User's Guide for the MESSAGE Computer Program

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research memorandum
RM–78–26
Addendum
JUNE 1978

Addendum to:
RM-78-26

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May, 1978

TABLE OF CONTENTS

1. INTRODUCTION

This paper is a description of MESSAGE as it is implemented on the computer. At the same time it is intended as a user's guide for the implemention of these programs. The paper is divided into 5 parts: Section 2 gives a complete list of the equations generated by the matrix generator program and its input file of data. The source code of the matrix generator, the input file, and a sample control program are listed in Section 6. Sections 3 through 5 describe the usage of the program in increasingly greater detail.

Before turning to this description, a few words should be said about the procedure of how to run MESSAGE on the computer. As shown in Figure 1.1, this procedure involves five major steps: To begin with, the input file (step 1), required for the matrix generating program (step 2), must be prepared. The matrix generator (a FORTRAN program) reads this input file from unit 5 and then writes the LP matrix in standard MPS format* to logical unit 8 (step 3). An intermediate file (logical unit 9) is used by the matrix generator for the conversion of the input data format. A control output, consisting of the input data in more readable form, is written to unit 6. A small control

* Descriptions of the MPS format are found in any detailed manual on LP packages.

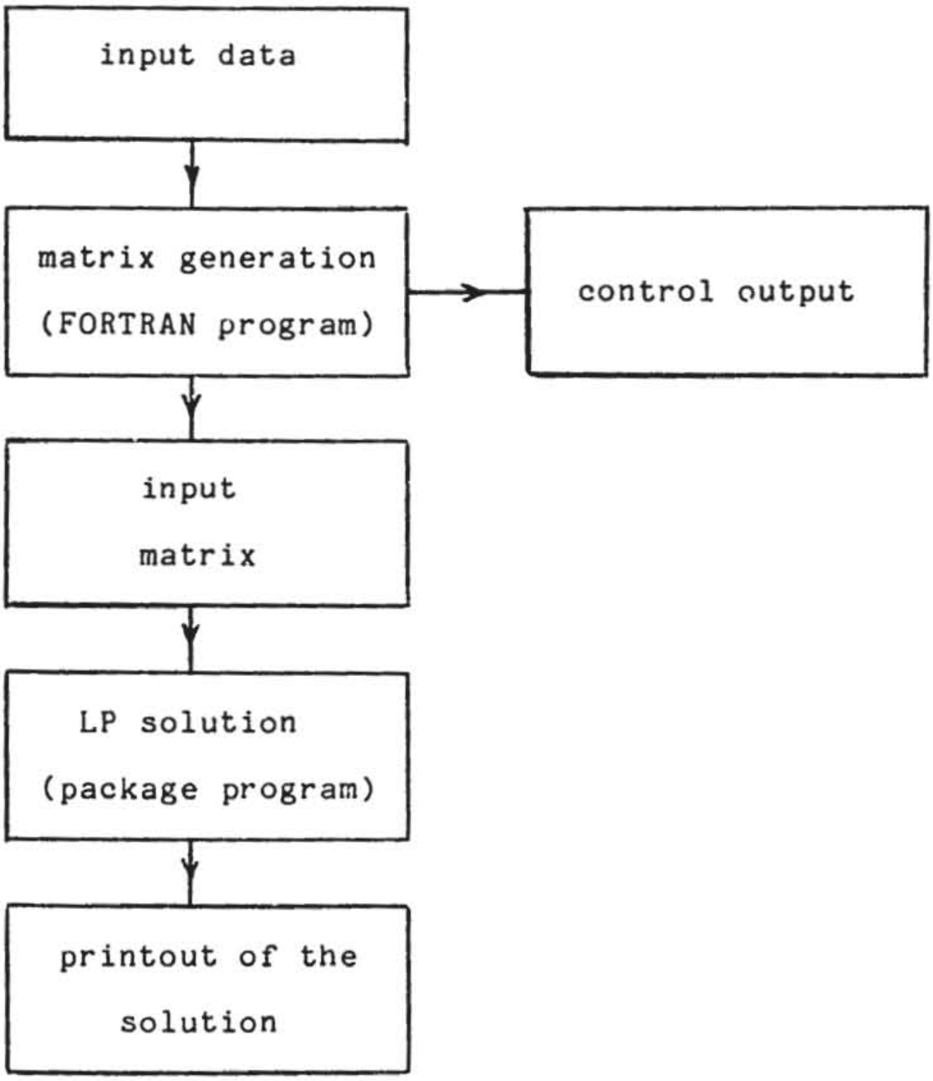

Figure 1.1 Steps for a computer run of MESSAGE.

program (step 4) must be provided to find the actual optimal solution. This control program as well as the final output of the solution (step 5) are dependent on the particular LP package used. This paper will concentrate on steps 1 and 2 but, as an example, describe the control program required for running the model with the MPSX LP code.

2. COMPLETE LIST OF EQUATIONS

This Section is a list of all equations generated by the documented program and its input. These equations correspond to MESSAGE I, the first version of the model, as it is described in [1]. As this paper focuses on the implementation of the model on the computer it does not contain much background information about the model itself. Therefore, the meaning of the equations is not easily understandable without knowledge of the model description.

Before the equations are presented, several remarks are in order: the model variables, and only these, are denoted by upper case single letters. The parameters (which are the variables in the matrix generator program) are denoted by their actual name in the program (in lower case letters) with one exception: Since it helps one, both in formulating and in understanding the equations, two of the parameters that can be chosen by the model user - the length of a time period and the length of service life of technologies - are denoted by the values they assume in the input file sample documented at the end of the Annex, namely a five year period for the first and a six period (= 30 years) service life for all technologies for the second.

Demand for electricity

$$\sum_i eta_i X^t_{i,m} \geq dm^t_{ELEC} pr_{ELEC,m} \qquad (2.1)$$

units: [GWyr]

$t = 1,\ldots,13$ (time periods)

$m = 1,2,3$ (load regions)

dm^t_{ELEC} annual demand for electricity in time period t

eta_i efficiency of supply technology i

$X^t_{i,m}$ energy output of technology i in load region m

$pr_{ELEC,m}$ fraction of total demand that occurs in load region m

i = UEA* (light water reactor)

PEA (fast breeder reactor)

CEA (conventional coal fired electricity plant)

AEA (advanced coal fired electricity plant)

HEA (hydroelectric and geothermal power)

SEA (solar-electric power)

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* The acronyms used here are those used to identify the model variables in the input for (and the output of) the LP code. An explanation of how to arrive at these particular acronyms will follow. Since, for the purpose of this paper, a technology is sufficiently described by the set of input data (i. e. numbers) referring to it, a more detailed description of technologies than the above rough classification will not be given.

EEA (electrolytic hydrogen * supplying liquid fuel demand)

BEA (electrolytic hydrogen supplying gaseous fuel demand)

LEA (oil-fired electricity plant)

GEA (gas-fired steam generating electricity plant)

JEA (gas turbines)

Demand for liquid fuels

$$\sum_i eta_i X_i^t - \sum_k eff_k X_k^t \geq dm^t_{LIQUID} \qquad (2.2)$$

units: [GWyr-out]

i = ALA (coal liquefaction)

RLA (crude oil refinery)

ILA ("inexhaustible"** supply of liquids)

dm^t_{LIQUID} annual demand for liquid fuels in time period t

eff_k specific consumption of liquid fuels by technology k in [kWh input/kWh output]

k = EEA (electrolytic hydrogen supplying demand * for liquid fuels)
LEA (liquid fuel fired power plant)

---

* The signs of eta_{EEA} and eta_{BEA} are negative indicating that these technologies "produce" negative amounts of (i.e. consume) electricity. This way of formulating the equations allows one to fit the special case of electrolysis into the more general framework both of this description and of the computer program.

** The "inexhaustible" technologies are dummy variables which have been included in the program to prevent infeasibilities. Their cost figures are such that these technologies are the least preferred ones, so that all other technologies are fully used before these dummy variables enter the solution.

Demand for coal

$$eta_{COAL} X^t_{COAL} \geq dm^t_{COAL} \qquad (2.3)$$

dm_{COAL} annual demand for coal in time period t

Demand for gaseous fuels

$$\sum_i eta_i X^t_i - \sum_k eff_k X^t_k \geq dm^t_{GAS} \qquad (2.4)$$

units: [GWyr-th]

dm^t_{GAS} annual demand for gas in time period t

i = AGA (coal gasification)
NGA (natural gas)
IGA ("inexhaustible" supply for gas)

k = BEA (electrolytic hydrogen supplying demand for gaseous fuels)
GEA (gas-fired steam generating electricity plant)
JEA (gas turbines)

Balance equations for man-made materials

$$5 \sum_{i,m} qcon_{i,l} X^t_{i,m} + 5 \sum_i qinv_{i,l} Y^t_i$$

$$- 5 \sum_i qret_{i,l} Y^{t-6}_i + S^{t-1}_l - S^t_l = 0 \qquad (2.5)$$

units: [tons]

l = plutonium

$qcon_{i,l}$ fuel requirements for man-made fuel l by technology i in [t/GWyr]

$qinv_{i,l}$ inventory requirement for man-made fuel l by technology i in [t/GW]

$qret_{i,l}$ retired fuel (end of plant life) of kind l in [t/GW]

Y_i^t annual increment of new capacity of technology i between capacity levels at periods t-1 and t

Y_i^{t-6} annual retirement of old capacity of technology i between capacity levels at periods t-1 and t (i.e. construction activities 30 years earlier)

S_l^t stockpile of man-made fuel l in time period t

The constant factor 5 reflects the five year time period.

Fossil fuel requirement

$$\sum_{i,m} fcon_{i,l} X_{i,m}^t - \sum_j R_{l,j}^t \leq 0 \qquad (2.6)$$

units [GWyr-th]

l = coal, oil, gas

j = 1,ngr(l)+imp(l)*

$R_{l,j}^t$ total annual consumption of fossil resource l, category j in time period t.

$fcon_{i,l}$ specific annual consumption of fossil fuel l by technology i.

Nuclear fuel requirement

$$\sum_{i,m} ncon_{i,l} X_{i,m}^t + \sum_i ninv_{i,l} Y_i^t$$

$$- \sum_i nret_{i,l} Y_i^{t-6} - \sum_l R_{l,j}^t \leq 0 \qquad (2.7)$$

units: [10^3 tons]

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* ngr(l) is the number of domestic categories of the resource l; imp(l) is the number of import categories of that resource - it can be 0 or 1.

l = natural uranium

$j = 1,3$

$R^t_{l,j}$ total annual consumption of nuclear resource l, category j in time period t

$ncon_{i,l}$ specific annual consumption of nuclear fuel l by technology i

$ninv_{i,l}$ inventory requirement of nuclear fuel l by technology i

$nret_{i,l}$ inventory retirement of nuclear fuel l by technology i.

The variables Y^t_i for $t<1$ are fixed at levels determined by virtue of the the data on initial capacity and historical growth rate of technologies. For further details, see the description of the input file and Section 5.

