CSMP III

A Beginner's Guide

Michael K. Stenstrom

Civil Engineering Department

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I. INTRODUCTION

"Continuous Systems" is a term used by many people without really understanding what it means. There is a relatively precise mathematical definition of the word continuous as applied to mathematical functions. The definition can be found in almost any college freshman math text, but an intuitive idea of continuous functions can be based upon the notion of "smoothness." Continuous, differentiable functions are "smooth" at all points in their domain. They possess no sharp breaks, nor do they have points where they tend to infinity. In short, this says that they have slopes everywhere; that is to say, a tangent line can be drawn to the function everywhere. For certain special functions that are continuous, but not differential, the slopes at the "break points" are defined by definition. Furthermore, the slope of the tangent line is a physical representation of the derivative. This tangent line represents the rate of change of the function with respect to the independent variable. By our restriction to continuous functions, this slope cannot be infinite, i.e., no tangent line can be vertical. Figure 1 shows a continuous function with tangent line at a point in the domain. Continuous systems are described by the previously mentioned continuous functions and the slopes of the functions.

Systems described by the continuous function only are called zero-order systems and are usually rare in nature. An example of a zero-order system would be a surface rate controlled reaction. Systems described by both the continuous function and the slope of the function are called first-order systems. Many chemical reactions are of this type. Systems described by the continuous function, the slope of the continuous function, and the slope of the slope of the continuous function are second-order systems. An automobile suspension is a second-order system. It should be obvious at this point that the order of the system is the same as the order of the derivatives or slopes. It may seem that solution of these types of problems is difficult, since the slope of the functions must be calculated before the calculation of the function. In reality, solutions of most of these types of problems are very easy, once the tools of solution are learned.

Generally speaking there are three methods of solution of these continuous systems or sets of differential equations:

1. Analytical Methods

2. Analog Methods

3. Numerical Methods

For the sake of illustration, consider a simple example. A first-order reaction in a batch reactor can be described by the following mass balance:

Accumulation = In - Out + Reaction

$$V \frac{dC}{dt} = 0 - 0 - KCV \quad (1)$$

where

V	=	volume of reactor (1^3),
C	=	concentration at any time ($m/1^3$),
K	=	reaction rate constant ($time^{-1}$),
$\frac{dC}{dt}$	=	first derivative of concentration with respect to time (m/l^3 time).

Simplifying

$$\frac{dC}{dt} = -KC \quad (2)$$

This equation states that the slope of concentration function is equal to -K times the value of the concentration. This differential equation can very easily be solved by any of the three methods described earlier. For this simple equation, an analytical solution is convenient. By separation of variables one obtains:

$$\frac{dC}{C} = -Kdt \tag{3}$$

Integrating

$$\ln C = -Kt + ln(Co) \tag{4}$$

where ln(Co) is some arbitrary constant which accounts for the initial conditions. By transposing and recalling that subtracting logs is the same as dividing by their antilogs, one obtains:

$$\ln \frac{C}{Co} = -Kt \tag{5}$$

Taking the exponential of both sides

$$\frac{C}{Co} = e^{-Kt} \tag{6}$$

$$C = Coe^{-Kt} \tag{7}$$

The arbitrary constant Co is the initial value of C at t = 0. This completes the analytical solution.

The third technique and the subject of this paper is the use of numerical techniques. The heart of any numerical technique is the integration method, which is simply an additional equation which approximates the derivative. Recalling equation (2), it can be seen that there are two unknowns, dC/dt and C. The integration method is the second equation which is necessary for solution. A convenient method of obtaining this second equation is by use of a Taylor series. The simplest method of integration is Euler or rectangular integration as described by equation 8.

$$\frac{dC}{dt} = \frac{C_{t+\Delta t} - C_t}{\Delta t} \tag{8}$$

where

C_t	=	Concentration at time t
$C_{t+\Delta t}$	=	Concentration at time t + Δt
Δt	=	time increment or integration interval

By simultaneously solving equations 2 and 8 one obtains:

$$-KC_t = \frac{C_t + \Delta t - C_t}{\Delta T} \tag{9}$$

$$-\Delta t K C_t = C_{t+\Delta t} - C_t \tag{10}$$

$$C_{t+\Delta t} = C_t \ - \Delta t K C_t \tag{11}$$

This equation must be solved for each time step. To illustrate the method and accuracy, the result of a few time steps are tabulated here.

Table 1

C_t	t	Exact
0.9500	0.05	0.9512
0.9025	0.10	0.9048
0.8574	0.15	0.8607
0.8145	0.20	0.8187
0.7738	0.25	0.7788
0.7351	0.30	0.7408

where

Δt = 0.05

K = 1.0

C_t = 1.0 at t = 0

The accuracy of solution depends upon the time step, Δt, For example, if Δt were chosen to be 0.2, as in Table 2, instead of 0.05, fewer time steps would be required to reach a certain value of time, but accuracy would be sacrificed. The user of numerical methods always has the task of deciding how much accuracy is required and, therefore, what size integration step to use. The problem becomes even more complicated when the selection of an integration method is also made.

Table 2

C_t	t	Exact
1.0	0.0	1.0
0.80	0.20	0.8187
0.64	0.40	0.670
0.512	0.6	0.5488
0.4186	0.8	0.4493
0.3349	1.0	0.3678

CSMP III (Continuous System Modeling Program) is a computer program which is specifically designed to solve differential equations with a minimum of effort on the part of the user. The user need not know fancy numerical methods, nor must he know detailed computer programming. CSMP III represents the most recent phase in the evolution of digital programs for solution of differential equations. It is the most advanced simulation language program in widespread use today. Figure 3 shows the evolution of continuous system simulation languages (CSSL). CSMP/360 is only slightly different from CSMP III and most of the descriptions here will also apply to CSMP/360.

II. BASIC STRUCTURE

CSMP III is composed of three basic segments. The segments are divided as to function, type, and time of execution. Some segments in CSMP III are called procedural and others are called parallel. A procedural segment is executed sequentially; the statements are executed in the order of appearance. A parallel segment is sorted by a phase of the CSMP III program into the proper sequence of execution. The following coding will best illustrate the differences in parallel and procedural sections.

B = A/2.

A = 10.0

C = 2.*A

If the section were procedural the results would be

A = 10.

B = ? (unidentified since A was undefined when B was calculated)

C = 20.

If the section were a parallel section, the sequence of statements would be rearranged by a section of the CSMP III program to the following

A = 10.0		A = 10.0
B = A/2.	or	C = 2.*A
C = 2.*A		B = A/2.

The results would be:

A = 10.

B = 5.

C = 20.

As mentioned previously there are three basic segments of the CSMP III structure. They are INITIAL, DYNAMIC, and TERMINAL. The INITIAL segment is a parallel segment which is executed at the beginning of the simulation. The TERMINAL section is a procedural section which is executed at the end of the simulation. The DYNAMIC section is the heart of the program where integration takes place. At this point an example will best illustrate the three CSMP III program sections.

Consider a CSTR Reactor with the first-order reaction described previously. From the following mass balance, the differential equation which describes the reactor can be developed.

Accumulation = In - Out + Reaction

$$V \frac{dC}{dt} = Q\ Co - Q\ C - K\ C\ V \tag{12}$$

$$\frac{dC}{dt} = (Q\ Co - Q\ C)/V - K\ C \tag{13}$$

or

$$\frac{dC}{dt} = \frac{(Co - C)}{\Theta} - K\ C \tag{14}$$

where

F = Flow into reactor ($1^3/t$)

V = Volume of reactor (1^3)

```
*       0 = ZERO , O = "OH"
* CSMP III EXAMPLE PROGRAM 1
* SIMPLE CSTR REACTION WITH FIRST ORDER REACTION
*
INITIAL
    PARAM V=10.,Q=2.0,K=1.0,CO=1.0,ICC=0.
    THETA=Q/F
DYNAMIC
    DCDT=(C=(CO-C)/THETA -K*C
    C=INTGRL(ICC,DCDT)
```

```
TERMINAL
*
TIMER FINTIM=15.0,PRDEL=0.5,OUTDEL=0.5,DELT=0.05
METHOD RECT
*
*
PRINT C,DCDT
OUTPUT C
END
STOP
ENDJOB
```

The preceding coding is all that is required to solve the differential equation. The asterisk (*) in column one denotes a comment card. The other cards with the exception of the "ENDJOB" card may begin in any column and must not continue past column 72. CSMP III coding is very nearly format free. The PARAM statement in the INITIAL section defines the values of variables used in the simulation. The PARAM statement performs a similar function to the FORTRAN DATA statement. All variables in CSMP are by default REAL*4 (floating point variables). Integer variables must be declared by the keyword FIXED.

Θ is only calculated once since it remains constant throughout the simulation. Consequently it is calculated in the INITIAL section. It would be wasteful to place the calculation of Θ in the DYNAMIC section since it would be done every time step. The two lines of coding in the DYNAMIC section are all that is required to define the differential equation. In general CSMP III requires that the highest derivative be solved and placed on the left. Each integration step must be defined by the INTGRL (X,Y) statement where X is the initial condition and Y is the quantity to be integrated with respect to the independent variable, which is usually TIME. The TIMER card is essential in every simulation. The word FINTIM must appear on the card. FINTIM is finish time. For this program the simulation will begin at TIME equal to 0 and will end at TIME equal to 15.0. PRDEL is the time interval for plotting out results. DELT is the integration time step. The user of CSMP III should specify all four of these time specifications except in the case where variable step integration methods are used; DELT need not be specified when variable steps are used. If OUTDEL or PRDEL is omitted a value of FINTIM/100 will be used by default by CSMP III. In all cases DELT, PRDEL, and OUTDEL must be a factor of FINTIM. If the user specifies some value which is not a factor of FINTIM, CSMP III round the value to be a factor of FINTIM. The PRINT statement specifies that variables C and DCDT will be printed every PRDEL. The PRINT statement can be used once during each simulation and can print a maximum of 55 variables. The OUTPUT statement is a very useful and flexible method of plotting or printing results. The options will be discussed later. The output statement can be used more than once in each simulation and can print or plot up to 55 variables for each statement. The METHOD card specifies that the method of integration will be simple Euler or rectangular. If the METHOD card is omitted, a variable step fourth order Runge-Kutta method will be used. The END, STOP, ENDJOB cards specify the end of the simulation. Reruns and changes in parameters can be made after each END statement. These options will be discussed later.

This completes the description of basic CSMP III structure.

III. CSMP III PROGRAM FEATURES

The IBM CSMP III manual describes the details of CSMP III programming. There is a tremendous amount of material in the manual which the beginning CSMP III programmer need not be familiar with. Consequently, many beginners become frustrated with all the details of the manual. This section is designed to acquaint the beginner with some of the details of CSMP III. It is not intended to substitute for the CSMP III manual, but only to provide an introduction to CSMP III. Statements which the beginning user should know are listed alphabetically and briefly described.

CONST, INCON, PARAM

PARAM, CONST, INCON are used to assign values to variable names. They are similar in nature to the FORTRAN DATA statement. The PARAM, CONST, and INCON statements are identical; only their names are different. An example of a parameter statement is

```
PARAM  A=1.0,B=23.,C=1.5E+06
```

The PARAM statement can also be used for multiple specifications. For example, if a user were searching for a value of "K" which best fits some objective function, he could use the following PARAM statement to investigate several values of "K".

```
PARAM  K= (0.1,0.3,4*0.2)
```

The above statement would result in six simulations for K = 0.1, 0.3, 0.5, 0.7, 0.9, 1.1. Only one multiple PARAM statement can be used per simulation. Initialization by PARAM statements is done before any other statements are executed. For example, if the following coding were in the INITIAL section of a CSMP III program, the value of B in the subsequent sections of the program would be

10., not 5.

```
   PARAM B=5.0
     B=10.
```

This brings us to another point; PARAM statements are executed only once. If a variable which is initialized by a PARAM statement is changed anywhere else in the CSMP III program, it will never be reset back to its initial value by the original PARAM statement. If a variable is initialized by a FORTRAN "equals" statement as in the previous example with "B = 10.", it will be reset to its initial value each time the statement is encountered.

DEBUG

CSMP III has a very useful debugging facility. If a user wishes to know the value of a certain variable at a certain time, he may use the CALL DEBUG (X, Y) statement. If CALL DEBUG is used, all the variables used in a simulation will be printed beginning at TIME = Y and will be printed for the next X time steps. It is very convenient to use the CALL DEBUG statement at the beginning of every simulation to check all initial conditions and values. For example, the coding

```
   NOSORT
     CALL DEBUG(1,0.0)
   TERMINAL
```

will result in all variables being printed out once at the beginning of a simulation. Also note that the CALL DEBUG statement must be placed in a PROCEDURAL (NOSORT) section of the program. The DEBUG statement may be used more than once. Other DEBUG options are described in the CSMP III manual.

END

The END statement signifies the end of a simulation, but not necessarily the end of the program. If one wishes to rerun with a different set of initial conditions, print variables, etc., additional PARAM cards, TIMER card, PRINT card, etc. may be inserted after the END card. For example, the following coding will result in a rerun of the original program with A = 1.0.

```
        .
        .
        .
  (CSMP III PROGRAM)
        .
        .
        .
        .
END
PARAM A=1.0
END
STOP
ENDJOB
```

Program structure cannot be changed after the END card.

FINISH

In many cases a user will want to terminate a run after a certain event has occurred, and not necessarily at some value of time. For example, the following coding in a CSMP III program would cause the simulation to end if S became equal to 12.

```
FINISH S=12.0
```

FIXED

All variables in CSMP III are, by default real, floating point variables. If an integer variable is required, it must be declared by the FIXED statement. For example, if a DO loop were used somewhere in CSMP III, it would require an integer counter. If this counter were the variable "A", it could be declared by the following coding.

```
FIXED A
```

FUNCTION BLOCKS

There are a great number of functions and types of functions in CSMP III. Most FORTRAN functions are available to CSMP III programmers, in addition to a large library of special, CSMP III functions. Many CSMP III functions are memory functions; they require not only information at the present value of time, but also at previous values of time. INTGRL and DERIV are examples of memory functions. There are many logic functions in CSMP III such as AND, OR, and others. Also there are periodic functions such as SINE (not to be confused with the FORTRAN SIN). The CSMP III function descriptions and their equivalent mathematical expressions can be found in the CSMP III manual. FORTRAN function descriptions can be found in almost any FORTRAN manual. Functions and subroutines in the IBM scientific subroutine package can also be used in CSMP III. *User supplied functions and subroutines can be inserted in the card deck between the STOP and ENDJOB cards.*

FUNCTION - AFGEN-NLFGEN

In many cases a user would like to use irregularly shaped functions somewhere in a CSMP III simulation. It is usually not very convenient to construct some mathematical correlation or expression which fits the irregular shape. To avoid this inconvenience CSMP III has built-in function generators which need only have the X and Y coordinate pairs specified. This feature is very flexible and allows the user to perform many otherwise difficult tasks. For example, CSMP III can be used to plot experimental data or to smooth experimental data.

Suppose a user wanted to code the following tabulated function:

Table 3

Velocity	Drag
0.0	0.0
0.1	2.5
0.2	6.4
0.3	12.5
0.5	26.4

This function would be coded as follows:

```
FUNCTION DRAG = 0.0,0.1,2.5,0.2,...
 6.4,0.3,12.5,0.5,26.4
```

The data is entered in X - Y pairs and must be entered in increasing value of X. The three consecutive periods indicate that the data is continued on the next card. DRAG is a unique name assigned to each function. To use this function in CSMP III it must be placed into a function generator. There are two types of function generators in CSMP III. The first type is an arbitrary function generator (AFGEN) which creates the function by linear interpolation between data points. The second type is a nonlinear function generator (NLFGEN) which uses parabolic interpolation among data points. The user must choose which function generator to use. The nonlinear function generator is usually the method of choice except where sharp breaks are encountered in the function. The nonlinear generator should not be used for such functions since parabolic interpolation cannot "bend" around sharp corners. The following coding shows how the NLFGEN and AFGEN statements are used.

```
FORCE1=AFGEN(DRAG,VEL)
*
FORCE2=NLFGEN(DRAG,VEL)
```

FORCE1 and FORCE2 must be unique names. VEL is the independent variable which must be calculated somewhere in the CSMP III program. TIME can also be used as an independent variable. The independent variable must not exceed the limits of the function; for this case VEL should never be larger than 0.6 or smaller than 0.0. If the independent variable is out of the function's domain, the highest (or lowest) value of the domains will be used to calculate the dependent variable. Also a warning message will be printed. FORCE1 and FORCE2 are now legitimate CSMP III functions which may be plotted, integrated, differentiated, or used in any manner that other CSMP III functions are used. There is also a function generator available for functions of two independent variables.

LABEL

The LABEL statement allows the user to print a heading at the top of each page of printed or plotted material resulting from an OUTPUT statement. LABEL statements which are placed before the first OUTPUT statement will refer to all subsequent OUTPUT statements. LABEL statements placed after an OUTPUT statement refer to it. LABEL statements may have one continuation card to give a total width of 120 characters. Each OUTPUT statement may have up to five LABEL statements. The following is an example of a LABEL statement.

LABEL CONCENTRATION VS. TIME

METHOD

The METHOD statement allows the user to specify the method of integration that CSMP III will use. The type of problem will determine which method is most efficient.

The following table summarizes the integration methods available in CSMP III.

Table 4

METHOD	CSMP III NAMER	ORDER OF CORRECTNESS	TYPE
Rectangular or Simple Euler	RECT	1	Fixed Step
Adams	ADAMS	2	Fixed Step
Trapezoidal or Modified Euler	TRAP	2	Fixed Step
Simpson's Rule	SIMP	2	Fixed Step
Runge-Kutta	RKSFX	4	Fixed Step
Runge-Kutta Double Precision	RKSDP	4	Fixed Step
Milne Predictor Corrector Method	MILNE	4	Variable Step
Runge-Kutta	RKS	4	Variable Step
Method Specifically designed for "stiff" sets of differential equations	STIFF	2	Variable Step

If no method card is inserted, the Runge-Kutta variable step method will be used. This method in almost all cases will assure satisfactory solution. It is generally the best method for initial selection. The variable step method also has the advantage in some equilibrium type problems. A small time step is used at the beginning of the problem and as equilibrium is reached and the magnitude of the derivative becomes smaller, the time step is increased. The maximum time step that can be used is the PRDEL or OUTDEL increment, whichever is smaller. The smallest time step is a value set inside CSMP III, called DELMIN. If the time step becomes smaller than DELMIN, the simulation will be terminated with the error message "DELT LESS THAN DELMIN". In this case, it will be necessary to specify a fixed step method. The value of DELMIN can also be specified on the TIMER card.

There are many trade-offs to consider when selecting an integration method. The methods which have a high order of correctness require more computations per time step but the time step can generally be made larger. Methods of low order of correctness take very little time per step, but require smaller steps.

Most of the problems in the Environmental Engineering courses can be integrated by variable step Runge-Kutta very efficiently. Simulations which use large amounts of logic and use the CSMP III functions STEP, IMPULS, PULSE, DELAY, PIPE, and other similar functions should be integrated by fixed step methods with DELT synchronized with the times of logic decisions and the times of forcings.

Large systems of equations can often be most efficiently integrated by rectangular integration. Most of the large research problems are in this category. The author recommends for simple problems that the variable step Runge-Kutta method be used as the initial method, unless the previously mentioned CSMP III functions are used in the simulation. If a fixed step method is required, the Modified Euler (TRAP) is recommended. For large systems of equations the stiff (STIFF) method and Rectangular (RECT).

