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Basic Model of Health Care Systems

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BASIC MODEL OF HEALTH CARE SYSTEMS

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<u>Basic Model of Health Care System</u>

The philosophy of health care system modelling is described in [1,2,3] and elsewhere.

The first version of a mathematical model of health care system at IIASA's Bio-Medical Project was worked out by Dr. A. Klementiev. It consisted of a population block and elements for patient treatment and population screening.

One of the goals of this model was to examine the possibility of redistributing health care resources between treatment and screening.

The resources of health care system--personnel, equipment, etc.--were generalized and represented by "the total number of doctors in practice".

The model was constructed in somewhat general terms and lacked the elaboration of its "fine structure" to become an operating model. This work is a natural continuation of the work on modelling commenced in [3] and [4].

Before elaborating an operating model it is necessary to develop a basic model that should later grow upon itself the needed details to become an operating model. The first step in this direction was the working out of the model's demographic subsystem which would represent population aging dynamics. This subsystem is described in [4].

The structure of the basic model is shown in Figure 1:

1. Population prevalence dynamics.
2. Population aging dynamics.
3. Population aging update as interface between (1) and (2).
4. Treatment section.
5. Screening section.
6. Request for admission into health care system.

In this model the following categorization of diseases is accepted. It is presumed that there are three kinds of diseases [3]:

1. Diseases of the degenerative type have distinctly identified phases and lead to gradual deterioration and death. Examples of this type of disease are cancer, hypertension, TBC, syphilis and alcoholism. We consider three phases of such diseases: phases A, B and C. Phase C may lead to disease-specific death.

2. Acute diseases--accidents, appendicitis, etc.

3. "Non-diseases" that can be eradicated by vaccination--small-pox, polio, diptheritis, etc.

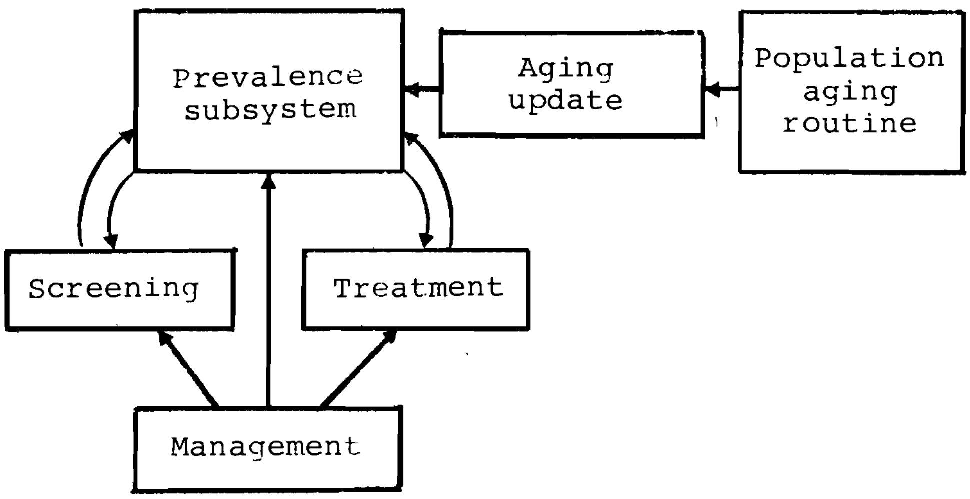

Figure 1. The Schematic of the Basic Model of the Health Care System

The model at its present stage is being elaborated for a certain disease of Type 1.

Description of Prevalence Dynamics

The population is divided into three categories: healthy people (HP), latent sick (LS) and registered sick (RS). Each category of sickness is divided into three groups with regard to phase of the disease.

The HP may become latent sick in Phase A with a definite morbidity rate. The LS cannot spontaneously recover. They have either to be admitted for treatment or to deteriorate until death occurs.

The RS receive treatment. Phase A corresponds to outpatients, Phase B to inpatients, and Phase C to invalids with irreversible disabilities.

Phase A RS may recover and become HP while Phase B RS cannot immediately recover but may undergo remission and become Phase A RS. Phase C RS deteriorate until death.

Disease-specific death rate in Phase C LS is supposed to be greater than that in Phase C RS, and both - greater than the non-specific death rate.

The HP and LS are the subjects of medical screening to identify sick persons. There is also a natural demand for treatment from those LS who become aware of their disease.

The sick detected by screening plus people who have become aware of their illness by themselves form the treatment demand rate for given phases of the disease.

This pattern of prevalence dynamics seems to be good as a first approximation. It may be subsequently refined in further development of the operating model.

Accumulation and flow patterns for different categories of the population can be described by ordinary differential equations which can be easily entered into a computer.

Health Care Activities

Health care resources are represented by the number of physicians.

Health care resources (doctors) should be redistributed according to the existing RS distribution profile for different phases of the disease. This redistribution may be controlled by HCS managers and usually occurs after a certain delay.

The number of sick (PCTD) that doctors serving different phases of the disease can treat is determined by standard workloads (SWL) set either by the authorities or by other means.

If the number of patients that can be treated by doctors (PCTD) is greater than the number of RS in a given phase of a disease, the difference between these two figures can be admitted to health care system from the LS forming treatment demand rate.

People admitted to health care determine the real admission rate (REAR). This may be equal to zero if there are less PCTD than RS for a given phase of a disease. In this case the doctors (i.e. health care resources) are overloaded, and the health care system is able to function due to its inherent resilience.

As stated above, the treatment demand rate is composed of three components: sick detected by screening carried out by doctors, screening carried out by automated equipment, and natural treatment demand.

The natural treatment demand is a function of sanitary education, which is an important aspect of any prophylaxis measures.

Automated screening is more efficient as well as more expensive than screening done by physicians.

To provide for better detection of LS, health care managers should increase investments in automated screening equipment and select the best possible proportion between time doctors spend in screening and that they spend in treatment.

If this proportion is selected incorrectly (for example, if not enough resources are given to screening programs) then all the LS will very quickly pass down to Phase C illness which is an incurable, high death rate state.

If at the other extreme all resources were to go into detection, then the detected sick would stay in line for admission--admission which would never occur. In this case the RS would not be treated and would never recover.

One of the main reasons for playing games with this model is to determine the golden mean for this kind of situation. The optimal solution here may well be some kind of impulse regime for screening.

Aging Update

All that was said above about dynamics still disregards population aging. The described pattern corresponds to a certain age stratum. The real problem now is how to introduce updates for aging.

It was decided to run in parallel prevalence dynamics equations and the population aging routine, the latter described in [4], both subsystems of the model being divided into equivalent sex-age strata and the prevalence subsystem strata being periodically fed with updates from the aging routine structure.

Due to the fact that the sick people with a given disease are usually just a small fraction of the total population and due to the conservative nature of changes in sex-age structure, the aging routine is run less frequently, say, in time increments equal to one year.

The time increments in the prevalence subsystem are set at 0.2 year because of the need to trace out transient effects affected by health care policies.

Thus the basic model operates in the following mode:

- one run of the aging routine is followed by five runs of the prevalence equations--one year passes; then one more run of the aging routine and five runs of the prevalence equations--one more year passes; and so forth.

Each year any given sex-age stratum in the aging routine loses some people due to aging and their transfer into another stratum, and gains some people from a "previous stratum". The difference between the numbers of these people for a given stratum constitutes a yearly aging update for the stratum.

In more technical terms, these updates are recalculated by special subroutines and added to those people contained in each stratum of each phase of the disease in each step of integration of the prevalence equations.

A yearly "immigration" for a specific phase of a given stratum is equal to the fraction of people in this phase of a "previous stratum" times the portion (one-fifth) of yearly "immigration into this stratum of the aging routine. A yearly "emigration" for a phase of the stratum is equal to the fraction of people in this phase of this stratum times the same portion (one-fifth) of yearly "emigration" from the considered stratum of the aging routine. The stratum update is the difference between these "immigration" and "emigration" figures.