Availability of natural resources

$$5\sum_t R^t_{l,j} \leq rlim_{l,j} \tag{2.8}$$

units: [GWyr] for fossil, [10^3 tons] for nuclear resources.

l = coal, oil, gas, natural uranium

$j = 1,ngr(l)+imp(l)$

$rlim_{l,j}$ total availability of resource l, category j over the planning horizon.

Annual extraction of domestic resources

$$\sum_{j=1}^{ngr(l)} R_{l,j}^{t} \leq pm_{l}^{t} \qquad (2.9)$$

units: [GWyr] for fossil, [10^3 tons] for nuclear resources.

pm_l^t maximal annual extraction of domestic resource l.

Capacities of technologies

$$X_{i,m}^{t} - \sum_{\tau=t-5}^{t} 5pf_i yf_{j,m} Y_i^{\tau} \leq 0 \qquad (2.10)$$

units: [GWyr]

pf_i plant factor of technology i

$yf_{j,m}$ fraction of time in which load region m in demand sector j is operating.

Market penetration constraints

$$Y_i^t - gam_i Y_i^{t-1} \leq g_i \qquad (2.11)$$

units: [GW]

gam_i growth parameter

g_i parameter allowing for a start-up of a technology.
A market penetration constraint is generated only if $gam_i \neq 0$.

Emission of pollutants

$$\sum_{i,m} em_{i,l} x^t_{i,m} - B^t_l = 0 \qquad (2.12)$$

units: [emissions/GWyr]

l = krypton, tritium, co2, particul, nox, sox, hydcarb, m-co*

$em_{i,l}$ specific emission of pollutant l by technology i. For the units of these emissions see the description of the input data in the next Section.

B^t_l total emissions of pollutant l at time t.

Concentration of pollutants

$$\sum_{\tau=1}^{t} 2^{5(\tau-t)/t2_l} B^{\tau}_l \qquad (2.13)$$

units: [specific to pollutant]

$t2_l$ half-life of pollutant l.

l = krypton, tritium, co2

Upper bounds for conservation technologies

$$x^t_i \leq .15 dm^t_j \qquad (2.14)$$

units: [GWyr]

i = KLA, KLB, KGA, KGB

j = LIQUID, GAS

* In order to ensure that the LP names generated by the matrix generator are unique, some real names had to be changed (see description of lines 33-34 in the input file).

Upper bounds on construction activities

$$Y_i^t \leq bv_i^t \qquad (2.15)$$

units: [GW]

bv_i^t upper bound* on annual construction rate for technology i in period t.

Upper bounds on annual imports of natural resources

$$R_{l,j}^t \leq px_l^t \qquad (2.16)$$

units: [GWyr]

Although implemented in the program, there is no equation of this type in the documented version of the model.

px_l^t maximal annual import of resource l in time period t.

Cost and investment functions

Operating costs:

$$\sum_{t,i,m} 5X_{i,m}^t cur_i \beta^{5t-2.5} \qquad (2.17)$$

units: [10^6 \$74]

Capital costs:

$$\sum_{t,i} 5Y_i^t cap_i \beta^{5t-5}(1-tv_t) \qquad (2.18)$$

units: [10^6 \$74]

* Optionally, fixed and lower bounds may also be specified (see description of input data in the next Section).

Fuel costs:

$$\sum_{t,l,j} 5R^t_{l,j} rc_{l,j} \beta^{5t-2.5} \qquad (2.19)$$

units: [10^6 \$74]

Investments:

$$\sum_{t,i} 5Y^t_i cap_i \qquad (2.20)$$

units: [10^6 \$74]

β one year discount factor (here, the superscripts are exponents*)

cur_i current costs of technology i

cap_i capital costs of technology i

tv terminal valuation factor: $\beta^{5(14-t)}$ if t>7, else tv=0. tv approximates the value of the capacity of the technologies that is still operating at the end of the planning horizon. This factor is included to correct the value of the objective function for the value of the energy supply system existing after the end of the planning horizon.

$rc_{l,j}$ cost of resource l, category j

<u>Objective function</u>

The objective function is the sum of operating, capital, and fuel costs.

* The difference in the exponents of β in the various cost functions depends on the interpretation of the variables.

3. THE PARAMETERS

This Section contains the basic information for using the matrix generator and running the model. Subsection 3.1 is an explanation of the variable and row names as they are used in the computer program. Subsection 3.2 describes that part of the input to the program which comprises parameters that can readily be changed, i. e. without change of any other data in the input file.

3.1 Names

Understanding the programs described here begins with an understanding of the ultimate output (the LP solution). Therefore we start this description by explaining the names of the LP activities and constraints (columns and rows).

With the only exception of the cost functions all LP names consist of an 8-character string. In this string, the last three characters are reserved for the identification of the world region (place 6) and for the number of the time period (places 7 and 8). The first character is always a letter which identifies all variables or rows of one class. The meaning of the remaining four places (2 to 5) depends on this classification letter. These letters are interpretated individually below.

Just as the LP names are important for understanding the LP output, there is another set of names behind the LP names (the understanding of which is even more crucial for preparing the input to the matrix generator), the input names. These input names can be divided into the names of technologies, demand sectors, natural resources, man made resources, and pollutants. The input names are used to form the LP names, i. e. the LP name uses the initial letter of the input name. Thus, all names within each of the above mentioned groups of input names must start with different letters. However, input names in different groups may well start with the same letter (e. g. resource category "coal" and demand sector "coal" are different). There is one exception to these rules: Input names of technologies may start with the same letter since the distinction of variable (row) names can also be achived by other means. How this is done will be explained below.

A variable (row) name in the LP matrix consists of eight characters of upper case letters, dots, and numbers in exactly the same way as in the following list of names. A dot (".") is used to pack space. Lower case letters in this description stand proxy for other upper case letters with which the matrix generator replaces them.

3.1.1 List of Variables

The X variables

Xijnkwtt are the activities for the production of final energy. The meaning of the last three letters was explained above (world region and time index); X is the classification character.

i is the first letter of the name of the technology as it appears in the input file.

j is the first letter of the demand sector that is supplied by that technology.

n is an additional identifier which can be used to distinguish technologies with names starting with the same letter, e. g. different versions of the same technology.

m is the number of the load region in demand category j if j has more than one category. If there is only one load region in a demand sector, m is replaced by a dot.

Thus, for the program any technology is defined by the parameters i, j, and n. Therefore, different technologies must have names that are different in at least one of these three parameters. Also, since the emphasis of this paper is on the computer program rather than on the model, from now on technologies will be described only in terms of these identifiers.

For example: XCEA1W05 is the name of the production activity of electricity by technology CEA (coal fired electric plant) in load region 1 in time period 5 and in world region "w".

The Y variables

Yijn.wtt are the construction activities for technology ijn. The meaning of the identifiers is the same as in the X-activities above, but there is no more need to distinguish between load regions.

The R variables

Rlm..wtt are the natural resource activities.

l is the kind of the natural resource considered (e. g. oil, gas).

m is the cost category. If an import category is defined for any kind of natural resources it is denoted by the highest "m" in the corresponding group of LP names.

The S variables

Sl...wtt are the stockpiles for man-made resources.

l is the kind of man-made resource (e. g. plutonium).

The I variables

Il...wtt are the emission variables.

l is the kind of pollutant emitted (e. g. tritium).

3.1.2 List of Row Names

The sequence of the row names described here is the same as that generated by the sample program documented in Section 6.

FUNC	objective function, equations (2.17), (2.18), (2.19)
CCUR	current costs, eq. (2.17)
CCAP	capital costs, eq. (2.18)
FCST	fuel costs, eq. (2.19)
INVSTwtt	annual investments, eq. (2.20)
D.j.mwtt	the demand equations, eq's (2.1) - (2.4)
El...wtt	balance equations for man-made materials , eq. (2.5)
Ll...wtt	balance equations for natural resources, eq's (2.6), (2.7)
Alj..wtt	availabilities of natural resources, eq. (2.8)
Pl...wtt	maximal extraction of domestic resources , eq. (2.9)
Cijnmwtt	capacity equations, eq. (2.10)
Mijn.wtt	market penetration constraints, eq. (2.11)
Im...wtt	emission constraints, eq. (2.12)
Fm...wtt	concentration of pollutants, eq. (2.13)

3.1.3 Other Names

RHSn right hand side vector n

BNDn bounds set n

3.2 Numbers

The numerical input for the matrix generator consists of two kinds or levels of information: the first kind is data that are straightforward to change, whereas the second are data that cannot, in general, be changed without changing the structure of the input file or without changing the amount of data required at other places. This Subsection will deal exclusively with the first kind of data, the second kind will be described in the next Section.

Before starting to discuss the content of the input file (a complete listing of which is given in Section 6 of this paper) some general remarks about its format are in order:

i) The program assumes initialization of all variables to zero value.

ii) The input is in card image form, i.e. not more than 80 characters can be in any one line. Column 80 must be blank.

iii) The items of data are separated by an arbitrary number of blanks. Within these separators, the following FORTRAN formats are assumed:

a8 for character strings

i4 for integers*

g12.5 for real numbers

iv) If in any line, a data item starts with a semicolon, the rest of this line following and including the semicolon will be interpreted as a comment and is therefore ignored.

v) The end-of-input is an 'at-sign'.

The rest of this Subsection is the program description on the first level - it describes input data that can be readily changed.

Line 2 — Discount rate in percent. The one-year discount factor [$\beta = 1/(1+\text{discount rate}/100)$] is calculated by the program.

Lines 5-12 — The average annual demand figures for the four demand sectors in [GWyr], 13 entries, one for each (5 year) time period required.

Line 13 — Weights allocating the total demand of one sector to the load regions of this sector (factors $pr_{j,m}$ in eq's (2.1) - (2.4)). Three factors are for the three load regions of demand for electricity, the factors for the other three demand sectors are all equal to unity since they are not subdivided into load regions.

Line 14 — Duration of load regions, expressed in fractions of a year ($yf_{j,m}$ in eq. (2.10)).

Lines 17-19 — Total availabilities of fossil fuels in [GWyr] and (the one) nuclear fuel in [10^3 tons]. There is one entry for each fuel type (coal,oil and gas) and each category (2 for coal, 3 for domestic oil, 1 for imported oil, 3 for natural gas, and 3 for natural uranium ($rlim_{1,j}$ in eq. (2.8))

* On some systems this means that "1" e. g. must be written as "0001". This, because all data are written to and read from an intermediate file.

Line 21 "Extra" switches. A "0" entry means no extra feature for this particular resource, the entry "1" in the second place means that the price for imported oil rises at 2 percent per year till $ 30/bbl. This is the only way these switches can be used in the resource part so far. Nevertheless, this general way seems to be the most practical way of programming since it helps to avoid frequent compilation of the source program.

Lines 22-29 Upper limits (bounds) for the annual extraction of domestic coal and domestic oil in [GWyr/yr], 13 entries each (one per time period). ($pm_{1,j}$) in eq. (2.9))

Lines 30-31 The cost figures for natural resources in [10^6 \$/GWyr] for fossil fuels and [10^6 \$/10^3 t] for natural uranium. They are in the same order as the figures for the availabilities above ($rc_{1,m}$ in eq. (2.19)).