OUTPUT

The OUTPUT statement is the most useful and flexible of the CSMP III print statements. The OUTPUT statement may be used more than once in a simulation and can print up to 55 variables per statement. If 1 to 5 variables are specified on the OUTPUT statement, the variables will be print-plotted. If 6 to 9 variables are specified, the results will be printed in columns. For 10 to 55 variables, the results will be printed in rows. The PAGEW statement can be used to modify the conventional output to provide shade, contour, or Calcomp plots. The options are discussed in the CSMP III manual.

It is important to note that all values in the OUTPUT statements are scaled or ranged before any printing or plotting occurs. Consequently all values must be stored until the completion of a simulation. If a particular simulation is stopped because of excessive CPU time, no output will be printed or plotted, and the user will have no information about the simulation. If the user is not sure how much time his simulation will require, he should always use the PRINT statement in addition to or instead of the OUTPUT statement.

PRINT

The PRINT statement will print up to 55 variables and prints them as they are calculated. The PRINT statement may be used only once; if more than one PRINT statement is used, all but the last statement will be ignored.

RESET

The RESET statement is used to nullify previous execution and control statements such as PRINT, FINISH, OUTPUT, PREPAR, and RANGE. For example, suppose that in the first run of a program a PRINT statement was used that is not needed in the second run. The second run could use a RESET statement as follows:

```
END
RESET PRINT
   (ETC)
```

STORAGE

In certain cases it is more desirable to work with arrays than ordinary, nonsubscripted variables. One dimensional arrays can be dimensional with the storage statement such as the one that follows:

```
STORAGE A(10),B(5)
```

SORT, NOSORT

These two cards should be used in pairs to indicate sections of the program which are procedural rather than parallel. The user can declare that a block of statements is a procedural block. For example, the following coding shows how SORT-NOSORT statements are used.

```
DYNAMIC
  .      (PARALLEL SECTION ONE)
  .
  .
  .
  .
NOSORT
     IF(TIME.GE.TCOUNT) GO TO 20
     GO TO 40
  20 TCOUNT=TCOUNT+DEL
     WRITE(3,30) VEL,TIME
  30  FORMAT(1X,2(F10.2,5X))
```

```
 40 CONTINUE
SORT
  .
  .
  .
  .
  .
  .    (PARALLEL SECTION TWO)
TERMINAL
```

It is important to realize that the inclusion of this SORT-NOSORT section creates two parallel sections which are independently sorted.

TABLE

The TABLE statement is used in the exact same way that the PARAM statement is used except that the TABLE statement is used for subscripted variables. Example:

```
STORAGE A(3)
TABLE A(1)=1.0,A(2)=2.0,A(3)=3.0
```

TITLE

The TITLE statement is similar to the LABEL statement except that TITLE refers to PRINT statements.

IV. BIBLIOGRAPHY

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V. APPENDIX. ADDITIONAL EXAMPLE PROBLEMS

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M3   TRANSLATOR OUTPUT$$$

*   CSMP III EXAMPLE PROBLEM 2
*   CSTR TRACER SIMULATION
*   IMPULSE,PULSE, AND STEP INPUTS
*   IMPULSE FORCING FIRST
INITIAL
PARAM CO=10.,ICC=10.,V=10.,F=2.0,FLAG=-1.0,X1=0.
      THETA= V/F
DYNAMIC
*   INPUT SELECTION
      X2=STEP(0.0)
      Z1=IMPULS(1.,20.)
      X3=PULSE(5.0,Z1)
      CIN=CO*FCNSW(FLAG,X1,X2,X3)
*   MASS BALANCE
      CDOT=(CIN-C)/THETA
      C=INTGRL(ICC,CDOT)
TERMINAL
TIMER FINTIM=15.,PRDEL=0.25,OUTDEL=0.25
PRINT C,CDOT,CIN
OUTPUT TIME,C,CIN
PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
LABEL  C,CIN VS. TIME  (IMPULSE INPUT)
END
*   STEP FORCING  NEXT
PARAM FLAG=0.,ICC=0.
OUTPUT TIME,C,CIN
PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
LABEL C,CIN  VS. TIME  (STEP INPUT)
END
*   PULSE FORCING NEXT
PARAM FLAG=1.0
OUTPUT TIME,C,CIN
PAGE XYPLOT,C,CIN
LABEL C,CIN VS. TIME  (PULSE INPUT)
END
STOP

OUTPUT VARIABLE SEQUENCE
THETA  X2     Z1     X3     CIN    CDOT   C
```

$$$ TRANSLATION TABLE CONTENTS $$$	CURRENT	MAXIMUM
MACRO AND STATEMENT OUTPUTS	13	600
STATEMENT INPUT WORK AREA	45	1900
INTEGRATORS+MEMORY BLOCK OUTPUTS	1 + 0	300
PARAMETERS+FUNCTION GENERATORS	9 + 0	400
STORAGE VARIABLES+INTEGRATOR ARRAYS	0 + 0/2	50
HISTORY AND MEMORY BLOCK NAMES	21	50
MACRO DEFINITIONS AND NESTED MACROS	6	50
MACRO STATEMENT STORAGE	13	125
LITERAL CONSTANT STORAGE	0	100
SORT SECTIONS	2	20
MAXIMUM STATEMENTS IN SECTION	6	600

```
$$$ CONTINUOUS SYSTEM MODELING PROGRAM III   V1M3    EXECUTION OUTPUT $$$

 PARAM CO=10.,ICC=10.,V=10.,F=2.0,FLAG=-1.0,X1=0.
 TIMER FINTIM=15.,PRDEL=0.25,OUTDEL=0.25
 PRINT C,CDOT,CIN
 OUTPUT TIME,C,CIN
 PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
 LABEL  C,CIN VS. TIME  (IMPULSE INPUT)
 END

TIMER VARIABLES      RKS      INTEGRATION       START TIME  =  .0
   DELT          DELMIN       FINTIM        PRDEL         OUTDEL        DELMAX
  1.5625D-02  1.5000D-06   15.000        .25000        .25000        .25000
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	C	CDOT	CIN
.0	10.000	-2.0000	.0
.250000	9.5123	-1.9025	.0
.500000	9.0484	-1.8097	.0
.750000	8.6071	-1.7214	.0
1.00000	8.1873	-1.6375	.0
1.25000	7.7880	-1.5576	.0
1.50000	7.4082	-1.4816	.0
1.75000	7.0469	-1.4094	.0
2.00000	6.7032	-1.3406	.0
2.25000	6.3763	-1.2753	.0
2.50000	6.0653	-1.2131	.0
2.75000	5.7695	-1.1539	.0
3.00000	5.4881	-1.0976	.0
3.25000	5.2205	-1.0441	.0
3.50000	4.9658	-.99317	.0
3.75000	4.7237	-.94473	.0
4.00000	4.4933	-.89866	.0
4.25000	4.2741	-.85483	.0
4.50000	4.0657	-.81314	.0
4.75000	3.8674	-.77348	.0
5.00000	3.6788	-.73576	.0
5.25000	3.4994	-.69987	.0
5.50000	3.3287	-.66574	.0
5.75000	3.1664	-.63327	.0
6.00000	3.0119	-.60239	.0
6.25000	2.8650	-.57301	.0
6.50000	2.7253	-.54506	.0
6.75000	2.5924	-.51848	.0
7.00000	2.4660	-.49319	.0
7.25000	2.3457	-.46914	.0
7.50000	2.2313	-.44626	.0
7.75000	2.1225	-.42449	.0
8.00000	2.0190	-.40379	.0
8.25000	1.9205	-.38410	.0
8.50000	1.8268	-.36536	.0
8.75000	1.7377	-.34755	.0
9.00000	1.6530	-.33060	.0
9.25000	1.5724	-.31447	.0
9.50000	1.4957	-.29913	.0
9.75000	1.4227	-.28455	.0
10.0000	1.3533	-.27067	.0
10.2500	1.2873	-.25747	.0
10.5000	1.2245	-.24491	.0
10.7500	1.1648	-.23297	.0
11.0000	1.1080	-.22160	.0
11.2500	1.0540	-.21080	.0
11.5000	1.0026	-.20051	.0
11.7500	.95368	-.19074	.0
12.0000	.90717	-.18143	.0
12.2500	.86292	-.17258	.0
12.5000	.82084	-.16417	.0
12.7500	.78080	-.15616	.0
13.0000	.74272	-.14854	.0
13.2500	.70650	-.14130	.0
13.5000	.67204	-.13441	.0
13.7500	.63927	-.12785	.0
14.0000	.60809	-.12162	.0

```
$$$ CONTINUOUS SYSTEM MODELING PROGRAM III   V1M3    EXECUTION OUTPUT $$$

 PARAM FLAG=0.,ICC=0.
 OUTPUT TIME,C,CIN
 PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
 LABEL C,CIN  VS. TIME  (STEP INPUT)
 END

TIMER VARIABLES       RKS      INTEGRATION        START TIME  =  .0
   DELT          DELMIN        FINTIM       PRDEL          OUTDEL         DELMAX
  1.5625D-02  1.5000D-06   15.000        .25000         .25000         .25000
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	C	CDOT	CIN
.0	.0	2.0000	10.000
.250000	.48771	1.9025	10.000
.500000	.95163	1.8097	10.000
.750000	1.3929	1.7214	10.000
1.00000	1.8127	1.6375	10.000
1.25000	2.2120	1.5576	10.000
1.50000	2.5918	1.4816	10.000
1.75000	2.9531	1.4094	10.000
2.00000	3.2968	1.3406	10.000
2.25000	3.6237	1.2753	10.000
2.50000	3.9347	1.2131	10.000
2.75000	4.2305	1.1539	10.000
3.00000	4.5119	1.0976	10.000
3.25000	4.7795	1.0441	10.000
3.50000	5.0341	.99317	10.000
3.75000	5.2763	.94473	10.000
4.00000	5.5067	.89866	10.000
4.25000	5.7258	.85483	10.000
4.50000	5.9343	.81314	10.000
4.75000	6.1326	.77348	10.000
5.00000	6.3212	.73576	10.000
5.25000	6.5006	.69988	10.000
5.50000	6.6713	.66574	10.000
5.75000	6.8336	.63328	10.000
6.00000	6.9880	.60239	10.000
6.25000	7.1349	.57301	10.000
6.50000	7.2747	.54507	10.000
6.75000	7.4076	.51848	10.000
7.00000	7.5340	.49320	10.000
7.25000	7.6543	.46914	10.000
7.50000	7.7687	.44626	10.000
7.75000	7.8775	.42450	10.000
8.00000	7.9810	.40380	10.000
8.25000	8.0795	.38410	10.000
8.50000	8.1732	.36537	10.000
8.75000	8.2622	.34755	10.000
9.00000	8.3470	.33060	10.000
9.25000	8.4276	.31448	10.000
9.50000	8.5043	.29914	10.000
9.75000	8.5772	.28455	10.000
10.0000	8.6466	.27067	10.000
10.2500	8.7126	.25747	10.000
10.5000	8.7754	.24492	10.000
10.7500	8.8351	.23297	10.000
11.0000	8.8920	.22161	10.000
11.2500	8.9460	.21080	10.000
11.5000	8.9974	.20052	10.000
11.7500	9.0463	.19074	10.000
12.0000	9.0928	.18144	10.000
12.2500	9.1370	.17259	10.000
12.5000	9.1791	.16417	10.000
12.7500	9.2192	.15617	10.000
13.0000	9.2572	.14855	10.000
13.2500	9.2935	.14131	10.000
13.5000	9.3279	.13441	10.000
13.7500	9.3607	.12786	10.000
14.0000	9.3919	.12162	10.000

```
$$$ CONTINUOUS SYSTEM MODELING PROGRAM III   V1M3    EXECUTION OUTPUT $$$

 PARAM FLAG=1.0
 OUTPUT TIME,C,CIN
 PAGE XYPLOT,C,CIN
 LABEL C,CIN VS. TIME  (PULSE INPUT)
 END

TIMER VARIABLES      RKS      INTEGRATION      START TIME  =  .0
   DELT         DELMIN       FINTIM      PRDEL       OUTDEL       DELMAX
  1.5625D-02  1.5000D-06  15.000      .25000       .25000       .25000
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	C	CDOT	CIN
.0	.0	.0	.0
.250000	.0	.0	.0
.500000	.0	.0	.0
.750000	.0	.0	.0
1.00000	.0	2.0000	10.000
1.25000	.48771	1.9025	10.000
1.50000	.95163	1.8097	10.000
1.75000	1.3929	1.7214	10.000
2.00000	1.8127	1.6375	10.000
2.25000	2.2120	1.5576	10.000
2.50000	2.5918	1.4816	10.000
2.75000	2.9531	1.4094	10.000
3.00000	3.2968	1.3406	10.000
3.25000	3.6237	1.2753	10.000
3.50000	3.9347	1.2131	10.000
3.75000	4.2305	1.1539	10.000
4.00000	4.5119	1.0976	10.000
4.25000	4.7795	1.0441	10.000
4.50000	5.0341	.99317	10.000
4.75000	5.2763	.94473	10.000
5.00000	5.5067	.89866	10.000
5.25000	5.7258	.85483	10.000
5.50000	5.9343	.81314	10.000
5.75000	6.1326	.77348	10.000
6.00000	6.3212	.73576	10.000
6.25000	6.0135	-1.2027	.0
6.50000	5.7202	-1.1440	.0
6.75000	5.4413	-1.0883	.0
7.00000	5.1759	-1.0352	.0
7.25000	4.9234	-.98469	.0
7.50000	4.6833	-.93667	.0
7.75000	4.4549	-.89098	.0
8.00000	4.2376	-.84753	.0
8.25000	4.0310	-.80620	.0
8.50000	3.8344	-.76688	.0
8.75000	3.6474	-.72948	.0
9.00000	3.4695	-.69390	.0
9.25000	3.3003	-.66006	.0
9.50000	3.1393	-.62786	.0
9.75000	2.9862	-.59724	.0
10.0000	2.8406	-.56812	.0
10.2500	2.7020	-.54041	.0
10.5000	2.5703	-.51405	.0
10.7500	2.4449	-.48898	.0
11.0000	2.3257	-.46513	.0
11.2500	2.2122	-.44245	.0
11.5000	2.1043	-.42087	.0
11.7500	2.0017	-.40034	.0
12.0000	1.9041	-.38082	.0
12.2500	1.8112	-.36224	.0
12.5000	1.7229	-.34458	.0
12.7500	1.6389	-.32777	.0
13.0000	1.5589	-.31179	.0
13.2500	1.4829	-.29658	.0
13.5000	1.4106	-.28212	.0
13.7500	1.3418	-.26836	.0
14.0000	1.2763	-.25527	.0

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III    V1M3    TRANSLATOR OUTPUT$$$

 *   CSMP III EXAMPLE PROBLEM 3
 *   CSTR WITH VARIABLE  FLOWS
 INITIAL
 PARAM CO=10.,ICC=0.,V=10.
 DYNAMIC
      F= 1.5 +0.5*SINE(0.0,6.28/24.,0.0)
      CDOT= F*(CO-C)/V
      C=INTGRL(ICC,CDOT)
 TERMINAL
 PRINT F,CDOT,C
 TIMER FINTIM=24.,PRDEL=0.5,OUTDEL=0.5
 END
 STOP

OUTPUT VARIABLE SEQUENCE
F      CDOT   C

 $$$ TRANSLATION TABLE CONTENTS $$$        CURRENT           MAXIMUM

   MACRO AND STATEMENT OUTPUTS               9                 600
   STATEMENT INPUT WORK AREA                37                1900
   INTEGRATORS+MEMORY BLOCK OUTPUTS          1 +  0            300
   PARAMETERS+FUNCTION GENERATORS            6 +  0            400
   STORAGE VARIABLES+INTEGRATOR ARRAYS       0 +  0/2           50
   HISTORY AND MEMORY BLOCK NAMES           21                  50
   MACRO DEFINITIONS AND NESTED MACROS       6                  50
   MACRO STATEMENT STORAGE                  13                 125
   LITERAL CONSTANT STORAGE                  0                 100
   SORT SECTIONS                             1                  20
   MAXIMUM STATEMENTS IN SECTION             3                 600


$$$END OF TRANSLATOR OUTPUT$$$
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	F	CDOT	C
.0	1.5000	1.5000	.0
.500000	1.5652	1.4498	.73770
1.00000	1.6293	1.3933	1.4487
1.50000	1.6912	1.3310	2.1300
2.00000	1.7499	1.2636	2.7789
2.50000	1.8042	1.1921	3.3929
3.00000	1.8534	1.1175	3.9704
3.50000	1.8965	1.0412	4.5102
4.00000	1.9329	.96421	5.0115
4.50000	1.9618	.88783	5.4745
5.00000	1.9829	.81306	5.8996
5.50000	1.9957	.74080	6.2880
6.00000	2.0000	.67181	6.6410
6.50000	1.9958	.60664	6.9604
7.00000	1.9831	.54569	7.2483
7.50000	1.9621	.48919	7.5068
8.00000	1.9333	.43726	7.7382
8.50000	1.8970	.38987	7.9448
9.00000	1.8540	.34691	8.1289
9.50000	1.8049	.30819	8.2925
10.0000	1.7506	.27349	8.4377
10.5000	1.6920	.24253	8.5666
11.0000	1.6301	.21504	8.6808
11.5000	1.5660	.19072	8.7821
12.0000	1.5008	.16929	8.8720
12.5000	1.4356	.15047	8.9519
13.0000	1.3714	.13400	9.0229
13.5000	1.3095	.11966	9.0862
14.0000	1.2508	.10721	9.1429
14.5000	1.1964	9.6464E-02	9.1937
15.0000	1.1472	8.7233E-02	9.2396
15.5000	1.1039	7.9356E-02	9.2812
16.0000	1.0675	7.2685E-02	9.3191
16.5000	1.0385	6.7084E-02	9.3540
17.0000	1.0173	6.2427E-02	9.3864
17.5000	1.0044	5.8600E-02	9.4166
18.0000	1.0000	5.5492E-02	9.4451
18.5000	1.0041	5.3000E-02	9.4722
19.0000	1.0167	5.1022E-02	9.4982
19.5000	1.0376	4.9464E-02	9.5233
20.0000	1.0663	4.8232E-02	9.5477
20.5000	1.1025	4.7238E-02	9.5715
21.0000	1.1455	4.6398E-02	9.5949
21.5000	1.1945	4.5636E-02	9.6179
22.0000	1.2487	4.4882E-02	9.6406
22.5000	1.3073	4.4079E-02	9.6628
23.0000	1.3691	4.3177E-02	9.6846
23.5000	1.4332	4.2140E-02	9.7060
24.0000	1.4984	4.0944E-02	9.7267

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M3   TRANSLATOR OUTPUT$$$

*   CSMP III EXAMPLE PROBLEM 4
*   FIVE CSTR'S IN SERIES WITHOUT USING  A
*    PROCEDURE SECTION
INITIAL
     PARAM VTOTAL=10.,F=2.0,C0=10.
*   DIVIDE TO OBTAIN CORRECT VOLUMES
     V=VTOTAL/5.
     PARAM IC1=0.,IC2=0.,IC3=0.,IC4=0.,IC5=0.
     THETA=V/F
DYNAMIC
      C1DOT=(C0-C1)/THETA
      C1=INTGRL(IC1,C1DOT)
      C2DOT=(C1-C2)/THETA
      C2=INTGRL(IC2,C2DOT)
      C3DOT=(C2-C3)/THETA
      C3=INTGRL(IC3,C3DOT)
      C4DOT=(C3-C4)/THETA
      C4=INTGRL(IC4,C4DOT)
      C5DOT=(C4-C5)/THETA
      C5=INTGRL(IC5,C5DOT)
TERMINAL
TIMER FINTIM=15.0,OUTDEL=0.25,PRDEL=0.25
PRINT C1,C1DOT,C2,C2DOT,C3,C3DOT,C4,C4DOT,...
      C5,C5DOT
OUTPUT C1,C2,C3,C4,C5
PAGE GROUP
END
STOP

