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LOW-GRADE COAL UTILIZATION BASED ON BULGARIAN EXPERIENCE

Prof. G. Moumdjian, Dr. Sc. - Bulgaria

I. Characteristics of the low-rank coal properties

The utilization of low-rank coals for energy generation requires considerable information on their properties.

On the one hand, they are determined by the specific demands of each technology used, on the other hand, they have different components, depending on the aim of application in the frames of a given technology.

Usually, the contents of coal properties is classified in separate groups and subgroups, depending on defined technology characteristics like for instance:

a) heating value, Q_i^r

b) ballast, A^d, W^r

c) elementary composition of the coal organic ingredient,
C^r, H^r, S^r, O^r, N^r

d) characteristics of the combustible ingredient-volatile matter and fixed carbon content - V^{daf}, K

e) ballast chcracteristics
- moisture composition, W_{ex}^r, W_h^r
- ash composition

f) physical properties - bulk, optical, real density -
- ρ_{bulk}, ρ_{op}, ρ_r
- free-swelling index, W_{max}^r
- shear resistance, τ_{shear}
- dynamic and static repose angle, β_{stat}, β_{dyn}
- friction factor, K_{ins}

590

g) characteristics, concerning the milling of coal - K_{mill}, etc

It is convenient to present all these parameters as a multitude or as separate, functionally determined multitudes. In particular cases, it is possible to set these parameters in a matrix form with dimensions (m x n) where n is the number of the parameters' subgroups (fig. 1).

The information matrix (1) should generate matrices or vectors of smaller dimensions being part of it, as a result of various mathematical operations.

The information matrix of the coal properties could have both numerical as well as information elements.

Depending on the degree of accuracy determined by the specific use of infromation on a given coal deposit, the evaluation of its properties is done as follows:

a) the matrix elements a_{ij} are numbers which stand for average evaluations of the whole deposit;

b) all matrix elements or part of them are function of the space coordinates (of the deposit) and of time t i.e.

$$a_{ij} = f(x, y, z, t)$$

c) expression of the coal properties by stochastic parameters, represented by their basic statistical characteristics - mean and dispersion

$$a_{ij} = M\{a_{ij}\} + D\{a_{ij}\}$$

This expression is suitable for low-rank coals of variable properties, usually described by the normal AYC distribution law as are Bulgarian lignites of the Maritsa Iztok basin.

d) definition of the information matrix of coal properties throug mean and variance of the qualitative parameters

a_{ij} regarded in relation to the space coordinates and the time t i.e.

$$\| a_{ij} \| = \| M\{a_{ij}(x, y, z, t)\} + D\{a_{ij}(x, y, z, t)\} \|$$

Evaluation of the utilization possibilities of low-rank coal and the choice of optimal energy technology require construction of a most complete model of coal properties, reflecting their non-stionary and stichastic character.

On the other hand, identification of coal properties devoid of a utilization target, through evaluation by means of time series is often useless in spite of the considerable efforts.

The required size of the matrix G depends on the structure, substructural variation and parameters of the particular combustion technology.The study of fuel influence on the design, construction and operation of certain subsystems (substructures) of energy conversion technology requires information for a definite extract from the matrix

Each technology and subtechnology gives specific importance to every element in the matrix and in some cases certain elements might have ignorable sensitivity.

The matrix G should be formed in a way which will allow, while solving the problem of synthesis of a utilization technology to produce matrices or vectors of smaller dimensions whose elements are elements of the original matrix (fig. 1).

Reduction of matrix rank R could be done by investigation of the correlation of the individual coal parameters.Practically, some of these correlations are strong enough, including (statistically), which allows the application of indirect estimation of some parameters by direct measurement and evaluation of others.This provides a possibility to reduce the efforts and resources for experiments, for design of information systems, etc.

Thus, the existence of correlation between moisture, ash, heating value and other chemical components in the coal deposits of the Marits region (PR of Bulgaria) is a sufficient condition for their application in direct parameter estimation, where in accuracy is justified.

The use of an iterative approach to provide the necessary informational data bank for the selection of technology is justified, too.

The initial step could be based on a matrix of limited information which still has a sufficient number of elements for a rough estimation of the prospective technologies, structures and substructures, having in mind the accumulated experince in the field.

This basic matrix could be modified or expanded, according to the particular problem. (fig. 2)

It is necessary to emphasize that knowledge of the coal properties is important not only at the technology synthesis stage.This problem is equally important at the design and construction stage and particularly at the atage of operation.

The discussed approach for utilization of the existing or newly discovered correlations between the separate parameters, the transition to modified matrices of the coal parameters of relative inaccuracy and the error estimation will be illustrated by the results of a research on various types of coals (low-rank, brown coals, etc.).When this approach is used, the criterion for the sensitivity of each factor will be accuracy of coal heating value Q_i^r which is a basic parameter of fuel quality (fig.3).

That is why, the correlations between mean values of basic coal parameters, characterizing the heating values from 50 coal deposits in Europe and Asia have been analysed.Heating values were divided into four groups, depending on their mean.

I group - heating value between 3.4 and 32 MJ/kg
from 50 deposits;
II group - heating value between 3.4 and 25 MJ/kg
from 31 deposits;
III group- heating value between 3.4 and 21 MJ/kg
from 21 deposits;
IV group- heating value between 3.4 and 17 MJ/kg
from 16 deposits.

Fig. 4 and 5 show the correlation coefficient for these groups between the heating value and part of the basic parameters.

Fig. 6 and 7 show the same correlation coefficients for three groups of deposits, classified by their geographical situation.

Group X-1 includes 15 values for deposits in Mongolia.

Group X-2 includes 19 values from deposits in Middle Europe.

Group X-3 includes 16 values from deposits in Europe. Comparison between these correlation coefficients and those of the low-rank coal of the Maritsa Iztok region (Bulgaria) is shown on fig. 8.

The following conclusions can be made, based on analysis of the results of this large scale research work.

1. There is a strongly expressed negative correlation between the mean value of moisture content and the heating value from the above-defined four groups of deposits and the correlation coefficient has a relatively high value and varies within certain limits for the different groups.

$$r_{wQ} \in (-0,835 \div -0,9723)$$

Concerning the groups X formed on the basis of their geographical location, this relation is strongest for coals in Middle Europe

$$r_{wQ} = -0,9723$$

2. Among the coefficients defining the correlation between heating value and the elementary composition, it is and which are relatively significant and stable in all observed groups.

$$r_{QC} \in (0,7528 \div 0,9364)$$

$$r_{QO} \in (-0,7838 \div -0,9659)$$

For the fourth group of the first classification including a population of lower heating values, these correlations are relatively weak.

If we agree that for coals of one and the same deposit, the composition of the combustible matter is almost stable, then the heating value will be determined by the composition and relation of the ballast components. The increase of ash content will reduce to a greater degree the heating value of the coal, rather than influence the moisture containing components of the coal. This explains the relatively weak correlation between heating value and moisture content of the coal in the studied depodit. The high values of r_{WA}^{MI} and r_{AQ}^{MI} confirm the hypothesis. (fig.9).

The basic results drawn from this analysis lead to the following general conclusions:

1. In the cases of the observed groups, heating value is influenced mainly by moisture content, followed by ash content. The rating of the reamining factors varies from group to group. With the decrease of the mean heating value of the regarded groups dcreases the influence of C^r and V^{daf} and respectively increases the influence of O^r and N^r.

2. In high-rank coals the influence of the moisture content on the heating value is stronger and therefore the regressional relation between Q_i^r and W^r can be used with relatively fair accuracy.

For evaluation of low-rank coals it is necessary to introduce no less than two parameters (W^r and A^r) in the regressional equation, depending on the accepted accuracy criterion (fig.3).

