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TEXAS
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HIGHWAY
DEPARTMENT

COOPERATIVE
RESEARCH

COST-EFFECTIVENESS PROGRAM FOR ROADSIDE SAFETY IMPROVEMENTS ON TEXAS HIGHWAYS--VOLUME TWO, COMPUTER PROGRAM DOCUMENTATION MANUAL

in cooperation with the
Department of Transportation
Federal Highway Administration

RESEARCH REPORT 15-1
STUDY 2-10-74-15
ROADSIDE SAFETY IMPROVEMENTS

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16. Abstract

This report represents the final report (Volume 2 of 3) of Research Study 2-10-74-15, entitled, "Cost-Effectiveness Priority Program for Roadside Safety Improvements on Non-Controlled Access Roadways," a follow-on to Research Study 2-8-72-11, "Cost-Effectiveness Priority Program for Roadside Safety Improvements on Texas Freeways."

In the follow-on study, the computer program developed for controlled access highways was substantially modified after extensive field trial implementation in the Ft. Worth District (District 2) and the concept and procedures were adapted to accommodate non-controlled access rural highways. The resulting product of the two studies is a procedure that is applicable for both types of highways and utilizing a general computer program to accommodate both.

This report presents documentation of the computer model including descriptions of computer variables, discussion of assumptions made, and flow charts for the major subroutines comprising the model. The research studies are documented in three volumes as follows:

Volume 1: Procedures Manual

Volume 2: Computer Program Documentation Manual

Volume 3: Cost-Effectiveness Analysis Manual

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COST-EFFECTIVENESS PROGRAM FOR ROADSIDE SAFETY IMPROVEMENTS ON TEXAS HIGHWAYS

VOLUME 2: COMPUTER PROGRAM DOCUMENTATION MANUAL

by

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Research Report 15-1

Research Studies 2-8-72-11 and 2-10-74-15

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TEXAS A&M UNIVERSITY

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IMPLEMENTATION

The cost-effectiveness analysis procedure for roadside safety improvement evaluation has been developed on an immediate implementation basis. This report provides documentation of the computer model developed to evaluate safety improvement alternatives. The model is applicable for both controlled and non-controlled access rural highways. Immediate implementation of the computer model is anticipated on a statewide basis.

DISCLAIMER

SUMMARY

This report represents the final report (Volume 2 of 3) of Research Study 2-10-74-15, entitled, "Cost-Effectiveness Priority Program for Roadside Safety Improvements on Non-Controlled Access Roadways," a follow-on to Research Study 2-8-72-11, "Cost-Effectiveness Priority Program for Roadside Safety Improvements on Texas Freeways."

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This report presents documentation of the computer model including descriptions of computer variables, discussion of assumptions made, and flow charts for the major subroutines comprising the model. The research studies are documented in three volumes as follows:

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1. INTRODUCTION

Roadside safety improvement programs, like any phase of highway construction or maintenance, must compete for limited funds. As increasing emphasis is being directed toward roadside safety, it is apparent that a definite need exists for methods by which administrators may evaluate alternative safety improvements and program those to realize the greatest return within the budget constraints of their available roadside safety improvement funds.

The National Cooperative Highway Research Program (NCHRP) Project 20-7, Task Order 1 (1) presented a conceptual probabilistic model to be used as a management tool in establishing the priority for roadside safety improvements on freeways. The requirement that this research be applicable on a national scale resulted in a high degree of generalization in the model and, therefore, it was not implementable in its current form for specific needs. It was expected that each state would adapt the findings of this research to its own specific needs and administrative structure if the concept was to be implemented.

In this regard, the Texas Highway Department (THD) and the Texas Transportation Institute (TTI), through the cooperative research program, developed a formalized implementation procedure, compatible with Texas Highway Department policy, to program roadside safety improvements on freeways (2) based on the generalized NCHRP 20-7 research. In a follow-on study (3), the concept and procedure were adapted to include non-controlled access roadways as well. The resulting product of the two research studies is a procedure that is applicable for the two types of highways and utilizing a general computer program to accommodate both.

The computer program, written in Fortran IV, was developed to provide a rapid and overall objective basis for evaluating the cost-effectiveness of roadside safety improvements on Texas highways--controlled and non-controlled access. This report presents technical material related to the development of the computer program.

The complete research study is documented in three volumes as follows:

Volume 1: Procedures Manual

Volume 2: Computer Program Documentation Manual

Volume 3: Cost-Effectiveness Analysis Manual

2. HAZARD CLASSIFICATION

Accepted practice in most existing roadside improvement programs has been to consider the primary and secondary recovery areas, which would benefit approximately 85 percent of drivers encroaching the roadside (4). The inventory procedure proposed in this study includes all applicable roadside hazards located within a median and a 30-ft lateral distance adjacent to the outer edge of the traveled lane.

Uniformity in inventory procedure and content is essential to the operation of the cost-effectiveness computer program. Therefore, those roadside obstacles that will be included in the inventory have been identified and assigned an input coding system as shown in Table 2-1. Hazards are grouped by descriptive title under general identification code designation and, where necessary, each general classification is sub-divided into several categories with each being identified by a descriptor code designation. This classification system permits greater flexibility in recording hazards by allowing the addition of new general categories or, more often, additional descriptor codes when "special" or unusual hazards are encountered during the field inventory. Any code additions would necessitate computer program modification prior to implementation. Table 2-1 includes a comprehensive list of hazards, but it is anticipated that additional descriptor codes will be needed to accommodate all hazards that can be found along the roadway, and provisions for including these are made in the computer cost-effectiveness program.

TABLE 2-1

HAZARD CLASSIFICATION CODES

Note: Circled Codes denote Point Hazard

Identification Code		Descriptor Codes
(01.)	Utility Poles	(00)
(02.)	Trees	(00)
(03.)	Rigid Signpost	(01) single-pole-mounted (02) double-pole-mounted (03) triple-pole-mounted (04) cantilever support (05) overhead sign bridge
(04.)	Rigid Base Luminaire Support	(00)
05.	Curbs	(01) mountable design (02) non-mountable design less than 10 inches high (03) barrier design greater than 10 inches high
06.	Guardrail or Median Barrier	(01) w-section with standard post spacing (6 ft-3 in.) (including departing guardrail at bridge) (02) w-section with other than standard post spacing (including departing guardrail at bridge) (03) approach guardrail to bridge—decreased post spacing (3 ft-1 in.) adjacent to bridge (04) approach guardrail to bridge--post spacing not decreased adjacent to bridge (05) post and cable (06) Metal Beam Guard Fence (Barrier) (in median) (07) median barrier (CMB design or equivalent)
07.	Roadside Slope	(01) sod positive slope (02) sod negative slope (03) concrete-faced positive slope

TABLE 2-1, CONTINUED

Identification Code	Descriptor Codes
07. Roadside Slope, cont.	(04) concrete-faced negative slope (05) rubble rip-rap positive slope (06) rubble rip-rap negative slope
08. Ditch (includes erosion, rip-rap runoff ditches, etc.--does not include ditches formed by intersection of front and back slopes)	(00)
09. Culverts	(01) headwall (or exposed end of pipe culvert) (02) gap between culverts on parallel roadways (03) sloped culvert with grate (04) sloped culvert without grate
10. Inlets	(01) rasied drop inlet (tabletop) (02) depressed drop inlet (03) sloped inlet
11. Roadway under Bridge Structure	(01) bridge piers (02) bridge abutment, vertical face (03) bridge abutment, sloped face
12. Roadway over Bridge Structure	01 open gap between parallel bridges 02 closed gap between parallel bridges (03) rigid bridgerail--smooth and continuous construction (04) semi-rigid bridgerail--smooth and continuous construction (05) other bridgerail--probable penetration, snagging, pocketing or vaulting (06) elevated gore abutment
13. Retaining Wall	(01) face 02 exposed end

For purposes of inventorying, all hazards have been categorized in three major classifications:

(1) point hazards (codes circled in Table 2-1)

(2) longitudinal hazards

(3) slopes

The above general classification system was selected to facilitate recording inventory data and to organize the computer program logic. To maintain uniformity between hazard inventory and hazard improvement procedures, the same classification system was used for the improvement data input.

3. INVENTORY AND IMPROVEMENT FORM COMPUTER VARIABLE NAMES

ROADSIDE HAZARD INVENTORY FORM

The extremely large number of hazards that must be inventoried along a section of roadway necessitates use of a systematic coding process for eventual analysis by computer. The roadside hazard inventory form shown in Figure 3-1 has been designed to accomplish this. The form is applicable for both controlled and non-controlled access roadways, the analysis procedures being accommodated internally within the computer program depending on the highway type and classification code entered on the form.

The computer variable names assigned to the roadside hazards are shown on the Roadside Hazard Inventory Form in Figure 3-1 and listed in Table 3-1. The two dimensional array names are written as:

Hazard Names = Hn(I,J)

where

n = hazard descriptor (i.e., n=1...hazard number)

I = hazard numbers in a group ($1 \leq I \leq 15$)

J = 1

Hazard input data are read in subroutine INVTRY.

ROADSIDE HAZARD IMPROVEMENTS FORM

The roadside hazard improvement form (Figure 3-2) has been designed to provide a system whereby feasible safety improvements

ROADSIDE HAZARD INVENTORY

Inventory Conducted by____________ Date________ Hazard Description____________

HIGHWAY (BOX 1)

- H8 — 1 2 — Highway Type: 08 IH; 01 US; 02 SH; 05 FM-RM
- H2 — 3 4 5 6 — Highway Number
- H9 — 7 — Classification: Full Control Access: 1. Interstate; 2. Non-Interstate. Non-Control Access: 3. Two-Lane; 4. Multilane Divided; 5. Multilane Undivided
- H3 — 8 9 10 — County Code
- H4 — 11 12 13 14 — Control Number
- H5 — 15 16 — Section Number
- H51 — 17 18 — Total Width, Center Line to Shoulder on Inventory Side (Undivided Highway Only)
- H7 — 19 20 21 — ADT (Total Both Directions 1000's)
- H6 — 22 — Recording Direction: 1 With Milepost; 2 Against Milepost

HAZARD CLASSIFICATION (BOX 2)

- H1 — 23 24 25 26 — Hazard Number
- H11 — 27 28 — Identification Code
- H12 — 29 30 — Descriptor Code
- H13 — 31 — Offset Code: 1. Right; 2. Median or Left Side
- H15 — 32 33 34 — Median Width (ft) (Leave Blank if Median Inventoried on Near Side Only)
- H16 — 35 36 37 38 — Grouping Number

MILE POINT AT HAZARD

- H17 — 39 40 41 42 43 44 — Beginning
- H18 — 45 46 47 48 49 50 — End (Except for Point Hazard)

POINT HAZARDS (BOX 3)

- H19 — [1] — 51
- H20 — 52 53 — Hazard Offset, D (ft)
- H23 — 54 55 56 — Width (W)(ft)
- H24 — 57 58 59 — Length (L)(ft)
- Drop Inlets Only: H21 — 60 61 62 — Height (ft) or H22 — 63 64 65 — Depth (ft)

LONGITUDINAL HAZARDS (Curbs, Bridgerails, Barriers, Guardrails, Ditches, and Retaining Walls) (BOX 4)

- H19 — [2] — 51
- Hazard Offset, D (ft): H25 — 52 53 — Beginning; H26 — 54 55 — End
- H27 — 56 57 58 — Height (ft) or Depth (ft)
- H28 — 59 60 — Width (W)(ft)
- END TREATMENT
  - H29 — 61 — 1. Not Beginning of Structure - Safety Treated; 2 Not Beginning of Structure - Not Safety Treated; 3. Beginning of Structure - Full Beam Connection; 4 Beginning of Structure - Not Full Beam Connection
  - Guardrail Only
  - H30 — 62 — 1 Not Ending of Structure - Safety Treated; 2 Not Ending of Structure - Not Safety Treated; 3 Ending of Structure - Full-Beam Connection; 4 Ending of Structure Not Full Beam Connection

SLOPES (BOX 5)

FRONT SLOPE

- H19 — [3] — 51
- Hinge Point Offset, D_0, (ft): H31 — 52 53 — Beginning; H32 — 54 55 — End
- Steepness: H33 — 56 57 — Beginning :1; H34 — 58 59 — End :1
- Distance "D_1" (ft): H35 — 60 61 — Beginning; H36 — 62 63 — End
- H37 — 64 — Slope Face Erosion Code: 1 Slight or None; 2 Severe (Ruts >1 ft)
- H38 — 65 — Slope Direction Positive; 2 Negative

2nd or BACK SLOPE (Except for Level Terrain)

- Steepness: H39 — 66 67 — Beginning :1; H40 — 68 69 — End :1
- Distance "D_2" (ft): H41 — 70 71 — Beginning; H42 — 72 73 — End
- H43 — 74 — Slope Face Erosion Code: 1 Slight or None; 2 Severe (Ruts >1 ft)
- H44 — 75 — Slope Direction: 1 Positive; 2 Negative

[/] Card Type — 77

Recommendations:____________

Figure 3-1. Computer variables--Roadside hazard inventory form.

TABLE 3-1

COMPUTER PROGRAM VARIABLES

(Roadside Hazard Inventory Form)

Variable Name	Column	Description
H1	(23-26)	Hazard number
H2	(3-6)	Highway number
H3	(8-10)	County code
H4	(11-14)	Control number
H5	(15-16)	Section number
H6	(22)	Recording direction (H6 = 1 ... with milepost) (H6 = 2 ... against milepost)
H7	(19-21)	Average daily traffic ÷ 1000
H8	(1-2)	Highway type
H9	(7)	Highway classification
H10		Nonexisting on form
H11	(27-28)	Hazard identification code (see hazard classification code, table 2-1)
H12	(29-30)	Hazard descriptor code (see hazard classification code)
H13	(31)	Offset code (H13 = 1 ... right side) (H13 = 2 ... median or left side)
H14		Nonexisting on form
H15	(32-34)	Median width
H16	(35-38)	Grouping number

TABLE 3-1, CONTINUED

Variable Name	Column	Description
H17	(39-44)	Milepoint at beginning of hazard
H18	(45-50)	Milepoint at end of hazard
H19	(51)	Hazard category (H19 = 1 ... point hazard) (H19 = 2 ... longitudinal hazard) (H19 = 3 ... slope hazard)
H20	(52-53)	Point hazard offset
H21	(60-62)	Height of a raised drop inlet
H22	(63-65)	Depth of a depressed drop inlet
H23	(54-56)	Point hazard width
H24	(57-59)	Point hazard length
H25	(52-53)	Offset at beginning of longitudinal hazard
H26	(54-55)	Offset at end of the longitudinal hazard
H27	(56-58)	Height or depth of longitudinal hazard
H28	(59-60)	Width of longitudinal hazard
H29	(61)	Descriptor of guardrail end treatment at beginning of hazard (H29 = 1 ... safety treated--not beginning at structure) (H29 = 2 ... not safety treated--not beginning at structure) (H29 = 3 ... full beam connection--beginning at structure) (H29 = 4 ... not full beam connection--beginning at structure)

TABLE 3-1, CONTINUED

Variable Name	Column	Description
H30	(62)	Descriptor of guardrail end treatment at end of hazard (H30 = 1 ... safety treated--not ending at structure) (H30 = 2 ... not safety treated--not ending at structure) (H30 = 3 ... full beam connection--ending at structure) (H40 = 4 ... not full beam connection--ending at structure)
H31	(52-53)	Hinge-point offset at the beginning of front slope
H32	(54-55)	Hinge-point offset at the end of front slope
H33	(56-57)	Beginning steepness of the front slope
H34	(58-59)	Ending steepness of the front slope
H35	(60-61)	Front slope face length (measured up or down slope surface) at the beginning milepoint
H36	(62-63)	Front slope face length (measured up or down slope surface) at the ending milepoint
H37	(64)	Front slope face erosion code (H37 = 1 ... slight or none) (H37 = 2 ... severe, ruts = 1 ft.+)
H38	(65)	Front slope direction (H38 = 1 ... positive) (H38 = 2 ... negative)
H39	(66-67)	Steepness of the back slope at the beginning milepoint
H40	(68-69)	Steepness of the back slope at the ending milepoint
H41	(70-71)	Back slope face length (measured up slope surface) at the beginning milepoint

TABLE 3-1, CONTINUED

Variable Name	Column	Description
H42	(72-73)	Back slope face-length (measured up slope surface) at the ending milepoint
H43	(74)	Back slope face erosion code (H43 = 1 ... slight or none) (H43 = 2 ... severe, ruts = 1 ft.+)
H44	(75)	Back slope direction (H44 = 1 ... positive) (H44 = 2 ... negative)
	(77)	Card type (type 1 for inventory card)

for each category of hazard can be coded and evaluated in the cost-effectiveness program. The improvement form, similar in format to the hazard inventory form, is applicable for all types of rural highways.

The computer variable names assigned to a roadside improvement are shown on the Roadside Hazard Improvements Form in Figure 3-2 and listed in Table 3-2. The two dimensional array names are written as:

Improvement Names = Cn(I,J)

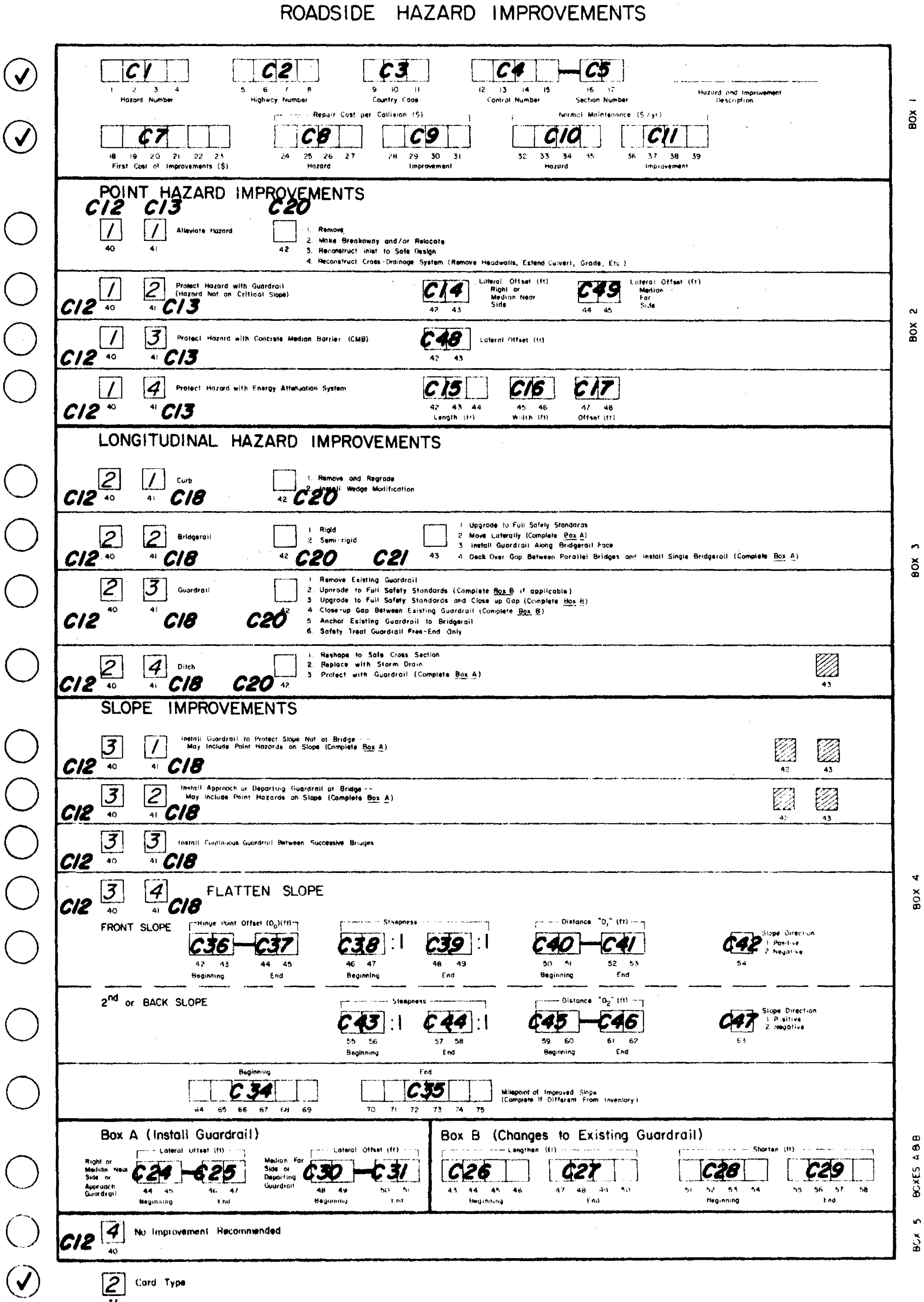
where

n = hazard descriptor

I = hazard number in a group ($1 \leq I \leq 15$)

J = improvement alternative in a group ($2 \leq J \leq 5$)

Improvement data are read in subroutine INVTRY.



ROADSIDE HAZARD IMPROVEMENTS

BOX 1

C1 — Hazard Number (1 2 3 4)
C2 — Highway Number (5 6 7 8)
C3 — Country Code (9 10 11)
C4 — C5 — Control Number (12 13 14 15), Section Number (16 17)
Hazard and Improvement Description

C7 — First Cost of Improvements ($) (18 19 20 21 22 23)
Repair Cost per Collision ($): C8 — Hazard (24 25 26 27); C9 — Improvement (28 29 30 31)
Normal Maintenance ($/yr): C10 — Hazard (32 33 34 35); C11 — Improvement (36 37 38 39)

BOX 2

POINT HAZARD IMPROVEMENTS

C12 [1] 40, C13 [1] 41 — Alleviate Hazard; C20 [ ] 42 — 1. Remove 2. Make Breakaway and/or Relocate 3. Reconstruct inlet to Safe Design 4. Reconstruct Cross-Drainage System (Remove Headwalls, Extend Culvert, Grade, Etc.)

C12 [1] 40, C13 [2] 41 — Protect Hazard with Guardrail (Hazard Not on Critical Slope); C14 (42 43) Lateral Offset (ft) Right or Median Near Side; C49 (44 45) Lateral Offset (ft) Median Far Side

C12 [1] 40, C13 [3] 41 — Protect Hazard with Concrete Median Barrier (CMB); C48 (42 43) Lateral Offset (ft)

C12 [1] 40, C13 [4] 41 — Protect Hazard with Energy Attenuation System; C15 Length (ft) (42 43 44); C16 Width (ft) (45 46); C17 Offset (ft) (47 48)

BOX 3

LONGITUDINAL HAZARD IMPROVEMENTS

C12 [2] 40, C18 [1] 41 — Curb; C20 [ ] 42 — 1. Remove and Regrade 2. Install Wedge Modification

C12 [2] 40, C18 [2] 41 — Bridgerail; C20 [ ] 42 — 1. Rigid 2. Semi-rigid; C21 [ ] 43 — 1. Upgrade to Full Safety Standards 2. Move Laterally (Complete Box A) 3. Install Guardrail Along Bridgerail Face 4. Deck Over Gap Between Parallel Bridges and Install Single Bridgerail (Complete Box A)

C12 [2] 40, C18 [3] 41 — Guardrail; C20 [ ] 42 — 1. Remove Existing Guardrail 2. Upgrade to Full Safety Standards (Complete Box B if applicable) 3. Upgrade to Full Safety Standards and Close up Gap (Complete Box B) 4. Close-up Gap Between Existing Guardrail (Complete Box B) 5. Anchor Existing Guardrail to Bridgerail 6. Safety Treat Guardrail Free-End Only

C12 [2] 40, C18 [4] 41 — Ditch; C20 [ ] 42 — 1. Reshape to Safe Cross Section 2. Replace with Storm Drain 3. Protect with Guardrail (Complete Box A); 43

BOX 4

SLOPE IMPROVEMENTS

C12 [3] 40, C18 [1] 41 — Install Guardrail to Protect Slope Not at Bridge — May Include Point Hazards on Slope (Complete Box A); 42 43

C12 [3] 40, C18 [2] 41 — Install Approach or Departing Guardrail at Bridge — May Include Point Hazards on Slope (Complete Box A); 42 43

C12 [3] 40, C18 [3] 41 — Install Continuous Guardrail Between Successive Bridges

C12 [3] 40, C18 [4] 41 — FLATTEN SLOPE

FRONT SLOPE: Hinge Point Offset (O_H)(ft): C36 Beginning (42 43) — C37 End (44 45); Steepness: C38 Beginning (46 47) :1, C39 End (48 49) :1; Distance "D_1" (ft): C40 Beginning (50 51) — C41 End (52 53); C42 Slope Direction 1. Positive 2. Negative (54)

2nd or BACK SLOPE: Steepness: C43 Beginning (55 56) :1, C44 End (57 58) :1; Distance "D_2" (ft): C45 Beginning (59 60) — C46 End (61 62); C47 Slope Direction 1. Positive 2. Negative (63)

Milepoint of Improved Slope (Complete If Different From Inventory): C34 Beginning (64 65 66 67 68 69); C35 End (70 71 72 73 74 75)

BOXES A & B

Box A (Install Guardrail): Lateral Offset (ft) — Right or Median Near Side or Approach Guardrail: C24 Beginning (44 45) — C25 End (46 47); Lateral Offset (ft) — Median Far Side or Departing Guardrail: C30 Beginning (48 49) — C31 End (50 51)

Box B (Changes to Existing Guardrail): Lengthen (ft): C26 Beginning (43 44 45 46), C27 End (47 48 49 50); Shorten (ft): C28 Beginning (51 52 53 54), C29 End (55 56 57 58)

BOX 5

C12 [4] 40 — No Improvement Recommended

[2] 77 Card Type

Figure 3-2. Computer variables--Roadside hazard improvements form.