Such a simple interpolation taking equal portions of an aging "migration" in updates may be erroneous. Work with the basic model will clarify this matter.

Conclusions

A FORTRAN program for this basic model has been written and debugged. The problem now is to compile an array of test data. The first runs with primitive test data are shown in Appendix 3.

After finishing the implementation of inner feedbacks, the time will come to try various decision-making options.

The flow chart of the basic model in terms of system dynamics is shown in Figure 2. The variables and equations are presented in Appendices 1 and 2.

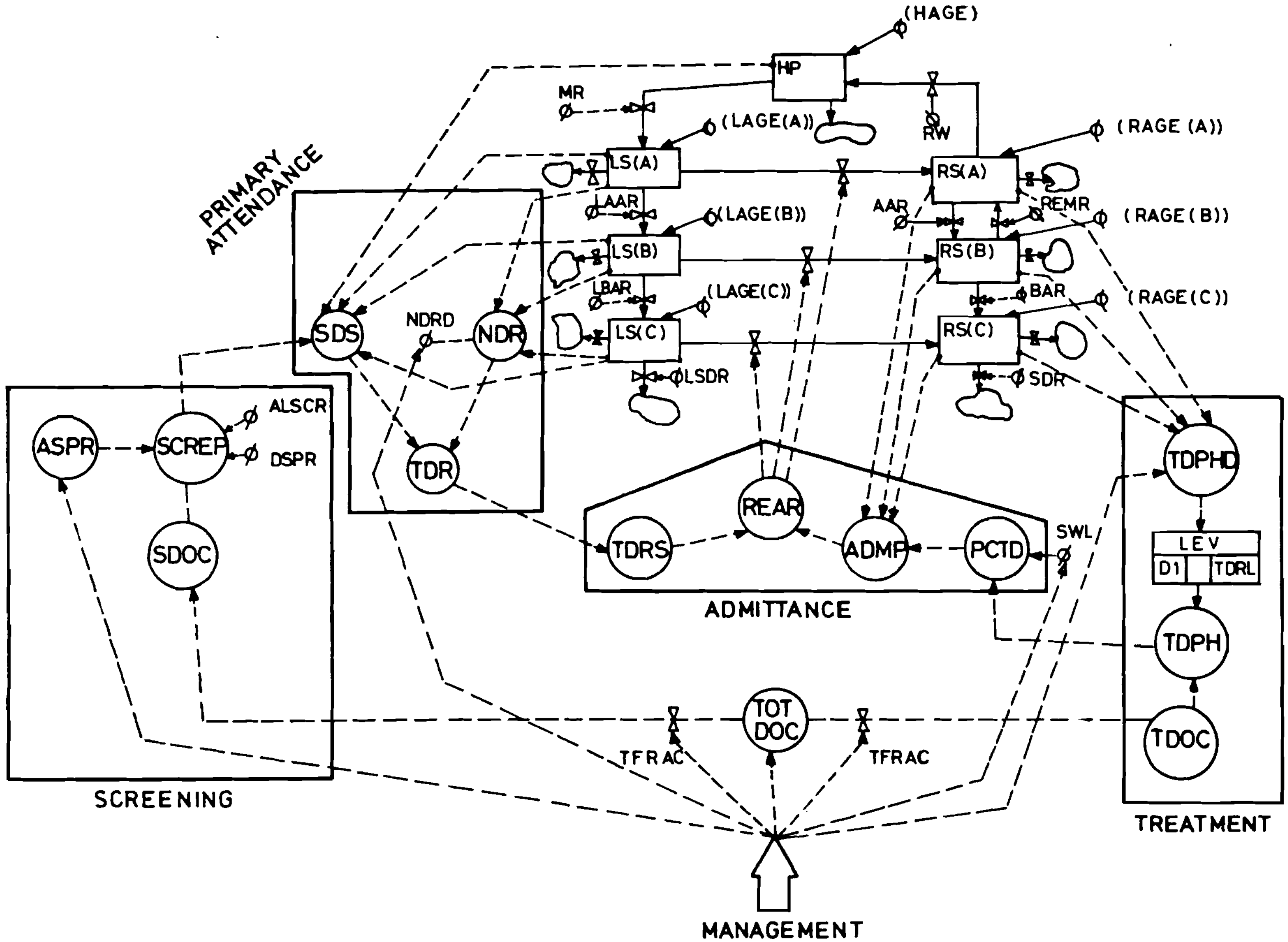
(HAGE)
HP
MR
RW
(LAGE(A))
LS(A)
RS(A)
(RAGE (A))
LAAR
(LAGE(B))
AAR
REMR
(RAGE(B))
LS(B)
RS(B)
LBAR
(LAGE(C))
BAR
(RAGE(C))
LS(C)
RS(C)
LSDR
SDR
PRIMARY ATTENDANCE
SDS
NDRD
NDR
TDR
SCREENING
ASPR
SCREP
ALSCR
DSPR
SDOC
ADMITTANCE
REAR
TDRS
ADMP
PCTD
SWL
TREATMENT
TDPHD
LEV
D1
TDRL
TDPH
TDOC
TOT DOC
TFRAC
TFRAC
MANAGEMENT

Figure 2

Acknowledgements

This work was discussed in detail with Alexandre Klementiev. Peter Fleissner happened to squash a pair of bugs in the program. I am also thankful to James Curry, William Webb and Mark Pearson, who helped me saddle the PDP.

I have also to acknowledge my thanks to Günther Fischer, who issued a fine lineprinter plotting routine [5], which is very simple to be employed by any user.

All comments are welcome and should be directed to the IIASA Bio-Medical Group.

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[1] Systems Aspects of Health Planning, Bailey, N.T.J., and M. Thompson, eds., North Holland/American Elsevier, Amsterdam, 1975.

[2] Kiselev, A. A Systems Approach to Health Care, RM-75-31, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1975.

[3] Venediktov, D., et al. Health Care: A Systems Approach, CP-76-__, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976, forthcoming.

[4] Klementiev, A.A. A Computer Method for Projecting a Population's Sex-Age Structure, RM-76-36, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976.

[5] Fischer, G. Multilevel Computer Model of World Development System - Part II, Internal Paper, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1975.

Appendix 1

Prevalence Sector Variables

AAR(I)	-	aggravation rate from phase A
BAR(I)	-	aggravation rate from phase B
DR(I)	-	death rate
$HAGE_t(I)$	-	healthy persons' aging rate
$HP_t(I)$	-	healthy persons
LAAR(I)	-	aggravation rate from phase A for latent side
$LAGE_t(I,J)$	-	latent sick aging rate
LAT(J)	-	latent sick in phase J
LATS	-	all latent sick
LBAR(I)	-	aggravation rate from phase B for latent sick
$LS_t(I,J)$	-	latent sick (LD)
LSDR(J)	-	specific death rate for non-attendent sick
MR(I)	-	morbidity rate
$RAGE_t(I,J)$	-	registered sick aging rate
$REAR_t(I,J)$	-	admission rate (REAR)
$RECOV_t(I)$	-	recovery rate
REG(J)	-	registered sick in phase J
REGS	-	all registered sick
REMR(I)	-	remission rate
$RS_t(I,J)$	-	registered sick
RW(I)	-	recovery weights
SDR(I)	-	specific death rate

General Part Variables

$ADMP_t(J)$ - admission possibility

ALSCR(J) - probability not to detect a sick in screening

$ASPR_t$ - automated screening productivity

DSPR - doctor's screening productivity

$HP_t(I)$ - healthy population in strata

HPS_t - healthy population summed

LEV(J) - level for the delay in doctors' requirement adjustment

$LS_t(I,J)$ - latent sick (detailed)

LSF_t - latent sick fraction in non-registered population (to be screened)

LSS_t - latent sick summed

$NDR_t(I,J)$ - natural treatment demand rate

NDRD(I,J) - natural treatment demand rate density

$PCTD_t(J)$ - patients that can be treated by doctors

$REAR_t(J)$ - real admission rate

$RS_t(I,J)$ - registered sick (detailed)

$RSS_t(J)$ - registered sick in phases

$SCREP_t$ - screening productivity

$SDOC_t$ - number of screening doctors

$SDS_t(I,J)$ - rate of sick detected by screening

$SFRAC_t$ - fraction of doctor's activities in screening

$SWL_t(J)$ - standard workload for a doctor (i.e. patients in phase J per doctor)

$TDOC_t$ - number of treatment doctors

$TDPH_t(J)$ - treatment doctors in a phase of a disease

$TDPHD_t(J)$ - density of treatment doctors in a phase of a disease

$TDR_t(I,J)$ - treatment demand rate (detailed)

TDRL - time lag in doctors' requirement

$TDRS_t(J)$ - treatment demand rate in phases

$TOTDOC_t$ - total doctors in practice

$TFRAC_t$ - fraction of doctors' activities in treatment

Appendix 2

I signifies a sex-age structure;
J - a phase of the disease: A, B or C.