Change of moisture and ash content by 1% leads to changes in heating value as follows:

$$\Delta Q_i^r = 315 \div 402 \ \mathrm{kJ/kg}$$

$$\Delta Q_i^r = 315 \div 423 \ \mathrm{kJ/kg}$$

The above established statistical relationships between parameters of the elements of composition of the coals which apply for groups of coal deposits can be applied to a certain coal deposit only when immediate but fairly rough information is needed. The matrix of the coal of a given deposit cannot be used as a basis for the choice of combustion technology, valid for another investigated coal deposit.

This is why the applied statistical approach should be concentrated on sets of parameters, pertaining to a particular deposit and on formation of the time series of various frequency.The latter are used for dynamic evaluation of particular coal properties which are important for the side of combustion technology.

II. General Outlines of Coal Utilization Technologies

It is possible to conver the chamical energy of solid fossil fuels into a thermal one through a wide spectrum of technologies.The basic process is the conversion of the potential fuel energy into heat of th fuel gases through combustion.The following heat exchange between the fuel gases and the steam duct in the steam generator can be designed with relative independence in the frames of a certain combustion technology.Bearing in mind, by synthesis or choice of a technological scheme for low-rank coal utilization we will understand the combustion and all preparation technologies or[illegible]

Secondly, it should be kept in mind that the essential techno-economic indices of the steam generator and the problems, connected with the environment are predetermined mainly in the frames of a generation cycle of flue gases(of a given temperature potential), namely:

- the essential share of heat losses in the environment is directly dependent on flue gas flow rate and temperature.
- by unburnt fuel;
- by the ash particles released in the environment;
- by the chemical pollutants released in the environment.

By coal utilization technology and low-rank coal utilization technology, in particular, one should understand the integrated technology for low-rank coal utilization through its burning for energy generation.The above technology covers the technological process of transport, crushing, milling, drying and burning.

The combustion of these processes can be "amorphous", it is possible that these processes are connected or differentiated, or partially overlapping, as it is also possible for some of them to be missing, eic. (fig.11).The relative share of these processes in the whole integrated technology, as well as their structural realization predetermine the variety of technological schemes of the integrated technology.

The main problem, arising, therefore, under this position is as follows.Is it possible in the presence of such a number of structurally variable technologies and is there a system of criteria present which could direct this choice to an optimal structure?And finally - is this structure entirely stable to certain small deviations in the values of the factors parameters, used for its determination.

The answers to the above questions will provide the solution of the defined problem.

For the solution of this problem it is important to situate the possble structural parametric variations of the technological schemes in an interval limited by two boundaries B_1 and B_N , i.e.

$$B \in (B_1 , B_N)$$

Such boudaries could be the stoker firing technology on travelling grate and pulverized-coal combustion - fig.12.

Assuming the possibility for certain interval variations in each structure of the integrated technology, including the boundary solutions we come to a sequence of structures with relatively wide internal possibilities of variations (fig.13).

A characteristic feature of the left boundary solution is the high value (and the possibility for control) of the fuel residence time in the combustion chamber.This proves that the above technology is practically appropriate for fuels with relatively small specific reaction surface i.e. larger size of the single coal pieces and its combustion is predetermined by the possible rate of oxygen suppl to the reaction surface.The existing restrictions over this rate determine also the necessary time T of coal combustion, this time being a functional dependence on the size of the coal particles.

It is obvious that fuel residence time in the furnace should be in a rigorous relation with the combustion time T.Thus, we come to the natural conclusion that an increase of this time will reduce the specific thermal load of the furnace.The latter conclusion itself is already a serious limitation in the effort to construct combustion chambers (steam generators respectively) with high single capacity.

This limitation becomes stricter with the increase of the fuel ballast share.In the presence of greater ash content it is due to the decrease of the fuel reactional ability, while with the increase of moisture - to the necessity of a definite time, needed for the process of drying.

The outlined trend for [illegible] of the [illegible] "boundary" [illegible] ker firing technology in the field of small single capacities is accompanied by two significant advantages, increasing with the increase of the coal ballast content.

The first is the lack of elutriation of ash particles in the environment and the second is that the entraining of coal particles is avoided.

The considered technology of stoker firing has yet another essential advantage as it integrates all processes, preceeding the combustion process.

The requirement for larger thermal load of the combustion chamber requires an increase of the specific reaction surface of the fuel, obtained by crushing.It is imperative that a volumetric distribution of the coal particles in the combustion chamber is obtained in order to ensure a sufficient access of axygen to the greater reacting surface, so that combustion time is shorter.

Meeting of the above conditions can be effected by raising the coal particles in the chamber volume, using fluidized-bed combustion technology. In this way, the transition from stoker firing to fluidize bed combustion is the natural path to increase the furnace thermal load intensity. It is therefore important to meet certain requirements related to the formation of a cloud of floating coal particles. These requirements are reduced to the presence of proper aerodynamic condit ions, providing a stable coal particles movement in the fluidized bed and the necessary fuel residence time.

Meeting these requirements by the fluidized-bed combustion technology has two of the major advantages of stoker firing, namely: the possibility for separation of a large part of the coal ash particles from the furnace, avoiding their release to the environment and the controllability of fuel residence time. There follows from the first advantage that [illegible] residue after desulphurization by solid additives can be separated together with the ash particles.

Both the technologies considered up till now - stoker firing and fluidized-bed combustion have a common positive quality: possibility for parametric adaptation of the technological scheme to certain deviations in the coal quality. This adaptation is guaranteed by the possibility for control of grate travelling velocity and oxygen feeding (in stoker firing) and the pressure drop of the bed and of the air supply (in fluidized-bed combustion). The air fed in FBC has two purposes - as a carrier of dispersed coal particles and as oxidizer simultaneously.

It is obvious that the increase of the fuel ballast will cause certain difficulties in meeting the velocity time condition due to the restriction of the needed air quantity.

The controllability of the two technologies at varying fuel quality should be considered, assuming minimum variation in size of the coal particles.

As an illustration of the statistical heterogeneity at a given value of the specific reaction surface may surve the results from the analysis of the size distribution of coal particles along the technological path including transport, crushing, milling, drying and separation of low-rank lignite coal from the Maritsa Iztok region (fig. 14).

The need to increase the specific thermal load in the combustion chamber makes imperative a turn to higher values of the specific reaction surface, particularly at higehr ballast content of the coal. The presence of a recirculation by FBC-technology gives a chance to correct what is not done in the combustor.It has the role of a specific filter which equalizes the deviations in the combustion rate of different fractions.It has, however, the negative effect of decreasing the heat release rate of the combustor, due to the necessary larger combustion time for coal particles with diameter bigger than the one, specified by the combustion chamber size.The development of the combustion technologies directed at the increase of the combustion chamber load, particularly for high ballast coals is achieved by the respective further increase of the specific reactive surface.

Finer coal dust can be produced in the milling systems, configurated depending on the specific characteristics of the coal, like grindability, abrasiveness, volatile matter content, etc.The shorter combustion time and the high intensity inside the combustion chamber give rise to serious problems, concerning the mixing of the oxidize (air) with the coal particles inside the chamber.This problem deepens with the increase of moisture content of the coal.When the moisture content is high, alongside with grinding, drying also becomes a necessity.Thus, by the preliminary transition of the matrix of the fuel characteristics from one quality level to another, the necessary fuel properties can be secured.

Consequently, the problem of synthesis of a pre-combustion treatment system for low-rank coal depends mainly on the combustion proprocesses and this dependence is becoming particularly important.

