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Chapter 2.1 SAMBA Computer Program

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The SPOC Manual

Chapter 2.1 SAMBA Computer Program

SAMBA - Program for Sensitivity Analysis of Sampling Data Used for Material Balance Computations

H.W. Smith, D. Burroughs, D. Laguitton

Editor: D. Laguitton

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Mineral Processing Plant Simulation
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THE SPOC MANUAL

The **SPOC*** manual consists of eighteen chapters, published separately. Their numbers and short titles are as follows:

1. Summary
2. Sampling Methodology
2.1 SAMBA Computer Program
2.2 Grinding Circuit Sampling
3. Material Balance
3.1 BILMAT Computer Program
3.2 MATBAL Computer Program
4. Modelling and Simulation
4.1 Industrial Ball Mill Modelling
5. Unit Models: Part A
5.1 Unit Models: Part B
5.2 Unit Models: Part C
6. Flowsheet Simulators
7. Model Calibration
7.1 STAMP Computer Program
7.2 FINDBS Computer Program
7.3 RTD and MIXERS Computer Programs
8. Miscellaneous Computer Programs

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Technology Information Division
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Ottawa, Ontario

*Simulated Processing of Ore and Coal

FOREWORD

High energy costs and depleting ore reserves combine to make process evaluation and optimization a challenging goal in the 80's. The spectacular growth of computer technology in the same period has resulted in widely available computing power that can be distributed to the most remote mineral processing operations. The SPOC project, initiated at CANMET in 1980, has undertaken to provide Canadian industry with a coherent methodology for process evaluation and optimization assisted by computers. The SPOC Manual constitutes the written base of this methodology and covers most aspects of steady-state process evaluation and simulation. It is expected to facilitate industrial initiatives in data collection and model upgrading.

Creating a manual covering multidisciplinary topics and involving contributions from groups in universities, industry and government is a complex endeavour. The reader will undoubtedly notice some heterogeneities resulting from the necessary compromise between ideals and realistic objectives or, more simply, from oversight. Critiques to improve future editions are welcomed.

D. Laguitton
SPOC Project Leader
Canada Centre for Mineral and Energy Technology

AVANT-PROPOS

La croissance des coûts de l'énergie et l'appauvrissement des gisements ont fait de l'évaluation et de l'optimisation des procédés un défi des années 80 au moment même où s'effectuait la dissémination de l'informatique jusqu'aux concentrateurs les plus isolés. Le projet SPOC, a été lancé en 1980 au CANMET, en vue de développer pour l'industrie canadienne, une méthodologie d'application de l'informatique à l'évaluation et à l'optimisation des procédés minéralurgiques. Le Manuel SPOC constitue la documentation écrite de cette méthodologie et en couvre les différents éléments. Les retombées devraient en être une vague nouvelle d'échantillonnages et d'amélioration de modèles.

La rédaction d'un ouvrage couvrant différentes disciplines et rassemblant des contributions de groupes aussi divers que les universités, l'industrie et le gouvernement est une tâche complexe. Le lecteur notera sans aucun doute des ambiguïtés ou contradictions qui ont pu résulter de la diversité des sources, de la traduction ou tout simplement d'erreurs. La critique constructive est encouragée afin de parvenir au format et au contenu de la meilleure qualité possible.

D. Laguitton
Chef du projet SPOC,
Centre canadien de la technologie des minéraux et de l'énergie

ABSTRACT

SAMBA is a conversational implementation of the method of flowsheet sensitivity analysis described in Chapter 2 of the SPOC manual (1), Section 5. For a given flowsheet and sampling data set the user can compare the flow rates obtained for different sampling designs and select a solution of least sensitivity to experimental errors.

RÉSUMÉ

Le programme SAMBA permet d'utiliser de façon conversationelle la méthode d'analyse de sensibilité de données de bilans matière décrite à la section 5 du chapitre 2 du manuel SPOC (1). Pour un flowsheet et des résultats d'échantillonnage donnés, l'utilisateur peut comparer les débits obtenus pour différents scénarios d'échantillonnage et choisir une solution qui soit la moins sensible aux erreurs expérimentales.

ACKNOWLEDGEMENTS

The SPOC project has benefited from such a wide range of contributions throughout the industry, the university, and the government sectors that a nominal acknowledgement would be bound to make unfair omissions. The main groups that contributed are: the various contractors who completed project elements; the Industrial Steering Committee members who met seven times to provide advice to the project leader; the various users of project documents and software who provided feedback on their experience; the CANMET Mineral Sciences Laboratories staff members who handled the considerable in-house task of software development, maintenance, and documentation; the EMR Computer Science Centre staff who were instrumental in some software development; and the CANMET Publications Section. Inasmuch as in a snow storm, every flake is responsible, their contributions are acknowledged.

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FIGURES

1. PROGRAM IDENTIFICATION

Program Title: Sensitivity Analysis for Material BAlance.

Program Code Name: SAMBA.

Authors: H.W. Smith, D. Burroughs, D. Laguitton.

Organization: Energy, Mines and Resources, Canada Centre for Mineral and Energy Technology, Mineral Processing Laboratory.

Date: November 1982.

Updates: Major update, June 1984. Previous code is obsolete.

Source Language: CDC FORTRAN Extended 4.8 (American National Standard Institute FORTRAN X3.9 – 1966).

Availability: Complete program listing is available from:
CANMET,
Energy, Mines and Resources
Technology Information Division,
555 Booth Street
Ottawa, Ontario
K1A 0G1.

```
 SSSSSS   AAAAA    MMMMMMMMMM     BBBBBB     AAAAA
SSSSSSS  AAAAAAA   MMMMMMMMMMM    BBBBBBB   AAAAAAA
SSSSSSS  AAAAAAA   MMMMMMMMMMM    BBBBBBB   AAAAAAA
SSS      AAA AAA   MMM MMM MMM    BBB BBB   AAA AAA
SSSSSS   AAA AAA   MMM MMM MMM    BBBBBBB   AAA AAA
SSSSSSS  AAA AAA   MMM MMM MMM    BBBBBB    AAA AAA
 SSSSSS  AAAAAAA   MMM MMM MMM    BBBBBBB   AAAAAAA
    SSS  AAAAAAA   MMM MMM MMM    BBB BBB   AAAAAAA
SSSSSSS  AAAAAAA   MMM MMM MMM    BBBBBBB   AAAAAAA
SSSSSSS  AAA AAA   MMM MMM MMM    BBBBBBB   AAA AAA
SSSSSS   AAA AAA   MMM MMM MMM    BBBBBB    AAA AAA
```

2. ENGINEERING DOCUMENTATION

2.1 NARRATIVE DESCRIPTION

This program is an interactive implementation of the method of flowsheet sensitivity analysis described in Chapter 2, Section 5 of the SPOC Manual (1). In addition to yielding sensitivity information – singular values, singular vectors, and sensitivity measure for the flowsheet – it computes a mass balance for the flowsheet, i.e., all solids mass flows. It does not, however, compute adjusted assays. The program is capable of accepting up to ten simultaneous assays on each stream, as well as measured mass flow data. Since the mass balance is computed by a weighted node imbalance method, its results should only be regarded as a good approximation to the more precise solution obtained by minimum-variance techniques.

2.2 METHOD OF SOLUTION

2.2.1 Preparation for Analysis

The flowsheet should be analysed in terms of simple separators and (possibly complex) junctions as illustrated in Chapter 2 of the SPOC manual. Each node (called a 'unit' in this implementation) is assigned a number by the analyst, as is each process stream. The network topology should be recorded as shown in Fig. 1. For each node (unit), the unit number is printed and the user is asked to enter the node type and total number of streams attached to the node on one line, followed by the stream numbers of each input stream (positive) and output stream (negative) in any order. The number of feed streams (F), junctions (J), and simple separators (S) should also be recorded.

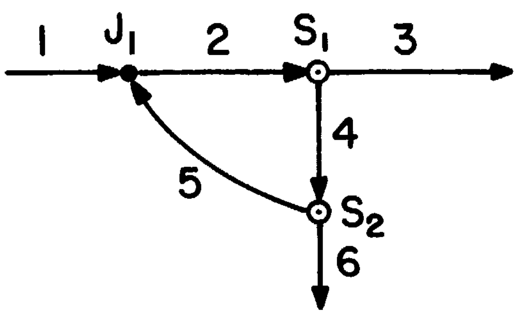


Fig. 1 – Simple circuit

2.2.2 Topological Analysis

The numbers F, S and J are requested by the program. The number of unknown mass flows NU, the total number of streams NS, and the minimum number of streams, NSMIN for a one-component balance are calculated:

$$NU = F + S$$
$$NS = F + J + 2S$$
$$NSMIN = 2(F + S) - 1$$

In addition to returning this information, the program stores the results for later dimensioning of arrays.

2.2.3 Formation of the Incidence Matrix

The circuit description is now requested. This is transformed into an incidence matrix M. For example, line 1 in the circuit of the example implies the equation

$$w_1 - w_2 + w_5 = 0$$

The program scans the description and generates the first row of an NU by NS matrix

$$M_1 = \quad 1 \; -1 \quad 0 \quad 0 \quad 1 \quad 0$$

and continues line by line until the matrix is complete:

$$M = \begin{matrix} 1 & -1 & 0 & 0 & 1 & 0 \\ 0 & 1 & -1 & -1 & 0 & 0 \\ 0 & 0 & 0 & +1 & -1 & -1 \end{matrix}$$

To avoid data entry error, the program also requests the numbers of circuit feed and product streams, and constructs a mask vector $\underline{m}'$ with +1 for feeds, −1 for products. In the example,

$$\underline{m}' = \quad (1 \quad 0 \; -1 \quad 0 \quad 0 \; -1)$$

is compared with the column sums of M; a diagnostic is printed.

The incidence matrix is a compact representation of the equations

$$M \underline{w} = 0$$

where $\underline{w}$ is the vector (NS by 1) of mass flows.

2.2.4 Assay Data Entry

Entry of assay data is now requested. The data for each assay type are normalized to the reference stream (the main feed if available, otherwise the feed stream first found). Working units are thus ratios of concentrations: as long as assays of a single type are in consistent units, consistency between types is not required. This also produces an appropriate initial scaling of the problem.

Assays are now checked for consistency. Assays of each type are checked at each node to ensure that

a. for separators, the feed composition lies between the product compositions;

b. for junctions, the product composition lies between the highest and lowest compositions in the feed streams.

If this test fails, warning is given. Since minor element assays are often inaccurate, the option is available of deleting entire assay types at this point (one at a time).

The final data requested are the relative precisions of the analyses for each assay type. The assays are then rescaled by a multiplying factor, which is the ratio of the lowest relative precision to the relative precision of the corresponding assay type. The problem is now ready for analysis. The largest expected assay error is printed and is used as the criterion for satisfactory singular values, that is, the smallest singular value must be greater than this criterion for the design to be acceptable.

2.2.5 Selection of Independent Mass Flows

Since the incidence equations

$$M \underline{w} = 0$$

are overdetermined, it is necessary to select

$$NU = F + S$$

independent mass flows to be solved for. This set can be user-specified, or can be automatically computed. The algorithm used selects the set of all feeds, reference feed first, and the higher composition product from each separator. This set then forms a vector $\underline{w}_s$, and the corresponding columns of M form a matrix MS. The remainder form a vector $\underline{w}_n$, and the remaining columns of M a matrix MN. Thus the incidence equations can be written

$$MS\ \underline{w}_s + MN\ \underline{w}_n = 0$$

MS is of dimension (J + S) by (F + S), while MN is a square matrix of dimension (J + S). If the $\underline{w}_s$'s are the independent streams, MN is invertible. An incorrectly user-specified set will generate an error message. Thus

$$\underline{w}_n = MN^{-1} MS\ \underline{w}_s = MT\ \underline{w}_s$$

where MT is called the transformation matrix.

2.2.6 Equation Generation

If stream **i** has composition X_i, the component mass balance equation is

$$MS\ \ X_s \underline{w}_s + MN\ X_n \underline{w}_n = 0$$

where X_s and X_n are diagonal matrices of compositions in sets (s) and (n). This can be written

$$(MS\ X_s + MN\ X_n MT)\underline{w}_s = 0$$

For programming purposes, X_s and X_n need not be generated: the columns of MS are multiplied by the elements of a vector X_s (and similarly for MN, X_n). Defining

$$\hat{A} = MS\ X_s + MN\ X_n MT$$

we have

$$\hat{A}\ \underline{w}_s = 0$$

The reference feed is the first element of $\underline{w}_s$, so this is equivalent to

$$(\underline{a}, A) \binom{1}{\underline{w}} = \underline{a}_1 + A\underline{w} = 0$$

i.e., $A\underline{w} = -\underline{a}_1$

The singular value analysis is done in this form, with the addition of a circuit equation found by summing the rows of $\hat{A}$.

If analytic data are missing, this is conventionally indicated by zero entries in the composition vector. This makes it necessary to preprocess the incidence matrix before computing MS and MN for that component. For each zero element, the procedure is:

1. Locate the corresponding column of M.
2. If this column has only one non-zero entry, delete the row containing it.
3. If this column has two non-zero entries, add the lower row containing a non-zero entry to the upper row and delete the lower row.

This is continued until all streams have been processed or the matrix vanishes (resulting in an error message). MS and MN are formed as before, **A** is generated, and joined row-wise to all A's previously found. The circuit equation is added after this check for missing assays and a 0.0 assay for a feed or product stream is therefore used as such in the circuit equation.

2.2.7 Singular Value Decomposition

The algorithm used is a standard algorithm (F232, SVD, from the eigensystem subroutine package EISPACK) (2). Results displayed are:

a. smallest singular values σ_{min}
b. solution $\underline{w}_s$
c. singular vector corresponding to σ_{min}
d. sensitivity measure (Chapter 2, Section 5.3 of SPOC manual, Eq 47).

The problem is now ready for interactive analysis. If the singular values are unsatisfactory (see Section 5.3), the corresponding singular vectors will help to locate the mass flows which are badly determined. Data can be modified by:

a. combining units
b. adding measured mass flows
c. deleting units.

2.2.8 Combining Units

Frequently, balancing around a separator with its feed junction will convey more information than balancing either or both alone. Combining units corresponds to adding their nodal equation and appending the sum to the system.

2.2.9 Adding Mass Flow Measurements

The first element of $\mathbf{\underline{w}_s}$ is the reference mass flow, by convention, and all others are normalized to it. To add a mass flow, stream number, flow rate and relative precision are specified. The ensuing calculation follows two paths:

a. If the flow is independent, its index in $\underline{w}_s$ is reduced by 1, and a row is appended to A containing all zeros except for a 1 in the indexed position; the measured flow is appended to $-a_1$.
b. If the flow is dependent, its index in $\underline{w}_n$ is found, and the corresponding row of MT is appended to A, the first element being removed and appended to $\underline{b}$ with its sign reversed; the measured flow is added to the last element of $\underline{b}$.

