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Developing a Computer Model and Its Application in Evaluating Forward Cleaner Sequences

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DEVELOPING A COMPUTER MODEL AND ITS APPLICATION IN EVALUATING FORWARD CLEANER SEQUENCES

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Abstract

The objective of this work was to establish a usable format for developing an idea into a working model and to verify that format by example.

The format is outlined as follows:

Establish a need
Set Objectives/Criteria
Synthesis
Analysis
Selection
Decision/Action
Communication

The example used to verify the format was a comparison of various forward cleaner sequences to determine if an improvement could be made over the current cascade system. After completion of the model format, it was determined that an alpha/alpha cleaning system would prove more cost effective than a cascade system if it was run at feed consistencies greater than .55%. The incremental cleaning efficiency would allow for lower cost stocks to be used, thus defraying the increased capital costs. The overall application of the model format proved very effective.

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Introduction

The objective of this work was to establish a usable format for developing an idea into a working model and to verify that format by example. The concept of having an established format for developing an idea was meant not inhibit creativity but rather to channel creative thoughts into a valid format for business interpretation.

The short term objective of this work was to evaluate various forward cleaner sequences to determine if an improvement could be made over the current cascade system. In order to evaluate these sequences accurately, the model format again was applied, showing its effectiveness in various applications.

Whether a model format is applied that produces a computer model, a mechanical model or a paper and pen model, the same purpose and principles apply. An individual is usually trying to present an idea in a clear, concise manner, showing that the idea was well thought out, demonstrate the decision making process and establish the value of the idea. The model format outlined as follows helps to do all the above:

Establish a need
Set objectives/Criteria
Synthesis
Analysis
Selection
Decision/Action
Communication

The following work will detail the model format and demonstrate one of its applications.

BACKGROUND/THEORETICAL DISCUSSION

What is a Model?

The earliest use of the word "model" denoted a set of architects' plans.(4) Models were also constructed as a means of illustrating "elementary" mathematics(4). A model was made (of a square for example) and used as a physical demonstration of the fact which it illustrates. Early models provided tangible objects to bring reality into the symbolic world of mathematics. Any figure drawn on paper as a tangible aid to understanding could be justifiably called a model.

Why use a Model?

A model is often used to illustrate a "real-life" situation when a large number of variables are under consideration or when common sense dictates.

The type of model under consideration in this paper is not a model of an already proven fact, but a model of a new system design. This type of model will aid in ;

- illustrating an idea for something new or different
- solving a problem and getting an answer in a satisfactory or useful form.
- making a decision by choosing between two or more alternatives.

When designing a system (and a model of that system) several terms must be defined to avoid misunderstanding.

System - A system is a set of components arranged to perform some wanted operation(s). A complex system performing one operation may be composed of many single systems, each with one input and one output that when combined, achieve the whole operation.

Design - A design is the work of a human mind or minds to coordinate separate parts or acts to produce a result. Design always involves the following information:

1. Information in the form of facts and data
2. Information in the form of patterns and relations between the items of 1.
3. Information processing using 1 & 2.

System Design/Modeling Steps

The first step in any design is getting an idea. The original idea is worked over, modified and worked over again until several ideas are available for consideration. Before going further, it is necessary to choose the best proposal. The second step is to set objectives for the design.

Objectives and goals guide and limit the design work. Objectives and goals can be classified as follows:

1. MUSTS - The set of performance and other requirements that must be met.

2. MUST NOTS - The set of constraints stating what the system must not exceed.

3. WANTS - These are not hard and fast requirements.

4. DON'T WANTS - Exactly what the words say.

Tolerance is the amount of variation that can be accepted in input and output information. Objectives, goals and tolerances must be identified and accepted before work proceeds further.

Step three is identifying the environment. The environment consists of everything outside the system that either affects the performance or is affected by the operation, or both. A designer must carefully consider all of the effects of environment upon the design. For a sizable system, the conceivable number of inputs and outputs may be extremely large. In practice a designer must select those effects believed to be most important thus dividing the possible interactions into those which are known to be important and those which can be safely neglected.

Synthesis is next and is the first real step of design work. Synthesis involves finding any collection of objects that can perform all the wanted functions and meet all of the requirements of the specifications. All available information on the objects proposed for use must be organized and classified. Hopefully there will be several tentative collections that promise to do the job. The next step is analysis.

In system design, analysis means that any tentative collection must be studied and checked to make certain that it meets all of the objectives. At this point, repeatedly using the synthesis and analysis steps, an optimum design is developed.

After analysis comes selection. There should be more than one collection available that will meet the objectives and the best alternative must be selected. Some times a choice between alternatives is clear-cut based on the objectives and rules previously established and sometimes a choice must be made on the basis of minor differences.

Once a selection is made, a decision is aimed at what action to take and how to effectively communicate the results of the work.

A model, along this vein, may be a paper and pencil reproduction of the system design or it may be a hands-on working representation. A model should provide information that may have been overlooked originally and help identify any mistakes that have been made.

The information gained from the model may require rethinking of the entire design problem. A different collection of elements to meet the requirements may be needed and occasionally (but not often) objectives must be changed.

At this point, it can be seen that the system design and modeling steps will be repeated until the design selection and the model are in agreement with the set objectives and tolerances. The next portion of this paper will demonstrate the applications of the modeling steps in system design and selection. A summary of these steps is as follows:

1. A need or a problem exists
   - All available information related to the problem must be gathered.
2. Objectives and tolerances must be set
   - Musts, Must-Nots
   - Wants, Don't Wants
   - Environment must be considered and requirements established
3. Synthesis - collection that performs wanted functions.
   - All available information related to the objects in the collection must be gathered.
4. Analysis - Double check, optimum design
5. Selection - Review solution vs. initial objectives
6. Decision/Action
7. Communication of Results

APPLICATION OF MODELING STEPS

Need

A question was raised by Scott Paper Company as to whether or not a forward cleaner system could be developed for use with secondary fiber slurries that was more cost effective than the cascade system predominant in the pulp and paper industry.

Information Related to the Problem:

In order to reduce the processing costs associated with a forward cleaner system one must optimize yield, cleaning efficiency, water consumption and equipment costs. A system that could yield more fiber for a given input, provide cleaner pulp, use less water or require fewer cleaners than a cascade system would help fill the need to be more cost efective. A cascade system using 3" cleaners is assumed satisfactory unless an improved design can be developed.

Objectives/Tolerances

Musts: - Consist of on-the-market 3" centrifugal cleaners

- Cost no more than $250,000

- Have a yield as high as or higher than a cascade system

- Provide a pulp as clean as or cleaner than a cascade system

Wants:*- Accept consistency .4% or greater

- 80% minimum yield

- Cleaning efficiencies 50%

* See Appendix II for details of yield and cleaning efficiency calculations.

Environment:

- Stock being fed to the cleaners is at 80-90°F (1), .55-.65% consistency, 30-50 ppm dirt count.

- Pressure drops between feed to accept lines will be 40 psig (1).

- All dilution water will be a closed system @ .01% consistency.

These conditions are considered representative of desired operating conditions. Figure 1 displays the known relationship between feed consistency and thickening factor for 3" forward cleaners. This relationship was experimentally determined at at earlier date. (See Appendix III).

Figure 2 displays the known relationship between feed consistency and cleaning efficiency. This relationship was experimentally determined at an earlier date. (See Appendix III).

FIGURE 1

FEED CONSISTENCY VS. THICKENING FACTOR FOR 3" CENTRIFUGAL CLEANERS

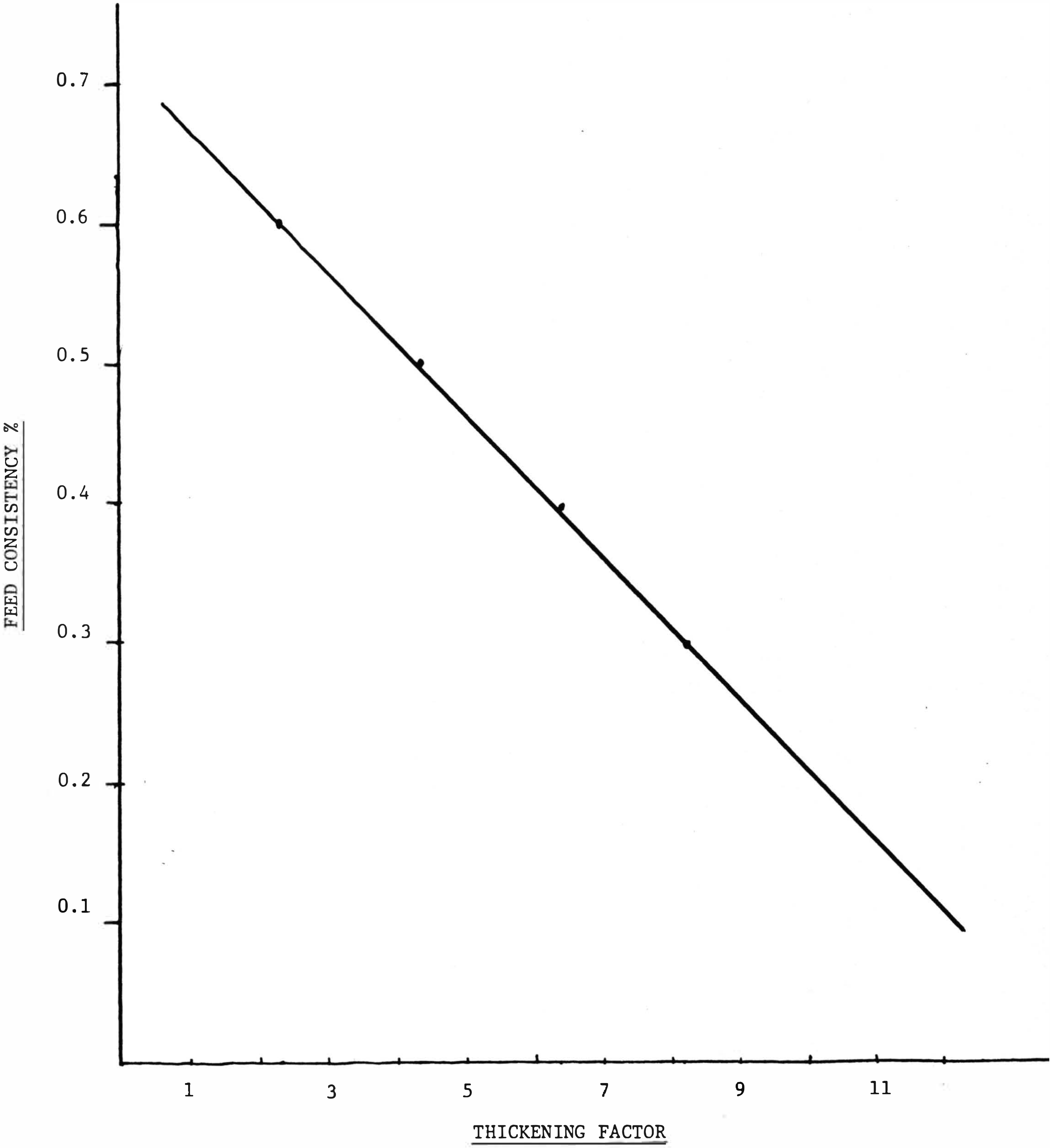
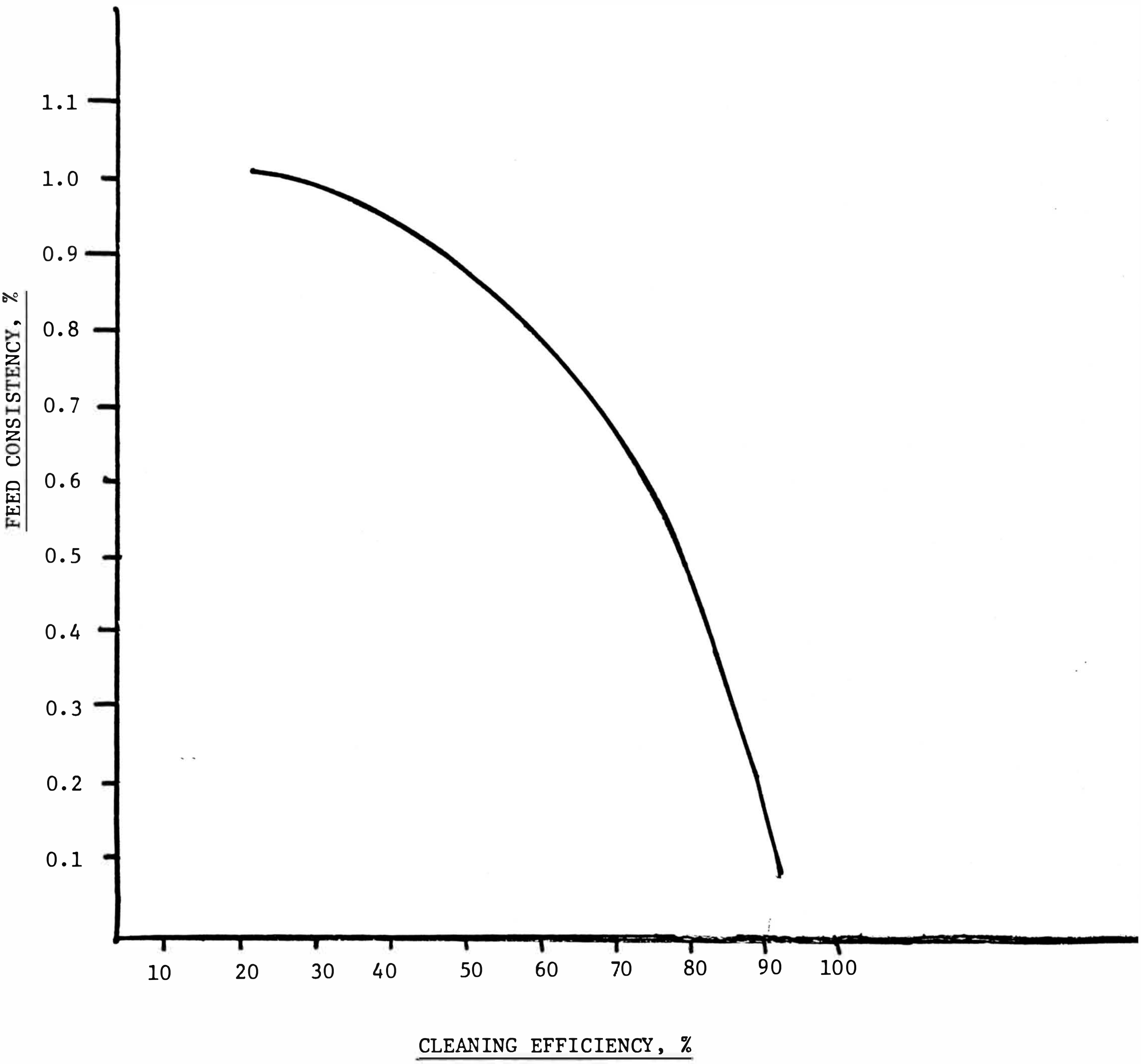


FIGURE 2

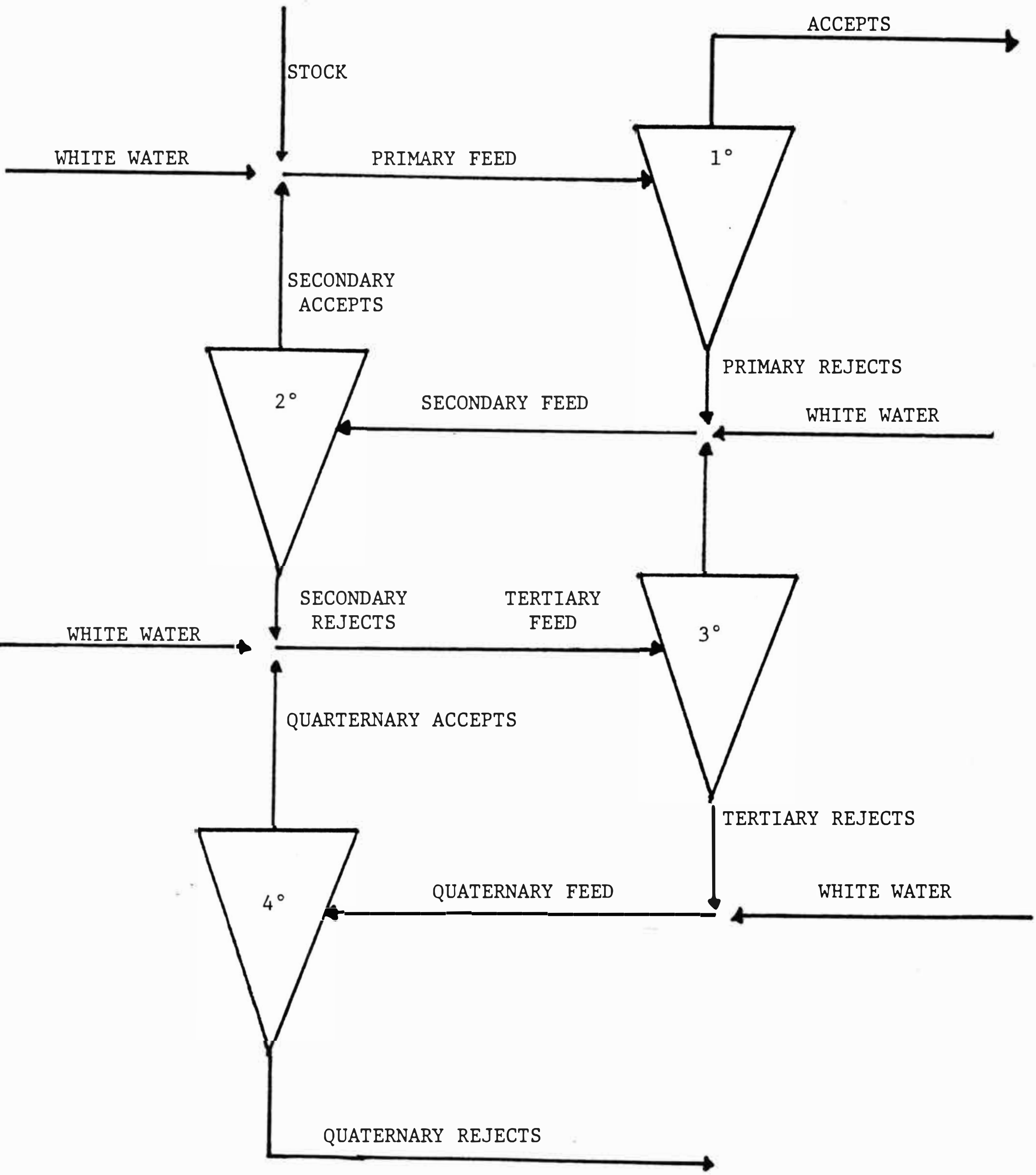
FEED CONSISTENCY VS. CLEANING EFFICIENCY - (30-50 PPM DIRT IN FEED)