Line 35 Half-lives of pollutants ($t2_1$ in eq. (2.13)). These entries also have a meaning as keys. Concentration constraints are generated for those pollutants that have a non-zero half-life. Additionally, the names of pollutants must be grouped in such a way that all pollutants with non-zero half-life come first.

Line 38 This is the beginning of the description of the technologies. Each technology is described by a standard set of data beginning with the name of the technology. The next two entries complete the identification of the technology as described in the previous Subsection. The explanation of the rest of the entries uses the example of the LWR in the sample input listing. The sequence of the coefficients is the same, of course, for all technologies.

42.3 current cost in [10^6 \$/GWyr]; cur in eq. (2.17)

585. capital cost in [10^6 \$/GW]; cap in eq. (2.18)

1.5 growth factor [1/period]; gam in eq. (2.11) This entry is also used as a key: If it is equal to zero, no market penetration equation is generated by the program.

2. Start-up factor [GW]; g in eq. (2.11)

.703 Max. plant factor [100 %]; pf in eq. (2.10)

3*0. Fossil fuel consumption [GWyr-in/Gwy-out]; fcon in eq. (2.6). These zeroes are the consumption figures for the fossil fuels coal,oil and natural gas. For the nuclear fuel "natural uranium" as well as for the artificial fuel "plutonium" more than one coefficients are needed:

.171 Natural uranium consumption [10^3t/GWyr]; ncon in eq. (2.7)

.408 Natural uranium inventory [10^3t/GW]; ninv in eq. (2.7)

0. Natural uranium retirement [10^3t/GW]; nret in eq. (2.7)

-.215 Plutonium consumption [t/GWyr]; qcon in eq. (2.5)

0. Plutonium inventory [t/GW]; qinv in eq. (2.5)

0. Plutonium retirement [t/GW]; qret in eq. (2.5)

4*0. Inputs from other demand sectors [GW_{in}/GW_{out}]; one entry for each demand sector is needed; eff in eq's (2.1) - (2.4)

1.25 Historical annual growth rate of Y activities. For technologies that have a non-zero initial capacity (see next entry), this growth rate is used for the calculation of the initial conditions (the Y activities for time periods less than 1). Assuming that the initial capacity of a technology consists of all those plants constructed within the last 30 years and that the construction activities for these technologies have increased at a constant historical growth rate, the following formulae apply for the calculation of the initial conditions (see eq. (2.10)) :

$$y^0 = c0 \frac{gr^{-5}-1}{5(gr^{-30}-1)} \qquad (3.1)$$

$$y^{-t} = y^0 gr^{-5t} \qquad t=1,\ldots,5$$

This looks like a complicated formula but it has the advantage that only two paramaters must be specified. Of course, the initial conditions can also be explicitly specified if the matrix generator is changed. This is not a major change and is described in Section 5.

32.6 Initial capacity in [GW].

0 Key. If equal to 1 this key has to be followed by 14 entries: the first entry denotes the kind of bounds to be imposed on the Y variables. This descriptor is the same as it is in the MPS format in the input matrix (i. e. "fx", "up" and "lo" are the ones in question specifying fixed, upper, or lower bounds, respectively). The values of bounds that follow are used as keys too: no bound will be generated if the value of an entry is greater than 900. Any bound with zero value gets a "fx" entry in the LP input.

0 Key. This is the last entry in the description of a technology except for the emission coefficients. It is used in the same way as the "extra" switches in the resource part of the input file. In the documented pogram, there are two possibilities for these extra switches: "1" means that a technology supplies only demand of load region 1 of "its" demand sector, "2" means that a technology is not allowed to supply more than 15 percent of demand in its sector (here used for the conservation technologies).

5.3e+5 ... 0.65e-01 Specific emissions of pollutants named in lines 33 and 34. The units are cu/GWyr for the radioactive pollutants and tons/GWyr for all others.

4. THE REST OF THE INPUT FILE

In the previous Section only those parameters were described whose value did not have impact on other parts of the input file. This Section completes the description of the input file by giving the other parameters and the changes they cause at other places of the input file. The ranges for some parameters are limited because FORTRAN does not allow for dynamic allocation of storage. How to change these fixed ranges for the parameters will be described in Section 5.

Line 1: Sometimes it happens (especially when a new input file is set up) that one is only interested in the control output of the matrix generator but not in the matrix itself. This can be achieved by setting the first switch in this line to "1". Any other integer in this place will also cause the matrix to be generated.

The second parameter switches the generation of the environmental submodel on (if set to "1") and off (any other integer). Not generating the environmental submodel has also the effect that no input data (the names of the emittants, the half-lives and the emission coefficients of the technologies) are expected to be read by the matrix generator and therefore must be omitted in the input file.

The third parameter (13 in the example given in Section 6) indicates for how many time periods the input data are given. Thus, whenever the program asks for one input parameter per time period, exactly this number of input parameters per time period must be provided (an excellent occasion for erraneously setting up the input file *). This parameter must be less than or equal to 15.

The fourth parameter gives the number of time periods for which the model is to be set up (here: 13). Of course, this number must be less than or equal to the previous one (usually used for testing and set at a low value).

The next parameters (here: 5 and 6) are the length of a time period of the model in years and the length of the plant life of the technologies in periods.

In that part of the input file which concerns the data for natural resources, both fossil and nuclear resources are treated in the same way. But, for the description of a technology a distinction must be made between (fossil) fuels which are sim-

* There are many more sources of error, but it was decided that this was the lesser evil than the necessity to change the code of the matrix generator for different runs of the model. Also, running the matrix generator in "test mode" (The first switch is set to "1") effectively discloses this kind of error (Input conversion error).

ply consumed at a certain annual rate depending on the output of a technology and (nuclear) fuels which are both consumed at a certain annual rate and required for (and recovered from) inventories. Therefore, the natural resources must be divided accordingly, and the seventh parameter in this line (here: 4) is the number of the first resource of the second (nuclear) type. Using a normal FORTRAN compiler this number cannot exceed the number of resources (line 15) nor can it be equal to 1 for the same reason. In other words, at least one resource of either kind must be defined (even if it is not used by any technology).

The last two parameters (here: "1" and "1") give the numbers of right hand side (RHS) vectors and bounds sets to be generated. Up to three RHS vectors and two bounds sets are possible. For a quick reference, those (groups of) data that must be given for each RHS vector (bounds set) are summarized. In this summary, the data are grouped in the same way as they must be grouped in the input file, i. e. a group of data must not be separated in the in the input file or, in other words, all data belonging to one group must be specified for the RHS vector 1 (bounds set 1) and then for each subsequent one.

<u>Right hand side</u>

- Demand figures (lines 5 to 12) and the parameters for the distribution of demand into the load regions (line 13).
- Availabilities of natural resources (lines 17 to 18).
- Maximal extraction of domestic natural resources (lines 22 to 30).
- Right hand side value of market penetration constraint (one parameter for each technology must be specified; cf. description of technology data).

<u>Bounds set</u>

- Growth rate and initial capacity for the initial conditions (cf. eq. (3.1)), and the switch for bounds on the Y activities: if equal to 1, this switch must be followed by the kind of bounds to be generated and by its values as described above (Subsection 3.2).
- Switches for annual imports restriction (line 20).
- Maximal annual imports of resources.

Line 3 The number of demand sectors (≤ 7), followed by their names. The number of demand sectors determines the number of load region data and the data for total demand (lines 4 to 10). Furthermore, in the description of the technologies (under the label "other inputs") one parameter for each demand sector is expected.

Together with the number of load regions per demand sector, other parts of the input file are affected. These will be described below.

Line 4: Number of load regions ($\leq$ 4) in each demand sector, one per sector. The data depending on these numbers are the distribution factors (line 13) and the durations of each load region (line 14). In both cases one entry must be specified for each load region of each demand sector, the sequence being all data for the second one, etc.

Line 15: This is the beginning of the resource part of the input file. Its structure is very similar to the demand data part. Again it starts with the number of resources ($\leq$ 5) followed by their names. The number of natural resources determines the number of parameters in line 20 (switches for the maximal extraction of domestic resources and maximal annual imports) and line 21 (extra switches). In the description of technologies, one entry (the annual consumption) must be provided for each fossil fuel and three entries for each nuclear fuel (one each for annual consumption, inventory requirement and inventory retirement at the end of plant life)* .

* Recall the description of line 1 in this Subsection for the difference between fossil and nuclear fuels as recognized by the program.

Line 16: The first four entries in this line are the numbers of cost categories (≤ 4) of each kind of resources. These numbers refer to the domestic resources only. Furthermore, one additional import category can be specified with the second group of entries in this line.

Line 20: This line consists of two groups of switches: the first is for the limitation of annual extraction of domestic resources (cf. eq. (2.9)), and the second for the annual limits of imports (cf. eq. (2.10)). In either case, a constraint is generated on a "1" entry and no constraint is generated on any other integer entry. For each switch that is set, a time series of data must be specified in the according place.

Line 32: Number and names of man-made fuels (≤ 3). For each of them three entries must be provided in the description of the technologies (annual consumption, inventory requirement, and retirement at the end of plant life). Again, in the present version of the program, the set of man-made fuels may not be empty for the same reasons as mentioned above.

Lines 33-34: Number and names of emittants (≤ 10). Here it is possible to include no emittants at all in the model: By setting the switch in line 1 accordingly, the environmental submodel is omitted in the matrix generation.

Line 37: Start of description of ($\leq$ 25) technologies.

This completes the description of the input file. The next Section describes the matrix generator in as much detail as seems nessecary in order to implement major changes in the model.

5. PROGRAM DESCRIPTION

This Section contains the description of the FORTRAN program as listed in Section 6. It will focus on those parts of the program that are most likely subject to change, and it will only touch lightly those parts that are likely to remain unchanged. It is assumed that the reader is already familiar with the structure of the input file.

Before we start with the description of the program we give a list of variables and a summary of those changes in the declaration part of the program that must be made if one wants to increase parameter values beyond the limits described in Section 4. The list of variables appears twice, once ordered by the sequence in which the variables are defined in the program and once ordered alphabetically. If a variable has been explained in the description of the input file, the number of that line where it was explained will also be given. Some variables such as names that are printed in A-format in the control output or in the matrix will remain without further explanation.