TABLE 3-2

COMPUTER PROGRAM VARIABLES

(Roadside Hazard Improvements Form)

Variable Name	Column	Description
C1	(1-4)	Hazard number
C2	(5-8)	Highway number
C3	(9-11)	County code
C4	(12-15)	Control number
C5	(16-17)	Section number
C6	---	Non-existing on form
C7	(18-23)	First cost of the improvement ($)
C8	(24-27)	Repair cost per collision ($) for the existing hazard
C9	(28-31)	Repair cost per collision ($) for the proposed improvement
C10	(32-35)	Normal maintenance ($/yr) for the existing hazard
C11	(36-39)	Normal maintenance ($/yr) for the proposed improvement

Point Hazard Improvement Variable Names

C12	(40)	Improvement category (C12=1 ... Point hazard improvement) (C12=2 ... Longitudinal hazard improvement) (C12=3 ... Slope hazard improvement) (C12=4 ... No improvement recommended)

TABLE 3-2, CONTINUED

Variable Name	Column	Description
C13	(41)	Point hazard improvement category (C13=1 ... Alleviate hazard) (C13=2 ... Protect hazard with guardrail--(Hazard not on critical slope) (C13=3 ... Protect hazard with concrete median barrier (CMB)) (C13=4 ... Protect hazard with energy attenuation system)
C14	(42-43)	Lateral offset to proposed guardrail (right side or median near side)
C15	(42-44)	Length of the proposed energy attenuation system
C16	(45-46)	Width of the proposed energy attenuation system
C17	(47-48)	Offset of the proposed energy attenuation system
C20	(42)	Alleviate point hazard alternatives (If C13=1 and C20=1 ... Remove hazard) (If C13=1 and C20=2 ... Make breakaway and/or relocate) (If C13=1 and C20=3 ... Reconstruct an inlet to safe design standards) (If C13=1 and C20=4 ... Reconstruct cross-drainage system (remove headwalls, extend culverts, grade, etc.))
C48	(42-43)	Lateral offset of proposed concrete median barrier
C49	(44-45)	Lateral offset to proposed guardrail (median far side)

TABLE 3-2, CONTINUED

Variable Name	Column	Description
Longitudinal Hazard Improvement Variable Names		
C12	(40)	Improvement category (C12=1 ... Point hazard improvement) (C12=2 ... Longitudinal hazard improvement) (C12=3 ... Slope hazard improvement) (C12=4 ... No improvement recommended)
C18	(41)	Longitudinal hazard improvement classification (C18=1 ... Curb hazard) (C18=2 ... Bridgerail hazard) (C18=3 ... Guardrail hazard) (C18=4 ... Ditch hazard)
C19	---	Non-existing on form
C20	(42)	Longitudinal hazard improvement alternatives (If C18=1 and C20=1 ... Remove & regrade curb) (If C18=1 and C20=2 ... Install wedge modification to curb) (If C18=2 and C20=1 ... Rigid bridgerail installed) (If C18=2 and C20=2 ... Semi-rigid bridgerail installed) (If C18=3 and C20=1 ... Remove existing guardrail) (If C18=3 and C20=2 ... Upgrade to full safety standards) (If C18=3 and C20=3 ... Upgrade to full safety standards & close-up gap) (If C18=3 and C20=4 ... Close-up gap between existing guardrail) (If C18=3 and C20=5 ... Anchor existing guardrail to bridgerail) (If C18=3 and C20=6 ... Safety treat guardrail free-end only) (If C18=4 and C20=1 ... Reshape ditch to safe cross section) (If C18=4 and C20=2 ... Replace ditch with storm drain)

TABLE 3-2, CONTINUED

Variable Name	Column	Description
C20 cont.	(42)	(If C18=4 and C20=3 ... Protect ditch with a guardrail--see box "A" on form)
C21	(43)	Improvement alternative for rigid or semi-rigid bridgerail (C18=2 and C20=1 or 2) (C21=1 ... Upgrade to full safety standards) (C21=2 ... Move laterally) See box "A" on form (C21=3 ... Install guardrail along bridgerail face) (C21=4 ... Deck over gap between parallel bridges and install single bridgerail) See box "A" on form

Slope Hazard Improvement Variable Names

Variable Name	Column	Description
C12	(40)	Improvement category (C12=1 ... Point hazard improvement) (C12=2 ... Longitudinal hazard improvement) (C12=3 ... Slope hazard improvement) (C12=4 ... No improvement recommended)
C18	(41)	Slope hazard improvement classification (C18=1 ... Install guardrail to protect slope not at a bridge--may include point hazards on slope) (C18=2 ... Install approach or departing guardrail at bridge--may include point hazards on slope) (C18=3 ... Install continuous guardrail between successive bridges) (C18=4 ... Flatten slope)
C34	(64-69)	Beginning milepoint of the improved slope if different from inventory
C35	(70-75)	Ending milepoint of the improved slope if different from inventory
C36	(42-43)	Hinge-point offset at the beginning of the improved slope
C37	(44-45)	Hinge-point offset at the end of the improved slope

TABLE 3-2, CONTINUED

Variable Name	Column	Description
C38	(46-47)	Front slope steepness at the beginning milepoint of improved slope
C39	(48-49)	Front slope steepness at the ending milepoint of improved slope
C40	(50-51)	Front slope face length (measured up or down slope surface) at beginning milepoint of improved slope
C41	(52-53)	Front slope face length (measured up or down slope surface) at ending milepoint of improved slope
C42	(54)	Front slope direction of the improved slope (C42=1 ... Positive slope) (C42=2 ... Negative slope)
C43	(55-56)	Back slope steepness at the beginning milepoint of improved slope
C44	(57-58)	Back slope steepness at the ending milepoint of improved slope
C45	(59-60)	Back slope face length at the beginning milepoint of improved slope
C46	(60-61)	Back slope face length at the ending milepoint of improved slope
C47	(63)	Back slope direction of the improved slope
C48 & C49		See point hazard improvement category above

Box A--Improvement Variable Names (Install Guardrail)

Variable Name	Column	Description
C24	(44-45)	Lateral offset at beginning milepoint of proposed guardrail installation (right or median near side; or approach guardrail)
C25	(46-47)	Lateral offset at the ending milepoint of proposed guardrail installation (right or median near side; or approach guardrail)

TABLE 3-2, CONTINUED

Variable Name	Column	Description
C30	(48-49)	Lateral offset at beginning milepoint of proposed guardrail installation (median far side or departing guardrail)
C31	(50-51)	Lateral offset at ending milepoint of proposed guardrail installation (median far side or departing guardrail)
Box B--Improvement Variable Names (Changes to Existing Guardrail)		
C26	(43-46)	Lengthening change at the beginning of existing guardrail
C27	(47-50)	Lengthening change at the end of existing guardrail
C28	(51-54)	Shortening change at the beginning of existing guardrail
C29	(55-58)	Shortening change at the end of existing guardrail
No Improvement Recommended Category		
C12	(40)	C12=4 ... No improvement recommended
Card Type		
---	(77)	Card type (type 2 for improvement card)

4. SEVERITY INDICES

Establishment of the severity of impact with various types of roadside hazards was accomplished by asking representatives from highway design, traffic engineering, maintenance and law enforcement to rate the severity of impact with the object or situation on a linear scale from 0 to 10; with 0 indicating no significant injury to vehicle occupants and 10 indicating a certain fatality for all vehicle occupants. This scale is indicated in Figure 4-1.

The linear scale while convenient for consistent ratings from field personnel, has some inherent disadvantages in the cost effectiveness model. In particular, a unit numerical change in the Severity Index means two entirely different things depending upon the end of the scale involved. For example, a change from 9 to 7 represents a reduction from a highly probable fatal impact to one producing only injury, whereas a similar numerical change from 4 to 2 represents only minor significance, both being in the property-damage-only region of severity. Therefore, the linear severity indices were adjusted on a non-linear scale essentially the same as the cost relationships associated with Property Damage Accidents only (PDO), Injury Accidents (I), and Fatal Accidents (F).

ADJUSTMENT OF SEVERITY INDICES

To establish the relationship between accident cost and the descriptors used in the establishment of the linear severity indices,

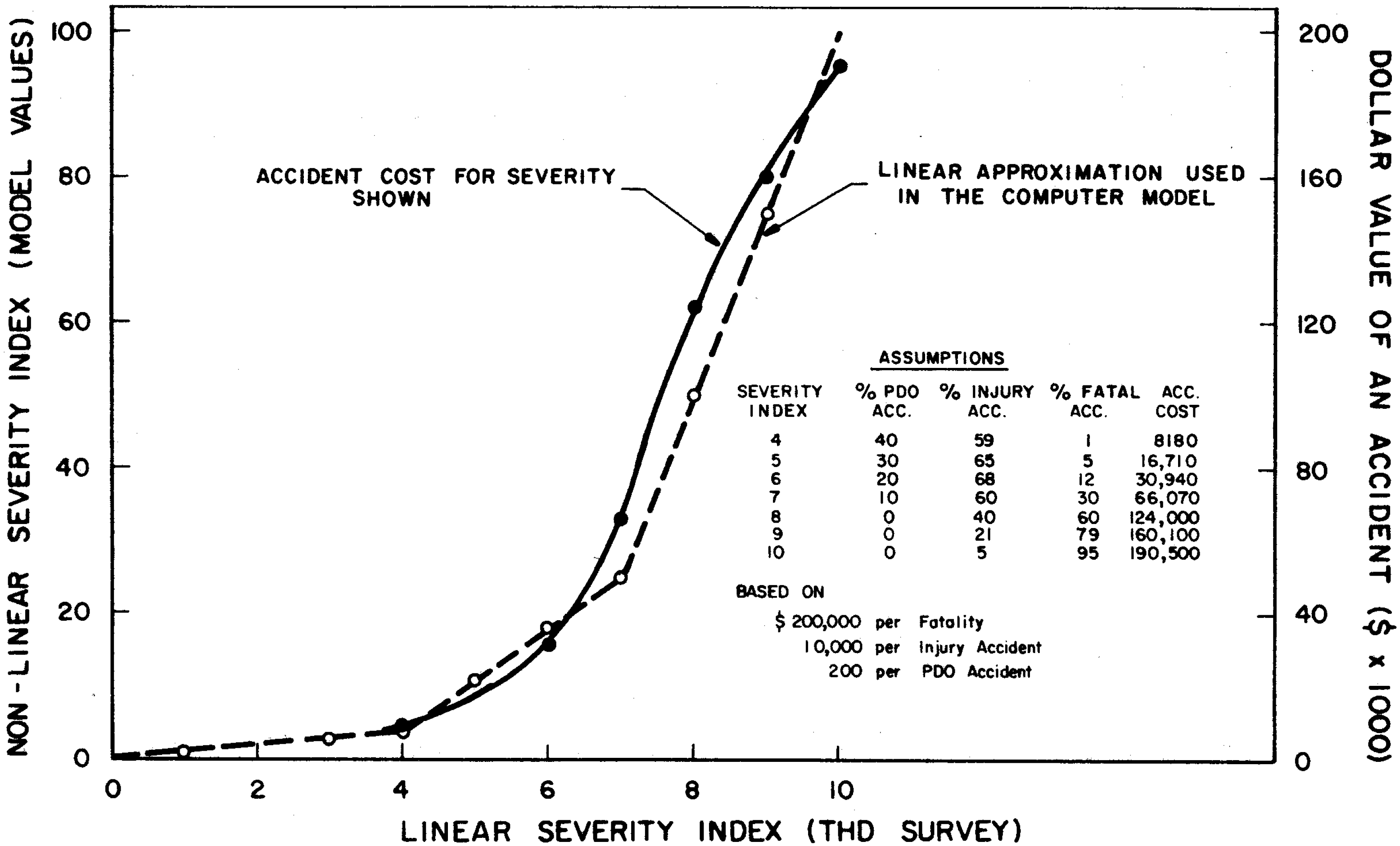


Figure 4-1. Severity index adjustment relationships.

it was necessary to make specific assumptions regarding the percentage of PDO, I, and F accidents and specific costs for each accident type. It soon became apparent that the assumptions regarding the cost per accident influenced the relationship very little provided the total cost for a fatal incident was equated with 10 on the linear severity index scale.

The cost data used to adjust the severity index represent rounded values from a U. S. Department of Transportation preliminary report (5). The PDO cost values presented in the report were applicable to both urban and rural accidents. Therefore, to more appropriately reflect only the higher speed rural accidents and assuming a factor due to increased repair costs, the PDO cost used in the severity index adjustment were 700 dollars per accident. The costs used were:

$200,000 per fatality accident

$ 10,000 per injury accident

$ 700 per property damage only accident

Further, the relationship between the linear severity index and the percentage PDO, I and F accident occurrence given an impact with the object or situation had to be defined. These values were established in a conference meeting involving the project staff, representatives of the Texas Highway Department and the Federal Highway Administration. These assumptions are presented in Table 4-1.

These total cost values are plotted in Figure 4-1 (solid curve). The non-linear relationship of accident cost and severity index was

TABLE 4-1

ASSUMPTIONS
IN THE DEVELOPMENT OF THE NON-LINEAR
SEVERITY INDICES

$700 $10,000 $200,000

Linear Severity Index	% PDO Accidents	% Injury Accidents	% Fatal Accidents	Total Accident Cost*
0	100	0	0	$ 700
1	85	15	0	2,095
2	70	30	0	3,490
3	55	45	0	4,885
4	40	59	1	8,180
5	30	65	5	16,710
6	20	68	12	30,940
7	10	60	30	66,070
8	0	40	60	124,000
9	0	21	79	160,100
10	0	5	95	190,500

*Based on the cost assumptions for accidents presented above.

determined by equating the maximum accident cost ($200,000) to a non-linear severity index of 100. For each programming, the curve presented in Figure 4-1 was approximated by a series of three linear relationships.

$$Y = X \text{ for the region } 0 < X \leq 4$$

$$Y = 7X - 24 \text{ for the region } 4 < X \leq 7$$

$$Y = 25X - 150 \text{ for the region } 7 < X \leq 10$$

Using these equations results in some substantial differences as indicated in Table 4-2. These differences were, however, not considered to be of great concern especially in light of the subjective manner of establishing the linear severity indices and conversion to the non-linear indices.

Table 4-3 presents a listing of severity indices used in the computer program. The identification and descriptor codes agree with those listed in Table 2-1 of this document.

TABLE 4-2

COMPARISON OF LINEAR AND NON-LINEAR HAZARD INDICES

Linear Severity Index	Severity Index Based on Cost	Approximation Using Three Linear Equations	Percentage Difference
0	0	0	NA
1	1	1	0
2	2	2	0
3	3	3	0
4	4.5	4	+12.5%
5	8.6	11	+27.9%
6	15.5	18	+16.1%
7	33.0	25	-32.0%
8	62.0	50	-19.3%
9	81.0	75	- 7.4%
10	95.5	100	+ 4.8%

TABLE 4-3

SEVERITY INDICES

Identification Code	Descriptor Code	End Treatment Code Beginning	End Treatment Code Ending	Severity-Index Survey	Severity-Index Adjusted
1. Utility Pole					
1	0	-	-	7.1	27.5
2. Trees					
2	0	-	-	8.0	50.0
3. Rigid Signpost					
3	1	-	-	4.7	8.9
3	2	-	-	7.2	30.0
3	3	-	-	7.2	30.0
3	4	-	-	7.2	30.0
3	5	-	-	8.1	52.5
4. Rigid Base Luminaire Support					
4	0	-	-	7.5	37.5
5. Curbs					
5	1	-	-	2.4	2.4
5	2	-	-	4.1	4.7
5	3	-	-	3.7	3.7
6. Guardrail or Median Barrier					
6	1	1	1	3.7	3.7
6	1	1	2	4.0	4.0
6	1	1	3	3.6	3.6
6	1	1	4	4.5	7.5
6	1	2	1	5.6	15.2
6	1	2	2	5.7	15.9
6	1	2	3	5.3	13.1
6	1	2	4	5.7	15.9
6	1	3	1	3.3	3.3
6	1	3	2	3.3	3.3
6	1	3	3	3.3	3.3
6	1	3	4	4.6	8.2
6	1	4	1	4.5	7.5
6	1	4	2	4.7	8.9
6	1	4	3	4.5	7.5
6	1	4	4	5.0	11.0
6	2	1	1	3.9	3.9
6	2	1	2	4.2	5.4
6	2	1	3	3.8	3.8

TABLE 4-3, CONTINUED

Identification Code	Descriptor Code	End Treatment Code Beginning	End Treatment Code Ending	Severity-Index Survey	Severity-Index Adjusted
6	2	1	4	4.7	8.9
6	2	2	1	5.8	16.6
6	2	2	2	5.9	17.3
6	2	2	3	5.5	14.5
6	2	2	4	5.9	17.3
6	2	3	1	3.5	3.5
6	2	3	2	3.5	3.5
6	2	3	3	3.5	3.5
6	2	3	4	4.8	9.6
6	2	4	1	4.7	8.9
6	2	4	2	4.9	10.3
6	2	4	3	4.7	8.9
6	2	4	4	5.0	11.0
6	3	1	1	3.7	3.7
6	3	1	2	4.0	4.0
6	3	1	3	3.3	3.3
6	3	1	4	4.5	7.5
6	3	2	1	5.6	15.2
6	3	2	2	5.0	11.0
6	3	2	3	3.9	3.9
6	3	2	4	5.0	11.0
6	3	3	1	3.2	3.2
6	3	3	2	3.2	3.2
6	3	3	3	3.2	3.2
6	3	3	4	4.4	6.8
6	3	4	1	4.0	4.0
6	3	4	2	4.5	7.5
6	3	4	3	3.9	3.9
6	3	4	4	4.7	8.9
6	4	1	1	3.7	3.7
6	4	1	2	4.0	4.0
6	4	1	3	3.6	3.6
6	4	1	4	4.5	7.5
6	4	2	1	5.6	15.2
6	4	2	2	5.7	15.9
6	4	2	3	5.3	13.1
6	4	2	4	5.7	15.9
6	4	3	1	3.3	3.3
6	4	3	2	3.3	3.3
6	4	3	3	3.3	3.3
6	4	3	4	4.6	8.2
6	4	4	1	4.5	7.5
6	4	4	2	4.7	8.9

TABLE 4-3, CONTINUED

Identification Code	Descriptor Code	End Treatment Code Beginning	End Treatment Code Ending	Severity-Index Survey	Severity-Index Adjusted
6	4	4	3	4.5	7.5
6	4	4	4	5.0	11.0
6	5	1	1	3.9	3.9
6	5	1	2	3.9	3.9
6	5	1	3	3.9	3.9
6	5	1	4	3.9	3.9
6	5	2	1	3.9	3.9
6	5	2	2	3.9	3.9
6	5	2	3	3.9	3.9
6	5	2	4	3.9	3.9
6	5	3	1	3.9	3.9
6	5	3	2	3.9	3.9
6	5	3	3	3.9	3.9
6	5	3	4	3.9	3.9
6	5	4	1	3.9	3.9
6	5	4	2	3.9	3.9
6	5	4	3	3.9	3.9
6	5	4	4	3.9	3.9
6	6	1	1	4.4	6.8
6	6	1	2	4.4	6.8
6	6	1	3	4.4	6.8
6	6	1	4	5.0	11.0
6	6	2	1	5.6	15.2
6	6	2	2	5.7	15.9
6	6	2	3	5.3	13.1
6	6	2	4	5.7	15.9
6	6	3	1	4.0	4.0
6	6	3	2	4.4	6.8
6	6	3	3	4.0	4.0
6	6	3	4	4.6	8.2
6	6	4	1	4.5	7.5
6	6	4	2	4.7	8.9
6	6	4	3	4.5	7.5
6	6	4	4	5.0	11.0
6	7	1	1	4.2	5.4
6	7	1	2	4.2	5.4
6	7	1	3	4.2	5.4
6	7	1	4	4.2	5.4
6	7	2	1	4.2	5.4
6	7	2	2	4.2	5.4
6	7	2	3	4.2	5.4
6	7	2	4	4.2	5.4
6	7	3	1	4.2	5.4

TABLE 4-3, CONTINUED

Identification Code	Descriptor Code	End Treatment Code Beginning	End Treatment Code Ending	Severity-Index Survey	Severity-Index Adjusted
6	7	3	2	4.2	5.4
6	7	3	3	4.2	5.4
6	7	3	4	4.2	5.4
6	7	4	1	4.2	5.4
6	7	4	2	4.2	5.4
6	7	4	3	4.2	5.4
6	7	4	4	4.2	5.4
7. Roadside Slope					
7	1	-	-	3.0	3.0
7	2	-	-	3.0	3.0
7	3	-	-	2.5	2.5
7	4	-	-	2.5	2.5
7	5	-	-	5.1	11.7
7	6	-	-	5.1	11.7
8. Ditch					
8	0	-	-	0.0	0.0
9. Culverts					
9	1	-	-	7.9	47.5
9	2	-	-	5.5	14.5
9	3	-	-	3.3	3.3
9	4	-	-	7.7	42.5
10. Inlets					
10	1	-	-	5.7	15.9
10	2	-	-	3.1	3.1
10	3	-	-	3.3	3.3
11. Roadway Under Bridge Structure					
11	1	-	-	9.3	82.5
11	2	-	-	9.3	82.5
11	3	-	-	2.5	2.5
12. Roadway Over Bridge Structure					
12	1	-	-	7.2	30.0
12	2	-	-	5.5	14.5
12	3	-	-	3.3	3.3
12	4	-	-	3.0	3.0
12	5	-	-	9.3	82.5
12	6	-	-	9.3	82.5

TABLE 4-3, CONTINUED

Identification Code	Descriptor Code	End Treatment Code Beginning	End Treatment Code Ending	Severity-Index Survey	Severity-Index Adjusted
13. Retaining Wall					
13	1	-	-	3.3	3.3
13	2	-	-	9.3	82.5

5. GUARDRAIL INSTALLATIONS

The guardrail criteria used by the Texas Highway Department (6) are incorporated in the computer program. Guardrail improvements are treated in several subroutines (see Table 8-1) depending on the hazard it is to protect.

GUARDRAIL NOT AT BRIDGE

The computer variable names assigned to the installation of guardrail to protect hazards not adjacent to a bridge are shown in Figures 5-1 and 5-2. The upstream length of guardrail needed is computed by the following equations:

$$HL1 = 400\ (D3 - D2)/D3 \quad \text{(Eqn. 5-1)}$$

$$HL2 = 400\ (D9 - D8)/D9 \quad \text{(Eqn. 5-2)}$$

Other imposed conditions for guardrail protecting a point hazard or ditch that are not on a critical slope (critical slope is defined as a slope with steepness of 3.5:1 or steeper) are as follows.

1. Lateral offset of point hazard

$$D1 \leq 30 \text{ ft.}$$

$$D10 \leq 30 \text{ ft.}$$

2. Lateral offset of ditch

$$D3 \leq 30 \text{ ft.}$$

$$D9 \leq 30 \text{ ft.}$$

3. Clearance between point hazard and guardrail

$$(D1-D2) \geq 3 \text{ ft.}$$

$$(D10-D8) \geq 3 \text{ ft.}$$

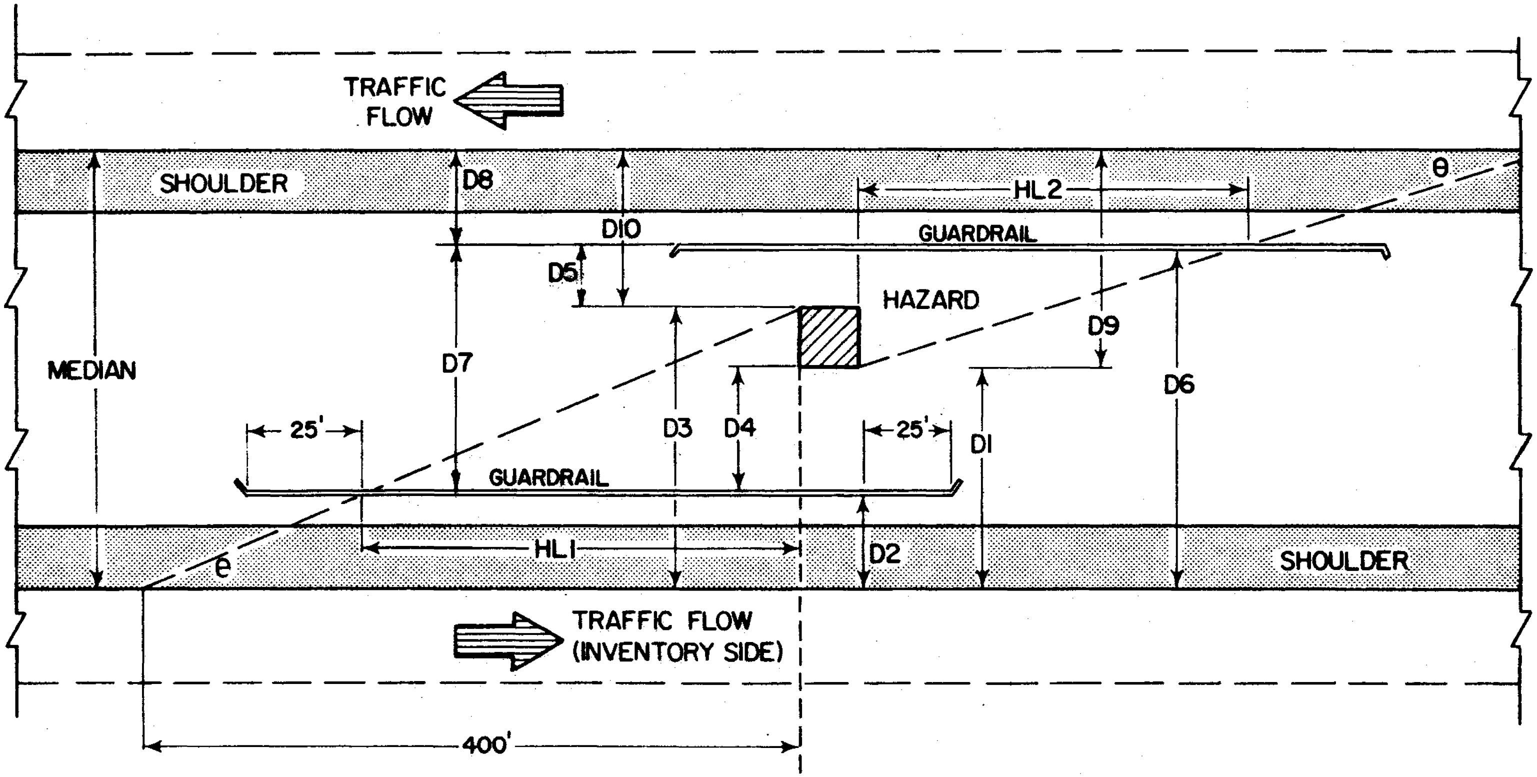


Figure 5-1. Computer variables--Guardrail installation.