Generalization of world experience in low-rank coal combustion and particularly the research and technological investigations in Bulgaria have proved the advantages of the direct firing pulverized closed system for lignite coal of 50-58% moisture content, 13-22% ash content and calorific value of 4.8÷6.4 MJ/kg (fig.15).This scheme was proved as an optimum system after solving some important specific problems considering the coal treatment facilities for homogenizing, grinding, milling, drying and burning.A typical property of the Bulgarian lignite coal is the high clay content in the mineral part, which together with the external moisture cuase an increased adhesion and difficulties in transportation and grinding and crushing.

One of the serieous problems in the operation of the boilers is the uninterrupted flow in the coal bunkers without clogging or coal hang-up.

The Bulgarian theoretical and industrial studies and experience aimed at optimizing the processes of milling and drying of the coal gives results in the creation of a precombustion treatment systems with optimum characteristics of the fan and parameters of drying gasses taken from the combustion chamber.

The application of these gases as a drying agent leads to their use as a carrier of coal particles and the and the mixture requires air supply as an oxidizer for the coal particles in flue gas carrier. The structure of pre-combustion system in respect to its basic and output parameters, the connection of the combustion chamber is determined by the distribution of the gas and air flows and fuel fractions along the height of the combustion chamber in compliance with the specific requirements of the combustion process.

The stability of the combustion process is determined basically by the stable heat output supported by the burners, located in several rows of the combustion chamber and by expansion of the isotherms along the furnace height.

The organization of the combustion process is necessary for the strongly determined location of the isotherms in the volume of the combustion chamber.This is done by tangential organization of the flow-out from the multi tier (2-4 tiers) parallel tip-port burners, creation of a positive jet velocity gradient and decreasing the jet slopes from the bottom to the top burners;in the same time to create negative gradient of the distribution of pulverized coal along the height of the burners.Secondly, air is approximately proportional to the coal distribution along the height of the burners.

When low-rank coal whose reduced moisture content exceeds 110 g/M the closed direct system loses its advantage over the semi-open firing system.

The prospect of burning coal with calorific value below 4.5 MJ/kg and reduced moisture content above 110 g/MJ by applying the direct closed firing system is determined mainly not by the conditions,providing stable combustion but by the development and improvement of the equipment.

All these determine the relatively high sensitivity of this technology to deviations from the coal quality, independently of the fact that in the pre-combustion subsystems there are some technological possibilities for adaptation to the variable properties.

The same problems arize from the variable heat power of the boiler.

This technology also puts the problems of rational solutions in an ecological aspect.These solutions should be looked for in the slag and flying ash separation, flue gases cleaning and chemical treament, etc.

In this connection, the rhetoric question arising from here - which is the absolute minimum of low-rank coal heating value which still secures efficiency of their utilisation through combustion, has a well justified answer which should be wearched mainly in a technological aspect.This means that the absolute minimum should be determined, provided that the fuel utilization efficiency even with an optimal technology is assessed by the annual expenses criterion, expressed by the annual energy proeudtion.

The degree of efficiency of the low-rank coal utilization for each particular country is determined by comparison of this efficiency with one of the other energy sources and technology, which make up the national fuel-energy balance.

Thus, in the various countries, the assessment for the low-rank coal utilization efficiency is different.There are also differences in the assessments of the values of the basic low-rank coal characteristics.

III. Choice of Alternative Solutions for a Technological Scheme

The combustion technologies analysis in the present paper shows that their variety is due to the change of particular factors and the transition from one into another is, in fact, a continuous one. Here, under variety of particular technology one should understand its variety due to the structural, substrustural and parametric diversity in the frames of the established continuous spectrum of technologies.

The accepted approach of looking for an optimal solution necessitates the formulation of a criteria system, correct and corresponding to the specific aims and limitations in the systems for which this solution is valid.

The basic stages of selection of optimal technology can be outlined as follows (fig. 16).

The first stage covers the collection of information on the coal properties, on the gained experience concerning the technologies and technological schemes of low-rank coal utilization and the methodology for evaluation of the economic efficiency.

The essence of the second stage lies in the establishment of all possible technological alternatives which are technically feasible and promising in view of the specific conditions for each country. The number of these alternatives is determined by an expert assessmen

The third stage includes the generation of a set of alternatives - project technological solutions which meet already defined requirements for minimum economic effectiveness.

This stage is iterative. In the cases when the alternatives do not meet the requirements for "minimum economic effectiveness" there should be a return to the generated set of technically feasible solutions.

The economic effectiveness of a given technology is evaluated on the basis of detailed computation of the capital investment costs and running expenses.

In calculations of the economic effectiveness, it is important to accept a base year for evaluations. This can be the year of implementation (or the preceeding year) for a specific technological solution.

The long period of design, construction and commissioning of the regarded systems make imperative the fourth stage - evaluation of the economic risks and hazards.

The following fifth significant stage is the multicriteria evaluation of the alternative solution.It is carried out on the basis of a well-justified system of indices.

The determination of the global effectiveness by the partial criteria can be done through various methods for their classification and ranking which permits certain favouring or limiting the influence of some of them.The last stage of decision making allows a great flexibility in the multi-criteria analysis of the alternatives (fig.17).

The economic risks and hazards criterion is formed on the basis of the indices:change in the construction period and capital investments, change in the fuel and electricity prices, change in the reliability evaluation for a given alternative solution (fig. 18).

The criterion called "future prospects" characterizes quantitatively qualities of a given alternative technology.It is determined by the indices:scientific and technical level, development possibilities. degree of automation and personnel availability.

By "personnel availability" is meant the quantitative evaluation of the adequate contingents of manpower, resposible to carry out design, construction, maintenance and operation tasks.

The quantitative evaluations of the indices of this criterion are subject to expert assessment.

The "ecological" criterion is determined on the basis of the indices shown on fig. 18 through their concentration C_i in $/m^3$ gases and the absolute quantities released in the atmosphere.

The different physical nature of the partial criteria, however, does not allow for determination of the global criterion, as was the case with the quantitative evaluation of the ecological criterion.

The overcoming of this difficulty can be done through evaluating the criteria by a dimensionless rating scale.

The method of establishing the quantitative relations between the indices and the partial criteria in the criteria tree is a specific problem for each particular country and is solved by expertize.

This approach may lose its global character and have some simplified modifications, assuming that some factors, indices or partial criteria are preliminarily eliminated from the process of decision making.

Conclusion

It is a very important task for a small country like Bulgaria to solve the power generation problems on the basis of brown coal, and particularly on the basis of low-rank coal. There are however some successful results and experiments achieved by our relatively small staff potential in the field of development, construction, reconstruction and operation of technology of low grade lignite and brown coal utilization for heat and electricity production.

Considering the integrated technology in the wide sense, including also the processes of mining (mainly open pit) and transport we gained considerable and significant experience in this area at home and abroad, which continues to develop, of course, by the joint work and cooperation with other countries.

With the gained research and technological experience it was natural to accumulate some theoretical results, which are useful for attaining by choice of the optimal technology of low-rank coal utilization in power engineering.