Natural Treatment Demand Rate

$$NDR(I,J) = NDRD(I,J) \cdot LS(I,J)$$

NDRD is the fraction of LS in phase J that seek treatment on their own initiative.

Sick Detected by Screening

$$SDS(I,J) = SCREP \cdot LS(I,J)/(LATS + HPS) \cdot ALSCR(J)$$

Here

SCREP is screening productivity;

$SCREP = ASPR + DSPR \cdot SDOC$;

ASPR is automated screening productivity;

DSPR is the screening productivity of a physician;

SDOC is the number of doctors in screening;

$SDOC = TOTDOC \cdot SFRAC$;

TOTDOC are all the doctors in practice;

SFRAC is the fraction of doctor's activities in screening;

LATS are all the LS: $LATS = \sum_J \sum_I LS(I,J)$

HPS are all the HP: $HP = \sum_I HP(I)$;

ALSCR(J) is probability to identify a Phase J LS in screening.

Admission Demand Rate

$$TDR(I,J) = NDR(I,J) + SDS(I,J)$$

Admission Demand Rate in Phases

$$TDRS(J) = \sum_{I} TDR(I,J)$$

Patients that can be Treated by Doctors

$$PCTD(J) = SWL(J) \cdot TDPH(J)$$

Here

SWL(J) is the number of Phase J sick that can be treated by a doctor regularly, i.e. standard workload of a doctor;

TDPH(J) is the distribution of health care resources (doctors) in phases of the disease, TDPH(J) should be proportional to the RS in phase (J):

$$TDPH(J) \text{ should} = REG(J)/REGS \cdot TDOC \quad ;$$

$$REG(J) = \sum_{I} RS(I,J) \quad ;$$

$$REGS = \sum_{J} \sum_{I} RS(I,J) \quad .$$

In practice, this equality is presumed to hold with delay:

TDRL is the lag time;

TDOC are the doctors (health care resources) in treatment:

$$TDOC = TOTDOC \cdot TFRAC \quad ;$$

TFRAC is the fraction of a doctor's activities in treatment.

Admission Possibility

$$ADMP(J) = PCTD(J) - REG(J)$$

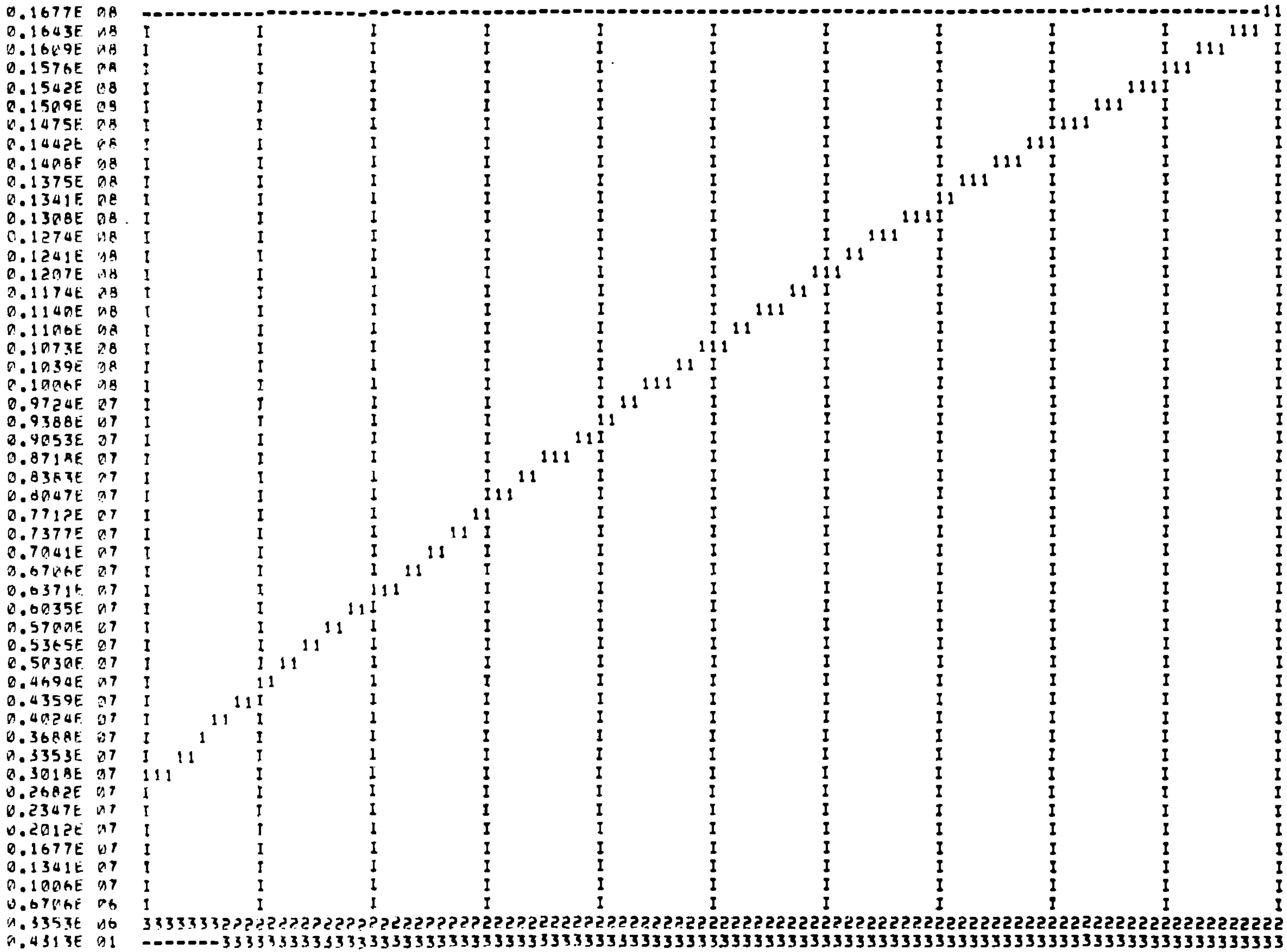
Real Admission Rate

$$
REAR(J) = \begin{cases} TDRS(J) \quad , & \text{if } ADMP(J) > 0,\ ADMP(J) \geq TDRS(J) \\ ADMP(J) \quad , & \text{if } ADMP(J) > 0,\ ADMP(J) < TDRS(J) \\ 0 \quad , & \text{if } ADMP(J) \leq 0 \quad . \end{cases}
$$