Flow equations are prescaled by computing the average of the minimum and maximum absolute values of all elements of the right-hand side vector, setting the measured flow rate to this value and scaling the left-hand side by the ratio of the average value to the flow rate value. By doing this, the magnitudes of the flow equations are comparable with other $\underline{b}$ elements. They are then scaled in a way similar to assays.

2.2.10 Computation of Residuals

In order to determine, once an acceptable design has been found, whether unusually noisy data are present, the residuals

$$\underline{r} = A\underline{w} - \underline{b}$$

are computed using double precision (rounded to single for output). The 10% probable error limit (1.65 × sample standard deviation) is shown for comparison.

2.2.11 Removal of Equations

If residual analysis indicates that rows should be removed, options are provided for doing this.

2.2.12 Back-up and Restart Options

After any equation addition or deletion, if singular values are adversely affected, an option is provided which permits backing up one step to recover. It is also possible to return to the initial system through a restart option, that is, the entry of assays or of assay errors or of independent flow rates.

2.3 PROGRAM CAPABILITIES

Limitations on problem size are strictly dependent on array dimensions. Default values are:

Number of streams: 25

Number of assay types: 10

Number of measured flows: 25

Number of units: 15

Number of independent streams: 11

Number of total equations in array AA: 165

A number of large test programs have been run without difficulty. Solutions approximate those obtained by minimum variance methods (i.e., MATBAL, BILMAT).

2.4 DATA INPUT, PROGRAM OPTIONS, OUTPUT

All data inputs are prompted for by the interactive program, and are entered in free format, i.e., in sequence, using either blanks or commas as separators. Input data may be read to disk storage for re-entry where a problem will be subjected to extensive analysis over more than one terminal session.

The basic program flow is as follows:

a. topological analysis: minimal design
b. flowsheet configuration entry
c. assay entry
d. assay error entry
e. independent streams selection
f. singular value analysis (SVA)
g. option for next design: go to c, d, e, h, i, j, k, l, m or n
h. unit combination, go to f
i. addition of mass flow data, go to f
j. deletion of equations, go to f
k. computation of residuals, go to g
l. final results
m. restore previous SVA design, go to g
n. immediate exit.

Program options available at each step are noted and prompted for. All output is displayed at the terminal following each step.

2.5 FLOWSHEET

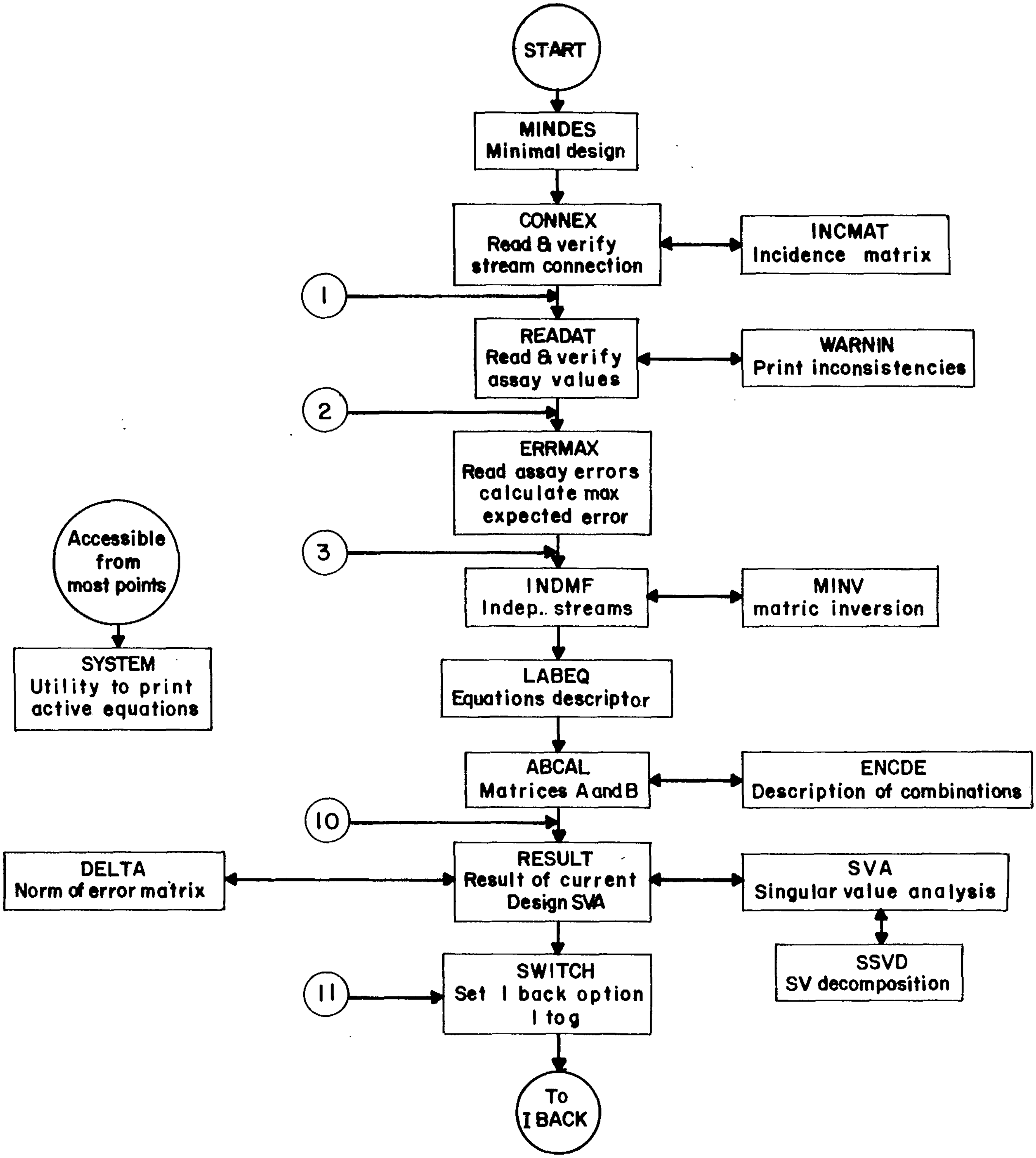
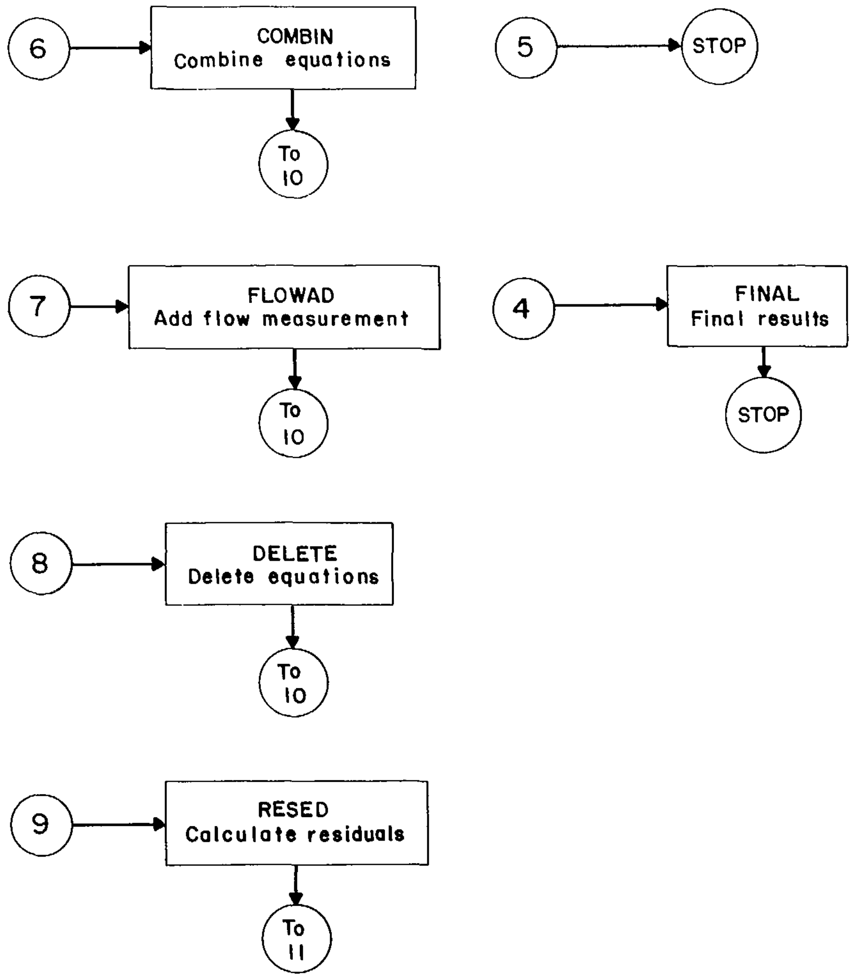


Fig. 2 – General flowsheet of SAMBA


6
COMBIN
Combine equations
To 10
5
STOP
7
FLOWAD
Add flow measurement
To 10
4
FINAL
Final results
STOP
8
DELETE
Delete equations
To 10
9
RESED
Calculate residuals
To 11

2.6 SAMPLE RUNS

Two sample runs are given to illustrate the use of the program, as well as to allow program testing. Users should be aware that, in difficult cases, the results of singular value analysis may show machine dependence. The program was developed on a CDC machine using its single precision arithmetic (16 decimal digits): used on, for example, IBM processors with single-precision arithmetic yielding 6.3 decimal digits may give slightly different results, although the print precision used in the program will normally mask such differences.

2.6.1 Sample Run 1

The flowsheet for this example is reproduced in Fig. 3, and the assay data in Table 1. This sample run is characterized by relatively limited and imprecise assay data supplemented by mass flow measurements. The terminal session for this flowsheet is reproduced in Appendix A.

2.6.2 Sample Run 2

Source: SPOC Manual, Chapter 3.2, Sample Run 1.

The flowsheet for this example is reproduced in Fig. 4 and the assay data in Table 2. This sample run is characterized by voluminous assay data, much of which is for minor elements whose assays may be of doubtful accuracy. No mass flow measurements are available. The terminal session for this flowsheet is reproduced in Appendix B.

Sample Run 2a is identical to Sample Run 2 except that only assay types 1, 2 and 5 are used. It is reproduced in Appendix C. Table 3 shows a comparison of results obtained with SAMBA and MATBAL for this data subset.