List of variables

The variables are ordered by their appearance in the input file.

an	alphanumeric constants
itest	switch for matrix generation (line 1)
ise	switch for environmental submodel (line 1)
nt	number of time periods (input) (line 1)
ntrun	number of time periods (matrix) (line 1)
lp	length of time period [years] (line 1)
ipl	length of plant life [periods] (line 1)
jfn	number of first nuclear fuel (line 1)
nrhs	number of RHS vectors in the matrix (line 1)
nbnd	number of bounds sets in the matrix (line 1)
dr	discount rate [%] (line 2)
beta	annual discount factor (line 2)
nd	number of demand sectors (line 3)
d	names of demand sectors (line 3)
lr	number of load regions per demand sector (line 4)
dem	annual demands [GWyr] (line 5)
pr	distribution factors for demands (line 13)
lx	maximum number of load regions in demand sectors
yf	duration of load regions [1/year] (line 14)
nr	number of natural resources (line 15)
r	names of natural resources (line 15)
ngr	number of categories per resource (line 16)
imp	switch for import categories (line 16)
rlim	availability of natural resources [GWyr] or [10^3 t] (line 17)

mx	maximal number of categories of resources
imr	switch for max. extraction of domestic resources (line 20)
imm	switch for import restrictions (line 20)
msr	extra switches (line 21)
pm	max. extraction of resources [GWyr] or [10^3 t] (line 22)
px	max. annual imports [GWyr] or [10^3 t] (line 20)
rc	cost of resources [10^6 $/GWyr] or [$10^6$ $/$10^3$ t] (line 31)
nq	number of man-made fuels (line 32)
q	names of man-made fuels (line 32)
ne	number of pollutants (line 33)
e	names of pollutants (line 33)
t2	half-lives of pollutants (line 35)
s	names of technologies (line 38)
ito	demand sector supplied by technologies (line 38)
ial	additional identifier for technologies (line 38)
eta	supply/demand conversion ratios (line 38)
cur	current costs [10^6 $/GWyr] (line 38)
cap	capital costs [10^6 $/GW] (line 38)
gam	growth factor (line 38)
g	start-up parameter [GW] (line 38)
pf	plant factors [1/year] (line 38)
jf	number of fossil fuels
fcon	consumption of fossil fuels [GWyr in/GWyr out] (line 38)
ncon	consumption of nuclear fuels [10^3 t/GWyr] (line 38)
ninv	inventory requirements of nuclear fuels [10^3 t/GW]

(line 38)

nret inventory retirements of nuclear fuels [10^3 t/GW] (line 38)

qcon consumption of man-made fuels [10^3 t/GWyr] (line 38)

qinv inventory requirements of man-made fuels [10^3 t/GW] (line 38)

qret inventory retirements of man-made fuels [10^3 t/GW] (line 38)

eff specific consumption of final energy (line 38)

gr historical growth rates for initial capacities (line 38)

dep initial capacities (line 38)

iub switch for upper bounds (line 38)

bk type of upper bound (line 38)

bv value of upper bound (line 38)

em specific emissions (line 38)

np number of technologies (line 38)

nh number of pollutants for which concentrations are calculated (line 38)

List of variables (ordered alphabetically)

an alphanumeric constants

beta annual discount factor (line 2)

bk type of upper bound (line 38)

bv value of upper bound (line 38)

cap capital costs [10^6 \$/GW] (line 38)

cur current costs [10^6 \$/GWyr] (line 38)

d names of demand sectors (line 3)

dem annual demands [GWyr] (line 5)

dep initial capacities (line 38)

dr	discount rate [%] (line 2)
e	names of pollutants (line 33)
eff	specific consumption of final energy (line 38)
em	specific emissions (line 38)
eta	supply/demand conversion ratios (line 38)
fcon	consumption of fossil fuels [GWyr in/GWyr out] (line 38)
g	start-up parameter [GW] (line 38)
gam	growth factor (line 38)
gr	historical growth rates for initial capacities (line 38)
ial	additional identifier for technologies (line 38)
imm	switch for import restrictions (line 20)
imp	switch for import categories (line 16)
imr	switch for max. extraction of domestic resources (line 20)
ipl	length of plant life [periods] (line 1)
ise	switch for environmental submodel (line 1)
itest	switch for matrix generation (line 1)
ito	demand sector supplied by technologies (line 38)
iub	switch for upper bounds (line 38)
jf	number of fossil fuels
jfn	number of first nuclear fuel (line 1)
lp	length of time period [years] (line 1)
lr	number of load regions per demand sector (line 4)
lx	maximum number of load regions in demand sectors
msr	extra switches (line 21)
mx	maximal number of categories of resources
nbnd	number of bounds sets in the matrix (line 1)

ncon consumption of nuclear fuels [10^3 t/GWyr] (line 38)

nd number of demand sectors (line 3)

ne number of pollutants (line 33)

ngr number of categories per resource (line 16)

nh number of pollutants for which concentrations are calculated (line 38)

ninv inventory requirements of nuclear fuels [10^3 t/GW] (line 38)

np number of technologies (line 38)

nq number of man-made fuels (line 32)

nr number of natural resources (line 15)

nret inventory retirements of nuclear fuels [10^3 t/GW] (line 38)

nrhs number of RHS vectors in the matrix (line 1)

nt number of time periods (input) (line 1)

ntrun number of time periods (matrix) (line 1)

pf plant factors [1/year] (line 38)

pm max. extraction of resources [GWyr] or [10^3 t] (line 22)

pr distribution factors for demands (line 13)

px max. annual imports [GWyr] or [10^3 t] (line 20)

q names of man-made fuels (line 32)

qcon consumption of man-made fuels [10^3 t/GWyr] (line 38)

qinv inventory requirements of man-made fuels [10^3 t/GW] (line 38)

qret inventory retirements of man-made fuels [10^3 t/GW] (line 38)

r names of natural resources (line 15)

rc cost of resources [10^6 \$/GWyr] or [10^6 \$/10^3 t] (line 31)

rlim availability of natural resources [GWyr] or [10^3 t]

(line 17)

s names of technologies (line 38)

t2 half-lives of pollutants (line 35)

yf duration of load regions [1/year] (line 14)

Variable array sizes

The following is a summary of parameters that influence the dimensions of other variables. Each parameter is followed by a list of those variables in which a dimension has to match the parameter in size.

nt: t(nt) * , bv(.,.,nt), dem(.,.,nt), pm(.,.,nt), px(.,.,nt)

lp: $tt(\max_i \{ipl(i)/lp-1\})$ *

jfn: fcon(.,jfn-1), ncon(.,nr-jfn+1), ninv(.,nr-jfn+1), nret(.,nr-jfn+1)

nrhs: dem(nrhs,.,.), g(nrhs,.), pm(nrhs,.,.), px(nrhs,.,.), pr(nrhs,.,.), rlim(nrhs,.,.)

nbnd: bk(nbnd,.), bv(nbnd,.,.), dep(nbnd,.), gr(nbnd,.), imm(nbnd,.), iub(nbnd,.)

nd: d(nd), dem(.,nd,.), eff(.,nd), lr(nd), pr(.,nd,.), yf(nd,.)

lr(j): $pr(.,.,\max_j \{lr(j)\})$, $yf(.,\max_j \{lr(j)\})$, $an(\max_{j,l} \{lr(j),ngr(l)+imp(l)\})$*

nr: imm(.,nr), imp(nr), imr(nr), msr(nr), ngr(nr), ncon(.,nr-jfn+1), ninv(.,nr-jfn+1), nret(.,nr-jfn+1), pm(.,nr), px(.,nr,.), r(nr), rc(nr,.), rlim(.,nr,.)

ngr(l): $rc(.,\max_l \{ngr(l)+imp(l)\})$, $rlim(.,\max_l$

---

* If this parameter is changed, changes in the data initializatin part of the matrix generator must be made, too. See description of corresponding part of the program description.

{ngr(l)+imp(l)})

imp(l): rc(.,$\max_l$ {ngr(l)+imp(l)}), rlim(.,$\max_l$ {ngr(l)+imp(l)})

nq: q(nq), qcon(.,nq), qinv(.,nq), qret(.,nq)

ne: e(ne), em(.,ne)

nh: t2(nh)

np: bk(.,np), bv(.,np,.), cap(np), cur(np), dep(.,np), eff(np,.), em(np,.), eta(np), fcon(np,.), g(.,np), gam(np), gr(.,np), ial(np), ipl(np), ito(np), iub(.,np), mst(np), ncon(np,.), ninv(np,.), nret(np,.), pf(np), qcon(np,.), qinv(np.,), qret(np,.), s(np)

So far the program description has been oriented mainly towards the description of changes that may turn out to be desirable for an extended version of MESSAGE. To explain in full detail the full FORTRAN code documented would first require a rearrangement of the LP matrix by columns. That and a line-by-line description of the program will be omitted here. If one really wants to understand each statement of the program, one would have to work out a column-wise description of the LP matrix for oneself. In fact, the column-wise description of the matrix can almost directly be read from the program listed. The rest of this Section will give a rough guide through the program.

Declaration and initialization (lines 1 to 28)

Little needs to be said about this Subsection but that there might be some data left (from history) that are not being used in the sequel. The data statements for the initialization of the following variables have to be changed according to certain parameter changes (as indicated above): t, tt, an, ipl.

Line 30: This is a very local dialect. It defines logical unit 9 within the FORTRAN program. In many other systems this can be done only externally.

Input file conversion (lines 32 to 47)

This part processes the input file. It eliminates the comments and writes the data to an intermediate file (unit 9), one in a line. On encountering the end-of-input ('at-sign'), the intermediate file is rewound for subsequent use by the program.

Input and control output (lines 49 to 356)

Here, the values for the variables are read from the intermediate file and the control output is written to unit 6. Subroutine wr reads an integer variable from unit 9 and prints its value together with an 8-character information on the control output. Subroutine wrb(n,x) writes the real number x to the n-th place ($n \leq 12$) of a line without putting out a line feed. This subroutine is used to avoid the writing of too many zeros in the control printout: blanks are printed instead. Subroutine wrc prints a header. The programming of this part is straightforward, only some additional remarks might be helpful.

Line 61: Calculation of the one-year discount factor from the discount rate.

Lines 77 to 79: The variable lx becomes the maximum number of load regions.

Lines 119 to 122: The variable mx becomes the maximum number of resource categories (domestic plus import).

Line 192: This is the beginning of the loop for reading the data that describe the technologies. This loop does not expect to read more than 100 technologies, which has been always sufficient so far.

Line 193: On encountering an end-of-input on file 9 the loop is left.

Line 208: The sign of gam(i) is reversed for later use in writing the matrix.

Line 226 to 227: Here the historical growth rate and the initial capacities are read. If the user prefers to specify the initial conditions explicitly, these two lines must be replaced accordingly, and the writing of the corresponding bounds must be modified as described below.

Lines 322 to 323: The variables dep(n,i) which have been read as initial capacities become the (initial condition) Y^0 according to formula 3.1.

Lines 349 to 351: Variable nh becomes the number of those pollutants for which concentration equations are generated.

Matrix generation (lines 362 to 663)

The matrix is generated only if the test switch is on (line 360). The matrix is written to file 8, beginning with the problem name.

Lines 366 to 413: Definition of rows. The names and the sequence of the generation of row identifications were explained in Subsection 3.1. The type of a constraint is specified according to the requirements of the MPS-format.

Lines 375 to 376: If the number of load regions of a demand sector is equal to one, the corresponding identifier (LP name) is a "." rather than a "1" for the sake of readability of the names in the matrix. These sequence of statements will occur more often below.

Line 426 demonstrates the implementation of the "extra" switches. Here, if the extra switch for technologies (mst(i)) is equal to one, no X-activity for a load region greater than one is generated. This feature is used for the technology "jetgas" in the input file.