REFERENCES

1.* Todoriev N., Ganchev R. - Experience and state-of-the-arts in the arts in the utilization of low-grade lignite and brown coal in power engineering in Bulgaria

2.* Moumdjian G., Todoriev H., Latinski K., Bonev B. - Selection of an optimal technology for low-rank coal utilization

3.* Hristov H., Ganchev R., Bonev D., Sharkova T - Some results from the introduction of original Bulgarian technologies for milling and burning of low-grade lignite and brown coal abroad

4. Coal utilization, International forum on new technologies, UNESCO UNIDO, Essen, 1982

5. Coal development potential and prospects in the developing countries, World Bank Washington, 1979.

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* Workshop on Low-Rank Coal Utilization, October, 1986, Varna, Bulgaria

$$G=|a_{ij}|=\left|\begin{array}{cccccccc}
Q_i^r & A^d & C^r & V^{daf} & Al_2O_3 & \rho_{bulk} & k_{mill} & - \\
0 & W^r & H^r & K & SiO_2 & \rho_{ap} & 0 & - \\
0 & 0 & S^r & 0 & FeO & \dot{\rho}_r & 0 & - \\
0 & 0 & O^r & 0 & Fe_2O_3 & W^r_{max} & 0 & - \\
0 & 0 & N^r & 0 & CaO & \tau_{shear} & 0 & - \\
0 & 0 & 0 & 0 & MgO & \beta_{stat} & 0 & - \\
0 & 0 & 0 & 0 & Na_2O & \beta_{dyn} & 0 & - \\
0 & 0 & 0 & 0 & K_2O & k_{ins} & 0 & - \\
0 & 0 & 0 & 0 & W^r_{ex} & 0 & 0 & - \\
0 & 0 & 0 & 0 & W^r_h & 0 & 0 & - \\
- & - & - & - & - & - & - & -
\end{array}\right|$$

FIG.1

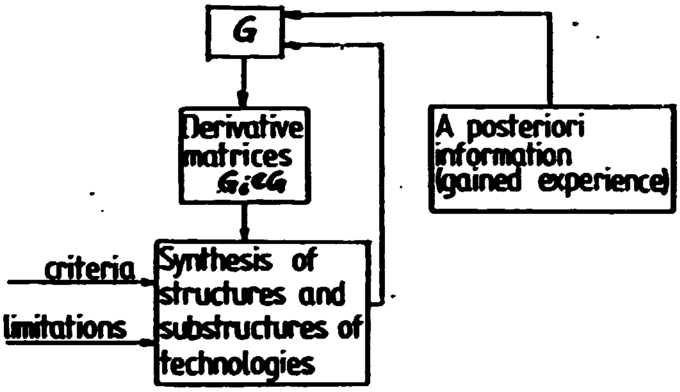

FIG.2

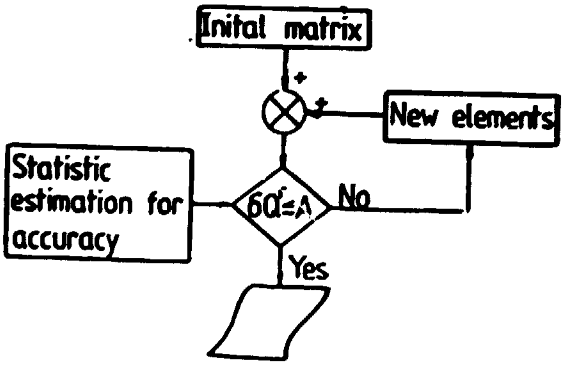

FIG.3

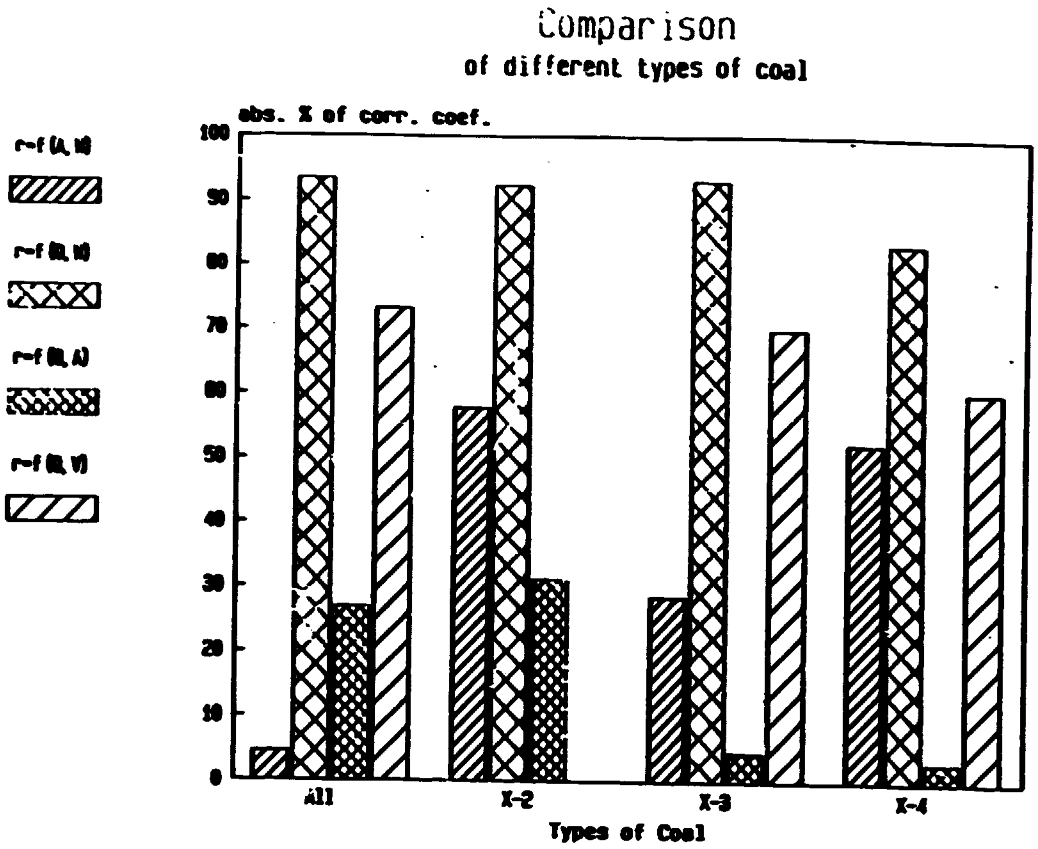
Comparison
of different types of coal
abs. % of corr. coef.
100
90
80
70
60
50
40
30
20
10
0
All
X-2
X-3
X-4
Types of Coal
r=f (A, M)
r=f (B, M)
r=f (B, A)
r=f (B, V)