Synthesis

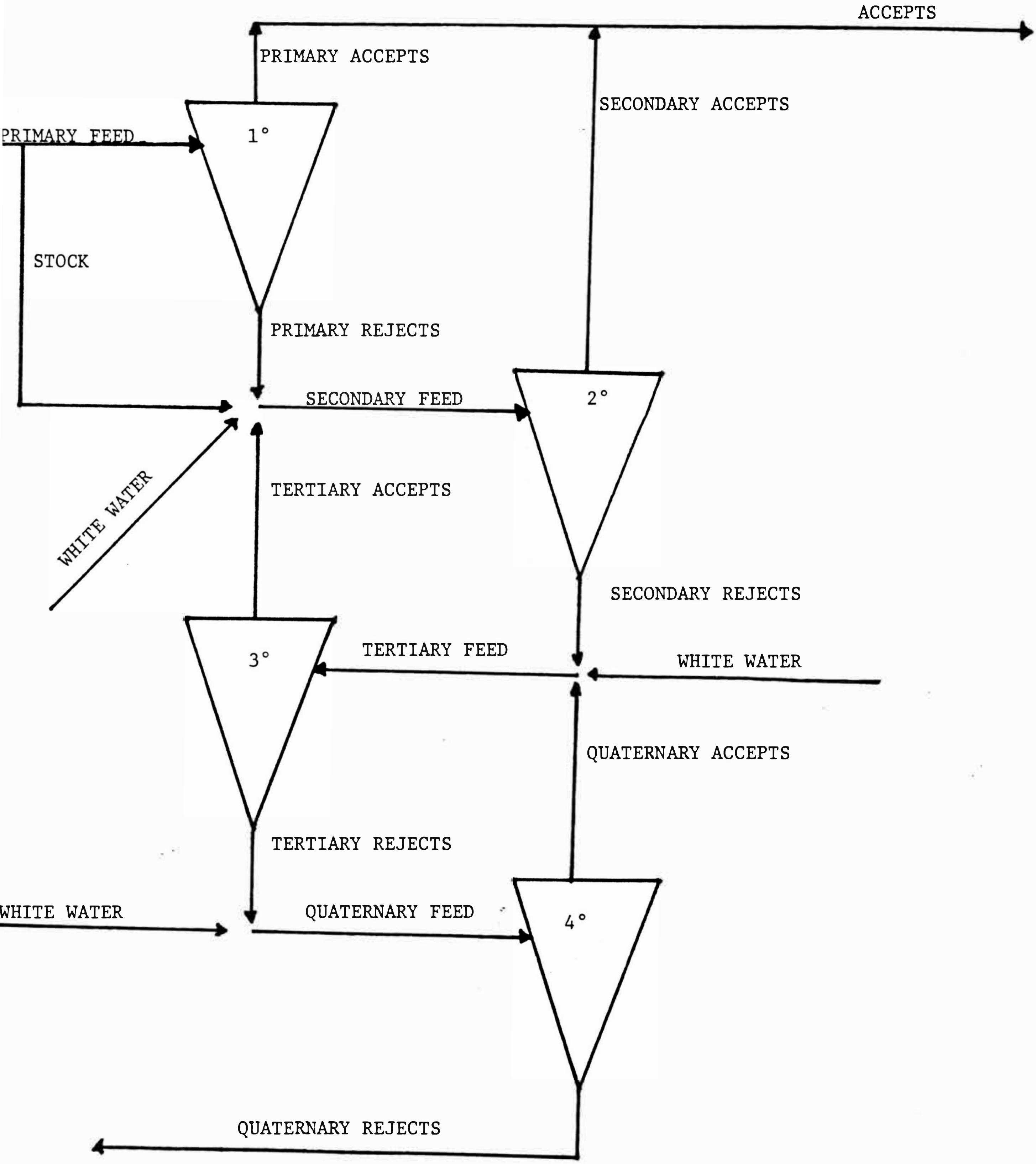
Collection 1

Collection 1 demonstrates the popular 4 stage cascade system that will be modeled for comparison to and evaluation against other collections.



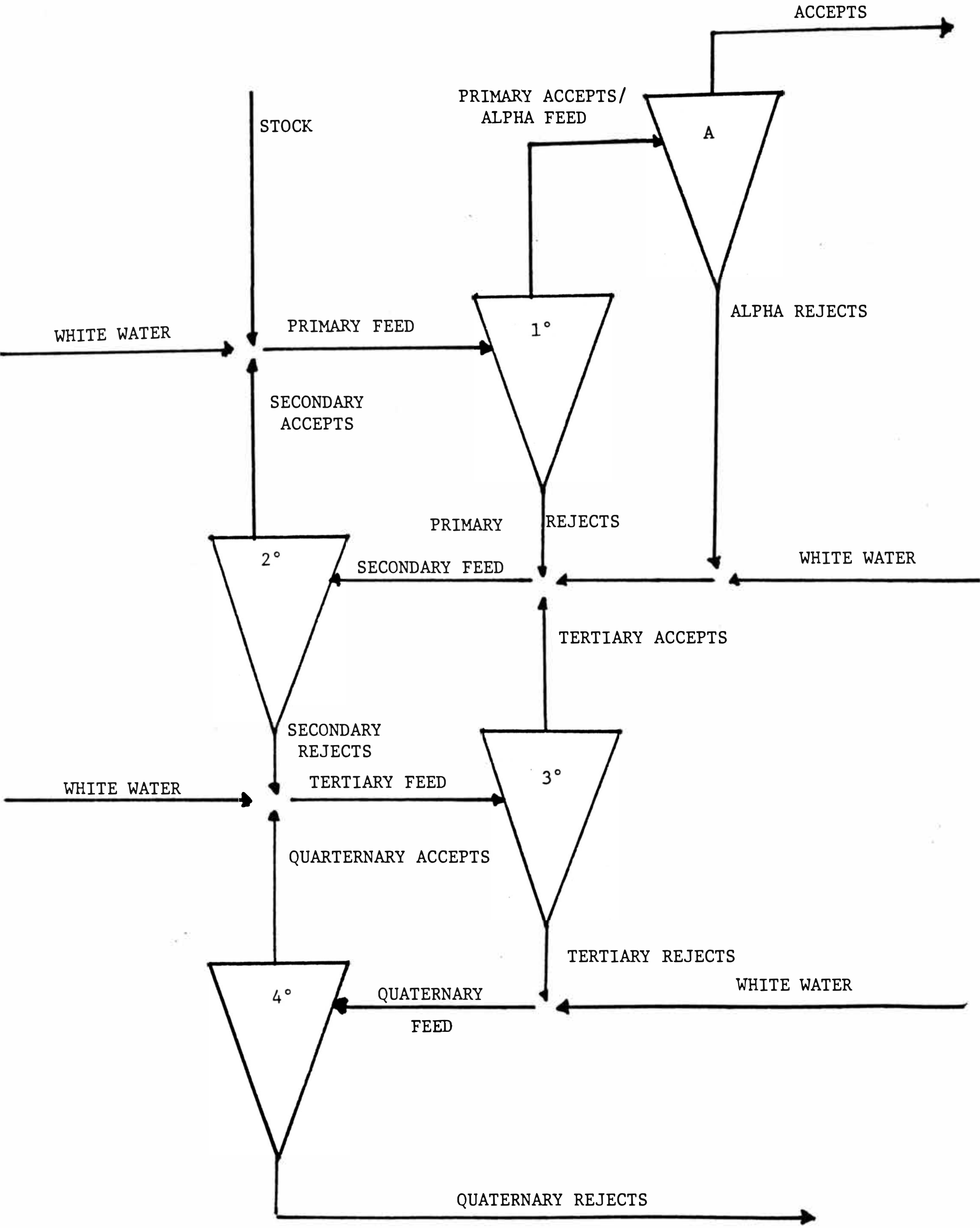
Collection 2

Collection two demonstrates a "split/feed - feed forward" system that is a possible alternative to the cascade system



COLLECTION 3

Collection 3 demonstrates an "alpha-alpha" system that is a possible alternative to the cascade system.



Analysis

Based on the objectives and tolerances listed previously, one must obtain the following information for each system:

- Total number of cleaners needed
- Gallons fed to system
- Gallons accepted from system
- Gallons rejected from system
- Tons of stock fed to system
- Tons accepted from system
- Tons rejected from system
- Dirt count entering the system
- Dirt count leaving the system
- Accepted stock consistency

With this information, total cost, space requirements, yield and cleaning efficiencies can be caluclated and compared. To obtain this information a mass and flow balance must be performed on each system.

Because of the interaction between stages a series of equations representing the mass and flow splits must be performed in a loop sequence until there is no change in the system and thus it is balanced. To perform these equations by hand would require several hours per system for each set of conditions.

At this time, it was decided that a mathematical model that represented each collection and could be programmed into a computer/calculator should be developed. This would aid in the understanding of what actually happens with each collection and form a basic analysis structure for quick evaluation of future collections.

Development of these models follows the same steps as previously outlined:

- Define the problem
- Set objectives
- Synthesis
- Analysis
- Selection
- Action

The basic problem was a need for a computer program that would simulate each of the cleaner systems. When gathering pertinent information it was discovered that two such programs (for cascade systems) already existed, (2, 3).

The objectives set for these models are that they must be accurate, easy to apply and provide information in a usable format.

When synthesizing these models, the programs written previously by Mr. V. Kumar and Mr. K. J. Laurinolli (2, 3) were reviewed. Mr. Kumar's program is 100% accurate but the format can only be applied to a HP-97 calculator. Mr. Laurinolli's program is accurate to .00001/GPM, makes several assumptions as to thickening factors and is applicable only to a TI-59 calculator. It was decided at that time to apply several of the principles of Mr. Kumar's program with the format of Mr. Laurinalli's program to develop an accurate cascade flow balance that could be used with a TI-59 calculator (easily available to the author) or programed in the FORTRAN language. The principles of this hybrid program, if successful, would then be applied to each of the other collections under consideration and they could then be balanced and evaluated under the same criteria.

The final algorithms for each collection are listed on the following pages. Details of the actual programming steps can be found in Appendix I.

MODEL SYNTHESIS

WITH ALGORITHMS

COLLECTION 1

NOMENCLATURE

Symbols

TF = Thickening Factor

T = B.D. tons per day

C = B.D. consistency (not %)

G = Gallons per minute

R = Reject rate by weight

Subscripts:

1 = Primary stage

2 = Secondary stage

3 = Tertiary stage
4 = Quaternary Stage
A = Accepts

F = Feed

R = Rejects

W = Dilution water

S = Initial thick stock

Input

TAA

C_1F

C_2F

C_3F

C_4F

R_1

R_2

R_3

R_4

TF_1

TF_2

TF_3

TF_4

C_1W

C_2W

C_3W

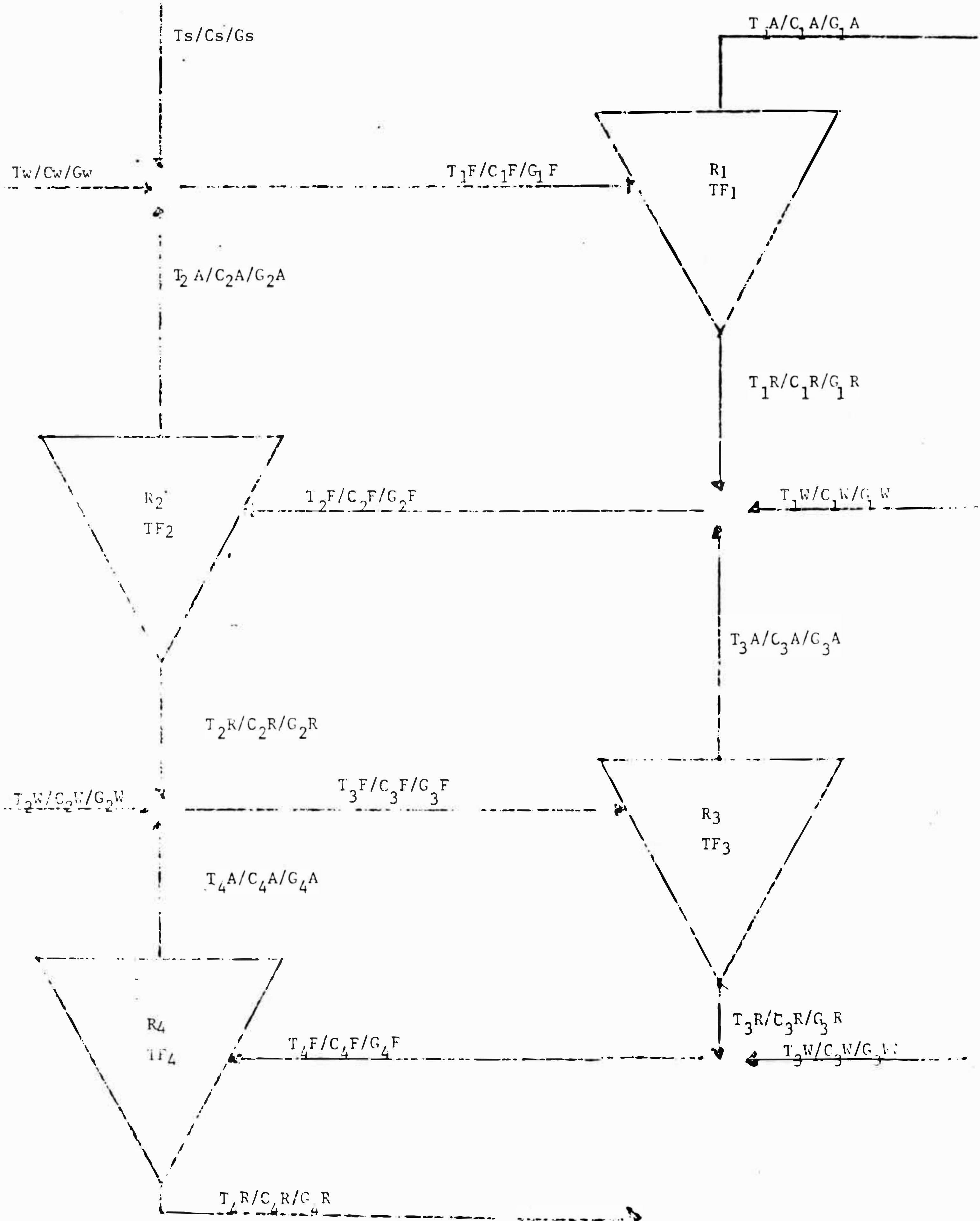
C_4W

CS

T_4R - initial

SYMBOL IDENTIFICATION

Collection I



1) $$G_4R = \frac{T_4R}{C_4R \ 6.008}$$

2) $$T_4F = \frac{T_4R}{R_4}$$

3) $$G_4F = \frac{T_4F}{C_4F \ 6.008}$$

4) $$G_4A = G_4F - G_4R$$

5) $$T_4A = T_4F - T_4R$$

6) $$C_4A = \frac{T_4A}{G_4A \ 6.008}$$

7) $$C_3R = C_3F \ TF_3$$

8) $$\frac{(C_4F - C_3R) \ G_4F}{(C_3W - C_3R)} = G_3W$$

9) $$G_3R = G_4F - G_3W$$

10) $$T_3R = G_3R \ C_3R \ 6.008$$

11) $$T_3W = G_3W \ C_3W \ 6.008$$

12) $$T_3F = \frac{T_3R}{R_3}$$

13) $$G_3F = \frac{T_3F}{C_3F \ 6.008}$$

14) $$T_3A = T_3F - T_3R$$

15) $$G_3A = G_3F - G_3R$$

16) $$C_3A = \frac{T_3A}{G_3A \ 6.008}$$

17) $C_2R = C_2F\ TF_2$

18) $$G_2W = \frac{G_3F\ (C_3F - C_2R) + G_4A\ (C_2R - C_4A)}{(C_2W - C_2R)}$$

19) $G_2R = G_3F - G_2W - G_4A$

20) $T_2W = C_2W\ G_2W\ 6.008$

21) $T_2R = C_2R\ G_2R\ 6.008$

22) $$T_3F = \frac{T_2R}{R_2}$$

23) $$G_2F = \frac{T_2F}{C_2F\ 6.008}$$

24) $T_2A = T_2F - T_2R$

25) $G_2A = G_2F - G_2R$

26) $$C_2A = \frac{T_2A}{G_2A\ 6.008}$$

27) $C_1R = C_1F\ TF_1$

28) $$G_1W = \frac{G_2F\ (C_2F - C_1R) + G_3A\ (C_1R - C_3A)}{C_1W - C_1R}$$

29) $G_1R = G_2F - G_3A - G_1W$

30) $T_1R = G_1R\ C_1R\ 6.008$

31) $$T_1F = \frac{T_1R}{R_1}$$

32) $$G_1F = \frac{T_1F}{C_1F\ 6.008}$$

33) $T_1A = T_1F - T_1R$

34) $G_1A = G_1F - G_1R$

35) $$\frac{G_1A - \text{Known}}{G_1A - \text{Calculated}} = X$$

36) $G_4R\ X = G_4R\ \text{Actual}$

37) $G_4R\ (\text{Actual})\ C_4R\ 6.008 = T_4R$

38) Repeat 1-37 until X =1 (Step 35)

39) $$GW = \frac{G_1F\ (C_1F - CS) + G_2A\ (CS - C_2A)}{CW - CS}$$

40) $GS = G_1F - G_2A - GW$

41) $TW = CW\ GW\ 6.008$

42) $TS = CS\ GS\ 6.008$

COLLECTION 2

NOMENCLATURE

Symbols

TF = Thickening factor

T = B.D. tons per day

C = B.D. consistency (not %)

G = Gallons per minute

R = Reject rate by weight

Pct = Percentage of feed flow that goes to primary stage

Subscripts:

1 = Primary stage

2 = Secondary stage

3 = Tertiary stage
4 = Quaternary Stage
A = Accepts

F = Feed

R = Rejects

W = Dilution water

S = Initial thick stock

Input

T_1A

C_1F

C_2F

C_3F

C_4F

R_1

R_2

R_3

R_4

TF_1

TF_2

TF_3

TF_4

C_1W

C_2W

C_3W

C_4W

CS
T_4R
Pct

1) $$G_4R = \frac{T_4R}{C_4R \ 6.008}$$

2) $$T_4F = \frac{T_4R}{R_4}$$

3) $$G_4F = \frac{T_4F}{C_4F \ 6.008}$$

4) $$G_4A = G_4F - G_4R$$

5) $$T_4A = T_4F - T_4R$$

6) $$C_4A = \frac{T_4A}{G_4A \ 6.008}$$

7) $$C_3R = C_3F \ TF_3$$

8) $$\frac{(C_4F - C_3R)\ G_4F}{(C_3W - C_3R)} = G_3W$$

9) $$G_3R = G_4F - G_3W$$

10) $$T_3R = G_3R \ C_3R \ 6.008$$

11) $$T_3W = G_3W \ C_3W \ 6.008$$

12) $$T_3F = \frac{T_3R}{R_3}$$

13) $$G_3F = \frac{T_3F}{C_3F \ 6.008}$$

14) $$T_3A = T_3F - T_3R$$

15) $$G_3A = G_3F - G_3R$$

16) $$C_3A = \frac{T_3A}{G_3A \ 6.008}$$

17) $C_2R = C_2F\ TF_2$

18) $$G_2W = \frac{G_3F\ (C_3F - C_2R) + G_4A\ (C_2R - C_4A)}{(C_2W - C_2R)}$$

19) $G_2R = G_3F - G_2W - G_4A$

20) $T_2W = C_2W\ G_2W\ 6.008$

21) $T_2R = C_2R\ G_2R\ 6.008$

22) $$T_3F = \frac{T_2R}{R_2}$$

23) $$G_2F = \frac{T_2F}{C_2F\ 6.008}$$

24) $T_2A = T_2F - T_2R$

25) $G_2A = G_2F - G_2R$

26) $$C_2A = \frac{T_2A}{G_2A\ 6.008}$$

27) $C_1R = C_1F\ TF_1$

28) $G = G_2F\ (C_2F - C_2W) + G_3A\ (C_2W - C_3A)$

29) $$A = C_1R + \frac{C_1R\ (1 - pct)}{R1\quad Pct} - C_2W\ \frac{C_1R - (1-pct)}{C_1F\ R_1\ Pct}$$

30) $G_1R = G/A$

31) $$G_1F = \frac{G_1R\ \ C_1R\ \ (1 - Pct)}{C1F\ \ R1\ \ Pct}$$

32) $G_2W = G_2F - G_1R - G_{13}H$

33) $T_1H = GH \quad C_1F \quad 6.008$

34) $T_1R = G_1R \quad C_1R \quad 6.008$

35) $T_2W = G_2W \quad C_2W \quad 6.008$

36) $T_1F = T_1R/R_1$

37) $G_1F = T_1F/C_1F \quad 6.008$

38) $T_1A = T_1F - T_1R$

39) $TAA\ Calc. = T_1A + T_2A$

40) $X = TAA/TAA\ Calc.$

41) $T_4R\ New = T_4R \quad X$

42) $T_4R = T_4R\ New$

43) $G_1A = G_1F - G_1R$

44) $C_1A = T_1A/\ (G_1A \quad 6.008)$

45) $$GS = \frac{G_1F \quad (C_1F - C_1W + GH\ (C_1F - C_1W)}{CS - C1W}$$

46) $G_1W = GH - G_1F - GS$

47) $T_1W = C_1W \quad G_1W - \quad 6.008$

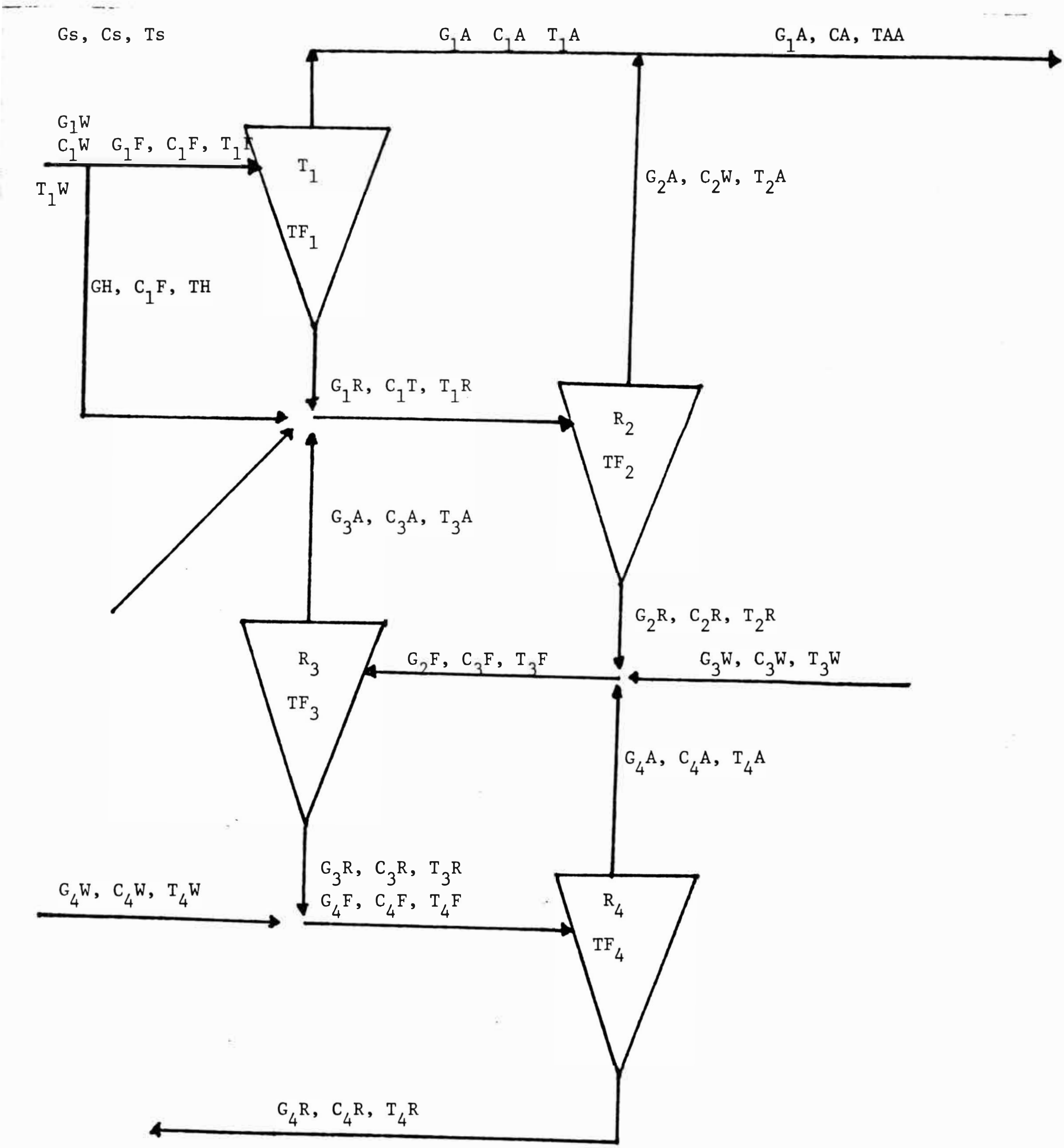
48) $TS = GS \quad CS \quad 6.008$

49) $GA = G_1A + G_2A$

50) $CA = TAA/\ (GA \quad 6.008)$

SYMBOL IDENTIFICATION

COLLECTION 2



NOMENCLATURE

Symbols

TF = Thickening factor

T = B.D. tons per day

C = B.D. consistency (not %)

G = Gallons per minute

R = Reject rate by weight

A = Alpha stage

Subscripts

1 = Primary stage

2 = Secondary stage

3 = Tertiary stage
4 = Quaternary Stage
A = Accepts

F = Feed

R = Rejects

W = Dilution water

S = Initial thick stock

Input

TAA

C_1F

C_2F

C_3F

C_4F

R_1

R_2

R_3

R_4

RA

TF_1

TF_2

TF_3

TF_4

TFA

C_1W

C_2W

C_3W

C_4W

CS

T_4R - initial

C - Initial

1) $$G_4R = \frac{T_4R}{C_4R\ 6.008}$$

2) $$T_4F = \frac{T_4R}{R_4}$$

3) $$G_4F = \frac{T_4F}{C_4F\ 6.008}$$

4) $$G_4A = G_4F - G_4R$$

5) $$T_4A = T_4F - T_4R$$

6) $$C_4A = \frac{T_4A}{G_4A\ 6.008}$$

7) $$C_3R = C_3F\ TF_3$$

8) $$\frac{(C_4F - C_3R)\ G_4F}{(C_3W - C_3R)} = G_3W$$

9) $$G_3R = G_4F - G_3W$$

10) $$T_3R = G_3R\ C_3R\ 6.008$$

11) $$T_3W = G_3W\ C_3W\ 6.008$$

12) $$T_3F = \frac{T_3R}{R_3}$$

13) $$G_3F = \frac{T_3F}{C_3F\ 6.008}$$

14) $$T_3A = T_3F - T_3R$$

15) $$G_3A = G_3F - G_3R$$

16) $$C_3A = \frac{T_3A}{G_3A\ 6.008}$$

17) $C_2R = C_2F\ TF_2$

18) $$G_2W = \frac{G_3F\ (C_3F - C_2R) + G_4A\ (C_2R - C_4A)}{(C_2W - C_2R)}$$

19) $G_2R = G_3F - G_2W - G_4A$

20) $T_2W = C_2W\ G_2W\ 6.008$

21) $T_2R = C_2R\ G_2R\ 6.008$

22) $$T_3F = \frac{T_2R}{R_2}$$

23) $$G_2F = \frac{T_2F}{C_2F\ 6.008}$$

24) $T_2A = T_2F - T_2R$

25) $G_2A = G_2F - G_2R$

26) $$C_2A = \frac{T_2A}{G_2A\ 6.008}$$

27) $C_1R = C_1F\ TF_1$

28) $C = 0.5 \text{ X } C_1R$

29) $G = (G_2F\ (C_2F - C_1R) + G_3A\ (C_1R - C_3A))/\ (C - C_1R)$

30) $T = G \text{ X } C \text{ X } 6.008$

31) $G_1R = G_2F - G - G_3A$

32) $T_1R = G_1R \text{ X } C_1R \text{ X } 6.008$

33) $T_1F = T_1R/R_1$

34) $T_1A = T_1F - T_1R$

35) $TR = T_1A \text{ X } RA$

36) $G_1F = T_1F/\ (C_1F \text{ X } 6.008)$

37) $G_1A = G_1F - G_1R$

38) $C_1A = T_1A / (G_1A \times 6.008)$

39) $CR = C_1F \times TFA$

40) $GR = TR/(CR \times 6.008)$

41) $G_2W = G - G_1R$

42) $T_2W = T - TR$

43) $TAA\ Calc. = T_1A - T_1R$

44) $X = TAA/TAA\ Calc.$

45) $T_4R\ New = T_4R \times X$

46) $T_4R = T_4R\ New$

47) $GA = G_1A - G_1R$

48) $CA = TA / (GA \times 6.008)$

49) $GS = G_1F\ (C_1W - C_1F) + G_2A \times (C_2A - C_1W) / (C_1W - CS)$

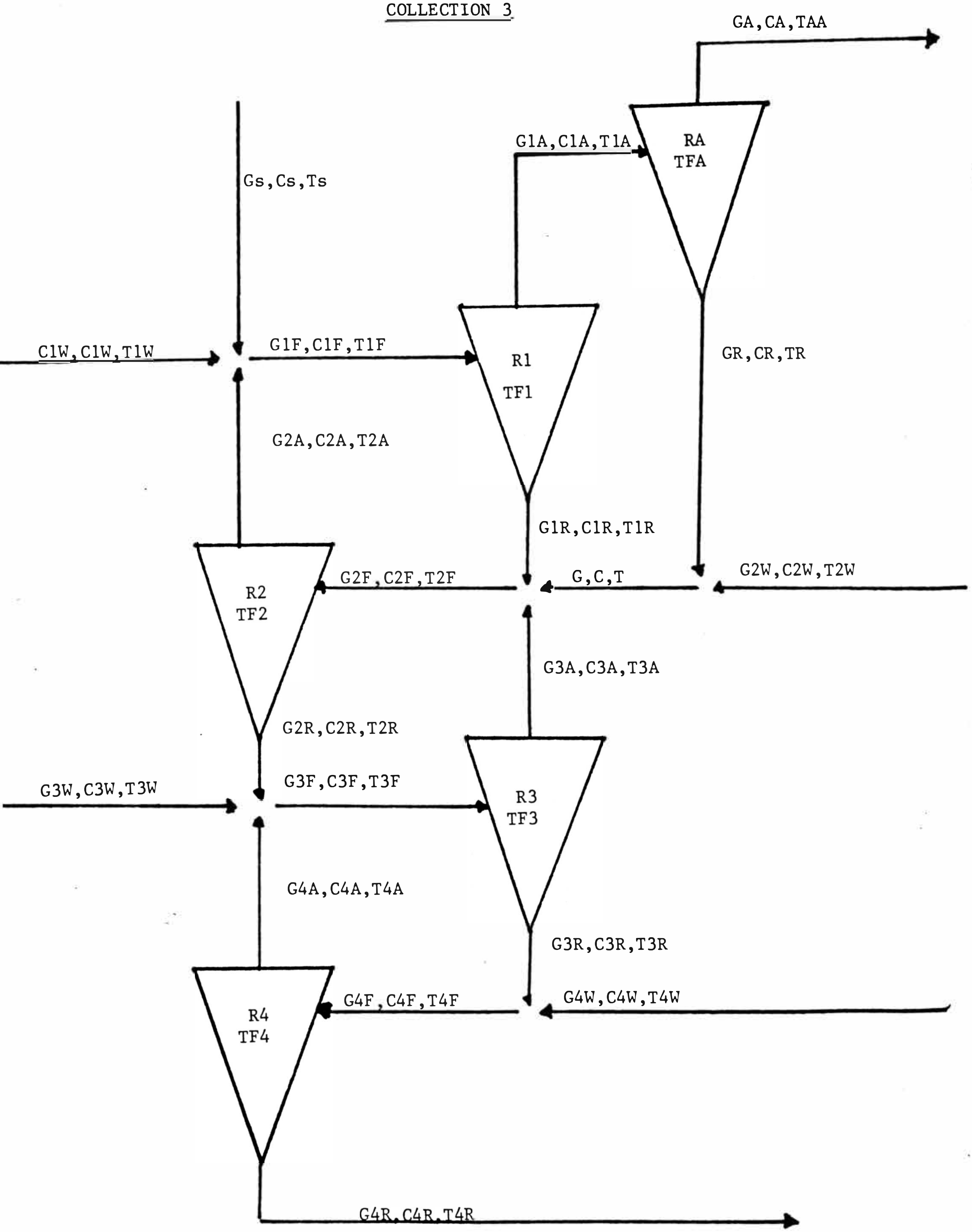
50) $TS = GS \times CS \times 6.008$

51) $T_1W = T_1F - TS - T_2A$

52) $G_1W = T_1W / (C_1W \times 6.008)$

SYMBOL IDENTIFICATION

COLLECTION 3



Analysis

The following data was run through each collection:

	Input 1	Input 2	Input 3
TA, TAA	150	150	150
C_1F	.006	.0050	.005
C_2F	.0055	.005	.0045
C_3F	.005	.0045	.004
C_4F	.0045	.004	.0035
R_1	.348	.348	.348
R_2	.474	.474	.474
R_3	.665	.665	.665
R_4	.939	.939	.939
TF_1	2.3	3.3	4.3
TF_2	3.3	4.3	5.3
TF_3	4.3	5.3	6.3
TF_4	5.3	6.3	7.3
C_1W	.0001	.0001	.0001
C_2W	.0001	.0001	.0001
C_3W	.0001	.0001	.0001
C_4W	.0001	.0001	.0001
PPM	50	50	50
RA	.297	.297	.297
TFA	5.3	6.3	7.3
PCT	0.8	0.8	0.8
C =	0.1xCIR	0.1xCIR	0.1xCIR

The data previously determined to be necessary for evaluation (pg. 14) was assembled on the following pages. Detailed model results are in Appendix IV.

Analysis

Input 1

	Collection 1	Collection 2	Collection 3
Total number of cleaners	560	466	1158
Gallons fed to system	5629	6373	7596
Gallons accepted from system	5417	6142	7273
Gallons rejected from system	212	231	323
Tons fed to system	181	183	196
Tons accepted from system	150	150	150
Tons rejected from system	31	33	46
Dirt count fed stock (ppm)	50	50	50
Dirt count accepted stock (ppm)	38.4	37.7	36.8
Dirt count rejected stock (ppm)	102.5	100.4	148.9
Accepted stock consistency, %	.461	.406	.343
Yield, % (TS)	82.9	82.0	76.5
Cleaning efficiency, %	35.1	36.9	45.5
Total cost $ (equipment)	140,580	150,760	209,820

Analysis

Input 2

	Collection 1	Collection 2	Collection 3
Total number of cleaners	605	513	1327
Gallons fed to system	6429	7263	8774
Gallons accepted from system	6228	7044	8442
Gallons rejected from system	201	219	331
Tons fed to system	181	183	200
Tons accepted from system	150	150	150
Tons rejected from system	31	33	50
Dirt count feed stock (ppm)	50	50	50
Dirt count accepted stock (ppm)	35.5	34.3	39.6
Dirt count rejected stock (ppm)	116	115	122.2
Accepted stock consistency, %	.401	.354	.296
Yield, % (TS)	82.9	82.0	75.0
Cleaning efficiency, %	40.0	42.6	50.8
Total cost $ (equipment)	158,830	170,910	241,830

Analysis

Input 3

	Collection 1	Collection 2	Collection 3
Total number of cleaners	673	572	1528
Gallons fed to system	7240	8200	9962
Gallons accepted from system	7039	7983	9605
Gallons rejected from system	201	217	357
Tons fed to system	181	183	205
Tons accepted from system	150	150	150
Tons rejected from system	31	33	55
Dirt count fed stock (ppm)	50	50	50
Dirt count accepted stock (ppm)	33	32.3	36.1
Dirt count rejected stock (ppm)	126	124	115
Accepted stock consistency, %	.355	.313	.260
Yield, %	82.9	82.0	73.2
Cleaning efficiency, %	43.8	45.8	53.9
Total cost $ (equipment)	178,447	192,600	275,640

Selection

When selecting a solution to the original need, one must review the initial criteria:

Must:
- Consist of on-the-market 3" centrifugal cleaners
- Have a yield as high as, or higher than, a cascade system
- Provide a pulp at least 5% cleaner than a cascade system

Must not:
- Exceed $250,000

Wants:
- Accept consistency .4% or greater
- 75% minimum yield
- 50% minimum cleaning efficiency

Yield

All collections exceed the 75% minimum yield except Collection 3, Input 3. Because feed consistencies are lowest, the cleaners are more efficient and reject more material thus lowering yield. Collections 1 and 2 do not appear to be as sensitive to consistency and yield losses.

The cascade system (Collection 1) shows 82.9% yield in each data case while the split feed-feed forward system (Collection 2) shows 82% of yield. One objective emphasized earlier was that yield must be greater than or equal to a cascade yield, in this case no yield of other collections met that criteria, but the less than one percent difference is within experimental error, thus Collection 1 and Collection 2 meet yield requirements.