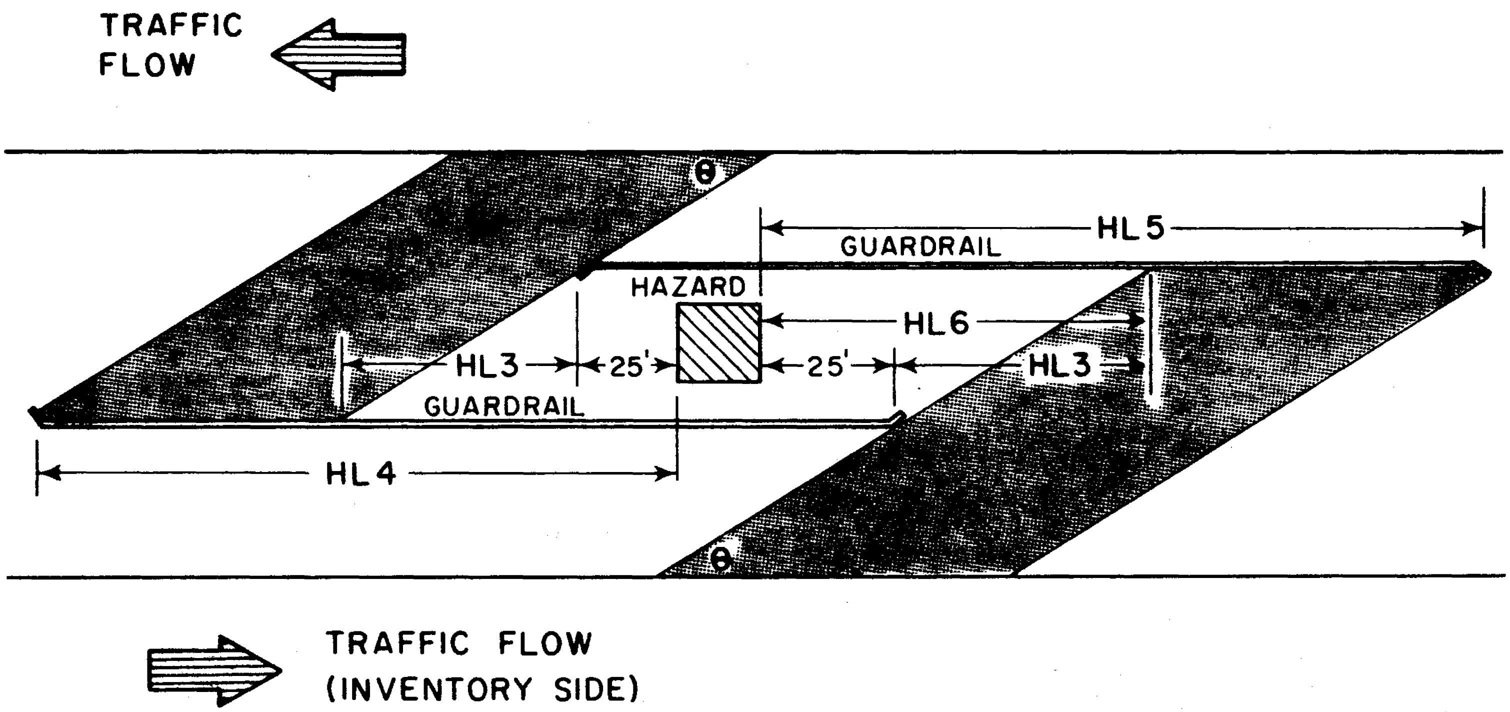


Figure 5-2. Computer variables--Guardrail shadow effect.

4. Length of guardrail needed

$$HL1 \geq 150 \text{ ft.}$$

$$HL2 \geq 150 \text{ ft.}$$

The shadowed encroachment paths in Figure 5-2 represent encroachments in which an errant vehicle can cross the median and strike the backside of the far-side guardrail that is protecting opposing traffic flow from a hazard. For non-critical slopes, the imposed conditions for crossover median encroachments are:

$$D6 \leq 30 \text{ ft.}$$

$$(D7+D8) \leq 30 \text{ ft.}$$

The total length (L) of guardrail needed to protect a hazard is:

$$L = \begin{matrix} HL1 \\ HL2 \end{matrix} + \text{(Hazard Length)} + \text{(25 ft Safety Treatment at Each End)} \quad \text{. . . . . (Eqn. 5-3)}$$

GUARDRAIL AT BRIDGE

The length (Y) of guardrail needed adjacent to a bridge is computed from the appropriate idealized linear curve in Figure 5-3. The lateral offset (X) in Figure 5-3 is the lateral distance between the beginning and end points of the guardrail.

The imposed condition for guardrail length is:

$$Y \geq 150 \text{ ft.}$$

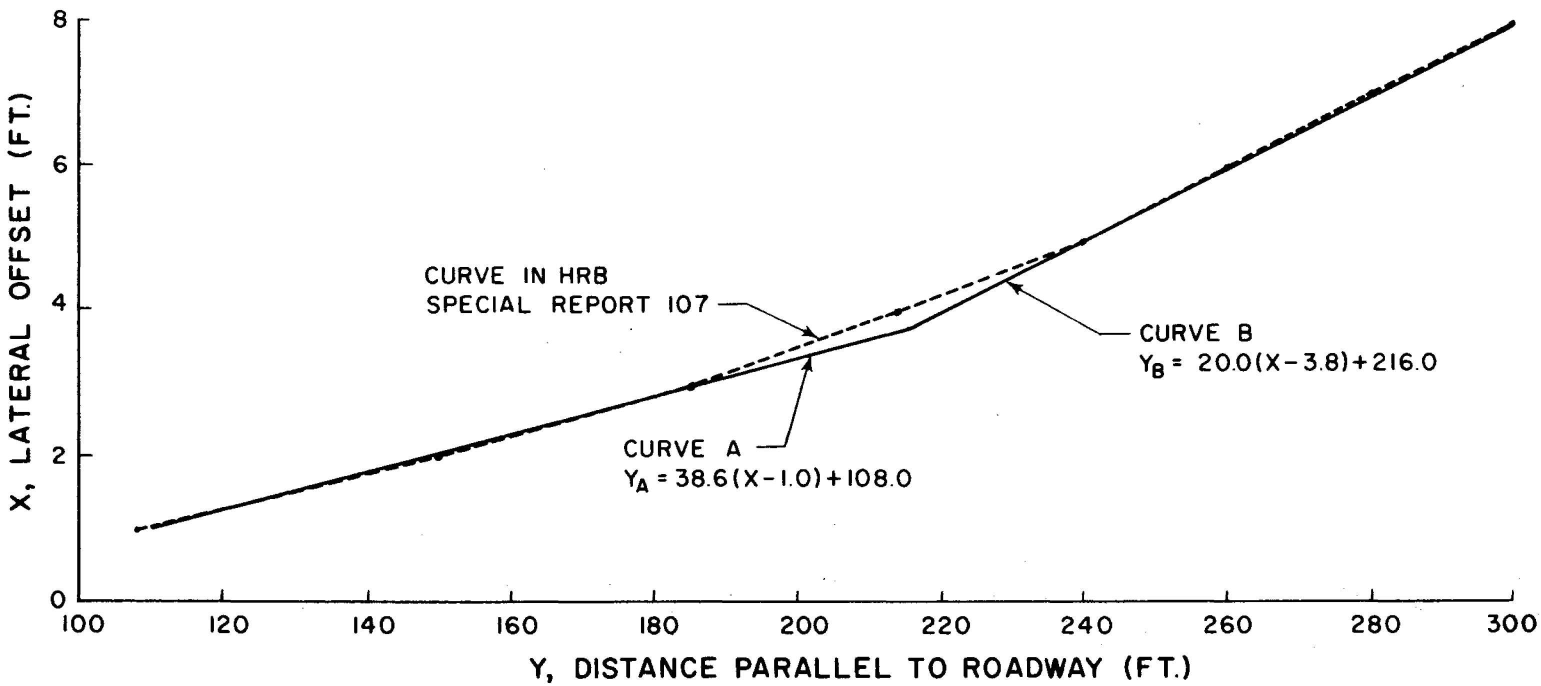


Figure 5-3. Computer idealization of guardrail need at bridges.

6. SLOPES

The severity associated with slope traversal, other than vehicle rollover on a steep front slope, is dependent predominantly on the vehicle g-forces experienced as it travels through the region at the toe-of-slope. The combination of front and back slope, therefore, influences the severity.

Several assumptions were made in the model to define the hazard associated with slope traversal. It was assumed that vehicle control could be maintained on slopes 3.6:1 and flatter and not on slopes 3.5:1 and steeper. Therefore, the severity of the slope is dependent primarily on the front slope steepness. The severity of roadside slope combinations is determined by a fictitious hazard assumed to be located at the toe-of-slope offset. The severity indices used are computed in subroutine VDITCH.

Based on the vehicle control assumption, a second assumption was made regarding hazard offset on slopes. If a point hazard is located on a critical slope, its offset is temporarily moved to the hinge point of the slope prior to hazard index computations because it is assumed that if a vehicle encroaches to the hinge-point, it will continue traveling uncontrolled to the toe-of-the-slope, therefore, the hazard actually becomes critical at the time the vehicle reaches the hinge-point. On non-critical slopes, the lateral offset remains as inventoried in the field. The above assumptions pertain to hazards of all three categories--point hazards, longitudinal hazards, and the slope itself.

Slope severity indices are computed in subroutine VDITCH using variables shown in Figure 6-1. The variables shown in Figure 6-1 are used in subroutine SLOPE1.

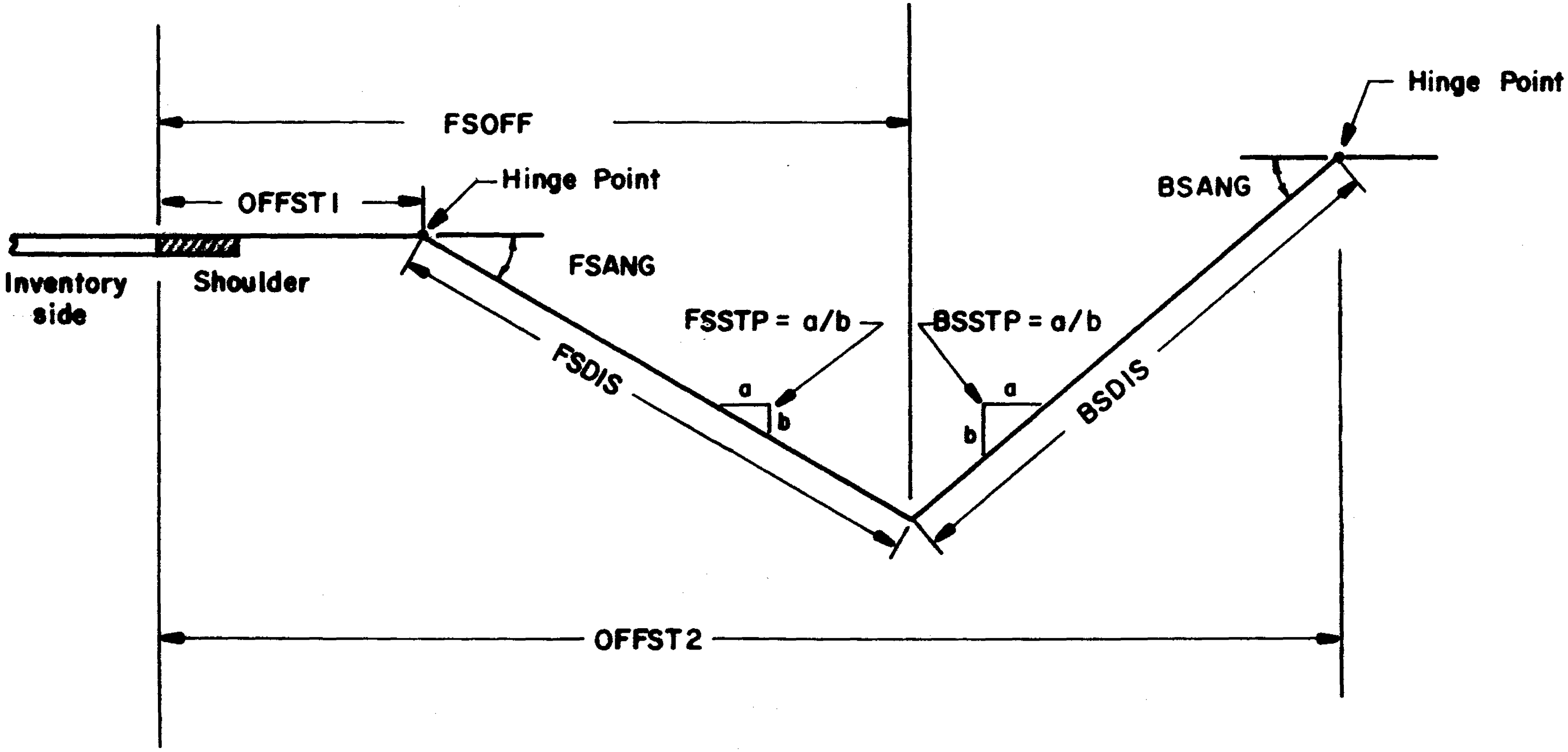


Figure 6-1. Computer variables--Roadside slope geometry.

7. COST-EFFECTIVENESS

As defined by Glennon (1), the cost-effectiveness of a safety improvement alternative is the cost in dollars required to reduce one injury (fatal or non-fatal) accident. Thus,

$$\text{Cost-Effectiveness} = \frac{\text{Annualized Cost of Improvement Alternative}}{\text{Hazard Reduction Achieved}}$$

The cost-effectiveness expressed in terms of the assigned computer names is as follows:

$$CE = \frac{UPAY}{HIB - HIA} \quad \text{. . . . . (Eqn. 7-1)}$$

where:

UPAY = Annualized costs

HIB = Hazard index before improvements

HIA = Hazard index after improvements

HAZARD-INDEX

The hazard-index for a group of existing hazards (before making improvements) is expressed as:

$$(HIB)_J = \sum_{I=1}^{I} HI1(I,1) + HI1(I,2)] \quad \text{. . . . (Eqn. 7-2)}$$

where:

I = Hazard number ($1 \leq I \leq 15$)

J = Improvement alternative ($2 \leq J \leq 5$)

HI1(I,1) = Encroachment from inventory traffic lanes (existing hazard)

HI1(I,2) = Encroachment from opposing traffic lanes (existing hazard)

The hazard-index for a group of hazards after making improvements is expressed as:

$$(HIA)_J = \sum_{I=1}^{I} [HI2(I,1) + HI2(I,2)] \quad . . . . (Eqn. 7-3)$$

where:

I = Hazard number $(1 \leq I \leq 15)$

J = Improvement alternative $(2 \leq J \leq 5)$

HI2(I,1) = Encroachment from inventory traffic lanes (improved hazard)

HI2(I,2) = Encroachment from opposing traffic lanes (improved hazard)

The hazard-index is dependent upon the conditions of: (a) encroachment frequency, (b) severity-index, (c) hazard lateral offset, (d) hazard dimensions of length and width, (e) vehicle width, and (f) critical or non-critical slope. Referring to Figure 7-1, the hazard index is expressed as:

$$HI(I,i) = \frac{E_f S}{10560} \left\{ \ell P[y] + d \csc\theta \; P[y + \frac{d}{2}] + \frac{w \cot\theta}{n} \sum_{j=1}^{n} P[y + d + \frac{w(2j-1)}{2n}] \right\} \quad . . (Eqn. 7-4)$$

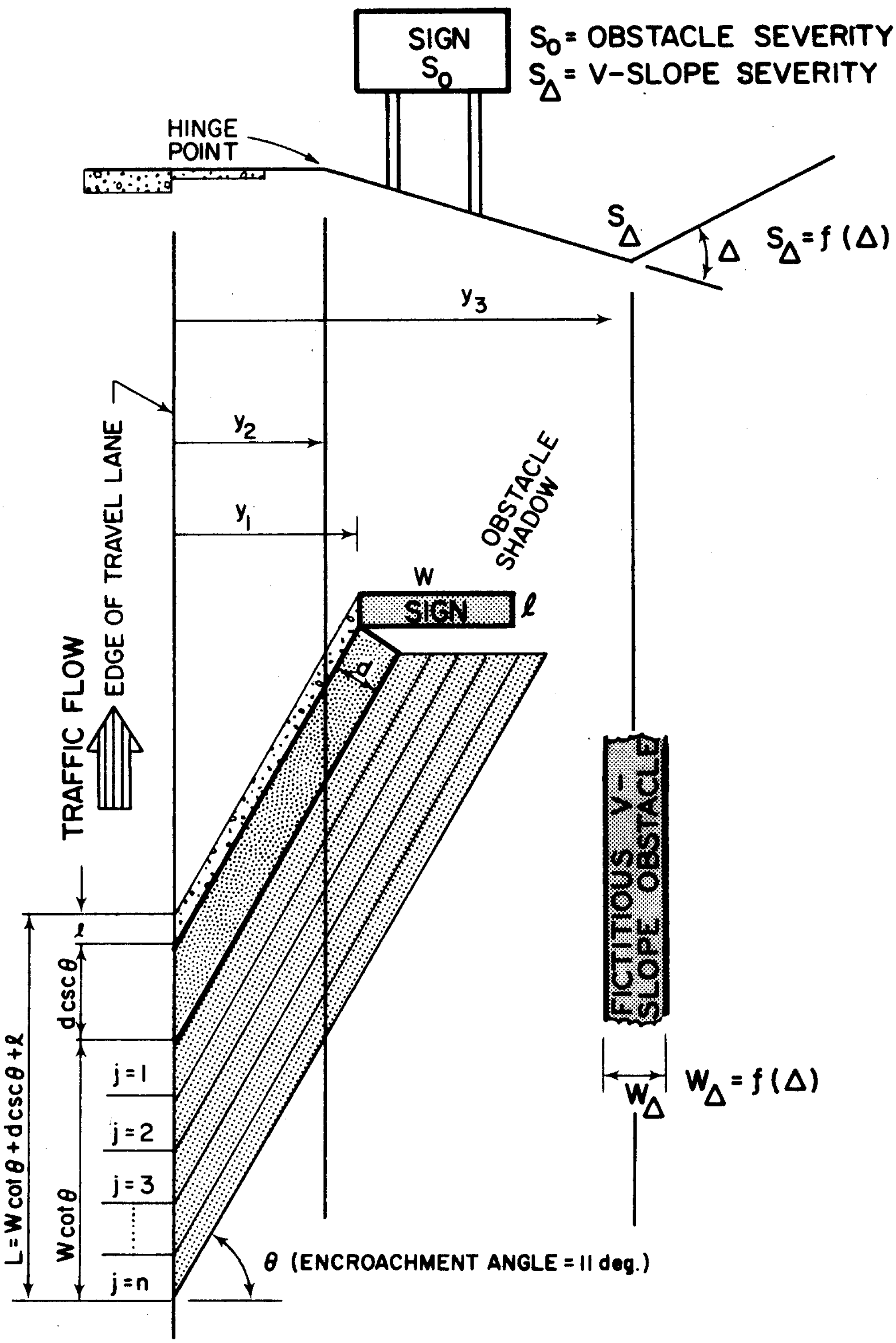


Figure 7-1. Determination of hazard index. (1)

where:

HI = Hazard-index. Number of injury (fatal or non-fatal) accidents per year associated with one-directional roadway. For medians the hazard-index is computed for each roadway separately, and the two values are added.

E_f = Encroachment frequency. Number of roadside encroachments per mile per year. Frequency computed from curve in Figure 2 in reference (1) for various ADT's.

= EF···computer name.

S = Severity-index. Indices obtained from an adjustment of THD survey. For slopes and ditches, however, the indices were obtained from a table incorporating the change-in-angle between front and back slopes. Refer to subroutines VDITCH and WASOUT.

= SI(I,J)···computer name.

ℓ = Longitudinal length of hazard.

= HLENG(I,J)···computer name (Figure 7-2).

W = Lateral width of hazard. Slopes assigned a fictitious hazard width in subroutine VDITCH.

= HWID(I,J)···computer name (Figure 7-2).

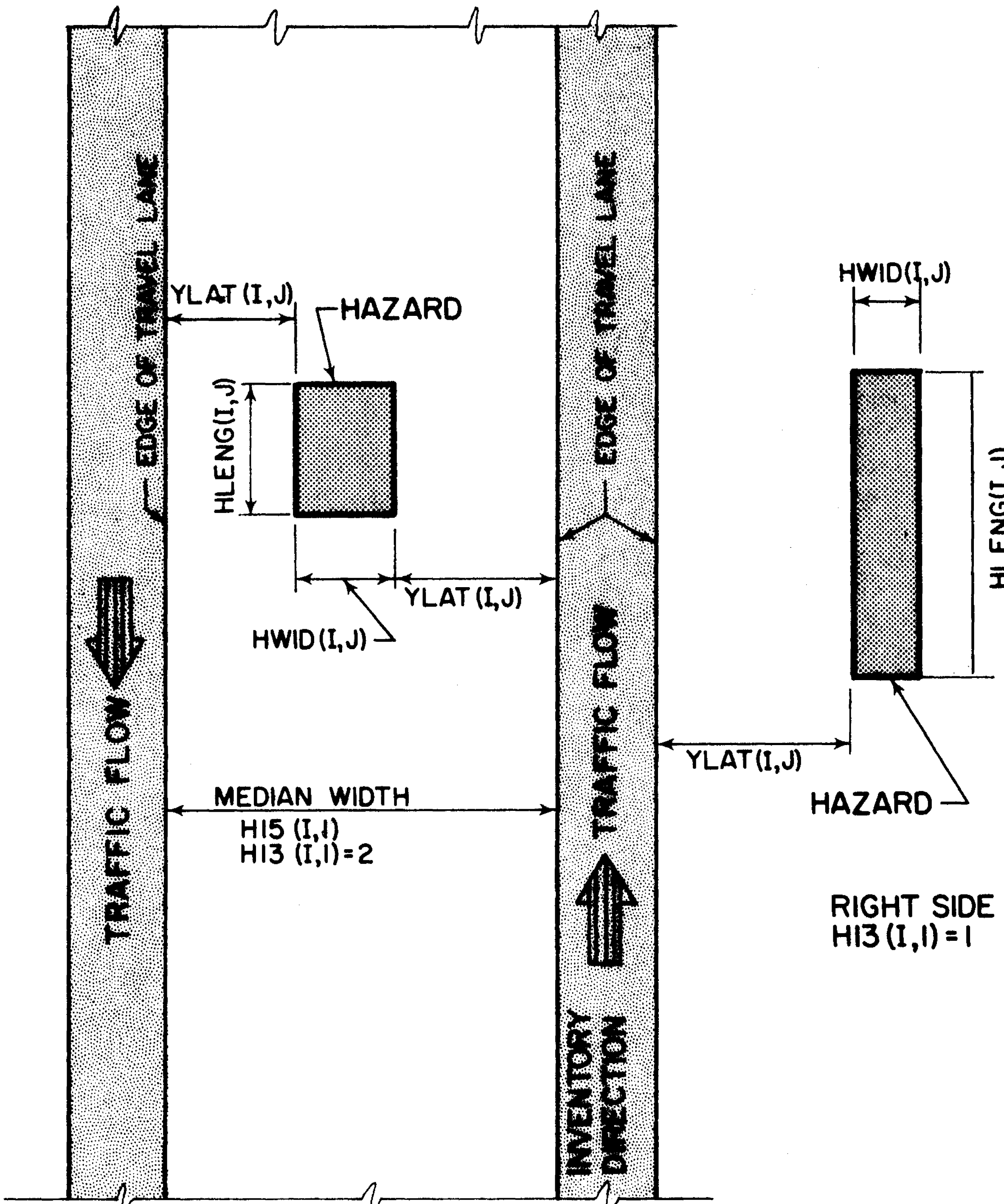
y = Lateral offset distance to hazard measured from roadway edge.

= YLAT(I,J)···computer name (Figure 7-2).

P = Probability of vehicle lateral movement greater than some value. Probability computed from curve in Figure 4 of Reference (1).

n = Number of increments in which hazard width is subdivided. One increment for each 2.5 feet of width (Figure 7-1).

j = Hazard width increment starting consecutively with J=1 at increment furthest downstream (Figure 7-1).



NOTE: IF HAZARD ON CRITICAL SLOPE, THEN YLAT(I,J) IS SET EQUAL TO HINGE POINT LATERAL OFFSET.

Figure 7-2. Computer variables--Hazard index.

8. SUBROUTINE DESCRIPTIONS

The computer program, to be comprehensive and responsive to the extremely large number of possible alternatives, is composed of thirty-nine subroutines and a MAIN program. This technique permits considerable flexibility in program modifications or additions and greatly reduces "de-bugging" effort.

Table 8-1 presents a description of each subroutine function. Table 8-2 provides a cross-reference listing of all subroutines and the MAIN program. Presented in Table 8-3 are descriptions of the major computer variables used in each subroutine and in the MAIN program.