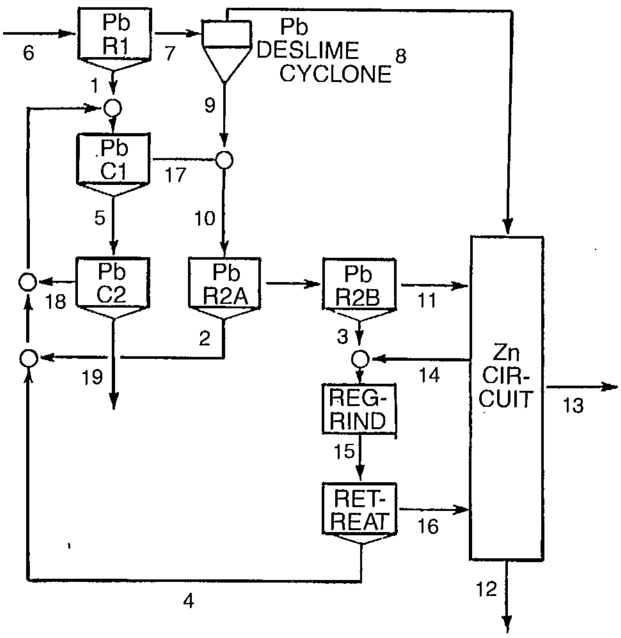


Fig. 3a – Flowsheet for Sample Run 1

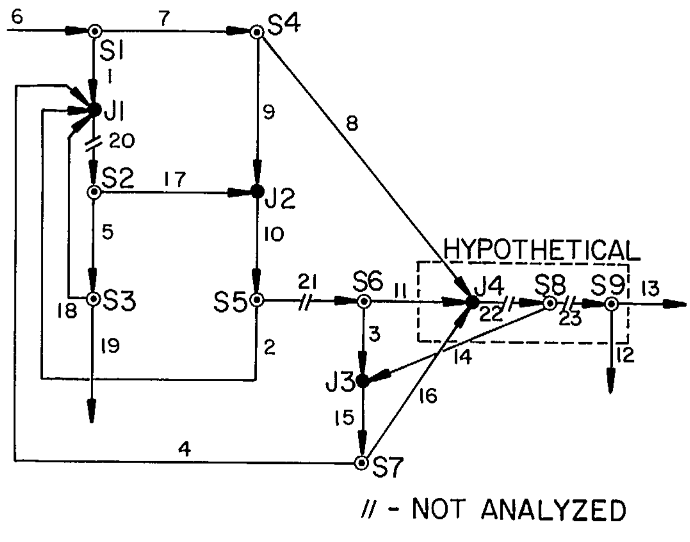


Fig. 3b – Nodal representation for Sample Run 1

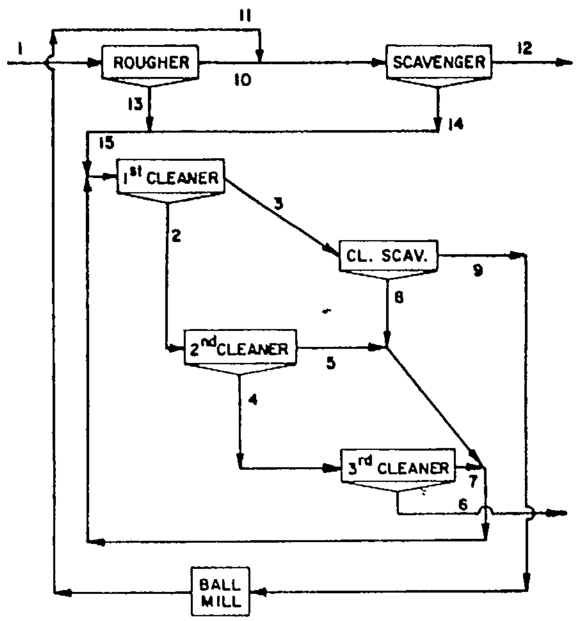


Fig. 4a – Flowsheet for Sample Run 2

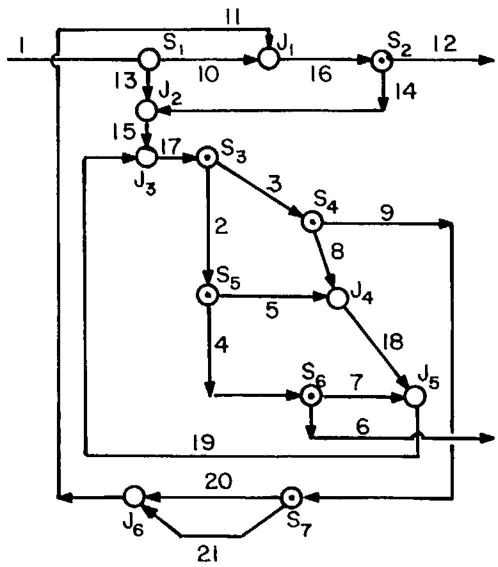


Fig. 4b – Nodal representation for Sample Run 2

Table 1 – Data for Sample Run 1

Stream No.	Name	% Pb	% Zn	% −74 μm	Flow (t/h)
1	Lead first rougher conc	37.66	9.30	—	26.38
2	Lead sec. rougher conc A	16.31	11.35	—	14.01
3	Lead sec. rougher conc B	11.91	19.50	—	11.87
4	Retreat conc	14.00	22.70	—	9.77
5	Lead first cleaner conc	36.00	10.00	—	36.06
6	Lead first rougher feed	7.89	6.62	—	167.28
7	Lead first rougher tails	2.34	6.01	38.20	—
8	Lead deslime cyclone o/f	0.59	5.94	82.60	—
9	Lead deslime cyclone u/f	2.92	6.08	24.10	—
10	Lead sec. rougher feed	4.56	8.52	—	—
11	Lead sec. rougher tails	1.65	6.97	—	—
12	Zinc final conc	1.70	55.20	—	—
13	Final tails	1.27	1.66	—	—
14	Zinc deslime cyclone u/f	6.80	26.30	—	—
15	Retreat feed	9.10	22.90	—	—
16	Retreat tails	5.90	22.30	—	—
17	Lead first cleaner tails	10.40	18.00	—	—
18	Lead sec. cleaner tails	17.00	15.60	—	—
19	Lead final conc	52.70	6.00	—	—
20	Hypothetical stream	—	—	—	—
21	Hypothetical stream	—	—	—	—
22	Hypothetical stream	—	—	—	—
23	Hypothetical stream	—	—	—	—

Table 2 – Experimental data for Sample Run 2

Stream	Cu %	Pb %	Zn %	Fe %	Ag PPM	Sb PPM	In PPM	Bi PPM	Sn PPM	Hg PPM
1	0.18	4.49	9.03	28.71	105	500	70	60	980	9
2	0.81	23.15	14.20	23.58	497	1320	100	300	1150	7
3	0.59	9.49	13.73	29.84	303	950	70	140	1040	6
4	1.00	34.87	11.12	18.66	628	1650	70	310	980	5
5	0.65	15.84	14.64	26.56	403	1300	100	270	1200	8
6	1.10	36.69	10.42	18.35	665	1590	60	340	840	6
7	0.56	17.29	15.33	25.43	393	1180	100	200	1140	8
8	0.90	15.26	16.40	25.53	445	1510	120	240	1480	5
9	0.49	5.21	11.17	33.94	188	830	70	120	830	5
10	0.14	1.99	9.48	29.44	59	350	60	30	850	7
11	0.51	7.02	10.72	32.79	202	830	60	160	840	6
12	0.13	1.55	9.54	27.58	50	300	60	40	780	8
13	0.61	25.10	10.32	25.48	480	1370	70	230	970	6
14	0.73	10.89	13.31	29.86	310	1140	80	190	1220	7
15	0.67	16.88	12.07	30.14	393	1280	80	200	1200	6
16	—	—	—	—	—	—	—	—	—	—
17	—	—	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	—	—

Precision: All assays assumed to have a 5% standard deviation

Table 3 – Comparison of flow rate values with MATBAL and SAMBA for Sample Run 2a

M	Stream	Observed	Calculated	
			MATBAL	SAMBA
1	Rougher feed	1.0000	1.0000	1.0000
2	First cleaner conc	N-O	0.2246	0.2145
3	First cleaner tail	N-O	0.2121	0.2065
4	Sec. cleaner conc	N-O	0.0902	0.0874
5	Sec. cleaner tail	N-O	0.1344	0.1271
6	Third cleaner conc	N-O	0.0788	0.0777
7	Third cleaner tail	N-O	0.0115	0.0097
8	Cl Scv. conc	N-O	0.0783	0.0749
9	Cl Scv. tail	N-O	0.1338	0.1317
10	Rougher tail	N-O	0.8979	0.8971
11	Mill discharge	N-O	0.1338	0.1317
12	Scav. tail	N-O	0.9214	0.9223
13	Rougher conc	N-O	0.1022	0.1029
14	Scav. conc	N-O	0.1104	0.1064
15	Rougher + Scav. conc	N-O	0.2125	0.2094

3. SYSTEM DOCUMENTATION

3.1 COMPUTER EQUIPMENT

SAMBA runs on a CDC 730 Cyber computer with a maximum 77K words (octal) of core memory available for time sharing jobs. SAMBA can also work on other computers with very minor changes.

3.2 PERIPHERAL EQUIPMENT

A time-sharing terminal is the normal way to run this conversational program. Data can be stored on disk files. A speed of 9600 bauds is recommended due to the length of display.

3.3 SOURCE PROGRAM

Complete listing of the program can be obtained from:

CANMET,
Energy, Mines and Resources
Technology Information Division,
555 Booth Street
Ottawa, Ontario
K1A 0G1

3.4 VARIABLES AND SUBROUTINES

3.4.1 Variables

A list of the variables names, dimensions and definitions is given in Table 4 (page 13). This list is also given in the prologue of the main program listing. Most variables are transmitted by labelled COMMON blocks and it is the responsibility of the user to ensure that the assays have dimensions that accomodate the size of the problem to be solved. The use of EQUIVALENCE statements in some subroutines is to be understood before modifying the code.

The Equation Descriptor LABEL(I,J)

This variable is a 10 digit descriptor of each equation used in the SAMBA solution. It contains one row per equation and each of the 10 positions is set as follows:

Col. 1	S	if the equation is that of a separator
	J	if the equation is that of a junction
	C	if the equation is that of a combination
	T	if the equation is that of the complete circuit
	F	if the equation is that of a measured flow rate
Col. 2	for S or J	the initial unit number
	for C	the number of units in the combination
	for F	the measured flow rate number
	for T	zero
Col. 3	for S or J	the number of streams connected
	for C	the number of the first unit in the combination
	for F or T	zero
Col. 4 to 10	for S or J	the connected stream numbers, positive or negative
	for C	the numbers of the remaining units in the combination
	for F or T	zeroes

3.4.2 Main Program SAMBA and Associated Subroutines

The main program consists essentially of a series of CALL statements controlled by the flowsheet logics as given in Fig. 2. An extensive prologue of comments lists the program variables and gives indications on proper dimensioning.

The following subroutines are part of the **SAMBA** package:

1. **MINDES** to calculate the minimal design
2. **CONNEX** to read and verify the stream connections
3. **READAT** to read and verify the assay values
4. **ERRMAX** to read the assay errors and calculate the largest expected error
5. **INDMF** to calculate the list of independent streams
6. **LABEQ** to establish a descriptor of the independent equations
7. **ABCAL** to calculate the coefficients of matrices AA and BB in AA*W = BB
8. **RESULT** to calculate the node imbalance minimization results
9. **SWITCH** to print a menu of options and control backtracking
10. **COMBIN** to combine rows of AA matrix
11. **FLOWAD** to add flow rate measurement equations
12. **DELETE** to delete rows of AA matrix
13. **RESID** to calculate equation residuals
14. **FINAL** to calculate and print final results
15. **DELTA** to calculate the norm of the assay errors
16. **INCMAT** to calculate the initial incidence matrix
17. **ENCDE** to establish descriptions of combination equations

18. **SYSTEM** to print the equation descriptions and coefficients
19. **SVA** to control the singular value analysis of a design
20. **SSVD** to calculate the singular values and vectors of a matrix
21. **WARNIN** to verify consistency of assays around a unit and print diagnostic
22. **MINV** to calculate inverse of a matrix

3.5 DATA STRUCTURES

SAMBA reads data in free field format on unit 5 declared as input file or on unit 1 declared as disk file. When data is read on unit 5, all data is subsequently written on unit 1 for later permanent storage if required. However it is the responsibility of the user to declare unit 1 as a permanent storage device and to verify the content of unit 1 after an execution since the options for backtracking in SAMBA may produce an overwriting or duplication of parts of the data.

3.6 STORAGE REQUIREMENT

It depends on the size of the arrays used in the COMMON blocks. As an example, the two sample runs 1 and 2 were executed on a CDC CYBER 730 and required 57 400 octal words, i.e., 24 192 decimal words.

3.7 MAINTENANCE AND UPDATES

CANMET does not provide any formal maintenance of the program. Several updates are expected to evolve from the source program distributed to users. CANMET would appreciate receiving comments on modifications which could substantially improve the overall program performance. A major improvement would be to write a pre-set dimensioning driver for SAMBA. In the past, such driver programs (e.g., DIMSET for MATBAL) have provided an optimum use of storage.

Table 4 – Variable names, dimensions and definitions

Name	Dimension	Definition	Name	Dimension	Definition
NF	1	number of circuit feed streams	S	2	sensitivity measure
NPS	1	number of circuit product streams	SIGMF	1	std. dev. of measured flow rates
NS	1	number of simple separators	STDDEV	1	equation residuals std. deviation
NJ	1	number of junctions	MDEPVR	NEMAX	number of the dependent flow rates
NU	1	number of unknown independent flow rates	NEQN	NEMAX,10	node equation coefficients
NTS	1	number of streams	MI	NEMAX,NTS	incidence matrix
NEMAX	1	max. no. of indep. equations			
NSMIN	1	min. no. of streams which must be sampled	IPRST	NPS	numbers of the circuit product streams
NI	1	number of the input file	INDEPV	NU+1	numbers of the independent flow rates
NO	1	number of the output file	IFEST	NF	numbers of the circuit feed streams
NA	1	number of assay types	LABEL	IMAT,10	descriptor of equations
MAJNA	1	number of the major assay type	MASK	IMAT	mask for equations
MRECOV	1	number of the reference stream			
NBMS	1	number of measured flow rates	ERREST	NA	std. dev. of the assay types
BEST	1	smallest assay type standard deviation	VALMS	NBMS	values of the measured flow rates
ERROR	1	largest expected assay error	CONDAT	NTS,NA	assay values
IMAT	1	row dimension of arrays MASK, LABEL			
IADD	1	(NEMAX+1)*i, i=1,NA			
IEND	1	row dimension of arrays AA,BB in execution	A	NEMAX, NU+1	coefficient matrix of each assay type
			B	NEMAX,1	right-hand side vector of each assay type
			AA	IEND,NU	coefficient matrix of all assay types
NDIM	1	row dimension of arrays AA,BB in COMMON	BB	IEND,1	right-hand side vector of all assay types
SUMNA	1	norm of assay errors			
SIGMA	1	smallest singular value	MT	NEMAX,NU+1	transformation matrix: dependent vs independent streams
IERR	1	error code for subroutine SSVD	MS	NEMAX,NU+1	work area
WRK1	NTS2	working area	MN	NEMAX,NEMAX	work area
WRK2	NTS2	working area	W	NU+1	independent flow rates estimates
U	NDIM,10	working area	IBACK	1	backtracking option
IWRK1	NTS	working area	REFLOW	1	value of the reference flow rate
IWRK2	NTS	working area	SOLD	1	value of S for the previous SVA calculation

4. OPERATING DOCUMENTATION

4.1 OPERATOR INSTRUCTIONS

SAMBA has been developed and tested on the CYBER 730 computer.

4.2 OPERATING MESSAGES

Normal system messages are produced by the NOS/BE 1 and INTERCOM systems. Special diagnostics are issued on the output file when abnormal conditions occur during the program execution. These are listed in Table 5.

4.3 CONTROL CARDS

SAMBA was designed to be used interactively. Therefore, NOS/BE 1 control cards are not applicable to run this program. INTERCOM commands to use SAMBA are as follows:

0. %LP 132
1. ATTACH,TAPE1,(PFN,ID),MR=1 (optional)
2. ATTACH,SAMBA,(PFN,ID),MR=1
3. SAMBA

0 Sets printer to 132 characters per line.
1 Attaches input data file, if previously stored.
2 Attaches the compiled program SAMBA.
3 Executes SAMBA.

4.4 ERROR RECOVERY

Program must be restarted on error.

4.5 RUN TIME

Run time depends on the problem size and on the chosen options. It also depends on the precision of the flow rate estimates that the user is aiming for. Sample Run 1, with 13 units, 23 streams and 3 assay types, required 5.89 seconds of execution time to obtain good flow rate estimates. Sample Run 2, with 13 units, 21 streams and 10 assay types, required 3.41 seconds of execution time to obtain rough estimates of the flow rates (no combination, measured flow or equation deletion).

REFERENCES

1. Smith, H.W. "SPOC Manual, Chapter 2: Sampling methodology for ore and coal process evaluation and modelling"; SP 85-1/2 CANMET, Energy, Mines and Resources Canada; 1984.
2. Forsythe, G.E.; Malcolm, M.A.; Moler, C.B. "Computer methods for mathematical computations"; Prentice Hall, Inc. Englewoods Cliffs, N.J. 07632; 1977.

Table 5 – SAMBA diagnostics

Message	Meaning	Action
Data for stream xx is inconsistent.	Stream xx has been given as a circuit feed or product and appears as an inter-unit stream or has not been given as a feed or product and does not appear as an inter-unit stream.	Use modify option to correct entry error.
Matrix MN is singular – illegal set of independent variables.	Set of independent streams is wrong.	Re-enter or use program selection.
Matrix has only one row and contains a non zero element. Data is useless. Program will terminate.	Incidence matrix has only one row and some assays are missing. No combination is possible.	Eliminate incomplete assay types.
Singular value was not found within 30 iterations — end program.	Abnormal difficulty in finding singular values.	Verify data and array dimensions.
Data inconsistency in unit xx for assay type yy.	All feed assays of a junction are larger or smaller than the product assays or both product assays of a separator are larger or smaller than the feed assay.	Use assay modification option if desired.