The Prevalence Equations

```
              MORR=MR(S)*HP(S)
              RECOV=RR(S)*RS(S,1)
              REMIS=REMR(S)*RS(S,2)
              AAGGR=AAR(S)*RS(S,1)
              RAGGR=RAR(S)*RS(S,2)
              LAAGGR=LAAR(S)*LS(S,1)
              LRAGGR=LRAR(S)*LS(S,2)
C
C
C
C
      HP(S)=HP(S)+DT*(RECOV-MORR-DR*HP(S)+HAGE(S))
        IF(HP(S) .LT. 0.) HP(S)=0.
      RS(S,1)=RS(S,1)+DT*(REMIS-AAGGR-DR*RS(S,1)-RECOV+
&           RAGE(S,1)+REAR(S,1))
C
      RS(S,2)=RS(S,2)+DT*(AAGGR-RAGGR-DR*RS(S,2)-REMIS+
&           RAGE(S,2)+REAR(S,2))
C
      RS(S,3)=RS(S,3)+DT*(RAGGR-SUR(S)*RS(S,3)+
&           RAGE(S,3)+REAR(S,3))
C
      LS(S,1)=LS(S,1)+DT*(MORR-LAAGGR-DR*LS(S,1)+
&           LAGE(S,1)-REAR(S,1))
C
      LS(S,2)=LS(S,2)+DT*(LAAGGR-LRAGGR-DR*LS(S,2)+
&           LAGE(S,2)-REAR(S,2))
C
C
      LS(S,3)=LS(S,3)+DT*(LRAGGR-LSUR(S)*LS(S,3)+
&           LAGE(S,3)-REAR(S,3))
C
C
        DO 332 K=1,3
        IF(RS(S,K) .LT. 0.) RS(S,K)=0.
        IF(LS(S,K) .LT. 0.) LS(S,K)=0.
332     CONTINUE
```

F I G U R E : The Latent Sick



Appendix 3

F I G U R E : The Registered Sick

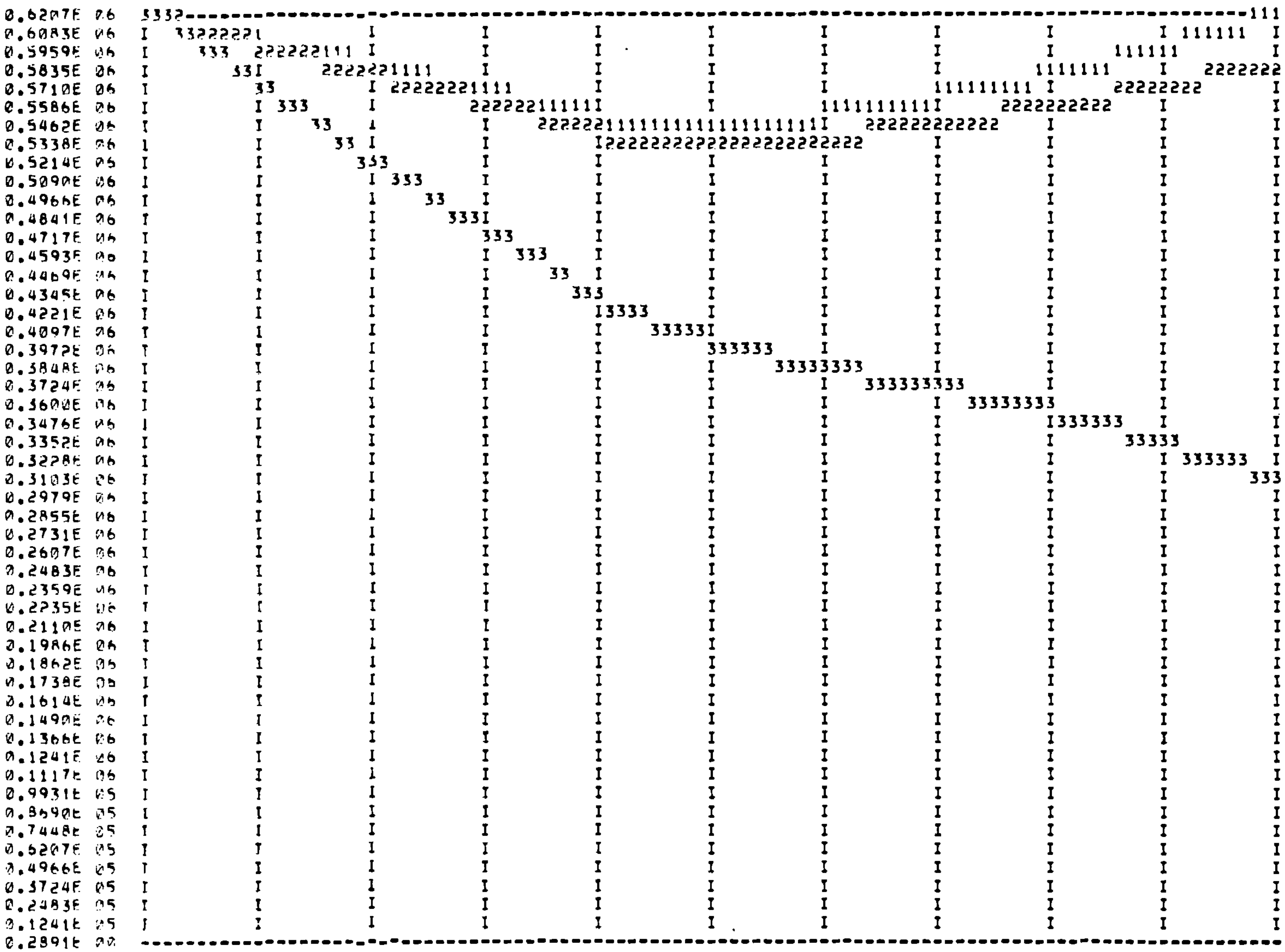
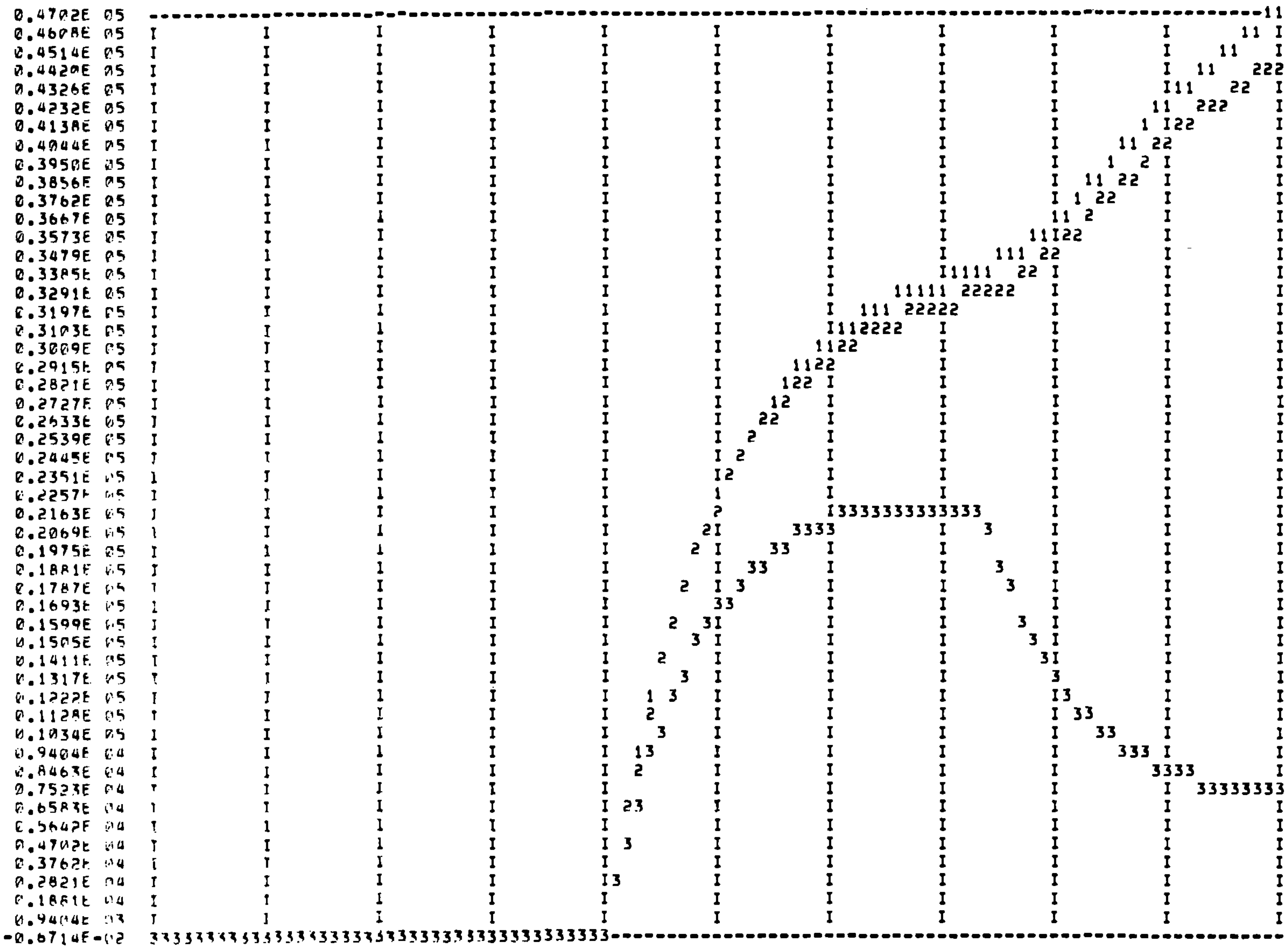
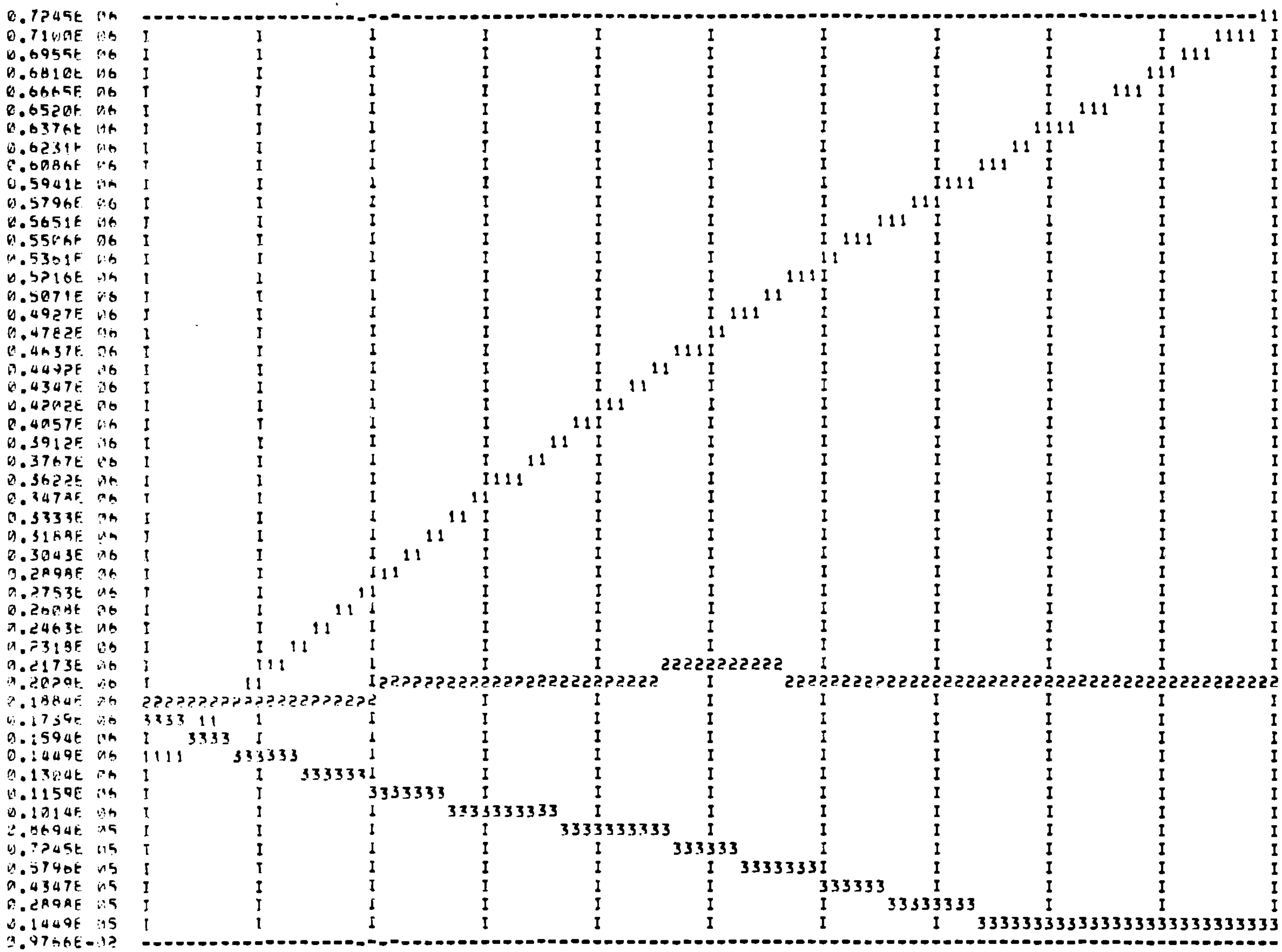