Cleaning Efficiency

Only Collection 3 exceeds the 50% cleaning efficiency desired, while both Collections 2 and 3 exceed the efficiency of the cascade system, both Collection 3 is above the 50% minimum efficiency that is required.

Cost

Collection 3, Input 3 exceeds the $250,000 limit and is, therefore, eliminated.

All other collections fall below the cost limit.

Comparison

Input 1

	Cascade	Collection 2	Collection 3
Yield	82.9	-1.0%	-6.4%
Cleaning efficiency	35.1	+1.8%	+10.4%
Cost	140,580	+6.8%	+33%
Acc. Cons. >.4%	Y	Y	N
		Choice -	Collection 3

Input 2

	Cascade	Collection 2	Collection 3
Yield	82.9	-1.0%	-7.9%
Cleaning efficiency	40.0	+2.6%	+10.8%
Cost	158,830	+7.1%	+34.3%
Acc. Cons. >.4%	Y	N	N
		Choice -	Collection 3

Input 3

	Cascade	Collection 2	Collection 3
Yield	82.9	-1.0%	-9.7%
Cleaning efficiency	43.8	+2.0%	+10.1%
Cost	178,447	+7.3%	+35.3%
Acc. Cons. >.4%	N	N	N
		Choice -	Collection 1

The selection and recommendation in this case is that for new installations, Collection 3 would be the most acceptable. Also included is the stipulation that it be run at .6% primary feed consitency or higher.

The comparison shows that even though Collection 3 has a high capital cost, it is below the limits by $40,000. The incremental cleaning efficiency should allow dirtier stocks to be processed. These dirtier stocks are cheaper than cleaner stocks and the lower pulp costs justify the capital costs. A pulp cost, lower by 25#/ton, would return the difference in capital costs in one year at 150 TPD of production. Also, as primary feed consistency increases the yield difference between the cascade system and Collection 3 decreases.

Decision/Action

The decision based on the information provided, is that Collection 3 would be a cost-effective substitute for a cascade system.

The action recommended at this point is to obtain a wider range of input data and evaluate further. The possibility of building a prototype should also be investigated.

Conclusions

The idea of using a model to help illustrate a point is not new but many applications in system design are as yet untried.

This paper presents one sequence of modeling steps and applies that sequence twice in an effort to solve a practical problem in system design. The conclusions reached are:

1. The modeling steps provide an orderly thought process for developing and evaluating a process system.

2. The steps can be applied in their entirety to single elements of a system thus building a complex system one step at a time.

3. The decision reached by following these modeling steps may propose a solution, and/or may also propose further analysis.

4. The forward cleaner sequences modeled in this paper were to be evaluated based on a set of criteria and given input data. From this evaluation a decision was reached that an "Alpha-Alpha" cleaning sequence could be a cost effective replacement for the traditional cascade cleaner system.

5. The action step recommendations were to first expand the given input data base, then perform further analysis to either verify or disqualify the initial decision.