OUTPUT VARIABLE SEQUENCE
V      THETA  C1DOT  C1     C2DOT  C2     C3DOT  C3     C4DOT  C4
C5DOT  C5

 $$$ TRANSLATION TABLE CONTENTS $$$        CURRENT          MAXIMUM

   MACRO AND STATEMENT OUTPUTS              18                 600
   STATEMENT INPUT WORK AREA                59                1900
   INTEGRATORS+MEMORY BLOCK OUTPUTS          5 +  0            300
   PARAMETERS+FUNCTION GENERATORS           11 +  0            400
   STORAGE VARIABLES+INTEGRATOR ARRAYS       0 +  0/2           50
   HISTORY AND MEMORY BLOCK NAMES           21                  50
   MACRO DEFINITIONS AND NESTED MACROS       6                  50
   MACRO STATEMENT STORAGE                  13                 125
   LITERAL CONSTANT STORAGE                  0                 100
   SORT SECTIONS                             2                  20
   MAXIMUM STATEMENTS IN SECTION            10                 600



$$$END OF TRANSLATOR OUTPUT$$$
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	.0	.25000	.50000	.75000	1.0000	1.2500	1.5000	1.7500	2.0000
C1	.0	2.2120	3.9347	5.2763	6.3212	7.1349	7.7687	8.2622	8.6466
C1DOT	10.000	7.7880	6.0653	4.7237	3.6788	2.8651	2.2313	1.7378	1.3534
C2	.0	.26499	.90205	1.7336	2.6424	3.5537	4.4218	5.2212	5.9399
C2DOT	.0	1.9470	3.0326	3.5427	3.6788	3.5813	3.3469	3.0410	2.7067
C3	.0	2.1614E-02	.14386	.40603	.80299	1.3153	1.9115	2.5603	3.2332
C3DOT	.0	.24338	.75819	1.3286	1.8394	2.2383	2.5102	2.6609	2.7067
C4	.0	1.3344E-03	1.7523E-02	7.2926E-02	.18988	.38269	.65642	1.0081	1.4288
C4DOT	.0	2.0279E-02	.12634	.33211	.61311	.93262	1.2551	1.5522	1.8045
C5	.0	6.6035E-05	1.7217E-03	1.0650E-02	3.6602E-02	9.1246E-02	.18576	.32902	.52653
C5DOT	.0	1.2684E-03	1.5801E-02	6.2277E-02	.15328	.29144	.47066	.67908	.90223

TIME	2.2500	2.5000	2.7500	3.0000	3.2500	3.5000	3.7500	4.0000	4.2500
C1	8.9460	9.1791	9.3607	9.5021	9.6123	9.6980	9.7648	9.8168	9.8574
C1DOT	1.0540	.82086	.63929	.49788	.38775	.30198	.23518	.18316	.14265
C2	6.5745	7.1270	7.6027	8.0085	8.3521	8.6411	8.8829	9.0842	9.2511
C2DOT	2.3715	2.0521	1.7580	1.4936	1.2602	1.0569	.88192	.73263	.60623
C3	3.9066	4.5619	5.1854	5.7681	6.3043	6.7915	7.2293	7.6190	7.9629
C3DOT	2.6679	2.5652	2.4173	2.2404	2.0478	1.8496	1.6536	1.4653	1.2882
C4	1.9057	2.4242	2.9696	3.5277	4.0859	4.6337	5.1623	5.6653	6.1379
C4DOT	2.0009	2.1376	2.2158	2.2404	2.2184	2.1579	2.0670	1.9537	1.8250
C5	.78014	1.0882	1.4462	1.8474	2.2835	2.7455	3.2245	3.7116	4.1988
C5DOT	1.1255	1.3360	1.5234	1.6803	1.8025	1.8881	1.9378	1.9537	1.9391

TIME	4.5000	4.7500	5.0000	5.2500	5.5000	5.7500	6.0000	6.2500	6.5000
C1	9.8889	9.9135	9.9326	9.9475	9.9591	9.9682	9.9752	9.9807	9.9850
C1DOT	.11110	8.6522E-02	6.7385E-02	5.2480E-02	4.0872E-02	3.1832E-02	2.4791E-02	1.9308E-02	1.5038E-02
C2	9.3890	9.5025	9.5957	9.6720	9.7344	9.7852	9.8265	9.8600	9.8872
C2DOT	.49991	.41096	.33690	.27650	.22478	.18301	.14873	.12066	9.7728E-02
C3	8.2642	8.5265	8.7535	8.9488	9.1162	9.2590	9.3803	9.4830	9.5696
C3DOT	1.1248	.97602	.84224	.72317	.61813	.52616	.44618	.37704	.31761
C4	6.5770	6.9811	7.3497	7.6833	7.9830	8.2505	8.4879	8.6975	8.8815
C4DOT	1.6872	1.5454	1.4037	1.2656	1.1332	1.0085	.89235	.78551	.68814
C5	4.6789	5.1460	5.5951	6.0222	6.4248	6.8009	7.1494	7.4701	7.7633
C5DOT	1.8981	1.8351	1.7547	1.6610	1.5582	1.4497	1.3385	1.2274	1.1182

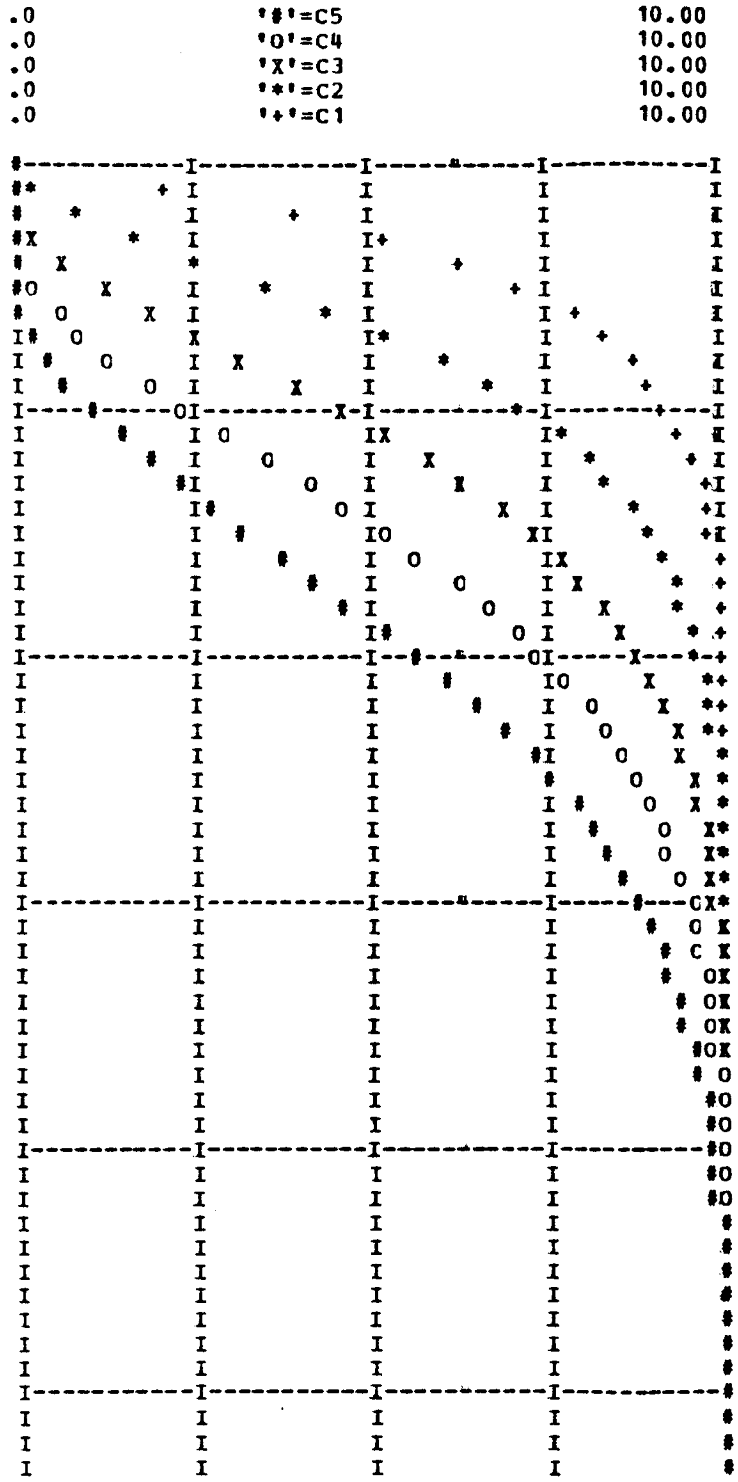
TIME	6.7500	7.0000	7.2500	7.5000	7.7500	8.0000	8.2500	8.5000	8.7500
C1	9.9883	9.9909	9.9929	9.9945	9.9957	9.9966	9.9974	9.9980	9.9984
C1DOT	1.1712E-02	9.1219E-03	7.1049E-03	5.5342E-03	4.3116E-03	3.3588E-03	2.6169E-03	2.0390E-03	1.5888E-03
C2	9.9092	9.9270	9.9414	9.9530	9.9623	9.9698	9.9758	9.9807	9.9845
C2DOT	7.9039E-02	6.3836E-02	5.1492E-02	4.1486E-02	3.3386E-02	2.6840E-02	2.1557E-02	1.7299E-02	1.3869E-02
C3	9.6425	9.7036	9.7548	9.7974	9.8329	9.8624	9.8869	9.9072	9.9239
C3DOT	.26674	.22341	.18665	.15656	.12936	.10735	8.8913E-02	7.3505E-02	6.0664E-02
C4	9.0423	9.1823	9.3037	9.4065	9.4988	9.5762	9.6424	9.6989	9.7469
C4DOT	.60017	.52130	.45106	.38889	.33418	.28627	.24450	.20826	.17693
C5	8.0296	8.2701	8.4862	8.6794	8.8513	9.0037	9.1381	9.2563	9.3599
C5DOT	1.0128	.91226	.81754	.72917	.64746	.57253	.50429	.44255	.38703

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	9.0000	9.2500	9.5000	9.7500	10.000	10.250	10.500	10.750	11.000
C1	9.9988	9.9990	9.9992	9.9994	9.9995	9.9996	9.9997	9.9998	9.9998
C1DOT	1.2388E-03	9.6607E-04	7.5245E-04	5.8746E-04	4.5872E-04	3.5763E-04	2.7943E-04	2.1839E-04	1.7166E-04
C2	9.9877	9.9901	9.9921	9.9837	9.9950	9.9960	9.9968	9.9975	9.9980
C2DOT	1.1110E-02	8.8930E-03	7.1144E-03	5.6868E-03	4.5424E-03	3.6268E-03	2.8944E-03	2.3088E-03	1.8396E-03
C3	9.9377	9.9490	9.9584	9.9660	9.9723	9.9774	9.9816	9.9851	9.9879
C3DOT	4.9984E-02	4.1121E-02	3.3780E-02	2.7711E-02	2.2703E-02	1.8578E-02	1.5182E-02	1.2395E-02	1.0109E-02
C4	9.7877	9.8222	9.8514	9.8760	9.8966	9.9140	9.9285	9.9407	9.9508
C4DOT	.14995	.12678	.10697	9.0056E-02	7.5671E-02	6.3464E-02	5.3133E-02	4.4407E-02	3.7053E-02
C5	9.4503	9.5291	9.5974	9.6565	9.7075	9.7514	9.7890	9.8213	9.8489
C5DOT	.33737	.29318	.25403	.21950	.18917	.16262	.13946	.11934	.10189

TIME	11.250	11.500	11.750	12.000	12.250	12.500	12.750	13.000	13.250
C1	9.9999	9.9999	9.9999	9.9899	9.9999	10.000	10.000	10.000	10.000
C1DOT	1.3447E-04	1.0586E-04	8.2970E-05	6.4850E-05	5.0545E-05	4.0054E-05	3.2425E-05	2.5749E-05	2.0981E-05
C2	9.9984	9.9987	9.9990	9.9892	9.9994	9.9995	9.9996	9.9997	9.9997
C2DOT	1.4668E-03	1.1683E-03	9.3079E-04	7.4196E-04	5.9128E-04	4.7016E-04	3.7384E-04	2.9755E-04	2.3746E-04
C3	9.9902	9.9920	9.9935	9.9848	9.9958	9.9966	9.9972	9.9978	9.9982
C3DOT	8.2350E-03	6.7024E-03	5.4502E-03	4.4279E-03	3.5944E-03	2.9163E-03	2.3642E-03	1.9150E-03	1.5488E-03
C4	9.9593	9.9663	9.9722	9.9771	9.9811	9.9844	9.9872	9.9895	9.9914
C4DOT	3.0869E-02	2.5680E-02	2.1333E-02	1.7698E-02	1.4664E-02	1.2134E-02	1.0028E-02	8.2788E-03	6.8283E-03
C5	9.8725	9.8925	9.9095	9.9240	9.9362	9.9465	9.9552	9.9626	9.9688
C5DOT	8.6817E-02	7.3827E-02	6.2662E-02	5.3088E-02	4.4901E-02	3.7912E-02	3.1961E-02	2.6903E-02	2.2612E-02

TIME	13.500	13.750	14.000	14.250	14.500	14.750	15.000
C1	10.000	10.000	10.000	10.000	10.000	10.000	10.000
C1DOT	1.7166E-05	1.4305E-05	1.2398E-05	1.0490E-05	8.5831E-06	7.6294E-06	7.6294E-06
C2	9.9998	9.9998	9.9999	9.9999	9.9999	9.9999	9.9999
C2DOT	1.8883E-04	1.5068E-04	1.2016E-04	9.6321E-05	7.8201E-05	6.2943E-05	4.9591E-05
C3	9.9985	9.9988	9.9990	9.9992	9.9994	9.9995	9.9996
C3DOT	1.2531E-03	1.0128E-03	8.1825E-04	6.6090E-04	5.3310E-04	4.3011E-04	3.4714E-04
C4	9.9929	9.9942	9.9952	9.9961	9.9968	9.9974	9.9979
C4DOT	5.6248E-03	4.6291E-03	3.8052E-03	3.1252E-03	2.5644E-03	2.1029E-03	1.7233E-03
C5	9.9739	9.9783	9.9819	9.9850	9.9875	9.9896	9.9914
C5DOT	1.8978E-02	1.5906E-02	1.3314E-02	1.1430E-02	9.2936E-03	7.7505E-03	6.4564E-03



TIME	C1	C2	C3	C4	C5
.0	.0	.0	.0	.0	.0
.25000	2.2120	.26499	2.1614E-02	1.3344E-03	6.6035E-05
.50000	3.9347	.90205	.14386	1.7523E-02	1.7217E-03
.75000	5.2763	1.7336	.40503	7.2926E-02	1.0650E-02
1.0000	6.3212	2.6424	.80299	.18988	3.6602E-02
1.2500	7.1349	3.5537	1.3153	.38269	9.1246E-02
1.5000	7.7687	4.4218	1.9115	.65642	.18576
1.7500	8.2622	5.2212	2.5603	1.0081	.32902
2.0000	8.6466	5.9399	3.2332	1.4288	.52653
2.2500	8.9460	6.5745	3.9066	1.9057	.78014
2.5000	9.1791	7.1270	4.5619	2.4242	1.0882
2.7500	9.3607	7.6027	5.1854	2.9696	1.4462
3.0000	9.5021	8.0085	5.7681	3.5277	1.8474
3.2500	9.6123	8.3521	6.3043	4.0859	2.2835
3.5000	9.6980	8.6411	6.7915	4.6337	2.7455
3.7500	9.7648	8.8829	7.2293	5.1623	3.2245
4.0000	9.8168	9.0842	7.6190	5.6653	3.7116
4.2500	9.8574	9.2511	7.9629	6.1379	4.1988
4.5000	9.8889	9.3890	8.2642	6.5770	4.6789
4.7500	9.9135	9.5025	8.5265	6.9811	5.1460
5.0000	9.9326	9.5957	8.7535	7.3497	5.5951
5.2500	9.9475	9.6720	8.9488	7.6833	6.0222
5.5000	9.9591	9.7344	9.1162	7.9830	6.4248
5.7500	9.9682	9.7852	9.2590	8.2505	6.8009
6.0000	9.9752	9.8265	9.3803	8.4879	7.1494
6.2500	9.9807	9.8600	9.4830	8.6975	7.4701
6.5000	9.9850	9.8872	9.5696	8.8815	7.7633
6.7500	9.9883	9.9092	9.6425	9.0423	8.0296
7.0000	9.9909	9.9270	9.7036	9.1823	8.2701
7.2500	9.9929	9.9414	9.7548	9.3037	8.4862
7.5000	9.9945	9.9530	9.7974	9.4085	8.6794
7.7500	9.9957	9.9623	9.8329	9.4988	8.8513
8.0000	9.9966	9.9698	9.8624	9.5762	9.0037
8.2500	9.9974	9.9758	9.8869	9.6424	9.1381
8.5000	9.9980	9.9807	9.9072	9.6989	9.2563
8.7500	9.9984	9.9845	9.9239	9.7469	9.3599
9.0000	9.9988	9.9877	9.9377	9.7877	9.4503
9.2500	9.9990	9.9901	9.9490	9.8222	9.5291
9.5000	9.9992	9.9921	9.9584	9.8514	9.5974
9.7500	9.9994	9.9937	9.9660	9.8760	9.6565
10.000	9.9995	9.9950	9.9723	9.8966	9.7075
10.250	9.9996	9.9960	9.9774	9.9140	9.7514
10.500	9.9997	9.9968	9.9816	9.9285	9.7890
10.750	9.9998	9.9975	9.9851	9.9407	9.8213
11.000	9.9998	9.9980	9.9879	9.9508	9.8489
11.250	9.9999	9.9984	9.9902	9.9593	9.8725
11.500	9.9999	9.9987	9.9920	9.9663	9.8925
11.750	9.9999	9.9990	9.9935	9.9722	9.9095
12.000	9.9999	9.9992	9.9948	9.9771	9.9240
12.250	9.9999	9.9994	9.9958	9.9811	9.9362
12.500	10.000	9.9995	9.9966	9.9844	9.9465
12.750	10.000	9.9996	9.9972	9.9872	9.9552
13.000	10.000	9.9997	9.9978	9.9895	9.9626
13.250	10.000	9.9997	9.9982	9.9914	9.9688
13.500	10.000	9.9998	9.9985	9.9929	9.9739