TABLE 8-1

LIST OF SUBROUTINES

Number	Subroutine Name	Description of Subroutine
1	SLIST	Listing of subroutines.
2	HWY	Subroutine contains description of highway (type and classification).
3	DIST	Subroutine reads and stores information on the relationship between county and district numbers.
4	ERROR	Subroutine contains error or flag messages that are built into the computer program.
5	SEVRTY	Subroutine to read and store severity-indices obtained from THD. These indices are adjusted to take into consideration the higher damage costs associated with fixed hazards such as a bridge pier.
6	ADJUST	Subroutine to adjust severity indices calculated in subroutine VDITCH
7	INVTRY	Subroutine reads and stores hazard and improvement data obtained in field. Maximum number of hazards per group is 15. Maximum number of improvement alternatives per hazard is 4.
8	ORDER1	Subroutine to re-arrange the hazards in ascending order based on lateral offset distance from edge of travelled lane.
9	ORDER2	Subroutine to rearrange hazards longitudinally to define beginning and end boundaries of a group of point hazards for protection by single G.R. or hazard groups of successive bridges
10	CONST1	Subroutine to compute constant values.

TABLE 8-1, CONTINUED

Number	Subroutine Name	Description of Subroutine
11	HAZARD	Subroutine calls up the appropriate primary subroutine for one of the three defined type hazards (point, longitudinal, and slope). Except for several special cases, the severity-indices for the hazard are obtained from storage arrays.
12	PTHAZ	Point hazard subroutine. (Primary subroutine)
13	LGHAZ	Longitudinal hazard subroutine (primary subroutine).
14	SLHAZ	Slope hazard subroutine (primary subroutine).
15	CMBPT	Point hazard improvement subroutine. Protect hazard with concrete median barrier (CMB).
16	SOFT	Point hazard improvement subroutine. Protect hazard with energy attenuation system.
17	ZERO	Point hazard improvement subroutine. Alleviate hazard. Severity-index assumed to be equal to a value of zero.
18	RAIL	Longitudinal hazard improvement subroutine where guardrail is used.
19	RAIL1	Longitudinal hazard improvement subroutine. Remove existing guardrail.
20	RAIL2	Longitudinal hazard improvement subroutine. (1) Upgrade guardrail to full safety standards, or (2) Upgrade guardrail to full safety standards and close-up gap, or (3) Close-up gap between existing guardrail or (4) Safety treat guardrail, free-end only.
21	RAIL6	Longitudinal hazard improvement subroutine. Anchor existing guardrail to bridge structure.

TABLE 8-1, CONTINUED

Number	Subroutine Name	Description of Subroutine
22	PTRAIL	Point hazard improvement subroutine. Protect hazard with guardrail. Hazard not on critical slope (3.5 to 1 or steeper). Guardrail length needed based on THD criteria.
23	DTRAIL	Subroutine to install guardrail to protect a washout or runoff ditch only.
24	SLRAIL	Longitudinal hazard improvement subroutine. Install guardrail to protect slope not at bridge--may include point hazards.
25	CURB	Longitudinal hazard improvement subroutine -- curbs.
26	BRIDGE	Longitudinal hazard improvement subroutine -- bridgerail.
27	BRGR	Longitudinal hazard improvement subroutine. Install guardrail at bridge approach, or install guardrail departing bridge.
28	BRGR1	Subroutine used to place guardrail between successive bridges in line. Program permits up to 5 bridges in one group.
29	SLOPE1	Subroutine to compute geometric properties of slopes such as the horizontal offset distances and slope angles.
30	VDITCH	Subroutine to calculate the severity index, SI, for the V-DITCH or intersection of the front and back slopes located within 30 feet of the traveled way. In addition, the width, W, of the imaginary longitudinal hazard is assigned.
31	DITCH	Longitudinal hazard improvement subroutine -- ditches.
32	WASOUT	Subroutine to compute the severity-index of a ditch or washout.

TABLE 8-1, CONTINUED

Number	Subroutine Name	Description of Subroutine
33	FLATEN	Slope hazard improvement subroutine -- flatten slopes.
34	GRAIL	Subroutine locates the position of existing guardrail. NGR = 1 no guardrail IGR = 0 no guardrail on right side of roadway or on one side of median IGR = 1 guardrail on both sides of median.
35	HINDEX	Hazard-index subroutine. Hazard-index is defined as the number of fatal or non-fatal accidents per year associated with a one directional roadway. For median analysis, the hazard-index is computed for each roadway separately, and the two measures are added. Refer to equation 3 on pages 19 and 20 in NCHRP Project 20-7, Task Order 1/1, TTI Report RF 625 (1).
36	PROB	Subroutine to compute probability of a vehicle lateral displacement greater than some offset distance. Encroachment angle equal to 11 degrees. (Figure 4 in NCHRP 20-7) (1).
37	FREQ	Subroutine to compute the encroachment frequency expressed as the number of roadside encroachments per mile per year. (Figure 2 in NCHRP 20-7) (1).
38	COSTS	Subroutine to compute annualized costs taking into consideration (1) first costs of improvement, (2) normal maintenance costs of hazard and improvement, and (3) repair costs of hazard and improvement following a collision. Compound interest is used with an assumed interest rate of 8 percent and a 20 year life. Refer to the equation on pages 49 and 50 in NCHRP Project 20-7, Task Order 1/1, TTI Report RF 625 (1).
39	OUTPUT	Subroutine to print the output from the computer program.

TABLE 8-2

CROSS-REFERENCE LISTING OF SUBROUTINES

Subroutine Name	Called In	Calls For
*MAIN	---	OUTPUT SLIST DIST ERROR SEVRTY INVTRY ORDER1 HAZARD HWY
1. SLIST	*MAIN	---
2. HWY	*MAIN	---
3. DIST	*MAIN	---
4. ERROR	*MAIN	---
5. SEVRTY	*MAIN	---
6. ADJUST	SLHAZ WASOUT FLATEN	---
7. INVTRY	*MAIN	---
8. ORDER1	*MAIN	SLOPE1
9. ORDER2	PTRAIL BRGR BRGR1	---
10. CONST1	PTRAIL SLHAZ SLOPE1 HINDEX	---
11. HAZARD	*MAIN	PTHAZ LGHAZ SLHAZ

*The MAIN Program is not a Subroutine

TABLE 8-2, CONTINUED

Subroutine Name	Called In	Calls For
12. PTHAZ	HAZARD	SLOPE1
		HINDEX
		COSTS
		ZERO
		PTRAIL
		CMBPT
		SOFT
		GRAIL
13. LGHAZ	HAZARD	WASOUT
		SLOPE1
		HINDEX
		COSTS
		CURB
		BRIDGE
		RAIL
		DITCH
		GRAIL
14. SLHAZ	HAZARD	CONST1
		SLOPE1
		VDITCH
		HINDEX
		COSTS
		FLATEN
		ADJUST
		BRGR
		SLRAIL
		BRGR1
		GRAIL
15. CMBPT	PTHAZ	HINDEX
		COSTS
		GRAIL
16. SOFT	PTHAZ	HINDEX
		COSTS
		GRAIL
17. ZERO	PTHAZ	GRAIL
18. RAIL	LGHAZ	RAIL1
		RAIL2
		RAIL6

TABLE 8-2, CONTINUED

Subroutine Name	Called In	Calls For
19. RAIL1	RAIL	COSTS GRAIL
20. RAIL2	RAIL	GRAIL HINDEX COSTS
21. RAIL6	RAIL	HINDEX COSTS
22. PTRAIL	PTHAZ	HINDEX CONST1 COSTS ORDER2
23. DTRAIL	DITCH	GRAIL HINDEX COSTS
24. SLRAIL	SLHAZ	GRAIL HINDEX COSTS
25. CURB	LGHAZ	HINDEX COSTS
26. BRIDGE	LGHAZ	HINDEX COSTS
27. BRGR	SLHAZ	HINDEX COSTS ORDER2
28. BRGR1	SLHAZ	ORDER2 HINDEX COSTS
29. SLOPE1	ORDER1 PTHAZ LGHAZ SLHAZ FLATEN	CONST1

TABLE 8-2, CONTINUED

Subroutine Name	Called In	Calls For
30. VDITCH	SLHAZ FLATEN WASOUT	---
31. DITCH	LGHAZ	COSTS GRAIL DTRAIL
32. WASOUT	LGHAZ	VDITCH ADJUST
33. FLATEN	SLHAZ	SLOPE1 VDITCH HINDEX COSTS GRAIL ADJUST
34. GRAIL	ZERO RAIL1 RAIL2 DITCH FLATEN PTHAZ LGHAZ SLHAZ CMBPT SOFT SLRAIL	---
35. HINDEX	PTHAZ PTRAIL CMBPT SOFT LGHAZ RAIL2 RAIL6 CURB BRIDGE SLHAZ FLATEN SLRAIL BRGR	CONST1 FREQ PROB

TABLE 8-2, CONTINUED

Subroutine Name	Called In	Calls For
36. PROB	HINDEX	---
37. FREQ	HINDEX	---
38. COSTS	PTHAZ PTRAIL CMBPT SOFT LGHAZ RAIL1 RAIL2 BRGR RAIL6 CURB BRIDGE DITCH SLHAZ FLATEN BRGR1 SLRAIL	---
39. OUTPUT	*MAIN	---

TABLE 8-3

SUBROUTINE COMPUTER VARIABLE NAMES

MAIN PROGRAM

LC1=1	Variable to be used in a subsequent subroutine
LIST=0	Kicker for command to print title and heading paragraph
LIST=1	Skip previous command
MESAGE=0	Initialize message counters
MES=0	Initialize message counters
LP1	Variable to be used in a subsequent subroutine
MESI=0	Initialize variables for use in a subsequent subroutine
IPRINT=0	Initialize variables for use in a subsequent subroutine
UPAY=0.0	Initialize variables for use in a subsequent subroutine
PSUM=0.0	Initialize variables for use in a subsequent subroutine
HIB=0.0	Initialize variables for use in a subsequent subroutine
HIA=0.0	Initialize variables for use in a subsequent subroutine
IGAP=0	Initialize variables for use in a subsequent subroutine
MGR=0	Initialize variables for use in a subsequent subroutine
ICRSL=0	Initialize variables for use in a subsequent subroutine
IPRINT=2	Initialize variables for use in a subsequent subroutine
MESAGE=100	Decision code kicker to print error message no. 23
MES=1 to 36	Flag to indicate which message is to be printed in the output
IPRINT	Decision code to alternate format used in the output to show "Group" and "End of Group" (IPRINT=0,1,2)
NCONTR	Roadway Identification NCONTR=0 -- Fully controlled access roadway or non-controlled access roadway from first of two directions of impact

TABLE 8-3, CONTINUED

MAIN PROGRAM (Continued)

	NCONTR=1 -- Non-controlled access roadway from second of two directions of impact
HIB	Total sum of the incremental values of the hazard index before the proposed improvement is implemented
HIA	Total sum of the incremental values of the hazard index after the proposed improvement has been implemented
HI1(I,1)	Incremental value of the hazard index before due to a possible hit from the inventory direction
HI1(I,2)	Incremental value of the hazard index before due to a possible hit from the opposing direction
HI2(I,1)	Incremental value of the hazard index after due to a possible hit from the inventory direction
HI2(I,2)	Incremental value of the hazard index after due to a possible hit from the opposing direction

Subroutine SLIST

NSUB	Total number of subroutines
NAME(40,2)	Alpha-numeric array consisting of the names of subroutines used in the program
K	Key to signal the start of a subroutine description
IDESC(40,19)	Alpha-numeric array consisting of the descriptions of the subroutines used in the program
J	Key to signal the completion of a subroutine description

Subroutine HWY

TYPE(L,M)	Alpha-numeric array of highway type
CLASS(L,M)	Alpha-numeric array of highway classification
L	Counter
M	Counter

Subroutine DIST

IDSIT(255)	Integer array for information on the relationship between county and district numbers

TABLE 8-3, CONTINUED

Subroutine DIST (Continued)

I	Counter

Subroutine ERROR

NMES	Number of messages built into the program for purposes of flagging errors to its users
NAME(40,4)	Alpha-numeric array consisting of the names of the subroutine in which all corresponding errors were detected
MG(40,20)	Alpha-numeric array consisting of the messages to be listed in the output for each detected error

Subroutine SEVRTY

J=0	Initialize severity indices array variables
K=0	Initialize severity indices array variables
L=0	Initialize severity indices array variables
IJ=1	Unity variables for those values sought from the array that are less than four-dimensional
IK=1	Unity variables for those values sought from the array that are less than four-dimensional
IL=1	Unity variables for those values sought from the array that are less than four-dimensional
JJ	Number of hazard descriptor codes associated with a given identification code
S(13,7,4)	Four-dimensional array consisting of the severity indices corresponding to all hazards as obtained from the THD and as adjusted
X	Temporary variable for adjusted severity-indices
J	Value of hazard descriptor code to be used in array computations
K	Value of the beginning end treatment code to be used in array computations
L	Value of the ending end treatment code to be used in array computations
I	Hazard identification code variable (I=1 to 13) (I=01 ... Utility poles) (I=02 ... Trees) (I=03 ... Rigid signpost) (I=04 ... Rigid base luminaire support) (I=05 ... Curbs) (I=06 ... Guardrail or median barrier) (I=07 ... Roadside slope)

TABLE 8-3, CONTINUED

Subroutine SEVRTY (Continued)

I	(I=08 ... Ditch) (I=09 ... Culverts) (I=10 ... Inlets) (I=11 ... Roadway under bridge structure) (I=12 ... Roadway over bridge structure) (I=13 ... Retaining wall)

Subroutine ADJUST

SD	Temporary factor equal to the severity index to be used to transfer through common block "HDITCH"
SDA	Adjusted severity index from that calculated in subroutine "VDITCH"

Subroutine INVTRY

H1(15,1) through H44(15,1)	Input variables--see names of variables from hazard inventory form
C1(15,5) through C49(15,5)	Input variables--see names of variables from hazard improvements form
I	Hazard number within a group
J	Improvement alternative number acting upon a group
NH	Total number of hazards counted as being associated with a given group
X80	Input data indicator (X80=1 ... Indicates the end of the data associated with one hazard within a group of hazards) (X80=2 ... Indicates the end of the data associated with single hazard or a group of hazards) (X80=3 ... Indicates the end of all data to be evaluated and end of program)
LP1	Number of hazards within a group
NC(I)	An array to store the number count of the alternative improvements
X(79)	Array to store all information to be found in the first 79 spaces of each input card as raw data

TABLE 8-3, CONTINUED

Subroutine ORDER1

NCOUNT(15)=1	Temporary variable for value or hazard classification
IH19	Temporary variable for value or hazard classification
HOFF(15,1)	Offset to each hazard as determined from equations in program (HOFF(N,1) ... Offset of the hazard presently being evaluated in the program) (HOFF(K,1) ... Offset of the next hazard in a numerical order by milepost)
TEMP	Temporary storage variable for the transferred value of HOFF(N,1) to exchange positions with HOFF(K,1)
MM(-)	Storage array for hazard numbers with respect to a numerical order by milepost
ITEMP	Temporary storage variable for MM array during reordering process with respect to offset distance
A1(- , -) through A44(- , -)	Temporary storage arrays for H1(- , -) through H44 (- , -) during reordering process with respect to offset distance
B1(- , -) through B49(- , -)	Temporary storage arrays for C1(- , -) through C49 (- , -) during reordering process with respect to offset distance
LP1	Number of alternative improvements offered for a hazard or group hazard

Subroutine ORDER2

MM(-)	Array of hazard numbers to be rearranged in longitudinal order
IH6	Equal to H6
ITEMP	Temporary storage variable for MM array value during reordering process with respect to longitudinal position
II	Hazard number of first "longitudinal" hazard to be protected by a single length of guardrail
JJ	Hazard number of last "longitudinal" hazard to be protected by a single length of guardrail
HLGTH	Total length of combined hazard to be protected by guardrail

TABLE 8-3, CONTINUED

Subroutine HAZARD

NC(15)	An array to store all of the values of the counts of alternatives corresponding to each hazard within a group
I1	Dimensioning variables for the 4-dimensional severity-indices array
I2	Dimensioning variables for the 4-dimensional severity-indices array
I3	Dimensioning variables for the 4-dimensional severity-indices array
I4	Dimensioning variables for the 4-dimensional severity-indices array
SI(15)	Severity number for each hazard in data group (SI(I) = S(I1, I2, I3, I4)/10)
SI1(15,1)	Revised severity number

Subroutine PTHAZ

HWID(- , -)	An array for the widths of the hazards measured perpendicular to the edge of the travel lane
HLENG(- , -)	An array for the lengths of the hazards measured parallel to the edge of the travel lane
YLAT1	Lateral offset from the inventory roadway
YLAT2	Lateral offset from the opposing direction roadway
IRAIL	Flag to check for branching to subroutine RAIL5 for installation of guardrail to protect slope not a bridge
ISL	Kicker to detect the presence of a slope within the group (ISL=0 ... Slope present) (ISL=1 ... No Slope)
ISLP1	Kicker to detect the location of the point hazard (ISLP1=1 ... Not on a critical slope) (ISLP1=2 ... On a critical slope)
ISLOPE	
YLAT(- , -)	Lateral offset of the point hazard from the inventory roadway on the right side
YLAT1(- , -)	Lateral offset of a point hazard within the median from the near side
YLAT2(- , -)	Lateral offset of a point hazard within the median from the far side

TABLE 8-3, CONTINUED

Subroutine LGHAZ

BREND	Coefficient for the hazard index of a bridge to adjust for the existance of protective guard-rail for the bridge end assumed to be a 40% reduction from open bridge end.
LL=1	Initialize subscript value corresponding to a hazard
NOSL=0	Initialize flag
YLAT1=0.0	Initialize an offset distance
YLAT2=0.0	Initialize an offset distance
L	Counter used to determine the hazard number ("I" value) within the reordered group of various specific types of hazards.
OFFSET	Average offset from the roadway to the longitudinal hazard
WD	Actual width of a washout ditch either parallel or perpendicular (WD=3.0 ... Those perpendicular ditches narrower than the minimum recording of mile-post (0.001 mile) are approximated to be 3.0 ft wide)
DT	Lateral offset to a ditch to be used in Subroutine DITCH
DTL	Longitudinal distance parallel to the roadway of a washout ditch (to be used in Subroutine DITCH)
FSDIR	Front slope direction
FSOFF	Front slope offset
BSSTP	Back slope steepness
FSSTP	Front Slope steepness
HLENG	Absolute value of (end milepoint - beginning mile-point)
HWID	Width of longitudinal hazard
NOSL=1	No slope hazard of any kind in group
ISLOPE=1	No "critical" slope in group
ISLOPE=2	Critical slope exists in hazard grouping
ASSUMPTION	For those perpendicular washout ditches with lon-gitudinal lengths less than 0.001 miles (5 ft), the longitudinal length is assumed to be 3.0 ft.
ISLP1=1	Non-critical front slope
ISLP1=2	Critical front slope
ISLP2=1	Non-critical back slope
ISLP2=2	Critical back slope
ASSUMPTION	The minimum length of a perpendicular ditch is 3.0' The minimum length of a parallel ditch is 6.0 ft

TABLE 8-3, CONTINUED

Subroutine SLHAZ

LL=1	Subscript value indicating hazard as it exists
HLSL	Length of the slope as inventoried in the field
CORNER	Increment of the shadowing effect of the corner of an obstacle as developed in the NCHRP report by J.C. Glennon
K=I	Subscript variable necessary in subroutine SLOPE1
FSERS	Front slope erosion code (FSERS=1 ... Slight or none) (FSERS=2 ... Severe)
SIF=1.2	Erosion factor to increase the severity of the "V" ditch by 20%
HLGTH=0.0	Initialize variable
SHLGT	Length of the slope "V" hazard that cannot be reached due to a single point hazard obstacle shadowing a portion of the "V"
HLGTH	Total shadowing effect of all obstacles within the group
NH	Total number of hazards in the group
FSSTP	Front slope steepness
ISLOPE=1	No critical slope
ISLOPE=2	Critical slope exists
BSERS	Back slope erosion code (BSERS=1 ... Slight or none) (BSERS=2 ... Severe)
SIF	Erosion factor to increase the severity of the "V" ditch by 20%
BSSTP	Back slope steepness
ISLOPE=1	No critical slope
ISLOPE=2	Critical slope exists
OFFST3	Offset to back slope hinge point from the opposing traffic roadway

Subroutine CMB

XLGTH=70.0	Assumed minimum length of the proposed concrete median barrier (35 ft. each for build-up and build-down)
HWID(I,J)=2.5	Normal construction width assumed for a CMB
SM=0.8	Severity modifier to calculate 0.8 of the severity index of a rigid continuous guardrail
C	Costs not doubled
YLAT(I,J)	Lateral offset of the proposed CMB
HLENG(I,J)	Total length of the hazard after CMB has been installed

TABLE 8-3, CONTINUED

Subroutine CMB (Continued)

SI(I)	Calculated severity index
SI2(I,J)	Revised severity index for improvement
ISLOPE=1'	No critical slope exists on front slope
OFFST4	Lateral offset from opposing direction roadway to the concrete median barrier
UPAY and PSUM	Note: Costs are not doubled for CMB since normally one installation will protect a median from both travel directions

Subroutine SOFT

SV	Assigned severity index for an energy attenuation system
ISLOPE	No critical slope exists on front slope
SI2(I,J)	Revised severity index of the improvement
OFFST4=H15(I,1) -H20(I,1)-H23 (I,1)	Distance from opposing roadway to point hazard
C7 and C11	Double costs variables for installation of dual energy attenuation systems for protection to encroachments from either direction
IGR=1	Guardrail exists on both sides of hazard

Subroutine ZERO

NGR=1	No existing guardrail in inventoried group
IGR=0	Guardrail does not exist on both sides of median
K1	The value of the reordered hazard number corresponding to the first section of guardrail on the near side when guardrail is present on both sides of median
K2	The value of the reordered hazard number corresponding to the first section of guardrail on the near side when guardrail is present on both sides of median
K	The value of the reordered hazard number corresponding to the first section of guardrail on a single side of roadway

TABLE 8-3, CONTINUED

Subroutine RAIL

IC20	Temporary non-array variable for guardrail improvement alternatives

Subroutine RAIL1

SI(I)=1.0	Fictitious severity index for guardrails that have been removed (for computations)
SI2(I,J)=0.0	Real value of the severity-index for the removed guardrail
N	The inventory number of the guardrail within the median on the near side within the reordered group
IGR=1	Guardrail on both sides of median
IRAIL1	Counter for the number of sections of guardrail within a group that are proposed to be removed
ASSUMPTION	When guardrail is to be removed from one of the two sides, all sections of guardrail on a common side must be removed
KK1	Number of sections of guardrail on near side of median (from GRAIL)
KK2	Number of sections of guardrail on far side of median (from GRAIL)
MES=29	Not permitted to remove 1 guardrail from median side if other guardrail are not removed from same side

Subroutine RAIL2

HL1	Longitudinal hazard length in ft.
HL2	Total length of guardrail to be added to existing guardrail
HL3	Total length of guardrail to be removed from existing guardrail
YL1	Average lateral offset for guardrail hazards
M1	Variable name for the identification code subscript of the severity index array
M2	Variable name for the descriptor code subscript of the severity index array
M3	Variable name for the beginning end treatment code subscript of the severity index array
M4	Variable name for the ending end treatment code subscript of the severity index array

TABLE 8-3, CONTINUED

Subroutine RAIL2 (Continued)

KK1	Total number of sections of guardrail on the near side of median or right side of road
ISLOPE=1	No critical slope present on front slope
IGR=0	Guardrail on right side or on one side of median

Subroutine RAIL6

ISLOPE=1	No critical slope exists on front slope
M	Subscript for descriptor code of the hazard to be looked at
HWID(I,J)=1.5	Assumed width of proposed guardrail installation

Subroutine PTRAIL

KORDER	Kicker to detect the presence of all point hazards within the group and all improvements recorded as protect with guardrail (KORDER=1 ... Above is true--call subroutine ORDER2)
NNN	Counter to search throughout all the hazard numbers for their values of C12 and C13
D1	Lateral offset to the point hazard
D2	Lateral offset to the proposed near side guardrail
D3	Lateral offset to the far side of the point hazard
D4	Lateral distance proposed to separate the front side of the near side guardrail from the point hazard
ISLP1	
ISLOPE	Key for detection of critical slopes
D6	Lateral offset from the inventory roadway to the front face of the proposed far side guardrail
D7	Lateral distance between the front face of the proposed sections of guardrail on both sides of the median
D8	Lateral offset from the opposing traffic roadway to the front face of the proposed far side guardrail
D9	Lateral offset from the opposing traffic roadway to the near side of the point hazard
HL1	Length of guardrail needed in advance of a point hazard on the right side or median near side
HL2	Length of guardrail needed in advance of a point hazard on the far side of the median

TABLE 8-3, CONTINUED

Subroutine PTRAIL (Continued)

HL3	Longitudinal distance from the end of a proposed section of guardrail to the possible beginning of a shadowing effect of collisions with the backside of the guardrail on the opposite side
HL4	Length of guardrail proposed for the near side in advance of a point hazard including 25 ft. for safety end treatment
HL5	Length of guardrail proposed for the far side in advance of a point hazard including 25 ft. for safety end treatment

Subroutine DTRAIL

D1=DT	Both variables indicate the offset to a ditch hazard
DLGTH=DTL	Longitudinal distance parallel to the roadway of a ditch hazard
JGR	Proposed guardrail installation locator (JGR=0 ... Initialize JGR) (JGR=1 ... Installation on far side of median only) (JGR=2 ... Installation on right side of median near side either with or without far side installation)
ISLOPE=1	No critical slope exists on front slope
D2	Average offset of the proposed guardrail installation
D3	Offset of the far side of the ditch
D4	Average distance between the proposed guardrail and the ditch hazard
HL1	Computed length of needed protective guardrail as based on criteria developed by Paul Tutt, THD
N	Counter used as a hazard subscript to search out all other hazards that may be present behind the proposed guardrail installation
NGR=1	No existing guardrail within the hazard group
NH	Total number of hazards existing in a group
D6	Average offset to the proposed far side guardrail
D8	Average offset from the opposing direction roadway to the proposed far side guardrail
D9	Lateral distance between the near side of the hazard and the opposing roadway
HL2	Proposed needed length of guardrail installation for the side based on criteria developed by Paul Tutt, THD.

