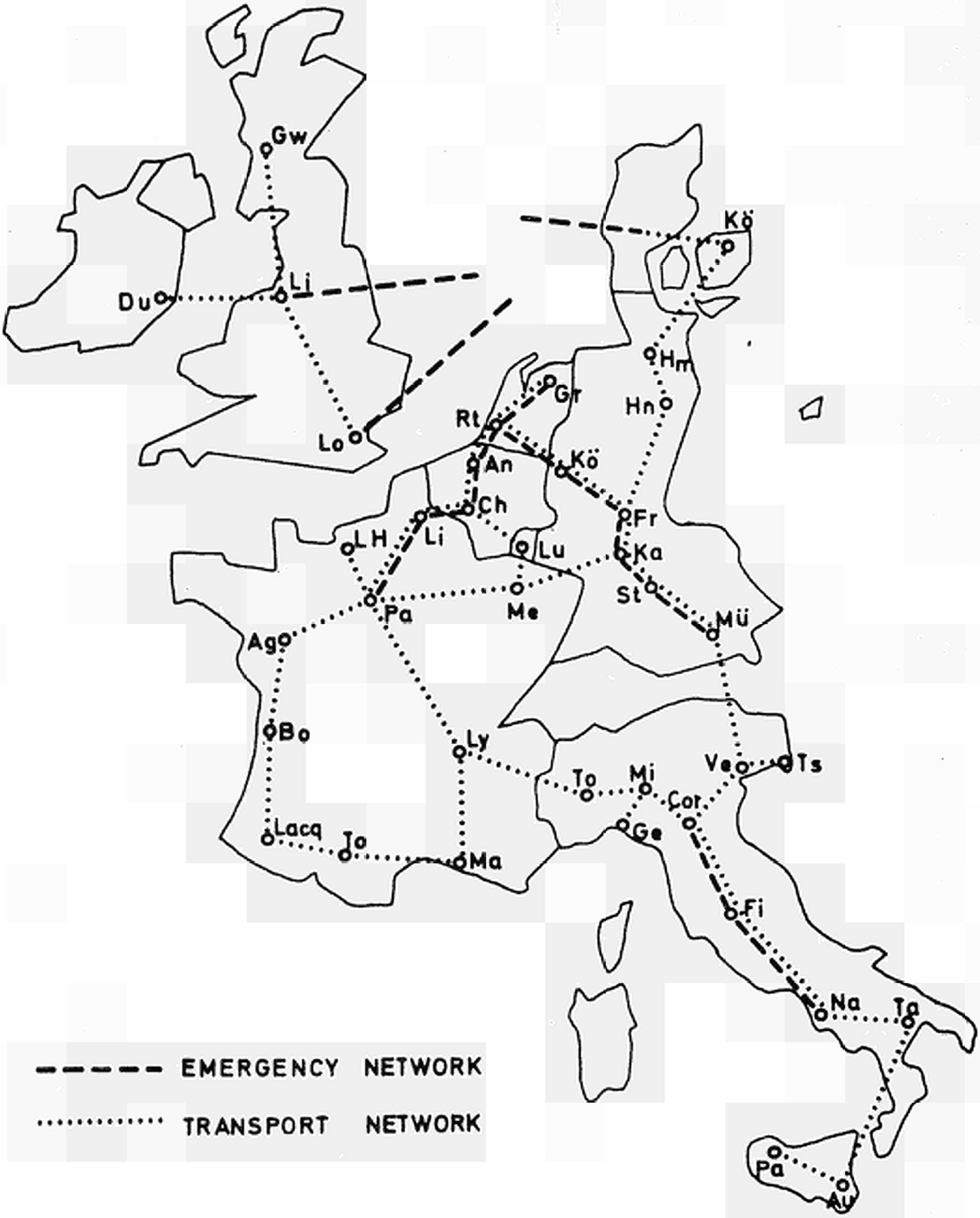


Fig. 4

Number of years the reserves will last when used for replacing oil imports as at the year 1982.