4.4

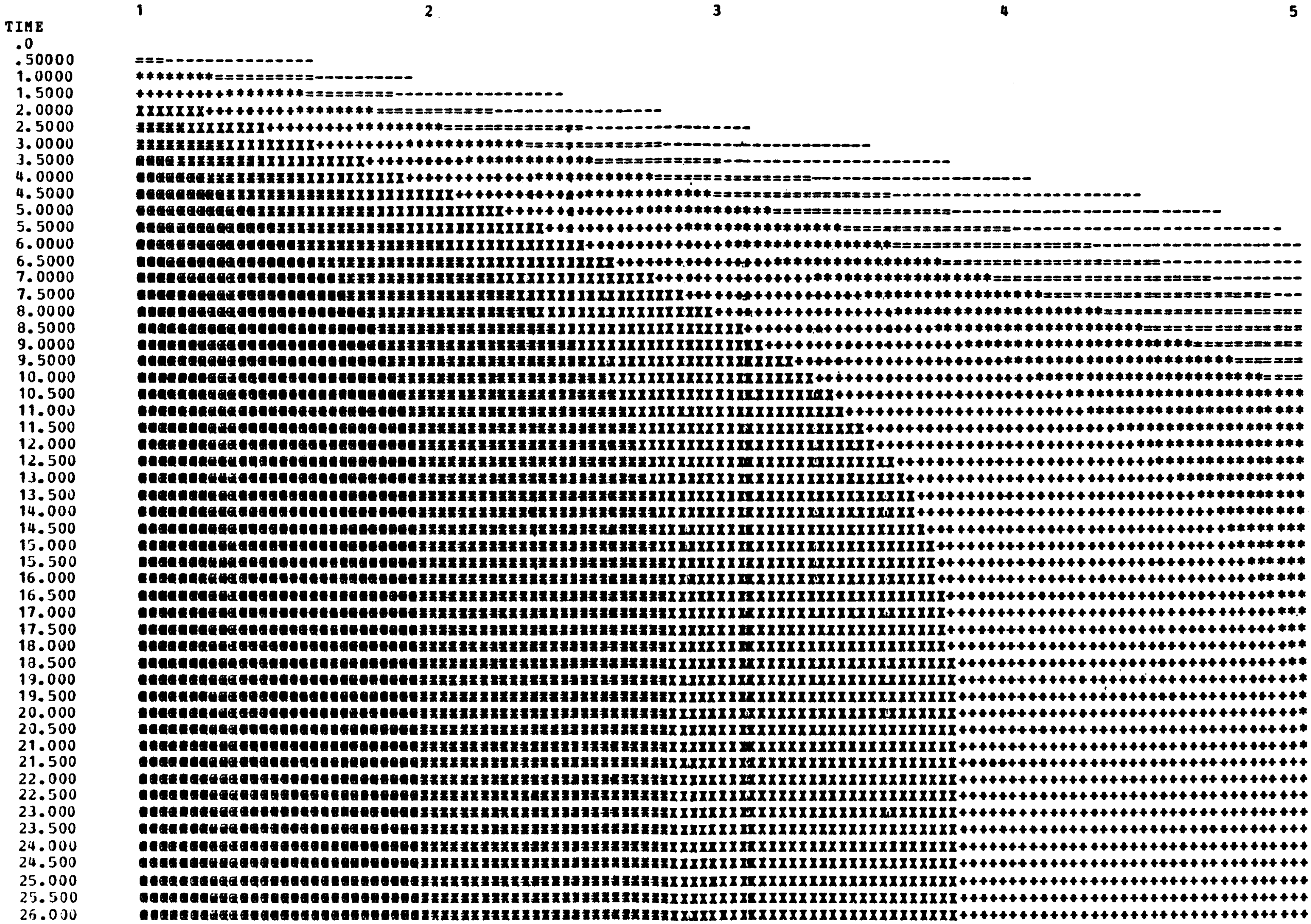
```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M3   TRANSLATOR OUTPUT$$$

*   CSMP III EXAMPLE PROBLEM 5
*   FIVE REACTORS IN SERIES USING  A
*    PROCEDURE SECTION  WITH A FIRST ORDER REACTION
INITIAL
     PARAM  Z=0., VTOTAL=20.,F=2.0,M=5,CO=10.,K=0.1
FIXED I,J,M
NOSORT
*   INSERT THE INITIAL CONDITIONS
*   'DO LOOPS' MUST BE USED ONLY IN  PROCEDURAL SECTIONS
      DO 10 I=1,M
10    ICC(I)=Z
SORT
*
*
*
      THETA=VTOTAL/(FLOAT(M)*F)
DYNAMIC
      C=INTGRL(ICC,CDOT,5)
*   THIS TYPE OF INTGRL SPECIFICATION AUTOMATICALLY
*    CREATES ARRAYS CALLED C,ICC,CDOT
PROCEDURE CDOT=SOLVE(C,ICC,CO,K)
      CDOT(1)=  (CO-C(1))/THETA -K*C(1)
      DO 20 J=2,M
      CDOT(J)=(C(J-1)-C(J))/THETA -K*C(J)
20    CONTINUE
ENDPROCEDURE
*
*
TERMINAL
PRINT C(1-5)
OUTPUT C(1-5)
PAGE SHADE
OUTPUT C(1-5)
PAGE CONTOUR
TIMER FINTIM=30.,OUTDEL=0.5,PRDEL=0.5
END
* COMPARE  THE PREVIOUS CASES TO THE CASE WITH NO REACTION
PARAM K=0.
END
* NOW RUN AN IMPULSE TEST
PARAM Z=10.,CO=0.0
END
* NOW RUN AN IMPULSE TEST WITH REACTION
PARAM K=0.1
END
STOP

OUTPUT VARIABLE SEQUENCE
ZZ1000 THETA  CDOT   C
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	C(1)	C(2)	C(3)	C(4)	C(5)
.0	.0	.0	.0	.0	.0
.500000	2.1598	.25650	2.0829E-02	1.2826E-03	6.3383E-05
1.00000	3.7599	.84656	.13375	1.6201E-02	1.5863E-03
1.50000	4.9452	1.5800	.36373	6.4908E-02	9.4233E-03
2.00000	5.8234	2.3429	.69739	.16285	3.1132E-02
2.50000	6.4739	3.0707	1.1062	.31656	7.4654E-02
3.00000	6.9558	3.7303	1.5589	.52424	.14631
3.50000	7.3128	4.3082	2.0276	.77814	.24967
4.00000	7.5773	4.8025	2.4901	1.0671	.38527
4.50000	7.7733	5.2176	2.9304	1.3788	.55094
5.00000	7.9184	5.5615	3.3380	1.7012	.74241
5.50000	8.0260	5.8431	3.7070	2.0238	.95409
6.00000	8.1056	6.0716	4.0350	2.3379	1.1798
6.50000	8.1646	6.2557	4.3222	2.6367	1.4131
7.00000	8.2084	6.4029	4.5704	2.9157	1.6484
7.50000	8.2408	6.5201	4.7825	3.1718	1.8804
8.00000	8.2647	6.6130	4.9621	3.4036	2.1048
8.50000	8.2825	6.6862	5.1130	3.6108	2.3183
9.00000	8.2957	6.7437	5.2387	3.7939	2.5185
9.50000	8.3054	6.7888	5.3427	3.9542	2.7038
10.0000	8.3127	6.8239	5.4284	4.0933	2.8732
10.5000	8.3180	6.8513	5.4986	4.2131	3.0265
11.0000	8.3220	6.8726	5.5557	4.3154	3.1640
11.5000	8.3249	6.8891	5.6021	4.4023	3.2861
12.0000	8.3271	6.9019	5.6396	4.4757	3.3938
12.5000	8.3287	6.9118	5.6698	4.6373	3.4880
13.0000	8.3299	6.9194	5.6940	4.5887	3.5700
13.5000	8.3308	6.9253	5.7134	4.6315	3.6408
14.0000	8.3315	6.9298	5.7289	4.6669	3.7016
14.5000	8.3319	6.9332	5.7412	4.6962	3.7537
15.0000	8.3323	6.9359	5.7510	4.7202	3.7979
15.5000	8.3326	6.9379	5.7587	4.7398	3.8353
16.0000	8.3328	6.9395	5.7648	4.7558	3.8669
16.5000	8.3329	6.9406	5.7696	4.7689	3.8934
17.0000	8.3330	6.9415	5.7734	4.7795	3.9155
17.5000	8.3331	6.9422	5.7764	4.7881	3.9340
18.0000	8.3332	6.9428	5.7788	4.7950	3.9493
18.5000	8.3332	6.9432	5.7806	4.8005	3.9620
19.0000	8.3332	6.9435	5.7820	4.8050	3.9725
19.5000	8.3333	6.9437	5.7831	4.8086	3.9811
20.0000	8.3333	6.9439	5.7840	4.8115	3.9882
20.5000	8.3333	6.9440	5.7847	4.8138	3.9940
21.0000	8.3333	6.9441	5.7852	4.8156	3.9988
21.5000	8.3333	6.9442	5.7856	4.8170	4.0026
22.0000	8.3333	6.9443	5.7859	4.8182	4.0058
22.5000	8.3333	6.9443	5.7862	4.8191	4.0083
23.0000	8.3333	6.9443	5.7864	4.8198	4.0104
23.5000	8.3333	6.9444	5.7865	4.8204	4.0120
24.0000	8.3333	6.9444	5.7866	4.8209	4.0134
24.5000	8.3333	6.9444	5.7867	4.8212	4.0145
25.0000	8.3333	6.9444	5.7868	4.8215	4.0153
25.5000	8.3333	6.9444	5.7869	4.8217	4.0160
26.0000	8.3333	6.9444	5.7869	4.8219	4.0166
26.5000	8.3333	6.9444	5.7869	4.8220	4.0170
27.0000	8.3333	6.9444	5.7869	4.8221	4.0174
27.5000	8.3333	6.9444	5.7870	4.8222	4.0177
28.0000	8.3333	6.9444	5.7870	4.8223	4.0179

SHADED PRESENTATION FOR C(1)   GREY SCALE ' '= 1.00 OR LESS

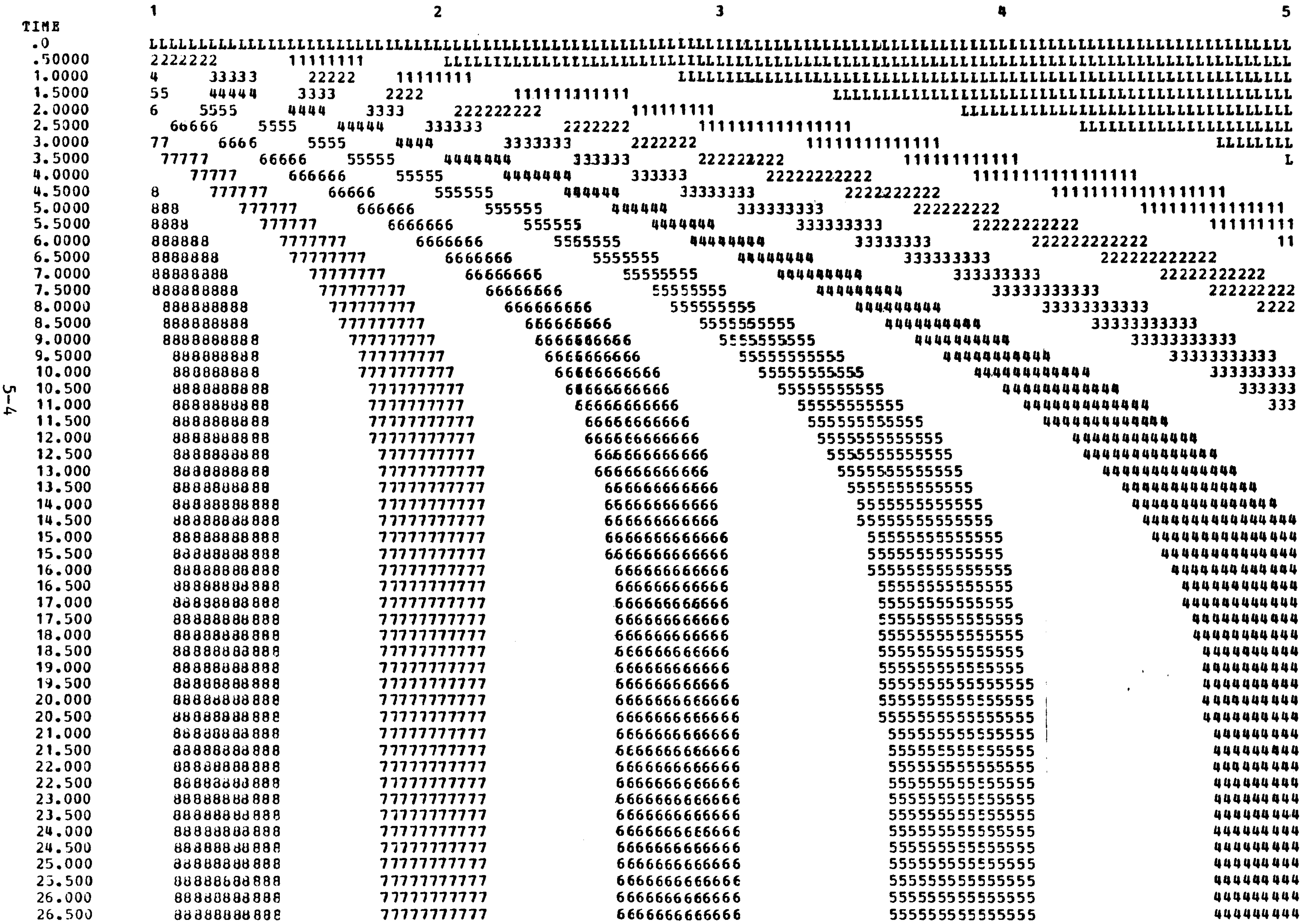
'-'= 1.00 TO 2.00   '='= 2.00 TO 3.00   '*'= 3.00 TO 4.00
'+'= 4.00 TO 5.00   'X'= 5.00 TO 6.00   '#'= 6.00 TO 7.00
'@'= 7.00 TO 8.00   '@'= 8.00 TO 9.00   '@'= 9.00 OR GREATER



CONTOUR PRESENTATION FOR C(1)

SCALE VALUES

				'L'= .0
'1'= 1.00	'2'= 2.00	'3'= 3.00	'4'= 4.00	'5'= 5.00
'6'= 6.00	'7'= 7.00	'8'= 8.00	'9'= 9.00	'H'= 10.0



CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	C(1)	C(2)	C(3)	C(4)	C(5)
.0	.0	.0	.0	.0	.0
.500000	2.2120	.26499	2.1614E-02	1.3344E-03	6.6035E-05
1.00000	3.9347	.90205	.14386	1.7523E-02	1.7217E-03
1.50000	5.2763	1.7336	.40503	7.2926E-02	1.0650E-02
2.00000	6.3212	2.6424	.80299	.18988	3.6602E-02
2.50000	7.1349	3.5537	1.3153	.38269	9.1246E-02
3.00000	7.7687	4.4218	1.9115	.65642	.18576
3.50000	8.2622	5.2212	2.5603	1.0081	.32902
4.00000	8.6466	5.9399	3.2332	1.4288	.52653
4.50000	8.9460	6.5745	3.9066	1.9057	.78014
5.00000	9.1791	7.1270	4.5619	2.4242	1.0882
5.50000	9.3607	7.6027	5.1854	2.9696	1.4462
6.00000	9.5021	8.0085	5.7681	3.5277	1.8474
6.50000	9.6123	8.3521	6.3043	4.0859	2.2835
7.00000	9.6980	8.6411	6.7915	4.6337	2.7455
7.50000	9.7648	8.8829	7.2293	5.1623	3.2245
8.00000	9.8168	9.0842	7.6190	5.6653	3.7116
8.50000	9.8574	9.2511	7.9629	6.1379	4.1988
9.00000	9.8889	9.3890	8.2642	6.5770	4.6789
9.50000	9.9135	9.5025	8.5265	6.9811	5.1460
10.0000	9.9326	9.5957	8.7535	7.3497	5.5951
10.5000	9.9475	9.6720	8.9488	7.6833	6.0222
11.0000	9.9591	9.7344	9.1162	7.9830	6.4248
11.5000	9.9682	9.7852	9.2590	8.2505	6.8009
12.0000	9.9752	9.8265	9.3803	8.4879	7.1494
12.5000	9.9807	9.8600	9.4830	8.6975	7.4701
13.0000	9.9850	9.8872	9.5696	8.8815	7.7633
13.5000	9.9883	9.9092	9.6425	9.0423	8.0295
14.0000	9.9909	9.9270	9.7036	9.1823	8.2701
14.5000	9.9929	9.9414	9.7548	9.3037	8.4862
15.0000	9.9945	9.9530	9.7974	9.4085	8.6794
15.5000	9.9957	9.9623	9.8329	9.4988	8.8513
16.0000	9.9966	9.9698	9.8624	9.5762	9.0037
16.5000	9.9974	9.9758	9.8869	9.6424	9.1381
17.0000	9.9980	9.9807	9.9072	9.6989	9.2563
17.5000	9.9984	9.9845	9.9239	9.7469	9.3599
18.0000	9.9988	9.9877	9.9377	9.7877	9.4503
18.5000	9.9990	9.9901	9.9490	9.8222	9.5291
19.0000	9.9992	9.9921	9.9584	9.8514	9.5974
19.5000	9.9994	9.9937	9.9660	9.8760	9.6565
20.0000	9.9995	9.9950	9.9723	9.8966	9.7075
20.5000	9.9996	9.9960	9.9774	9.9140	9.7514
21.0000	9.9997	9.9968	9.9816	9.9285	9.7890
21.5000	9.9998	9.9975	9.9851	9.9407	9.8213
22.0000	9.9998	9.9980	9.9879	9.9508	9.8489
22.5000	9.9999	9.9984	9.9902	9.9593	9.8725
23.0000	9.9999	9.9987	9.9920	9.9663	9.8925
23.5000	9.9999	9.9990	9.9935	9.9722	9.9095
24.0000	9.9999	9.9992	9.9948	9.9771	9.9240
24.5000	9.9999	9.9994	9.9958	9.9811	9.9362
25.0000	10.000	9.9995	9.9966	9.9844	9.9465
25.5000	10.000	9.9996	9.9972	9.9872	9.9552
26.0000	10.000	9.9997	9.9978	9.9895	9.9626
26.5000	10.000	9.9997	9.9982	9.9914	9.9688
27.0000	10.000	9.9998	9.9985	9.9929	9.9739
27.5000	10.000	9.9998	9.9988	9.9942	9.9783
28.0000	10.000	9.9999	9.9990	9.9952	9.9819

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M3   TRANSLATOR OUTPUT$$$

*   CSMP III EXAMPLE PROBLEM  6
*   BIOLOGICAL REACTOR WITH NO RECYCLE USING MONOD FUNCTION GROWTH
*    RATE KINETICS
INITIAL
     PARAM MUHAT=0.2,KD=0.005,KS=200.,Y=0.5
     PARAM V=10.,F=0.5,ICX1=50.,ICS1=5.0,XO=0.,SO=200.
      THETA=V/F
DYNAMIC
      MU=  MUHAT*S1/(KS+S1)
      X1DOT=(XO-X1)/THETA +MU*X1
      X1=INTGRL(ICX1,X1DOT)
      S1DOT=(SO-S1)/THETA -MU*X1/Y
      S1=INTGRL(ICS1,S1DOT)
*   USE THE DEBUG OUTPUT TO DETECT ERRORS
NOSORT
      CALL DEBUG(1,0.0)
TERMINAL
METHOD TRAP
TIMER FINTIM=60.,OUTDEL=1.0,PRDEL=1.0,DELT=0.05
PRINT MU,S1,X1
OUTPUT TIME,X1,S1
PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
LABEL X1,S1 VS. TIME FOR A CHEMOSTAT
END
STOP

OUTPUT VARIABLE SEQUENCE
THETA  MU     X1DOT  X1     S1DOT  S1     ZZ1002
```