TABLE 8-3, CONTINUED

Subroutine SLRAIL

HLSL	Length of the slope hazard as inventoried in the field
N	Subscript variable to locate possible hazards within the group
NH	Total number of hazards
K=I	Subscript variable used in subroutine SLOPE1 for a hazard number of a slope
D2	Lateral offset of the proposed guardrail installation on the right side or median near side
D3	Lateral offset to the toe-of-the-slope
HL1	Computed length of right side or near side needed guardrail based on criteria developed by Paul Tutt, THD
D6	Lateral offset of the proposed far side guardrail installation
D9	Lateral distance from the opposing traffic roadway to the toe-of-the-slope
D8	Lateral distance from the opposing traffic roadway to the proposed guardrail installation
HL2	Computed length of far side needed guardrail based on criteria developed by Paul Tutt, THD

Subroutine CURB

ASSUMPTION	A wedge modified curb is assumed to have a severity index of 0.9 of that assigned to a mountable curb hazard
ISLOPE=1	No critical slope present on front slope
YLAT1	Average hazard offset for near side curb hazard

Subroutine BRIDGE

XL	Temporary hazard length in miles
IBR	Kicker to detect a change in position of the bridgerail for the proposed improvement (IBR=0 ... No change in position with the proposed position) (IBR=1 ... Position of bridgerail changed by improvement proposal of either a lateral move or a decked over gap)

TABLE 8-3, CONTINUED

Subroutine BRGR

IBR=0, IBR1=0, INST=0	Initialize variable flags
IBR	Flag to determine position of installed guardrail at a bridge site (IBR=1 ... Install either approach or departing guardrail) (IBR=2 ... Install both approach and departing guardrail)
INST	Flag indicating an improvement proposal of guardrail at a bridge (INST=1 ... Install approach guardrail) (INST=0 ... Install departing guardrail)
IBR1	Flag to indicate the progress of the program (IBR1=1 ... Install one section of guardrail at a bridge site) (IBR1=2 ... Second section of guardrail installed at departing bridge site)
N	Counter used as a hazard subscript to search out all other hazards that may be present behind the proposed guardrail installation
D1	Offset of the free-end of either the proposed approach or departing guardrail
X1	Offset of the end of the guardrail connected to the bridge of either approach or departing guardrail)
X	Lateral distance for guardrail transition (difference between offsets of the ends of the proposed guardrail)
Y	Computed length of guardrail based on THD criteria
D2	Average offset of proposed guardrail installation
ISLOPE=1	No critical slope present on front slope

Subroutine BRGR1

NBR	Number of bridge structures in line within a group
MM(N)	Temporary rearrangement of bridge structures in longitudinal direction
NN(NBR)	Longitudinal position of bridge structures in line
SLMID	Longitudinal midpoint of slopes between successive bridge structures
NCONTR=0	Fully controlled access roadway .or. non-controlled access roadway from first of two directions of impact
NCONTR=1	Non-controlled access roadway from second of two directions of impact

TABLE 8-3, CONTINUED

Subroutine SLOPE1

FSDIR	Front slope direction (FSDIR=2 ... Negative slope) (FSDIR=1 ... Positive slope)
BSDIR	BAck slope direction (BSDIR=2 ... Negative slope) (BSDIR=1 ... Positive slope)
FSERS	Front slope erosion descriptor from inventory form
BSERS	Back slope erosion descriptor from inventory form
FSSTP	Front slope steepness
BSSTP	Back slope steepness
FSDIS	Slope face distance for front slope
BSDIS	Slope face distance for back slope
OFFST1	Lateral offset to hinge point of front slope
FSANG	Slope angle at front slope hinge point
BSANG	Slope angle at back slope hinge point
DELTA	Angle between the front and back slopes
FSOFF	Lateral offset to the "V" between the front and back slopes
OFFST2	Lateral offset to the hinge point of the back slope

Subroutine VDITCH

SI	Factor to be used to proportion the severity index of a V-ditch based on intersection of the front and back slopes (SI=0,80 ... Maximum assigned factor)
FSDIR	Front slope direction
FSSTP	Front slope steepness
DELTA	Angle formed between the front and back slope
FSOFF	Lateral offset to hinge point of front slope
W	Width of the imaginary longitudinal hazard associated with the V-ditch
SD	Factor equal to SI to be sent through common block "HDITCH"

TABLE 8-3, CONTINUED

Subroutine DITCH

NH	Total number of hazards
NGR	Flag from GRAIL to detect guardrail (NGR=1 ... No existing guardrail)
IGR	Flag from subroutine GRAIL to detect guardrail position (IGR=0 ... Guardrail on one side only) (IGR=1 ... Guardrail on both sides of median)
L	Value of the hazard number from the reordered group corresponding to the first section of guardrail located on the nearest side having existing guardrail
K	Value of the hazard number from the reordered group corresponding to the first section of guardrail located on the far side with existing guardrail on both sides of median

Subroutine WASOUT

Z	Temporary storage of average depth of ditch
FFSTP	Temporary storage of front slope steepness of a washout ditch as approximated
WD	Average width of the ditch
FSSTP	Front slope steepness
DELTA	Angle between the front and back slopes of the washout ditch as approximated
ASSUMPTION	The direction of the front slope of a washout ditch is always negative, therefore, FSDIR=2 and this should correspond to the coded inventory form
W	Fictitious width of obstacle to be used to determine hazard index

Subroutine FLATEN

K	Reset variable "K" equal to the appropriate hazard inventory number "I"
W	Fictitious hazard width to be used to determine hazard index
FSSTP	Front slope steepness
ISLOPE	Key used in other subroutines to check for presence of critical slopes (ISLOPE=1 ... No critical slope exists) (ISLOPE=2 ... One or more critical slopes exist)

TABLE 8-3, CONTINUED

Subroutine FLATEN (Continued)

FSOFF	Front slope offset
OFFST1	Offset one
NGR=1	No guardrail exists
BSSTP	Back slope steepness
IGR	Flag from subroutine GRAIL indicating guardrail exists within the hazard group (IGR=0 ... Guardrail exists on right side or on one side of median only) (IGR=1 ... Guardrail exists on both sides of median)
N	Temporary storage of corresponding hazard number of a section of guardrail
NSGR(1)	Hazard inventory number of the first section of guardrail that exists on the right side or median near side
FSGR(1)	Hazard index number of the first section of guard-rail that exists on the median far side

Subroutine GRAIL

N=0, L=1, IGR=0, NGR=0	Initialize variables
L	Counter for hazard inventory numbers
N	Counter for the total number of existing guardrail sections within the hazard group without differentiating by location
YDIST(—)	Array for the averages of the hazard offset of each guardrail section existing in order of their lateral offset
M(—)	Array for the hazard index numbers of each section of guardrail existing within the hazard group
NGR=1	No guardrail exists within the hazard group if and only if N=0
L=1, KK1=1, KK2=1	Initialize counters
KK1	Counter for total number of section of guardrail existing on only one side of a roadway
KK2	Counter for total number of sections of guardrail on the far side when guardrail exists on both sides of the median
D1, D2, D3	Temporary fictitious lateral offsets to determine if two numerically ordered sections of guardrail exist on the same side

TABLE 8-3, CONTINUED

Subroutine GRAIL (Continued)

ASSUMPTION	More than five feet laterally, separate sections of median guardrail
IGR	Flag indicating that at least one section of guardrail exists (IGR=0 ... Guardrail on right side of roadway or on one side of median) (IGR=1 ... Guardrail on both sides of median)

Subroutine HINDEX

NCONTR	Decision key (NCONTR=0 ... Fully controlled access roadway or non-controlled access roadway from first of two directions of impact) (NCONTR=1 ... Non-controlled access roadway from second of two directions of impact)
YLAT(- , -)	Array of lateral offsets to be used in determining hazard index
ADT	Average daily traffic
Y	Temporary storage of the lateral offset for the proposed improvement
W	Temporary storage for the width of the proposed improvement
AL	Temporary storage for the length of the proposed improvement
EF	Encroachment frequency expressed as the number of roadside encroachments per mile per year
SI(I)	Severity index of the hazard based on THD criteria
C4	Sum of the total probability of an encroachment greater than or equal to the lateral offset of the hazard and impacting a hazard with given dimensions
H	Hazard HINDEX equal to the product of the severity of an impact times the probability of an impact to a hazard of given dimension due to an encroachment with a calculated frequency

TABLE 8-3, CONTINUED

Subroutine PROB

Y	Lateral offset distance to obstacle (ft)
Y2	Square of the value of Y
Y3	Cube of the value of Y
PP	Probability of a vehicle's lateral displacement greater than some offset distance
ASSUMPTION	The angle of encroachment used to determine the probability of this event is equal to 11 degrees
ASSUMPTION	If the lateral offset distance is less than or equal to 6 ft, then the probability is 100%. If the distance proposed is greater than 44 ft, the probability is 0%.

Subroutine FREQ

ADT	Average daily traffic as determined from inventory form
EF	Encroachment frequency based on ADT of roadway expressed as the number of roadside encroachments per mile per year
NOTE	The EF is a step function of the ADT with three levels: less than 3200 ADT; 3200 to 5500 ADT; and greater than 5500 ADT

Subroutine COSTS

RI	Rate of interest as assumed in CONST1 (currently 8%)
LIFE	Life expectancy for computations of compound interest (currently 20 years as assumed in CONST1)
A1	Annual compound interest factor
A3	Interest times the compound interest
A4	Present value compound interest factor
A5	The reciprocal of A4
LL	Value of second subscript ("J" value) for hazard array
HINDEX	Hazard index
CI	Annualized maintenance repair cost for collisions with the improvement
CF	Annualized first cost for the improvement
R	Annualized total cost
P	Present value of total cost
CO	Annualized maintenance repair cost of collisions with the hazard

9. DATA INPUT-OUTPUT

DATA DECK ARRANGEMENT

Correct type, location, and amount of data on an inventory or improvement form are imperative to successful operation of the computer program. It is equally important that the data deck be correctly arranged so that an equal number of improvement alternatives are provided for each hazard within a hazard grouping.

The computer program is capable of evaluating a grouping containing a maximum of 15 hazards and 4 improvement alternatives per hazard. Four alternatives were ample in all cases during field testing; in only rare instances were more than two alternatives required.

In any hazard/improvement set, the improvement card (or cards) follows immediately behind the hazard card to which it applies. A maximum of four improvements is allowed per hazard. Particular care must be exercised in arranging the sequence of improvement cards within a grouping. The program evaluates the improvements in a prescribed sequence. For example, using Figure 9-1 to illustrate, in the grouping of 3 hazards with 2 improvement alternatives, the analysis procedure for the first improvement considers improvement alternative 1 with the first hazard, alternative 1 with the second hazard and alternative 1 with the third hazard as a single grouping evaluation. A grouping cost effectiveness is computed. The process is then repeated using improvement alternative 2 with each of the

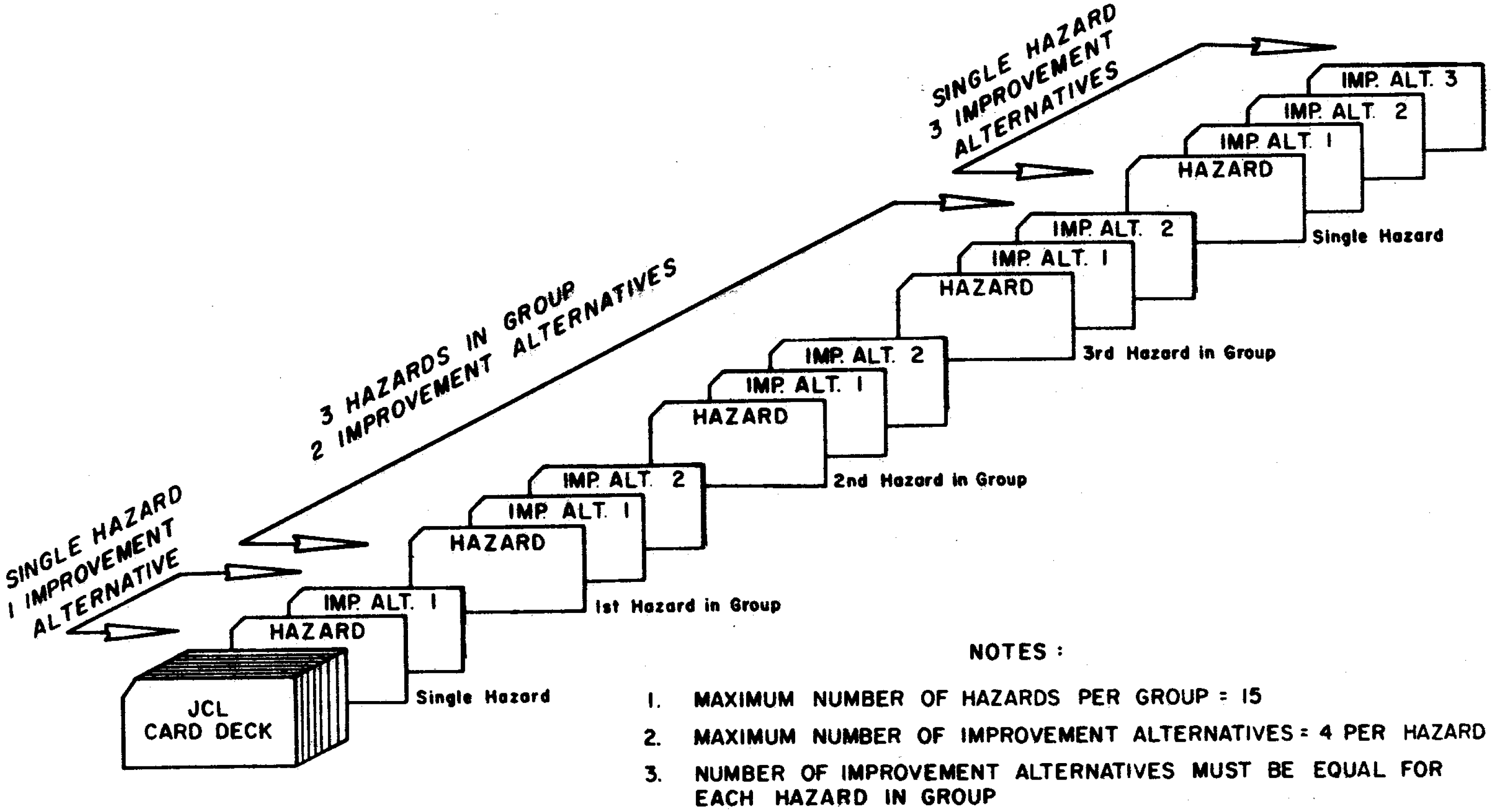


Figure 9-1. Arrangement of input data cards.

three hazards and a grouping cost-effectiveness is again computed. Therefore, compatible alternatives must be in the proper sequence throughout the grouping deck arrangement.

Since a grouping cost-effectiveness is computed in the above described manner, it should be noted that within each grouping, the same number of improvement alternatives must be specified for each hazard, even if for one hazard in the grouping, a "No Improvement" alternative is recommended. For example, if in a three-hazard grouping, two improvement alternatives are recommended, two improvement alternative cards must be inserted behind each of the three hazard inventory cards. If two improvement alternative cards were inserted for the first two hazards and only one for the third hazard, the omission error would be detected during data reading, and no computer execution would occur on either of the two improvement alternatives even though the error applied only to the second improvement alternative. An error message, therefore, would be printed on the output data and no grouping cost-effectiveness would be computed for either improvement alternative.

REMOTE TERMINAL OPERATION

The computer program is accessed from the D-19 automation computer facilities by remote terminals in each District. Control cards for remote terminal operation will be supplied each District.

10. ERROR MESSAGES

Since computer program execution is highly dependent on precise data input both in type and location, error messages have been incorporated into the program to "flag" input errors. Due to the complexity of the program and extensive branching within subroutines from several key data sources, it is expected that errors will occur. To avoid program termination (which would normally occur for each data error), the program has been developed to bypass the erroneous data, print out an error message, and continue with the next data input.

Fifty-one error messages have been incorporated. They are listed in Table 10-1. In most cases, the message is self-explanatory. Each error message is identified on the data output by reference number. The list of messages is printed out for each computer run. Also printed out is the location within the program or subroutine in which the data error affected the program execution. The message indicates the type of error and provides direction to remedy the data error. The program will automatically terminate if 100 error messages are printed during any run.

A message, "Hazard Improvement Not Cost-Effective," may appear in the data output. This is not an error message, and is not included in the 100-maximum count for automatic program termination. It indicates that the recommended improvement produces, for all intents and purposes, no safety benefit over the hazard currently

TABLE 10-1

LIST OF ERROR OR FLAG MESSAGES

Message Number	Subroutine Calling Message	Description of Message
1	HAZARD	End milepoint at hazard not specified
2	PTHAZ	Unmatched point hazard and improvement codes
3	PTHAZ	Non-existing improvement classification specified in column 41 of improvement form
4	DITCH	Non-existing ditch improvement code classification
5	RAILNG	Guardrail installation not necessary--reexamine roadway group hazard
6	HAZARD	Non-existing hazard classification specified in column 51 of inventory form
7	PTHAZ	Non-existing point hazard improvement code (column 40)
8	PTHAZ	No improvement needed, flat slopes and/or offset greater than 30 ft (right side or median near side)
9	PTRAIL	Distance between guardrail and obstacle less than 3.0 ft
10	LGHAZ	No improvement needed, flat slopes and/or offset to longitudinal hazard > 30 ft (full median)
11	CURB	Non-existing curb improvement classification specified in column 42 of improvement form
12	BRIDGE	Non-existing bridgerail improvement classification specified in column 42 of improvement form
13	BRIDGE	Non-existing bridgerail improvement classification specified in column 43 of improvement form

TABLE 10-1, CONTINUED

Message Number	Subroutine Calling Message	Description of Message
14	RAIL	Non-existing guardrail improvement classification specified in column 42 of improvement form
15	RAIL6	Guardrail end-treatment adjacent to bridge incorrectly specified
16	LGHAZ	Longitudinal hazard offset on non-critical slopes greater than 30 ft (right or median near side)
17	SLOPE1	Non-existing slope direction classification specified on inventory form
18	LGHAZ	Curb improvement valid only for curb hazard
19	ZERO, DITCH	Logic breakdown--vehicle not permitted to penetrate guardrail
20	PTHAZ	No improvement needed, flat slopes and/or offset greater than 30 ft (median inventoried across)
21	ZERO	Logic breakdown in subroutine ZERO--refer to flow charts
22	PTHAZ	Point hazard offset greater than 30 ft on right or median near side (critical slopes)
23	MAIN PROGRAM	Stop computer program -- 100 or more errors
24	HAZARD	Unmatched hazard numbers on inventory and improvement form
25	LGHAZ	Bridgerail improvement valid only for bridgerail hazard
26	LGHAZ	Guardrail improvement valid only for guardrail hazard
27	INVTRY	End of data and program

TABLE 10-1, CONTINUED

Message Number	Subroutine Calling Message	Description of Message
28	HAZARD	Unequal number of improvement alternatives per hazard in group
29	RAIL1	Not permitted to remove 1 group on median side if other group on same side is not removed
30	MAIN PROGRAM	*Hazard improvement not cost-effective*
31	HAZARD	Hazards on right side and left side of roadway cannot be grouped together
32	HAZARD	Guardrail end treatment code not specified on inventory form
33	HAZARD	Guardrail end treatment code not defined--value greater than 4.
34	HAZARD	Improvement costs not specified
35	HAZARD	Guardrail hazard repair and/or maintenance costs not specified
36	HAZARD	Guardrail improvement repair and/or maintenance costs not specified
37	LGHAZ	Longitudinal hazard offset greater than 30 ft (critical slopes) on right or median near side
38	ZERO	Logic breakdown in group consisting of point hazards and group on both sides of median
39	ZERO	Improvement not needed for existing point hazard behind existing guardrail
40	----	Reserved for future use
41	BRIDGE	Median inventoried across width allowed only for improvement codes 2 or 4 in column 43

TABLE 10-1, CONTINUED

Message Number	Subroutine Calling Message	Description of Message
42	DITCH	Ditch improvement not needed behind existing guardrail
43	LGHAZ	Ditch improvement valid only for ditch hazard
44	BRGR	Approach and departing guardrail offsets not specified in columns 44 through 51
45	LGHAZ	Non-existing improvement classification specified in column 41 of improvement form
46	DTRAIL	Median inventoried across full width but no group specified to protect far side
47	SLHAZ	Slope improvement not specified in columns 40 or 41 on improvement form
48	SLRAIL	Inventory median full width only if group also needed on far side to protect slope
49	LGHAZ	Non-existing longitudinal hazard improvement code (column 40)
50	BRGR1	Logic breakdown in placing guardrail between successive bridges
51	BRGR	Bridge approach or departing guardrail lateral offset in wrong location in Box A

existing. Under certain circumstances, it indicates that the recommended improvement in fact produces a more hazardous situation than the existing one. The message may be obtained under two circumstances as shown below.

The simplified cost-effectiveness ratio is determined by:

$$\text{Cost-Effectiveness} = \frac{\text{Cost}}{H_B - H_A}$$

where

H_A = Hazard index after improvement

H_B = Hazard index before improvement (existing)

If H_A is greater than H_B, the denominator becomes negative. This means that the recommended alternative, is in fact, more hazardous than the existing situation. Obviously, it is impractical to incur costs to produce a more critical situation than currently exists; therefore, the flag message "Hazard Improvement Not Cost-Effective" is printed out when this occurs and the cost-effectiveness ratio is not computed.

When H_A is only slightly less than H_B, the denominator becomes very small numerically, hence the cost-effectiveness ratio becomes very large. Based on statistical logic, a lower cut-off level has been incorporated into the model such that when the numerical value of $H_B - H_A$ is less than 0.02, the flag message is printed out and the cost-effectiveness ratio is not computed. The 0.02 level indicates a 55-percent probability of no hazard reduction.

The message, "No Improvements Recommended" merely indicates that for that particular hazard, the recommended safety improvement was "No Improvement Recommended" (code 4, column 40, improvement form). It is not counted as an error message for program termination.

If a data error occurs within a grouping, a group cost-effectiveness cannot be determined. Therefore, an error message will be printed out and the message, "End Group" will also appear where the grouping cost-effectiveness value would normally appear. The message "Group" denotes that the cost-effectiveness value represents a total grouping value.

11. COMPUTER PROGRAM OPERATIONAL DESCRIPTION

An overall systems flow chart depicting the operation of the cost-effectiveness model on the Texas Highway Department computer facilities is shown in Figure 11-1. Figure 11-2 presents a cross-referencing of all common statements.

Figure 11-3 illustrates table input data. The program read structure is such that the table-ordering shown must be adhered to precisely. Although interpreted as "data," the seven tables are not input with field inventory data; rather, they are incorporated in the program and called prior to execution.

Table 11-1 describes the table format for the tables shown in Figure 11-3. Strict adherence to the format, which differs for individual tables, is necessary for correct reading. The table data are read in the subroutines listed in Figure 11-3, the subroutines being called in the MAIN program.