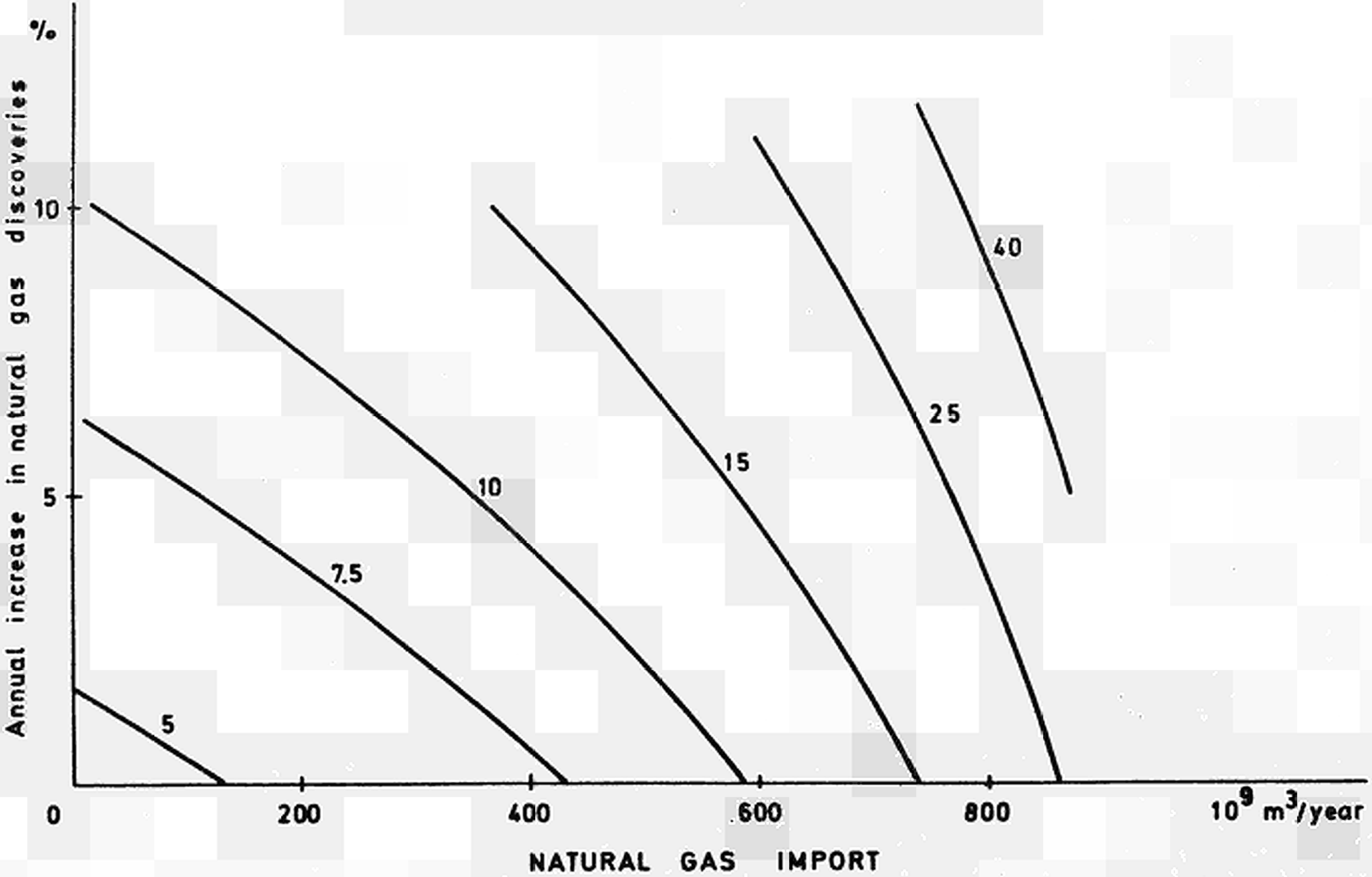


Fig. 5

Corrigendum to addendum to Report EUR 5140 e

In Fig. 3 the multiplier of the ordinate values must be 10^2 instead of 10^3.