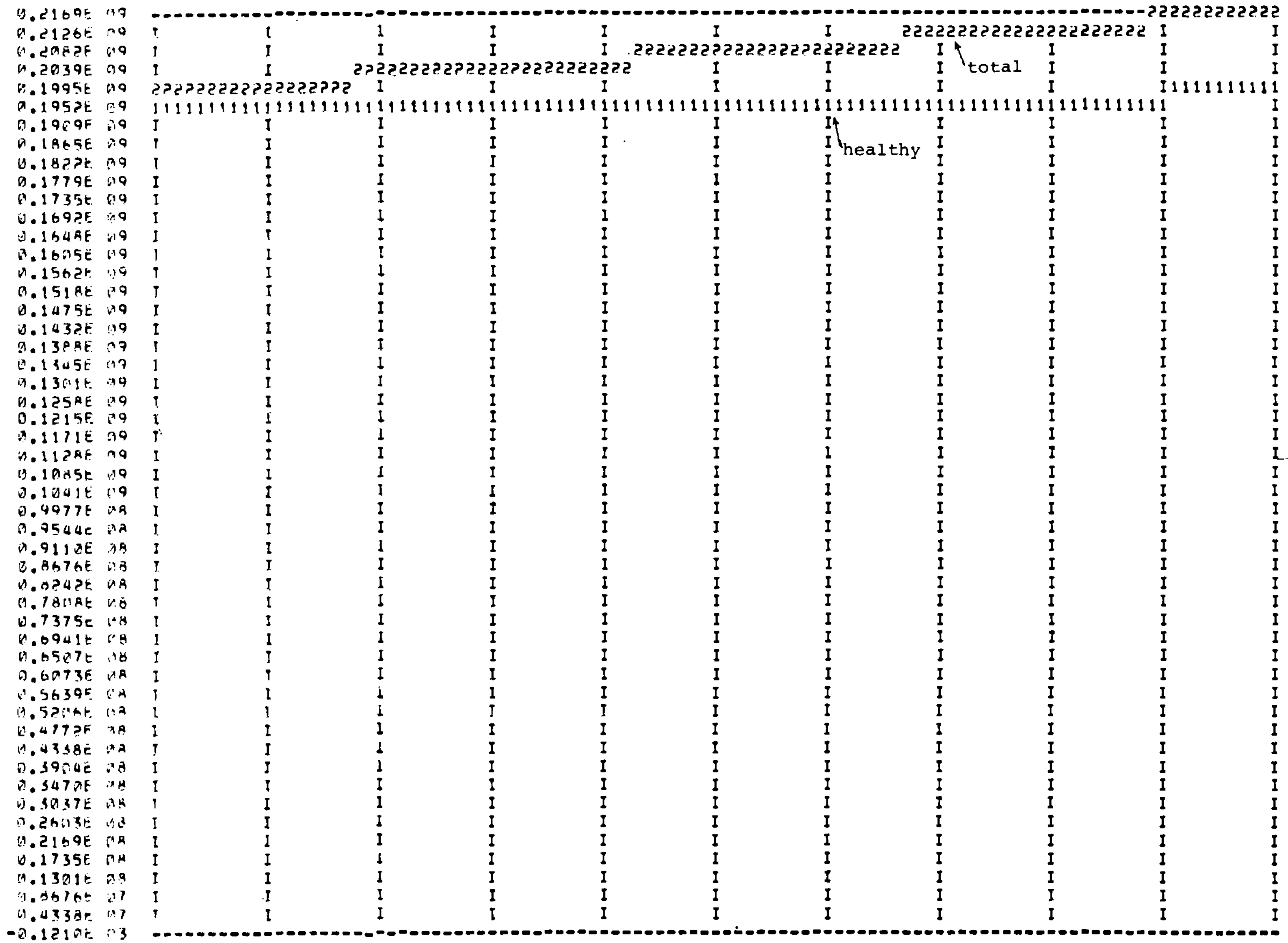
FIGURE: Admission



F I G U R E: Demand for Admission



F I G U R E: Population Growth



PROGRAM TERMINATED

APPENDIX 4

```
JUL  4 13:52 1976  MAIN.F PAGE 1

C*************************************************************************
C
C
C       THIS IS A BASIC MODEL OF HEALTH CARE SYSTEM
C
C
      IMPLICIT REAL (A-Z)
      INTEGER T, SPAN,I,K,S,NINT,IND,INDEX,PHASE,NS
      DIMENSION PN(23),PCSM(23),PUDRO(23),PVH(23),PVIH(23),
&         AAR(23),BAR(23),HAGE(23),HP(23),LAAR(23),LAGE(23,3),
&         LBAR(23),LS(23,3),LSDR(23),MR(23),RAGE(23,3),REAR(23,3),
&         REMP(23),RS(23,3),RW(23),SDR(23),ADMP(3),
&         ALSCR(3),NDR(23,3),NDRD(23,3),PCTD(3),ENT(3),SWL(3),
&         TOPH(3),TOPHD(3),TDR(23,3),TDRS(3),RS1(23),RS2(23),RS3(23),
&         LS1(23),PREPC(23),LEV(3),LS2(23),LS3(23),XRS(3),XLS(3),UPSI(3)
C
        DIMENSION OUT1(306),OUT2(306),OUT3(306),
&       OUT12(153),OUT22(153)
        COMMON/PLOT/OUT1,OUT2,OUT3,PNP,TM
C- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
        INTEGER TM
        INTEGER AD,AS
        COMMON/SERA/ PCDJ,PCDM
        COMMON/SUMS/ HPS,LATS,REGS,LAT(3),REG(3),DT,LEV,PRIORT(23)
C
C
C
        EQUIVALENCE    (RS1(1),RS(1,1)),
&                       (RS2(1),RS(1,2)),
&                       (RS3(1),RS(1,3)),
&                       (LS1(1),LS(1,1)),
&                       (LS2(1),LS(1,2)),
&                       (LS3(1),LS(1,3))
C
C
C
        EQUIVALENCE (OUT12(1),OUT1(154)),
&       (OUT22(1),OUT2(154))
C . . . . . . . I N P U T S . . . . . . . . . . . .
C               ----------
C
C
C  POPULATION  IN STRATA
C       PN
C
C  DEATH RATE IN STRATA
C       PCSM
C
C  BIRTH RATE IN STRATA
C       PUDRO
C
C  PERINATAL DEATH RATE
C       PCSMNO
C
C  SEX  RATIO
C       PCDJ    PCDM
```

```
C
C  INTEGRATION  STEP     AND     INTEGRATION PERIOD
C       DTPOP,                     SPAN
C
C  STRATUM  DEPTH,  AGED STRATUM DEPTH,  NUMBER OF STRATA
C       T1                 T2                 NS
C
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C
C           INPUT FOR PREVALENCE EQUATIONS
C           ------------------------------
C
C    POPULATION IN STRATA AND THE DESEASE PHASES
C       HP,             LS,         RS
C
C  DEATH RATES IN STRATA
C       DR
C
C  SPECIFIC DEATH RATES
C     SDR,   LSDR
C
C  AGGRAVATION RATES IN PHASES AND STRATA, MORBIDITY RATE
C     AAR,  BAR,  LAAR,  LBAR,  MR
C
C  RECOVERY AND REMISSION WEIGHTS
C       RW,         REMR
C
C  TIME LAG IN DOCTORS REQUIREMENT ADJUSTMENT
C               TDRL
C
C  INTEGRATION STEP
C       DT
C- - - - - - - - - - - - - - - - - - - - - - - - -
C
C
C
C              INPUT  TO  GENERAL  PART
C              ------------------------
C
C  PROBABILITY  TO DETECT A SICK IN SCREENING
C       ALSCR
C
C  AUTOMATED AND DOCTOR'S SCREENING PRODUCTIVITY
C       ASPR,        DSPR
C
C  NUMBER OF DOCTORS AND THEIR DISTRIBUTION
C              IN TREATMENT AND SCREENING
C       TOTDOC,  TFRAC,         SFRAC
C
C  STANDARD WORKLOAD FOR A DOCTOR
C         SWL
C
      READ(5,922) AD
922   FORMAT(/I2)
      READ(5,902) NS,DTPOP,DT,SPAN,T1,T2,PCDJ,PCDM,PCSMNO,TDRL
```

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```
        READ(5,903) TOTDOC,SFRAC,TFRAC
        READ(5,904) ALSCR,ASPR,DSPR,SWL
        READ(5,905) NDRD
        READ(5,911) SDR
        READ(5,911) LSDR
        READ(5,911) MR
        READ(5,912) RW
        READ(5,912) REMR
        READ(5,912) AAR
        READ(5,912) BAR
        READ(5,912) LAAR
        READ(5,912) LBAR
        READ(5,913) PREPC
        READ(5,907) LATS,LAT,REGS,REG
        READ(5,908) PN
        READ(5,909) PCSM
        READ(5,910) PUDRO
C
C================================================================
C
C
        DO 601 I=1,23
        PN(I)=PN(I)*1000.
        UM=1.-PREPC(I)
        HP(I)=UM*PN(I)
        X=PREPC(I)*PN(I)
        Y=X*LATS
        LS(I,1)=Y*LAT(1)
        LS(I,2)=Y*LAT(2)
        LS(I,3)=Y*LAT(3)
        Y=X*REGS
        RS(I,1)=Y*REG(1)
        RS(I,2)=Y*REG(2)
        RS(I,3)=Y*REG(3)
C
601     CONTINUE
C
C
C       SCREENING PRODUCTIVITY
C
            TOTDOC=TOTDOC*1000.
            SCREP=ASPR+DSPR*TOTDOC*SFRAC
            TDOC=TOTDOC*TFRAC
C
C----------------------------------------------------------------
C  NUMBER OF INTEGRATIONS IN THE PREVALENCE SECTOR
C  PRIOR TO THE TOTAL POPULATION INTEGRATION
            ST=DTPOP/DT
            NINT=(ST+.5)
C
        UM=0.
        DO 605 I=1,NS
605     UM=UM+PN(I)
        TM=0
        DO 410 I=1,306
        OUT1(I)=0.
```