APPENDIX I

PROGRAM DETAILS

```
C
C
      PROGRAM BALANCE 1
C
C
      IMPLICIT INTEGER*2 (I-N)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
C
C
      INTEGER*4 INPUTNAM(18)
C
      REAL*8 INPUT(18)
C
      LOGICAL MAX(19),MIN(19)
      REAL*8 INMAX(19),INMIN(19)
C
C
      LOGICAL TRACE
      INTEGER*1 IRESP
C
C
      EQUIVALENCE (INPUT(1),T1A)
      EQUIVALENCE (INPUT(2),C1F)
      EQUIVALENCE (INPUT(3),C2F)
      EQUIVALENCE (INPUT(4),C3F)
      EQUIVALENCE (INPUT(5),C4F)
      EQUIVALENCE (INPUT(6),R1)
      EQUIVALENCE (INPUT(7),R2)
      EQUIVALENCE (INPUT(8),R3)
      EQUIVALENCE (INPUT(9),R4)
      EQUIVALENCE (INPUT(10),TF1)
      EQUIVALENCE (INPUT(11),TF2)
      EQUIVALENCE (INPUT(12),TF3)
      EQUIVALENCE (INPUT(13),TF4)
      EQUIVALENCE (INPUT(14),C1W)
      EQUIVALENCE (INPUT(15),C2W)
      EQUIVALENCE (INPUT(16),C3W)
      EQUIVALENCE (INPUT(17),C4W)
      EQUIVALENCE (INPUT(18),CS)
C
C
      DATA FACTOR / 6.0D8 /
```

```
      DATA XMAX / 1.000001 /
      DATA XMIN / .999999 /
C
C
C  NOTE THAT T4R ALSO HAS LIMITS (INDEX = 19 FOR THESE LOOKUPS..)
C
      DATA MAX / .FALSE. , 17* .TRUE. , .FALSE. /
C
C   NEGATIVE ENTRIES ARE NEVER ALLOWED, REGARDLESS OF EXISTENCE
C   OF A SPECIFIED MINIMUM VALUE
C
      DATA MIN / 5 * .TRUE. , 13 * .FALSE. , .TRUE. /
C
C
      DATA INMAX / 0. , 4 * 0.1 , 4* 1.0 , 4* 100.0 , 4* 0.01, 1.0 , 0 /
C
      DATA INMIN / 1.0 , 4* 0.001 , 13* 0.0 , 1.0 /
C
C
C
C
      DATA INPUTNAM / 'T1A', 'C1F', 'C2F', 'C3F', 'C4F', 'R1', 'R2', 'R3',
     *       'R4', 'TF1', 'TF2', 'TF3', 'TF4', 'C1W', 'C2W', 'C3W', 'C4W', 'CS' /
C
C
C
C
      DO 10 IA=1,18
C
   11 WRITE ('CRT',1001) INPUTNAM(IA)
 1001 FORMAT (' PLEASE ENTER THE VALUE OF ',A4,'         ')
C
      READ ('KYB',1002) INPUT(IA)
 1002 FORMAT (F12.4)
C
      IF (INPUT(IA).LT.0.0) GO TO 12
      IF (MIN(IA).AND.INPUT(IA).LT.INMIN(IA)) GO TO 12
      IF (MAX(IA).AND.INPUT(IA).GT.INMAX(IA)) GO TO 13
C
      GO TO 10
C
   12 WRITE ('CRT',1030)
 1030 FORMAT (' *** VALUE IS BELOW MINIMUM. PLEASE RE-ENTER...')
C
      GO TO 11
C
   13 WRITE ('CRT',1031)
 1031 FORMAT (' *** VALUE IS ABOVE MAXIMUM. PLEASE RE-ENTER...')
C
      GO TO 11
C
C
   10 CONTINUE
C
      IA = 19
C
   21 WRITE ('CRT',1003)
 1003 FORMAT (' PLEASE ENTER THE ASSUMED INITIAL VALUE OF T4R...    ')
```

```
C
C
      IF (T4RINIT.LT.0.0) GO TO 22
      IF (MIN(IA).AND.T4RINIT.LT.INMIN(IA)) GO TO 22
      IF (MAX(IA).AND.T4RINIT.GT.INMAX(IA)) GO TO 23
C
      GO TO 30
C
   22 WRITE ('CRT',1030)
C
      GO TO 21
C
   23 WRITE ('CRT',1031)
C
      GO TO 21
C
   30 WRITE ('CRT',1005)
 1005 FORMAT (' DO YOU WISH TO TRACE THE ITERATIONS...  ')
C
      READ ('KYB',1008) IRESP
 1008 FORMAT (A1)
C
      IF (IRESP.EQ.'Y') TRACE = .TRUE.
C
      WRITE ('CRT',1004)
 1004 FORMAT (/' THANK YOU...')
C
      T4R = T4RINIT
C
C
C
   20 CONTINUE
      T4F = T4R / R4
C
      G4F = T4F / (C4F * FACTOR)
C
      C4R = C4F * TF4
C
      G4R = T4R / (C4R * FACTOR)
C
      G4A = G4F - G4R
C
      T4A = T4F - T4R
C
      C4A = T4A / (G4A * FACTOR)
C
      C3R = C3F * TF3
C
      G4W = ((C4F-C3R)*G4F) / (C4W-C3R)
C
      G3R = G4F - G4W
C
      T4W = G4W * C4W * FACTOR
C
      T3R = G3R * C3R * FACTOR
C
      T3F = T3R / R3
```

```
      G3A = G3F - G3R
      T3A = T3F - T3R
      C3A = T3A / (G3A * FACTOR )
      C2R = C2F * TF2
      G2R = ((G3F * (C3F - C3W)) + G4A * (C3W - C4A)) / (C2R - C3W)
      G3W = G3F - G4A - G2R
      T2R = G2R * C2R * FACTOR
      T3W = G3W * C3W * FACTOR
      T2F = T2R / R2
      G2F = T2F / (C2F * FACTOR)
      T2A = T2F - T2R
      G2A = G2F - G2R
      C2A = T2A / (G2A * FACTOR)
      C1R = C1F * TF1
      G1R = ((G2F * (C2F - C2W)) + G3A * (C2W - C2A)) / (C1R - C2W)
      G2W = G2F - G1R - G3A
      T1R = G1R * C1R * FACTOR
      T2W = G2W * C2W * FACTOR
      T1F = T1R / R1
      G1F = T1F / (C1F * FACTOR)
      GS = ((G1F * (C1F - C1W)) + G2A * (C1W - C2A)) / (CS - C1W)
      G1W = G1F - GS - G2A
      TS = GS * CS * FACTOR
      T1W = G1W * C1W * FACTOR
      T1ACALC = T1F - T1R
      X = T1A / T1ACALC
      T4RNEW = T4R * X
      IF (.NOT.TRACE) GO TO 80
      WRITE ('CRT',1006) X,T4RNEW
```

```
   80 IF (X.LT.XMAX.AND.X.GT.XMIN) GO TO 90
C
      T4R = T4RNEW
C
      GO TO 20
C
C
   90 WRITE ('CRT',1007)
 1007 FORMAT (' ITERATIONS COMPLETE    ')
C
      G1A = G1F - G1R
C
      C1A = T1A / (G1A * FACTOR)
C
C
C    CONSOLIDATE RESULTS FOR PRINTOUT
C
      CSX = CS * 100.0
C
      C1FX = C1F * 100.0
C
      C1AX = C1A * 100.0
C
      C1RX = C1R * 100.0
C
      C1WX = C1W * 100.0
C
      C2FX = C2F * 100.0
C
      C2AX = C2A * 100.0
C
      C2RX = C2R * 100.0

      C2WX = C2W * 100.0
C
      C3FX = C3F * 100.0
C
      C3AX = C3A * 100.0
C
      C3RX = C3R * 100.0
C
      C3WX = C3W * 100.0
C
      C4FX = C4F * 100.0
C
      C4AX = C4A * 100.0
C
      C4RX = C4R * 100.0
C
      C4WX = C4W * 100.0
C
C
C
      WRITE ('PTR',1009)
 1009 FORMAT (15X,'STOCK'//)
C
C
      WRITE ('PTR',1010) TS,CSX,GS
```

```
            10X, 'CONS.    ', F12.3,
            10X, 'GPM      ', F12.3/)
C
C
      WRITE ('PTR', 1011)
 1011 FORMAT (//15X, 'PRIMARY STAGE'//)
C
      WRITE ('PTR', 1012)
 1012 FORMAT (3X, 'FEED')
C
      WRITE ('PTR', 1010) T1F, C1FX, G1F
C
      WRITE ('PTR', 1013)
 1013 FORMAT (3X, 'ACCEPTS')
C
      WRITE ('PTR', 1010) T1A, C1AX, G1A
C
      WRITE ('PTR', 1014)
 1014 FORMAT (3X, 'REJECTS')
C
      WRITE ('PTR', 1010) T1R, C1RX, G1R
C
C
      WRITE ('PTR', 1015)
 1015 FORMAT (3X, 'WHITEWATER')
C
      WRITE ('PTR', 1010) T1W, C1WX, G1W
C
C
C
      WRITE ('PTR', 2011)
 2011 FORMAT (//15X, 'SECONDARY STAGE'//)
C
      WRITE ('PTR', 1012)

      WRITE ('PTR', 1010) T2F, C2FX, G2F
C
      WRITE ('PTR', 1013)
C
      WRITE ('PTR', 1010) T2A, C2AX, G2A
C
      WRITE ('PTR', 1014)
C
      WRITE ('PTR', 1010) T2R, C2RX, G2R
C
C
      WRITE ('PTR', 1015)
C
      WRITE ('PTR', 1010) T2W, C2WX, G2W
C
C
C
C
      WRITE ('PTR', 3011)
 3011 FORMAT (//15X, 'TERTIARY STAGE'//)
C
      WRITE ('PTR', 1012)
C
      WRITE ('PTR', 1010) T3F, C3FX, G3F
```

```
      WRITE ('PTR',1013)
C
      WRITE ('PTR',1010) T3A,C3AX,G3A
C
      WRITE ('PTR',1014)
C
      WRITE ('PTR',1010) T3R,C3RX,G3R
C
C
      WRITE ('PTR',1015)
C
      WRITE ('PTR',1010) T3W,C3WX,G3W
C
C
C
C
      WRITE ('PTR',4011)
 4011 FORMAT (//15X,'QUARTENARY STAGE'//)
C
      WRITE ('PTR',1012)
C
      WRITE ('PTR',1010) T4F,C4FX,G4F
C
      WRITE ('PTR',1013)
C
      WRITE ('PTR',1010) T4A,C4AX,G4A
C
      WRITE ('PTR',1014)
C
      WRITE ('PTR',1010) T4R,C4RX,G4R
C
C
      WRITE ('PTR',1015)

      WRITE ('PTR',1010) T4W,C4WX,G4W
C
C
C
C
      WRITE ('CRT',1020)
 1020 FORMAT (A'   ***  FINISHED')
C
      STOP
      END
$IFT ABORT ABEND
$ALLOCATE 20000
$CATALOG
ASSIGN4 CRT=UT
ASSIGN4 KYB=UT
ASSIGN2 PTR=SLO,999
CATALOG BALANCE U NOM
$DEFNAME ABEND
$EOJ
$$
```

```
C
      PROGRAM BALANCE 2
C
C
      IMPLICIT INTEGER*2 (I-N)
      IMPLICIT REAL*8 (A-H)
      IMPLICIT REAL*8 (O-Z)
C
C
      INTEGER*4 INPUTNAM(19)
C
      REAL*8 INPUT(19)
C
      LOGICAL MAX(20),MIN(20)
      REAL*8 INMAX(20),INMIN(20)
C
C
      LOGICAL TRACE
      INTEGER*1 IRESP
C
C
      EQUIVALENCE (INPUT(1),TAA)
      EQUIVALENCE (INPUT(2),C1F)
      EQUIVALENCE (INPUT(3),C2F)
      EQUIVALENCE (INPUT(4),C3F)
      EQUIVALENCE (INPUT(5),C4F)
      EQUIVALENCE (INPUT(6),R1)
      EQUIVALENCE (INPUT(7),R2)
      EQUIVALENCE (INPUT(8),R3)
      EQUIVALENCE (INPUT(9),R4)
      EQUIVALENCE (INPUT(10),TF1)
      EQUIVALENCE (INPUT(11),TF2)
      EQUIVALENCE (INPUT(12),TF3)
      EQUIVALENCE (INPUT(13),TF4)
      EQUIVALENCE (INPUT(14),C1W)
      EQUIVALENCE (INPUT(15),C2W)
      EQUIVALENCE (INPUT(16),C3W)
      EQUIVALENCE (INPUT(17),C4W)
      EQUIVALENCE (INPUT(18),CS)
C
      EQUIVALENCE (INPUT(19),PCT)
C
```

```
      DATA FACTOR / 6.008 /
C
C
      DATA XMAX / 1.000001 /
      DATA XMIN /  .999999 /
C
C
C  NOTE THAT T4R ALSO HAS LIMITS (INDEX = 20 FOR THESE LOOKUPS..)
C
      DATA MAX / .FALSE. , 18* .TRUE. , .FALSE. /
C
C   NEGATIVE ENTRIES ARE NEVER ALLOWED, REGARDLESS OF EXISTENCE
C   OF A SPECIFIED MINIMUM VALUE
C
      DATA MIN / 5 * .TRUE. , 13 * .FALSE. , 2* TRUE. /
C
C
      DATA INMAX / 0 , 4 * 0.1 , 4* 1.0 , 4* 100.0 , 4* 0.01, 2*01.0, 0/
C
      DATA INMIN / 1.0 , 4* 0.001 , 13* 0.0 , .0001, 1.0 /
C
C
C
C
      DATA INPUTNAM / 'T1A', 'C1F', 'C2F', 'C3F', 'C4F', 'R1', 'R2', 'R3',
     .        'R4', 'TF1', 'TF2', 'TF3', 'TF4', 'C1W', 'C2W', 'C3W', 'C4W', 'CS' /
     .   'PCT' /
C
C
C
      DO 10 IA=1,19
C
   11 WRITE ('CRT',1001) INPUTNAM(IA)
 1001 FORMAT (' PLEASE ENTER THE VALUE OF ',A4          ')
C
      READ ('KYB',1002) INPUT(IA)
 1002 FORMAT (F12.4)
C
      IF (INPUT(IA).LT.0.0) GO TO 12
      IF (MIN(IA).AND.INPUT(IA).LT.INMIN(IA)) GO TO 12
      IF (MAX(IA).AND.INPUT(IA).GT.INMAX(IA)) GO TO 13
C
      GO TO 10
C
   12 WRITE ('CRT',1030)
 1030 FORMAT (' *** VALUE IS BELOW MINIMUM, PLEASE RE-ENTER...')
C
      GO TO 11
C
   13 WRITE ('CRT',1031)
 1031 FORMAT (' *** VALUE IS ABOVE MAXIMUM, PLEASE RE-ENTER...')
C
      GO TO 11
C
C
   10 CONTINUE
C
      IA = 20
C
   21 WRITE ('CRT',1003)
```

```
 1003 FORMAT (' PLEASE ENTER THE ASSUMED INITIAL VALUE OF T4R...     ')
C
      READ ('KYB',1002) T4RINIT
C
C
      IF (T4RINIT.LT.0.0) GO TO 22
      IF (MIN(IA).AND.T4RINIT.LT.INMIN(IA)) GO TO 22
      IF (MAX(IA).AND.T4RINIT.GT.INMAX(IA)) GO TO 23
C
      GO TO 30
C
   22 WRITE ('CRT',1030)
C
      GO TO 21
C
   23 WRITE ('CRT',1031)
C
      GO TO 21
C
   30 WRITE ('CRT',1005)
 1005 FORMAT (' DO YOU WISH TO TRACE THE ITERATIONS...  ')
C
      READ ('KYB',1008) IRESP
 1008 FORMAT (A1)
C
      IF (IRESP.EQ.'Y') TRACE = .TRUE.
C
      WRITE ('CRT',1004)
 1004 FORMAT (/' THANK YOU   ')
C
      T4R = T4RINIT
C
C
C
   20 CONTINUE
C
      T4F = T4R / R4
C
      G4F = T4F / (C4F * FACTOR)

      C4R = C4F * TF4
C
      G4R = T4R / (C4R * FACTOR)
C
      G4A = G4F - G4R
C
      T4A = T4F - T4R
C
      C4A = T4A / (G4A * FACTOR)
C
      C3R = C3F * TF3
C
      G4W = ((C4F-C3R)*G4F) / (C4W-C3R)
C
      G3R = G4F - G4W
C
      T4W = G4W * C4W * FACTOR
C
      T3R = G3R * C3R * FACTOR
C
```

```
      T3F = T3R / R3
C
      G3F = T3F / (C3F * FACTOR)
C
      G3A = G3F - G3R
C
      T3A = T3F - T3R
C
      C3A = T3A / (G3A * FACTOR )
C
      C2R = C2F * TF2
C
      G2R = ((G3F * (C3F - C3W)) + G4A * (C3W - C4A)) / (C2R - C3W)
C
      G3W = G3F - G4A - G2R
C
      T2R = G2R * C2R * FACTOR
C
      T3W = G3W * C3W * FACTOR
C
      T2F = T2R / R2
C
      G2F = T2F / (C2F * FACTOR)
C
      T2A = T2F - T2R
C
      G2A = G2F - G2R
C
      C2A = T2A / (G2A * FACTOR)
C
      C1R = C1F * TF1
-
      G   = (G2F*(C2F-C2W)+G3A(C2W-C3A))
      A   = (C1R+(C1R*(1-PCT))/(R1*PCT)-(C2W*C1R*(1-PCT)/(C1F*R1*PCT)))
      G1R   = G /  A
C
      GH = (G1R*C1R*(1-PCT))/ (C1F*R1*PCT)
      G2W = G2F - G1R - G3A - GH
C
      TH = GH * C1F * FACTOR
      T1R = G1R * C1R * FACTOR
C
      T2W = G2W * C2W * FACTOR
C
      T1F = T1R / R1
C
      G1F = T1F / (C1F * FACTOR)
C
      T1A = T1F - T1R
C
      TAACALC = T1A + T2A
C
       X = TAA / TAACALC
C
       T4RNEW = T4R * X
C
C
C
C
      IF (.NOT.TRACE) GO TO 80
```

```
C
      WRITE ('CRT',1006) X,T4RNEW
 1006 FORMAT (' RATIO IS ',F12.9,2X,'NEW T4R IS ',F14.6)
C
   80 IF (X.LT.XMAX.AND.X.GT.XMIN) GO TO 90
C
      T4R = T4RNEW
C
      GO TO 20
C
C
   90 WRITE ('CRT',1007)
 1007 FORMAT (' ITERATIONS COMPLETE ... ')
C
      G1A = G1F - G1R
C
      C1A = T1A / (G1A * FACTOR)
      GS = (G1F*(C1F-C1W)+GH*(C1F-C1W))/(CS-C1W)
      G1W = GH - G1F - GS
      T1W = C1W * G1W * FACTOR
      TS - GS * CS * FACTOR
      GA = G1A + G2A
      CA = TAA / (GA * FACTOR)
C
C
C    CONSOLIDATE RESULTS FOR PRINTOUT
C
      CSX = CS * 100.0
C
      C1FX = C1F * 100.0
C
      C1AX = C1A * 100.0

      C1RX = C1R * 100.0
C
      C1WX = C1W * 100.0
C
      C2FX = C2F * 100.0
C
      C2AX = C2A * 100.0
C
      C2RX = C2R * 100.0
C
      C2WX = C2W * 100.0
C
      C3FX = C3F * 100.0
C
      C3AX = C3A * 100.0
C
      C3RX = C3R * 100.0
C
      C3WX = C3W * 100.0
C
      C4FX = C4F * 100.0
C
      C4AX = C4A * 100.0
C
      C4RX = C4R * 100.0
C
      C4WX = C4W * 100.0
```

```
C
C
      CAX = CA * 100.0
C
      WRITE ('PTR',1009)
 1009 FORMAT (15X,'STOCK'//)
C
C
      WRITE ('PTR',1010) TS,CSX,GS
 1010 FORMAT (10X,'TPD    ',F12.3/
     .          10X,'CONS.  ',F12.3/
     .          10X,'GPM    ',F12.3/)
C
C
      WRITE ('PTR',1011)
 1011 FORMAT (//15X,'PRIMARY STAGE'//)
C
      WRITE ('PTR',1012)
 1012 FORMAT (3X,'FEED')
C
      WRITE ('PTR',1010) T1F,C1FX,G1F
C
      WRITE ('PTR',1013)
 1013 FORMAT (3X,'ACCEPTS')
C
      WRITE ('PTR',1010) T1A,C1AX,G1A
C
      WRITE ('PTR',1014)
 1014 FORMAT (3X,'REJECTS')
C
      WRITE ('PTR',1010) T1R,C1RX,G1R

C
      WRITE ('PTR',1015)
 1015 FORMAT (3X,'WHITE WATER')
C
      WRITE ('PTR',1010) T1W,C1WX,G1W
C
C
C
      WRITE ('PTR',2011)
 2011 FORMAT (//15X,'SECONDARY STAGE'//)
C
      WRITE ('PTR',1012)
C
      WRITE ('PTR',1010) T2F,C2FX,G2F
C
      WRITE ('PTR',1013)
C
      WRITE ('PTR',1010) T2A,C2AX,G2A
C
      WRITE ('PTR',1014)
C
      WRITE ('PTR',1010) T2R,C2RX,G2R
C
C
      WRITE ('PTR',1015)
C
      WRITE ('PTR',1010) T2W,C2WX,G2W
C
```

```
C
C
C
      WRITE ('PTR',3011)
 3011 FORMAT (//15X,'TERTIARY STAGE'//)
C
      WRITE ('PTR',1012)
C
      WRITE ('PTR',1010) T3F,C3FX,G3F
C
      WRITE ('PTR',1013)
C
      WRITE ('PTR',1010) T3A,C3AX,G3A
C
      WRITE ('PTR',1014)
C
      WRITE ('PTR',1010) T3R,C3RX,G3R
C
C
      WRITE ('PTR',1015)
C
      WRITE ('PTR',1010) T3W,C3WX,G3W
C
C
C
C
      WRITE ('PTR',4011)
 4011 FORMAT (//15X,'GUARTENARY STAGE'//)
C
      WRITE ('PTR',1012)
C
      WRITE ('PTR',1010) T4F,C4FX,G4F

      WRITE ('PTR',1013)
C
      WRITE ('PTR',1010) T4A,C4AX,G4A
C
      WRITE ('PTR',1014)
C
      WRITE ('PTR',1010) T4R,C4RX,G4R
C
C
      WRITE ('PTR',1015)
C
      WRITE ('PTR',1010) T4W,C4WX,G4W
      WRITE ('PTR',5011)
 5011 FORMAT (//15X, 'SYSTEM ACCEPTS'//)
      WRITE ('PTR', 1010) TAA,CAX,GA
C
C
C
C
      WRITE ('CRT',1020)
 1020 FORMAT (/'      FINISHED')
C
      STOP
      END
$IFT ABORT ABEND
$ALLOCATE 20000
$CATALOG
```

```
ASSIGN4 CRT=UT                                                  0421.00
ASSIGN4 KYB=UT                                                  0422.00
ASSIGN2 PTR=SLO,999                                             0423.00
CATALOG BALANCE2 U NOM                                          0424.00
$DEFNAME ABEND                                                  0425.00
$EOJ                                                            0426.00
$$                                                              0427.00
```

```
C
      PROGRAM BALANCE [illegible]
C
C
      IMPLICIT INTEGER [illegible]
      IMPLICIT REAL*8 [illegible]
      IMPLICIT REAL [illegible]
C
C
      INTEGER*4 IN[illegible](20[illegible]
C
      REAL*8 INPUT(20)
C
      LOGICAL MAX(2[illegible]
      REAL*8 INMA[illegible]
C
C
      LOGICAL TRACE
      INTEGER*1 IR[illegible]
C
C
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE (INPUT(15),IR[illegible]
      EQUIVALENCE (INPUT(16),(1[illegible]
      EQUIVALENCE (INPUT(17[illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
      EQUIVALENCE [illegible]
C
```

```
C
      DATA FACTOR
C
      DATA XMAX /
      DATA XMIN /
C
C     NOTE THAT T4R
C
      DATA MAX / .FALSE.
C
C     NEGATIVE ENTRIES ARE NEVER        OF EXISTENCE
C     OF A SPECIFIED
C
      DATA MIN / 5
C
C
      DATA INMAX /
C
      DATA INMIN /
C
C
C
      DATA INPUTNA
     *   'R4',
     *   'C4W',
C
C
C
      DO 10
   11 WRITE (CRT
 1001 FORMAT (
C
      READ (KYB
 1002 FORMAT (F12
C
      IF
      IF
      IF
C
      GO TO 10
C
   12 WRITE (CRT
 1030 FORMAT (
C
      GO TO 11
C
   13 WRITE ('CRT'
 1031 FORMAT (
C
      GO TO 11
C
C
   10 CONTINUE
C
      IA = 21
C
   21 WRITE ('CRT
 1003 FORMAT (
C
```

```
      READ ('KYB', [illegible]) T4RINIT
C
C
      IF (T4RINIT .LT. [illegible]) GO TO [illegible]
      IF (MIN(IA) [illegible] T4RINIT [illegible]
      IF (MAX(IA) [illegible] T4RINIT [illegible] MAX(IA) [illegible]
C
      GO TO 30
C
   22 WRITE ('CRT', [illegible])
C
      GO TO 21
C
   23 WRITE ('CRT', [illegible])
C
      GO TO 21
C
   30 WRITE ('CRT', [illegible])
 1003 FORMAT (' DO [illegible] WISH TO TRACE THE [illegible]
C
      READ ('KYB', [illegible])
 1008 FORMAT (A1)
C
      IF (IRESP.EQ [illegible]) TRACE [illegible]
C
      WRITE ('CRT', [illegible])
 1004 FORMAT (/' [illegible]
C
      T4R = T4RINIT
C
C
C
   20 CONTINUE
      T4F = T4R / [illegible]
C
      G4F = T4F / [illegible]
C
      C4R = C4F * [illegible]
C
      G4R = T4R / (C4R * FACTOR)
C
      G4A = G4F - [illegible]
C
      T4A = T4F - [illegible]
C
      C4A = T4A / (G4A * FACTOR)
C
      C3R = C3F * [illegible]
C
      G4W = ((C4F-[illegible])*G4F) / ([illegible]-C3R)
C
      G3R = G4F - [illegible]
C
      T4W = G4W * [illegible]
C
      T3R = G3R * [illegible]
C
      T3F = T3R / [illegible]
C
```

```
C     G3F = T3F [illegible]
C     G3A = G3F - [illegible]
      T3A = T3F [illegible]
C     C3A = T3A / [illegible]
C     G2R = G2F * [illegible]
C     G2R = ((G3R [illegible] G4A [illegible] 4A) ) / (G2R - G3W)
C     G3W = G3F [illegible]
C     T1R = G2F * [illegible]
C     T3W = G3W * [illegible]
C     T2F = T2R / [illegible]
C     G2F = T2F / [illegible]
C     T2A = T2F - T2[illegible]
C     G2A = G2F - [illegible]
C     C2A = T2A / (G2A * FACTOR)
C     C1R = C1F * [illegible]
      C = 1 * C1F
      G = (G2F*(C2[illegible] [illegible] G2A [illegible]
      T = G * C * [illegible]
      G1R = G2F - [illegible]
C
C
      T1R = G1R * [illegible] FACTOR
C
      T1F = T1R / [illegible]
      T1A = T1F - T1[illegible]
      TR = T1A * F
      G1F = T1F / [illegible]
C
      G1A = G1F - [illegible]
C
      C1A = T1A / [illegible] FACTOR
      CR = C1A * [illegible]
      GR = TR / (C[illegible]
      G2W = G - GR
      T2W = G2W * [illegible] FACTOR
C
   62 TA4CALC = [illegible]
C
      X = T4A / [illegible]
C
      TA4NEW = T4[illegible]
C
      IF (.NOT.[illegible]
```

```
C
      WRITE (CR [illegible]
 1006 FORMAT ( [illegible]
      WRITE (CRT [illegible]
 8006 FORMAT ( [illegible]
      WRITE (CRT [illegible]
 9006 FORMAT ( [illegible]
   80 IF (X.LT.XM [illegible]
C
      T4R = T4RNEW
C
      GO TO 20
C
C
   90 WRITE (CRT [illegible]
 1007 FORMAT ( [illegible]
C
      GA = G1A - GR
C
      CA = TAA / (G [illegible] FACTOR)
C
      GS = ((G1F * [illegible]
      TS = GS * CS [illegible] FACTOR
      T1W = T1F - TS - T2A
      G1W = T1W / (C1W * FACTOR)
C
C     CONSOLIDATE RESULTS [illegible]
C
      CSX = CS * 100.0
C
      C1FX = C1F * [illegible]
C
      C1AX = C1A * [illegible]
C
      C1RX = C1R * [illegible]
C
      C1 [illegible] 1W
C
      C2FX = C2F * [illegible]
C
      C2AX = C2A * [illegible]
C
      C2RX = C2R * [illegible]
C
      C2WX = C2W * [illegible]
C
      C3FX = C3F * [illegible]
C
      C3AX = C3A * 100.0
C
      C3RX = C3R * 100.0
C
      C3WX = C3W * 100.0
C
      C4FX = C4F * 100.0
C
      C4AX = C4A * [illegible]
C
      C4RX = C4R * [illegible]
```

```
C
      CAW? = C4W + [illegible]
C
       CAAX = CA + [illegible]
       CARX = CR + [illegible]
C
      WRITE ('PTR',1009)
 1009 FORMAT (15X, [illegible]
C
C
      WRITE ('PTR',1010) TB,05X,G[illegible]
 1010 FORMAT (10X,'TCD  ',F12.3,
     *        10X,'[illegible]  ',F12.3,
     *        10X,'GPM  ',F12.3)
C
C
      WRITE ('PTR',1011)
 1011 FORMAT (//15X,'PRIMARY [illegible]
C
      WRITE ('PTR',1012)
 1012 FORMAT (3X,'FE[illegible]
C
      WRITE ('PTR',1010) T1P,C1P,G1P
C
      WRITE ('PTR',1013)
 1013 FORMAT (3X,'A[illegible]
C
      WRITE ('PTR',1010) [illegible]
C
      WRITE ('PTR',1014)
 1014 FORMAT (3X,[illegible]
C
      WRITE ('PTR',1010) [illegible]
C
C
      WRITE ('PTR',1015)
 1015 FORMAT (3X,[illegible]
C
      WRITE ('PTR',1010) [illegible]
C
C
C
      WRITE ('PTR',2011)
 2011 FORMAT (//15X,'SECONDARY [illegible]
C
      WRITE ('PTR',1012)
C
      WRITE ('PTR',1010) [illegible]
C
      WRITE ('PTR',1013)
C
      WRITE ('PTR',1010) T2A,C2A,G2A
C
      WRITE ('PTR',1014)
C
      WRITE ('PTR',1010) [illegible]
C
C
      WRITE ('PTR',1015)
C
```

```
      WRITE ('PTR',1[illegible]
C
C

C
      WRITE ('PTR',3011)
 3011 FORMAT (//15X,'TERTIARY STAGE'//)
C
      WRITE ('PTR',1012)
C
      WRITE ('PTR',1010) T3F,C[illegible]
C
      WRITE ('PTR',1[illegible]
C
      WRITE ('PTR',1[illegible]
C
      WRITE ('PTR',1[illegible]
C
      WRITE ('PTR',1[illegible]
C
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
C
C
C
C
      WRITE ('PTR',[illegible]
 4011 FORMAT (//15[illegible]
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
C
      WRITE ('PTR',[illegible]
 5011 FORMAT (//15X,[illegible]
      WRITE ('PTR',1012)
      WRITE ('PTR',1010) T1[illegible]
      WRITE ('PTR',1013)
      WRITE ('PTR',1010) TA[illegible]
      WRITE ('PTR',1014)
      WRITE ('PTR',1010) TE[illegible]
C
      WRITE ('PTR',1[illegible]
C
      WRITE ('PTR',1[illegible]
C
C
C
C
      WRITE ('CRT',[illegible]
```

```
 1020 FORMAT (//
C
      STOP
      END
$IFT ABORT ABEND
$ALLOCATE 20000
$CATALOG
ASSIGN4 CPI=UT
ASSIGN4 PYR=UT
ASSIGN2 PTR=SLO,
CATALOG BALANCE3
$DEFNAME ABEND
$EOJ
$
```

TITLE Cleaner Balance 1 **PAGE** 1 **OF** 5

PROGRAMMER Diane Krumwiede **DATE** 10/81

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
0		01				sto	Prim. Thick.	11		21	Quat. Feed
1		X≷T	Store			10	Factor				TPD
2		CLR	1=T			Prt					
3		LBL				R/S				÷	
4		CMS				sto	Sec. Thick.			(	
5		ADV		6		11	Factor			RCL	
6		OP				Prt				05	
7		00				R/S				×	
8		7				sto	Tert. Thick			RCL	
9		1				12	Factor			20	
10		OP				Prt		12		)	
11		02				R/S				=	
12		OP				sto	Quad. Thick			STO	Quat Feed
13		05				13	Factor			22	GPM
14		ADV				Prt				RCL	
15		R/S		7		AdV				05	
16		sto	Prim Acc			R/S				×	
17		01	BD TPD			sto	Prim WW			RCL	
18		Prt				14	cons-dec			13	
19		Adv				Prt				=	
20		R/S				R/S		13		STO	Quat Rej.
21		sto	Prim Feed			sto	Sec WW			23	Consistency
22		02	Cons-Dec.			15	cons-dec			RCL	
23		Prt				Prt				19	
24		Adv				R/S				÷	
25		R/S		8		sto	Tert-WW			(	
26		sto	Sec. Feed			16	cons-dec			RCL	
27		03	Cons-Dec			Prt				23	
28		Prt				R/S				×	
29		R/S				sto	Quat-WW			RCL	
30		sto				17	cons-dec	14		20	
31		04	Tert. Feed			Prt				)	
32		Prt	cons-dec			Adv				=	
33	R/S	sto				R/S				sto	Quat. Rej.
34		05	Quad. Feed			sto	Thick Stock			24	GPM
35		Prt	cons-dec.	9		18	Cons-dec			RCL	
36		Adv				Prt				22	
37		R/S				Adv				−	
38		sto	Prim. Rej			R/S	Assumption			RCL	
39		06	rate-dec			sto	Quat Reject			24	
40		Prt				19	TPD	15		=	
41		R/S				Prt				STO	Quat Acc
42		sto	Sec. Rej			R/S				25	GPM
43		07	rate-dec			sto	6oc8 factor			RCL	
44		Prt				20				21	
45		R/S		10		Prt				−	
46		sto	Tert. Rej.			ADV				RCL	
47		08	rate-dec			ADV				19	
48		Prt				RCL				=	
49		R/S				19				sto	
50		sto	Quad. Rej.			÷					
51		09	rate-dec.			RCL					
52		Prt				09					
53		Adv				=					
54		R/S				sto					