FIG.4

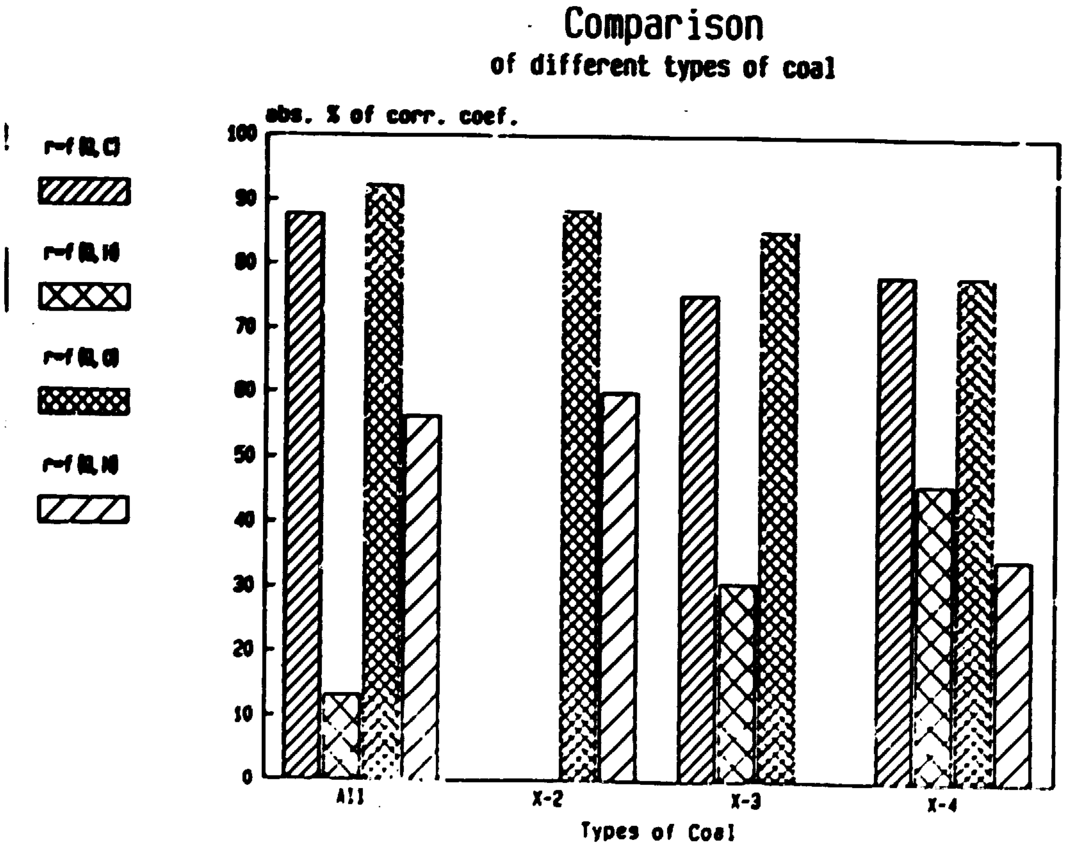
Comparison
of different types of coal
abs. % of corr. coef.
100
90
80
70
60
50
40
30
20
10
0
All
X-2
X-3
X-4
Types of Coal
r=f (B, C)
r=f (B, H)
r=f (B, O)
r=f (B, N)

FIG.5

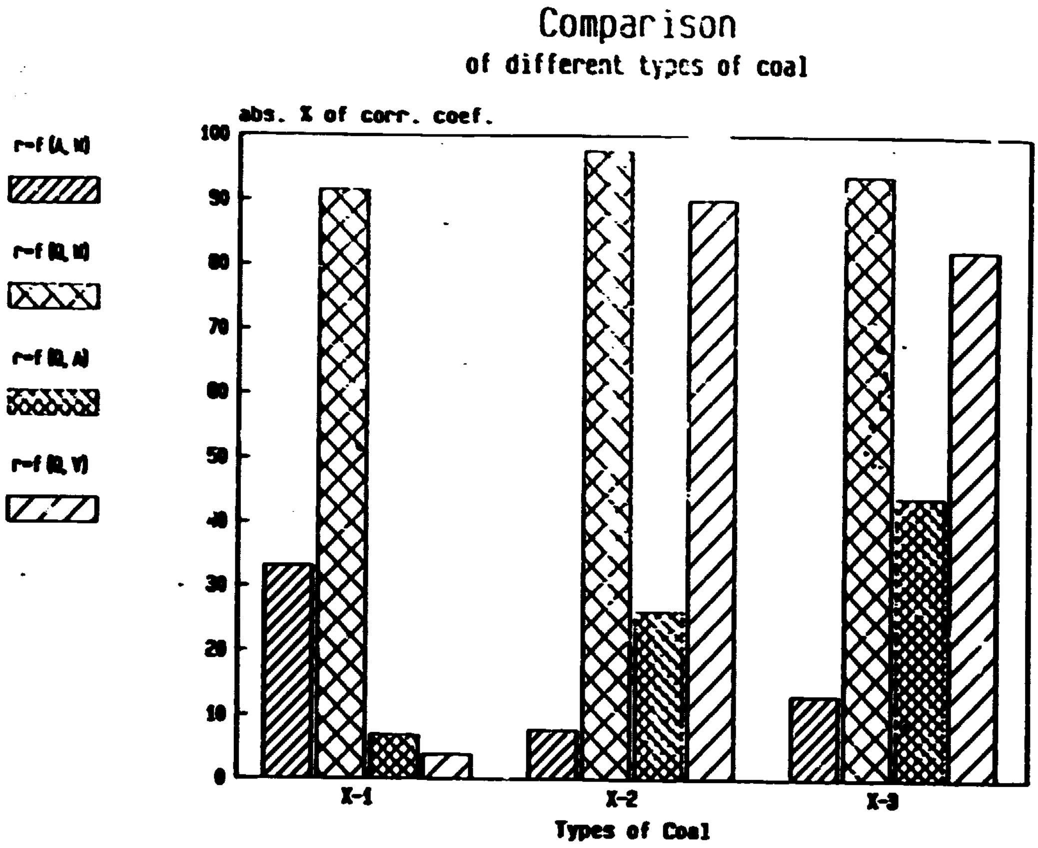
Comparison
of different types of coal
abs. % of corr. coef.
100
90
80
70
60
50
40
30
20
10
0
X-1
X-2
X-3
Types of Coal
r=f (A, M)
r=f (Q, M)
r=f (Q, A)
r=f (Q, V)

FIG.6

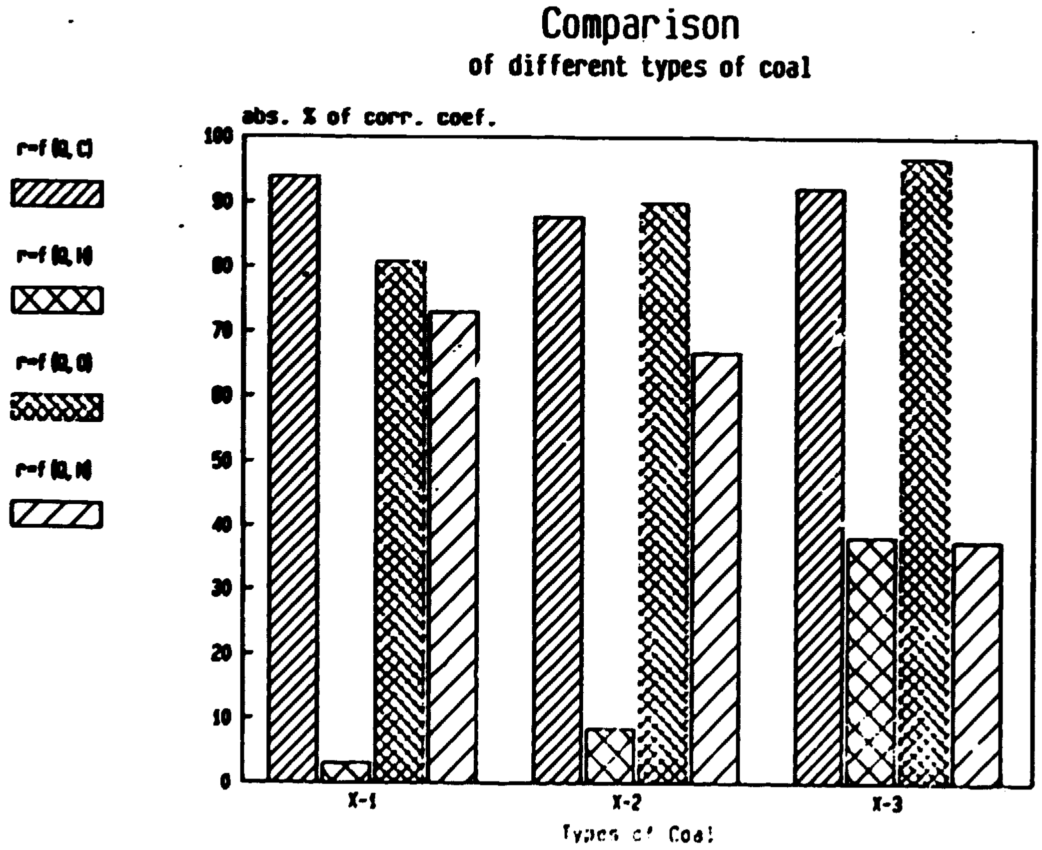
Comparison
of different types of coal
abs. % of corr. coef.
100
90
80
70
60
50
40
30
20
10
0
X-1
X-2
X-3
Types of Coal
r=f (Q, C)
r=f (Q, H)
r=f (Q, O)
r=f (Q, N)