APPENDIX A
SAMPLE RUN 1

```
MINIMAL DESIGN CONFIGURATION
****************************


ENTER NO. OF FEED STREAMS,SIMPLE SEPARATORS & JUNCTIONS
1 9 4                                                            $$$NOTE  1 *

THERE ARE  9 INDEP. UNKNOWN MASS FLOWS TO BE DETERMINED          $$$NOTE  2

THE TOTAL NUMBER OF STREAMS IS 23

THE MAX. NUMBER OF INDEP. MASS BALANCE EQUATIONS THAT
CAN BE WRITTEN IS 13 PER ASSAY TYPE

THE MIN. NUMBER OF STREAMS WHICH MUST BE SAMPLED IS 19


INPUT OF CIRCUIT CONFIGURATION DATA
***********************************


IS YOUR DATA ALREADY STORED ON TAPE1?(Y OR N)                    $$$NOTE  3
Y

ENTER DATA IN THE FOLLOWING FORM:                                $$$NOTE  4
ITYPE,N :     WHERE ITYPE=1 DEFINES UNIT AS A JUNCTION,
                    ITYPE=2 DEFINES UNIT AS A SEPARATOR AND
                    N IS THE NUMBER OF STREAMS COMPOSING UNIT
STREAMS :    THE LABELS (NUMBERS) OF THE UNIT STREAMS
             EX.: 1,-5,-7 DEFINES 1 AS INPUT AND 5,7 AS OUTPUT STREAMS

UNIT NO. 1:                                                      $$$NOTE  5
2 3
STREAMS    :
6 -7 -1

UNIT NO. 2:
1 5
STREAMS    :
1 2 4 18 -20

UNIT NO. 3:
2 3
STREAMS    :
20 -5 -17

UNIT NO. 4:
1 3
STREAMS    :
9 17 -10

UNIT NO. 5:
2 3
STREAMS    :
5 -18 -19

UNIT NO. 6:
2 3
STREAMS    :
7 -8 -9
```

* Notes appear on page 29.

```
UNIT NO. 7:
2 3
STREAMS    :
10 -2 -21

UNIT NO. 8:
2 3
STREAMS    :
21 -3 -11

UNIT NO. 9:
1 3
STREAMS    :
3 14 -15

UNIT NO.10:
2 3
STREAMS    :
15 -4 -16

UNIT NO.11:
1 3
STREAMS    :
8 16 -22

UNIT NO.12:
2 3
STREAMS    :
22 -23 -14

UNIT NO.13:
2 3
STREAMS    :
23 -12 -13

ENTER ALL FEED STREAMS NUMBERS

6

NUMBER OF PRODUCT STREAMS AND THEIR NUMBERS

3 12 13 19


DATA CONSISTENCY CHECK
**********************

THE CIRCUIT THAT YOU HAVE JUST ENTERED IS:                       $$$NOTE  6

UNIT NO.   TYPE           EQUATION
    1      S                6  -7  -1
    2      J                1   2   4  18 -20
    3      S               20  -5 -17
    4      J                9  17 -10
    5      S                5 -18 -19
    6      S                7  -8  -9
    7      S               10  -2 -21
    8      S               21  -3 -11
    9      J                3  14 -15
   10      S               15  -4 -16
   11      J                8  16 -22
   12      S               22 -23 -14
   13      S               23 -12 -13

DO YOU WISH TO CHANGE THIS CIRCUIT DESCRIPTION?(Y OR N)
N                                                                $$$NOTE  7
```

```
DATA FOR STREAM 11 IS INCONSISTENT                          $$$NOTE  8
PLEASE RE-CHECK COEFFICIENTS FOR STREAM NO. 11

WHAT IS THE NO. OF THE UNIT YOU WANT TO CORRECT?(1-13)
11


ENTER NEW DATA FOR UNIT 11

ITYPE,N
STREAMS

UNIT NO. 11 : 1 4                                           $$$NOTE  9

STREAMS     : 8 11 16 -22


DO YOU WISH TO CHANGE DATA FOR ANOTHER UNIT?(Y OR N)
N

THE CIRCUIT THAT YOU HAVE JUST ENTERED IS:

UNIT NO.  TYPE          EQUATION
    1      S              6  -7  -1
    2      J              1   2   4  18 -20
    3      S             20  -5 -17
    4      J              9  17 -10
    5      S              5 -18 -19
    6      S              7  -8  -9
    7      S             10  -2 -21
    8      S             21  -3 -11
    9      J              3  14 -15
   10      S             15  -4 -16
   11      J              8  11  16 -22
   12      S             22 -23 -14
   13      S             23 -12 -13

DO YOU WISH TO CHANGE THIS CIRCUIT DESCRIPTION?(Y OR N)
N


DATA IS CONSISTENT WITH LIST OF FEED AND PRODUCT            $$$NOTE 10


INPUT OF ANALYTICAL DATA
************************

ENTER NUMBER OF ASSAY TYPES

3

ENTER CONCENTRATION DATA ONE ASSAY TYPE AT A TIME

IF MISSING DATA,I.E.,STREAMS FOR WHICH ASSAY TYPE
WASN'T ANALYZED, ENTER A VALUE OF ZERO(0.0)
                                                            $$$NOTE 11

37.66 16.31 11.91 14. 36. 7.89 2.34 .59 2.92 4.56 1.65 1.7 1.27
6.8 9.1 5.9 10.4 17. 52.7 0. 0. 0. 0.
9.3 11.35 19.5 22.7 10. 6.62 6.01 5.94 6.08 8.52 6.97 55.2 1.66
26.3 22.9 22.3 18. 15.6 6. 0. 0. 0. 0.
0. 0. 0. 0. 0. 0. 38.2 82.6 24.1 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 0. 0. 0.                                              $$$NOTE 12
```

```
ENTER NUMBER OF THE MAJOR ASSAY TYPE

1                                                               $$$NOTE 13

THE ASSAY VALUES CURRENTLY USED ARE :                           $$$NOTE 14

ASSAY TYPE  1
37.66 16.31 11.91 14. 36. 7.89 2.34 .59 2.92 4.56 1.65 1.7 1.27
6.8 9.1 5.9 10.4 17. 52.7 0. 0. 0. 0.

ASSAY TYPE  2
9.3 11.35 19.5 22.7 10. 6.62 6.01 5.94 6.08 8.52 6.97 55.2 1.66
26.3 22.9 22.3 18. 15.6 6. 0. 0. 0. 0.

ASSAY TYPE  3
0. 0. 0. 0. 0. 0. 38.2 82.6 24.1 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 0. 0. 0.

   CHOSE OPTION: 1=DELETE ASSAY TYPE                            $$$NOTE 15
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
4
                                                                $$$NOTE 16
    *******DATA INCONSISTENCY******* IN UNIT 10 FOR ASSAY TYPE  2

   CHOSE OPTION: 1=DELETE ASSAY TYPE
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
4                                                               $$$NOTE 17

REFERENCE STREAM NUMBER (USUALLY MAIN FEED) AND ITS FLOW RATE

6 167.28


ENTER ESTIMATES OF SAMPLING AND ANALYSIS ERROR(IN %)
FOR ASSAY TYPES:
1 2 3
10 10 5


$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

THE LARGEST EXPECTED ERROR IN THE DATA IS:    .417             $$$NOTE 18
FOR ASSAY TYPE  2 IN STREAM 12 .
FOR A GOOD DESIGN THE SMALLEST SINGULAR VALUE MUST BE LARGER
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$



SELECTION OF INDEPENDENT MASS FLOWS
***********************************

DO YOU WISH TO:
                1=ENTER USER SELECTION                          $$$NOTE 19
                2=USE COMPUTER DEFAULT SELECTION
2


AUTOMATIC SELECTION IS DONE BY THE PROGRAM
```

THE INDEPENDENT MASS FLOWS HAVE BEEN SELECTED,THEY ARE:

6 1 5 19 9 2 3 4 14 12 $$$NOTE 20

THE DEPENDENT MASS FLOWS ARE:

7 8 10 11 13 15 16 17 18 20 21 22 23

SINGULAR VALUE ANALYSIS
****

PRINT SYSTEM (Y/N)?Y

PRINT DESCRIPTOR (Y/N) ?Y

SYSTEM ROW NUMBERS AND DESCRIPTORS

ROW	DESCRIPTOR 1	2	3	4	5	6	7	8	9	10	ASSAYS
1	S	1	3	6	-7	-1	0	0	0	0	1
2	C	2	2	3	0	0	0	0	0	0	1
3	J	4	3	9	17	-10	0	0	0	0	1
4	S	5	3	5	-18	-19	0	0	0	0	1
5	S	6	3	7	-8	-9	0	0	0	0	1
6	C	2	7	8	0	0	0	0	0	0	1
7	J	9	3	3	14	-15	0	0	0	0	1
8	S	10	3	15	-4	-16	0	0	0	0	1
9	C	3	11	12	13	0	0	0	0	0	1
10	T	0	0	0	0	0	0	0	0	0	1
11	S	1	3	6	-7	-1	0	0	0	0	2
12	C	2	2	3	0	0	0	0	0	0	2
13	J	4	3	9	17	-10	0	0	0	0	2
14	S	5	3	5	-18	-19	0	0	0	0	2
15	S	6	3	7	-8	-9	0	0	0	0	2
16	C	2	7	8	0	0	0	0	0	0	2
17	J	9	3	3	14	-15	0	0	0	0	2
18	S	10	3	15	-4	-16	0	0	0	0	2
19	C	3	11	12	13	0	0	0	0	0	2
20	T	0	0	0	0	0	0	0	0	0	2
21	S	6	3	7	-8	-9	0	0	0	0	3
22	T	0	0	0	0	0	0	0	0	0	3

PRINT COEFFICIENTS AA AND BB (Y/N) ?Y

SYSTEM COEFFICIENTS $$$NOTE 21

```
ROW   B          A
  1   -.352      -2.238    0.000    0.000    0.000    0.000    0.000    0.000
0.000    0.000
  2   0.000       1.728   -1.204    -.418    0.000     .375    0.000     .228
0.000    0.000
  3   0.000        .370    0.000    -.370    -.104     .370    0.000     .370
0.000    0.000
  4   0.000       0.000    1.204   -2.262    0.000    0.000    0.000    0.000
0.000    0.000
  5   -.111       -.111    0.000    0.000    -.148    0.000    0.000    0.000
0.000    0.000
  6   0.000        .184    0.000    -.184     .184    -.745    -.650     .184
0.000    0.000
```

```
   7   0.000      0.000    0.000    0.000    0.000    0.000     .178    0.000
 -.146   0.000
   8   0.000      0.000    0.000    0.000    0.000    0.000     .203    -.513
  .203   0.000
   9    .043       .067    0.000    -.024     .067    0.000     .269    -.269
 -.057   -.027
  10   -.420      0.000    0.000   -3.259    0.000    0.000    0.000    0.000
 0.000   -.027
  11   -.046      -.248    0.000    0.000    0.000    0.000    0.000    0.000
 0.000   0.000
  12   0.000      -.657     .423     .181    0.000    -.502    0.000     .355
 0.000   0.000
  13   0.000       .716    0.000    -.716    -.184     .716    0.000     .716
 0.000   0.000
  14   0.000      0.000    -.423     .725    0.000    0.000    0.000    0.000
 0.000   0.000
  15   -.005      -.005    0.000    0.000    -.011    0.000    0.000    0.000
 0.000   0.000
  16   0.000       .117    0.000    -.117     .117    -.214    -.946     .117
 0.000   0.000
  17   0.000      0.000    0.000    0.000    0.000    0.000    -.257    0.000
 0.257   0.000
  18   0.000      0.000    0.000    0.000    0.000    0.000     .045    -.030
 0.045   0.000
  19   -.323       .078    0.000    -.401     .078    0.000    1.158   -1.158
 -.302  -4.044
  20   -.375      0.000    0.000    -.328    0.000    0.000    0.000    0.000
 0.000  -4.044
  21   1.162      1.162    0.000    0.000    1.531    0.000    0.000    0.000
 0.000   0.000
  22   1.162      1.162    0.000    0.000    1.531    0.000    0.000    0.000
 0.000   0.000

         THE NODE IMBALANCE MINIMIZATION SOLUTION IS              $$$NOTE 22

STREAM    FLOW RATE       SENSITIVITY

 W  1       26.3985            -.0109
 W  5       38.6827             .0280
 W 19       21.2711             .0082
 W  9      106.9097             .0033
 W  2       15.8028             .1629
 W  3       12.5628            -.2281
 W  4        9.2219            -.1210
 W 14       12.8369            -.9515                                $$$NOTE 24
 W 12       13.8001             .0195
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


THE SENSITIVITY MEASURE FOR THIS DESIGN IS:  40.711
       THE PREVIOUS DESIGN SENSITIVITY WAS:   0.000


ON THE BASIS OF THE SMALLEST SINGULAR VALUE (     .364)           $$$NOTE 23
AND WITH A LARGEST EXPECTED ERROR OF      .417

THIS DESIGN IS ****** UNACCEPTABLE ******
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


OPTIONS
-------

         1=BACK TO ASSAY MODIFICATION
         2=BACK TO ASSAY ERROR ENTRY
```

```
          3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
          4=TO PREVIOUS SVA DESIGN
          5=CONTINUE WITH CURRENT DESIGN
          6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
5



OPTIONS FOR NEXT DESIGN
-------

          1=TERMINATE WITH FINAL RESULTS
          2=EXIT IMMEDIATELY
          3=COMBINE EQUATIONS
          4=ADD FLOW RATE MEASUREMENTS
          5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
3                                                               $$$NOTE 25

NOTE:   ONLY ADJACENT UNITS CAN BE COMBINED AND HAVE A
        PHYSICAL SENSE.(EX. A UNIT WITH ITS FEED JUNCTION)

        A MAXIMUM OF 2 'UNITS' CAN BE COMBINED

PRINT INITIAL CIRCUIT DESCRIPTION (Y/N)?N

WOULD YOU LIKE THE SYSTEM TO BE PRINTED?(Y OR N)
N                                                               $$$NOTE 26

ENTER ROW NOS. OF THE 2 UNITS TO BE COMBINED,AND ASSAY TYPE

7 8 1                                                           $$$NOTE 27

   MORE COMBINATIONS BEFORE SVA ?
N



SINGULAR VALUE ANALYSIS
***********************



PRINT SYSTEM (Y/N)?N


          THE NODE IMBALANCE MINIMIZATION SOLUTION IS

STREAM    FLOW RATE       SENSITIVITY

 W  1       26.3805             .0094
 W  5       38.6861            -.0294
 W 19       21.2782            -.0079
 W  9      106.9255            -.0016
 W  2       15.8293            -.1696
 W  3       12.4711             .2306
 W  4        9.3709             .1454
 W 14       12.4374             .9462
 W 12       13.7798            -.0225
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


THE SENSITIVITY MEASURE FOR THIS DESIGN IS:  39.918
       THE PREVIOUS DESIGN SENSITIVITY WAS:  40.711
```

```
ON THE BASIS OF THE SMALLEST SINGULAR VALUE (     .371)
AND WITH A LARGEST EXPECTED ERROR OF      .417

THIS DESIGN IS ****** UNACCEPTABLE ******                        $$$NOTE 28
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


OPTIONS
-------

         1=BACK TO ASSAY MODIFICATION                            $$$NOTE 29
         2=BACK TO ASSAY ERROR ENTRY
         3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
         4=TO PREVIOUS SVA DESIGN
         5=CONTINUE WITH CURRENT DESIGN
         6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
5

OPTIONS FOR NEXT DESIGN
-------

         1=TERMINATE WITH FINAL RESULTS
         2=EXIT IMMEDIATELY
         3=COMBINE EQUATIONS
         4=ADD FLOW RATE MEASUREMENTS
         5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
3

NOTE:  ONLY ADJACENT UNITS CAN BE COMBINED AND HAVE A
       PHYSICAL SENSE.(EX. A UNIT WITH ITS FEED JUNCTION)

       A MAXIMUM OF 2 'UNITS' CAN BE COMBINED

PRINT INITIAL CIRCUIT DESCRIPTION (Y/N)?N

WOULD YOU LIKE THE SYSTEM TO BE PRINTED?(Y OR N)
N

ENTER ROW NOS. OF THE 2 UNITS TO BE COMBINED,AND ASSAY TYPE

17 18 2                                                          $$$NOTE 30

   MORE COMBINATIONS BEFORE SVA ?
N


SINGULAR VALUE ANALYSIS
***********************


PRINT SYSTEM (Y/N)?N

         THE NODE IMBALANCE MINIMIZATION SOLUTION IS

STREAM   FLOW RATE      SENSITIVITY

 W  1      26.3764           .0125
 W  5      38.6902          -.0442
 W 19      21.2807          -.0110
 W  9     106.9255          -.0035
 W  2      15.8538          -.2507
```

```
 W  3       12.4254              .3209
 W  4        9.3745              .2249
 W 14       11.4656              .8837
 W 12       13.8088             -.0183
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


THE SENSITIVITY MEASURE FOR THIS DESIGN IS:  34.624
       THE PREVIOUS DESIGN SENSITIVITY WAS:  39.918


ON THE BASIS OF THE SMALLEST SINGULAR VALUE (     .428)
AND WITH A LARGEST EXPECTED ERROR OF      .417

THIS DESIGN IS ****** ACCEPTABLE ******                   $$$NOTE 31
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


OPTIONS
-------

         1=BACK TO ASSAY MODIFICATION
         2=BACK TO ASSAY ERROR ENTRY
         3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
         4=TO PREVIOUS SVA DESIGN
         5=CONTINUE WITH CURRENT DESIGN
         6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
5


OPTIONS FOR NEXT DESIGN
-------

         1=TERMINATE WITH FINAL RESULTS
         2=EXIT IMMEDIATELY
         3=COMBINE EQUATIONS
         4=ADD FLOW RATE MEASUREMENTS
         5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
4                                                          $$$NOTE 32

ENTER STREAM NO.,VALUE AND STD DEV.(%) OF MEASURED FLOW:

3 11.87 10                                                 $$$NOTE 33

   MORE FLOWRATE ADDITIONS BEFORE SVA ?
N


SINGULAR VALUE ANALYSIS
***********************


PRINT SYSTEM (Y/N)?N
```