Line 481: Whereas the values of the initial conditions are specified in the bounds set, the columns that get fixed bounds are generated here. This is so only if the corresponding value in bounds set one is non-zero.

Lines 636 to 642: The values of the initial conditions are written here using formula 3.1. If the initial conditions were specified explicitly as indicated above, these lines must be modified accordingly.

BIBLIOGRAPHY

[1] Agnew M., Schrattenholzer L. and Voss A. 'A Model for Energy Supply Systems and Their General Environmental Impact' RM-78-26, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1978.

THE FORTRAN MATRIX GENERATOR PROGRAM

```
      DOUBLE PRECISION D(7),E(10),Q(5),R(7),S(25),PNAME
      INTEGER AN(10),IAL(25),IMM(2,7)
      INTEGER IMP(7),IMR(7),IPL(25),ITO(25),IUB(2,25),LR(7)
      INTEGER MSR(7),MST(25),NGR(7),T(20),TT(10)
      LOGICAL INVST(5)
      LOGICAL BL,DT,KLA,LS(80),LH(80),SC
      REAL BK(2,25),BV(2,25,15),CAP(25)
      REAL CUR(25),DEM(3,7,15),DEP(2,25),EFF(25,7),EM(25,10),ETA(25)
      REAL FCON(25,3),G(3,25),GAM(25),GR(2,25),HV(5)
      REAL LO,NCON(25,5),NINV(25,5)
      REAL NRET(25,5),PM(3,7,15),PX(3,7,15)
      REAL PR(3,7,4),PF(25),QCON(25,3),QINV(25,3),QRET(25,3)
      REAL RC(7,5),RLIM(3,7,5),T2(10),YF(7,5)
C
      DATA CCAP,CCUR,FCST/'CCAP','CCUR','FCST'/
      DATA CA,CD,CM,CR,X,XF,XI,Y/'A','D','M','R','X','F','I','Y'/
      DATA BL,DT,HS,KLA,SC/' ','.','S','0','1'/
      DATA F,GT,LT,EQ,XP/'N','G','L','E','P'/
      DATA REG,C/'W','C'/
      DATA B,COST/'B','FUNC'/
      DATA PNAME,FX,UP,LO/'MESSAGE','FX','UP','LO'/
      DATA INVST /'I','N','V','S','T'/
      DATA CM1,C1/-1.,1./
C
      DATA T/'01','02','03','04','05','06','07','08','09','10',
     &'11','12','13','14','15','16','17','18','19','20'/
      DATA TT/'-9','-8','-7','-6','-5','-4','-3','-2','-1','00'/
      DATA AN/'1','2','3','4','5','6','7','8','9','0'/
C
      CALL SETFIL(9,'DD ')
C
    6 READ (5,65) LS
      LH(1)=BL
      JP=0
      DO 8 I=1,80
      IF (LS(I).NE.BL) GOTO 170
      JX=I-JP-1
      JP=I
      IF (LH(1).EQ.KLA) GOTO 12
      IF (LH(1).EQ.SC) GOTO 6
```

```
      IF (JX.GT.0) WRITE (9,65) (LH(J),J=1,JX)
      GOTO 8
  170 LH(I-JP)=LS(I)
    8 CONTINUE
      GOTO 6
   12 CALL CLOSEF(9)
      CALL SETFIL(9,'DD ')
C
      CALL WR('TEST-SW ',ITEST)
      CALL WR('ENV-SW  ',ISE)
      CALL WR('PERIODS ',NT)
      CALL WR('MATR.PER',NTRUN)
      CALL WR('YRS/PER ',LP)
      CALL WR('PL LIFE ',INPL)
      CALL WR('1. NUCFL',JFN)
      CALL WR('# (RHS) ',NRHS)
      CALL WR('# (BNDS)',NBND)
C
      READ (9,17) DR
      WRITE (6,45) DR
      BETA=1./(1.+DR/100.)
C
      READ (9,3) ND
      DO 22 J=1,ND
   22 READ (9,11) D(J)
      DO 136 J=1,ND
  136 READ(9,3) LR(J)
C
      DO 144 N=1,NRHS
      DO 84 J=1,ND
      DO 84 K=1,NT
   84 READ (9,17) DEM(N,J,K)
      DO 144 J=1,ND
      DO 144 M=1,LR(J)
  144 READ (9,17) PR(N,J,M)
C
      DO 140 J=1,ND
      IF (LR(J).GT.LX) LX=LR(J)
  140 CONTINUE
      DO 336 J=1,ND
```

```
      DO 336 M=1,LR(J)
  336 READ (9,17) YF(J,M)
      CALL WRC('LOAD DURATION     ')
      WRITE (6,13) D
      DO 338 M=1,LX
      WRITE (6,15) T(M)
      DO 338 J=1,ND
      IF (LR(J).GE.M) CALL WRB(J,YF(J,M))
  338 CONTINUE
C
      DO 166 N=1,NRHS
      WRITE (6,57) N,NRHS
      CALL WRC('DEMANDS           ')
      WRITE (6,13) D
      DO 108 K=1,NT
  108 WRITE (6,51) T(K),(DEM(N,J,K),J=1,ND)
C
      CALL WRC('DEM DISTRIBUTION')
      WRITE (6,13) D
      DO 166 M=1,LX
      WRITE (6,15) T(M)
      DO 166 J=1,ND
      IF (LR(J).GE.M) CALL WRB(J,PR(N,J,M))
  166 CONTINUE
C
      READ (9,3) NR
      DO 32 J=1,NR
   32 READ (9,11) R(J)
      DO 36 J=1,NR
   36 READ (9,3) NGR(J)
      DO 300 L=1,NR
  300 READ (9,3) IMP(L)
      DO 82 N=1,NRHS
      DO 82 J=1,NR
      JH=NGR(J)+IMP(J)
      DO 82 M=1,JH
   82 READ (9,17) RLIM(N,J,M)
C
      DO 100 L=1,NR
      JH=NGR(L)+IMP(L)
```

```
      IF (JH.GT.MX) MX=JH
  100 CONTINUE
      DO 102 N=1,NRHS
      WRITE (6,57) N,NRHS
      CALL WRC('MAT AVAILABILITY')
      WRITE (6,13) R
      DO 102 M=1,MX
      WRITE (6,35) M
      DO 102 L=1,NR
      IF (NGR(L)+IMP(L).GE.M) CALL WRB(L,RLIM(N,L,M))
  102 CONTINUE
      DO 302 L=1,NR
  302 READ (9,3) IMR(L)
      DO 312 N=1,NBND
      DO 312 L=1,NR
  312 READ (9,3) IMM(N,L)
      DO 360 L=1,NR
  360 READ (9,3) MSR(L)
C
      DO 260 N=1,NRHS
      DO 304 L=1,NR
      DO 304 K=1,NT
      IF (IMR(L).EQ.1) READ (9,17) PM(N,L,K)
  304 CONTINUE
      CALL WRC('MAX RES EXTRACTN')
      WRITE (6,13) R
      DO 260 K=1,NT
      WRITE (6,15) T(K)
      DO 260 L=1,NR
      IF (IMR(L).EQ.1) CALL WRB(L,PM(N,L,K))
  260 CONTINUE
C
      DO 328 N=1,NBND
      WRITE (6,59) N,NBND
      DO 306 L=1,NR
      DO 306 K=1,NT
      IF (IMM(N,L).EQ.1) READ (9,17) PX(N,L,K)
  306 CONTINUE
      CALL WRC('MAX ANN IMPORTS ')
      WRITE (6,13) R
```

```
      DO 328 K=1,NT
      WRITE (6,15) T(K)
      DO 328 L=1,NR
      IF (IMM(N,L).EQ.1) CALL WRB(L,PX(N,L,K))
  328 CONTINUE
      DO 308 L=1,NR
      JM=NGR(L)+IMP(L)
      DO 308 J=1,JM
  308 READ (9,17) RC(L,J)
C
      WRITE (6,55)
      CALL WRC('MATERIAL COSTS  ')
      WRITE (6,13) R
      DO 106 M=1,MX
      WRITE (6,35) M
      DO 106 J=1,NR
      IF (NGR(J)+IMP(J).GE.M) CALL WRB(J,RC(J,M))
  106 CONTINUE
C
      READ (9,3) NQ
      DO 156 L=1,NQ
  156 READ (9,11) Q(L)
C
      IF (ISE.NE.1) GOTO 346
      READ (9,3) NE
      DO 264 M=1,NE
  264 READ (9,11) E(M)
      DO 270 M=1,NE
  270 READ (9,17) T2(M)
C
  346 WRITE (6,73)
      DO 310 I=1,100
      READ (9,11,END=354) S(I)
      READ (9,3) ITO(I)
      READ (9,1) IAL(I)
C
      READ (9,17) ETA(I)
      READ (9,17) CUR(I)
      READ (9,17) CAP(I)
      READ (9,17) GAM(I)
```

```
      DO 322 N=1,NRHS
  322 READ (9,17) G(N,I)
      READ (9,17) PF(I)
C
      WRITE (6,75) S(I),D(ITO(I)),IAL(I),ETA(I),CUR(I),CAP(I),
     &PF(I),GAM(I),(G(N,I),N=1,NRHS)
C
      GAM(I)=-GAM(I)
C
      JF=JFN-1
      DO 314 L=1,JF
  314 READ (9,17) FCON(I,L)
      DO 316 L=JFN,NR
      READ (9,17) NCON(I,L)
      READ (9,17) NINV(I,L)
  316 READ (9,17) NRET(I,L)
      DO 318 L=1,NQ
      READ (9,17) QCON(I,L)
      READ (9,17) QINV(I,L)
  318 READ (9,17) QRET(I,L)
C
      DO 320 J=1,ND
  320 READ (9,17) EFF(I,J)
C
      DO 326 N=1,NBND
      READ (9,17) GR(N,I)
      READ (9,17) DEP(N,I)
      READ (9,3) IUB(N,I)
      IF (IUB(N,I).EQ.1) READ (9,1) BK(N,I)
      DO 326 K=1,NT
      IF (IUB(N,I).EQ.1) READ (9,17) BV(N,I,K)
  326 CONTINUE
      READ (9,3) MST(I)
C
      IF (ISE.NE.1) GOTO 310
      DO 266 M=1,NE
  266 READ (9,17) EM(I,M)
  310 CONTINUE
C
  354 NP=I-1
```

```
      WRITE (6,85) NP
      CALL WRC('EXTRA SWITCHES  ')
      DO 368 I=1,NP
      IF (MST(I).NE.0) WRITE (6,81) S(I),D(ITO(I)),IAL(I),MST(I)
  368 CONTINUE
C
      DO 252 I=1,NP
  252 IPL(I)=INPL
      WRITE (6,55)
      CALL WRC('FOSS FUEL CONS   ')
      WRITE (6,13) BL,(R(L),L=1,JF)
      DO 128 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 128 L=1,JF