FIG.7

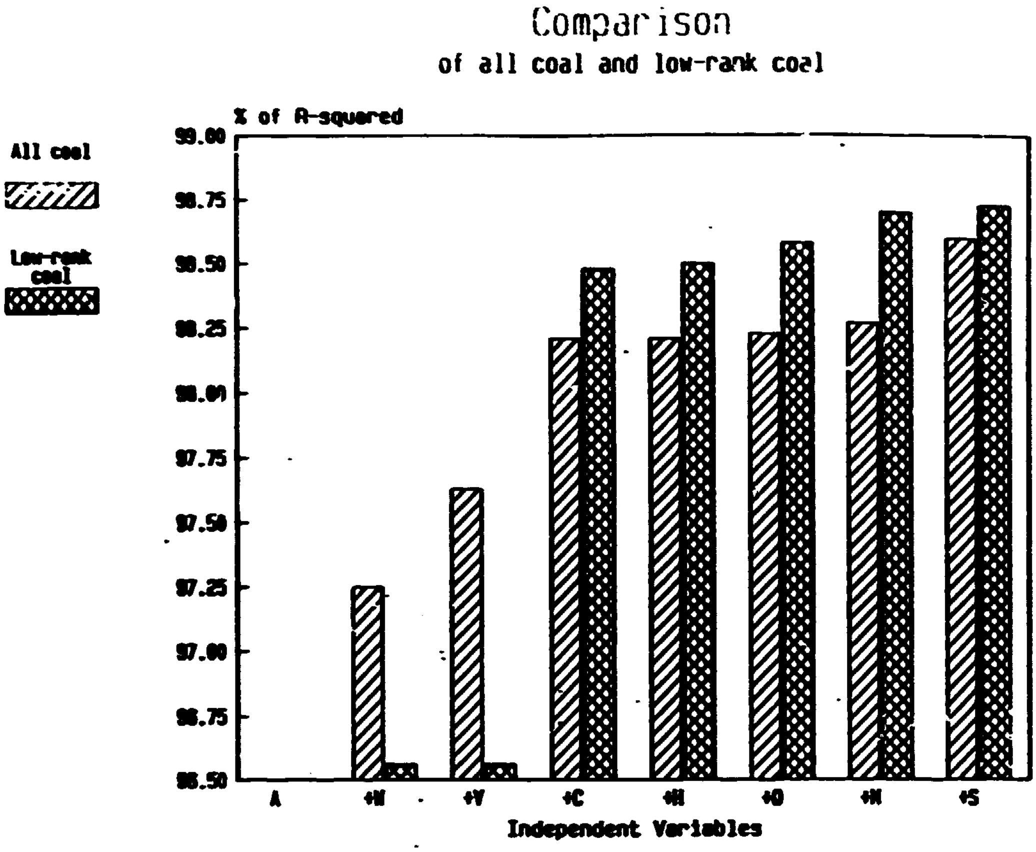
Comparison
of all coal and low-rank coal
% of R-squared
All coal
Low-rank coal
99.00
98.75
98.50
98.25
98.00
97.75
97.50
97.25
97.00
96.75
96.50
A
+W
+V
+C
+H
+O
+N
+S
Independent Variables

FIG.8

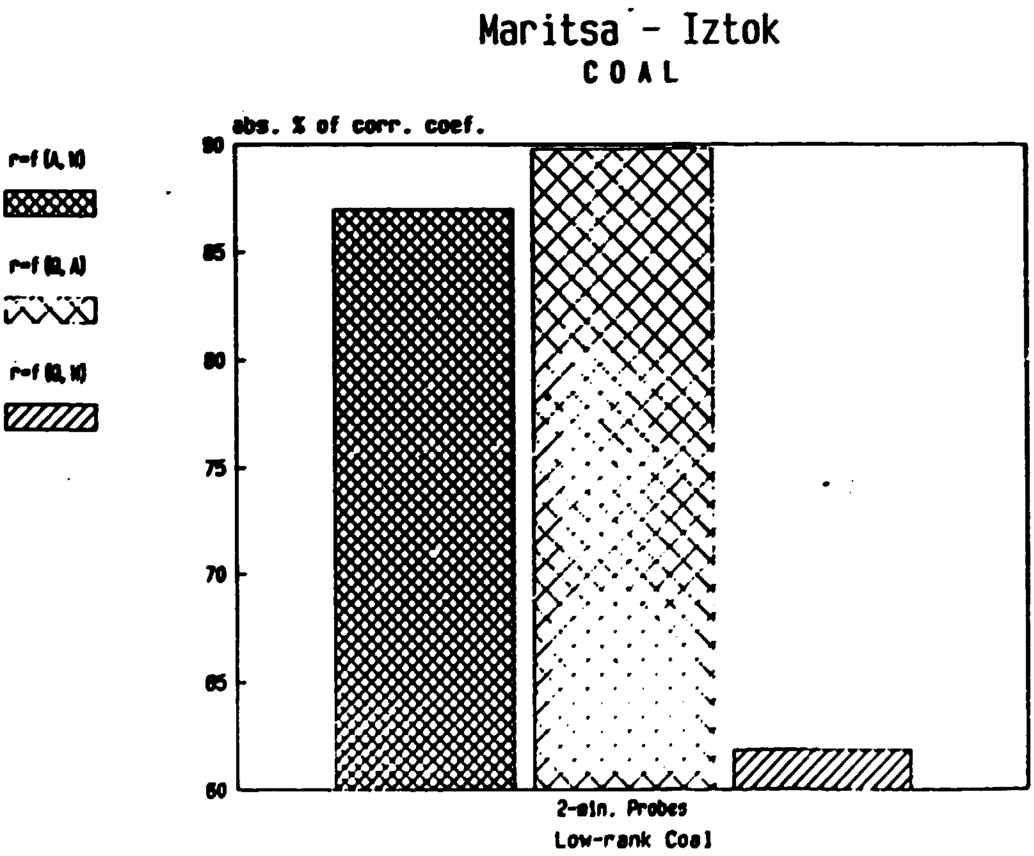
Maritsa - Iztok
COAL
abs. % of corr. coef.
r=f (A, W)
r=f (Q, A)
r=f (Q, W)
90
85
80
75
70
65
60
2-min. Probes
Low-rank Coal

FIG.9

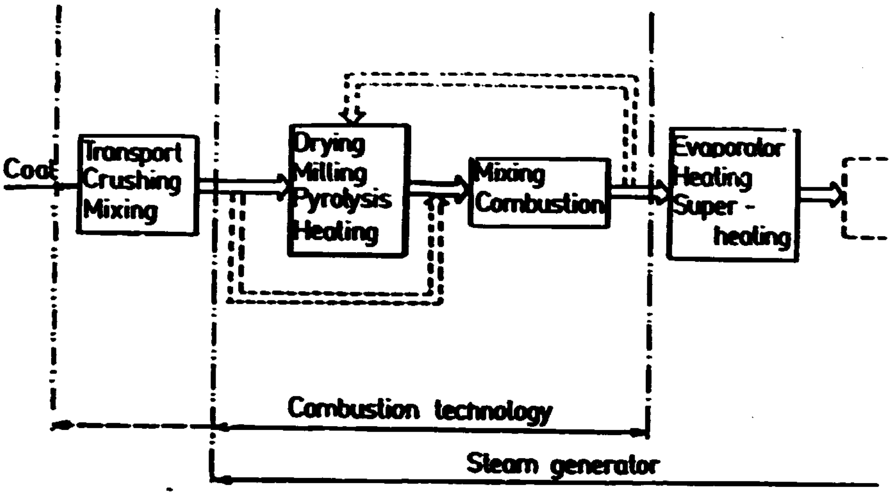
Coal
Transport
Crushing
Mixing
Drying
Milling
Pyrolysis
Heating
Mixing
Combustion
Evaporator
Heating
Super -
heating
Combustion technology
Steam generator