THE NODE IMBALANCE MINIMIZATION SOLUTION IS

STREAM	FLOW RATE	SENSITIVITY
W 1	26.3622	.0027
W 5	38.7477	-.0012
W 19	21.2945	-.0015
W 9	106.9259	.0008
W 2	16.2020	-.0070
W 3	11.8961	.0141
W 4	9.0216	-.0145
W 14	10.9808	.9992
W 12	13.8002	-.0334

$$

THE SENSITIVITY MEASURE FOR THIS DESIGN IS: 28.580 $$$NOTE 34
THE PREVIOUS DESIGN SENSITIVITY WAS: 34.624

ON THE BASIS OF THE SMALLEST SINGULAR VALUE (.518)
AND WITH A LARGEST EXPECTED ERROR OF .417

THIS DESIGN IS ****** ACCEPTABLE ******
$$

OPTIONS

1=BACK TO ASSAY MODIFICATION
2=BACK TO ASSAY ERROR ENTRY
3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
4=TO PREVIOUS SVA DESIGN
5=CONTINUE WITH CURRENT DESIGN
6=COMPUTE RESIDUALS

ENTER OPTION 1 TO 6 :
6

THE RESIDUALS ARE: $$$NOTE 40

ROW	DESCRIPTOR 1	2	3	4	5	6	7	8	9	10	ASSAYS	RESIDUAL
1	S	1	3	6	-7	-1	0	0	0	0	1	.0010
2	C	2	2	3	0	0	0	0	0	0	1	.0113
3	J	4	3	9	17	-10	0	0	0	0	1	-.0006
4	S	5	3	5	-18	-19	0	0	0	0	1	.0091
5	S	6	3	7	-8	-9	0	0	0	0	1	.0010
6	C	2	7	8	0	0	0	0	0	0	1	-.0150
7	J	9	3	3	14	-15	0	0	0	0	1	-.0031
8	S	10	3	15	-4	-16	0	0	0	0	1	-.0000
9	C	3	11	12	13	0	0	0	0	0	1	-.0060
10	T	0	0	0	0	0	0	0	0	0	1	-.0024
11	S	1	3	6	-7	-1	0	0	0	0	2	-.0069
12	C	2	2	3	0	0	0	0	0	0	2	.0120
13	J	4	3	9	17	-10	0	0	0	0	2	-.0119
14	S	5	3	5	-18	-19	0	0	0	0	2	.0057
15	S	6	3	7	-8	-9	0	0	0	0	2	.0023
16	C	2	7	8	0	0	0	0	0	0	2	.0033
17	J	9	3	3	14	-15	0	0	0	0	2	.0014
18	S	10	3	15	-4	-16	0	0	0	0	2	-.0046

19	C	3	11	12	13	0	0	0	0	0	2	-.0007
20	T	0	0	0	0	0	0	0	0	0	2	.0007
21	S	6	3	7	-8	-9	0	0	0	0	3	.0002
22	T	0	0	0	0	0	0	0	0	0	3	.0002
23	C	2	9	10	0	0	0	0	0	0	1	-.0031
24	C	2	9	10	0	0	0	0	0	0	2	-.0032
25	F	3	0	0	0	0	0	0	0	0	0	-.0006

```
1.65*SIGMA FOR THESE RESIDUALS IS :          .0125
YOU MAY WANT TO DELETE EQUATIONS WHITH LARGER RESIDUALS
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

OPTIONS
-------

         1=BACK TO ASSAY MODIFICATION
         2=BACK TO ASSAY ERROR ENTRY
         3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
         4=TO PREVIOUS SVA DESIGN
         5=CONTINUE WITH CURRENT DESIGN
         6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
5


OPTIONS FOR NEXT DESIGN
-------

         1=TERMINATE WITH FINAL RESULTS
         2=EXIT IMMEDIATELY
         3=COMBINE EQUATIONS
         4=ADD FLOW RATE MEASUREMENTS
         5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
5

PRINT SYSTEM TO GET ROW NUMBERS (Y/N)?N

 ROW NO. OF THE EQUATION YOU WANT TO DELETE : 6


   MORE EQUATION DELETIONS BEFORE SVA ?
N


SINGULAR VALUE ANALYSIS
***********************


PRINT SYSTEM (Y/N)?N


         THE NODE IMBALANCE MINIMIZATION SOLUTION IS

STREAM   FLOW RATE      SENSITIVITY

 W  1      26.7239          -.0012
 W  5      38.2571          -.0011
 W 19      21.1015           .0007
 W  9     106.6764          -.0021
 W  2      13.0776          -.0065
 W  3      11.8882          -.0140
 W  4       9.7813           .0178
 W 14      10.8579          -.9992
 W 12      13.7138           .0330
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

```
THE SENSITIVITY MEASURE FOR THIS DESIGN IS:  28.585
       THE PREVIOUS DESIGN SENSITIVITY WAS:  28.580



ON THE BASIS OF THE SMALLEST SINGULAR VALUE (     .518)
AND WITH A LARGEST EXPECTED ERROR OF      .417

THIS DESIGN IS ****** ACCEPTABLE ******
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$                      $$$NOTE 41


OPTIONS
-------

         1=BACK TO ASSAY MODIFICATION
         2=BACK TO ASSAY ERROR ENTRY
         3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
         4=TO PREVIOUS SVA DESIGN
         5=CONTINUE WITH CURRENT DESIGN
         6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
5



OPTIONS FOR NEXT DESIGN
-------

         1=TERMINATE WITH FINAL RESULTS
         2=EXIT IMMEDIATELY
         3=COMBINE EQUATIONS
         4=ADD FLOW RATE MEASUREMENTS
         5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
1                                                                     $$$NOTE 42
```

```
                                             *************
                                             FINAL RESULTS
                                             *************


PRINT SYSTEM (Y/N)?N

MINIMUM IMBALANCE FLOW-RATES
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$



REF.STREAM W  6      167.2800

IND.STREAM W  1       26.7239
IND.STREAM W  5       38.2571
IND.STREAM W 19       21.1015
IND.STREAM W  9      106.6764
IND.STREAM W  2       13.0776
IND.STREAM W  3       11.8882
IND.STREAM W  4        9.7813
IND.STREAM W 14       10.8579
IND.STREAM W 12       13.7138

DEP.STREAM W  7      140.5561
DEP.STREAM W  8       33.8797
DEP.STREAM W 10      135.1577
DEP.STREAM W 11      110.1919
DEP.STREAM W 13      132.4647
DEP.STREAM W 15       22.7461
DEP.STREAM W 16       12.9647
DEP.STREAM W 17       28.4813
DEP.STREAM W 18       17.1556
DEP.STREAM W 20       66.7384
DEP.STREAM W 21      122.0801
DEP.STREAM W 22      157.0364
DEP.STREAM W 23      146.1785


     STOP
     057400 MAXIMUM EXECUTION FL.
      2.485 CP SECONDS EXECUTION TIME.
```

Note 1. Free format data entry. 1 feed, 9 separators, 4 junctions.
Note 2. Topological analysis output.
Note 3. Direct data entry or from file.
Note 4. Program prompts for data entry format.
Note 5. Unit and stream numbers correspond to the nodal representation of Fig. 3b.
Note 6. Playback of data entry. Note that, for unit 8, stream 11 appears as an output: stream 11 does not appear as an input to any unit.
Note 7. The analyst has not noticed the incorrect entry.
Note 8. The program has detected that stream 11 is inconsistent.
Note 9. On checking, stream 11 is found to be an input to unit 11. Data for unit 11 are re-entered.
Note 10. The circuit configuration entered has been checked, and is internally consistent.
Note 11. Free format, using blanks or commas as separators: zeros for missing assays.
Note 12. 14 * 0 represents 14 zeros, missing assays in the data file.
Note 13. This data is used for automatic selection of independent mass flows. The major assay type should normally be selected as the assay for the component the circuit is designed to separate.
Note 14. Data playback for checking.
Note 15. User chooses to leave assays unchanged.
Note 16. The program indicates that for unit 10 (retreat unit), the assays of type 2 (Zn) are inconsistent: the feed is indeed higher in zinc than both the concentrate and tailing. For assay type 1 (Pb) as well, the existence of a missing assay in stream 22 (hypothetical stream created for the nodal representation) causes also a diagnostic of inconsistency for unit 11 (8 + 11 + 16 − 22), this latter can however be ignored since missing assays are treated automatically by the program.
Note 17. The analyst has decided that this does not invalidate all the zinc data and enters reference stream values.
Note 18. This is the test value criterion for the smallest singular value which should be greater than the largest expected error.
Note 19. Options are given in menu form, user chooses automatic selection of independent flow rates.
Note 20. Stream 6 is feed: remainder are lead concentrates from each separator. Ordering is arbitrary, except reference stream is always first.
Note 21. The system, normalized and scaled, is printed. Note that assay type 3 (size analysis) with only 5 per cent relative error is weighted more heavily than assays, as shown by larger coefficients.
Note 22. Least squares (minimum node imbalance) solution for independent mass flows.
Note 23. Smallest singular value is $0.364 < 0.417$: experiment is not sufficiently insensitive.
Note 24. The singular vector corresponding to the smallest singular value shows that the estimate of w_{14} is the most sensitive to error: w_2, w_3 and w_4 are somewhat sensitive: the other estimates are considerably less so.
Note 25. Proceed to unit combination.
Note 26. Printing suppressed for economy of time. Novice users should usually print.
Note 27. This does not combine <u>units</u> 7 and 8, but <u>rows</u> 7 and 8 (units 9 and 10, assay type 1), thus combining the retreat section with its feed junction for lead. Keeping this distinction clear (and it is admittedly awkward) is a good reason for printing, as recommended above. This combination is motivated by the warning (Note 16) that unit 10 is suspect.
Note 28. This has helped a little: the smallest singular value and the sensitivity measure are improved but not enough. The sensitive streams are the same as before.
Note 29. Menu selection of options.
Note 30. <u>Rows</u> 17, 18 (refer back to initial system print, Note 21) are retreat feed junction and retreat, i.e., the same units combined in Note 27, but now for zinc.
Note 31. Eureka! The smallest singular value is now all right, and the sensitivity measure has dropped. The analyst decides to move on to mass flow data. Note, though, that the sensitivity pattern (indicated by the singular vector) has not changed.
Note 32. Using the menu of options, the flow rate addition option is selected.
Note 33. Since stream 3 is most sensitive, the analyst adds it first.
Note 34. This improves the sensitivity which drops further.
Notes 35 to 39. Stream 14 which was not measured remains most sensitive.
Note 40. The data appears highly consistent: equation 6 has high residual.
Note 41. Not much change. The deletion of 6 is warranted.
Note 42. The user decides to terminate the run.

APPENDIX B
SAMPLE RUN 2

```
MINIMAL DESIGN CONFIGURATION                                    $$$NOTE 1 *
****************************


ENTER NO. OF FEED STREAMS,SIMPLE SEPARATORS & JUNCTIONS
1 7 6

THERE ARE  7 INDEP. UNKNOWN MASS FLOWS TO BE DETERMINED

THE TOTAL NUMBER OF STREAMS IS 21

THE MAX. NUMBER OF INDEP. MASS BALANCE EQUATIONS THAT
CAN BE WRITTEN IS 13 PER ASSAY TYPE

THE MIN. NUMBER OF STREAMS WHICH MUST BE SAMPLED IS 15


INPUT OF CIRCUIT CONFIGURATION DATA
***********************************


IS YOUR DATA ALREADY STORED ON TAPE1?(Y OR N)
Y

ENTER DATA IN THE FOLLOWING FORM:
ITYPE,N :     WHERE ITYPE=1 DEFINES UNIT AS A JUNCTION,
                    ITYPE=2 DEFINES UNIT AS A SEPARATOR AND
                    N IS THE NUMBER OF STREAMS COMPOSING UNIT
STREAMS :    THE LABELS (NUMBERS) OF THE UNIT STREAMS
             EX.: 1,-5,-7 DEFINES 1 AS INPUT AND 5,7 AS OUTPUT STREAMS

UNIT NO. 1:
2 3
STREAMS    :
1 -10 -13

UNIT NO. 2:
1 3
STREAMS    :
10 11 -16

UNIT NO. 3:
2 3
STREAMS    :
16 -12 -14

UNIT NO. 4:
1 3
STREAMS    :
13 14 -15

UNIT NO. 5:
1 3
STREAMS    :
15 19 -17

UNIT NO. 6:
2 3
STREAMS    :
17 -2 -3
```

* Notes appear on page 42.