      IF (FCON(I,L).NE.0.) CALL WRB(L+1,FCON(I,L))
  128 CONTINUE
C
      WRITE (6,55)
      CALL WRC('NUCL FUEL CONS  ')
      WRITE (6,13) BL,(R(L),L=JFN,NR)
      DO 48 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 48 L=JFN,NR
      HT=NCON(I,L)
      IF (HT.NE.0.) CALL WRB(L-JFN+2,HT)
   48 CONTINUE
      CALL WRC('MAT INVENTORIES ')
      WRITE (6,13) BL,(R(L),L=JFN,NR)
      DO 62 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 62 L=JFN,NR
      HT=NINV(I,L)
      IF (HT.NE.0.) CALL WRB(L-JFN+2,HT)
   62 CONTINUE
      CALL WRC('MAT RETIREMENTS ')
      WRITE (6,13) BL,(R(L),L=JFN,NR)
      DO 64 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 64 L=JFN,NR
      HT=NRET(I,L)
```

```
      IF (HT.NE.0.) CALL WRB(L=JFN+2,HT)
   64 CONTINUE
C
      WRITE (6,55)
      CALL WRC('STOCKS CONSUMPTN')
      WRITE (6,13) BL,Q
      DO 160 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 160 L=1,NQ
      IF (QCON(I,L).NE.0.) CALL WRB(L+1,QCON(I,L))
  160 CONTINUE
      CALL WRC('STOCKS INVENTORY')
      WRITE (6,13) BL,Q
      DO 162 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 162 L=1,NQ
      IF (QINV(I,L).NE.0.) CALL WRB(L+1,QINV(I,L))
  162 CONTINUE
      CALL WRC('STOCKS RETIREMNT')
      WRITE (6,13) BL,Q
      DO 164 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 164 L=1,NQ
      IF (QRET(I,L).NE.0.) CALL WRB(L+1,QRET(I,L))
  164 CONTINUE
      WRITE (6,55)
      CALL WRC('OTHER INPUTS    ')
      WRITE (6,13) BL,D
      DO 330 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 330 J=1,ND
      IF (EFF(I,J).NE.0.) CALL WRB(J+1,EFF(I,J))
  330 CONTINUE
C
      DO 324 N=1,NBND
      WRITE (6,59) N,NBND
      CALL WRC('INIT CAPACITIES ')
      WRITE (6,77)
      DO 332 I=1,NP
      IF (DEP(N,I).NE.0.) WRITE (6,75) S(I),D(ITO(I)),IAL(I),
```

```
     &GR(N,I),DEP(N,I)
      IF (DEP(N,I).NE.0.) DEP(N,I)=
     &DEP(N,I)/LP*(GR(N,I)**(-LP)-1.)/(GR(N,I)**(-IPL(I)*LP)-1.)
  332 CONTINUE
C
      CALL WRC('INTR RATES LIM   ')
      DO 324 I=1,NP
      IF (IUB(N,I).EQ.1) WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 324 K=1,NT
      JH=1975+5*K
      IH=0
      HV(N)=BK(N,I)
      HT=BV(N,I,K)
      IF (HT.EQ.0.) HV(N)=FX
      IF (HT.GE.0.AND.HT.LE.980.) IH=1
      IF (IUB(N,I).EQ.1.AND.IH.EQ.1) WRITE (6,79)
     &JH,HV(N),BV(N,I,K)
  324 CONTINUE
C
      WRITE (6,55)
      CALL WRC('EMISSIONS        ')
      WRITE (6,13) BL,E
      DO 274 I=1,NP
      WRITE (6,75) S(I),D(ITO(I)),IAL(I)
      DO 274 M=1,NE
      IF (EM(I,M).NE.0.) CALL WRB(M+1,EM(I,M))
  274 CONTINUE
C
      DO 370 M=1,NE
      IF (T2(M).NE.0.) NM=M
  370 CONTINUE
C
      CALL WRC('HALF LIFE TIMES ')
      WRITE (6,13) E
      WRITE (6,7)
      WRITE (6,67) (T2(M),M=1,NM)
C
C                    PROBLEM NAME
C
      IF (ITEST.EQ.1) STOP
```

```
      NT=NTRUN
      WRITE (8,19) PNAME
C
C                     ROWS DEFINITION
C
      WRITE (8,21)
      WRITE (8,47) F,COST
      WRITE (8,47) F,CCUR
      WRITE (8,47) F,CCAP
      WRITE (8,47) F,FCST
      DO 214 K=1,NT
  214 WRITE (8,33) F,INVST,REG,T(K)
      DO 26 J=1,ND
      DO 26 M=1,LR(J)
      IQ=AN(M)
      IF (LR(J).EQ.1) IQ=DT
      DO 26 K=1,NT
   26 WRITE (8,33) GT,CD,DT,D(J),DT,IQ,REG,T(K)
      DO 168 L=1,NQ
      DO 168 K=1,NT
  168 WRITE (8,33) EQ,EQ,Q(L),DT,DT,DT,REG,T(K)
      DO 76 L=1,NR
      DO 14 K=1,NT
   14 WRITE (8,33) LT,LT,R(L),DT,DT,DT,REG,T(K)
      JH=NGR(L)+IMP(L)
      DO 76 J=1,JH
      WRITE (8,33) LT,CA,R(L),AN(J),DT,DT,REG,T(NT)
   76 CONTINUE
      DO 254 J=1,NR
      DO 254 K=1,NT
      IF (IMR(J).NE.1) GOTO 254
      WRITE (8,33) LT,XP,R(J),DT,DT,DT,REG,T(K)
  254 CONTINUE
      DO 90 I=1,NP
      MM=LR(ITO(I))
      DO 90 M=1,MM
      IQ=AN(M)
      IF (MM.EQ.1) IQ=DT
      DO 90 K=1,NT
      WRITE (8,33) LT,C,S(I),D(ITO(I)),IAL(I),IQ,REG,T(K)
```

```
   90 CONTINUE
      DO 202 I=1,NP
      DO 202 K=1,NT
      IF (GAM(I).NE.0.) WRITE (8,33)
     &LT,CM,S(I),D(ITO(I)),IAL(I),DT,REG,T(K)
  202 CONTINUE
      IF (ISE.NE.1) GOTO 348
      DO 278 M=1,NE
      DO 278 K=1,NT
  278 WRITE (8,33) EQ,XI,E(M),DT,DT,DT,REG,T(K)
      DO 280 M=1,NH
      DO 280 K=1,NT
  280 WRITE (8,33) F,XF,E(M),DT,DT,DT,REG,T(K)
C
C                     X = COLUMNS
C
  348 WRITE (8,23)
      DO 38 I=1,NP
      J=ITO(I)
      MM=LR(J)
      DO 38 M=1,MM
      IQ=AN(M)
      IF (MM.EQ.1) IQ=DT
      DO 38 K=1,NT
C ###    ONLY FOR LOAD REGION 1
      IF (MST(I).EQ.1.AND.M.GE.2) GOTO 38
      QQ=LP*CUR(I)*BETA**(LP*K-LP/2.)
      IF (QQ.NE.0.) WRITE (8,49) X,S(I),D(J),IAL(I),IQ,REG,T(K),COST,QQ
      IF (QQ.NE.0.) WRITE (8,49) X,S(I),D(J),IAL(I),IQ,REG,T(K),CCUR,QQ
      WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),CD,DT,D(J),DT,IQ,
     &REG,T(K),ETA(I)
      WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),
     &C,S(I),D(J),IAL(I),IQ,REG,T(K),C1
  250 DO 240 L=1,JF
      HT=FCON(I,L)
      IF (HT.NE.0.) WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),
     &LT,R(L),DT,DT,DT,REG,T(K),HT
  240 CONTINUE
      DO 40 L=JPN,NR
      IF (NCON(I,L).EQ.0.) GOTO 40
```

```
      HT=NCON(I,L)
      IF (HT.NE.0.) WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),
     &LT,R(L),DT,DT,DT,REG,T(K),HT
   40 CONTINUE
      DO 154 L=1,NQ
      IF (QCON(I,L).EQ.0.) GOTO 154
      HT=QCON(I,L)*LP
      IF (HT.NE.0.) WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),
     &EQ,Q(L),DT,DT,DT,REG,T(K),HT
  154 CONTINUE
C
      DO 146 L=1,ND
      HT=-EFF(I,L)
      IQQ=IQ
      IF (LR(L).EQ.1) IQQ=DT
      IF (HT.NE.0.) WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),
     &CD,DT,D(L),DT,IQQ,REG,T(K),HT
  146 CONTINUE
      IF (ISE.NE.1) GOTO 38
      DO 288 L=1,NE
      IF (EM(I,L).NE.0.) WRITE (8,37) X,S(I),D(J),IAL(I),IQ,REG,T(K),
     &XI,E(L),DT,DT,DT,REG,T(K),EM(I,L)
  288 CONTINUE
   38 CONTINUE
C
C                      IC = COLUMNS
C
      DO 74 I=1,NP
      J=ITO(I)
      JH=IPL(I)-1
      DO 74 K=1,JH
      MM=LR(J)
      DO 74 M=1,MM
      IQ=AN(M)
      IF (MM.EQ.1) IQ=DT
      DO 74 IT=1,K
      IF (DEP(1,I).EQ.0.) GOTO 74
      IF (IT.GT.NT) GOTO 242
C
      HT=-LP*PF(I)*YF(J,M)
```

```
      WRITE (8,37) Y,S(I),D(J),IAL(I),DT,REG,TT(K-IPL(I)+11),
     &C,S(I),D(J),IAL(I),IQ,REG,T(IT),HT
C
  242 IF (GAM(I).EQ.0.) GOTO 74
      IF (K.EQ.JH.AND.M.EQ.1.AND.IT.EQ.K) WRITE (8,37)
     &Y,S(I),D(J),IAL(I),DT,REG,TT(10),
     &CM,S(I),D(J),IAL(I),DT,REG,T(1),GAM(I)
   74 CONTINUE
C
C                     Y - COLUMNS
C
      DO 50 I=1,NP
      DO 50 K=1,NT
      J=ITO(I)
      QQ=LP*CAP(I)*BETA**(LP*(K-1))
      IF (K.GT.NT-IPL(I)) QQ=QQ*(1.-BETA**(LP*(NT-K+1)))
      IF (QQ.NE.0.) WRITE (8,49) Y,S(I),D(J),IAL(I),DT,REG,T(K),COST,QQ
      IF (QQ.NE.0.) WRITE (8,49) Y,S(I),D(J),IAL(I),DT,REG,T(K),CCAP,QQ
      IF (QQ.NE.0.) WRITE (8,37) Y,S(I),D(J),IAL(I),DT,REG,T(K),
     &INVST,REG,T(K),CAP(I)
      IF (GAM(I).EQ.0.) GOTO 230
      WRITE (8,37) Y,S(I),D(J),IAL(I),DT,REG,T(K),
     &CM,S(I),D(J),IAL(I),DT,REG,T(K),C1
      IF (K.LT.NT) WRITE (8,37) Y,S(I),D(J),IAL(I),DT,REG,T(K),