FIG.10

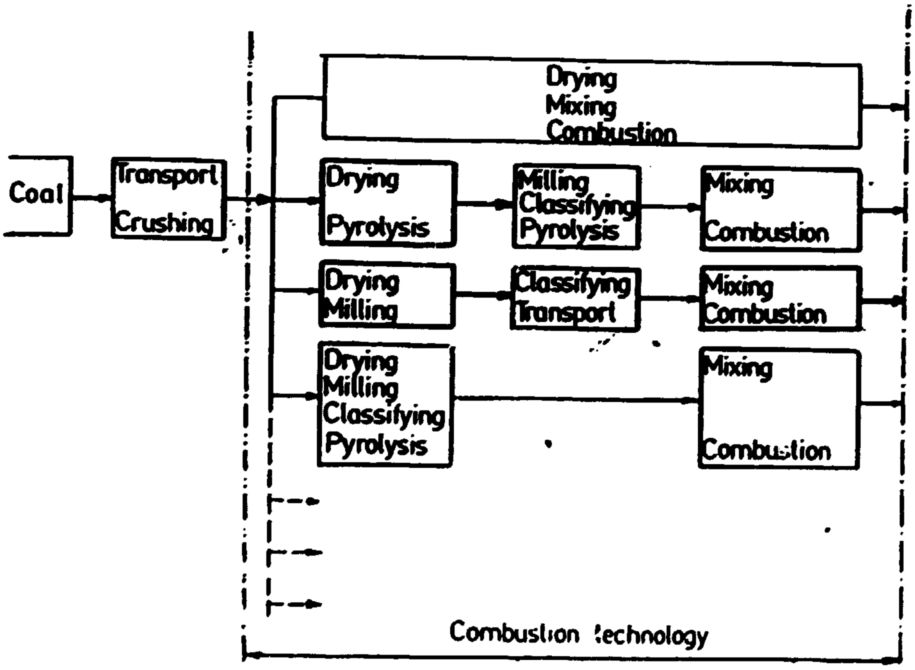
Coal
Transport
Crushing
Drying
Mixing
Combustion
Drying
Pyrolysis
Milling
Classifying
Pyrolysis
Mixing
Combustion
Drying
Milling
Classifying
Transport
Mixing
Combustion
Drying
Milling
Classifying
Pyrolysis
Mixing
Combustion
Combustion technology

FIG.11

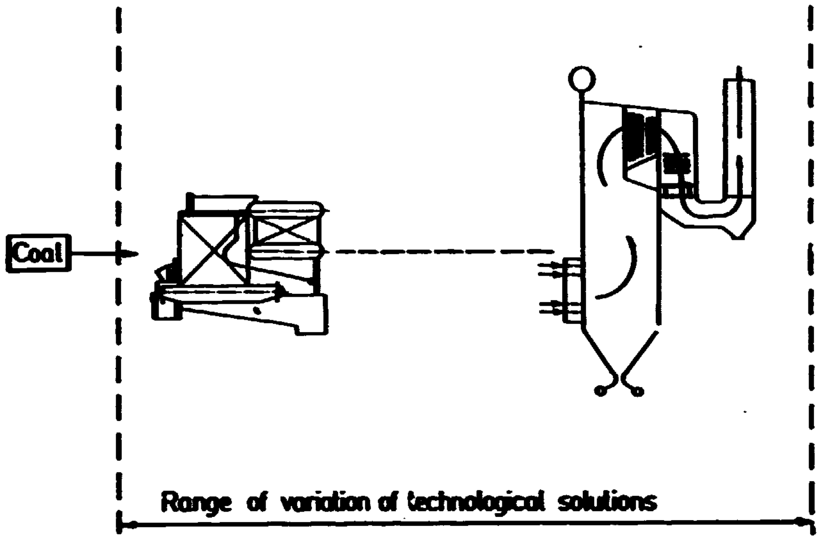
Coal
Range of variation of technological solutions

FIG.12

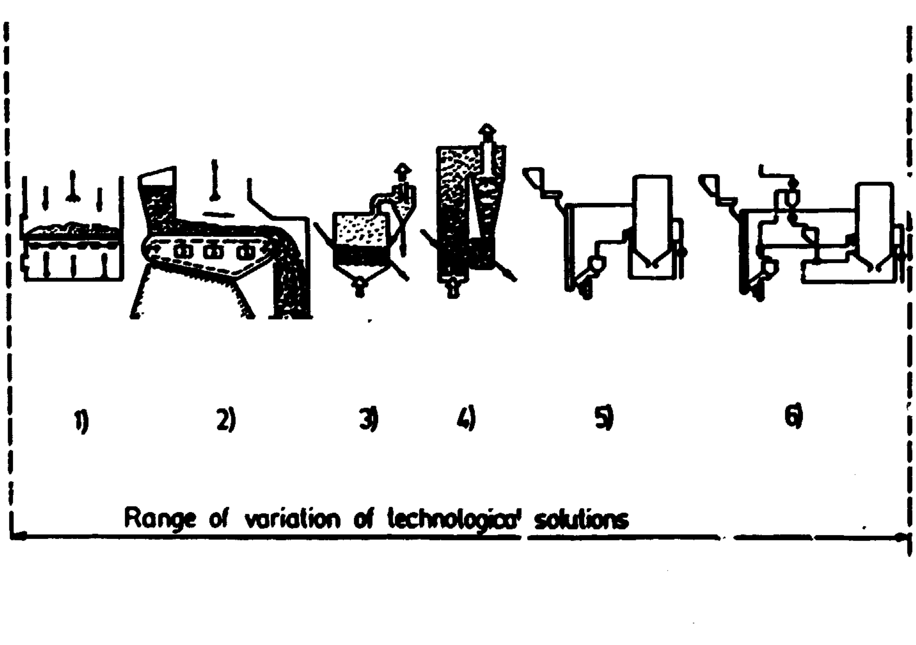
1)
2)
3)
4)
5)
6)
Range of variation of technological solutions