```
UNIT NO. 7:
2 3
STREAMS    :
3 -8 -9

UNIT NO. 8:
2 3
STREAMS    :
2 -4 -5

UNIT NO. 9:
1 3
STREAMS    :
5 8 -18

UNIT NO.10:
2 3
STREAMS    :
4 -6 -7

UNIT NO.11:
1 3
STREAMS    :
7 18 -19

UNIT NO.12:
2 3
STREAMS    :
9 -20 -21

UNIT NO.13:
1 3
STREAMS    :
20 21 -11

ENTER ALL FEED STREAMS NUMBERS

1

NUMBER OF PRODUCT STREAMS AND THEIR NUMBERS

2 6 12


DATA CONSISTENCY CHECK
**********************

THE CIRCUIT THAT YOU HAVE JUST ENTERED IS:

UNIT NO.   TYPE          EQUATION
    1       S              1 -10 -13
    2       J             10  11 -16
    3       S             16 -12 -14
    4       J             13  14 -15
    5       J             15  19 -17
    6       S             17  -2  -3
    7       S              3  -8  -9
    8       S              2  -4  -5
    9       J              5   8 -18
   10       S              4  -6  -7
   11       J              7  18 -19
   12       S              9 -20 -21
   13       J             20  21 -11

DO YOU WISH TO CHANGE THIS CIRCUIT DESCRIPTION?(Y OR N)
N
```

```
DATA IS CONSISTENT WITH LIST OF FEED AND PRODUCT


INPUT OF ANALYTICAL DATA
************************

ENTER NUMBER OF ASSAY TYPES

10

ENTER CONCENTRATION DATA ONE ASSAY TYPE AT A TIME

IF MISSING DATA,I.E.,STREAMS FOR WHICH ASSAY TYPE
WASN'T ANALYZED, ENTER A VALUE OF ZERO(0.0)                    $$$NOTE 2


.18 .81 .59 1. .65 1.1 .56 .9 .49 .14 .51 .13 .61 .73 .67 0.
0. 0. 0. 0. 0.
4.49 23.15 9.49 34.87 15.84 36.69 17.29 15.26 5.21 1.99 7.02
1.55 25.1 10.89 16.88 0. 0. 0. 0. 0. 0.
9.03 14.2 13.73 11.12 14.64 10.42 15.33 16.4 11.17 9.48 10.72
9.54 10.32 13.31 12.07 0. 0. 0. 0. 0. 0.
28.71 23.58 29.84 18.66 26.56 18.35 25.43 25.53 33.94 29.44
32.79 27.58 25.48 29.86 30.14 0. 0. 0. 0. 0. 0.
105. 497. 303. 628. 403. 665. 393. 445. 188. 59. 202. 50. 480.
310. 393. 0. 0. 0. 0. 0. 0.
500. 1320. 950. 1650. 1300. 1590. 1180. 1510. 830. 350. 830.
300. 1370. 1140. 1280. 0. 0. 0. 0. 0. 0.
70. 100. 70. 70. 100. 60. 100. 120. 70. 60. 60. 60. 70. 80.
80. 0. 0. 0. 0. 0. 0.
60. 300. 140. 310. 270. 340. 200. 240. 120. 30. 160. 40. 230.
190. 200. 0. 0. 0. 0. 0. 0.
980. 1150. 1040. 980. 1200. 840. 1140. 1480. 830. 850. 840.
780. 970. 1220. 1200. 0. 0. 0. 0. 0. 0.
9. 7. 6. 5. 8. 6. 8. 5. 5. 7. 6. 8. 6. 7. 6. 0. 0. 0. 0. 0.
0.

ENTER NUMBER OF THE MAJOR ASSAY TYPE

1

THE ASSAY VALUES CURRENTLY USED ARE :

ASSAY TYPE  1
.18 .81 .59 1. .65 1.1 .56 .9 .49 .14 .51 .13 .61 .73 .67 0.
0. 0. 0. 0. 0.

ASSAY TYPE  2
4.49 23.15 9.49 34.87 15.84 36.69 17.29 15.26 5.21 1.99 7.02
1.55 25.1 10.89 16.88 0. 0. 0. 0. 0. 0.

ASSAY TYPE  3
9.03 14.2 13.73 11.12 14.64 10.42 15.33 16.4 11.17 9.48 10.72
9.54 10.32 13.31 12.07 0. 0. 0. 0. 0. 0.

ASSAY TYPE  4
28.71 23.58 29.84 18.66 26.56 18.35 25.43 25.53 33.94 29.44
32.79 27.58 25.48 29.86 30.14 0. 0. 0. 0. 0. 0.

ASSAY TYPE  5
105. 497. 303. 628. 403. 665. 393. 445. 188. 59. 202. 50. 480.
310. 393. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  6
500. 1320. 950. 1650. 1300. 1590. 1180. 1510. 830. 350. 830.
300. 1370. 1140. 1280. 0. 0. 0. 0. 0. 0.
```

```
ASSAY TYPE  7
70. 100. 70. 70. 100. 60. 100. 120. 70. 60. 60. 60. 70. 80.
80. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  8
60. 300. 140. 310. 270. 340. 200. 240. 120. 30. 160. 40. 230.
190. 200. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  9
980. 1150. 1040. 980. 1200. 840. 1140. 1480. 830. 850. 840.
780. 970. 1220. 1200. 0. 0. 0. 0. 0. 0.

ASSAY TYPE 10
9. 7. 6. 5. 8. 6. 8. 5. 5. 7. 6. 8. 6. 7. 6. 0. 0. 0. 0. 0.
0.

   CHOSE OPTION: 1=DELETE ASSAY TYPE
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
 4
                                                                   $$$NOTE 3

    *******DATA INCONSISTENCY******* IN UNIT  1 FOR ASSAY TYPE  3
    *******DATA INCONSISTENCY******* IN UNIT  4 FOR ASSAY TYPE  4
    *******DATA INCONSISTENCY******* IN UNIT 10 FOR ASSAY TYPE  6
    *******DATA INCONSISTENCY******* IN UNIT  1 FOR ASSAY TYPE  7
    *******DATA INCONSISTENCY******* IN UNIT  4 FOR ASSAY TYPE  7
    *******DATA INCONSISTENCY******* IN UNIT  7 FOR ASSAY TYPE  7
    *******DATA INCONSISTENCY******* IN UNIT  8 FOR ASSAY TYPE  7
    *******DATA INCONSISTENCY******* IN UNIT  1 FOR ASSAY TYPE  9
    *******DATA INCONSISTENCY******* IN UNIT  1 FOR ASSAY TYPE 10
    *******DATA INCONSISTENCY******* IN UNIT  4 FOR ASSAY TYPE 10
    *******DATA INCONSISTENCY******* IN UNIT  7 FOR ASSAY TYPE 10
    *******DATA INCONSISTENCY******* IN UNIT 10 FOR ASSAY TYPE 10

   CHOSE OPTION: 1=DELETE ASSAY TYPE
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
 1
   ENTER ASSAY TYPE TO BE DELETED AND MAJOR TYPE AFTER CHANGE
 10 1

 THE ASSAY VALUES CURRENTLY USED ARE :

 ASSAY TYPE  1
 .18 .81 .59 1. .65 1.1 .56 .9 .49 .14 .51 .13 .61 .73 .67 0.
 0. 0. 0. 0. 0.

 ASSAY TYPE  2
 4.49 23.15 9.49 34.87 15.84 36.69 17.29 15.26 5.21 1.99 7.02
 1.55 25.1 10.89 16.88 0. 0. 0. 0. 0. 0.

 ASSAY TYPE  3
 9.03 14.2 13.73 11.12 14.64 10.42 15.33 16.4 11.17 9.48 10.72
 9.54 10.32 13.31 12.07 0. 0. 0. 0. 0. 0.

 ASSAY TYPE  4
 28.71 23.58 29.84 18.66 26.56 18.35 25.43 25.53 33.94 29.44
 32.79 27.58 25.48 29.86 30.14 0. 0. 0. 0. 0. 0.

 ASSAY TYPE  5
 105. 497. 303. 628. 403. 665. 393. 445. 188. 59. 202. 50. 480.
 310. 393. 0. 0. 0. 0. 0. 0.
```

```
ASSAY TYPE  6
500. 1320. 950. 1650. 1300. 1590. 1180. 1510. 830. 350. 830.
300. 1370. 1140. 1280. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  7
70. 100. 70. 70. 100. 60. 100. 120. 70. 60. 60. 60. 70. 80.
80. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  8
60. 300. 140. 310. 270. 340. 200. 240. 120. 30. 160. 40. 230.
190. 200. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  9
980. 1150. 1040. 980. 1200. 840. 1140. 1480. 830. 850. 840.
780. 970. 1220. 1200. 0. 0. 0. 0. 0. 0.

   CHOSE OPTION: 1=DELETE ASSAY TYPE
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
1
   ENTER ASSAY TYPE TO BE DELETED AND MAJOR TYPE AFTER CHANGE
7 1

THE ASSAY VALUES CURRENTLY USED ARE :

ASSAY TYPE  1
.18 .81 .59 1. .65 1.1 .56 .9 .49 .14 .51 .13 .61 .73 .67 0.
0. 0. 0. 0. 0.

ASSAY TYPE  2
4.49 23.15 9.49 34.87 15.84 36.69 17.29 15.26 5.21 1.99 7.02
1.55 25.1 10.89 16.88 0. 0. 0. 0. 0. 0.

ASSAY TYPE  3
9.03 14.2 13.73 11.12 14.64 10.42 15.33 16.4 11.17 9.48 10.72
9.54 10.32 13.31 12.07 0. 0. 0. 0. 0. 0.

ASSAY TYPE  4
28.71 23.58 29.84 18.66 26.56 18.35 25.43 25.53 33.94 29.44
32.79 27.58 25.48 29.86 30.14 0. 0. 0. 0. 0. 0.

ASSAY TYPE  5
105. 497. 303. 628. 403. 665. 393. 445. 188. 59. 202. 50. 480.
310. 393. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  6
500. 1320. 950. 1650. 1300. 1590. 1180. 1510. 830. 350. 830.
300. 1370. 1140. 1280. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  7
60. 300. 140. 310. 270. 340. 200. 240. 120. 30. 160. 40. 230.
190. 200. 0. 0. 0. 0. 0. 0.

ASSAY TYPE  8
980. 1150. 1040. 980. 1200. 840. 1140. 1480. 830. 850. 840.
780. 970. 1220. 1200. 0. 0. 0. 0. 0. 0.

   CHOSE OPTION: 1=DELETE ASSAY TYPE
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
4

REFERENCE STREAM NUMBER (USUALLY MAIN FEED) AND ITS FLOW RATE
1 100
```

```
ENTER ESTIMATES OF SAMPLING AND ANALYSIS ERROR(IN %)
FOR ASSAY TYPES:
1 2 3 4 5 6 7 8
5 5 5 5 10 10 10 10

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

THE LARGEST EXPECTED ERROR IN THE DATA IS:    .409
FOR ASSAY TYPE  2 IN STREAM  6 .
FOR A GOOD DESIGN THE SMALLEST SINGULAR VALUE MUST BE LARGER
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


SELECTION OF INDEPENDENT MASS FLOWS
***********************************


DO YOU WISH TO:

                1=ENTER USER SELECTION
                2=USE COMPUTER DEFAULT SELECTION
2

AUTOMATIC SELECTION IS DONE BY THE PROGRAM

THE INDEPENDENT MASS FLOWS HAVE BEEN SELECTED,THEY ARE:

1 13 14 2 8 4 6 21

THE DEPENDENT MASS FLOWS ARE:

3 5 7 9 10 11 12 15 16 17 18 19 20


SINGULAR VALUE ANALYSIS
**********************


PRINT SYSTEM (Y/N)?Y

PRINT DESCRIPTOR (Y/N) ?Y

SYSTEM ROW NUMBERS AND DESCRIPTORS                                    $$$NOTE 4
```

ROW	DESCRIPTOR 1	2	3	4	5	6	7	8	9	10	ASSAYS
1	S	1	3	1	-10	-13	0	0	0	0	1
2	C	2	2	3	0	0	0	0	0	0	1
3	J	4	3	13	14	-15	0	0	0	0	1
4	C	4	5	6	9	11	0	0	0	0	1
5	S	7	3	3	-8	-9	0	0	0	0	1
6	S	8	3	2	-4	-5	0	0	0	0	1
7	S	10	3	4	-6	-7	0	0	0	0	1
8	C	2	12	13	0	0	0	0	0	0	1
9	T	0	0	0	0	0	0	0	0	0	1
10	S	1	3	1	-10	-13	0	0	0	0	2
11	C	2	2	3	0	0	0	0	0	0	2
12	J	4	3	13	14	-15	0	0	0	0	2

13	C	4	5	6	9	11	0	0	0	0	2
14	S	7	3	3	-8	-9	0	0	0	0	2
15	S	8	3	2	-4	-5	0	0	0	0	2
16	S	10	3	4	-6	-7	0	0	0	0	2
17	C	2	12	13	0	0	0	0	0	0	2
18	T	0	0	0	0	0	0	0	0	0	2
19	S	1	3	1	-10	-13	0	0	0	0	3
20	C	2	2	3	0	0	0	0	0	0	3
21	J	4	3	13	14	-15	0	0	0	0	3
22	C	4	5	6	9	11	0	0	0	0	3
23	S	7	3	3	-8	-9	0	0	0	0	3
24	S	8	3	2	-4	-5	0	0	0	0	3
25	S	10	3	4	-6	-7	0	0	0	0	3
26	C	2	12	13	0	0	0	0	0	0	3
27	T	0	0	0	0	0	0	0	0	0	3
28	S	1	3	1	-10	-13	0	0	0	0	4
29	C	2	2	3	0	0	0	0	0	0	4
30	J	4	3	13	14	-15	0	0	0	0	4
31	C	4	5	6	9	11	0	0	0	0	4
32	S	7	3	3	-8	-9	0	0	0	0	4
33	S	8	3	2	-4	-5	0	0	0	0	4
34	S	10	3	4	-6	-7	0	0	0	0	4
35	C	2	12	13	0	0	0	0	0	0	4
36	T	0	0	0	0	0	0	0	0	0	4
37	S	1	3	1	-10	-13	0	0	0	0	5
38	C	2	2	3	0	0	0	0	0	0	5
39	J	4	3	13	14	-15	0	0	0	0	5
40	C	4	5	6	9	11	0	0	0	0	5
41	S	7	3	3	-8	-9	0	0	0	0	5
42	S	8	3	2	-4	-5	0	0	0	0	5
43	S	10	3	4	-6	-7	0	0	0	0	5
44	C	2	12	13	0	0	0	0	0	0	5
45	T	0	0	0	0	0	0	0	0	0	5
46	S	1	3	1	-10	-13	0	0	0	0	6
47	C	2	2	3	0	0	0	0	0	0	6
48	J	4	3	13	14	-15	0	0	0	0	6
49	C	4	5	6	9	11	0	0	0	0	6
50	S	7	3	3	-8	-9	0	0	0	0	6
51	S	8	3	2	-4	-5	0	0	0	0	6
52	S	10	3	4	-6	-7	0	0	0	0	6
53	C	2	12	13	0	0	0	0	0	0	6
54	T	0	0	0	0	0	0	0	0	0	6
55	S	1	3	1	-10	-13	0	0	0	0	7
56	C	2	2	3	0	0	0	0	0	0	7
57	J	4	3	13	14	-15	0	0	0	0	7
58	C	4	5	6	9	11	0	0	0	0	7
59	S	7	3	3	-8	-9	0	0	0	0	7
60	S	8	3	2	-4	-5	0	0	0	0	7
61	S	10	3	4	-6	-7	0	0	0	0	7
62	C	2	12	13	0	0	0	0	0	0	7
63	T	0	0	0	0	0	0	0	0	0	7
64	S	1	3	1	-10	-13	0	0	0	0	8
65	C	2	2	3	0	0	0	0	0	0	8
66	J	4	3	13	14	-15	0	0	0	0	8
67	C	4	5	6	9	11	0	0	0	0	8
68	S	7	3	3	-8	-9	0	0	0	0	8
69	S	8	3	2	-4	-5	0	0	0	0	8
70	S	10	3	4	-6	-7	0	0	0	0	8
71	C	2	12	13	0	0	0	0	0	0	8
72	T	0	0	0	0	0	0	0	0	0	8

```
PRINT COEFFICIENTS AA AND BB (Y/N) ?N

         THE NODE IMBALANCE MINIMIZATION SOLUTION IS

STREAM    FLOW RATE       SENSITIVITY

 W 13       10.3776             .0633
 W 14        9.7763             .3409
 W  2       19.4569             .8553
 W  8        5.7346             .3311
 W  4        8.1697             .1948
 W  6        7.4891             .0260
 W 21        0.0000            0.0000
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


THE SENSITIVITY MEASURE FOR THIS DESIGN IS: 105.297
       THE PREVIOUS DESIGN SENSITIVITY WAS:    0.000



ON THE BASIS OF THE SMALLEST SINGULAR VALUE (    1.493)
AND WITH A LARGEST EXPECTED ERROR OF      .409

THIS DESIGN IS ****** ACCEPTABLE ******                              $$$NOTE 5
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$



OPTIONS
-------

         1=BACK TO ASSAY MODIFICATION
         2=BACK TO ASSAY ERROR ENTRY
         3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
         4=TO PREVIOUS SVA DESIGN
         5=CONTINUE WITH CURRENT DESIGN
         6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
6                                                                    $$$NOTE 6

THE RESIDUALS ARE:
```

ROW	DESCRIPTOR 1	2	3	4	5	6	7	8	9	10	ASSAYS	RESIDUAL
1	S	1	3	1	-10	-13	0	0	0	0	1	.0487
2	C	2	2	3	0	0	0	0	0	0	1	.0087
3	J	4	3	13	14	-15	0	0	0	0	1	.0020
4	C	4	5	6	9	11	0	0	0	0	1	.0130
5	S	7	3	3	-8	-9	0	0	0	0	1	.0284
6	S	8	3	2	-4	-5	0	0	0	0	1	-.0141
7	S	10	3	4	-6	-7	0	0	0	0	1	.0250
8	C	2	12	13	0	0	0	0	0	0	1	.0141
9	T	0	0	0	0	0	0	0	0	0	1	.1258
10	S	1	3	1	-10	-13	0	0	0	0	2	-.0227
11	C	2	2	3	0	0	0	0	0	0	2	-.0388
12	J	4	3	13	14	-15	0	0	0	0	2	-.0596
13	C	4	5	6	9	11	0	0	0	0	2	.0151

14	S	7	3	3	-8	-9	0	0	0	0	2	-.0470
15	S	8	3	2	-4	-5	0	0	0	0	2	.0295
16	S	10	3	4	-6	-7	0	0	0	0	2	.0037
17	C	2	12	13	0	0	0	0	0	0	2	.0511
18	T	0	0	0	0	0	0	0	0	0	2	-.0687
19	S	1	3	1	-10	-13	0	0	0	0	3	.0595
20	C	2	2	3	0	0	0	0	0	0	3	.0302
21	J	4	3	13	14	-15	0	0	0	0	3	.0067
22	C	4	5	6	9	11	0	0	0	0	3	.0176
23	S	7	3	3	-8	-9	0	0	0	0	3	-.0189
24	S	8	3	2	-4	-5	0	0	0	0	3	-.0224
25	S	10	3	4	-6	-7	0	0	0	0	3	-.0026
26	C	2	12	13	0	0	0	0	0	0	3	-.0063
27	T	0	0	0	0	0	0	0	0	0	3	.0638
28	S	1	3	1	-10	-13	0	0	0	0	4	.0111
29	C	2	2	3	0	0	0	0	0	0	4	-.0733
30	J	4	3	13	14	-15	0	0	0	0	4	.0178
31	C	4	5	6	9	11	0	0	0	0	4	-.0220
32	S	7	3	3	-8	-9	0	0	0	0	4	.0095
33	S	8	3	2	-4	-5	0	0	0	0	4	-.0023
34	S	10	3	4	-6	-7	0	0	0	0	4	.0008
35	C	2	12	13	0	0	0	0	0	0	4	-.0051
36	T	0	0	0	0	0	0	0	0	0	4	-.0634
37	S	1	3	1	-10	-13	0	0	0	0	5	-.0110
38	C	2	2	3	0	0	0	0	0	0	5	-.0090
39	J	4	3	13	14	-15	0	0	0	0	5	-.0044
40	C	4	5	6	9	11	0	0	0	0	5	-.0021
41	S	7	3	3	-8	-9	0	0	0	0	5	-.0306
42	S	8	3	2	-4	-5	0	0	0	0	5	.0004
43	S	10	3	4	-6	-7	0	0	0	0	5	.0056
44	C	2	12	13	0	0	0	0	0	0	5	.0084
45	T	0	0	0	0	0	0	0	0	0	5	-.0426
46	S	1	3	1	-10	-13	0	0	0	0	6	-.0441
47	C	2	2	3	0	0	0	0	0	0	6	-.0298
48	J	4	3	13	14	-15	0	0	0	0	6	.0043
49	C	4	5	6	9	11	0	0	0	0	6	-.0677
50	S	7	3	3	-8	-9	0	0	0	0	6	.0169
51	S	8	3	2	-4	-5	0	0	0	0	6	.0247
52	S	10	3	4	-6	-7	0	0	0	0	6	-.0077
53	C	2	12	13	0	0	0	0	0	0	6	0.0000
54	T	0	0	0	0	0	0	0	0	0	6	-.1034
55	S	1	3	1	-10	-13	0	0	0	0	7	-.0770
56	C	2	2	3	0	0	0	0	0	0	7	.0702
57	J	4	3	13	14	-15	0	0	0	0	7	-.0178
58	C	4	5	6	9	11	0	0	0	0	7	-.0148
59	S	7	3	3	-8	-9	0	0	0	0	7	.0267
60	S	8	3	2	-4	-5	0	0	0	0	7	-.0214
61	S	10	3	4	-6	-7	0	0	0	0	7	.0125
62	C	2	12	13	0	0	0	0	0	0	7	.0422
63	T	0	0	0	0	0	0	0	0	0	7	.0206
64	S	1	3	1	-10	-13	0	0	0	0	8	-.0600
65	C	2	2	3	0	0	0	0	0	0	8	-.0139
66	J	4	3	13	14	-15	0	0	0	0	8	.0112
67	C	4	5	6	9	11	0	0	0	0	8	-.0280
68	S	7	3	3	-8	-9	0	0	0	0	8	-.0007
69	S	8	3	2	-4	-5	0	0	0	0	8	-.0042
70	S	10	3	4	-6	-7	0	0	0	0	8	-.0048
71	C	2	12	13	0	0	0	0	0	0	8	.0006
72	T	0	0	0	0	0	0	0	0	0	8	-.0997

1.65*SIGMA FOR THESE RESIDUALS IS : .0674
YOU MAY WANT TO DELETE EQUATIONS WHITH LARGER RESIDUALS
$$

```
OPTIONS
-------

          1=BACK TO ASSAY MODIFICATION
          2=BACK TO ASSAY ERROR ENTRY
          3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
          4=TO PREVIOUS SVA DESIGN
          5=CONTINUE WITH CURRENT DESIGN
          6=COMPUTE RESIDUALS
ENTER OPTION 1 TO 6 :
5


OPTIONS FOR NEXT DESIGN
-------

          1=TERMINATE WITH FINAL RESULTS
          2=EXIT IMMEDIATELY
          3=COMBINE EQUATIONS
          4=ADD FLOW RATE MEASUREMENTS
          5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
1                                                                      $$$NOTE 7


                                    *************
                                    FINAL RESULTS
                                    *************


PRINT SYSTEM (Y/N)?N

MINIMUM IMBALANCE FLOW-RATES
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


REF.STREAM W  1      100.0000

IND.STREAM W 13       10.3776
IND.STREAM W 14        9.7763
IND.STREAM W  2       19.4569
IND.STREAM W  8        5.7346
IND.STREAM W  4        8.1697
IND.STREAM W  6        7.4891
IND.STREAM W 21        0.0000

DEP.STREAM W  3       18.3994
DEP.STREAM W  5       11.2872
DEP.STREAM W  7         .6806
DEP.STREAM W  9       12.6649
DEP.STREAM W 10       89.6224
DEP.STREAM W 11       12.6649
DEP.STREAM W 12       92.5109
DEP.STREAM W 15       20.1539
DEP.STREAM W 16      102.2872
DEP.STREAM W 17       37.8563
DEP.STREAM W 18       17.0218
DEP.STREAM W 19       17.7024
DEP.STREAM W 20       12.6649
```

Note 1. Unit and stream numbers correspond to the nodal representation of Fig. 4b. The ball mill is represented by a separator followed by a junction (units 12, 13); streams 20 and 21 have no physical existence and will be indeterminate. As will be seen, this does not cause any problems.

Note 2. Assays in per cent and ppm can be mixed, as long as all assays of one type are entered in the same units.

Note 3. The data consistency check detects gross errors in assay type 7 (In) and 10 (Hg). The analyst decides to discard these.

Note 4. This is a typical fairly large system of 72 equations in 7 unknowns.

Note 5. Because of the way in which the ball mill has been described, there is a zero singular value, and w_{21} (a synthetic stream) is undetermined. The true smallest singular value is acceptable. The least well-determined mass flow is w_2.

Note 6. No units are combined and no mass flows are available.

Note 7. The residual analysis shows several large residuals, and the 10 per cent probable error is comparable in magnitude with many of the elements of the $\underline{b}$ vector (printed out at Note 4). A disturbing feature of the data is that circuit balances, which normally would be expected to contain useful data, have large residuals. Examining the original data, the analyst notes that both zinc products are richer than the feed: both iron products are poorer than the feed: both tin products are also poorer than the feed. Warnings were previously printed that internal inconsistencies were present for assay type 3 (Zn), 4 (Fe) and 6 (Sb). Only copper, lead and silver experience significant separation in this circuit. The analyst decides to end this run, and rebalance on assay types 1, 2 and 5 (Cu, Pb, Ag) only.

These modifications can be done only by using the backtracking option of the program. The original data being stored, the program execution is faster. To get assay types 1, 2 and 5, the user must delete all other assay types, starting with the highest rank number. The output up to entry of sampling and analysis error being the same as for Run 2, there is no need to repeat it here. The terminal session for Sample Run 2a is reproduced in Appendix C.

APPENDIX C
SAMPLE RUN 2a

```
MINIMAL DESIGN CONFIGURATION
****************************


ENTER NO. OF FEED STREAMS,SIMPLE SEPARATORS & JUNCTIONS
1 7 6

THERE ARE  7 INDEP. UNKNOWN MASS FLOWS TO BE DETERMINED

THE TOTAL NUMBER OF STREAMS IS 21

THE MAX. NUMBER OF INDEP. MASS BALANCE EQUATIONS THAT
CAN BE WRITTEN IS 13 PER ASSAY TYPE

THE MIN. NUMBER OF STREAMS WHICH MUST BE SAMPLED IS 15



INPUT OF CIRCUIT CONFIGURATION DATA
***********************************


IS YOUR DATA ALREADY STORED ON TAPE1?(Y OR N)
Y


ENTER DATA IN THE FOLLOWING FORM:
ITYPE,N :     WHERE ITYPE=1 DEFINES UNIT AS A JUNCTION,
                    ITYPE=2 DEFINES UNIT AS A SEPARATOR AND
                    N IS THE NUMBER OF STREAMS COMPOSING UNIT
STREAMS :    THE LABELS (NUMBERS) OF THE UNIT STREAMS
             EX.: 1,-5,-7 DEFINES 1 AS INPUT AND 5,7 AS OUTPUT STREAMS

UNIT NO. 1:
2 3
STREAMS    :
1 -10 -13

UNIT NO. 2:
1 3
STREAMS    :
10 11 -16

UNIT NO. 3:
2 3
STREAMS    :
16 -12 -14

UNIT NO. 4:
1 3
STREAMS    :
13 14 -15

UNIT NO. 5:
1 3
STREAMS    :
15 19 -17

UNIT NO. 6:
2 3
STREAMS    :
17 -2 -3
```

* Notes appear on page 51.