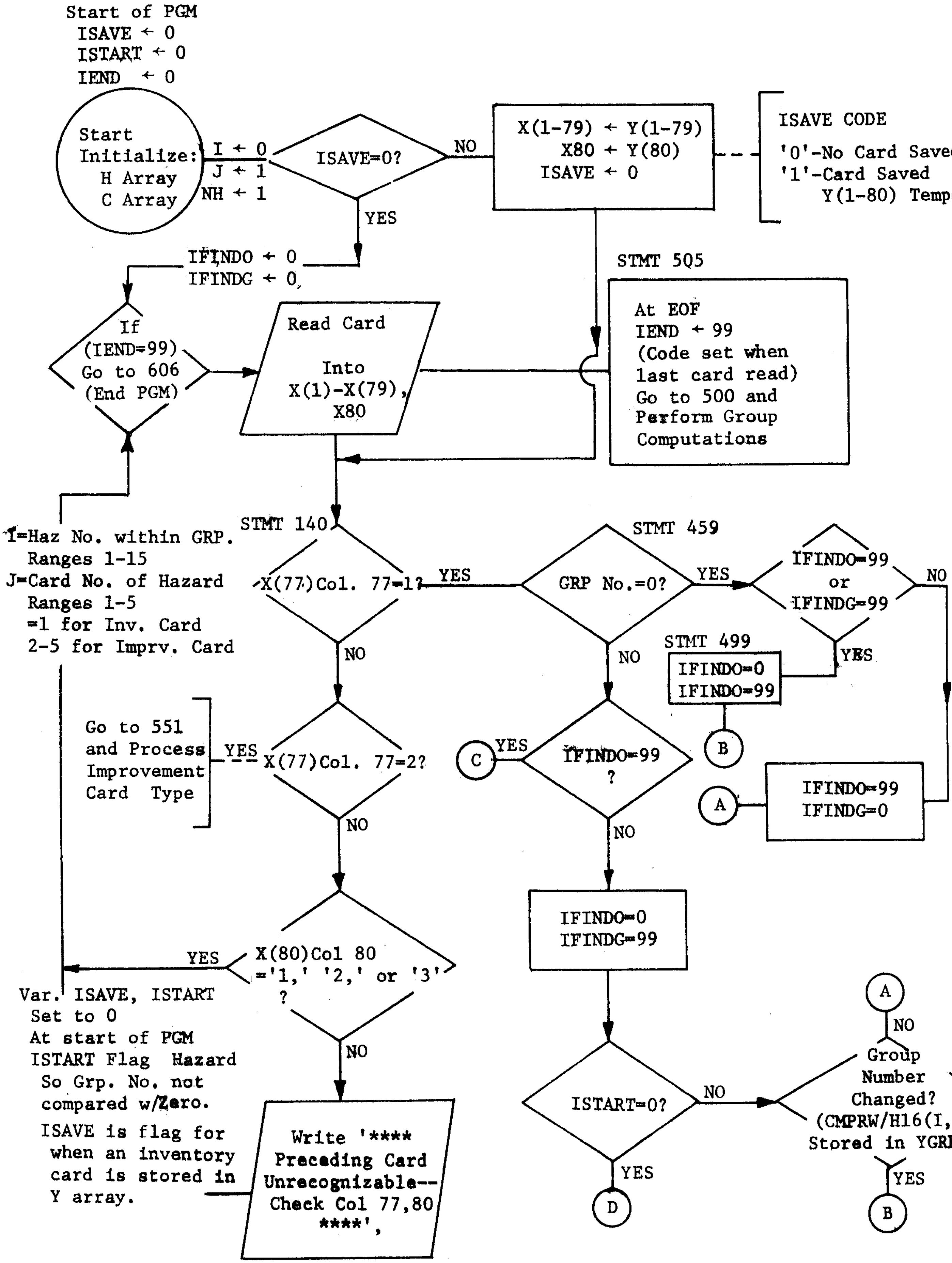
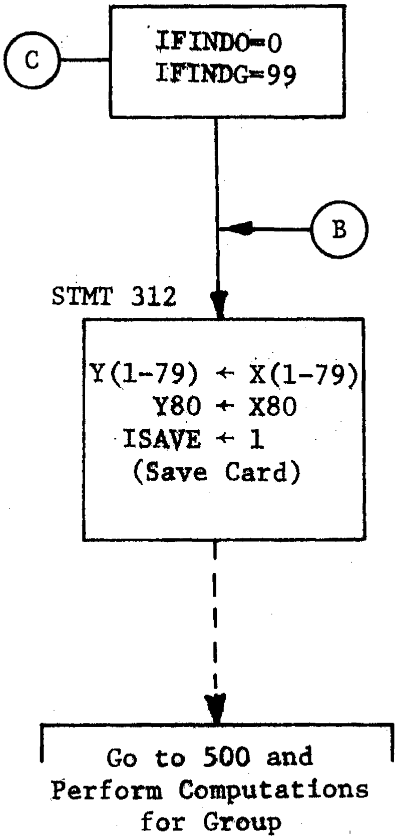
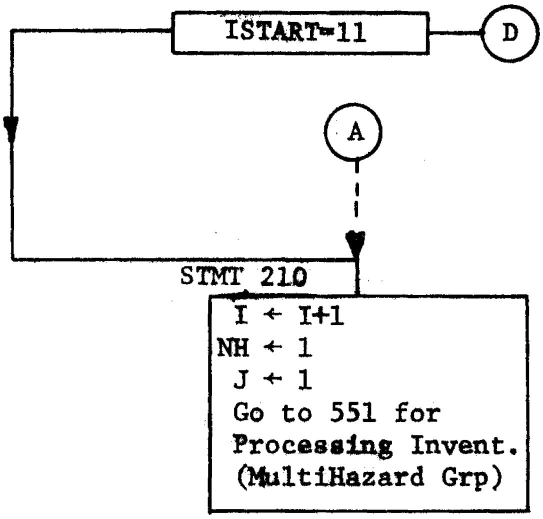


Figure 11-1. Cost-Effectiveness Computer Model Systems Flow Chart (1 of 3)





I Subscript for Invent/Improv Cards-
Set Twice: (Valid Values 1-15)

1. To '0' prior to entering routine to read data for a complete group
2. To I+1 for each successive hazard within group number

1-Haz Subs. 2-5 Imprv. Subs.

Var. 'IFINDO' - Code set to 99 When a Grp No.=0 Found (Single Haz Grp). Used to Branch to Computation & Store Inv Card for ≥2 such Haz in Succession. Set to 0 if Multi-Haz Grp.

'IFINDG' - Code set to 99 when a Grp No≠0 Found.

(J) Subscript for Hazard Number Within Grp
Set (Valid Values 1-5)

1. To '1' prior to entering routine to read data for a complete group
2. To '2' after invent. card processed
3. To J+1 after Imprv Card Processed
4. To '1' after reading another hazard with same grp no.

Figure 11-1. Cost-Effectiveness Computer Model Systems Flow Chart (2 of 3)

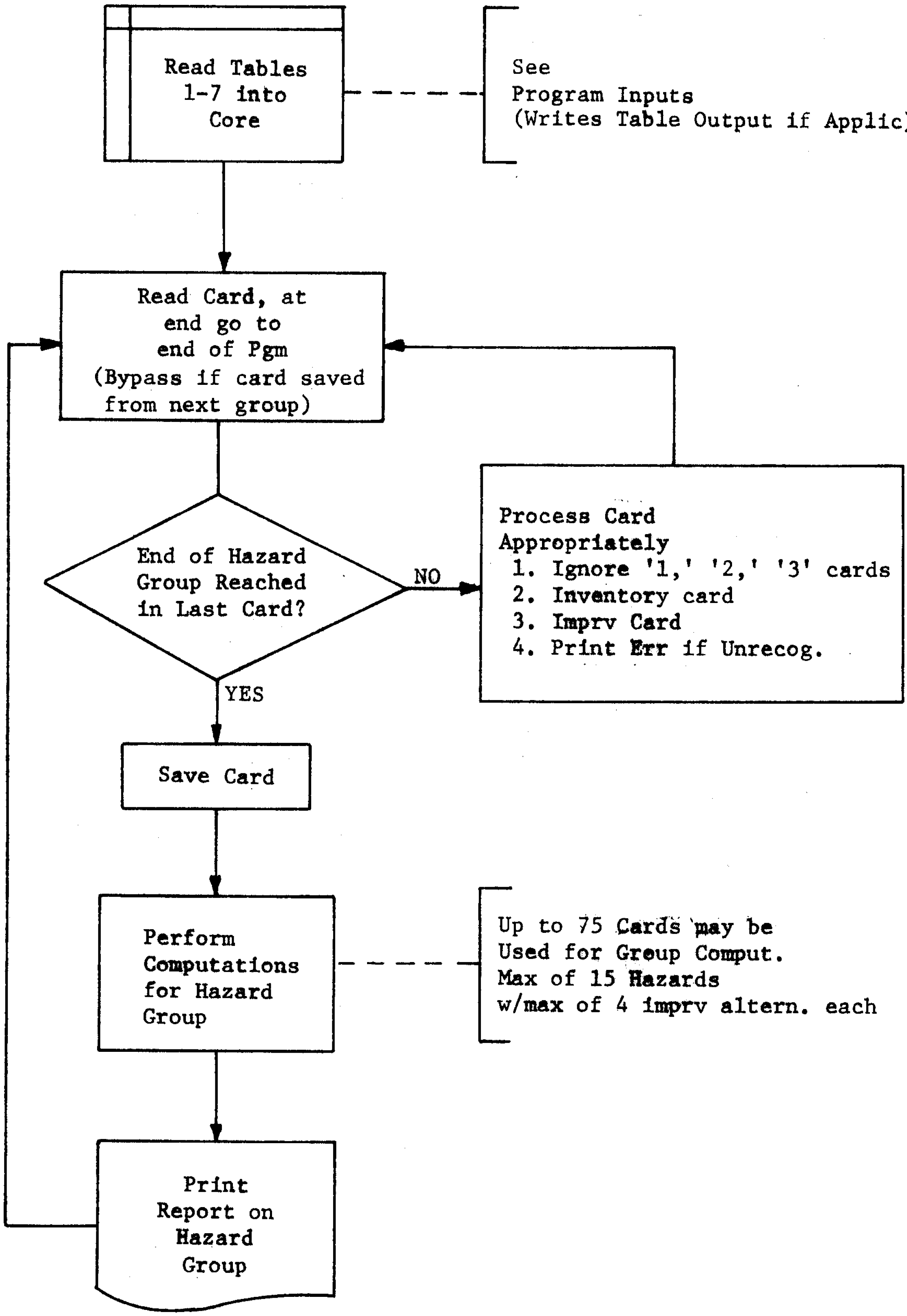
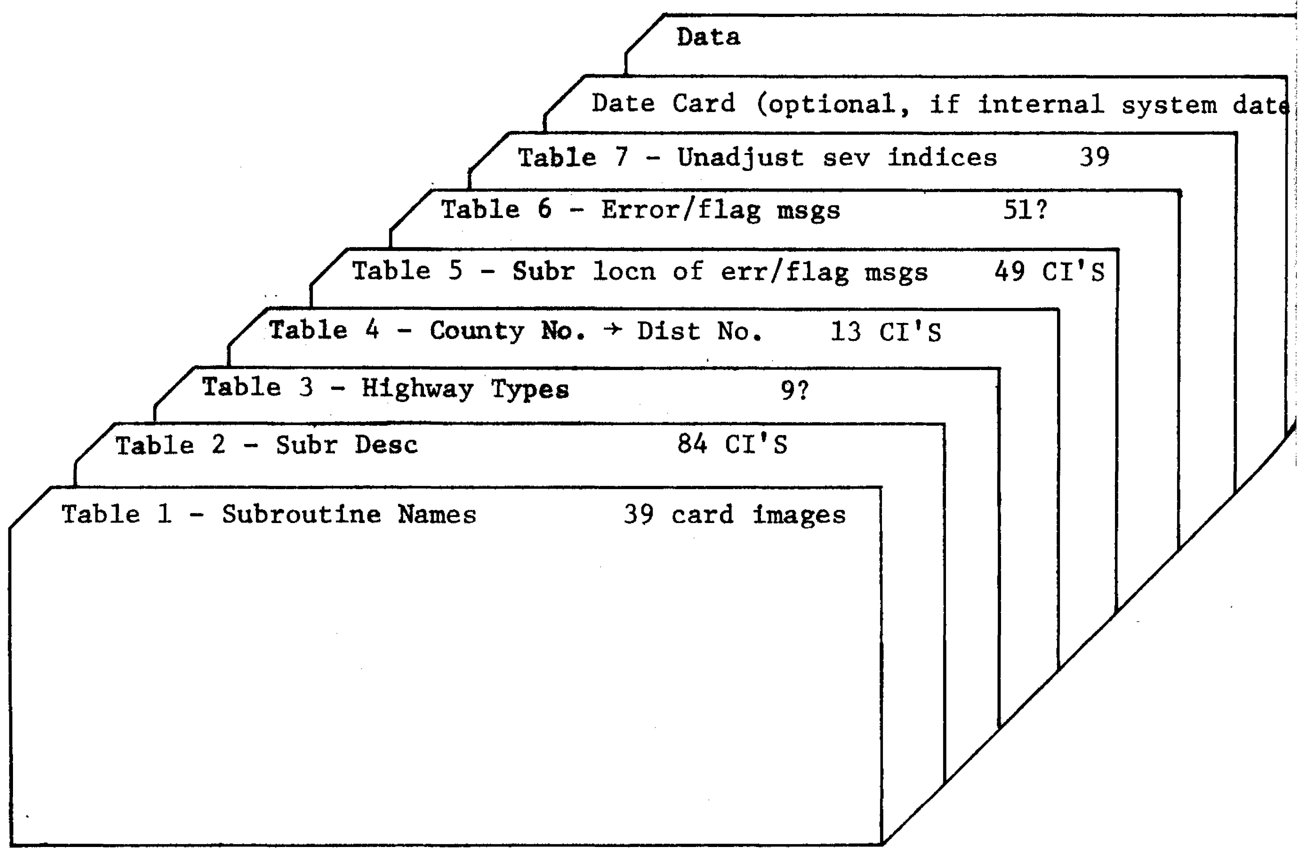


Figure 11-1. Cost-Effectiveness Computer Model Systems Flow Chart (3 of 3)

COMMON BLOCK NAME \ SUBROUTINE	MAIN	SLIST	HWY	DIST	ERROR	SEVRTY	ADJUST	INVTRY	ORDER1	ORDER2	CONST1	HAZARD	PTHAZ	LGHAZ	SLHAZ	CMBPT	SOFT	ZERO	RAIL	RAIL1	RAIL2	RAIL6	PTRAIL	DTRAIL	SLRAIL	CURB	BRIDGE	BRGR	BRGR1	SLOPE1	VDITCH	DITCH	WASOUT	FLATEN	GRAIL	HINDEX	PROB	FREQ	COSTS	OUTPUT
BRGR2										●																		●	●											
BRSLGR	●																		●																					
CINVNT	●							●	●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●					●	●
CONSNT	●										●	●	●	●	●				●				●							●						●			●	●
COUNT								●				●																												
DIST1	●			●																																				●
ERROR1	●				●																																			●
FRQNCY																																				●		●		
HASCND	●								●			●																												
HAZRDS	●											●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●			●		●		●			●	●
HDITCH							●						●	●	●																●		●	●						
HINVNT	●							●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●				●
HZINDX	●											●	●	●	●	●	●				●	●	●	●	●	●	●	●	●			●		●		●				
INFO			●																																					●
INPUTT												●																												
INVENT	●							●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●			●	●
KEYNUM													●	●	●	●	●	●	●	●	●			●	●							●		●	●					
NONHWY	●											●	●	●	●	●	●			●	●	●	●	●	●	●	●	●	●			●		●		●				●
OUTPT1	●																																							●
PROBTY																																				●	●			
PTHZGR	●									●			●	●									●																	
RAILS	●																			●																				
RDITCH													●	●	●									●																
SEVERE	●					●						●	●	●	●	●					●	●	●	●	●	●	●	●	●			●								
SIDENF	●											●	●	●	●	●	●	●	●	●	●											●		●	●					
SLOPES									●				●	●	●				●						●					●	●	●	●	●						
TITLE	●																																							●

Figure 11-2. Cross Reference of Common Statements

I. FT05F001 Card Images
(Normally //GO.SYSIN when executed from standard JCL procedure)



II. FT12F001 Card Images (If Applic) Read by
'PRINT' or 'SUPPR' - Optional Error/Flag Msgs - Subr ERROR
'PRINT' or 'SUPPR' - Optional Sever Ind. List - Subr SEVRTY

Location of Read Statements

Table	1	Subroutine SLIST
	2	SLIST
	3	HWY
	4	DIST
	5	ERROR
	6	ERROR
	7	SEVRTY
Date		MAIN
Data		INVTRY

Figure 11-3. Table Input Data

TABLE 11-1

Description of Table Input

Table 1 -- Subroutine Names

Each subroutine name is contained on a separate card beginning in column 1.

Table 2 -- Subroutine Description

The subroutine description for each subroutine contained in Table 1 is contained in consecutively arranged cards in Table 2. (The description and subroutine name must be compatible.) The lead card in Table 2 is "Listing of Subroutines." Cards are read in a 79-column alphanumeric read with as many cards as necessary to complete the description. The end card for each description must contain a 1 in column 80 to separate consecutive descriptions.

Table 3 -- Highway Types

Highway type codes are contained in Table 3. A card is included for codes from 01 to 08 in numerical order (cards 3, 4, 6, and 7 are blank cards). Cards 9 through 13 contain word descriptions of the numerical codes as follows:

Card 9: Controlled Access -- Interstate

Card 10: Controlled Access -- Non-Interstate

Card 11: Non-Controlled Access -- Two Lanes

Card 12: Non-Controlled Access -- Multilane Divided

Card 13: Non-Controlled Access -- Multilane Undivided

TABLE 11-1, CONTINUED

Table 4 -- County Number/District Number

The THD District number corresponding to increasing chronological county number are included on 13 cards in a 20I4 format. The county numbers agree with THD county reference numbers (District 26, Houston Urban is coded as County 255).

Table 5 -- Subroutine Location of Error Messages

Table 5 contains the name of the subroutine in which each error message is called, one card per subroutine name with subroutine name punched in alphanumeric beginning in column 1.

Table 6 -- Error/Flag Messages

Table 6 contains the 41 error messages, one message per card maximum. Each message must be completed within the 80 characters on a card.

Table 7 -- Unadjusted Severity Indices

Table 7 contains the unadjusted severity indices for each hazard identified in Table 2-1 (page 2-2). The severity indices for each descriptor code are contained in 10I8 format. If there is no descriptor code subcategory, the severity index applies to the complete identification code category and is contained on a single card with the one entry in columns 1 through 8. If there are several descriptor codes (example, code 03-01, 02, --- 05 as in Rigid Signpost, Table 2-2), the severity indices are contained on a single card in the 10I8 format.

12. COMPUTER PROGRAM FLOW CHARTS AND LISTING

The program contains a considerable amount of internal branching, hence the use of small package subroutines. Presented in this section are flow charts for the major decision-making subroutines. Also included is a listing of each subroutine that is not flow-charted. Descriptions of subroutine functions and computer variable names for each subroutine are presented in section 8 of this report.

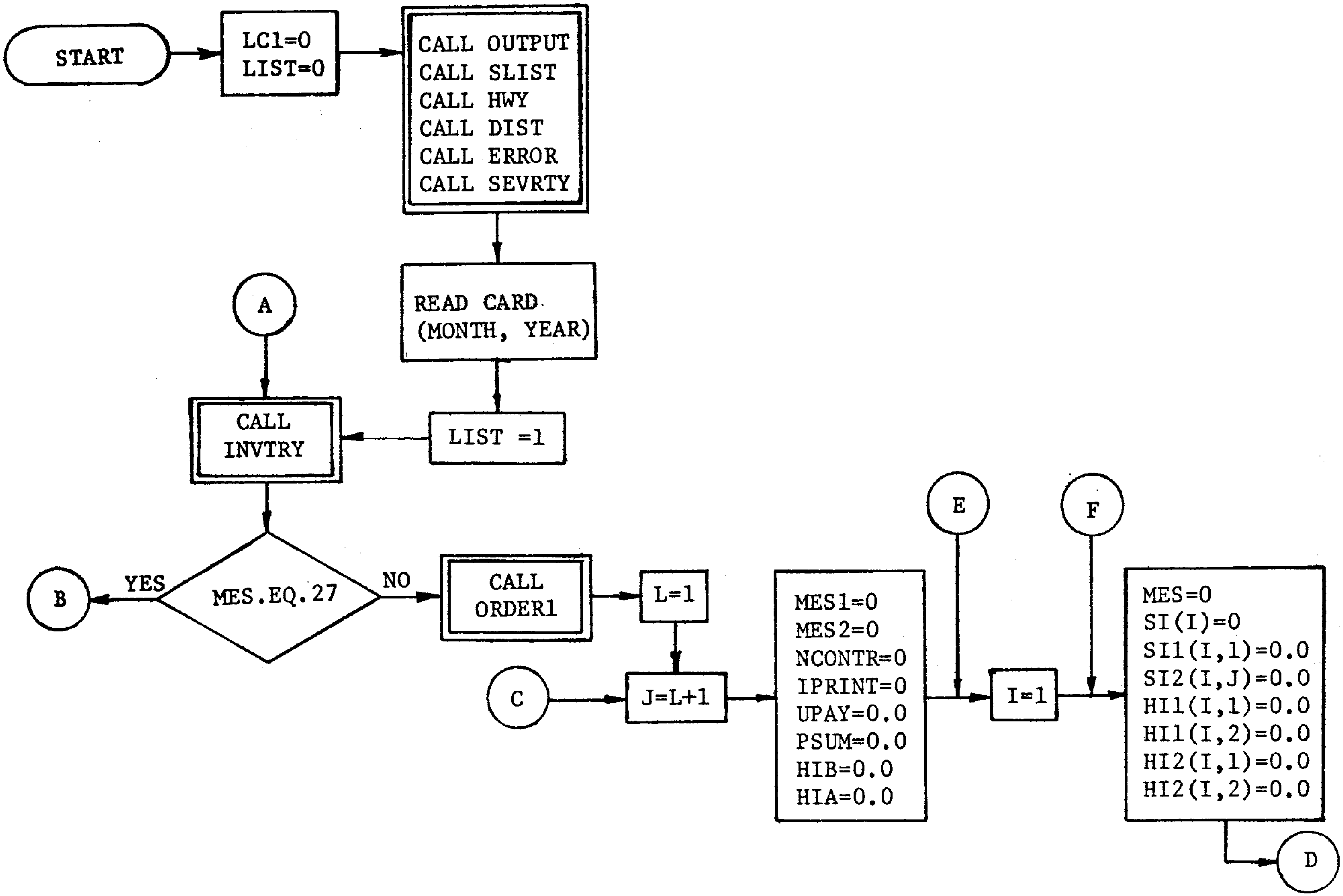


Figure 12-1. Flow Chart -- MAIN PROGRAM (1 of 3)

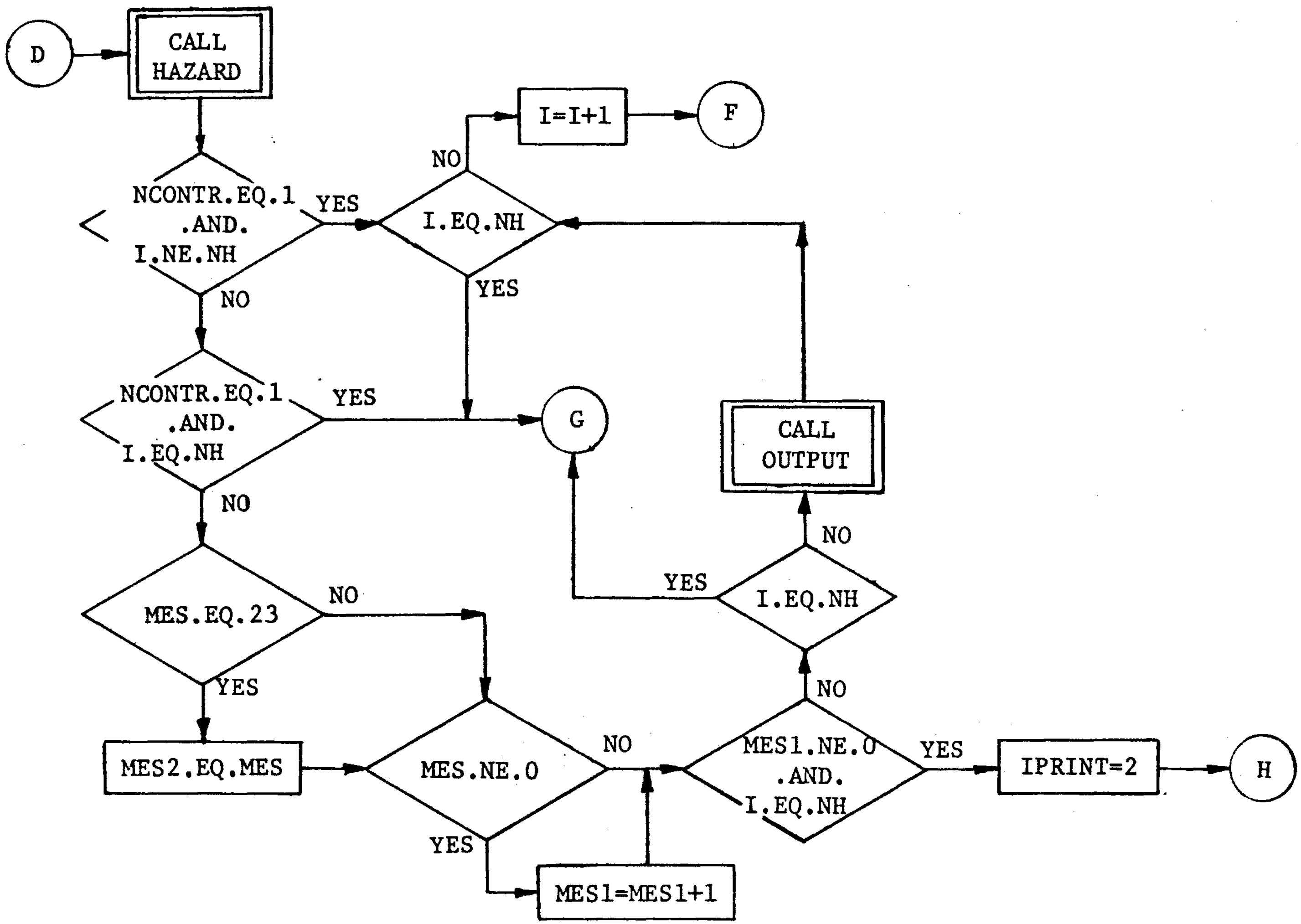


Figure 12-1. Flow Chart -- MAIN PROGRAM (Continued, 2 of 3)