```
      OUT2(I)=0.
410   OUT3(I)=0.
      OUT3(52)=UM
      CALL ADMIT(SCREP,SWL,HP,LS,RS,NORD,ALSCR,TORL,REAR,TOOC)
      DO 607 K=1,3
607   LEV(K)=TORL*REG(K)/REGS
      T=0
C
      WRITE(6,901)
      TOTAL=HPS+LATS+REGS
C
      DO 608 K=1,3
      REG(K)=REG(K)/REGS
608   LAT(K)=LAT(K)/LATS
      WRITE(6,900) T, HPS,LATS,REGS,TOTAL,UM,LAT,REG
C
      DO 666 K=1,NS
      PCSM(K)=PCSM(K)/1000.
      PUDRO(K)=PUDRO(K)/1000.
      SDR(K)=SDR(K)/1000.
      LSDR(K)=LSDR(K)/1000.
      MR(K)=MR(K)/1000.
      RW(K)=RW(K)/1000.
      REMR(K)=REMR(K)/1000.
      AAR(K)=AAR(K)/1000.
      BAR(K)=BAR(K)/1000.
      LAAR(K)=LAAR(K)/1000.
      LBAR(K)=LBAR(K)/1000.
666   CONTINUE
      PCSMNO=PCSMNO/1000.
C
C
C        ****BEGIN:****
C        **************
C
C
C
C     ****************
      DO 500 T=1,SPAN
C     ****************
C
C
C
C  NEWBORNS IN THE T-TH YEAR:
C
      PABRO=0.
      DO 100 I=4,16,2
100   PABRO=PABRO+PUDRO(I)*PN(I)
C
      PVH(1)=PABRO*(1.-PCSMNO)
C
C
C
C  POPULATION AGING ROUTINE
C  ----------------------
C
```

```
C
C
C
C       ************
        DO 18 I=1,23
C       ************
C
C
          PSM=PCSM(I)*PN(I)
         IF(I-22) 14,15,16
C
C  NON OLD PEOPLE:
14       U=(1.-PCSM(I))**T1
        PCDEM=U*PCSM(I)/(1.-U)
         PVIH(I)=PCDEM*PN(I)
C
         IF(I-3) 11,12,13
C
C  CHILDREN:
11        K=I+1
          PVH(K)=PVIH(I)
          GO TO 17
C---------------C
C
C
C YOUTHS:
12        PVH(4)=PVIH(3)*PCDJ
          PVH(5)=PVIH(3)*PCOM
          GO TO 17
C---------------C
C
C  ADULT PEOPLE:
13        K=I+2
          PVH(K)=PVIH(I)
          GO TO 17
C---------------C
C
C  ELDERLY PEOPLE:
15       PVH(22)=PVIH(20)+PVIH(21)
         U=(1.-PCSM(22))**T2
         PCDEM=U*PCSM(22)/(1.-U)
         PVIH(22)=PCDEM*PN(22)
         GO TO 17
C--------------C
C
C  OLD PEOPLE:
16       PVH(23)=PVIH(22)
         PVIH(23)=0.
C--------------C
C
17      CONTINUE
18      PN(I)=PN(I)+DTPOP*(PVH(I)-PVIH(I)-PSM)
C
C
C* * * * * * * * * ** * * * * * * * * * * * *
C
```

```
C
C*******************************************************************************
C
        DO 330 K=1,3
330     FNT(K)=0.
C
C
C       ****************
        DO 333 AS=1,NINT
C       ****************
C
        DO 331 S=1,23
C
C
C       A G I N G    U P D A T E S
C       --------------------------
C
C
        IND=INDEX(S)
        IF(IND-1) 1000,1001,1002
1001      DO 1101 PHASE=1,3
          XRS(PHASE)=0.
1101      XLS(PHASE)=0.
          XHP=PABRO
          XPNP=PABRO
          GO TO 1003
C------------------C
1002      XRS(1)=STBACK(S,IND,RS1)
          XRS(2)=STBACK(S,IND,RS2)
          XRS(3)=STBACK(S,IND,RS3)
          XLS(1)=STBACK(S,IND,LS1)
          XLS(2)=STBACK(S,IND,LS2)
          XLS(3)=STBACK(S,IND,LS3)
          XHP=STBACK(S,IND,HP)
          XPNP=XHP+XRS(1)+XRS(2)+XRS(3)+XLS(1)+XLS(2)+XLS(3)
C
C
1003    RSI=RS(S,1)+RS(S,2)+RS(S,3)
        LSI=LS(S,1)+LS(S,2)+LS(S,3)
        PNP=HP(S)+RSI+LSI
C
C
         PEM=PVIH(S)
         PIM=PVH(S)
         U1=PEM/PNP
         U2=PIM/XPNP
C
       DO 1102 PHASE=1,3
       RAGE(S,PHASE)=XRS(PHASE)*U2-RS(S,PHASE)*U1
1102   LAGE(S,PHASE)=XLS(PHASE)*U2-LS(S,PHASE)*U1
       HAGE(S)=XHP*U2-HP(S)*U1
C
331     CONTINUE
C
C*******************************************************************************
C
```

```
C
C
C
      CALL ADMIT(SCREP,SWL,HP,LS,RS,NORD,ALSCR,TORL,REAR,TOOC)
C     ----------------------------------------------------------
C
        DO 329 K=1,3
        DO 329 S=1,23
329     ENT(K)=ENT(K)+REAR(S,K)
C
C
        DO 333 S=1,23
C
C
C         PREVALENCE   EQUATIONS
C         ---------------------
C
        DR=((HP(S)+RS(S,1)+RS(S,2)+RS(S,3)+LS(S,1)+LS(S,2)+LS(S,3))*
&             PCSM(S)-RS(S,3)*SOR(S)-LS(S,3)*LSDR(S))/
&             (HP(S)+RS(S,1)+RS(S,2)+LS(S,1)+LS(S,2))
          MORB=MR(S)*HP(S)
          RECOV=RW(S)*RS(S,1)
          REMIS=REMR(S)*RS(S,2)
          AAGGR=AAR(S)*RS(S,1)
          BAGGR=BAR(S)*RS(S,2)
          LAAGGR=LAAR(S)*LS(S,1)
          LBAGGR=LBAR(S)*LS(S,2)
C
C
C
C
      HP(S)=HP(S)+DT*(RECOV-MORB-DR*HP(S)+HAGE(S))
        IF(HP(S) .LT. 0.) HP(S)=0.
      RS(S,1)=RS(S,1)+DT*(REMIS-AAGGR-DR*RS(S,1)-RECOV+
&           RAGE(S,1)+REAR(S,1))
C
      RS(S,2)=RS(S,2)+DT*(AAGGR-BAGGR-DR*RS(S,2)-REMIS+
&           RAGE(S,2)+REAR(S,2))
C
      RS(S,3)=RS(S,3)+DT*(BAGGR-SOR(S)*RS(S,3)+
&           RAGE(S,3)+REAR(S,3))
C
      LS(S,1)=LS(S,1)+DT*(MORB-LAAGGR-DR*LS(S,1)+
&           LAGE(S,1)-REAR(S,1))
C
      LS(S,2)=LS(S,2)+DT*(LAAGGR-LBAGGR-DR*LS(S,2)+
&           LAGE(S,2)-REAR(S,2))
C
C
      LS(S,3)=LS(S,3)+DT*(LBAGGR-LSDR(S)*LS(S,3)+
&           LAGE(S,3)-REAR(S,3))
C
C
        DO 332 K=1,3
        IF(RS(S,K) .LT. 0.) RS(S,K)=0.
        IF(LS(S,K) .LT. 0.) LS(S,K)=0.
```

```
332     CONTINUE
C
333           CONTINUE
C*****************************************************************
C
        DO 609 K=1,3
        REG(K)=REG(K)/REGS
609     LAT(K)=LAT(K)/LATS
        TOTAL=HPS+LATS+REGS
        UM=0.
        DO 606 I=1,NS
606     UM=UM+PN(I)
        WRITE(6,900) T, HPS,LATS,REGS,TOTAL,UM,LAT,REG
       /WRITE(6,980) ENT
980     FORMAT(7X,9HADMISSION  ,-3P3F10.3/)
C
500     CONTINUE
C================================================================
C
        WRITE(6,1055)
1055    FORMAT(20(/))
        CALL DRAWER(OUT1,3)
        CALL DRAWER(OUT12,3)
        CALL DRAWER(OUT2,3)
        CALL DRAWER(OUT22,3)
        CALL DRAWER(OUT3,2)
        WRITE(6,1051)
        CALL EXIT1