MERGED CODES

62	Pgm Ind	72	STO Ind	83	GTO Ind
63	Exc Ind	73	RCL Ind	84	Op Ind
64	Prd Ind	74	SUM Ind	92	INV SBR

TEXAS INSTRUMENTS INCORPORATED

TI-24181

TITLE Cleaner Balance 1 PAGE 2 OF 5

PROGRAMMER Diane Krumwiede DATE 10/81

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
0		26	Quat. Acc
1			TPD
2			
3		÷	
4		(	
5		RCL	
6		25	
7		×	
8		RCL	
9		20	
17 0		)	
1		=	
2		STO	Quat. Acc
3		27	Cons.
4		RCL	
5		04	
6		×	
7		RCL	
8		12	
9		=	
18 0		STO	Tert Rej
1		28	Cons.
2		(	
3		(	
4		RCL	
5		05	
6		−	
7		RCL	
8		28	
9		)	
19 0		×	
1		RCL	
2		22	
3		)	
4		)	
5		÷	
6		(	
7		RCL	
8		17	
9		−	
20 0		RCL	
1		28	
2		)	
3		=	
4		STO	Quat. WW
5		29	GPM
6		RCL	
7		22	
8		−	
9		RCL	
21 0		29	
1		=	
2		STO	Tert. Rej
3		30	GPM
4		RCL	

LOC	CODE	KEY	COMMENTS
		29	
		×	
		RCL	
		17	
		×	
22		RCL	
		20	
		=	
		STO	Quat. WW
		31	TPD
		RCL	
		30	
		×	
		RCL	
		28	
23		×	
		RCL	
		20	
		=	
		STO	Tert. Rej
		32	TPD
		÷	
		RCL	
		08	
24		=	
		STO	Tert Feed
		33	TPD
		÷	
		(	
		RCL	
		04	
25		×	
		RCL	
		20	
		)	
		=	
		STO	Tert. Feed
		34	GPM
		−	
		RCL	
26		30	
		=	
		STO	Tert. Acc
		35	GPM
		RCL	
		33	
		−	
		RCL	
		32	
		=	

LOC	CODE	KEY	COMMENTS
27		STO	Tert Acc
		36	TPD
		÷	
		(	
		RCL	
		35	
		×	
		RCL	
28		20	
		)	
		=	
		STO	Tert Acc
		37	Cons.
		RCL	
		03	
		×	
		RCL	
		11	
29		=	
		STO	Sec. Rej
		38	Cons.
		(	
		RCL	
		34	
		×	
		(	
		RCL	
		04	
30		−	
		RCL	
		16	
		)	
		+	
		(	
		RCL	
		25	
		×	
		(	
31		RCL	
		16	
		−	
		RCL	
		27	
		)	
		)	
		÷	
		(	
		RCL	

MERGED CODES

62	Pgm Ind		72	STO Ind		83	GTO Ind
63	Exc Ind		73	RCL Ind		84	Op Ind
64	Prd Ind		74	SUM Ind		92	INV SBR

TEXAS INSTRUMENTS INCORPORATED

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TITLE Cleaner Balance 1 PAGE 3 OF 5

PROGRAMMER Dane Krumwiede DATE 10/81

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
2 0		28	
1		−	
2		RCL	
3		16	
4		)	
5		=	
6		STO	Sec Rej. GPM
7		39	
8		RCL	
9		34	
33 0		−	
1		RCL	
2		25	
3		−	
4		RCL	
5		39	
6		=	
7		STO	Tert WW GPM
8		40	
9		RCL	
34 0		38	
1		x	
2		RCL	
3		39	
4		x	
5		RCL	
6		20	
7		=	
8		STO	Sec Rej TPD
9		41	
35 0		RCL	
1		40	
2		x	
3		RCL	
4		16	
5		x	
6		RCL	
7		20	
8		=	
9		STO	Tert WW TPD
36 0		42	
1		RCL	
2		41	
3		÷	
4		RCL	
5		07	
6		=	
7		STO	Sec Feed TPD
8		43	
9			
37 0			
1		÷	
2		(	
3		RCL	
4		03	

LOC	CODE	KEY	COMMENTS
		x	
		RCL	
		20	
		)	
		=	
38		STO	Sec Feed GPM
		44	
		RCL	
		43	
		−	
		RCL	
		41	
		=	
		STO	Sec Acc TPD
		45	
39		RCL	
		44	
		−	
		RCL	
		39	
		=	
		STO	Sec Acc GPM
		46	
		RCL	
		45	
40		÷	
		(	
		RCL	
		46	
		x	
		RCL	
		20	
		)	
		=	
		STO	Sec Acc Cons.
		47	
		RCL	
		02	
		x	
		RCL	
		10	
		=	
		STO	Prim Rej cons.
		48	
////	////	////	////
41		(	
		RCL	
		44	
		x	
		(	
		RCL	
		03	
		−	
		RCL	
		15	

LOC	CODE	KEY	COMMENTS
42		)	
		)	
		+	
		(	
		RCL	
		35	
		x	
		(	
		RCL	
		15	
43		−	
		RCL	
		37	
		)	
		)	
		)	
		÷	
		(	
		RCL	
		48	
44		x	
		RCL	
		15	
		)	
		=	
		STO	Prim Rej GPM
		49	
		RCL	
		44	
		−	
45		RCL	
		49	
		−	
		RCL	
		35	
		=	
		STO	Sec WW GPM
		50	
		RCL	
		49	
46		x	
		RCL	
		48	
		x	
		RCL	
		20	
		=	
		STO	Prim Rej TPD
		51	
		RCL	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

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TITLE Cleaner balance -1 PAGE 4 OF 5

PROGRAMMER Diane Krumwiede DATE 10/81

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
7 0		50	
1		x	
2		RCL	
3		15	
4		x	
5		RCL	
6		20	
7		=	
8		STO	Sec WW
9		52	TPD
48 0		RCL	
1		51	
2		÷	
3		RCL	
4		06	
5		=	
6		STO	Prim Feed
7		53	TPD
8			
9			
49 0		÷	
1		(	
2		RCL	
3		02	
4		x	
5		RCL	
6		20	
7		)	
8		=	
9		sto	Prim Feed
50 0		54	GPM
1			
2			
3			
4		x	
5		(	
6		RCL	
7		02	
8		−	
9		RCL	
51 0		14	
1		)	
2		+	
3		RCL	
4		46	
5		x	
6		(	
7		RCL	
8		14	
9		—	
52 0		RCL	
1		47	
2		)	
3		)	
4		=	

LOC	CODE	KEY	COMMENTS
		(	
		RCL	
		18	
		−	
		RCL	
53		14	
		)	
		=	
		STO	STOCK GPM
		55	
		RCL	
		54	
		−	
		RCL	
		55	
54		−	
		RCL	
		46	
		=	
		STO	Prim WW
		56	GPM
		RCL	
		55	
		x	
		RCL	
55		18	
		x	
		RCL	
		20	
		=	
		STO	STOCK TPD
		57	
		RCL	
		56	
		x	
56		RCL	
		14	
		x	
		RCL	
		20	
		=	
		STO	Prim WW
		58	TPD
		RCL	
		53	
57		−	
		RCL	
		51	
		=	
		STO	Prim Acc
		59	TPD - calc.
		RCL	
		01	
		÷	
		RCL	

LOC	CODE	KEY	COMMENTS
58		59	
		−	
		STO	4
		60	
		x:T	
		598	
		RCL	
		19	
59		x	
		RCL	
		60	
		=	
		STO	New Quat
		19	Req Rate
		GTO	
		103	
		RCL	
		54	
600		−	
		RCL	
		49	
		=	
		STO	Prim Acc
		61	GPM
		RCL	
		01	
		÷	
		(	
61		RCL	
		61	
		x	
		RCL	
		20	
		)	
		=	
		STO	Prim. Acc
		62	Cons.
		ADV	
620		ADV	
		OP	
		00	
		3	
		5	
		1	
		7	
		OP	
		01	
		1	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

TITLE Cleaner balance - 1 PAGE 5 OF 5

PROGRAMMER Diane Krumwiede DATE 10/81

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
63 0		3	
1		1	
2		6	
3		0	
4		0	
5		1	
6		5	
7		1	
8		3	
9		OP	
64 0		62	
1		3	
2		5	
3		1	
4		6	
5		0	
6		0	
7		0	
8		4	
9		0	
65 0		0	
1		OP	
2		63	
3		ADV	
4		ADV	Print:
5		OP	READ
6		05	CARD 3
7		ADV	
8		ADV	
9		ADV	
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			

MERGED CODES

62 Pgm Ind · 72 STO Ind · 83 GTO Ind
63 Exc Ind · 73 RCL Ind · 84 Op Ind
64 Prd Ind · 74 SUM Ind · 92 INV SBR

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TI Programmable Coding Form

PROGRAMMER Diane Krumwiede DATE

LOC	CODE	KEY	COMMENTS
000		LBL	
1		A	
2		OP	
3		60	
4		3	
5		6	
6		3	
7		7	
8		3	
9		2	
10		1	
1		5	
2		2	
3		6	
4		OP	
5		02	
6		OP	PRINT:
7		05	STOCK
8		ADV	
9		RCL	
20		57	
1		PRT	TPD
2		RCL	
3		55	
4		Prt	Flow
5		RCL	
6		18	
7		SBR	
8		sum	
9		Prt	%
30		ADV	
1		ADV	
2		ADV	
3		OP	
4		00	
5		3	
6		3	
7		3	
8		5	
9		2	
40		4	
1		0	
2		0	
3		OP	
4		02	
5		SBR	Print
6		LNX	PRI STAGE
7		ADV	
8		SBR	
9		CE	FEED
50		RCL	
1		53	
2		Prt	TPD
3		RCL	
4		54	
		Prt	Flow
		RCL	
		02	
		SBR	
		sum	
6		Prt	%
		SBR	Print:
		CLR	ACC.
		RCL	
		01	
		Prt	TPD
		RCL	
		61	
		Prt	Flow
		RCL	
7		62	
		SBR	
		sum	
		Prt	%
		SBR	
			PRINT:
		X≥T	RES
		RCL	
		51	
		Prt	TPD
8		RCL	
		49	
		PrT	Flow
		RCL	
		48	
		SBR	
		sum	
		Prt	%
		SBR	
		y^x	Print: WW
9		RCL	
		58	
		Prt	TPD
		RCL	
		56	
		Prt	Flow
		RCL	
		14	
		SBR	
		sum	
10		Prt	%
		ADV	
		ADV	
		ADV	
		OP	
		00	
		3	
		6	
		1	
		7	
11		1	
		5	
		0	
		0	
		OP	
		02	
		SBR	Print
		LNX	SEC STAGE
		ADV	
		SBR	
12		CE	Feed.
		RCL	
		43	
		PRT	TPD
		RCL	
		44	
		PRT	Flow
		RCL	
		63	
		SBR	
13		sum	
		PRT	%
		SBR	
		CLR	PRINT-ACC
		RCL	
		45	
		PrT	TPD
		RCL	
		46	
		Prt	Flow
14		RCL	
		47	
		SBR	
		sum	
		Prt	%
		SBR	Print: RES
		X≥T	
		RCL	
		41	
		Prt	TPD
150		RCL	
		39	
		Prt	Flow
		RCL	
		38	
		SBR	
		sum	
		Prt	%
		SBR	Print-WW
		y^x	

MERGED CODES

62	Pgm Ind	72 STO Ind	83 GTO Ind
63	Exc Ind	73 RCL Ind	84 Op Ind
64	Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

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TI Programmable Coding Form

PROGRAMMER D. Krumwiede DATE

LOC	CODE	KEY	COMMENTS
16 0		RCL	
1		52	
2		Prt	TPD
3		RCL	
4		50	
5		Prt	Flow
6		RCL	
7		15	
8		SBR	
9		Sum	
17 0		Prt	%
1		ADV	
2		ADV	
3		ADV	
4		OP	
5		00	
6		3	
7		7	
8		1	
9		7	
18 0		3	
1		5	
2		0	
3		0	
4		OP	
5		02	
6		SBR	Print:
7		LNX	TER STAGE
8		ADV	
9		SBR	
19 0		CE	FEED
1		RCL	
2		33	
3		Prt	TPD
4		RCL	
5		34	
6		Prt	Flow
7		RCL	
8		04	
9		SBR	
20 0		Sum	%
1		Print SBR	
2		CLR	PRINT: ACC
3		RCL	
4		36	
5		Prt	TPD
6		RCL	
7		35	
8		PRT	Flow
9		RCL	
21 0		37	
1		SBR	
2		Sum	
3		Prt	%
4		SBR	

LOC	CODE	KEY	COMMENTS
		X≷T	Print: REJ
		RCL	
		32	
		Prt	TPD
		RCL	
22		30	
		Prt	Flow
		RCL	
		28	
		SBR	
		Sum	
		Prt	%
		SBR	Print: WW
		y^x	
		RCL	
23		42	
		Prt	TPD
		RCL	
		40	
		Prt	Flow
		RCL	
		16	
		SBR	
		Sum	
		Prt	%
24		ADV	
		ADV	
		ADV	
		OP	
		00	
		3	
		4	
		3	
		5	
		3	
25		7	
		0	
		0	
		OP	
		02	
		SBR	PRINT:
		LNX	QRT STAGE
		ADV	
		SBR	
		CE	FEED
26		RCL	
		21	
		PRT	TPD
		RCL	
		22	
		PRT	Flow
		RCL	
		05	
		SBR	
		Sum	

LOC	CODE	KEY	COMMENTS
27		PRT	%
		SBR	
		CLR	PRINT: ACC
		RCL	
		26	
		PRT	TPD
		RCL	
		25	
		PRT	Flow
		RCL	
28		27	
		SBR	
		Sum	
		PRT	%
		SBR	
		X≷T	PRINT: REJ
		RCL	
		19	
		Prt	TPD
		RCL	
29		24	
		PRT	Flow
		RCL	
		23	
		SBR	
		Sum	
		Prt	%
		SBR	
		y^x	PRINT: WW
		RCL	
30		31	
		PRT	TPD
		RCL	
		29	
		PRT	Flow
		RCL	
		17	
		SBR	
		Sum	
		PRT	%
31		CLR	
		ADV	
		ADV	
		LBL	
		LNX	STAGE
		3	
		6	
		3	
		7	
		1	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

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TI Programmable Coding Form

PROGRAMMER D. Krumwiede DATE ______

LOC	CODE	KEY	COMMENTS
320		3	
1		2	
2		2	
3		1	
4		7	
5		OP	
6		03	
7		OP	
8		05	
9		RTN	
330		LBL	FEED
1		CE	
2		OP	
3		00	
4		2	
5		1	
6		1	
7		7	
8		1	
9		7	
340		1	
1		6	
2		0	
3		0	
4		OP	
5		01	
6		OP	
7		05	
8		RTN	
9		LBL	
350		CLR	ACC
1		OP	
2		00	
3		1	
4		3	
5		1	
6		5	
7		1	
8		5	
9		6	
360		0	
1		0	
2		0	
3		OP	
4		01	
5		OP	
6		05	
7		RTN	
8		LBL	
9		X⇌T	REG
370		OP	
1		00	
2		3	
3		5	
4		1	

LOC	CODE	KEY	COMMENTS
		7	
		2	
		5	
		0	
		0	
38		0	
		0	
		OP	
		01	
		OP	
		05	
		RTN	
		LBL	
		y^x	WW
		OP	
39		00	
		4	
		3	
		4	
		3	
		0	
		0	
		0	
		0	
		0	
40		0	
		OP	
		01	
		OP	
		05	
		RTN	
		LBL	
		SUM	
		X	
		1	
41		0	
		0	
		=	
		RTN	

LOC	CODE	KEY	COMMENTS

MERGED CODES

62 Pgm Ind		72 STO Ind		83 GTO Ind	
63 Exc Ind		73 RCL Ind		84 Op Ind	
64 Prd Ind		74 SUM Ind		92 INV SBR	

TEXAS INSTRUMENTS INCORPORATED

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TITLE Cleaner Balance - 2 PAGE 1 OF 2

TI Programmable Coding Form

PROGRAMMER ______ DATE ______

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
0		Repeat 00 - 408				66		52		RCL	
1		of Balance 1.				)				51	
2	412	RCL				)				x	
41 3	C	44				−				RCL	
4		x				RCL				15	
5		(		47		15				x	
6		RCL				)				RCL	
7		03				=				20	
8		−				STO				=	
9		RCL				49	Prim Rej GPM			STO	Sec WW
420		15				RCL		53		53	TPD
1		)				49				RCL	
2		+				x				49	
3		RCL				RCL				x	
4		35				48				RCL	
5		x		48		x				48	
6		(				.				x	
7		RCL				2				RCL	
8		15				5				20	
9		−				÷				=	
430		RCL				(		54		STO	Split to
1		37				RCL				54	Second stage
2		)				66				RCL	TPD
3		)				x				52	
4		÷				RCL				÷	
5		(		49		02				RCL	
6		(				)				06	
7		RCL				=				=	
8		48				STO	Split to			STO	Prim Feed
9		x				50	Second stage			55	TPD
440		.				RCL	GPM	55		RCL	
1		2				44				55	
2		5				−				÷	
3						RCL				(	
4		÷				50				RCL	
5		RCL		50		−				02	
6		06				RCL				x	
7		)				49				RCL	
8		−				−				20	
9		(				RCL				)	
450		RCL				35		56		=	
1		48				=				STO	Prim Feed
2		x				STO	Sec WW			56	GPM
3		RCL				51	GPM.			RCL	
4		15				RCL				55	
5		x		51		49				−	
6		.				x				RCL	
7		2				RCL				52	
8		5				48				=	
9		÷				x				STO	
460		(				RCL					
1		RCL				20					
2		02				=					
3		x				STO	Prim Rej.				
4		RCL				52	-PD.				