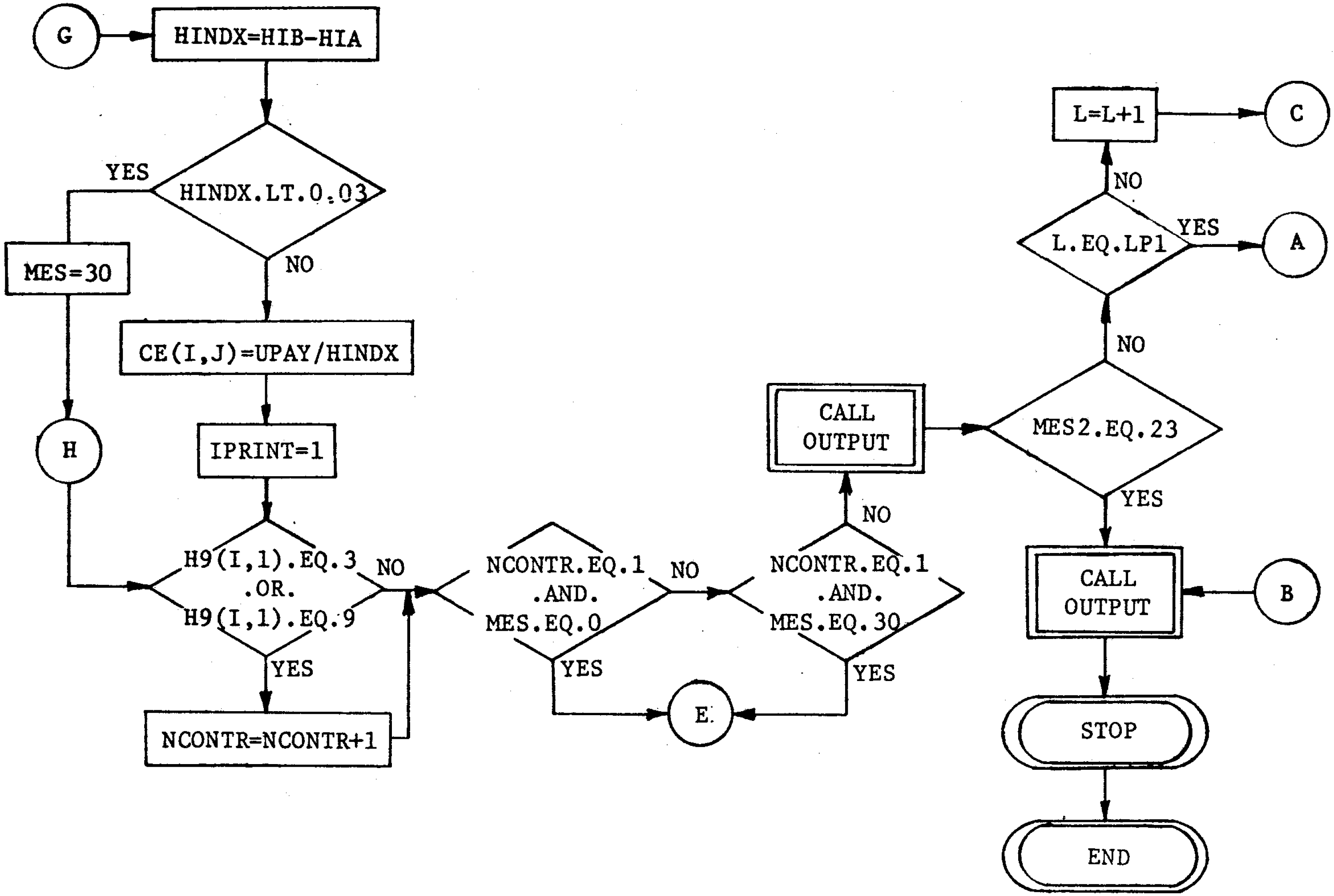


Figure 12-1. Flow Chart -- MAIN PROGRAM (Continued, 3 of 3)

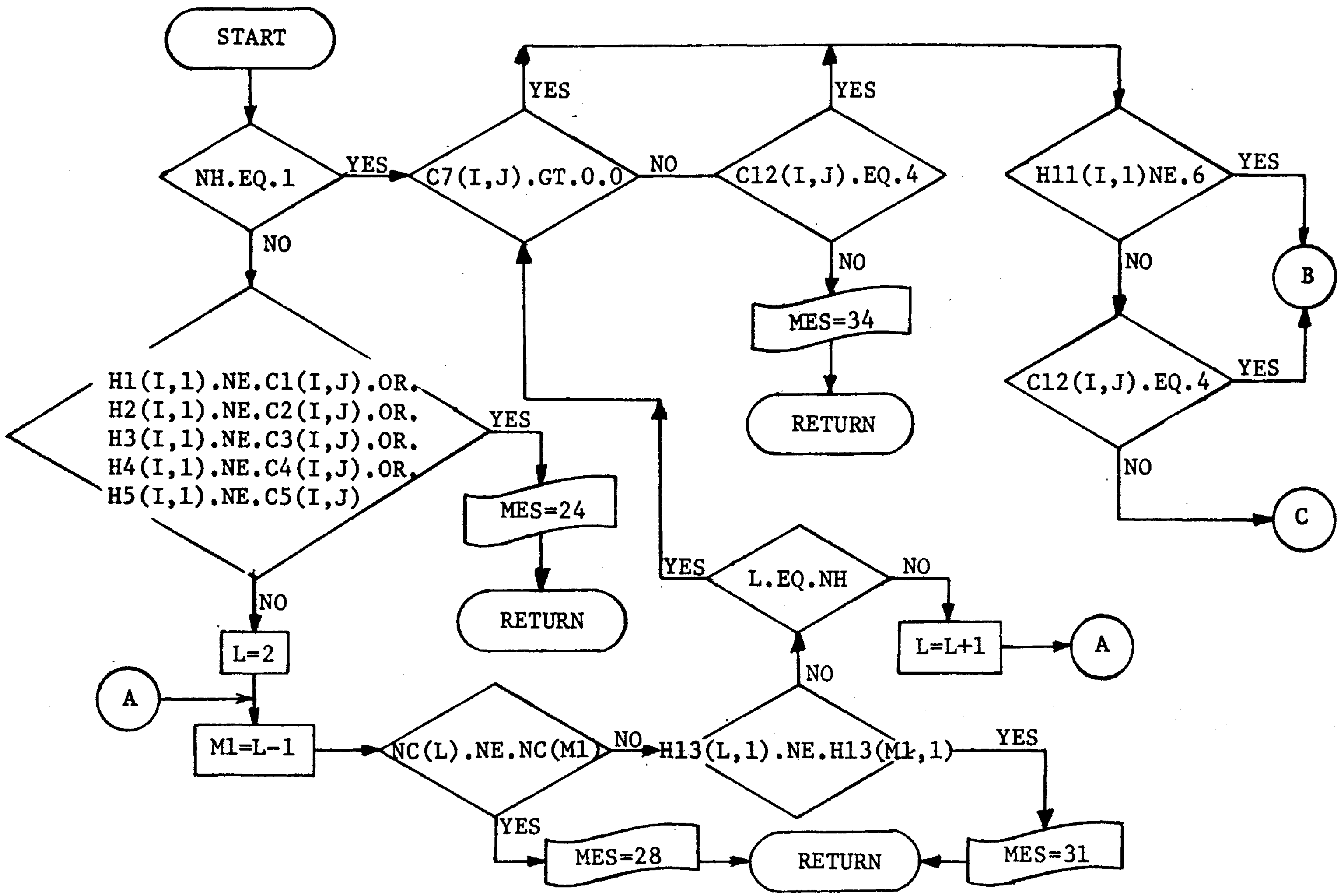


Figure 12-2. Flow Chart -- Subroutine HAZARD (1 of 4)

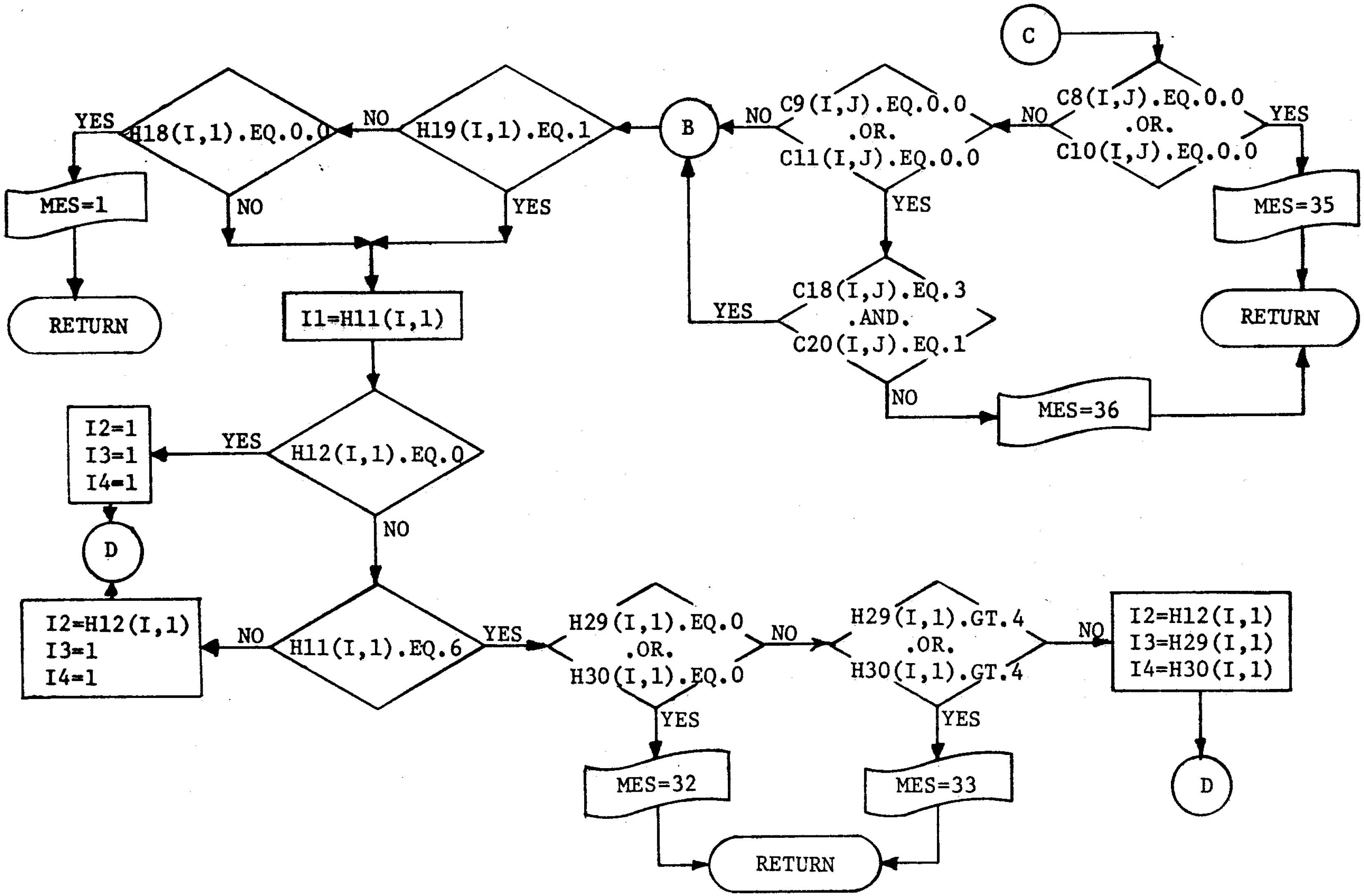


Figure 12-2. Flow Chart -- Subroutine HAZARD (Continued 2 of 4)

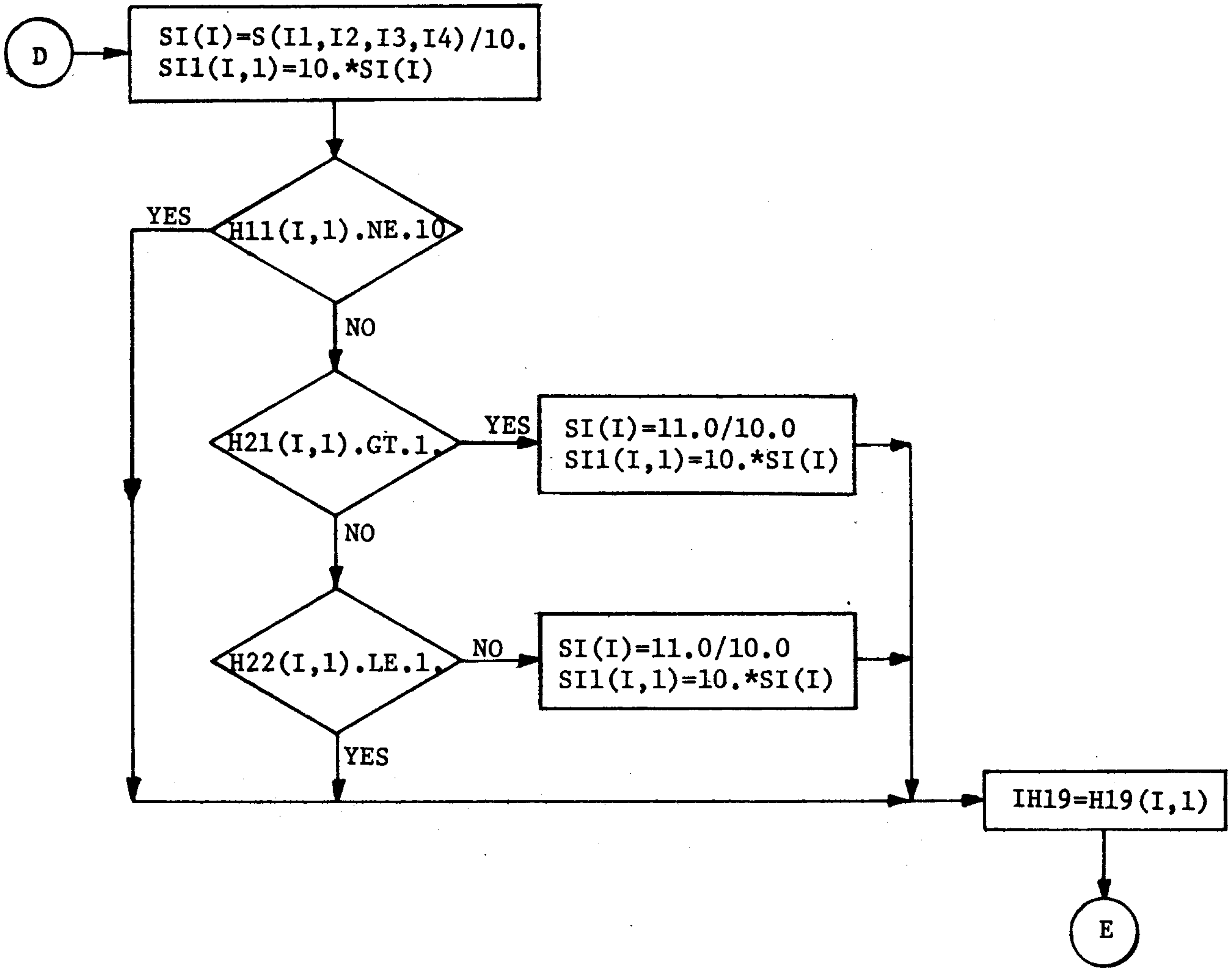


Figure 12-2. Flow Chart -- Subroutine HAZARD (Continued 3 of 4)

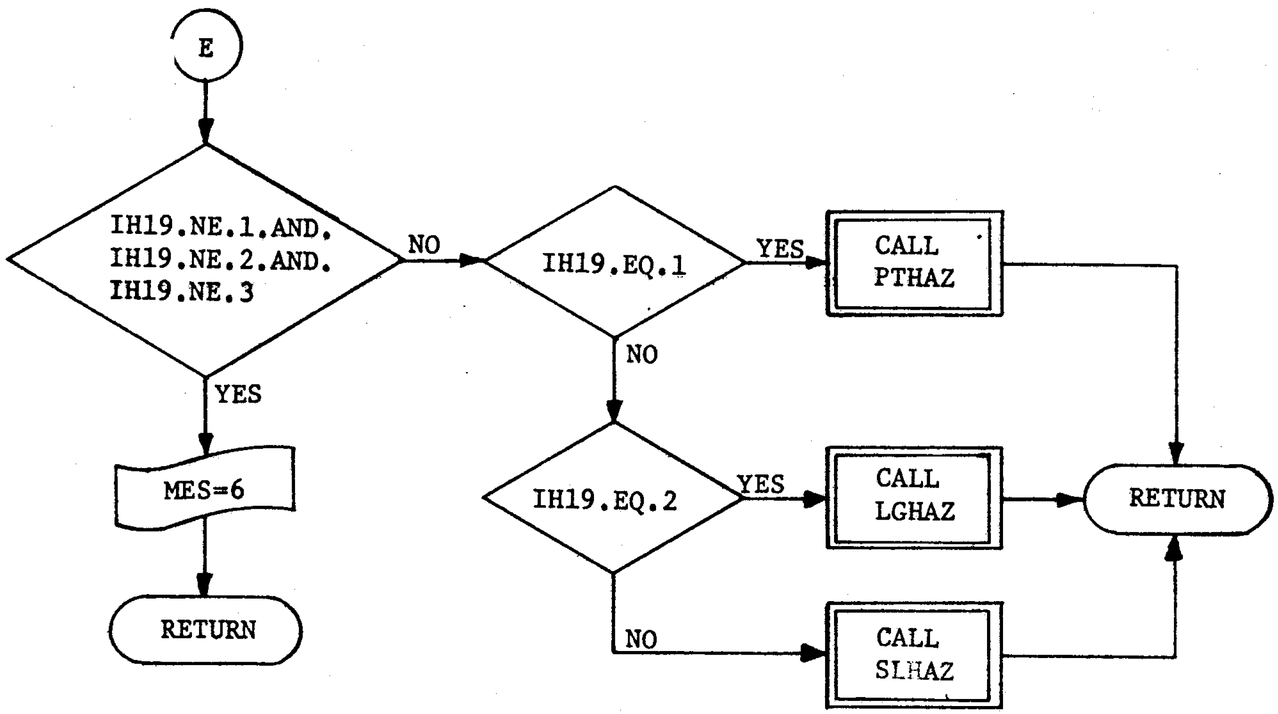


Figure 12-2. Flow Chart -- Subroutine HAZARD (Continued 4 of 4)

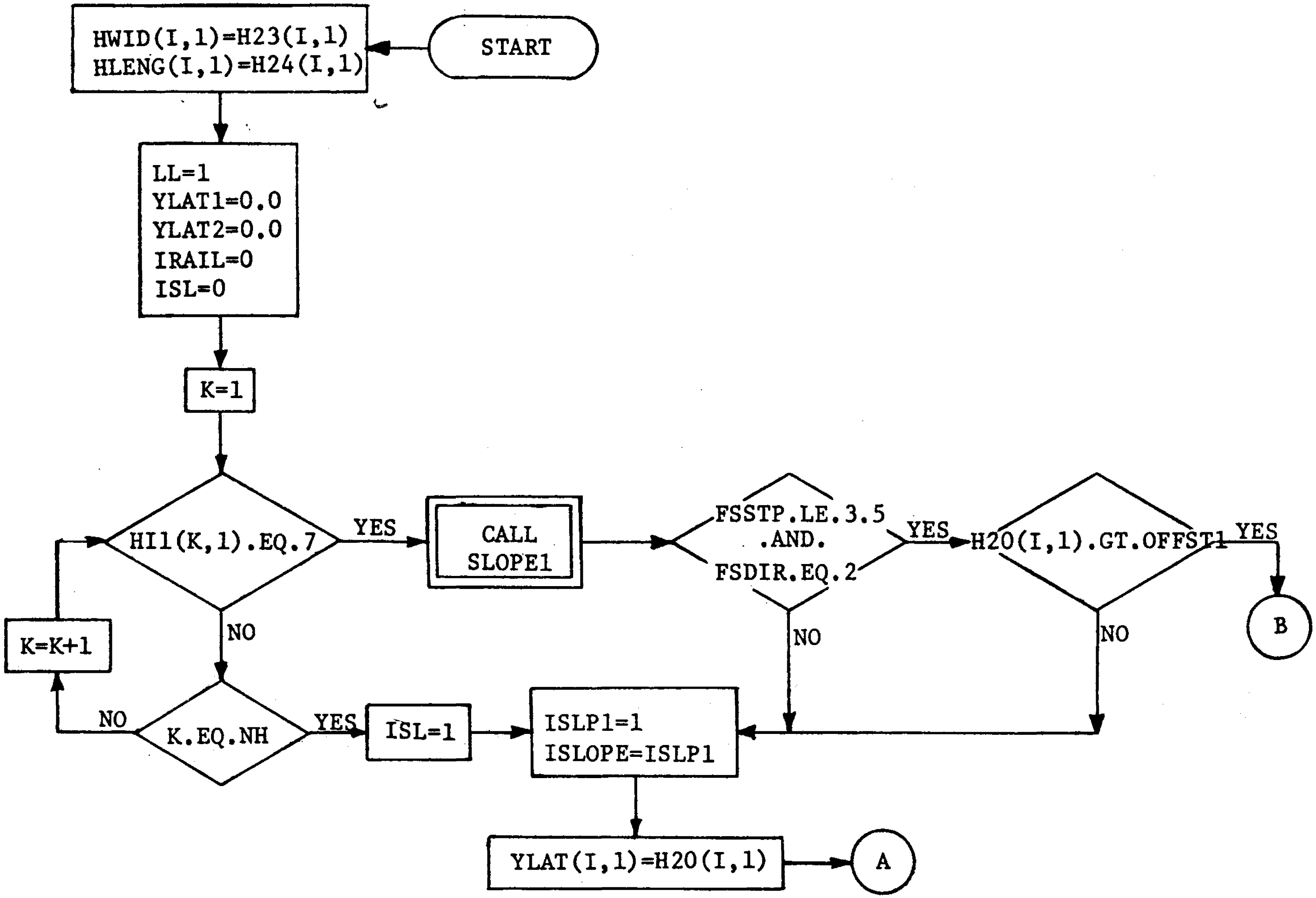


Figure 12-3. Flow Chart -- Subroutine PTHAZ (1 of 8)

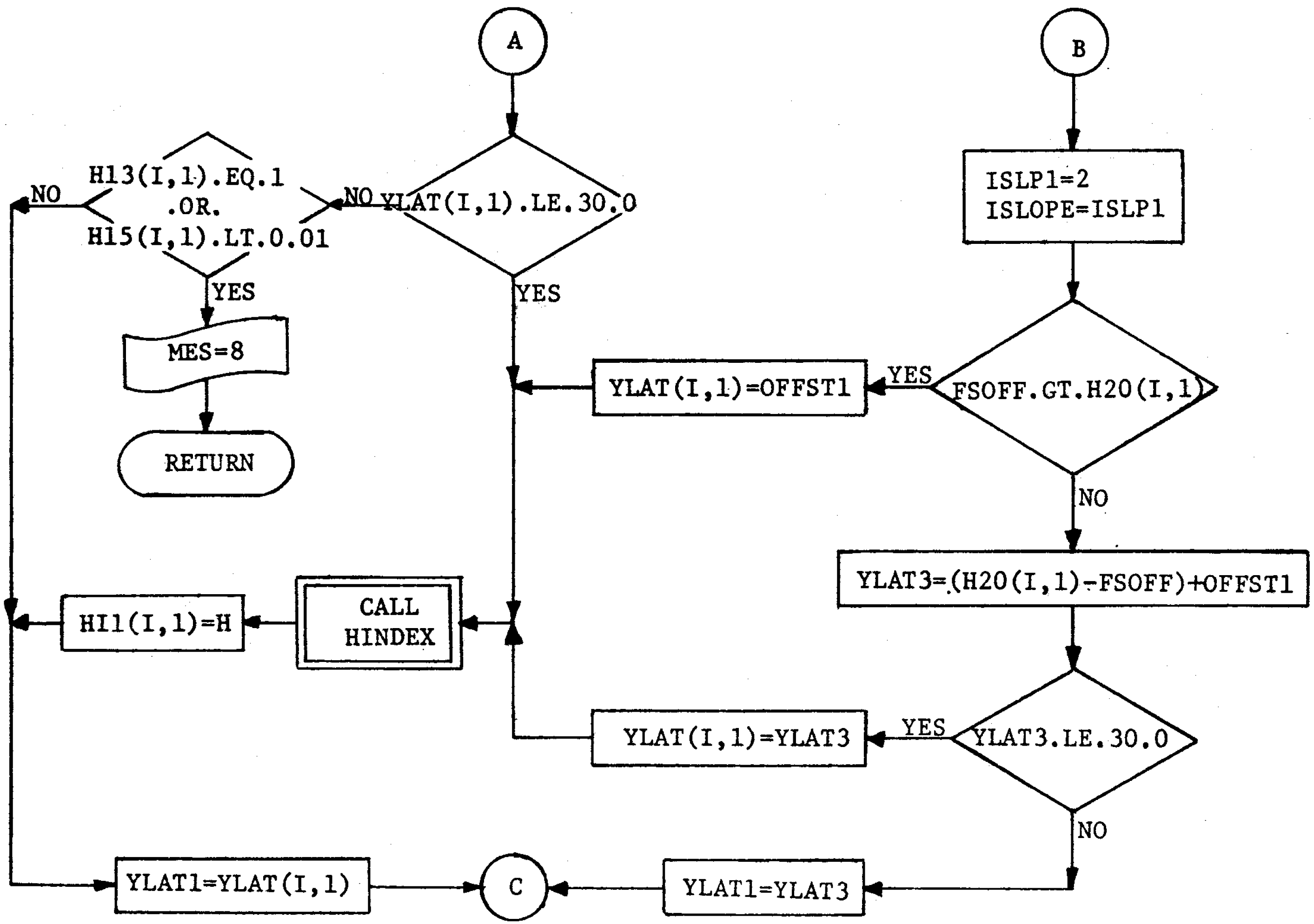


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 2 of 8)