$$$ TRANSLATION TABLE CONTENTS $$$	CURRENT	MAXIMUM
MACRO AND STATEMENT OUTPUTS	13	600
STATEMENT INPUT WORK AREA	50	1900
INTEGRATORS+MEMORY BLOCK OUTPUTS	2 + 0	300
PARAMETERS+FUNCTION GENERATORS	14 + 0	400
STORAGE VARIABLES+INTEGRATOR ARRAYS	0 + 0/2	50
HISTORY AND MEMORY BLOCK NAMES	21	50
MACRO DEFINITIONS AND NESTED MACROS	6	50
MACRO STATEMENT STORAGE	13	125
LITERAL CONSTANT STORAGE	0	100
SORT SECTIONS	2	20
MAXIMUM STATEMENTS IN SECTION	5	600

$$$END OF TRANSLATOR OUTPUT$$$

```
$$$ CONTINUOUS SYSTEM MODELING PROGRAM III   V1M3    EXECUTION OUTPUT $$$

      PARAM MUHAT=0.2,KD=0.005,KS=200.,Y=0.5
      PARAM V=10.,F=0.5,ICX1=50.,ICS1=5.0,XO=0.,SO=200.
 METHOD TRAP
 TIMER FINTIM=60.,OUTDEL=1.0,PRDEL=1.0,DELT=0.05
 PRINT MU,S1,X1
 OUTPUT TIME,X1,S1
 PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
 LABEL X1,S1 VS. TIME FOR A CHEMOSTAT
 END

TIMER VARIABLES     TRAPZ   INTEGRATION      START TIME  =  .0
   DELT         DELMIN       FINTIM       PRDEL        OUTDEL       DELMAX
 5.0000D-02  6.0000D-06   60.000       1.0000       1.0000       1.0000

 DEBUG     1     OUTPUT       1     KEEP 0      DELT   5.0000D-02     TIME 0.0
     PARAMETERS
         F          .50000      KD        5.0000E-03 KS        200.00     MUHAT    .20000     SO        200.00
         V          10.000      XO        .0         Y         .50000

     INTEGRATOR VARIABLES
 LOCATION    OUTPUTS               DERIVATIVES           INITIAL CONDITIONS
      1    X1         50.000        X1DOT     -2.2561      ICX1      50.000
      2    S1         5.0000        S1DOT      9.2622      ICS1      5.0000

     OUTPUT VARIABLES
         MU        4.8780E-03 THETA     20.000      ZZ1002    .0
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

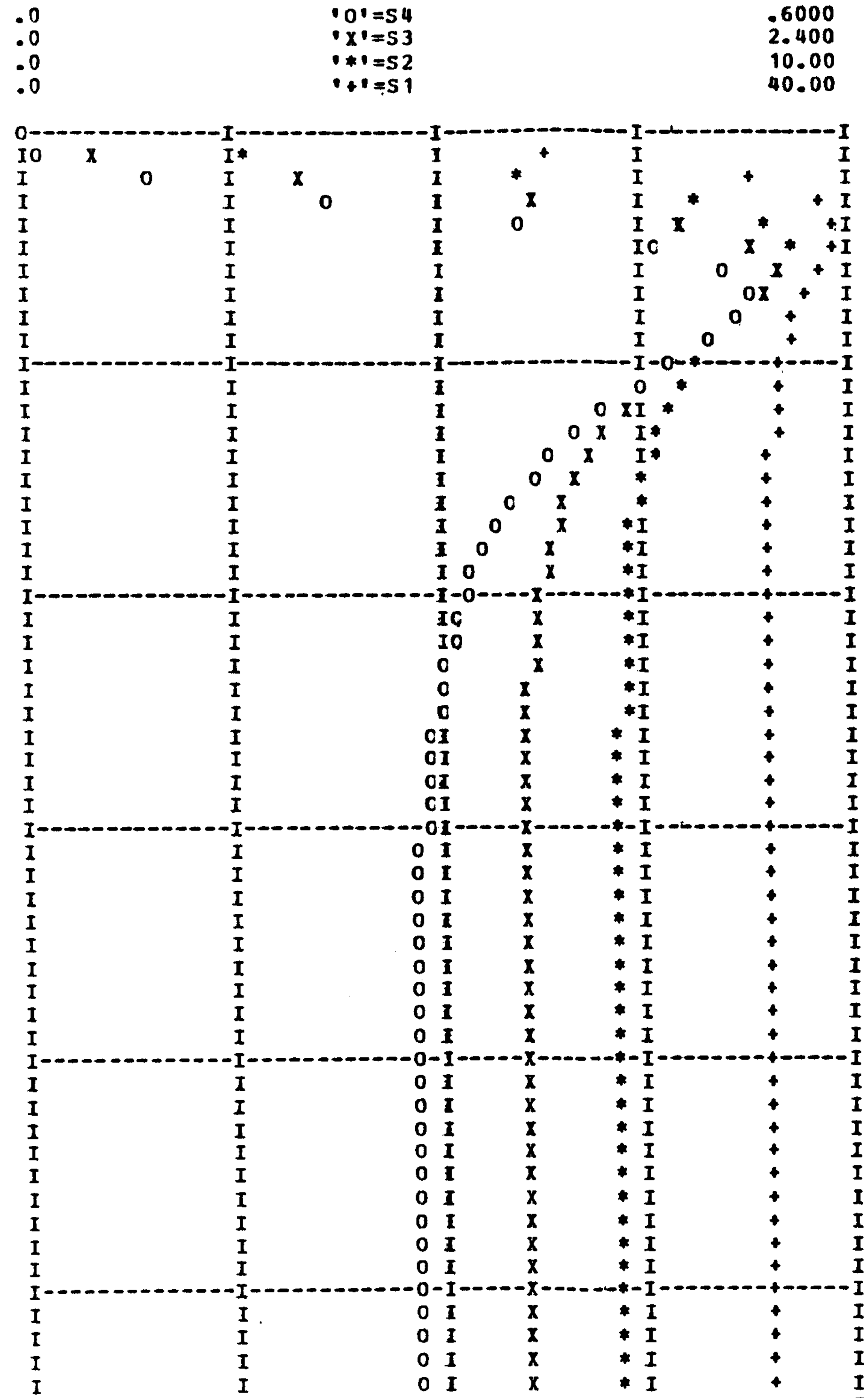
TIME	MU	S1	X1
.0	4.8780E-03	5.0000	50.000
1.00000	1.2780E-02	13.653	47.990
2.00000	1.9216E-02	21.259	46.390
3.00000	2.4573E-02	28.015	45.108
4.00000	2.9106E-02	34.063	44.078
5.00000	3.2991E-02	39.507	43.252
6.00000	3.6353E-02	44.428	42.596
7.00000	3.9286E-02	48.889	42.082
8.00000	4.1861E-02	52.941	41.688
9.00000	4.4132E-02	56.627	41.398
10.0000	4.6143E-02	59.981	41.197
11.0000	4.7928E-02	63.034	41.076
12.0000	4.9517E-02	65.811	41.024
13.0000	5.0932E-02	68.334	41.034
14.0000	5.2193E-02	70.623	41.098
15.0000	5.3317E-02	72.697	41.212
16.0000	5.4317E-02	74.569	41.370
17.0000	5.5206E-02	76.255	41.568
18.0000	5.5995E-02	77.768	41.801
19.0000	5.6692E-02	79.119	42.067
20.0000	5.7306E-02	80.320	42.363
21.0000	5.7843E-02	81.380	42.685
22.0000	5.8311E-02	82.308	43.031
23.0000	5.8714E-02	83.115	43.399
24.0000	5.9059E-02	83.807	43.787
25.0000	5.9349E-02	84.392	44.192
26.0000	5.9589E-02	84.879	44.612
27.0000	5.9783E-02	85.273	45.046
28.0000	5.9935E-02	85.581	45.493
29.0000	6.0047E-02	85.810	45.949
30.0000	6.0123E-02	85.965	46.415
31.0000	6.0166E-02	86.052	46.888
32.0000	6.0178E-02	86.077	47.368
33.0000	6.0161E-02	86.044	47.852
34.0000	6.0120E-02	85.959	48.339
35.0000	6.0054E-02	85.825	48.829
36.0000	5.9967E-02	85.648	49.321
37.0000	5.9861E-02	85.431	49.812
38.0000	5.9737E-02	85.178	50.302
39.0000	5.9597E-02	84.894	50.791
40.0000	5.9443E-02	84.582	51.277
41.0000	5.9276E-02	84.245	51.759
42.0000	5.9098E-02	83.886	52.236
43.0000	5.8911E-02	83.509	52.709
44.0000	5.8715E-02	83.115	53.175
45.0000	5.8512E-02	82.709	53.635
46.0000	5.8303E-02	82.292	54.088
47.0000	5.8089E-02	81.866	54.533
48.0000	5.7871E-02	81.435	54.969
49.0000	5.7651E-02	80.999	55.398
50.0000	5.7428E-02	80.560	55.817
51.0000	5.7205E-02	80.121	56.226
52.0000	5.6981E-02	79.683	56.627
53.0000	5.6757E-02	79.247	57.017
54.0000	5.6535E-02	78.814	57.397
55.0000	5.6314E-02	78.385	57.767
56.0000	5.6096E-02	77.963	58.126

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M3   TRANSLATOR OUTPUT$$$
*    CSMPIII EXAMPLE PROBLEM 7
*    FOUR BIOLOGICAL REACTORS IN SERIES WITH RECYCLE USING
*     A MACRO SECTION
MACRO  SJ,XJ,FTJ=CSTR(FRJ,FJ,SOJ,SRJ,XOJ,XRJ,MUHAT,KS,KD,Y,VJ,ICSJ,ICXJ)
*    ALL THE VARIABLES IN A MACRO SECTION ARE DUMMY VARIABLES
*    CONSTANTS SUCH AS KS,KD,Y, ETC. NEED NOT BE DUMMY VARIABLES,NOR
*    MUST THEY APPEAR IN THE MACRO LABEL
*    THIS SECTION OF THE PROGRAM IS CALLED THE MACRO SPECIFICATION
*    NO CONTINUATION CARDS ARE ALLOWED WITHIN THE MACRO SPECIFICATION
*     SECTION
       FTJ=FJ+FRJ
       XJDOT=(FJ*XOJ+FRJ*XRJ-XJ*FTJ)/VJ +MUJ*XJ -KD*XJ
       XJ=INTGRL(ICXJ,XJDOT)
       SJDOT=(FJ*SOJ+FRJ*SRJ-SJ*FTJ)/VJ -MUJ*XJ/Y
       SJ=INTGRL(ICSJ,SJDOT)
       MUJ=MUHAT*SJ/(SJ+KS)
ENDMAC
*    NOTICE THAT THE MACRO SPECIFICATION SECTION PRECEDES ALL OTHER
*     STRUCTURE STATEMENTS
INITIAL
PARAM SO=200.,XR=10000., KS=200.,KD=0.005,MUHAT=0.2,Y=0.5
PARAM F=2.0,VTOTAL=10.,FR=0.5,XO=0.
       V=VTOTAL/4.
       ICS1=0.
       ICS2=0.
       ICS3=0.
       ICS4=0.
       ICX1=1500.
       ICX2=1500.
       ICX3=1500.
       ICX4=1500.
       DYNAMIC
*    FIRST CSTR
       S1,X1,FT1=CSTR(FR,F,SO,SR,XO,XR,MUHAT,KS,KD,Y,V,ICS1,ICX1)
*    SECOND CSTR
       S2,X2,FT2=CSTR(0.0,FT1,S1,0.0,X1 ,0.0,MUHAT,KS,KD,Y,V,ICS2,ICX2)
*    THIRD  CSTR
       S3,X3,FT3=CSTR(0.0,FT2,S2,0.0,X2,0.0,MUHAT,KS,KD,Y,V,ICS3,ICX3)
*    FOURTH CSTR
       S4,X4,FT4=CSTR(0.0,FT3,S3,0.0,X3,0.0,MUHAT,KS,KD,Y,V,ICS4,ICX4)
*
       SR=S4
NOSORT
       CALL DEBUG(1,0.0)
TERMINAL
TIMER FINTIM=15.0,OUTDEL=0.25,PRDEL=0.25,DELT=0.05
METHOD TRAP
PRINT S1,S2,S3,S4,X1,X2,X3,X4
OUTPUT S1,S2,S3,S4
OUTPUT X1,X2,X3,X4
END
STOP
```