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

TITLE Cleaner Balance -2 PAGE 2 OF 2

TI Programmable Coding Form

PROGRAMMER ____________ DATE ____________

LOC	CODE	KEY	COMMENTS
57 0		57	PRIM ACC
1		RCL	TPD
2		57	
3		+	
4		RCL	
5		45	
6		=	
7		STO	System Acc
8		58	TPD
9		RCL	
58 0		01	
1		÷	
2		RCL	
3		58	
4		=	
5		STO	X
6		59	
7		RCL	
8		59	
9		x=t	
59 0		( )	
1		RCL	
2		19	
3		x	
4		RCL	
5		59	
6		=	
7		STO	New Quat
8		19	Req Rate
9		GTO	
60 0		103	
1		RCL	
2		56	
3		−	
4		RCL	
5		49	
6		=	
7		STO	PRIM ACC
8		60	GPM
9		RCL	
61 0		57	
1		÷	
2		(	
3		RCL	
4		60	
5		x	
6		RCL	
7		26	
8		)	
9		=	
62 0		STO	PRIM ACC
1		61	CONS.
2		(	
3		RCL	
4		56	

LOC	CODE	KEY	COMMENTS
		x	
		(	
		RCL	
		02	
		−	
63		RCL	
		14	
		)	
		+	
		RCL	
		50	
		x	
		(	
		RCL	
		02	
64		−	
		RCL	
		14	
		)	
		)	
		÷	
		(	
		RCL	
		18	
		−	
65		RCL	
		14	
		)	
		=	
		STO	STACK-GPM.
		62	
		RCL	
		50	
		+	
		RCL	
66		56	
		−	
		RCL	
		62	
		=	
		STO	Prim WW
		63	GPM
		RCL	
		63	
		x	
67 0		RCL	
1		14	
2		Y	
3		RCL	
4		20	
5		=	
6		STO	Prim WW
7		64	TPD
8		RCL	
9		62	

LOC	CODE	KEY	COMMENTS
68		x	
		RCL	
		18	
		y	
		RCL	
		20	
		=	
		STO	Thick Stack
		65	TPD
		ADV	
69		ADV	
		OP	
		00	
		3	
		5	
		1	
		7	
		OP	
		01	
		1	
70		3	
		1	
		6	
		0	
		0	
		1	
		5	
		1	
		3	
		OP	
71		02	
		3	
		5	
		1	
		6	
		0	
		0	
		0	
		4	
		0	
72		0	
1		OP	
2		03	
3		ADV	PRINT!
4		ADV	READ
5		OP	Card
6		05	3
7		ADV	
8		ADV	
9		ADV	

MERGED CODES

62	Pgm Ind		72	STO Ind		83	GTO Ind
63	Exc Ind		73	RCL Ind		84	Op Ind
64	Prd Ind		74	SUM Ind		92	INV SBR

TEXAS INSTRUMENTS INCORPORATED

TI-24181

TITLE Print Instructions -PROG II PAGE 1 OF 1

TI Programmable Coding Form

PROGRAMMER ____________ DATE ________

CHANGES FROM 1 AS FOLLOWS

LOC	CODE	KEY	COMMENTS
20		65	Replaces 57
23		62	Repl 55
50		55	Repl 53
54		56	Repl 54
67		60	Repl 61
70		61	Repl 62
78		52	Repl 51
91		64	Repl 58
94		63	Repl 56
161		53	Repl 52
164		51	Repl 50
166	Follows Rest of		
167	PROG. 1. exactly.		

MERGED CODES

62 [illegible] [illegible]	72 STO [illegible]	83 GTO [illegible]
63 [illegible] [illegible]	73 RCL [illegible]	84 [illegible] [illegible]
64 [illegible] [illegible]	74 SUM [illegible]	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

Cleaner Balance -3 PAGE 1 OF 3

TI Programmable Coding Form

PROGRAMMER ______ DATE ______

LOC	CODE	KEY	COMMENTS
0		Repeat 00 —	408
1		& balance	1
41 2		.	
3		0	
4		0	
5		5	
6		STO	Cons. of Combined stages.
7		49	
(41) 8		(	
9		RCL	
42 0		44	
1		x	
2		(	
3		03	
4		—	
5		RCL	
6		49	
7		)	
8		+	
9		RCL	
43 0		35	
1		x	
2		(	
3		RCL	
4		49	
5		—	
6		RCL	
7		37	
8		)	
9			
44 0		÷	
1		(	
2		RCL	
3		48	
4		—	
5		RCL	
6		49	
7		)	
8		=	
9		STO	Prim Rej GPM.
45 0		50	
1		RCL	
2		50	
3		x	
4		RCL	
5		48	
6		x	
7		RCL	
8		20	
9		=	
46 0		STO	Prim Rej. TPD
1		51	
2		RCL	
3		51	
4		÷	

LOC	CODE	KEY	COMMENTS
		RCL	
		06	
		=	
		STO	Prim Feed TPD
		52	
47		RCL	
		52	
		—	
		RCL	
		51	
		=	
		STO	Prim Acc TPD
		53	
		ADV	
		OP	
48		06	
		7	
		1	
		OP	
		02	
		OP	
		05	
		ADV	
		R/S	
		STO	ALPHA Rej RATE-DEC
49		54	
		Prt	
		R/S	
		STO	ALPHA Truck Factor.
		55	
		Prt	
		ADV	
		ADV	
		ADV	
		RCL	
50		53	
		x	
		RCL	
		54	
		=	
		STO	ALPHA Rej. TPD
		56	
		RCL	
		52	
		÷	
51		(	
		RCL	
		02	
		x	
		RCL	
		20	
		)	
		=	
		STO	Prim Feed - GPM
		57	

LOC	CODE	KEY	COMMENTS
52		RCL	
		57	
		—	
		RCL	
		50	
		=	
		STO	Prim Acc GPM
		58	
		RCL	
		53	
53		÷	
		(	
		RCL	
		58	
		x	
		RC	
		20	
		)	
		=	
		STO	Prim Acc Cons.
54		59	
		RCL	
		59	
		x	
		RCL	
		55	
		=	
		STO	ALPHA Rej Cons
		60	
		RCL	
55		56	
		÷	
		(	
		RC	
		60	
		x	
		RCL	
		20	
		)	
		=	
56		STO	ALPHA Rej. GPM.
		61	
		RCL	
		44	
		—	
		RCL	
		50	
		—	
		RCL	
		35	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

TITLE Cleaner Balance -3 PAGE 2 OF 3

PROGRAMMER ______ DATE ______

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
570		=				66	Calc-composite	68		58	
1		STO	Composite				consistency			—	
2		62	GPM			RCL				RCL	
3		RCL				49				61	
4		62				÷				=	
5		x		63		RCL				STO	ALPHA ACC
6		RCL				66				70	GPM
7		49				=				RCL	
8		x				STO	x			01	
9		RCL				67				÷	
580		20				RCL		69		(	
1		=				67				RCL	
2		STO	Composite			x=T				70	
3		63	TPD			(649)				x	
4		RCL				RCL				RCL	
5		62		64		49				20	
6		—				x				)	
7		RCL				RCL				=	
8		61				67				STO	ALPHA ACC
9		=				=				71	Cons.
590		STO	Sec WW			STO	New Composite	70		(	
1		64	GPM			49	Consistency			RCL	
2		RCL				GTO				57	
3		64				418				x	
4		x				RCL				(	
5		RCL		65		53				RCL	
6		15				—				14	
7		x				RCL				—	
8		RCL				56				RCL	
9		20				=				02	
600		=				STO	Syst. Acc-	71		)	
1		STO	Sec WW			68	Calc-TPD.			+	
2		65	TPD			RCL				RCL	
3		(				01				46	
4		RCL				÷				x	
5		56		66		RCL				(	
6		+				68				RCL	
7		RCL				=				47	
8		65				STO	x			—	
9		)				69				RCL	
610		÷				RCL		72		14	
1		(				69				)	
2		(				x=T				[illegible]	
3		RCL				(679)				÷	
4		61				RCL				(	
5		+		67		19				RCL	
6		RCL				x				14	
7		64				RCL				—	
8		)				69				RCL	
9		x				=				18	
620		RCL				STO	New Qual				
1		20				19	Rej. Rate				

MERGED CODES

62 [key] [key] 72 STO [key] 83 GTO [key]

63 [key] [key] 73 RCL [key] 84 [key] [key]

TITLE Cleaner balance 3 PAGE 3 OF 3

TI Programmable Coding Form

PROGRAMMER ____________ DATE ____________

LOC	CODE	KEY	COMMENTS
0		)	
1		=	
2		STO	Thick Stack
3		72	GPM.
4		RCL	
5		72	
6		×	
7		RCL	
8		18	
9		×	
0		RCL	
1		20	
2		=	
3		STO	Thick stack
4		73	TPD
5		RCL	
6		52	
7		−	
8		RCL	
9		73	
0		−	
1		RCL	
2		45	
3		=	
4		STO	Prim WW
5		74	TPD.
6		RCL	
7		74	
8		÷	
9		(	
0		RCL	
1		14	
2		×	
3		RCL	
4		20	
5		)	
6		=	
7		STO	Prim WW
8		75	GPM.
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			

MERGED CODES

62		Ind	72	STO	Ind	83	GTO	
63		Ind	73	RCL		84		
64		Ind	74	SUM		92	INV	SBR

TEXAS INSTRUMENTS INCORPORATED

TI-24151

TITLE Print Instructions PROG III PAGE 1 OF 1

TI Programmable Coding Form

PROGRAMMER ______ DATE ______

Changes from prog I as follows:

LOC	CODE	KEY	COMMENTS
No		New	old.
5 1		52	repl 53
2			
3			
5 4		57	repl 54
64 5		53	repl 01
6			
6 7		58	repl 61
8			
9			
7 0		59	repl 62
8 1		50	repl 49
2			
3			
4			
5			
6			
7			
8			
9			
0			
9 1		74	repl 58
2			
3			
9 4		75	repl 56
5			
6			
7			
8			
9			
0			
16 1		65	repl 52
2			
3			
16 4		64	repl 50
5			
6			
7	ADD at beginning of line 30		
8		ADV	
9		ADV	
0		ADV	
1		ADV	
2		OP	
3		00	
4		1	
5		0	
6		0	
7		0	
8		0	
9		0	
0		7	
1		3	
2		OP	
3		01	
4		OP	

LOC	CODE	KEY	COMMENTS
		2	
		1	
		3	
		3	
		2	
		3	
		1	
		3	
		0	
		0	
		OP	
		02	
		SBR	Print -
		LNX	ALPHA STAGE
		ADV	
		SBR	
		CE	Feed
		RCL	
		53	
		Prt	TPD
		RCL	
		58	
		PRT	flow
		RCL	
		59	
		SBR	
		SUM	
		Prt	%
		SBR	Print : ACC
		CLR	
		RCL	
		01	
		PRT	TPD
		RCL	
		70	
		Prt	Flow
		RCL	
		71	
		SBR	
		SUM	
		PRT	%
		SBR	
		X≷T	Print : REJ
		RCL	
		56	
		Prt	TPD
		RCL	
		61	
		Prt	Flow
		RCL	
		60	
		SBR	
		Sum	
		Prt	%
		ADV	
		ADV	

LOC	CODE	KEY	COMMENTS
		follow rest of prog I exactly.	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

TEXAS INSTRUMENTS INCORPORATED

TI-24151

APPENDIX II

YIELD, EFFICIENCY CALCULATIONS

Yield

Yield was calculated in the following manner:

TPD Feed (thick stock) + TPD white water = TPD Accepted + TPD Rejected.

$$\frac{\text{TPD Accepted}}{\text{TPD (thick stock) + TPD (white water)}} \times 100 = \text{BD Yield}$$

Cleaning Efficiency

Cleaning efficiency for the system as a whole was calculated as follows:

(TPD WW X PPM Dirt) + (TPD Feed X PPM Dirt) = (TPD Accepts X PPM Dirt) + (TPD Rejects X PPM Dirt)

$$\frac{\text{TPD Rejects X PPM Dirt}}{\text{(TPD WW X PPM Dirt) + (TPD Feed X PPM Dirt)}} \times 100 = \text{Cleaning Efficiency}$$

This calculation was verified by performing a dirt balance around each stage.

APPENDIX III

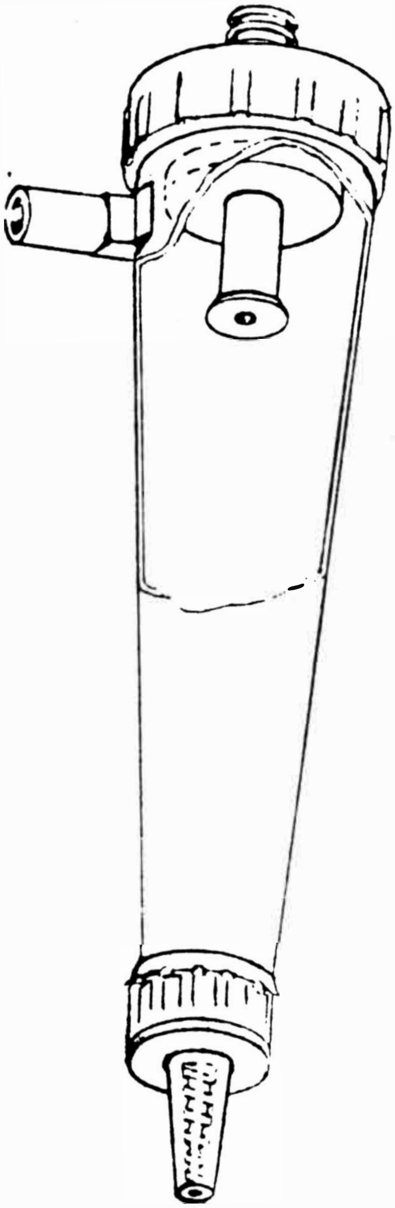
BACKGROUND DATA

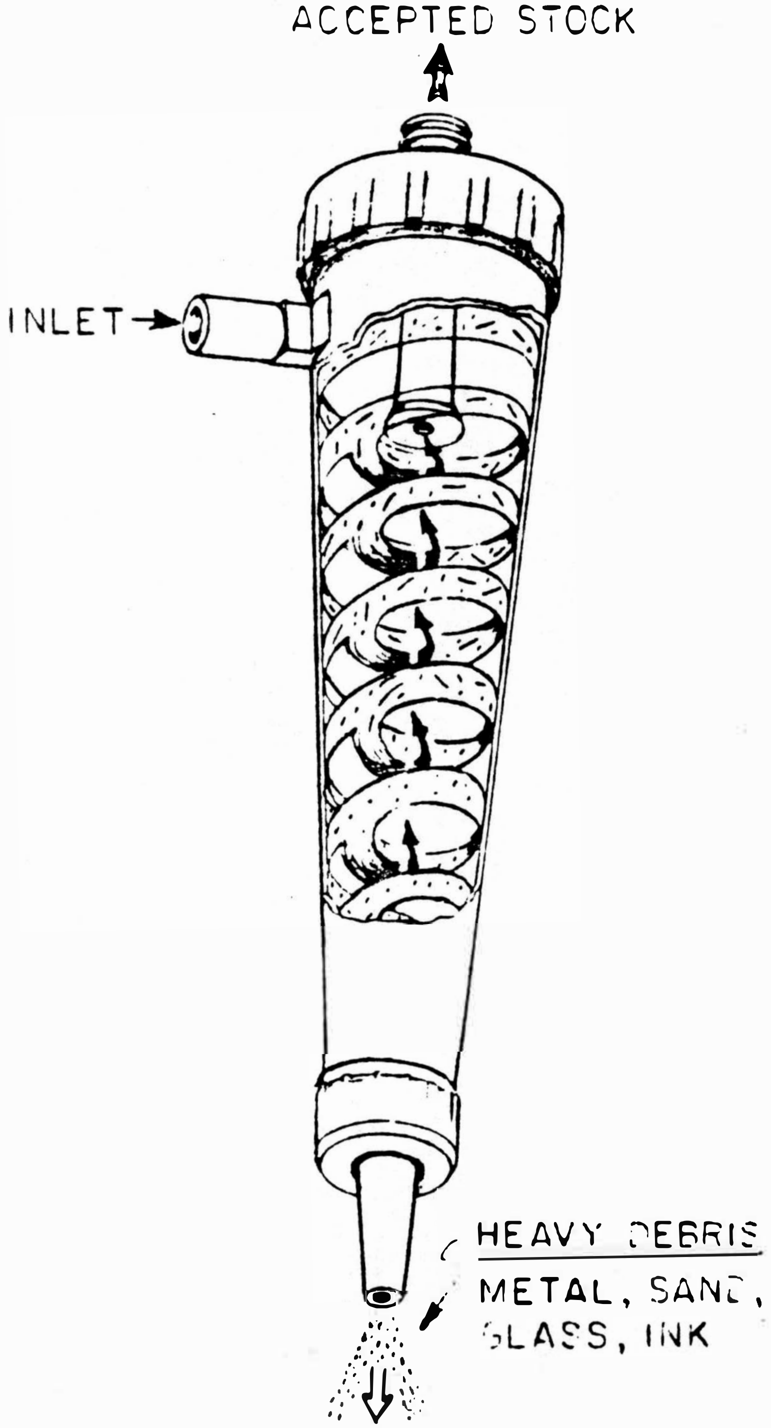
CLEANER PERFORMANCE

The following data was established through pilot plant experimentation with Bauer 3" centrifugal cleaners.

A heavily printed bleached kraft stock was defibered with 1% NaOH and 140°F water. This stock was chosen primarily because cleaning efficiency is easy to determine, but also because fiber length, and ash content are somewhat in the middle of the extremes for available market fiber.

A pressure drop of 40 psig was recommended by the manufacturer. A temperature of 80-90°F was chosen as a representative process temperature, again due to the manufacturers' recommendations.