     &CM,S(I),D(J),IAL(I),DT,REG,T(K+1),GAM(I)
  230 IX=K+IPL(I)-1
      MM=LR(J)
      DO 52 M=1,MM
      IQ=AN(M)
      IF (MM.EQ.1) IQ=DT
      DO 52 IT=K,IX
      HT=-LP*PF(I)*YF(J,M)
      IF (IT.GT.NT) GOTO 52
      WRITE (8,37) Y,S(I),D(J),IAL(I),DT,REG,T(K),
     &C,S(I),D(J),IAL(I),IQ,REG,T(IT),HT
   52 CONTINUE
      DO 58 L=JFN,NR
      HT=NINV(I,L)
      IF (HT.NE.0.) WRITE (8,37)
     &Y,S(I),D(J),IAL(I),DT,REG,T(K),LT,R(L),DT,DT,DT,REG,T(K),HT
```

```
      KH=K+IPL(I)
      IF (KH.GT.NT) GOTO 58
      HT=-NRET(I,L)
      IF (HT.NE.0.) WRITE (8,37)
     &Y,S(I),D(J),IAL(I),DT,REG,T(K),LT,R(L),DT,DT,DT,REG,T(KH),HT
   58 CONTINUE
      DO 152 L=1,NQ
      HT=QINV(I,L)*LP
      IF (HT.NE.0.) WRITE (8,37)
     &Y,S(I),D(J),IAL(I),DT,REG,T(K),EQ,Q(L),DT,DT,DT,REG,T(K),HT
      KH=K+IPL(I)
      IF (KH.GT.NT) GOTO 152
      HT=-QRET(I,L)*LP
      IF (HT.NE.0.) WRITE (8,37)
     &Y,S(I),D(J),IAL(I),DT,REG,T(K),EQ,Q(L),DT,DT,DT,REG,T(KH),HT
  152 CONTINUE
   50 CONTINUE
C
C                       RESOURCE - COLUMNS
C
      HT=LP
      DO 54 J=1,NR
      JH=NGR(J)+IMP(J)
      DO 54 M=1,JH
      DO 54 K=1,NT
      QQ=RC(J,M)
C ###     IMPORT PRICE FOR OIL RISES AT 2% PER YEAR TILL $30/BBL
      IF (MSR(J).NE.1.OR.M.LE.NGR(J)) GOTO 400
      QQ=QQ*1.02**(LP*K)
      IF (QQ.GE.154.5) QQ=154.5
  400 QQ=LP*QQ*BETA**(LP*K-LP/2.)
C ###     IMPORTED OIL PRICE RISES AL 1% PER YEAR
      IF (MSR(J).EQ.2.AND.M.EQ.NGR(J)) QQ=QQ*1.01**(LP*K)
      IF (QQ.NE.0.) WRITE (8,49) CR,R(J),AN(M),DT,DT,REG,T(K),COST,QQ
      IF (QQ.NE.0.) WRITE (8,49) CR,R(J),AN(M),DT,DT,REG,T(K),FCST,QQ
      WRITE (8,37) CR,R(J),AN(M),DT,DT,REG,T(K),LT,R(J),DT,DT,DT,REG,
     &T(K),CM1
      IF (M.LE.NGR(J).AND.IMR(J).EQ.1) WRITE (8,37)
     &CR,R(J),AN(M),DT,DT,REG,T(K),XP,R(J),DT,DT,DT,REG,T(K),C1
      WRITE (8,37) CR,R(J),AN(M),DT,DT,REG,T(K),CA,R(J),AN(M),DT,DT,
```

```
     &REG,T(NT),HT
   54 CONTINUE
C
C                       STOCK - COLUMNS
C
      DO 150 L=1,NQ
      DO 150 K=1,NT
      WRITE (8,37) HS,Q(L),DT,DT,DT,REG,T(K),EQ,Q(L),DT,DT,DT,REG,T(K)
     &,C1
      IF (K.NE.NT) WRITE (8,37)
     &HS,Q(L),DT,DT,DT,REG,T(K),EQ,Q(L),DT,DT,DT,REG,T(K+1),CM1
  150 CONTINUE
C
C                       EMISSION - COLUMNS
C
      IF (ISE.NE.1) GOTO 350
      DO 268 M=1,NE
      DO 268 K=1,NT
      WRITE (8,37) B,E(M),DT,DT,DT,REG,T(K),
     &XI,E(M),DT,DT,DT,REG,T(K),CM1
      DO 268 K1=K,NT
      IF (M.GT.NH) GOTO 268
      HT=2.**(5*(K-K1)/T2(M))
      WRITE (8,37) B,E(M),DT,DT,DT,REG,T(K),
     &XF,E(M),DT,DT,DT,REG,T(K1),HT
  268 CONTINUE
C
C                       RIGHT HAND SIDE
C
  350 WRITE (8,25)
      DO 92 N=1,NRHS
      DO 78 J=1,ND
      MM=LR(J)
      DO 78 M=1,MM
      IQ=AN(M)
      IF (MM.EQ.1) IQ=DT
      DO 78 K=1,NT
      HT=DEM(N,J,K)*PR(N,J,M)
   78 WRITE (8,53) N,CD,DT,D(J),DT,IQ,REG,T(K),HT
      DO 80 J=1,NR
```

```
      JH=NGR(J)+IMP(J)
      DO 80 M=1,JH
      IF (RLIM(N,J,M).NE.0.) WRITE (8,53)
     &N,CA,R(J),AN(M),DT,DT,REG,T(NT),RLIM(N,J,M)
   80 CONTINUE
      DO 206 I=1,NP
      J=ITO(I)
      DO 206 K=1,NT
      IF (GAM(I).NE.0.) WRITE (8,53)
     &N,CM,S(I),D(J),IAL(I),DT,REG,T(K),G(N,I)
  206 CONTINUE
      DO 256 J=1,NR
      DO 256 K=1,NT
      IF (IMR(J).EQ.1)
     &WRITE (8,53) N,XP,R(J),DT,DT,DT,REG,T(K),PM(N,J,K)
  256 CONTINUE
   92 CONTINUE
C
C                       BOUNDS SET
C
      WRITE (8,27)
      DO 96 N=1,NBND
      DO 190 I=1,NP
      J=ITO(I)
C ###    UPPER BOUNDS OF 15% DEMAND OF RHS 1
      IF (MST(I).NE.2.AND.MST(I).NE.4) GOTO 356
      DO 358 M=1,LR(J)
      IQ=AN(M)
      IF (LR(J).EQ.1) IQ=DT
      DO 358 K=1,NT
      HT=.15*DEM(1,J,K)
C ###    READ DIFFERENT UPPER BOUNDS
      IF (MST(I).EQ.4) READ (9,17) HT
      HT=HT*PR(1,J,M)
  358 WRITE (8,61) UP,N,X,S(I),D(J),IAL(I),IQ,REG,T(K),HT
  356 JH=IPL(I)-1
      DO 190 K=1,JH
      IF (DEP(1,I).EQ.0.) GOTO 190
      HT=0.
      IF (DEP(N,I).NE.0.) HT=DEP(N,I)*GR(N,I)**((K-JH)*LP)
```

```
      WRITE (8,61) FX,N,Y,S(I),D(J),IAL(I),DT,REG,TT(K=IPL(I)+11),HT
  190 CONTINUE
      DO 340 L=1,NR
      DO 340 K=1,NT
      IF (IMM(N,L).NE.1) GOTO 340
      HT=UP
      IF (PX(N,L,K).EQ.0.) HT=FX
      WRITE (8,61) HT,N,CR,R(L),AN(NGR(L)+1),DT,DT,REG,T(K),PX(N,L,K)
  340 CONTINUE
C
      DO 96 I=1,NP
      DO 96 K=1,NT
      IF (IUB(N,I).EQ.0) GOTO 96
      HT=BV(N,I,K)
      HU=BK(N,I)
      IF (HT.EQ.0.) HU=FX
      IF (HT.LE.900.) WRITE (8,61)
     &HU,N,Y,S(I),D(ITO(I)),IAL(I),DT,REG,T(K),HT
   96 CONTINUE
C
      WRITE (8,31)
C
      STOP
C
    1 FORMAT (12A4)
    3 FORMAT (I4)
    5 FORMAT (6A8)
    7 FORMAT (' ')
    9 FORMAT (2A4)
   11 FORMAT (A8)
   13 FORMAT (/,11X,12(2X,A8))
   15 FORMAT (1X,A8,12(F9.4,1X))
   17 FORMAT (G12.5)
   19 FORMAT ('NAME',10X,A8)
   21 FORMAT ('ROWS')
   23 FORMAT ('COLUMNS')
   25 FORMAT ('RHS')
   27 FORMAT ('BOUNDS')
   29 FORMAT ('RANGES')
   31 FORMAT ('ENDATA')
```

```
   33 FORMAT (1X,A1,2X,6A1,A2)
   35 FORMAT (' GRADE',I2)
   37 FORMAT (4X,2(6A1,A2,2X),F12.5)
   41 FORMAT (13X,12('(',I1,')',7X)/)
   45 FORMAT (/,' ***  DISCOUNT RATE ',F5.1,' %')
   47 FORMAT (1X,A1,2X,A4)
   49 FORMAT (4X,6A1,A2,2X,A4,6X,F12.5)
   51 FORMAT (' DMND',A2,4X,12(F9.4,1X))
   53 FORMAT (4X,'RHS',I1,6X,6A1,A2,2X,F12.5)
   55 FORMAT ('1')
   57 FORMAT ('1RHS ',I1,' OF ',I1,/)
   59 FORMAT ('1BOUNDS SET ',I1,' OF ',I1/)
   61 FORMAT (1X,A2,' BND',I1,6X,6A1,A2,2X,F12.5)
   63 FORMAT (//' ***   # OF LOAD REGIONS',12I4)
   65 FORMAT (80A1)
   67 FORMAT (12X,10(G12.5))
   69 FORMAT ('0ALTERNATIVE'2X,A2/)
   71 FORMAT (1X,12(F9.4,1X))
   73 FORMAT ('1NAME',4X,'TO',10X,'EFFICIENCY',4X,'CURRENT,'
     &,'CAPITAL COST  PLANT FACTOR  GAMMA(MP)   ',4HRHS','S (MP)'//)
   75 FORMAT (1X,2(A8,1X),A1,2X,9(G12.5))
   77 FORMAT (21X,'GROWTH RATES  INIT CAPACITIES')
   79 FORMAT (1X,I4,2X,8(A2,2X,G12.5))
   81 FORMAT (1X,2(A8,1X),A1,2X,I3)
   85 FORMAT (//' ***   ',I3,'  TECHNOLOGIES  ***')
      END
      SUBROUTINE WR(NAME,N)
      REAL NAME(2)
      READ (9,3) N
      WRITE (6,1) NAME,N
    1 FORMAT (' ',2A4,I4)
    3 FORMAT (I4)
      RETURN
      END
      SUBROUTINE WRB(N,Z)
      IF (N.EQ.1) WRITE (6,21) Z
      IF (N.EQ.2) WRITE (6,22) Z
      IF (N.EQ.3) WRITE (6,23) Z
      IF (N.EQ.4) WRITE (6,24) Z
      IF (N.EQ.5) WRITE (6,25) Z
```

```
      IF (N.EQ.6) WRITE (6,26) Z
      IF (N.EQ.7) WRITE (6,27) Z
      IF (N.EQ.8) WRITE (6,28) Z
      IF (N.EQ.9) WRITE (6,29) Z
      IF (N.EQ.10) WRITE (6,30) Z
      IF (N.EQ.11) WRITE (6,31) Z
      IF (N.EQ.12) WRITE (6,32) Z
      RETURN
   21 FORMAT ('+',10X,F10.3)
   22 FORMAT ('+',20X,F10.3)
   23 FORMAT ('+',30X,F10.3)
   24 FORMAT ('+',40X,F10.3)
   25 FORMAT ('+',50X,F10.3)
   26 FORMAT ('+',60X,F10.3)
   27 FORMAT ('+',70X,F10.3)
   28 FORMAT ('+',80X,F10.3)
   29 FORMAT ('+',90X,F10.3)
   30 FORMAT ('+',100X,F10.3)
   31 FORMAT ('+',110X,F10.3)
   32 FORMAT ('+',120X,F10.3)
      END
      SUBROUTINE WRC(NAME)
      REAL NAME(4)
      WRITE (6,1) NAME
      RETURN
    1 FORMAT (/,1X,'***   ',4A4,'    ***'/)
      END
```