FIG.13

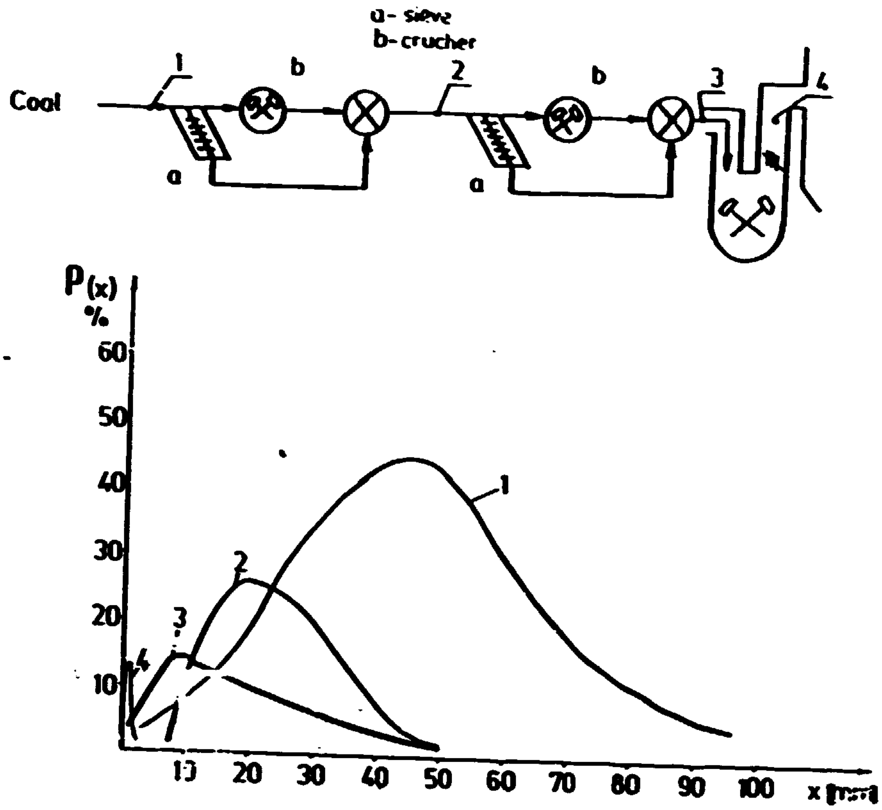
a- sieve
b- crucher
Coal
1
b
2
b
3
4
a
a
P(x)
%
60
50
40
30
20
10
1
2
3
4
10
20
30
40
50
60
70
80
90
100
x [mm]

FIG.14

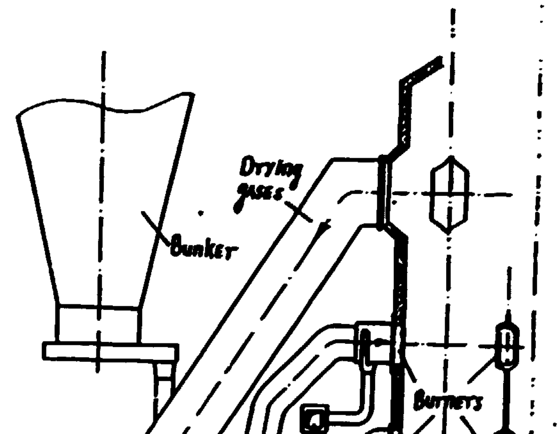
Drying gases
Bunker
Burners
Sec. Air
Mill

FIG.15

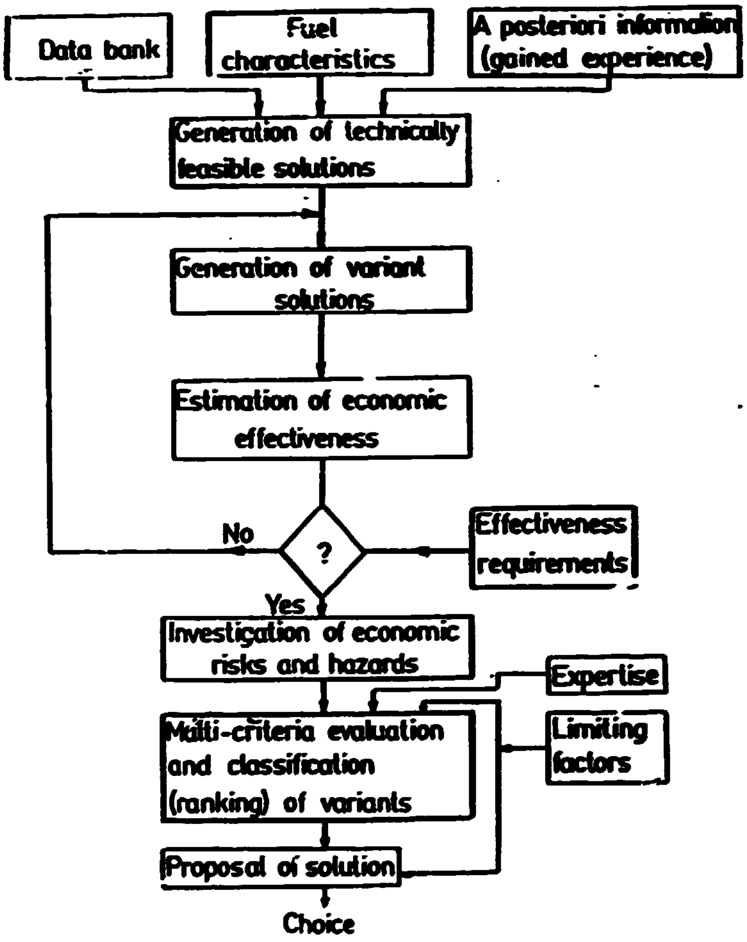
Data bank
Fuel characteristics
A posteriori information (gained experience)
Generation of technically feasible solutions
Generation of variant solutions
Estimation of economic effectiveness
No
?
Effectiveness requirements
Yes
Investigation of economic risks and hazards
Expertise
Multi-criteria evaluation and classification (ranking) of variants
Limiting factors
Proposal of solution
Choice

FIG.16

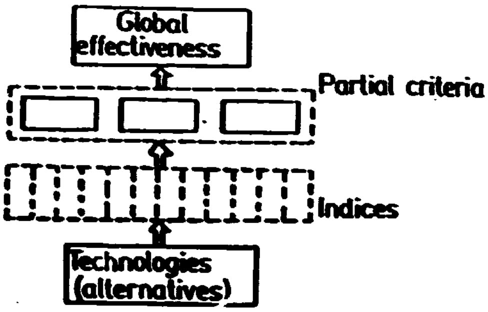
Global effectiveness
Partial criteria
Indices
Technologies (alternatives)

FIG.17

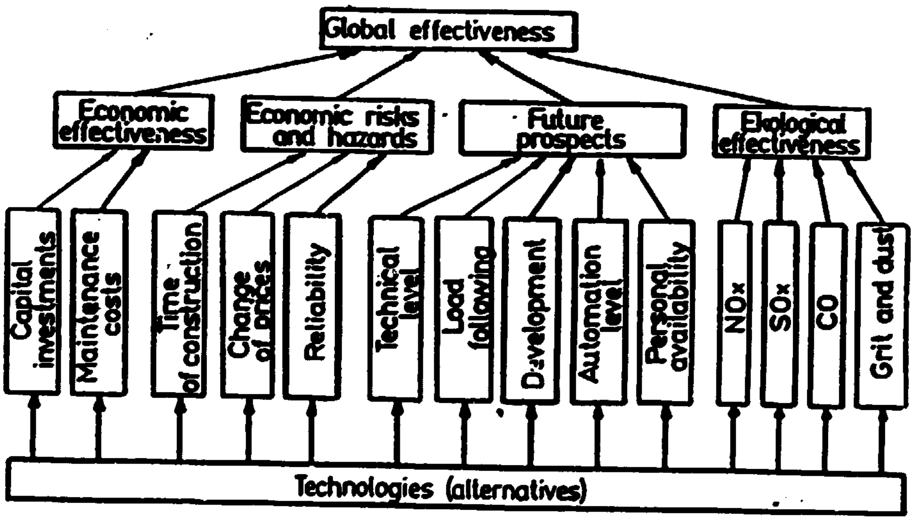
Global effectiveness
Economic effectiveness
Economic risks and hazards
Future prospects
Ekological effectiveness
Capital investments
Maintenance costs
Time of construction
Change of prices
Reliability
Technical level
Load following
Development
Automation level
Personal availability
NOx
SOx
CO
Grit and dust
Technologies (alternatives)

FIG.18