        STOP
C
1000    WRITE (6,920)
        STOP
C
C=====================================================================
C
C             F O R M A T S :
C
920     FORMAT(//'  INDEX IS NEGATIVE: STOP*******')
C
900     FORMAT(80('-')/2X,I2,2X,-3P5F14.3,/16X,0P3F6.3,2X,3F6.3/)
901     FORMAT(///80('=')//1X,'YEAR',8X,'HEALTHY',3X,'LATENT SICK',5X,'REGD.SICK',
$       9X,'TOTAL',2X,'TOTAL FROM POP')
902     FORMAT(///// I2,2X,F4.1,1X,F4.1,2X,I3,1X,F4.1,1X,F4.1,1X,
$                F5.3,1X,F5.3,1X,F6.2,1X,F7.3)
903     FORMAT(/F6.1,2F6.3)
904     FORMAT(/F5.3,2F6.3,5F8.1)
905     FORMAT(/2(3(7F5.3/),2F5.3/), 3(7F5.3/),2F5.3)
907     FORMAT(/F5.3, 7F6.3)
908     FORMAT(/2(9F8.1/), 5F8.1)
909     FORMAT(/2(10F7.2/), 3F7.2)
910     FORMAT(/2(10F6.1/), 3F6.1)
911     FORMAT(/3(7F8.3/), 2F8.3)
912       FORMAT(/3(7F6.2/), 2F6.2)
913     FORMAT(/3(7F8.5/), 2F8.5)
1051    FORMAT(//80('=')//10X,'PROGRAM TERMINATED')
```

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```
C
C
C
C
      FUNCTION DELAY(X,T,L,DT)
C     ------------------------
      REAL L
C
C  BEFORE CALLING 'DELAY' THE INITIAL CONDITIONS FOR 'L'
C  SHOULD BE ASSIGNED:  L=T*X.
C
C  HERE 'X' IS THE VARIABLE TO BE DELAYED,
C       'T' IS THE DELAY PARAMETER,
C       'L' IS THE LEVEL ACCUMULATED IN THE DELAY,
C       'DT' IS THE INTEGRATION STEP.
C
      DELAY=L/T
      L=L+DT*(X-DELAY)
      RETURN
      END
C
C
C
C
C
C
C=========================================================================
C
C
      FUNCTION  INDEX (I)
C     -------------------
C
      IF(I-1) 100,202,203
100    STOP 100
202   INDEX=1
      RETURN
203   IF(I-3) 204,204,205
204   INDEX=2
      RETURN
205   IF(I-4) 100,206,207
206   INDEX=3
      RETURN
207   IF(I-5) 100,208,209
208   INDEX=4
      RETURN
209   IF(I-21) 210,210,211
210   INDEX=5
      RETURN
211   IF(I-22) 100,212,213
212   INDEX=6
      RETURN
213   INDEX=7
      RETURN
      END
C
C
```

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```
C*****************************************************************************
C
      FUNCTION STBACK(I,IND,POP)
C     ------------------------
C
        REAL MALFR
      DIMENSION POP(1)
      COMMON/SERA/FEMFR,MALFR
C
C
      GO TO(1,2,3,4,5,6,2), IND
1     STBACK=1.
      RETURN
2     J=I-1
        STBACK=POP(J)
      RETURN
3     STBACK=FEMFR*POP(3)
      RETURN
4     STBACK=MALFR*POP(3)
      RETURN
5     J=I-2
      STBACK=POP(J)
      RETURN
6     STBACK=POP(20)+POP(21)
      RETURN
      END
C
C
C*****************************************************************************
C
       SUBROUTINE ADMIT(SCREP,SWL,HP,LS,RS,NDRD,ALSCR,TDRL,REAR,TDOC)
C      -----------------------------------------------------------------
       IMPLICIT REAL(A-Z)
       INTEGER J,I1,NS
       DIMENSION SWL(3),HP(23),LS(23,3),RS(23,3),NDRD(23,3),ALSCR(3),
&                REAR(23,3),TOPH(3)
       DIMENSION LSS(3),RSS(3),SDS(23,3),NDR(23,3),TDR(23,3),TDRS(3)
        DIMENSION OUT1(51,6),OUT2(51,6),OUT3(51,6)
        DIMENSION LSA(51),LSB(51),LSC(51),
&                 RSA(51),RSB(51),RSC(51),
&                 ADM(51,3),DEM(51,3),
&                 DDD(51),TOT(51)
        COMMON/SUMS/   HPS,LSSS,RSSS,LSS,RSS,DT,LEV(3),PRIORT(23)
        COMMON/PLOT/ OUT1,OUT2,OUT3,PNP,TM
        INTEGER TM
C
        EQUIVALENCE (LSA(1),OUT1(1,1)),
&               (LSB(1),OUT1(1,2)),
&               (LSC(1),OUT1(1,3)),
&               (RSA(1),OUT1(1,4)),
&               (RSB(1),OUT1(1,5)),
&               (RSC(1),OUT1(1,6)),
&               (ADM(1,1),OUT2(1,1)),
&               (ADM(1,2),OUT2(1,2)),
&               (ADM(1,3),OUT2(1,3)),
&               (DEM(1,1),OUT2(1,4)),
```

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```
&               (DEM(1,2),OUT2(1,5)),
&               (DEM(1,3),OUT2(1,6))
        EQUIVALENCE (OOO(1),OUT3(1,1)),
&               (TOT(1),OUT3(1,2))
C
C
C
        TM=TM+1
C
C
       HPS = 0.
       DO 399 I1=1,23
399       HPS = HPS+HP(I1)
C
C
       DO 400 J=1,3
          LSS(J)=0.
          RSS(J)=0.
          DO 400 I1=1,23
             LSS(J)=LSS(J)+LS(I1,J)
400          RSS(J)=RSS(J)+RS(I1,J)
C
C
       RSSS=0.
       LSSS=0.
       DO  401 J=1,3
           RSSS=RSSS+RSS(J)
401        LSSS=LSSS+LSS(J)
C
C
       Z=HPS+LSSS
        Z=SCREP/Z
C
C-----------------------------------------------------------------
C
        DO 500 J=1,3
        TORS(J)=0.
C
        DO 500 I1=1,23
        SDS(I1,J)=Z*ALSCR(J)*LS(I1,J)
        NDR(I1,J)=NDRD(I1,J)*LS(I1,J)
        TDR(I1,J)=NDR(I1,J)+SDS(I1,J)
500     TDRS(J)=TDRS(J)+TDR(I1,J)
C
C
        TDPHW=0.
        DO 300 J=1,3
        TDPH(J)=RSS(J)/SWL(J)
        TDPHW=TDPHW+TDPH(J)
300     CONTINUE
C
C
C
        DO 810 J=1,3
        PCTD=TDPH(J)/TDPHW*TOOC*SWL(J)
        ADMP=PCTD-RSS(J)
```

```
C
C
C
      IF(ADMP-0.) 450,450,460
C
450   DO 451 I1=1,23
451   REAR(I1,J)=0.
      GO TO 800
C
460   IF(ADMP-TDRS(J)) 470,480,480
C
470   DO 471 I1=1,23
      PRIORT(I1)=TDR(I1,J)/TDRS(J)
471   REAR(I1,J)=ADMP*PRIORT(I1)
      GO TO 800
C
C
480   DO 481 I1=1,23
481   REAR(I1,J)=TDR(I1,J)
800   CONTINUE
      DEM(TM,J)=TDRS(J)
      ADM(TM,J)=0.
      DO 812 I1=1,23
812   ADM(TM,J)=ADM(TM,J)+REAR(I1,J)
810   CONTINUE
C
      LSA(TM)=LSS(1)
      LSB(TM)=LSS(2)
      LSC(TM)=LSS(3)
      RSA(TM)=RSS(1)
      RSB(TM)=RSS(2)
      RSC(TM)=RSS(3)
      ODO(TM)=HPS
      TOT(TM)=HPS+LSSS+RSSS
      RETURN
      END
```