INPUT FILE SAMPLE

```
2 1 13 13 5 6 4 1 1 /TEST ENV-SWITCH NT NTRUN LP INPL JFN NRMS NBND
10. /DISC. RATE
4 ELEC LIQUID COAL GAS /DEMAND SECTORS
   3   1   1   1 /LOAD REGIONS
280. 350. 430. 520. 620. 730. 850. 970. 1090.     /DEM ELEC 1
1210. 1330. 1450. 1570.                           /DEM ELEC 2
1130. 1240. 1340. 1430. 1500. 1550. 1580. 1595.   /DEM LIQUID 1
1600. 1605. 1610. 1615. 1680.                     /DEM LIQUID 2
208. 240. 266. 285. 300. 305. 306. 304. 298.      /DEM COAL 1
292. 286. 280. 274.                               /DEM COAL 2
610. 630. 645. 655. 662. 667. 670.   670. 670.    /DEM GAS 1
670. 670. 670. 670.                               /DEM GAS 2
.259 .438 .303 1. 1. 1. /DISTR FACTORS
.184 .384 .432 1. 1. 1. /LOAD DURATIONS
4 COAL OIL GAS NATU /NAT RESOURCES
2 3 3 3 0 1 0 0 /GRADES IMPORTS
165000. 185000. 25150. 6240. 8620. 20000. /RLIM FOSS 1
23000. 7000. 3300. /RLIM FOSS 2
1577. 1270. 4230. /RLIM NUCL
1 1 0 0 0 0 0 0 /MAX DOM RES, ANNUAL IMPORT RESTRICTION
0 1 0 0 /EXTRA SWITCHES
   701.95465   895.89148  1143.40942  1459.31201
  1862.49255  2377.06396  3000.00000  3000.00000
  3000.00000  3000.00000  3000.00000  3000.00000
  3000.00000 /MAX COAL EXTR
   750.77478   828.91577   915.18982  1000.00000
  1000.00000  1000.00000  1000.00000  1000.00000
  1000.00000  1000.00000  1000.00000  1000.00000
  1000.00000 /MAX OIL EXTR
25. 41. 46.2 71.2 142.8 72.5  44.5 94.5 149.5 /FOSS FUEL COST
78. 156. 520. /NUCL FUEL COST
1 PLUTONM /MAN MADE RESOURCES
8 KRYPTON TRITIUM  CO2 PARTICUL NOX SOX HYDCARB
M-CO /EMITTANTS
10.6 12.26 1.E20 0. 0. 0. 0. 0. /HALF LIFES

/TECHNOLOGIES
U-LWR 1 A 1. 42.3 585. 1.5 2. .783 0. 0. 0. /TILL FOSS FUEL CCNS
.171 .408 0. -.215 0. 0. 0. 0. 0. 0.        /TILL EFF
1.25 32.6 0 0 /END LWR
```

```
;NUCL ; ELEC ; LWR  REACTOR
 5.30E+5  0.19E+5  0.65E-01 0.11      0.11
 0.77E-02 0.11E-01 0.65E-01

P-FBR 1 A 1. 41.2 770. 2. 2. .703 0. 0. 0.  ;TILL FOSS FUEL CONS
0. 0. 0. -.2 5. 5. 0. 0. 0. 0.              ;TILL EFF
0. 0. 1 UP 0. 0. 0. 0. 999. 999. 999. 999.  ;PART OF UB
999. 999. 999. 999. 999. 0 ;END FBR
;NUCL ; ELEC ; FB REACTOR
 1.04E+5  0.27E+5  0.65E-01 0.11      0.11
 0.77E-02 0.11E-01 0.65E-01

COAL 1 A 1. 19.3 460. 2. 2. .703 2.79 0. 0. ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.               ;TILL EFF
1.04 226. 0 0 ;END COAL-ELECTRIC
;COAL ; ELEC ; STEAM
 0.00      0.00      270.      2.0      35.
  19.      0.59      2.0

COAL 3 A 1. 0. 0. 0. 0. 1. 1. 0. 0.         ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.               ;TILL EFF
1.01 300. 0 0 ;END COAL-COAL
;COAL ; COAL
 0.00      0.00      100.      5.4      94.5
  51.3     1.59      5.40

ADVCOAL 1 A 1. 29.8 400. 2. 2. .703 2.5 0.  ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.            ;TILL EFF
0. 0. 1 UP 0. 0. 0. 999. 999. 999. 999.     ;PART OF UB
999. 999. 999. 999. 999. 999. 0 ;END ADVCOAL-ELEC
;COAL ; ELEC ; COMB. CYCLE 80M PRESS. BOILER
 0.00      0.00      270.      13.      2.3
  26.      0.00      0.00

ADVCOAL 2 A 1. 21. 345. 2. 6. .85 1.83 0. 0. ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.               ;TILL EFF
0. 0. 1 UP 0. 0. 0. 0. 999. 999. 999. 999. 999. ;UB
999. 999. 999. 999. 0 ;END CONV COAL LIQUEFACTION
;COAL ; LIQU ; CSF
 0.00      0.00      59.0      0.12      3.0
```

```
 0.61      0.15E-01 0.10

ADVCOAL 4 A 1. 9.6 312.5 2. 6. .85 1.87 0. 0. ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                  ;TILL EFF
0. 0. 1 UP 0. 0. 0.  999. 999. 999. 999. 999. ;UB
999. 999. 999. 999. 999. 0 ;END CONV COAL GASIFICATION
;COAL ; HGAS ; TYP. PROC
 0.00      0.00      59.0      0.50      4.5
  1.7      0.71E-01 0.24

REFCRUDE 2 A 1. 3.1 43. 0. 0. .85 0. 1.08 0. ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                ;TILL EFF
1.03 1220. 0 0 ;END REFINERY
;OIL  ; REF. ; AVERAGE REFINERY
 0.00      0.00      80.0      0.97E-01 0.70
 0.75      0.84      0.59E-02

NGAS 4 A 1. 0. 0. 0. 0. .85 0. 0. 1.         ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                ;TILL EFF
1.05 350. 0 0 ;END NGAS
;NGAS ; NGL  ; PROC H2S REMOVAL
 0.00      0.00      68.0      0.10E-02 0.67E-02
 1.89      48.6      0.76

HYDRO 1 A 1. 7. 520. 0. 0. .34 0. 0. 0.      ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                ;TILL EFF
1.01 55.4 1 FX 2. 2.25 2.5 2.75 3. 3.25 3.5  ;FX BND
3.5 3.5 3.5 3.5 3.5 3.5 0 ;END HYDRO
;HYDRO; ELEC
 0.0       0.0       0.0       0.0       0.0
0.0        0.0       0.0

SOLAR 1 A 1. 28.9 4250. 2. 2. .703 0. 0. 0.  ;TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                ;TILL EFF
0. 0. 1 UP 0. 0. 0. 0. 0. 999. 999. 999. 999. ;UB
999. 999. 999. 999. 0 ;END SOLAR
;SOLAR; ELEC
 0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0
```

```
IER 2 A 1. 87,6 5000. 0. 0. .85 0. 0. 0.      /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                 /TILL EFF
0. 0. 0 0 /END IER-LIQUID
0. 0. 0. 0. 0. 0. 0. 0.

IER 4 A 1. 87,6 5000. 0. 0. .85 0. 0. 0.      /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 0.                 /TILL EFF
0. 0. 0 0 /END IER-GAS
0. 0. 0. 0. 0. 0. 0. 0.

ELHY 1 A -1.18 6.13 150. 2. 6. 1. 0. 0. 0.   /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. -1. 0. 0.                 /TILL EFF
0. 0. 1 UP 0. 0. 0. 0. 0. 999. 999. 999. 999. /UB
999. 999. 999. 999. 0 /END ELHY-LIQUID
0. 0. 0. 0. 0. 0. 0. 0.

B-ELHY 1 A -1.18 6.13 150. 2. 6. 1. 0. 0. 0.   /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. -1.                 /TILL EFF
0. 0. 1 UP 0. 0. 0. 0. 0. 999. 999. 999. 999. /UB
999. 999. 999. 999. 0 /END ELHY-GAS
0. 0. 0. 0. 0. 0. 0. 0.

LIQPLANT 1 A 1. 15.8 290. 0. 0. .703 0. 0. 0. /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 2.7  0. 0.                 /TILL EFF
1.03 44. 1 UP 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. /UB
0. 0. 0 /END LIQ-ELEC
/OIL  ! ELEC ! STEAM BOILER
 0.00      0.00      216.0      2.6      34.
  31.      0.65      0.13E-01

GASSTEAM 1 A 1. 13.1 270. 0. 0. .703 0. 0. 0. /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 2.7                /TILL EFF
1.005 50. 1 UP 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.  /UB
0. 0. 0. 0 /END GASSTEAM
/NGAS ! ELEC ! STEAM
 0.00      0.00      183.0     0.70      18.
 0.28E-01  1.9       0.18E-01

JETGAS 1 A 1. 14.5 140. 0. 0. .703 0. 0. 0.   /TILL FOSS FUEL CONS
0. 0. 0. 0. 0. 0. 0. 0. 0. 3.33                /TILL EFF
```

```
1.06 41. 0 1 !END JETGAS
;NGAS ! ELEC ! JETGAS
 0.00      0.00       183.0     0.70      18.
 0.28E-01  1.9        1.8
@
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A SAMPLE CONTROL PROGRAM FOR THE LP SOLUTION

A SAMPLE CONTROL PROGRAM FOR THE LP SOLUTION


```
PROGRAM
INITIALZ
MOVE(XDATA,'MESSAGE')
MOVE(XPBNAME,'ENERGY')
CONVERT('FILE','INDATA')
CLOSEF('INDATA')
SETUP('BOUND','BND1')
MOVE(XOBJ,'FUNC')
MOVE(XRHS,'RHS1')
TITLE('DEMONSTRATION')
CRASH
PRIMAL
SOLUTION
EXIT
PEND
```