```
UNIT NO. 7:
2 3
STREAMS    :
3 -8 -9

UNIT NO. 8:
2 3
STREAMS    :
2 -4 -5

UNIT NO. 9:
1 3
STREAMS    :
5 8 -18

UNIT NO.10:
2 3
STREAMS    :
4 -6 -7

UNIT NO.11:
1 3
STREAMS    :
7 18 -19

UNIT NO.12:
2 3
STREAMS    :
9 -20 -21

UNIT NO.13:
1 3
STREAMS    :
20 21 -11

ENTER ALL FEED STREAMS NUMBERS

1

NUMBER OF PRODUCT STREAMS AND THEIR NUMBERS

2 6 12


DATA CONSISTENCY CHECK
**********************

THE CIRCUIT THAT YOU HAVE JUST ENTERED IS:

UNIT NO.  TYPE            EQUATION
    1      S                1 -10 -13
    2      J               10  11 -16
    3      S               16 -12 -14
    4      J               13  14 -15
    5      J               15  19 -17
    6      S               17  -2  -3
    7      S                3  -8  -9
    8      S                2  -4  -5
    9      J                5   8 -18
   10      S                4  -6  -7
   11      J                7  18 -19
   12      S                9 -20 -21
   13      J               20  21 -11

DO YOU WISH TO CHANGE THIS CIRCUIT DESCRIPTION?(Y OR N)
N
```

```
DATA IS CONSISTENT WITH LIST OF FEED AND PRODUCT


INPUT OF ANALYTICAL DATA
************************

ENTER NUMBER OF ASSAY TYPES

3                                                          $$$NOTE 1*

ENTER CONCENTRATION DATA ONE ASSAY TYPE AT A TIME

IF MISSING DATA,I.E.,STREAMS FOR WHICH ASSAY TYPE
WASN'T ANALYZED, ENTER A VALUE OF ZERO(0.0)


.18 .81 .59 1. .65 1.1 .56 .9 .49 .14 .51 .13 .61 .73 .67 0.
0. 0. 0. 0. 0.
4.49 23.15 9.49 34.87 15.84 36.69 17.29 15.26 5.21 1.99 7.02
1.55 25.1 10.89 16.88 0. 0. 0. 0. 0. 0.
105. 497. 303. 628. 403. 665. 393. 445. 188. 59. 202. 50. 480.
310. 393. 0. 0. 0. 0. 0. 0.

ENTER NUMBER OF THE MAJOR ASSAY TYPE

1

THE ASSAY VALUES CURRENTLY USED ARE :

ASSAY TYPE  1
.18 .81 .59 1. .65 1.1 .56 .9 .49 .14 .51 .13 .61 .73 .67 0.
0. 0. 0. 0. 0.

ASSAY TYPE  2
4.49 23.15 9.49 34.87 15.84 36.69 17.29 15.26 5.21 1.99 7.02
1.55 25.1 10.89 16.88 0. 0. 0. 0. 0. 0.

ASSAY TYPE  3
105. 497. 303. 628. 403. 665. 393. 445. 188. 59. 202. 50. 480.
310. 393. 0. 0. 0. 0. 0. 0.


   CHOSE OPTION: 1=DELETE ASSAY TYPE
                 2=ADD ASSAY TYPE
                 3=MODIFY ASSAYS
                 4=NO MODIFICATION
4


REFERENCE STREAM NUMBER (USUALLY MAIN FEED) AND ITS FLOW RATE
1 100

ENTER ESTIMATES OF SAMPLING AND ANALYSIS ERROR(IN %)
FOR ASSAY TYPES:
1 2 3
5 5 5
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

THE LARGEST EXPECTED ERROR IN THE DATA IS:   .409
FOR ASSAY TYPE  2 IN STREAM  6 .
FOR A GOOD DESIGN THE SMALLEST SINGULAR VALUE MUST BE LARGER
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

* Notes appear on page 51.

SELECTION OF INDEPENDENT MASS FLOWS
****

DO YOU WISH TO:
1=ENTER USER SELECTION
2=USE COMPUTER DEFAULT SELECTION
2

AUTOMATIC SELECTION IS DONE BY THE PROGRAM

THE INDEPENDENT MASS FLOWS HAVE BEEN SELECTED,THEY ARE:

1 13 14 2 8 4 6 21

THE DEPENDENT MASS FLOWS ARE:

3 5 7 9 10 11 12 15 16 17 18 19 20

SINGULAR VALUE ANALYSIS
****

PRINT SYSTEM (Y/N)?Y

PRINT DESCRIPTOR (Y/N) ?Y

SYSTEM ROW NUMBERS AND DESCRIPTORS $$$NOTE 2

ROW	DESCRIPTOR 1	2	3	4	5	6	7	8	9	10	ASSAYS
1	S	1	3	1	-10	-13	0	0	0	0	1
2	C	2	2	3	0	0	0	0	0	0	1
3	J	4	3	13	14	-15	0	0	0	0	1
4	C	4	5	6	9	11	0	0	0	0	1
5	S	7	3	3	-8	-9	0	0	0	0	1
6	S	8	3	2	-4	-5	0	0	0	0	1
7	S	10	3	4	-6	-7	0	0	0	0	1
8	C	2	12	13	0	0	0	0	0	0	1
9	T	0	0	0	0	0	0	0	0	0	1
10	S	1	3	1	-10	-13	0	0	0	0	2
11	C	2	2	3	0	0	0	0	0	0	2
12	J	4	3	13	14	-15	0	0	0	0	2
13	C	4	5	6	9	11	0	0	0	0	2
14	S	7	3	3	-8	-9	0	0	0	0	2
15	S	8	3	2	-4	-5	0	0	0	0	2
16	S	10	3	4	-6	-7	0	0	0	0	2
17	C	2	12	13	0	0	0	0	0	0	2
18	T	0	0	0	0	0	0	0	0	0	2
19	S	1	3	1	-10	-13	0	0	0	0	3
20	C	2	2	3	0	0	0	0	0	0	3
21	J	4	3	13	14	-15	0	0	0	0	3
22	C	4	5	6	9	11	0	0	0	0	3
23	S	7	3	3	-8	-9	0	0	0	0	3
24	S	8	3	2	-4	-5	0	0	0	0	3
25	S	10	3	4	-6	-7	0	0	0	0	3
26	C	2	12	13	0	0	0	0	0	0	3
27	T	0	0	0	0	0	0	0	0	0	3

PRINT COEFFICIENTS AA AND BB (Y/N) ?Y

SYSTEM COEFFICIENTS

ROW	B	A						
1	-.222	-2.611	0.000	0.000	0.000	0.000	0.000	0.000
2	-.056	2.056	-1.222	0.000	0.000	0.000	-2.111	0.000
3	0.000	-.333	.333	0.000	0.000	0.000	0.000	0.000
4	0.000	.444	.444	-.889	1.722	-.500	.167	0.000
5	0.000	.556	.556	0.000	-1.722	0.000	-.556	0.000
6	0.000	0.000	0.000	.889	0.000	-1.944	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	2.444	-3.000	0.000
8	0.000	-.111	-.111	0.000	0.000	0.000	.111	0.000
9	-.278	0.000	0.000	0.000	0.000	0.000	-5.389	0.000
10	-.557	-5.147	0.000	0.000	0.000	0.000	0.000	0.000
11	-.098	1.120	-.862	0.000	0.000	0.000	-1.218	0.000
12	0.000	1.831	-1.334	0.000	0.000	0.000	0.000	0.000
13	0.000	1.646	1.646	-1.628	1.285	.323	-1.737	0.000
14	0.000	.953	.953	0.000	-1.285	0.000	-.953	0.000
15	0.000	0.000	0.000	1.628	0.000	-4.238	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	3.915	-4.321	0.000
17	0.000	-.403	-.403	0.000	0.000	0.000	.403	0.000
18	-.655	0.000	0.000	0.000	0.000	0.000	-7.826	0.000
19	-.438	-4.010	0.000	0.000	0.000	0.000	0.000	0.000
20	-.086	1.362	-1.029	0.000	0.000	0.000	-1.448	0.000
21	0.000	.829	-.790	0.000	0.000	0.000	0.000	0.000
22	0.000	.857	.857	-.895	1.352	-.095	-.857	0.000
23	0.000	1.095	1.095	0.000	-1.352	0.000	-1.095	0.000
24	0.000	0.000	0.000	.895	0.000	-2.143	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000	2.238	-2.590	0.000
26	0.000	-.133	-.133	0.000	0.000	0.000	.133	0.000
27	-.524	0.000	0.000	0.000	0.000	0.000	-5.857	0.000

THE NODE IMBALANCE MINIMIZATION SOLUTION IS

STREAM	FLOW RATE	SENSITIVITY
W 13	10.2894	.0611
W 14	10.6472	.3250
W 2	21.4547	.8428
W 8	7.4854	.3784
W 4	8.7446	.1914
W 6	7.7702	.0229
W 21	0.0000	0.0000

$$

THE SENSITIVITY MEASURE FOR THIS DESIGN IS: 85.893
THE PREVIOUS DESIGN SENSITIVITY WAS: 0.000

ON THE BASIS OF THE SMALLEST SINGULAR VALUE (1.501)
AND WITH A LARGEST EXPECTED ERROR OF .409

THIS DESIGN IS ****** ACCEPTABLE ******
$$ $$$NOTE 3

OPTIONS

1=BACK TO ASSAY MODIFICATION
2=BACK TO ASSAY ERROR ENTRY
3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
4=TO PREVIOUS SVA DESIGN
5=CONTINUE WITH CURRENT DESIGN
6=COMPUTE RESIDUALS

ENTER OPTION 1 TO 6 :
6

THE RESIDUALS ARE: $$$NOTE 4

ROW	DESCRIPTOR										ASSAYS	RESIDUAL
	1	2	3	4	5	6	7	8	9	10		
1	S	1	3	1	-10	-13	0	0	0	0	1	.0464
2	C	2	2	3	0	0	0	0	0	0	1	.0271
3	J	4	3	13	14	-15	0	0	0	0	1	-.0012
4	C	4	5	6	9	11	0	0	0	0	1	-.0005
5	S	7	3	3	-8	-9	0	0	0	0	1	.0558
6	S	8	3	2	-4	-5	0	0	0	0	1	-.0207
7	S	10	3	4	-6	-7	0	0	0	0	1	.0193
8	C	2	12	13	0	0	0	0	0	0	1	.0146
9	T	0	0	0	0	0	0	0	0	0	1	.1409
10	S	1	3	1	-10	-13	0	0	0	0	2	-.0272
11	C	2	2	3	0	0	0	0	0	0	2	-.0268
12	J	4	3	13	14	-15	0	0	0	0	2	-.0463
13	C	4	5	6	9	11	0	0	0	0	2	.0153
14	S	7	3	3	-8	-9	0	0	0	0	2	-.0293
15	S	8	3	2	-4	-5	0	0	0	0	2	.0213
16	S	10	3	4	-6	-7	0	0	0	0	2	-.0067
17	C	2	12	13	0	0	0	0	0	0	2	.0531
18	T	0	0	0	0	0	0	0	0	0	2	-.0467
19	S	1	3	1	-10	-13	0	0	0	0	3	-.0255
20	C	2	2	3	0	0	0	0	0	0	3	-.0038
21	J	4	3	13	14	-15	0	0	0	0	3	-.0011
22	C	4	5	6	9	11	0	0	0	0	3	-.0137
23	S	7	3	3	-8	-9	0	0	0	0	3	-.0430
24	S	8	3	2	-4	-5	0	0	0	0	3	-.0047
25	S	10	3	4	-6	-7	0	0	0	0	3	.0056
26	C	2	12	13	0	0	0	0	0	0	3	.0176
27	T	0	0	0	0	0	0	0	0	0	3	-.0687

1.65*SIGMA FOR THESE RESIDUALS IS : .0781
YOU MAY WANT TO DELETE EQUATIONS WHITH LARGER RESIDUALS
$$

OPTIONS

1=BACK TO ASSAY MODIFICATION
2=BACK TO ASSAY ERROR ENTRY
3=BACK TO SELECTION OF INDEPENDENT MASS FLOWS
4=TO PREVIOUS SVA DESIGN
5=CONTINUE WITH CURRENT DESIGN
6=COMPUTE RESIDUALS

ENTER OPTION 1 TO 6 :
5

```
OPTIONS FOR NEXT DESIGN
-------

          1=TERMINATE WITH FINAL RESULTS
          2=EXIT IMMEDIATELY
          3=COMBINE EQUATIONS
          4=ADD FLOW RATE MEASUREMENTS
          5=DELETE EQUATIONS
ENTER OPTION 1 TO 5 :
1


                                   *************
                                   FINAL RESULTS
                                   *************


PRINT SYSTEM (Y/N)?N

MINIMUM IMBALANCE FLOW-RATES
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


REF.STREAM W  1      100.0000

IND.STREAM W 13       10.2894
IND.STREAM W 14       10.6472
IND.STREAM W  2       21.4547
IND.STREAM W  8        7.4854
IND.STREAM W  4        8.7446
IND.STREAM W  6        7.7702
IND.STREAM W 21        0.0000

DEP.STREAM W  3       20.6518
DEP.STREAM W  5       12.7101
DEP.STREAM W  7         .9745
DEP.STREAM W  9       13.1664
DEP.STREAM W 10       89.7106
DEP.STREAM W 11       13.1664
DEP.STREAM W 12       92.2298
DEP.STREAM W 15       20.9366
DEP.STREAM W 16      102.8770
DEP.STREAM W 17       42.1065
DEP.STREAM W 18       20.1955
DEP.STREAM W 19       21.1700
DEP.STREAM W 20       13.1664


     STOP
     057400 MAXIMUM EXECUTION FL.
      1.171 CP SECONDS EXECUTION TIME.
```

Sample Run 2a: Sample Run 2 with only assay types 1, 2 and 5

Note 1. There are only 3 assay types now after the user has deleted the other assays — the third one corresponding to assay type 5 of the original data. The relative precision for all three assay types is set to 5%.

Note 2. The system, normalized and scaled, is printed. The total number of equations is now reduced to 27.

Note 3. The 'true' smallest singular value, which is 1.501, is greater than the largest acceptable error, 0.409, and this design is very acceptable. The sensitivity measure for this design is less than for the one using eight assay types, so that this design is less sensitive to errors or data perturbation.

Note 4. There are still some large residuals, and one could test the result of deleting the equations corresponding to those residuals. But this refinement is barely justified, as this solution is recommended only for obtaining a starting point for minimum-variance material balance computations (see Table 3 for flow rate estimates obtained with SAMBA compared to those of MATBAL).

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