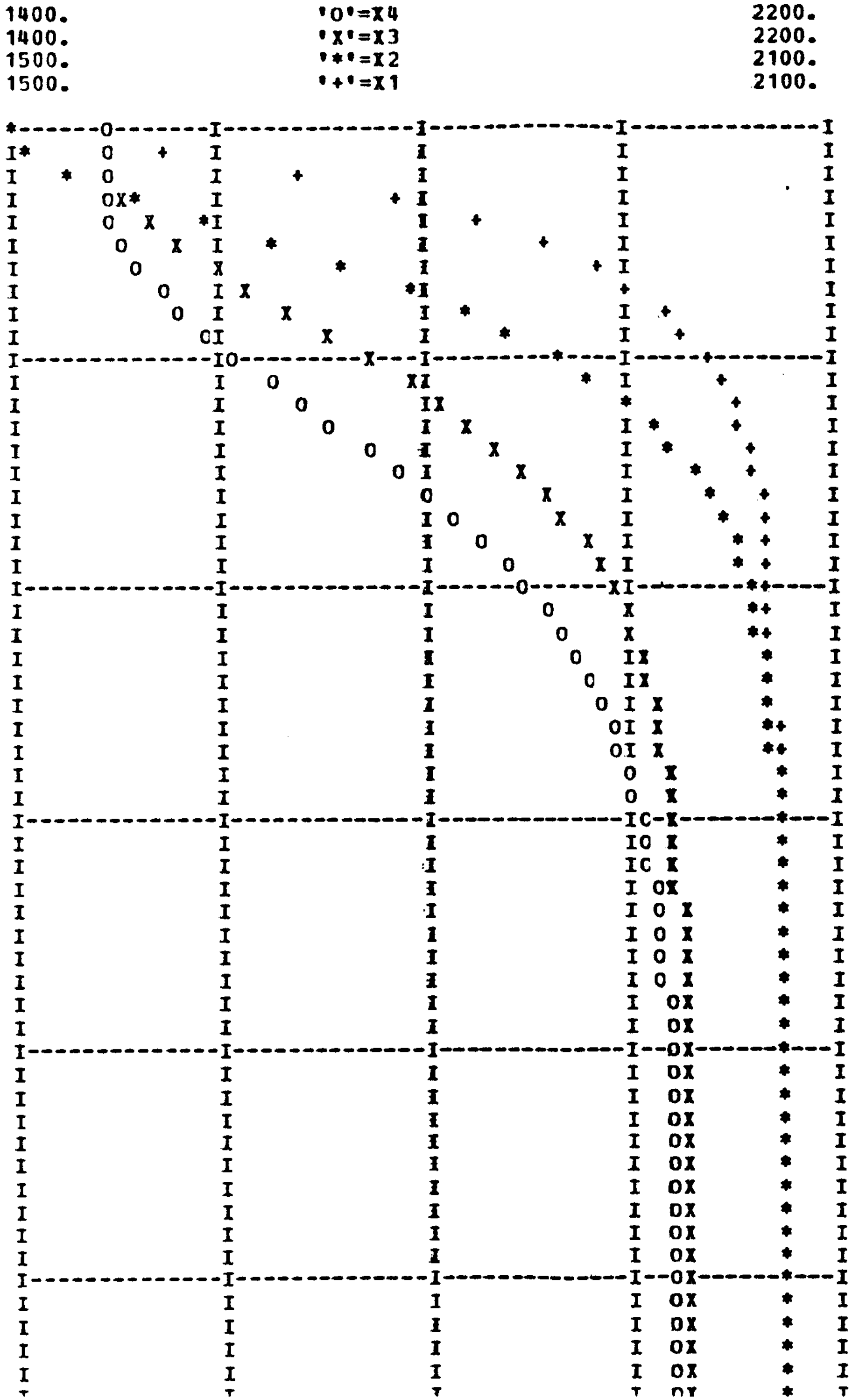
```
$$$ CONTINUOUS SYSTEM MODELING PROGRAM III   V1M3    EXECUTION OUTPUT $$$

 PARAM SO=200.,XR=10000., KS=200.,KD=0.005,MUHAT=0.2,Y=0.5
 PARAM F=2.0,VTOTAL=10.,FR=0.5,XO=0.
 TIMER FINTIM=15.0,OUTDEL=0.25,PRDEL=0.25,DELT=0.05
 METHOD TRAP
 PRINT S1,S2,S3,S4,X1,X2,X3,X4
 OUTPUT S1,S2,S3,S4
 OUTPUT X1,X2,X3,X4
 END

TIMER VARIABLES      TRAPZ   INTEGRATION       START TIME  =  .0
   DELT          DELMIN       FINTIM       PRDEL        OUTDEL       DELMAX
  5.0000D-02  1.5000D-06   15.000       .25000       .25000       .25000

 DEBUG    1      OUTPUT        1      KEEP 0      DELT    5.0000D-02     TIME 0.0
     PARAMETERS
        F         2.0000       FR        .50000      KD        5.0000E-03 KS         200.00      MUHAT    .20000
        SO        200.00       VTOTAL    10.000      XO        .0         XR         10000.      Y        .50000

     INTEGRATOR VARIABLES
 LOCATION    OUTPUTS                   DERIVATIVES              INITIAL CONDITIONS
      1     X1          1500.0       ZZ1000     492.50       ICX1        1500.0
      2     S1          .0           ZZ1001     160.00       ICS1        .0
      3     X2          1500.0       ZZ1005    -7.5000       ICX2        1500.0
      4     S2          .0           ZZ1006     .0           ICS2        .0
      5     X3          1500.0       ZZ1010    -7.5000       ICX3        1500.0
      6     S3          .0           ZZ1011     .0           ICS3        .0
      7     X4          1500.0       ZZ1015    -7.5000       ICX4        1500.0
      8     S4          .0           ZZ1016     .0           ICS4        .0

     OUTPUT VARIABLES
        FT1       2.5000       FT2       2.5000      FT3       2.5000      FT4       2.5000      SR       .0
        V         2.5000       ZZ1002    .0          ZZ1007    .0          ZZ1012    .0          ZZ1017   .0
        ZZ1020    .0
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	S1	S2	S3	S4	X1	X2	X3	X4
.0	.0	.0	.0	.0	1500.0	1500.0	1500.0	1500.0
.250000	25.505	2.7006	.20428	1.1532E-02	1613.8	1512.2	1499.2	1498.2
.500000	35.232	6.0554	.82629	9.1158E-02	1707.3	1545.7	1504.2	1497.2
.750000	38.516	8.1088	1.4675	.22538	1782.3	1591.1	1517.2	1498.5
1.00000	39.196	9.0034	1.9067	.35856	1841.5	1641.7	1538.2	1503.3
1.25000	38.926	9.2011	2.1235	.46504	1888.0	1692.9	1566.0	1512.6
1.50000	38.390	9.0646	2.1785	.50702	1924.3	1741.8	1598.8	1526.6
1.75000	37.849	8.8069	2.1409	.52266	1952.6	1787.0	1634.7	1545.1
2.00000	37.385	8.5327	2.0617	.51471	1974.7	1827.6	1672.1	1567.7
2.25000	37.010	8.2843	1.9712	.48434	1991.8	1863.4	1709.6	1593.5
2.50000	36.717	8.0740	1.8844	.46920	2005.2	1894.6	1746.1	1621.8
2.75000	36.489	7.9013	1.8074	.44375	2015.6	1921.4	1780.9	1651.7
3.00000	36.314	7.7614	1.7415	.42014	2023.6	1944.3	1813.4	1682.4
3.25000	36.178	7.6488	1.6862	.39921	2029.9	1963.7	1843.3	1713.1
3.50000	36.073	7.5582	1.6402	.38108	2034.8	1979.9	1870.5	1743.4
3.75000	35.992	7.4854	1.6019	.36557	2038.6	1993.5	1894.9	1772.5
4.00000	35.929	7.4268	1.5702	.35236	2041.6	2004.8	1916.6	1800.3
4.25000	35.880	7.3796	1.5439	.34115	2043.9	2014.1	1935.7	1826.4
4.50000	35.843	7.3417	1.5221	.33164	2045.7	2021.9	1952.5	1850.7
4.75000	35.813	7.3112	1.5040	.32357	2047.0	2028.2	1967.1	1873.0
5.00000	35.790	7.2866	1.4890	.31674	2048.1	2033.4	1979.7	1893.3
5.25000	35.773	7.2668	1.4766	.31094	2049.0	2037.7	1990.5	1911.7
5.50000	35.759	7.2509	1.4663	.30602	2049.6	2041.2	1999.8	1928.3
5.75000	35.748	7.2381	1.4578	.30186	2050.1	2044.0	2007.7	1943.0
6.00000	35.740	7.2278	1.4507	.29833	2050.5	2046.3	2014.4	1956.1
6.25000	35.733	7.2195	1.4449	.29534	2050.8	2048.2	2020.1	1967.6
6.50000	35.728	7.2129	1.4401	.29282	2051.1	2049.7	2024.9	1977.7
6.75000	35.724	7.2076	1.4361	.29068	2051.3	2050.9	2028.9	1986.6
7.00000	35.721	7.2033	1.4328	.28888	2051.4	2051.9	2032.3	1994.3
7.25000	35.719	7.1999	1.4301	.28736	2051.5	2052.7	2035.1	2000.9
7.50000	35.717	7.1972	1.4279	.28608	2051.6	2053.3	2037.5	2006.7
7.75000	35.715	7.1950	1.4261	.28500	2051.7	2053.8	2039.4	2011.6
8.00000	35.714	7.1932	1.4246	.28410	2051.7	2054.2	2041.0	2015.9
8.25000	35.713	7.1918	1.4233	.28334	2051.8	2054.6	2042.4	2019.5
8.50000	35.713	7.1907	1.4223	.28270	2051.8	2054.8	2043.5	2022.6
8.75000	35.712	7.1898	1.4215	.28217	2051.8	2055.0	2044.4	2025.2
9.00000	35.712	7.1891	1.4208	.28173	2051.8	2055.2	2045.1	2027.4
9.25000	35.711	7.1885	1.4203	.28136	2051.9	2055.4	2045.8	2029.3
9.50000	35.711	7.1881	1.4198	.28105	2051.9	2055.5	2046.3	2030.9
9.75000	35.711	7.1877	1.4195	.28079	2051.9	2055.6	2046.7	2032.2
10.0000	35.711	7.1874	1.4192	.28057	2051.9	2055.6	2047.0	2033.3
10.2500	35.710	7.1872	1.4189	.28039	2051.9	2055.7	2047.3	2034.3
10.5000	35.710	7.1870	1.4187	.28025	2051.9	2055.7	2047.5	2035.1
10.7500	35.710	7.1869	1.4186	.28012	2051.9	2055.8	2047.7	2035.7
11.0000	35.710	7.1868	1.4185	.28002	2051.9	2055.8	2047.9	2036.3
11.2500	35.710	7.1867	1.4184	.27994	2051.9	2055.8	2048.0	2036.7
11.5000	35.710	7.1866	1.4183	.27987	2051.9	2055.8	2048.1	2037.1
11.7500	35.710	7.1866	1.4182	.27981	2051.9	2055.8	2048.2	2037.4
12.0000	35.710	7.1865	1.4181	.27977	2051.9	2055.8	2048.3	2037.7
12.2500	35.710	7.1865	1.4181	.27973	2051.9	2055.9	2048.3	2037.9
12.5000	35.710	7.1864	1.4181	.27970	2051.9	2055.9	2048.3	2038.1
12.7500	35.710	7.1864	1.4180	.27967	2051.9	2055.9	2048.4	2038.2
13.0000	35.710	7.1864	1.4180	.27965	2051.9	2055.9	2048.4	2038.3
13.2500	35.710	7.1864	1.4180	.27963	2051.9	2055.9	2048.4	2038.4
13.5000	35.710	7.1864	1.4180	.27962	2051.9	2055.9	2048.5	2038.5
13.7500	35.710	7.1864	1.4180	.27960	2051.9	2055.9	2048.5	2038.6
14.0000	35.710	7.1864	1.4180	.27959	2051.9	2055.9	2048.5	2038.7



TIME	S1	S2	S3	S4
.0	.0	.0	.0	.0
.25000	25.505	2.7006	.20428	1.1532E-02
.50000	35.232	6.0554	.82629	9.1158E-02
.75000	38.516	8.1088	1.4675	.22538
1.0000	39.196	9.0034	1.9067	.35856
1.2500	38.926	9.2011	2.1235	.45504
1.5000	38.390	9.0646	2.1785	.50702
1.7500	37.849	8.8069	2.1409	.52266
2.0000	37.385	8.5327	2.0617	.51471
2.2500	37.010	8.2843	1.9712	.49434
2.5000	36.717	8.0740	1.8844	.46920
2.7500	36.489	7.9013	1.8074	.44375
3.0000	36.314	7.7614	1.7415	.42014
3.2500	36.178	7.6488	1.6862	.39921
3.5000	36.073	7.5582	1.6402	.38108
3.7500	35.992	7.4854	1.6019	.36557
4.0000	35.929	7.4268	1.5702	.35236
4.2500	35.880	7.3796	1.5439	.34115
4.5000	35.843	7.3417	1.5221	.33164
4.7500	35.813	7.3112	1.5040	.32357
5.0000	35.790	7.2866	1.4890	.31674
5.2500	35.773	7.2668	1.4766	.31094
5.5000	35.759	7.2509	1.4663	.30602
5.7500	35.748	7.2381	1.4578	.30186
6.0000	35.740	7.2278	1.4507	.29833
6.2500	35.733	7.2195	1.4449	.29534
6.5000	35.728	7.2129	1.4401	.29282
6.7500	35.724	7.2076	1.4361	.29068
7.0000	35.721	7.2033	1.4328	.28888
7.2500	35.719	7.1999	1.4301	.28736
7.5000	35.717	7.1972	1.4279	.28608
7.7500	35.715	7.1950	1.4261	.28500
8.0000	35.714	7.1932	1.4246	.28410
8.2500	35.713	7.1918	1.4233	.28334
8.5000	35.713	7.1907	1.4223	.28270
8.7500	35.712	7.1898	1.4215	.28217
9.0000	35.712	7.1891	1.4208	.28173
9.2500	35.711	7.1885	1.4203	.28136
9.5000	35.711	7.1881	1.4198	.28105
9.7500	35.711	7.1877	1.4195	.28079
10.000	35.711	7.1874	1.4192	.28057
10.250	35.710	7.1872	1.4189	.28039
10.500	35.710	7.1870	1.4187	.28025
10.750	35.710	7.1869	1.4186	.28012
11.000	35.710	7.1868	1.4185	.28002
11.250	35.710	7.1867	1.4184	.27994
11.500	35.710	7.1866	1.4183	.27987
11.750	35.710	7.1866	1.4182	.27981
12.000	35.710	7.1865	1.4181	.27977
12.250	35.710	7.1865	1.4181	.27973
12.500	35.710	7.1864	1.4181	.27970
12.750	35.710	7.1864	1.4180	.27967
13.000	35.710	7.1864	1.4180	.27965
13.250	35.710	7.1864	1.4180	.27963
13.500	35.710	7.1864	1.4180	.27962



TIME	X1	X2	X3	X4
.0	1500.0	1500.0	1500.0	1500.0
.25000	1613.8	1512.2	1499.2	1498.2
.50000	1707.3	1545.7	1504.2	1497.2
.75000	1782.3	1591.1	1517.2	1498.5
1.0000	1841.5	1641.7	1538.2	1503.3
1.2500	1888.0	1692.9	1566.0	1512.6
1.5000	1924.3	1741.8	1598.8	1526.6
1.7500	1952.6	1787.0	1634.7	1545.1
2.0000	1974.7	1827.6	1672.1	1567.7
2.2500	1991.8	1863.4	1709.6	1593.5
2.5000	2005.2	1894.6	1746.1	1621.8
2.7500	2015.6	1921.4	1780.9	1651.7
3.0000	2023.6	1944.3	1813.4	1682.4
3.2500	2029.9	1963.7	1843.3	1713.1
3.5000	2034.8	1979.9	1870.5	1743.4
3.7500	2038.6	1993.5	1894.9	1772.5
4.0000	2041.6	2004.8	1916.6	1800.3
4.2500	2043.9	2014.1	1935.7	1826.4
4.5000	2045.7	2021.9	1952.5	1850.7
4.7500	2047.0	2028.2	1967.1	1873.0
5.0000	2048.1	2033.4	1979.7	1893.3
5.2500	2049.0	2037.7	1990.5	1911.7
5.5000	2049.6	2041.2	1999.8	1928.3
5.7500	2050.1	2044.0	2007.7	1943.0
6.0000	2050.5	2046.3	2014.4	1956.1
6.2500	2050.8	2048.2	2020.1	1967.6
6.5000	2051.1	2049.7	2024.9	1977.7
6.7500	2051.3	2050.9	2028.9	1986.6
7.0000	2051.4	2051.9	2032.3	1994.3
7.2500	2051.5	2052.7	2035.1	2000.9
7.5000	2051.6	2053.3	2037.5	2006.7
7.7500	2051.7	2053.8	2039.4	2011.6
8.0000	2051.7	2054.2	2041.0	2015.9
8.2500	2051.8	2054.6	2042.4	2019.5
8.5000	2051.8	2054.8	2043.5	2022.6
8.7500	2051.8	2055.0	2044.4	2025.2
9.0000	2051.8	2055.2	2045.1	2027.4
9.2500	2051.9	2055.4	2045.8	2029.3
9.5000	2051.9	2055.5	2046.3	2030.9
9.7500	2051.9	2055.6	2046.7	2032.2
10.000	2051.9	2055.6	2047.0	2033.3
10.250	2051.9	2055.7	2047.3	2034.3
10.500	2051.9	2055.7	2047.5	2035.1
10.750	2051.9	2055.8	2047.7	2035.7
11.000	2051.9	2055.8	2047.9	2036.3
11.250	2051.9	2055.8	2048.0	2036.7
11.500	2051.9	2055.8	2048.1	2037.1
11.750	2051.9	2055.8	2048.2	2037.4
12.000	2051.9	2055.8	2048.3	2037.7
12.250	2051.9	2055.9	2048.3	2037.9
12.500	2051.9	2055.9	2048.3	2038.1
12.750	2051.9	2055.9	2048.4	2038.2
13.000	2051.9	2055.9	2048.4	2038.3
13.250	2051.9	2055.9	2048.4	2038.4
13.500	2051.9	2055.9	2048.5	2038.5
13.750	2051.9	2055.9	2048.5	2038.6

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M3   TRANSLATOR OUTPUT$$$

*   CSMP III EXAMPLE PROBLEM 8
*   THIS PROBLEM ILLUSTRATES HOW EXPERIMENTAL DATA CAN BE PLOTTED
INITIAL
DYNAMIC
*
     FUNCTION DATA1=0.0,1.0,4.0,0.5,5.0,0.45,6.0,0.4,8.0,0.55,10.,...
     1.15,11.0,1.3,12.0,1.3,16.0,1.15,18.5,1.17,20.,1.3,21.,1.1,24.,...
     1.0
*
*
     FUNCTION DATA2=0.0,79.,0.79,77.,1.58,75.0,2.37,73.,3.15,70.,...
     3.94,66.,4.73,60.,5.51,50.,6.30 ,33.,7.10,16.
*
     TH1=0.29583*TIME
     FLOW=AFGEN(DATA1,TIME)
     RRATE=NLFGEN(DATA2,TH1)
TERMINAL
     PRINT FLOW,TH1,RRATE
OUTPUT TIME,FLOW
PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
LABEL  FLOW (MGD) VS.  TIME (HRS)
OUTPUT TH1,RRATE
PAGE XYPLOT,HEIGHT=4.0,WIDTH=7.0
LABEL  REMOVAL EFFICIENCY (%) VS. OVERFLOW RATE
TIMER FINTIM=24.,PRDEL=0.5,OUTDEL=0.5
END
STOP

OUTPUT VARIABLE SEQUENCE
FLOW   TH1   RRATE

$$$ TRANSLATION TABLE CONTENTS $$$        CURRENT          MAXIMUM

  MACRO AND STATEMENT OUTPUTS              9                 600
  STATEMENT INPUT WORK AREA               37                1900
  INTEGRATORS+MEMORY BLOCK OUTPUTS         0 +   0           300
  PARAMETERS+FUNCTION GENERATORS           3 +   2           400
  STORAGE VARIABLES+INTEGRATOR ARRAYS      0 +   0/2          50
  HISTORY AND MEMORY BLOCK NAMES          21                  50
  MACRO DEFINITIONS AND NESTED MACROS      6                  50
  MACRO STATEMENT STORAGE                 13                 125
  LITERAL CONSTANT STORAGE                 0                 100
  SORT SECTIONS                            1                  20
  MAXIMUM STATEMENTS IN SECTION            3                 600


$$$END OF TRANSLATOR OUTPUT$$$
```

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	FLOW	TH1	BRATE
.0	1.0000	.0	79.000
.500000	.93750	.14791	78.625
1.00000	.87500	.29583	78.251
1.50000	.81250	.44374	77.877
2.00000	.75000	.59166	77.502
2.50000	.68750	.73957	77.128
3.00000	.62500	.88749	76.753
3.50000	.56250	1.0354	76.379
4.00000	.50000	1.1833	76.004
4.50000	.47500	1.3312	75.630
5.00000	.45000	1.4791	75.255
5.50000	.42500	1.6271	74.881
6.00000	.40000	1.7750	74.506
6.50000	.43750	1.9229	74.132
7.00000	.47500	2.0708	73.757
7.50000	.51250	2.2187	73.383
8.00000	.55000	2.3666	73.009
8.50000	.70000	2.5146	72.521
9.00000	.85000	2.6625	71.994
9.50000	1.0000	2.8104	71.431
10.0000	1.1500	2.9583	70.831
10.5000	1.2250	3.1062	70.195
11.0000	1.3000	3.2541	69.528
11.5000	1.3000	3.4020	68.829
12.0000	1.3000	3.5500	68.096
12.5000	1.2813	3.6979	67.329
13.0000	1.2625	3.8458	66.528
13.5000	1.2437	3.9937	65.655
14.0000	1.2250	4.1416	64.658
14.5000	1.2062	4.2895	63.591
15.0000	1.1875	4.4374	62.454
15.5000	1.1687	4.5854	61.247
16.0000	1.1500	4.7333	59.966
16.5000	1.1540	4.8812	58.378
17.0000	1.1580	5.0291	56.644
17.5000	1.1620	5.1770	54.764
18.0000	1.1660	5.3249	52.739
18.5000	1.1700	5.4728	50.568
19.0000	1.2133	5.6208	48.035
19.5000	1.2567	5.7687	45.197
20.0000	1.3000	5.9166	42.116
20.5000	1.2000	6.0645	38.793
21.0000	1.1000	6.2124	35.227
21.5000	1.0833	6.3603	31.710
22.0000	1.0667	6.5083	28.554
22.5000	1.0500	6.6562	25.405
23.0000	1.0333	6.8041	22.263
23.5000	1.0167	6.9520	19.129
24.0000	1.0000	7.0999	16.002

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III    V1M3    TRANSLATOR OUTPUT$$$

*   MICHAEL K. STENSTROM -- CHE 945 FALL 1973
/      COMMON /NAME1/ A(10,10),B(10,10)
PARAM V=0.2,D=25.,KP=0.30,KI=0.15,KD=0.05,CCONS=8.,FLAG1=-1.
PARAM TSAMP=0.02,TRIM=1.,VNORM=1
TABLE HOCL(1)=6.4E-4,HOCL(2)=-7.3E-4,HOCL(3)=9.12E-4,HOCL(4)=-1.3E-3
TABLE HOCL(5)=2.41E-3,HOCL(6)=-7.23E-3,HOCL(7)=9.35E-02
TABLE SBOD(1)=9.8,SBOD(2)=10.4,SBOD(3)=11.2,SBOD(4)=12.2,SBOD(5)=13.3
TABLE SBOD(6)=14.2,SBOD(7)=14.8,SBOD(8)=15.
TABLE NH3(1)=14.25,NH3(2)=14.25,NH3(3)=14.26,NH3(4)=14.26,...
NH3(5)=14.29,NH3(6)=14.29,NH3(7)=14.29,NH3(8)=17.04
TABLE MICRO(1)=1603.,MICRO(2)=1966.,MICRO(3)=3564.,MICRO(4)=5430.,...
MICRO(5)=9120.,MICRO(6)=13064.,MICRO(7)=16835.,MICRO(8)=20000.
TABLE NH2CL(1)=2.8,NH2CL(2)=3.4,NH2CL(3)=4.23,NH2CL(4)=5.2,NH2CL(5)=6.3
TABLE NH2CL(6)=7.3,NH2CL(7)=7.75,NH2CL(8)=8.0
PARAM L=500.
PARAM HOCLM=5.79E-04,NH3MAX=1.42E-03,NH2CLM=5.79E-04,MM=2.E+04
PARAM SBODM=20.,ERROR1=0.,ERROR2=0.,SHOLD=15.
PARAM K1=2.6E+04,K9=1.67E+04,K11=25.,K12=1.E-04
PARAM N=7
PARAM N1=-1
INITIAL
       FIXED I,J,N,N1
STORAGE HOCL(8),NH3(8),NH2CL(8),SBOD(8),MICRO(8)
      K12P=K12*0.85
       F=L/V
       G1=D/(V*L)
       G2=(K1*L/V)*NH3MAX
       G3=(K1*L/V)*HOCLM
       G4A=(K1*L/V)*(NH3MAX*HOCLM/NH2CLM)
       G4B=(K12*L/V)*SBODM
       G5=(K12*3.45E+04*L/V)*NH2CLM
       G6A=(K9*L/V)*HOCLM
       G6B=(K11*L/V)*NH2CLM
       PT=0.
        THETA=F
        CEFF=2.4
        CREQ=SOLVE(CEFF,SHOLD,THETA,K12P)
NOSORT
       IF(N1) 5,5,6
5      N1=N+1
* CALCULATE THE COEFFICIENTS FOR THE A,B,ARRAYS
       CALL SETUP
6      DO 10 I=1,N
       ICU(I)=HOCL(I)/(HOCLM*3.45E+04)
       ICM(I)=MICRO(I)/MM
       ICQ(I)=NH3(I)/(NH3MAX*1.2E+04)
       ICC(I)=NH2CL(I)/(NH2CLM*3.45E+04)
10     ICS(I)=SBOD(I)/SBODM
SORT
DYNAMIC
       G1=D/(V*L)
       G2=(K1*L/V)*NH3MAX
       G3=(K1*L/V)*HOCLM
       G4A=(K1*L/V)*(NH3MAX*HOCLM/NH2CLM)
       G4B=(K12*L/V)*SBODM
       G5=(K12*3.45E+04*L/V)*NH2CLM
       G6A=(K9*L/V)*HOCLM
       G6B=(K11*L/V)*NH2CLM
```