ACCEPTED STOCK
INLET
HEAVY DEBRIS
METAL, SAND,
GLASS, INK

RAW DATA

Consistencies vs. Thickening Factor

Primary Stage

T.F.	Feed Consistency	Reject Consistency	Accept Consistency
4.73	.52	2.46	.41
5.10	.60	3.06	.47
3.00	.68	2.04	.52
2.82	.61	1.72	.51
3.17	.70	2.22	.41
4.80	.47	2.26	.51
3.86	.50	1.93	.44
3.34	.56	1.87	.52
2.96	.48	1.42	.29
2.93	.45	1.32	.32
2.13	.46	.9 8	.26
2.23	.52	1.16	.60
3.62	.93	3.37	.65

	T.F.	Feed	Reject	Accept
$\bar{X}$ =	3.438	.575	1.985	.455
SD =	.949	.13	.705	.116
Var =	.831	0.17	.459	.012

Secondary Stage

T.F.	Feed Consistency	Reject Consistency	Accept Consistency
4.96	.47	2.436	.11
3.60	.94		.15
4.2	.65		.35
6.69	.35	2.588	.19
4.40	.57		.18
6.14	.50	2.540	.28
5.76	.37		.21
5.65	.49	2.507	.29
6.58	.36	2.579	.19
5.75	.28	2.506	.16
3.93	.30	2.346	.09
3.29	.34	2.290	.22
5.84	.57		.12
$\bar{X}$ = 5.138	.476	2.375	.195
SD = 1.144	.18	.729	.076
Var = 1.208	.03	.490	.005

Tertiary Stage

T.F.	Feed Consistency	Reject Consistency	Accept Consistency
5.55	.20	1.11	.07
5.57	.51	2.84	.03
4.92	.39	1.92	.20
12.62	.24	3.03	.11
6.48	.33	2.14	.30
7.58	.36	2.23	.12
6.62	.45	2.98	.14
3.00	.90	2.70	.43
5.48	.29	1.59	.08
5.55	.20	1.11	.09
3.53	.30	1.06	.10
7.15	.13	.93	.10
6.76	.29	1.96	.21
$\bar{X}$ = 6.216	.309	2.00	.152
SD = 2.334	.109	.794	.109
Var = 5.027	.011	.581	.012

APPENDIX IV

BALANCED SYSTEM

RESULTS, ALL COLLECTIONS

ALL DATA INPUTS

RAW DATA

Feed Consistency vs. Cleaning Efficiency (30-50 PPM)

Primary Stage

Feed Consistency	PPD Dirt Feed	Reject Rate	PPM Dirt Rejects	Cleaning Efficiency %
.52	32	21.5	187	77.5
.60	35	25.6	185	74.0
.68	42	31.6	195	68.0
.61	45	23.3	265	73.0
.70	47	50.8	139	66.5
.47	50	80.9	77	80.0
.50	33	15.5	271	78.5
.56	36	9.9	485	75.0
.48	42	49.7	107	79.0
.45	48	38.1	156	81.0
.46	46	59.2	97	80.5
.52	34	36.1	122	77.5
.93	35	37.3	230	41.0
$\overline{X}$ = .575	40.4	34.8	194	59.8

Secondary Stage

Feed Consistency	PPM Dirt Feed	Reject Rate	PPM Dirt Rejects	Cleaning Efficiency %
.47	177	80.2	319	80
.35	175	22.8	913	84
.50	185	32.7	770	78.5
.49	255	46.1	1975	78
.36	129	51.0	302	83.5
.28	67	45.8	170	86.0
.30	261	72.8	419	85.5
.34	375	39.0	1131	85.0
$\overline{X}$ = .476	203	47.5	744	57.4

Tertiary Stage

Feed Consistency	PPM Dirt Feed	Reject Rate	PPM Dirt Rejects	Cleaning Efficiency %
.20	310	69.4	507	88
.51	298	95.1	402	78
.39	460	54.4	1025	82.5
.24	280	56.2	569	87.5
.33	199	10.6	2208	85.0
.36	315	70.5	535	83.5
.45	320	72.3	546	81.0
.90	410	62.1	1375	48.0
.20	377	76.3	259	90
.22	365	60.4	687	88
.30	402	73.6	639	85.5
.13	354	25.9	1502	91.0
.29	332	30.9	1264	85.0
$\bar{X}$ = .309	340	66.5	886	57.7

RAW DATA

Feed Consistency vs. Reject Rate

Primary Stage

Feed Consistency	Reject Rate %
.52	21.5
.60	25.6
.68	31.6
.61	23.3
.70	50.8
.47	80.9
.50	15.5
.56	9.9
.48	49.7
.45	38.1
.46	59.2
.52	36.1
.93	37.3

$\bar{X}$	=	.575	34.8
SD	=	0.13	
Var	=	0.17	

Secondary Stage

Feed Consistency	Reject Rate %
.47	80.2
.35	22.8
.50	32.7
.49	46.1
.36	51.0
.28	45.8
.30	72.8
.34	39.0

$\overline{X}$	=	.476	47.4
SD	=	.18	
Var		.03	

Tertiary Stage

Feed Consistency	Reject Rate %
.20	69.4
.51	95.1
.39	54.4
.24	56.2
.33	10.6
.36	70.5
.45	72.3
.90	62.1
.29	76.3
.20	60.4
.30	73.6
.13	25.9
.29	30.9

$\overline{X}$	=	.309	66.5
SD	=	.109	
Var	=	.011	

COLLECTION 1

Results for Input 1

STOCK

TPD	177.775
CONS.	2.300
GPM	1286.507

PRIMARY STAGE

FEED	TPD	230.061
	CONS.	.600
	GPM	6382.084
ACCEPTS	TPD	150.000
	CONS.	.461
	GPM	5416.447
REJECTS	TPD	80.061
	CONS.	1.380
	GPM	965.637
WHITEWATER	TPD	1.560
	CONS.	.010
	GPM	2596.279

SECONDARY STAGE

FEED	TPD	96.439
	CONS.	.550
	GPM	2918.501
ACCEPTS	TPD	50.727
	CONS.	.338
	GPM	2499.298
REJECTS	T	
	TPD	45.712
	CONS.	1.815
	GPM	419.203
WHITEWATER	TPD	.365
	CONS.	.010
	GPM	607.783

TERTIARY STAGE

FEED	TPD	47.798
	CONS.	.500
	GPM	1591.155
ACCEPTS	TPD	16.012
	CONS.	.198
	GPM	1345.081
REJECTS	TPD	31.786
	CONS.	2.150
	GPM	246.074
WHITEWATER	TPD	.112
	CONS.	.010
	GPM	187.177

QUARTENARY STAGE

FEED	TPD	32.357
	CONS.	.450
	GPM	1196.814
ACCEPTS	TPD	1.974
	CONS.	.033
	GPM	984.775
REJECTS	TPD	30.383
	CONS.	2.385
	GPM	212.039
WHITEWATER	TPD	.571
	CONS.	.010
	GPM	950.740

COLLECTION 2

Results for Input 1

STOCK

TPD	179.615
CONS.	2.300
GPM	1299.825

PRIMARY STAGE

FEED		
	TPD	145.492
	CONS.	.600
	GPM	4036.067
ACCEPTS		
	TPD	94.861
	CONS.	.461
	GPM	3425.393
REJECTS		
	TPD	50.631
	CONS.	1.380
	GPM	610.675
WHITE WATER		
	TPD	2.250
	CONS.	.010
	GPM	3745.259

SECONDARY STAGE

FEED		
	TPD	104.827
	CONS.	.550
	GPM	3172.353
ACCEPTS		
	TPD	55.139
	CONS.	.338
	GPM	2716.687
REJECTS		
	TPD	49.688
	CONS.	1.815
	GPM	455.665
WHITE WATER		
	TPD	.051
	CONS.	.010
	GPM	84.501

TERTIARY STAGE

FEED		
	TPD	51.956
	CONS.	.500
	GPM	1729.560
ACCEPTS		
	TPD	17.405
	CONS.	.197
	GPM	
	GPM	1468.160
REJECTS		
	TPD	34.551
	CONS.	2.200
	GPM	261.399
WHITE WATER		
	TPD	.122
	CONS.	.010
	GPM	203.346

QUARTENARY STAGE

FEED		
	TPD	35.175
	CONS.	.450
	GPM	1301.056
ACCEPTS		
	TPD	2.146
	CONS.	.033
	GPM	1070.548
REJECTS		
	TPD	33.030
	CONS.	2.385
	GPM	230.508
WHITE WATER		
	TPD	.625
	CONS.	.010
	GPM	1039.656

SYSTEM ACCEPTS

TPD	150.000
CONS.	.406
GPM	6142.080

COLLECTION 3

Results for Input 2

STOCK

TPD	248.002
CONS.	2.300
GPM	1794.720

PRIMARY STAGE

FEED

TPD	327.257
CONS.	.600
GPM	9078.355

ACCEPTS

TPD	213.371
CONS.	.461
GPM	7704.760

REJECTS

TPD	113.885
CONS.	1.380
GPM	1373.595

WHITEWATER

TPD	2.092
CONS.	.010
GPM	3481.835

SECONDARY STAGE

FEED

TPD	146.698
CONS.	.550
GPM	4439.469

ACCEPTS

TPD	77.163
CONS.	.338
GPM	3801.800

REJECTS

TPD	69.535
CONS.	1.815
GPM	637.669

WHITEWATER

TPD	.353
CONS.	.010
GPM	588.051

TERTIARY STAGE

FEED

TPD	72.708
CONS.	.500
GPM	2420.381

ACCEPTS

TPD	24.357
CONS.	.198
GPM	2046.066

REJECTS

TPD	48.351
CONS.	2.150
GPM	374.315

WHITEWATER

TPD	.171
CONS.	.010
GPM	
GPM	284.724

QUARTENARY STAGE

FEED

TPD	49.220
CONS.	.450
GPM	1820.531

ACCEPTS

TPD	3.002
CONS.	.033
GPM	1497.987

REJECTS

TPD	46.217
CONS.	2.385
GPM	322.543

ALPHA STAGE

FEED

TPD	213.371
CONS.	.461
GPM	7704.760

ACCEPTS

TPD	150.000
CONS.	.343
GPM	7273.003

REJECTS

TPD	63.371
CONS.	.024
GPM	431.757

WHITEWATER

TPD	.869
CONS.	.010
GPM	1446.216

COLLECTION 1

Results for Input 2

STOCK

TPD	177.509
CONS.	2.300
GPM	1284.585

PRIMARY STAGE

FEED		
	TPD	230.061
	CONS.	.550
	GPM	6962.273
ACCEPTS		
	TPD	150.000
	CONS.	.401
	GPM	6228.070
REJECTS		
	TPD	80.061
	CONS.	1.815
	GPM	734.203
WHITEWATER		
	TPD	1.690
	CONS.	.010
	GPM	2813.625

SECONDARY STAGE

FEED		
	TPD	96.695
	CONS.	.500
	GPM	3218.889
ACCEPTS		
	TPD	50.862
	CONS.	.296
	GPM	2864.063
REJECTS		
	TPD	45.834
	CONS.	2.150
	GPM	354.826
WHITEWATER		
WHITEWATER		
	TPD	.560
	CONS.	.010
	GPM	932.643

TERTIARY STAGE

FEED		
	TPD	47.981
	CONS.	.450
	GPM	1774.720
ACCEPTS		
	TPD	16.074
	CONS.	.172
	GPM	1552.043
REJECTS		
	TPD	31.908
	CONS.	2.385
	GPM	222.677
WHITEWATER		
	TPD	.160
	CONS.	.010
	GPM	265.962

QUARTENARY STAGE

FEED		
	TPD	32.589
	CONS.	.400
	GPM	1356.046
ACCEPTS		
	TPD	
	TPD	1.988
	CONS.	.029
	GPM	1153.931
REJECTS		
	TPD	30.601
	CONS.	2.520
	GPM	202.115
WHITEWATER		
	TPD	.681
	CONS.	.010
	GPM	1133.369

COLLECTION 2

Results for Input 2

STOCK

TPD	179.318
CONS.	2.300
GPM	1297.674

PRIMARY STAGE

FEED	TPD	145.475
	CONS.	.550
	GPM	4402.478
ACCEPTS	TPD	94.850
	CONS.	.401
	GPM	3938.217
REJECTS	TPD	50.625
	CONS.	1.815
	GPM	464.261
WHITE WATER	TPD	2.527
	CONS.	.010
	GPM	4205.424

SECONDARY STAGE

FEED	TPD	104.848
	CONS.	.500
	GPM	3490.276
ACCEPTS	TPD	55.150
	CONS.	.296
	GPM	3105.534
REJECTS	TPD	49.698
	CONS.	
	CONS.	2.150
	GPM	384.742
WHITE WATER	TPD	.146
	CONS.	.010
	GPM	242.499

TERTIARY STAGE

FEED	TPD	52.027
	CONS.	.450
	GPM	1924.348
ACCEPTS	TPD	17.429
	CONS.	.172
	GPM	1682.896
REJECTS	TPD	34.598
	CONS.	2.385
	GPM	241.451
WHITE WATER	TPD	.173
	CONS.	.010
	GPM	288.386

QUARTENARY STAGE

FEED	TPD	35.336
	CONS.	.400
	GPM	1470.376
ACCEPTS	TPD	2.156
	CONS.	.029
	GPM	1251.220
REJECTS	TPD	33.181
	CONS.	2.520
	GPM	219.156
WHITE WATER	TPD	.738
	CONS.	.010
	GPM	1228.924

SYSTEM ACCEPTS

TPD	150.000
CONS.	.354
GPM	7043.751

COLLECTION 3

Results for Input 2

STOCK

TPD	241.698
CONS.	2.300
GPM	1749.104

PRIMARY STAGE

FEED

TPD	327.257
CONS.	.550
GPM	9903.660

ACCEPTS

TPD	213.371
CONS.	.401
GPM	8859.274

REJECTS

TPD	113.885
CONS.	1.815
GPM	1044.386

WHITEWATER

TPD	2.075
CONS.	.010
GPM	3453.545

SECONDARY STAGE

FEED

TPD	158.714
CONS.	.500
GPM	5283.416

ACCEPTS

TPD	83.483
CONS.	.296
GPM	4701.012

REJECTS

TPD	75.230
CONS.	2.150
GPM	582.404

WHITEWATER

TPD	.765
CONS.	.010
GPM	1273.889

TERTIARY STAGE

FEED

TPD	78.756
CONS.	.450
GPM	2912.987

ACCEPTS

TPD	26.383
CONS.	.172
GPM	2547.490

REJECTS

TPD	52.372
CONS.	2.385
GPM	365.497

WHITEWATER

TPD	.262
CONS.	.010
GPM	
GPM	436.545

QUARTENARY STAGE

FEED

TPD	53.490
CONS.	.400
GPM	2225.786

ACCEPTS

TPD	3.263
CONS.	.029
GPM	1894.038

REJECTS

TPD	50.227
CONS.	2.520
GPM	331.748

ALPHA STAGE

FEED

TPD	213.371
CONS.	.401
GPM	8859.274

ACCEPTS

TPD	150.000
CONS.	.296
GPM	8441.623

REJECTS

TPD	63.371
CONS.	.025
GPM	417.651

WHITEWATER

TPD	1.118
CONS.	.010
GPM	1860.288

COLLECTION 1

Results for Input 3

STOCK

TPD	177.229
CONS.	2.300
GPM	1282.560

PRIMARY STAGE

FEED		
	TPD	230.0[illegible]1
	CONS.	.5[illegible]
	GPM	7650.500
ACCEPTS		
	TPD	150.00[illegible]
	CONS.	.355
	GPM	7030.696
REJECTS		
	TPD	80.061
	CONS.	2.150
	GPM	619.804
WHITEWATER		
	TPD	1.870
	CONS.	.010
	GPM	2112.850

SECONDARY STAGE

FEED		
	TPD	96.866
	CONS.	.450
	GPM	3583.585
ACCEPTS		
	TPD	50.962
	CONS.	.260
	GPM	3263.091
REJECTS		
	TPD	45.924
	CONS.	2.385
	GPM	320.494
WHITEWATER		
	TPD	.705
	CONS.	.010
	GPM	1172.851

TERTIARY STAGE

FEED		
	TPD	48.119
	CONS.	.400
	GPM	2002.292
ACCEPTS		
	TPD	16.120
	CONS.	.180
	GPM	1790.930
REJECTS		
	TPD	31.9[illegible]
	CONS.	2.520
	GPM	211.352
WHITEWATER		
	TPD	.194
	CONS.	.010
	GPM	[illegible]

QUARTENARY STAGE

FEED		
	TPD	32.809
	CONS.	.350
	GPM	1560.275
ACCEPTS		
	TPD	2.001
	CONS.	.028
	GPM	1359.576
REJECTS		
	TPD	30.808
	CONS.	2.556
	GPM	200.698
WHITEWATER		
	TPD	.810
	CONS.	.010
	GPM	1248.920

COLLECTION 2

Results for Input 3

STOCK

TPD	178.963
CONS.	2.300
GPM	1295.110

PRIMARY STAGE

FEED	TPD	145.457
	CONS.	.500
	GPM	4842.124
ACCEPTS	TPD	94.839
	CONS.	.355
	GPM	4450.250
REJECTS	TPD	50.619
	CONS.	2.150
	GPM	391.874
WHITE WATER	TPD	2.858
	CONS.	.010
	GPM	4757.545

SECONDARY STAGE

FEED	TPD	104.870
	CONS.	.450
	GPM	3878.913
ACCEPTS	TPD	55.162
	CONS.	.260
	GPM	3532.006
REJECTS	TPD	49.709
	CONS.	2.385
	GPM	346.907
WHITE WATER	TPD	
	TPD	.203
	CONS.	.010
	GPM	337.985

TERTIARY STAGE

FEED	TPD	52.084
	CONS.	.400
	GPM	2167.292
ACCEPTS	TPD	17.448
	CONS.	.150
	GPM	1938.523
REJECTS	TPD	34.636
	CONS.	2.520
	GPM	228.770
WHITE WATER	TPD	.210
	CONS.	.010
	GPM	348.765

QUARTENARY STAGE

FEED	TPD	35.513
	CONS.	.350
	GPM	1688.859
ACCEPTS	TPD	2.166
	CON	
	CONS.	.025
	GPM	1471.621
REJECTS	TPD	33.347
	CONS.	2.555
	GPM	217.238
WHITE WATER	TPD	.877
	CONS.	.010
	GPM	1460.089

SYSTEM ACCEPTS

TPD	150.000
CONS.	.313
GPM	7982.256

COLLECTION 3

Results for Input 3

STOCK

TPD	234.550
CONS.	2.300
GPM	1697.376

PRIMARY STAGE

FEED	TPD	327.257
	CONS.	.500
	GPM	10894.026
ACCEPTS	TPD	213.371
	CONS.	.355
	GPM	10012.370
REJECTS	TPD	113.885
	CONS.	2.150
	GPM	881.656
WHITEWATER	TPD	2.037
	CONS.	.010
	GPM	3391.117

SECONDARY STAGE

FEED	TPD	172.375
	CONS.	.450
	GPM	6375.741
ACCEPTS	TPD	90.669
	CONS.	.260
	GPM	5805.533
REJECTS	TPD	81.706
	CONS.	2.385
	GPM	570.208
WHITEWATER	TPD	1.142
	CONS.	.010
	GPM	1900.397

TERTIARY STAGE

FEED	TPD	85.611
	CONS.	.400
	GPM	3562.362
ACCEPTS	TPD	28.680
	CONS.	.150
	GPM	3186.335
REJECTS	TPD	56.931
	CONS.	2.520
	GPM	376.027
WHITEWATER	TPD	.344
	CONS.	.010
	GPM	
	GPM	573.262

QUARTENARY STAGE

FEED	TPD	58.373
	CONS.	.350
	GPM	2775.965
ACCEPTS	TPD	3.561
	CONS.	.025
	GPM	2418.892
REJECTS	TPD	54.812
	CONS.	2.555
	GPM	357.073

ALPHA STAGE

FEED	TPD	213.371
	CONS.	.355
	GPM	10012.370
ACCEPTS	TPD	150.000
	CONS.	.260
	GPM	9605.017
REJECTS	TPD	63.371
	CONS.	.026
	GPM	407.353
WHITEWATER	TPD	1.442
	CONS.	.010
	GPM	2399.938

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