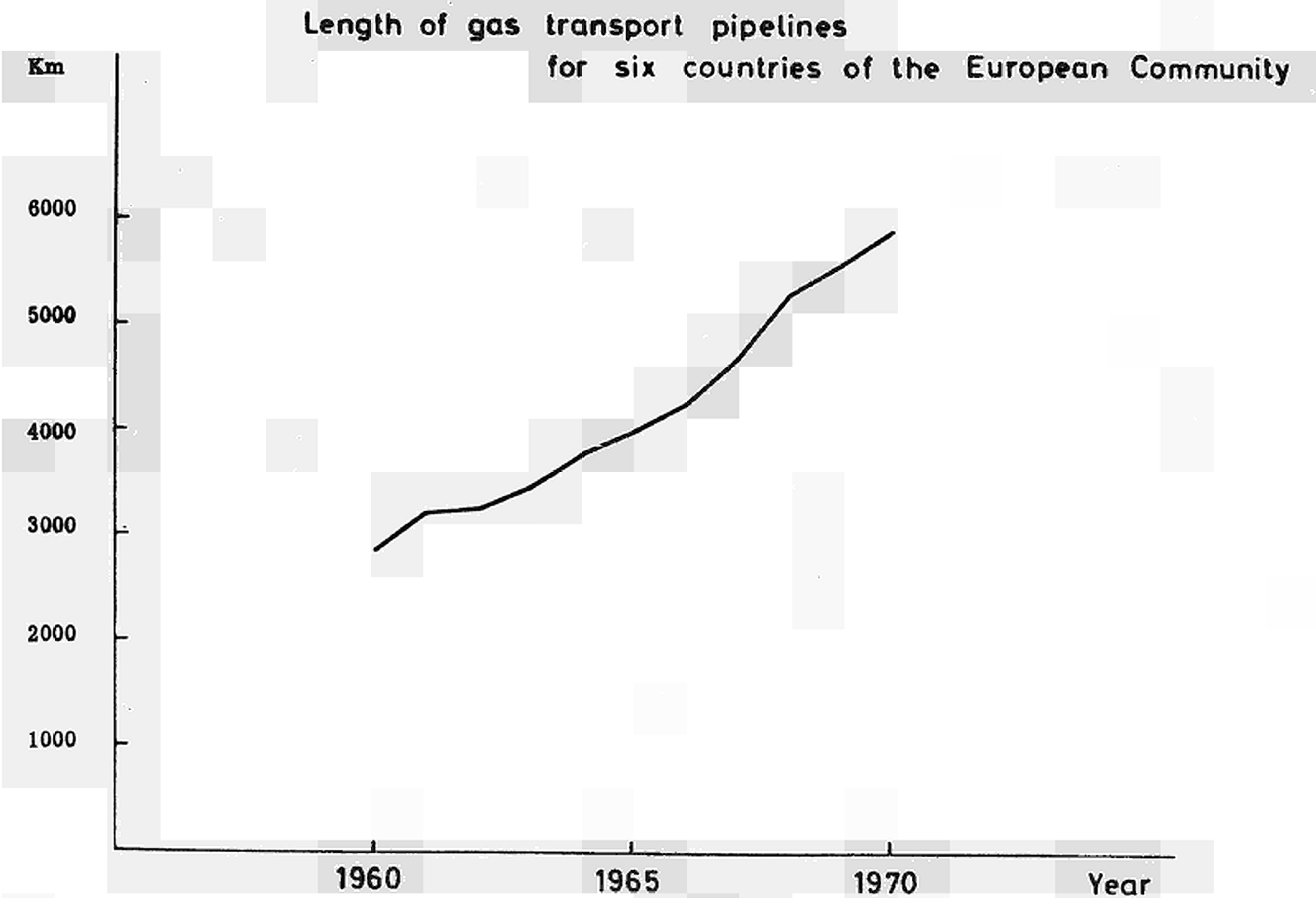

Length of gas transport pipelines
for six countries of the European Community
Km
6000
5000
4000
3000
2000
1000
1960
1965
1970
Year

Fig. 3

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Alfred Nobel

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