```
      TV=IMPULS(2.,3.)
      DS=0.*PULSE(0.5,TV)
      BCDI=INTGRL(15.,DS)
      SETP=THETA*NH2CL(1)
      TRIGS=IMPULS(0.,TSAMP)
PROCEDURE VHOLD,SHOLD=DIV(V,BCDI,TRIGS)
      VHOLD=ZHOLD(TRIGS,V)
      SHOLD=ZHOLD(TRIGS,BCDI)
      VHOLD=FCNSW(VHOLD,0.4,0.4,VHOLD)
      SHOLD=FCNSW(SHOLD,15.,15.,SHOLD )
ENDPRO
 PROCEDURE CICR,TRIM,THETA,ERROR,ERROR1,ERROR2,CREQ,CDELAY=CONTRO(...
      U,S,KP,KI,KD,TSAMP,TRIGS)
      IF(TRIGS.LE.0.0) GO TO 1000
      THETA=L/VHOLD
      CEFF=INSW((TIME-2.),1.,1.)
      V=INSW((TIME-2.),0.2,0.4)
      CREQ=SOLVE(CEFF,SHOLD,THETA,K12P)
      CDELAY=PIPE(1000,CEFF,1.02,1.,CEFF,1)
      ERROR=CDELAY-C(1)*NH2CLM*3.45E+04
     DTRIM=KP*(ERROR-ERROR1)+KI*TSAMP*ERROR+KD/TSAMP*(ERROR-2.*ERROR1...
      +ERROR2)
      TRIM=TRIM+DTRIM
      CICR=TRIM*CREQ
      ERROR2=ERROR1
      ERROR1=ERROR
1000    CONTINUE
 ENDPRO
      CCHLO=REALPL(8.0,0.016,CICR)
*     CII=DELAY(100,0.02,CCHLO)
CII=CCHLO
     CI=INSW(FLAG1,CII,CCONS)
      BU=CI/(HOCLM*3.45E+04)
      BM=1.
      BQ=1.
      BC=0.
      BS=BCDI/SBCDM
      U=INTGRL(ICU,UDOT,7)
      S=INTGRL(ICS,SDOT,7)
      Q=INTGRL(ICQ,QDOT,7)
      M=INTGRL(ICM,MDOT,7)
      C=INTGRL(ICC,CDOT,7)
PROCEDURE UDOT,QDOT,MDOT,CDOT,SDOT=SOLVE(U,Q,M,C,S,G1,G2,G3,G4A,...
G4B,G5,G6A,G6B,N,BU,BQ,BS,BC,BM)
      DO 20 J=1,N
      UDOT(J)=(G1*B(J,1)+A(J,1))*U(1)+(G1*B(J,2)+A(J,2))*U(2)+ ...
      (G1*B(J,3)+A(J,3))*U(3)+(G1*B(J,4)+A(J,4))*U(4)+(G1*B(J,5) ...
      +A(J,5))*U(5)+(G1*B(J,6)+A(J,6))*U(6)+(G1*B(J,7)+A(J,7))*U(7)...
      +(G1*B(J,8)+A(J,8))*BU    -G2*Q(J)*U(J)
      QDOT(J)=(G1*B(J,1)+A(J,1))*Q(1)+(G1*B(J,2)+A(J,2))*Q(2)+ ...
      (G1*B(J,3)+A(J,3))*Q(3)+(G1*B(J,4)+A(J,4))*Q(4)+(G1*B(J,5) ...
      +A(J,5))*Q(5)+(G1*B(J,6)+A(J,6))*Q(6)+(G1*B(J,7)+A(J,7))*Q(7)...
      +(G1*B(J,8)+A(J,8))*BQ    -G3*Q(J)*U(J)
      CDOT(J)=(G1*B(J,1)+A(J,1))*C(1)+(G1*B(J,2)+A(J,2))*C(2)+ ...
      (G1*B(J,3)+A(J,3))*C(3)+(G1*B(J,4)+A(J,4))*C(4)+(G1*B(J,5) ...
      +A(J,5))*C(5)+(G1*B(J,6)+A(J,6))*C(6)+(G1*B(J,7)+A(J,7))*C(7)...
      +(G1*B(J,8)+A(J,8))*BC+G4A*Q(J)*U(J)-G4B*S(J)*C(J)
      SDOT(J)=(G1*B(J,1)+A(J,1))*S(1)+(G1*B(J,2)+A(J,2))*S(2)+ ...
      (G1*B(J,3)+A(J,3))*S(3)+(G1*B(J,4)+A(J,4))*S(4)+(G1*B(J,5) ...
```

```
       +A(J,5))*S(5)+(G1*B(J,6)+A(J,6))*S(6)+(G1*B(J,7)+A(J,7))*S(7)...
       +(G1*B(J,8)+A(J,8))*BS-G5*S(J)*C(J)
       MDOT(J)=(G1*B(J,1)+A(J,1))*M(1)+(G1*B(J,2)+A(J,2))*M(2)+ ...
       (G1*B(J,3)+A(J,3))*M(3)+(G1*B(J,4)+A(J,4))*M(4)+(G1*B(J,5) ...
       +A(J,5))*M(5)+(G1*B(J,6)+A(J,6))*M(6)+(G1*B(J,7)+A(J,7))*M(7)...
       +(G1*B(J,8)+A(J,8))*BM-G6A*M(J)*U(J)-G6B*M(J)*C(J)
 20    CONTINUE
 ENDPRO
 PROCEDURE TH1,HOCL,MICRO,NH2CL,SBOD,NH3=CONV(M,C,Q,U,S,BM,BC,BU,BS,BQ)
        DO 30 I=1,N
        HOCL(I)=HOCLM*U(I)*3.45E+04
        NH3(I)=NH3MAX*Q(I)*1.2E+04
        NH2CL(I)=C(I)*NH2CLM*3.45E+04
        SBOD(I)=SBODM*S(I)
 30     MICRO(I)=M(I)*MM
       MICRO(N+1)=MM*BM
       HOCL(N+1)=HOCLM*BU*3.45E+04
       NH3(N+1)=NH3MAX*BQ*1.2E+04
       SBOD(N+1)=SBODM*BS
       TH1=TIME*L/V
       IF(KEEP.NE.1) GO TO 200
       IF(TIME.LT.PT) GO TO 200
       PT=PT+PRDEL
 *     CALL SAMPLE(U,S,L,TH1,SMAX,CMAX)
 200   CONTINUE
 ENDPRO
 NOSORT
 CALL DEBUG(1,0.0)
 TERMINAL
 *
 METHOD STIFF
 TIMER FINTIM=6.0,OUTDEL=0.02,PRDEL=0.1,DELMIN=1.E-11,DELMAX=1.E-03,...
 DELT=1.E-06
 TERMINAL
 PRINT HOCL(1-8),SBOD(1-8),NH3(1-8),MICRO(1-8),NH2CL(1-8),TH1,...
 CEFF,CREQ,CDELAY,CICR,CCHLO,CI,TRIM,ERROR,VHOLD,SHCID
 *OUTPUT NH2CL(1),CEFF,CDELAY
 *PAGE WIDTH=58,GROUP
 *OUTPUT SETP
 END
 STOP

OUTPUT VARIABLE SEQUENCE
G1     G2     G3     G4A    G4B    G5     G6A    G6B    PT     CEFF
F      THETA  K12P   CREQ   ZZ1000 N1     TV     DS     BODI   TRIGS
CICR   ZZ1011 CCHLO  G1     G2     G3     G4A    G4B    G5     G6A
G6B    CII    CI     BU     BQ     BS     BC     BM     UDOT   U
SDOT   S      QDOT   Q      MDOT   M      CDOT   C      THETA  TH1
NH2CL  SETP   VHOLD  SHOLD  TRIM   ERROR  ERROR1 ERROR2 CREQ   CDELAY
ZZ1005 ZZ1008 HOCL   MICRO  SBOD   NH3    ZZ1017
```

$$$ TRANSLATION TABLE CONTENTS $$$

	CURRENT	MAXIMUM
MACRO AND STATEMENT OUTPUTS	75	600
STATEMENT INPUT WORK AREA	212	1900
INTEGRATORS+MEMORY BLOCK OUTPUTS	9 + 0	300
PARAMETERS+FUNCTION GENERATORS	31 + 0	400
STORAGE VARIABLES+INTEGRATOR ARRAYS	5 + 5/2	50
HISTORY AND MEMORY BLOCK NAMES	21	50
MACRO DEFINITIONS AND NESTED MACROS	6	50
MACRO STATEMENT STORAGE	13	125
LITERAL CONSTANT STORAGE	2	100
SORT SECTIONS	2	20
MAXIMUM STATEMENTS IN SECTION	86	600

```
      SUBROUTINE SAMPLE(ID,U,S,L,TH1,SMAX,CMAX)
      REAL L
      DOUBLE PRECISION A(100),B(100),C(100),D(100),Q(100),Z,DUMU(10),
     1 DUMS(10),DU(10),DS(10)
      DIMENSION U(1),S(1)
      COMMON /NAME2/ A,B,C,D,Q
      DATA N/7/
      N1=N+1
      DO 10 I=1,N
      DUMU(I)=U(I)
10    DUMS(I)=S(I)
      DUMU(N1)=1.0
      DUMS(N1)=1.0
      CALL GMPRD(Q,DUMU,DU,N1,N1,1)
      CALL GMPRD(Q,DUMS,DS,N1,N1,1)
C.. REUSE THE DUMU AND DUMS ARRAYS
      DO 15 I=1,10
      DUMU(I)=0.
15    DUMS(I)=0.
      X=0.1
      DO 30 J=1,9
      DO 20 I=1,N1
      DUMU(J)=X**(2*I-2)*DU(I)+DUMU(J)
20    DUMS(J)=X**(2*I-2)*DS(I)+DUMS(J)
30    X=X+0.1
      DUMU(10)=1.
      DUMS(10)=1.
      WRITE(3,35) TH1
35    FORMAT('  DISTANCE',5X,'CONCENTRATION 1',5X,'CONCENTRATION  2',
     1 5X, ' TH1=', F6.0)
      X=0.
      DO 40 I=1, 10
      J=11-I
      DUMS(J)=DUMS(J)*SMAX
      DUMU(J)=DUMU(J)*CMAX
      X1=X*L
      WRITE(3,50) X1,DUMU(J),DUMS(J)
40    X=X+0.1
50    FORMAT(' ',F5.0,7X,2(D15.7,5X))
      X1=500.
      DS(1)=DS(1)*SMAX
      DU(1)=DU(1)*CMAX
      WRITE(3,50) X1,DU(1),DS(1)
```

```
      RETURN
      END
      SUBROUTINE SETUP
C.. MICHAEL K. STENSTROM
C   CHE 945 FALL 1973
C   PROGRAM FOR DEVELOPING THE A AND B ARRAYS FOR N1 COLLOCATION POINTS
      DIMENSION L1(10),M1(10)
      DOUBLE PRECISION A(100),B(100),C(100),Q(100),R(10),Z,D(100)
      COMMON /NAME1/ A1(10,10),B1(10,10)
      COMMON /NAME2/ A,B,C,D,Q
      DATA N/7/
      DATA R / 0.10805494871 , 0.31911236893 , 0.51524863636 ,
     1 0.68729290481 , 0.82720131507 , 0.92843488366 , 0.98628380870,
     2 1.0D+00, 2*0.D+00 /
      N1=N+1
      WRITE(3,1015) N1
1015  FORMAT('1 MICHAEL K. STENSTROM',/,' CH.E. 945 FALL 1973',/,' GENER
     1AL PROGRAM FOR CALCULATING COLLOCATION MATRICIES FOR N1 COLLOCATIO
     2N POINTS',/,' N1=',I2)
      WRITE(3,1011)  (R(I),I=1,N1)
1011  FORMAT(' ROOTS',/,'0',10(D18.10,/,' '))
C.. GENERATE THE C,D,AND Q ARRAYS
      DO 10 I=1,N1
      DO 10 J=1,N1
      IN1=(I-1)*N1+J
      Q(IN1)=R(J)**(2*I-2)
      C(IN1)=FLOAT(2*I-2)*R(J)**(2*I-3)
      D(IN1)=FLOAT(4*I**2-10*I+6)*R(J)**(2*I-4)
10    CONTINUE
C.. WRITE OUT THE C,D,AND Q MATRIX
      WRITE(3,1020)
1020  FORMAT('  C MATRIX')
      CALL MWRITE(C,N1)
      WRITE(3,1030)
1030  FORMAT('- D MATRIX')
      CALL MWRITE(D,N1)
      WRITE(3,1040)
1040  FORMAT('- Q MATRIX')
      CALL MWRITE(Q,N1)
C.. INVERT THE Q ARRAY
      CALL MINV(Q,N1,Z,L1,M1)
C.. WRITE OUT THE INVERSE OF Q
      WRITE(3,1050)
1050  FORMAT('- Q INVERSE MATRIX')
      CALL MWRITE(Q,N1)
C.. MULTIPLY THE C,D,AND Q INVERSE ARRAYS TO GET A AND B
      CALL GMPRD(C,Q,A,N1,N1,N1)
      CALL GMPRD(D,Q,B,N1,N1,N1)
C.. WRITE OUT THE A AND B MATRICES
      WRITE(3,1060)
1060  FORMAT('- A MATRIX')
      CALL MWRITE(A,N1)
      WRITE(3,1070)
1070  FORMAT('- B MATRIX')
      CALL MWRITE(B,N1)
C.. INSERT THE COEFFICIENTS INTO THE ARRAYS TO BE USED BY CSMP
      DO 20 J=1,N1
      IK=N1*(N1-1)+J
      IJ=0
```

```
      DO 20 I=J,IK,N1
      IJ=IJ+1
      B1(J,IJ)=B(I)
20    A1(J,IJ)=A(I)
      RETURN
      END
      SUBROUTINE MWRITE(A,N1)
      DOUBLE PRECISION A(1)
      DO 10  J=1,N1
      IK=N1*(N1-1)+J
10    WRITE(3,1000)  (A(I),I=J,IK,N1)
1000  FORMAT(' ',8(D14.7,2X),/,8X,2(D15.7,2X))
      RETURN
      END
      SUBROUTINE MINV(A,N,D,L,M)
      DOUBLE PRECISION A,D,BIGA,HOLD,DABS
      DIMENSION A(1),L(1),M(1)
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
10    IF(DABS(BIGA)-DABS(A(IJ)))  15,20,20
15    BIGA=A(IJ)
      L(K)=I
      M(K)=J
20    CONTINUE
C
C     INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K)  35,35,25
25    KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
30    A(JI)=HOLD
C
C     INTERCHANGE COLUMNS
35    I=M(K)
      IF(I-K)  45,45,38
38    JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
40    A(JI)=HOLD
C
45    IF(BIGA)  48,46,48
```

```
46    D=0.
      RETURN
48    DO 55 I=1,N
      IF (I-K) 50,55,50
 50     IK=NK+I
      A(IK)=A(IK)/(-BIGA)
55    CONTINUE
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF (I-K) 60,65,60
60    IF(J-K) 62,65,62
62    KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
65    CONTINUE
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
70    A(KJ)=A(KJ)/BIGA
75    CONTINUE
      D=D*BIGA
      A(KK)=1.0/BIGA
80    CONTINUE
      K=N
100   K=(K-1)
      IF(K) 150,150,105
105   I=L(K)
      IF(I-K) 120,120,108
108   JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
      A(JK)=-A(JI)
110   A(JI)=HOLD
120   J=M(K)
      IF (J-K) 100,100,125
125   KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
130   A(JI)=HOLD
      GO TO 100
150   RETURN
      END
      SUBROUTINE GMPRD(A,B,R,N,M,L)
      DIMENSION A(1),B(1),R(1)
      DOUBLE PRECISION A,B,R
      IR=0
      IK=-M
      DO 10 K=1,L
      IK=IK+M
```

```
      DO 10 J=1,N
      IR=IR+1
      JI=J-N
      IB=IK
      R(IR)=0.
      DO 10 I=1,M
      JI=JI+N
      IB=IB+1
10    R(IR)=R(IR)+A(JI)*B(IB)
      RETURN
      END
       FUNCTION SOLVE(CEFF,SHOLD,THETA,K1)
       REAL K1,K2
       DATA CO/8.0/,K2/1./
       NC=2
      I=1
 5     P=(SHOLD-K2*CO)*THETA*K1
       COP=CEFF*SHOLD*EXP(P)/(SHOLD+CEFF*K2-K2*CO)
        WRITE(33,1000) CO,COP,I,CEFF
1000      FORMAT(1X,'CO=',E17.6,5X,'COP=',E17.6,4X,I3)
          I=I+1
       CALL CONV(CO,COP,1,NC)
       IF(NC-1)  5 ,20,5
 20    SOLVE=COP
       RETURN
       END
      SUBROUTINE CONV(X,Y,NR,NC)
      DIMENSION XA(10),YA(10)
      IF(ABS((X-Y)/(X+Y)).LT.0.001) GO TO 6
      IF(NC.LE.1) GO TO 5
      XT=(XA(NR)*Y-YA(NR)*X)/(XA(NR)-X+Y-YA(NR))
      XA(NR)=X
      YA(NR)=Y
      X=XT
      RETURN
 5    XA(NR)=X
      YA(NR)=Y
      X=Y
      NC=2
      RETURN
 6     X=Y
       NC=1
       RETURN
       END


$$$END OF TRANSLATOR OUTPUT$$$
```

MICHAEL K. STENSTROM
CH.E. 945 FALL 1973
GENERAL PROGRAM FOR CALCULATING COLLOCATION MATRICIES FOR N1 COLLOCATION POINTS
N1= 8
ROOTS

0.1080549359D+00
0.3191123605D+00
0.5152486563D+00
0.6872929335D+00
0.8272013068D+00
0.9284349084D+00
0.9862837791D+00
0.1000000000D+01

C MATRIX

0.0	0.2161099D+00	0.5046541D-02	0.8838413D-04	0.1375949D-05	0.2008175D-07	0.2813662D-09	0.3832728D-11
0.0	0.6382247D+00	0.1299843D+00	0.1985498D-01	0.2695848D-02	0.3431568D-03	0.4193350D-04	0.4981902D-05
0.0	0.1030497D+01	0.5471553D+00	0.2178891D+00	0.7712729D-01	0.2559480D-01	0.8153926D-02	0.2525500D-02
0.0	0.1374586D+01	0.1298631D+01	0.9201543D+00	0.5795396D+00	0.3421976D+00	0.1939733D+00	0.1068987D+00
0.0	0.1654403D+01	0.2264090D+01	0.2323846D+01	0.2120159D+01	0.1813430D+01	0.1489034D+01	0.1188704D+01
0.0	0.1856870D+01	0.3201212D+01	0.4139125D+01	0.4757187D+01	0.5125818D+01	0.5302093D+01	0.5332085D+01
0.0	0.1972568D+01	0.3837653D+01	0.5599648D+01	0.7262786D+01	0.8831145D+01	0.1030866D+02	0.1169910D+02
0.0	0.2000000D+01	0.4000000D+01	0.6000000D+01	0.8000000D+01	0.1000000D+02	0.1200000D+02	0.1400000D+02

D MATRIX

0.0	0.2000000D+01	0.1401104D+00	0.4089778D-02	0.8913652D-04	0.1672628D-05	0.2864310D-07	0.4611123D-09
0.0	0.2000000D+01	0.1221992D+01	0.3110970D+00	0.5913571D-01	0.9678132D-02	0.1445474D-02	0.2029527D-03
0.0	0.2000000D+01	0.3185774D+01	0.2114408D+01	0.1047826D+01	0.4470720D+00	0.1740775D+00	0.6371971D-01
0.0	0.2000000D+01	0.5668459D+01	0.6694047D+01	0.5902545D+01	0.4481027D+01	0.3104508D+01	0.2021966D+01
0.0	0.2000000D+01	0.8211144D+01	0.1404643D+02	0.1794136D+02	0.1973023D+02	0.1980095D+02	0.1868125D+02
0.0	0.2000000D+01	0.1034390D+02	0.2229087D+02	0.3586714D+02	0.4968831D+02	0.6281864D+02	0.7466016D+02
0.0	0.2000000D+01	0.1167307D+02	0.2838761D+02	0.5154652D+02	0.8058564D+02	0.1149722D+03	0.1542034D+03
0.0	0.2000000D+01	0.1200000D+02	0.3000000D+02	0.5600000D+02	0.9000000D+02	0.1320000D+03	0.1820000D+03

Q MATRIX

0.1000000D+01	0.1167587D-01	0.1363259D-03	0.1591724D-05	0.1858476D-07	0.2169932D-09	0.2533584D-11	0.2958180D-13
0.1000000D+01	0.1018327D+00	0.1036990D-01	0.1055995D-02	0.1075348D-03	0.1095056D-04	0.1115125D-05	0.1135562D-06
0.1000000D+01	0.2654812D+00	0.7048026D-01	0.1871118D-01	0.4967466D-02	0.1318769D-02	0.3501083D-03	0.9294717D-04
0.1000000D+01	0.4723716D+00	0.2231349D+00	0.1054026D+00	0.4978919D-01	0.2351900D-01	0.1110971D-01	0.5247909D-02
0.1000000D+01	0.6842620D+00	0.4682145D+00	0.3203814D+00	0.2192248D+00	0.1500072D+00	0.1026442D+00	0.7023555D-01

0.1000000D+01	0.8619914D+00	0.7430291D+00	0.6404847D+00	0.5520923D+00	0.4758988D+00	0.4102207D+00	0.3536067D+00
0.1000000D+01	0.9727557D+00	0.9462536D+00	0.9204736D+00	0.8953959D+00	0.8710015D+00	0.8472717D+00	0.8241883D+00
0.1000000D+01	0.1000000D+01	0.1000000D+01	0.1000000D+01	0.1000000D+01	0.1000000D+01	0.1000000D+01	0.1000000D+01

Q INVERSE MATRIX

0.1279480D+01	-0.4437179D+00	0.2889620D+00	-0.2352702D+00	0.2221719D+00	-0.2431709D+00	0.3410175D+00	-0.2094723D+00
-0.2604163D+02	0.4267679D+02	-0.2954153D+02	0.2444059D+02	-0.2322553D+02	0.2549402D+02	-0.3579729D+02	0.2199459D+02
0.1878374D+03	-0.4195398D+03	0.4348629D+03	-0.3929207D+03	0.3859624D+03	-0.4300174D+03	0.6077233D+03	-0.3739081D+03
-0.6607421D+03	0.1688376D+04	-0.2144496D+04	0.2247884D+04	-0.2344174D+04	0.2684243D+04	-0.3839176D+04	0.2368084D+04
0.1267694D+04	-0.3485028D+04	0.4989095D+04	-0.5880203D+04	0.6620771D+04	-0.7882189D+04	0.1147411D+05	-0.7104253D+04
-0.1356530D+04	0.3900292D+04	-0.6034391D+04	0.7765695D+04	-0.9412781D+04	0.1174860D+05	-0.1750407D+05	0.1089319D+05
0.7611251D+03	-0.2254500D+04	0.3680890D+04	-0.5063716D+04	0.6550229D+04	-0.8596031D+04	0.1317442D+05	-0.8252415D+04
-0.1746223D+03	0.5281669D+03	-0.8967087D+03	0.1299055D+04	-0.1777004D+04	0.2450143D+04	-0.3877549D+04	0.2448519D+04

A MATRIX

-0.4736606D+01	0.7250158D+01	-0.4372458D+01	0.3489703D+01	-0.3269757D+01	0.3566041D+01	-0.4993129D+01	0.3066048D+01
-0.2340472D+01	-0.1922138D+01	0.6621279D+01	-0.4236394D+01	0.3686783D+01	-0.3894840D+01	0.5379972D+01	-0.3294190D+01
0.7906684D+00	-0.3708981D+01	-0.1671884D+01	0.7215772D+01	-0.4876375D+01	0.4720294D+01	-0.6300351D+01	0.3830857D+01
-0.4010788D+00	0.1508279D+01	-0.4586224D+01	-0.2030103D+01	0.8874037D+01	-0.6654181D+01	0.8199701D+01	-0.4910429D+01
0.2417155D+00	-0.8442689D+00	0.1993506D+01	-0.5707806D+01	-0.3224341D+01	0.1283468D+02	-0.1251336D+02	0.7219871D+01
-0.1556358D+00	0.5265709D+00	-0.1139262D+01	0.2526834D+01	-0.7577382D+01	-0.7265932D+01	0.2653062D+02	-0.1344582D+02
0.9243038D-01	-0.3085077D+00	0.6449677D+00	-0.1320683D+01	0.3133478D+01	-0.1125294D+02	-0.3670832D+02	0.4571958D+02
-0.1443201D+00	0.4803308D+00	-0.9971834D+00	0.2011065D+01	-0.4597144D+01	0.1450146D+02	-0.1162541D+03	0.1049998D+03

B MATRIX

-0.2835683D+02	0.3317257D+02	-0.6490027D+01	0.2510941D+01	-0.1386256D+01	0.1032884D+01	-0.1153724D+01	0.6704382D+00
0.3479974D+02	-0.7356590D+02	0.4694065D+02	-0.1158342D+02	0.5460171D+01	-0.3772561D+01	0.4062121D+01	-0.2340811D+01
-0.7529800D+01	0.5191458D+02	-0.9452700D+02	0.6175844D+02	-0.1715732D+02	0.9686651D+01	-0.9520065D+01	0.5374513D+01
0.3438311D+01	-0.1511991D+02	0.7289015D+02	-0.1345048D+03	0.9201733D+02	-0.2961652D+02	0.2368811D+02	-0.1279269D+02
-0.2455664D+01	0.9220115D+01	-0.2619632D+02	0.1190387D+03	-0.2311797D+03	0.1716935D+03	-0.7795146D+02	0.3783071D+02
0.2773783D+01	-0.9657449D+01	0.2242131D+02	-0.5808302D+02	0.2602850D+03	-0.5693933D+03	0.5325631D+03	-0.1809094D+03
-0.7071630D+01	0.2373429D+02	-0.5029501D+02	0.1060336D+03	-0.2697225D+03	0.1215544D+04	-0.4328463D+04	0.3310240D+04
-0.2986740D+02	0.9921050D+02	-0.2049750D+03	0.4090880D+03	-0.9117560D+03	0.2639498D+04	-0.7461189D+04	0.5459991D+04

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	.0	.10000	.20000	.30000	.40000	.50000	.60000	.70000	.80000
HOCL(1)	6.4000E-04	1.4092E-04	1.5000E-04	1.7678E-04	2.0110E-04	2.1794E-04	2.2559E-04	2.2647E-04	2.2427E-04
HOCL(2)	-7.3000E-04	-1.6860E-04	-1.7724E-04	-2.0830E-04	-2.3772E-04	-2.5886E-04	-2.6910E-04	-2.7103E-04	-2.6894E-04
HOCL(3)	9.1200E-04	2.2110E-04	2.3013E-04	2.7179E-04	3.1237E-04	3.4243E-04	3.5762E-04	3.6119E-04	3.5882E-04
HOCL(4)	-1.3000E-03	-3.3209E-04	-3.5123E-04	-4.1902E-04	-4.8547E-04	-5.3493E-04	-5.6040E-04	-5.6643E-04	-5.6242E-04
HOCL(5)	2.4100E-03	6.5750E-04	7.0901E-04	8.5311E-04	9.9466E-04	1.0995E-03	1.1528E-03	1.1644E-03	1.1553E-03
HOCL(6)	-7.2300E-03	-2.2731E-03	-2.4567E-03	-2.9723E-03	-3.4765E-03	-3.8485E-03	-4.0355E-03	-4.0728E-03	-4.0365E-03
HOCL(7)	9.3500E-02	3.4357E-02	3.7025E-02	4.4925E-02	5.2633E-02	5.8307E-02	6.1106E-02	6.1625E-02	6.1041E-02
HOCL(8)	8.0000	3.4259	3.6690	4.3866	5.0640	5.5499	5.7849	5.8277	5.7786
SBOD(1)	9.8000	9.5894	9.4533	9.5656	9.8187	10.086	10.296	10.428	10.492
SBOD(2)	10.400	10.073	10.091	10.308	10.540	10.719	10.827	10.874	10.882
SBOD(3)	11.200	10.932	11.162	11.373	11.508	11.562	11.560	11.532	11.500
SBOD(4)	12.200	12.178	12.372	12.466	12.483	12.446	12.389	12.337	12.304
SBOD(5)	13.300	13.437	13.466	13.466	13.421	13.359	13.303	13.265	13.247
SBOD(6)	14.200	14.346	14.329	14.306	14.266	14.226	14.196	14.180	14.174
SBOD(7)	14.800	14.871	14.866	14.859	14.849	14.839	14.833	14.830	14.829
SBOD(8)	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
NH3(1)	14.250	14.252	14.338	14.542	14.753	14.916	15.020	15.071	15.088
NH3(2)	14.250	14.285	14.552	14.799	14.967	15.060	15.098	15.102	15.091
NH3(3)	14.260	14.523	14.940	15.121	15.186	15.181	15.146	15.107	15.079
NH3(4)	14.260	15.136	15.324	15.352	15.293	15.207	15.130	15.078	15.055
NH3(5)	14.290	15.685	15.575	15.470	15.315	15.178	15.087	15.045	15.038
NH3(6)	14.290	15.849	15.701	15.510	15.301	15.140	15.050	15.022	15.030
NH3(7)	14.290	15.865	15.766	15.531	15.302	15.136	15.053	15.036	15.051
NH3(8)	17.040	17.040	17.040	17.040	17.040	17.040	17.040	17.040	17.040
MICRO(1)	1603.0	1297.3	1330.0	1720.4	2203.4	2590.7	2803.7	2854.9	2805.9
MICRO(2)	1966.0	1751.9	2185.2	2776.7	3195.4	3387.8	3396.4	3305.0	3189.2
MICRO(3)	3564.0	3357.7	4437.7	4981.0	5142.6	5036.8	4821.2	4612.6	4466.9
MICRO(4)	5430.0	6817.9	7529.1	7623.2	7378.0	7005.8	6669.7	6445.1	6337.3
MICRO(5)	9120.0	11619.	11401.	11123.	10653.	10214.	9906.4	9748.1	9703.7
MICRO(6)	13064.	15578.	15219.	14837.	14384.	14018.	13801.	13717.	13716.
MICRO(7)	16835.	18366.	18233.	17987.	17737.	17550.	17453.	17427.	17439.
MICRO(8)	20000.	20000.	20000.	20000.	20000.	20000.	20000.	20000.	20000.
NH2CL(1)	2.8000	2.5909	2.2231	1.7557	1.4046	1.2013	1.1126	1.0938	1.1074
NH2CL(2)	3.4000	2.9991	2.2589	1.7634	1.5117	1.4196	1.4169	1.4509	1.4883
NH2CL(3)	4.2300	3.1973	2.2197	1.9053	1.8482	1.9116	2.0091	2.0919	2.1405
NH2CL(4)	5.2000	2.6889	2.3238	2.3300	2.5097	2.7177	2.8828	2.9781	3.0099
NH2CL(5)	6.3000	2.3579	2.6882	2.9847	3.3819	3.7126	3.9178	4.0008	4.0022
NH2CL(6)	7.3000	2.7815	3.1809	3.7078	4.2667	4.6900	4.9176	4.9810	4.9542
NH2CL(7)	7.7500	3.2516	3.5281	4.1987	4.8448	5.3125	5.5443	5.5912	5.5467
NH2CL(8)	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000
TH1	.0	250.00	500.00	750.00	1000.0	1250.0	1500.0	1750.0	2000.0
CEFF	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CREQ	4.0206	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748
CDELAY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CICR	-16.265	4.5513	5.7522	6.4066	6.4138	6.2528	6.0352	5.8259	5.6803
CCHLO	8.0000	3.4259	3.6690	4.3866	5.0640	5.5499	5.7849	5.8277	5.7786
CI	8.0000	3.4259	3.6690	4.3866	5.0640	5.5499	5.7849	5.8277	5.7786
TRIM	-4.0454	.55674	.70365	.78370	.78459	.76489	.73827	.71267	.69486
ERROR	-1.8000	-1.5909	-1.2231	-.75570	-.40459	-.20135	-.11260	-9.3789E-02	-.10741
VHOLD	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000
SHOLD	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000

CSMP III VERSION V1M3 SIMULATION OUTPUT

TIME	.90000	1.0000	1.1000	1.2000	1.3000	1.4000	1.5000	1.6000	1.7000
HOCL(1)	2.2104E-04	2.1791E-04	2.1535E-04	2.1394E-04	2.1296E-04	2.1211E-04	2.1133E-04	2.1065E-04	2.0987E-04
HOCL(2)	-2.6520E-04	-2.6146E-04	-2.5831E-04	-2.5653E-04	-2.5529E-04	-2.5431E-04	-2.5331E-04	-2.5245E-04	-2.5151E-04
HOCL(3)	3.5388E-04	3.4871E-04	3.4436E-04	3.4184E-04	3.4008E-04	3.3863E-04	3.3734E-04	3.3629E-04	3.3503E-04
HOCL(4)	-5.5436E-04	-5.4587E-04	-5.3874E-04	-5.3461E-04	-5.3186E-04	-5.2960E-04	-5.2770E-04	-5.2597E-04	-5.2405E-04
HOCL(5)	1.1374E-03	1.1192E-03	1.1042E-03	1.0956E-03	1.0901E-03	1.0855E-03	1.0815E-03	1.0782E-03	1.0743E-03
HOCL(6)	-3.9710E-03	-3.9067E-03	-3.8540E-03	-3.8245E-03	-3.8045E-03	-3.7889E-03	-3.7754E-03	-3.7638E-03	-3.7501E-03
HOCL(7)	6.0031E-02	5.9033E-02	5.8235E-02	5.7796E-02	5.7506E-02	5.7271E-02	5.7062E-02	5.6890E-02	5.6688E-02
HOCL(8)	5.6935	5.6095	5.5414	5.5042	5.4801	5.4601	5.4424	5.4278	5.4105
SBOD(1)	10.510	10.505	10.496	10.490	10.492	10.500	10.513	10.528	10.544
SBOD(2)	10.873	10.861	10.855	10.856	10.864	10.876	10.890	10.905	10.920
SBOD(3)	11.478	11.468	11.470	11.479	11.492	11.506	11.520	11.533	11.545
SBOD(4)	12.289	12.288	12.297	12.310	12.323	12.335	12.346	12.355	12.364
SBOD(5)	13.243	13.249	13.259	13.270	13.279	13.286	13.293	13.299	13.304
SBOD(6)	14.175	14.180	14.186	14.192	14.196	14.199	14.202	14.205	14.207
SBOD(7)	14.830	14.831	14.832	14.833	14.834	14.835	14.835	14.836	14.837
SBOD(8)	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
NH3(1)	15.087	15.079	15.073	15.071	15.073	15.079	15.086	15.094	15.102
NH3(2)	15.079	15.071	15.069	15.072	15.079	15.087	15.095	15.103	15.111
NH3(3)	15.065	15.063	15.069	15.079	15.090	15.099	15.108	15.116	15.123
NH3(4)	15.053	15.062	15.077	15.092	15.103	15.113	15.121	15.128	15.134
NH3(5)	15.050	15.070	15.091	15.106	15.117	15.125	15.132	15.139	15.145
NH3(6)	15.052	15.079	15.102	15.116	15.126	15.133	15.139	15.145	15.151
NH3(7)	15.079	15.108	15.131	15.144	15.153	15.159	15.166	15.171	15.177
NH3(8)	17.040	17.040	17.040	17.040	17.040	17.040	17.040	17.040	17.040
MICRO(1)	2721.5	2645.0	2595.2	2574.4	2576.4	2592.3	2614.1	2637.1	2659.2
MICRO(2)	3094.7	3037.5	3015.9	3020.7	3041.0	3067.1	3093.5	3118.2	3140.9
MICRO(3)	4391.4	4370.9	4385.4	4418.0	4454.0	4486.2	4513.8	4537.9	4559.6
MICRO(4)	6313.9	6339.4	6386.8	6437.6	6479.0	6511.2	6537.6	6560.9	6582.0
MICRO(5)	9725.5	9776.4	9834.1	9882.6	9916.4	9941.8	9962.6	9981.6	9999.4
MICRO(6)	13756.	13809.	13858.	13893.	13916.	13933.	13947.	13960.	13974.
MICRO(7)	17468.	17498.	17524.	17539.	17549.	17557.	17564.	17570.	17577.
MICRO(8)	20000.	20000.	20000.	20000.	20000.	20000.	20000.	20000.	20000.
NH2CL(1)	1.1285	1.1446	1.1520	1.1513	1.1455	1.1374	1.1290	1.1213	1.1143
NH2CL(2)	1.5136	1.5240	1.5224	1.5135	1.5018	1.4905	1.4805	1.4719	1.4642
NH2CL(3)	2.1574	2.1524	2.1361	2.1160	2.0981	2.0841	2.0726	2.0628	2.0542
NH2CL(4)	3.0015	2.9738	2.9408	2.9113	2.8904	2.8753	2.8628	2.8516	2.8415
NH2CL(5)	3.9631	3.9118	3.8632	3.8284	3.8064	3.7902	3.7766	3.7642	3.7519
NH2CL(6)	4.8893	4.8189	4.7590	4.7224	4.6987	4.6813	4.6658	4.6526	4.6374
NH2CL(7)	5.4667	5.3861	5.3195	5.2840	5.2603	5.2416	5.2239	5.2101	5.1933
NH2CL(8)	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000
TH1	2250.0	2500.0	2750.0	3000.0	3250.0	3500.0	3750.0	4000.0	4250.0
CEFF	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CREQ	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748	8.1748
CDELAY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CICP	5.5906	5.5417	5.5158	5.5120	5.5070	5.4937	5.4740	5.4564	5.4354
CCHLO	5.6935	5.6095	5.5414	5.5042	5.4801	5.4601	5.4424	5.4278	5.4105
CI	5.6935	5.6095	5.5414	5.5042	5.4801	5.4601	5.4424	5.4278	5.4105
TRIM	.68389	.67790	.67473	.67427	.67366	.67203	.66962	.66746	.66489
ERROR	-.12854	-.14463	-.15196	-.15135	-.14551	-.13736	-.12901	-.12126	-.11434
VHOLD	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000	.20000
SHOLD	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000