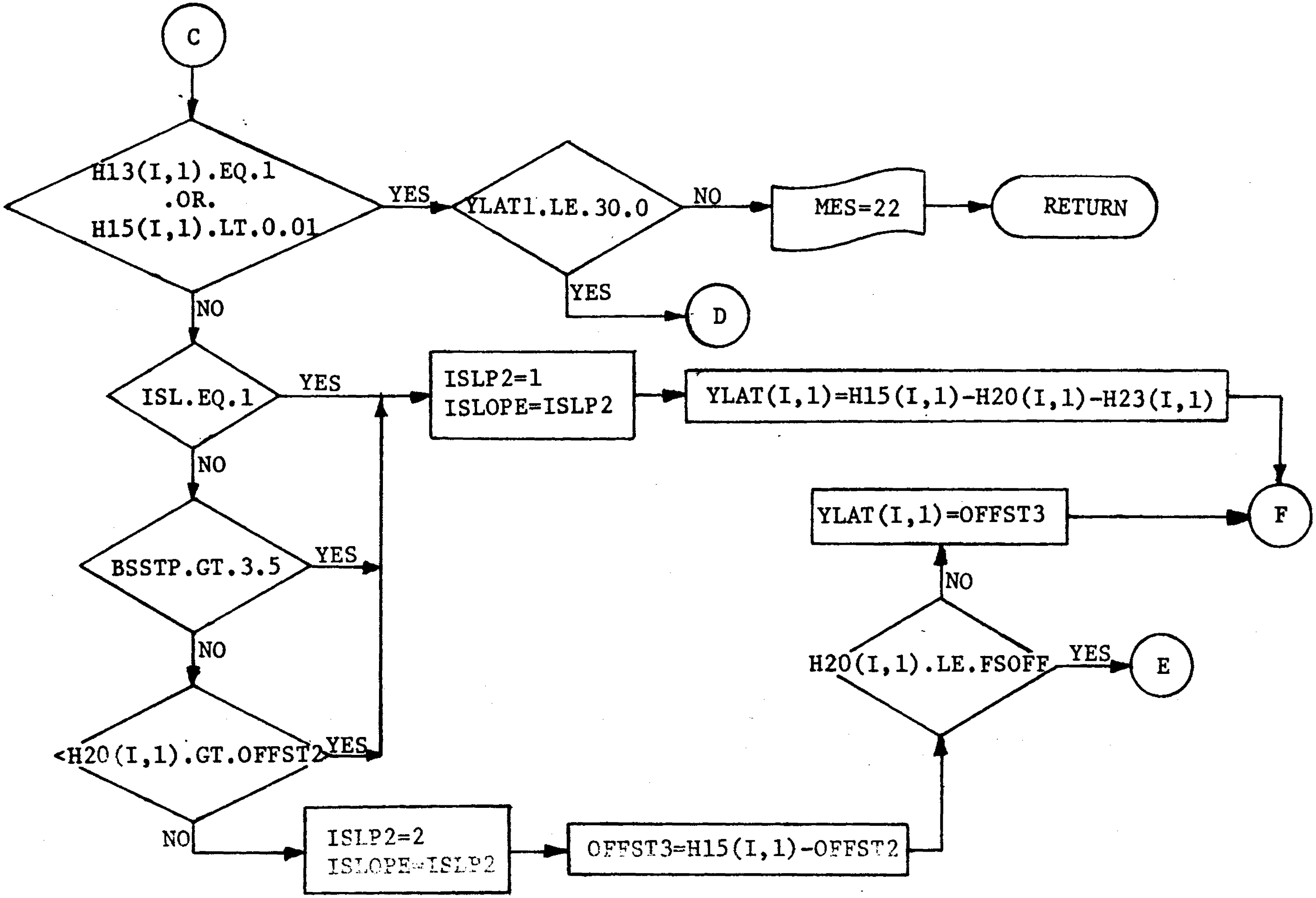


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 3 of 8)

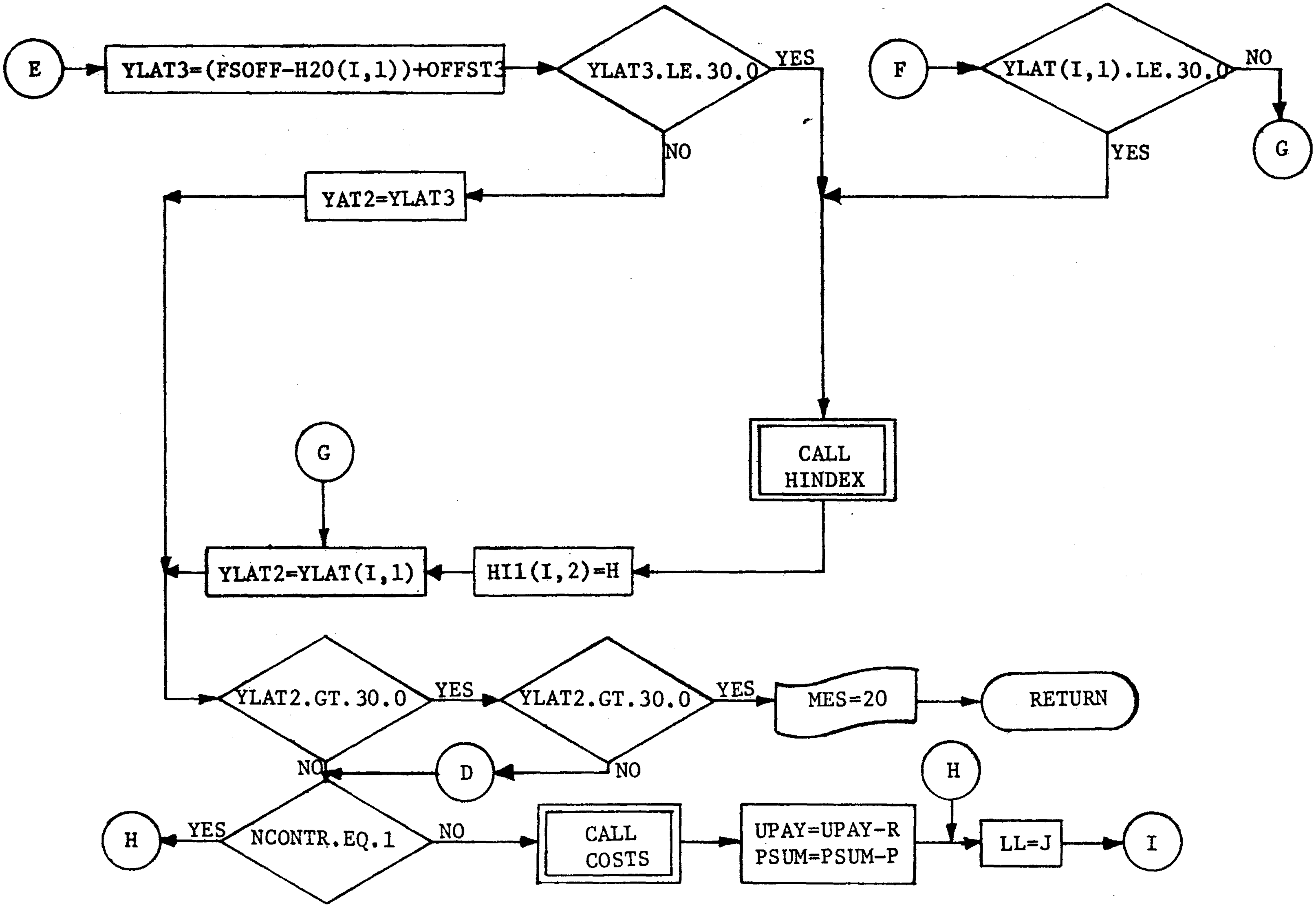


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 4 of 8)

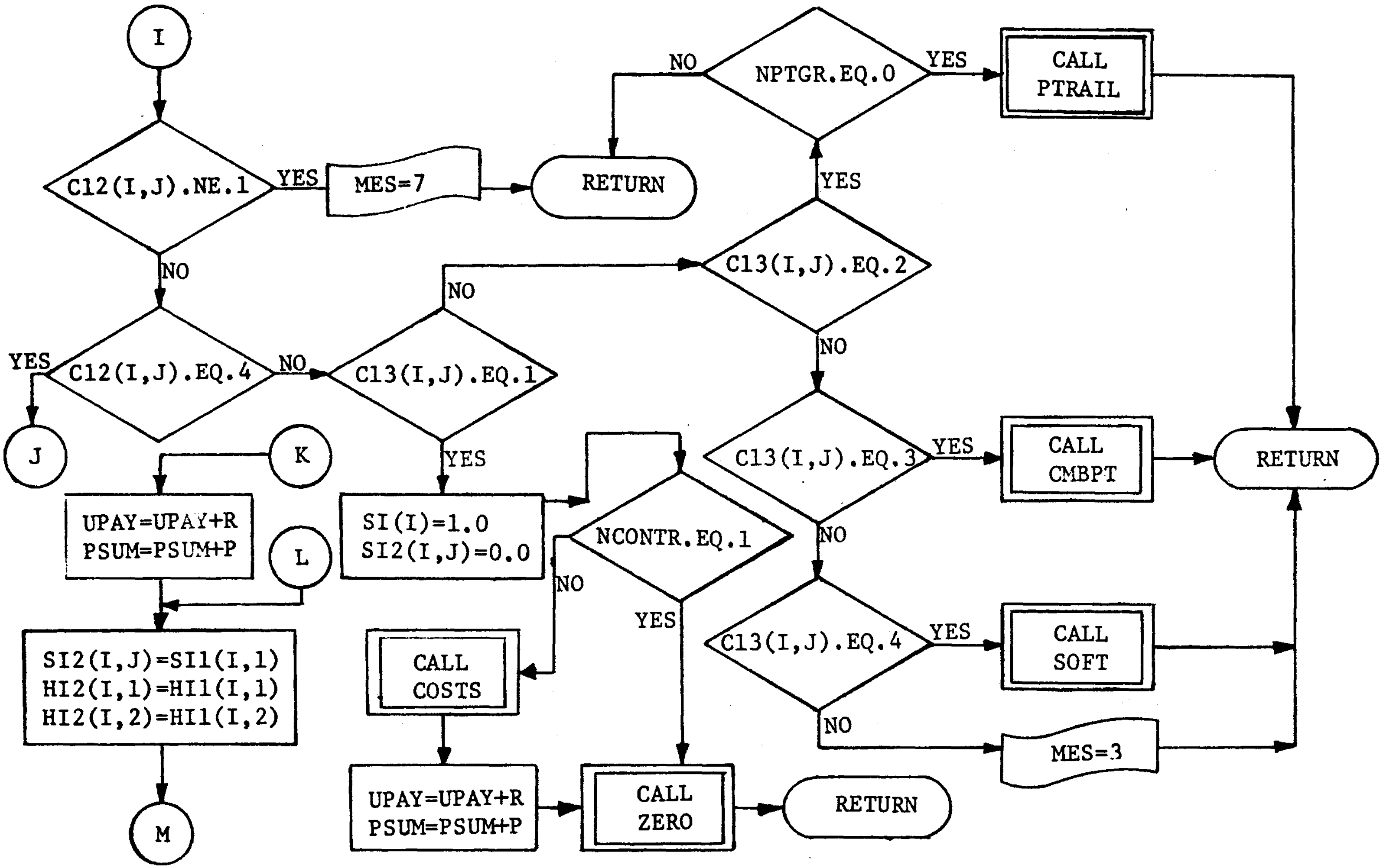


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 5 of 8)

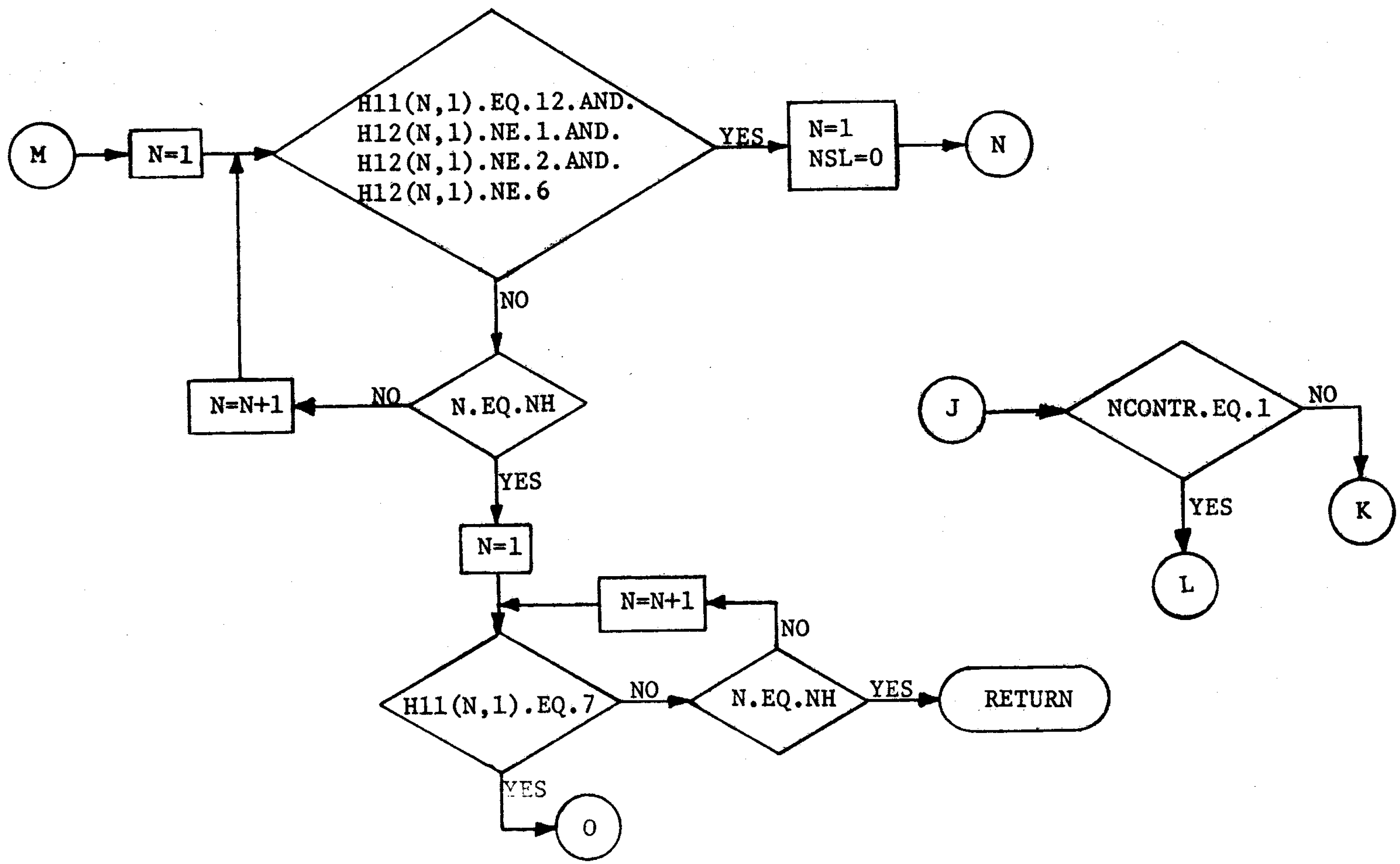


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 6 of 8)

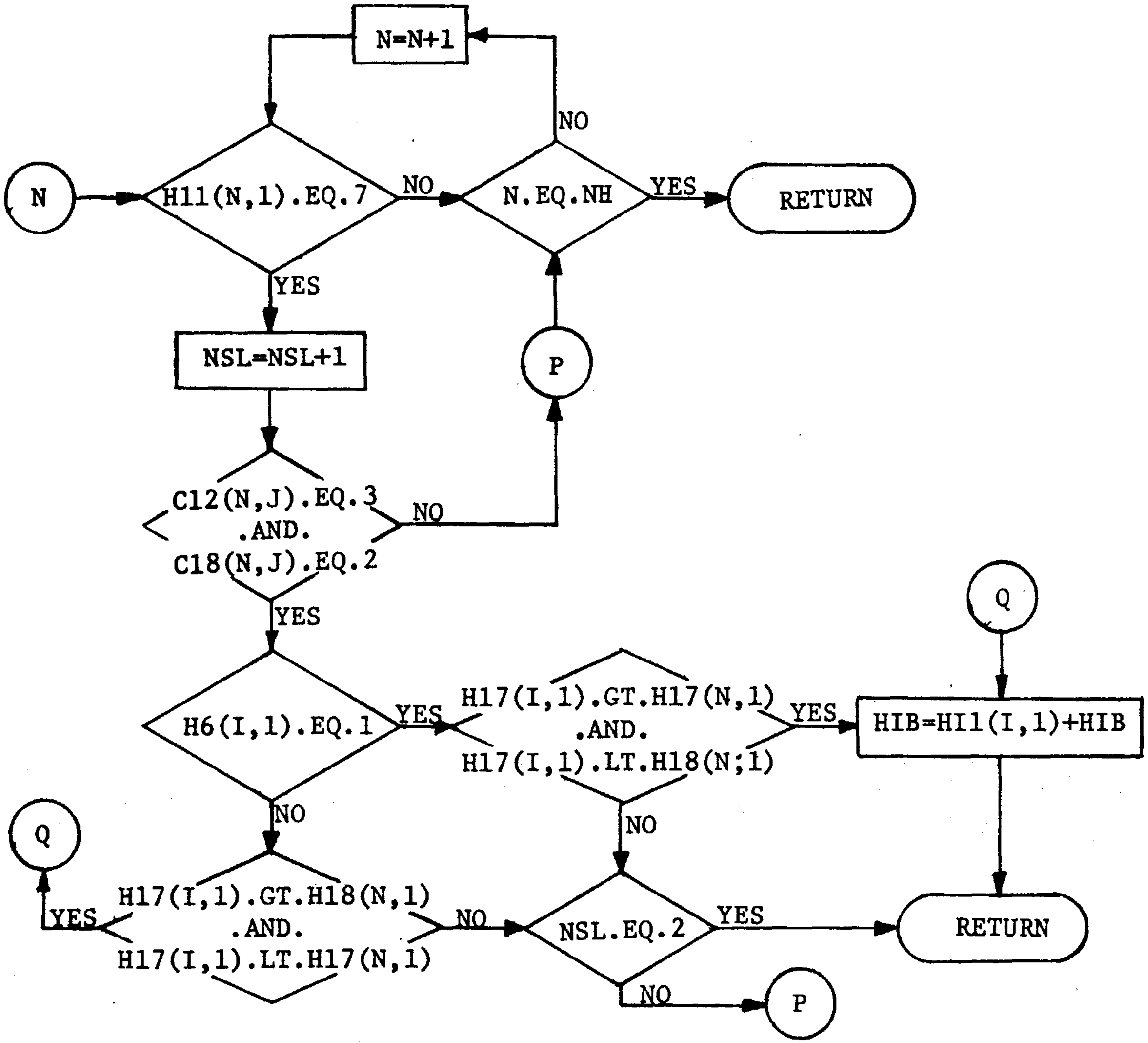


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 7 of 8)

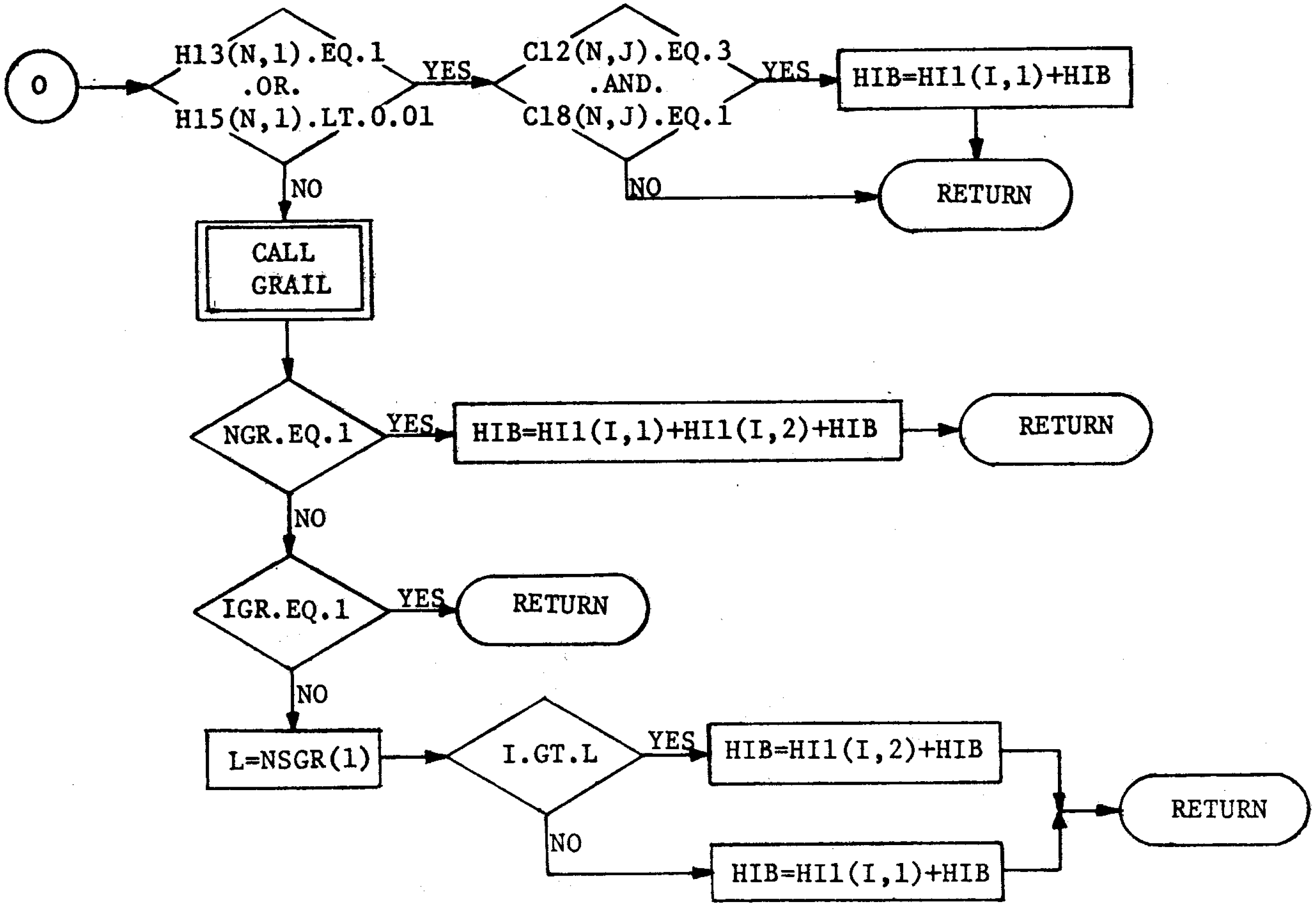


Figure 12-3. Flow Chart -- Subroutine PTHAZ (Continued 8 of 8)

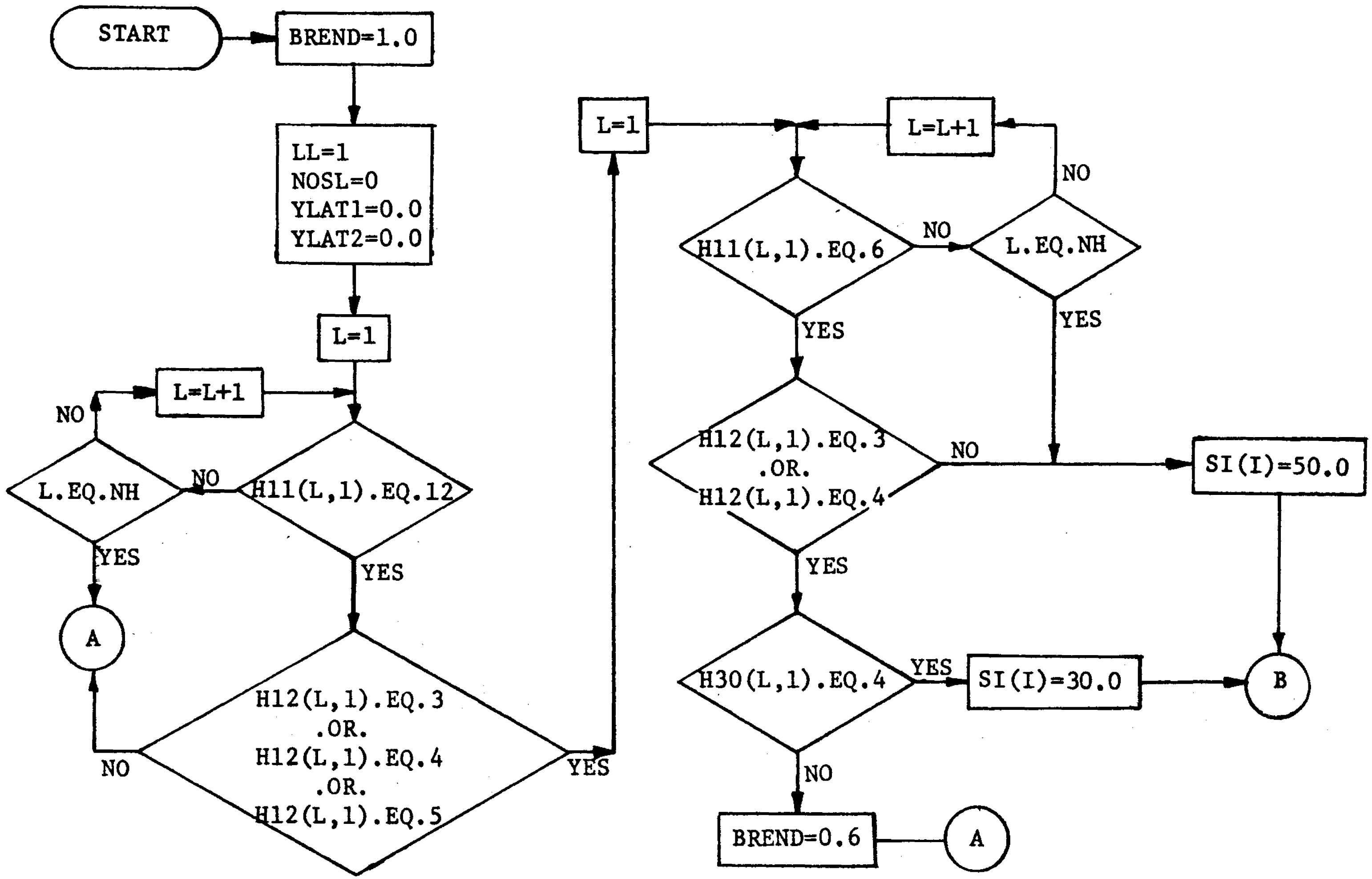


Figure 12-4. Flow Chart -- Subroutine LGHAZ (1 of 9)

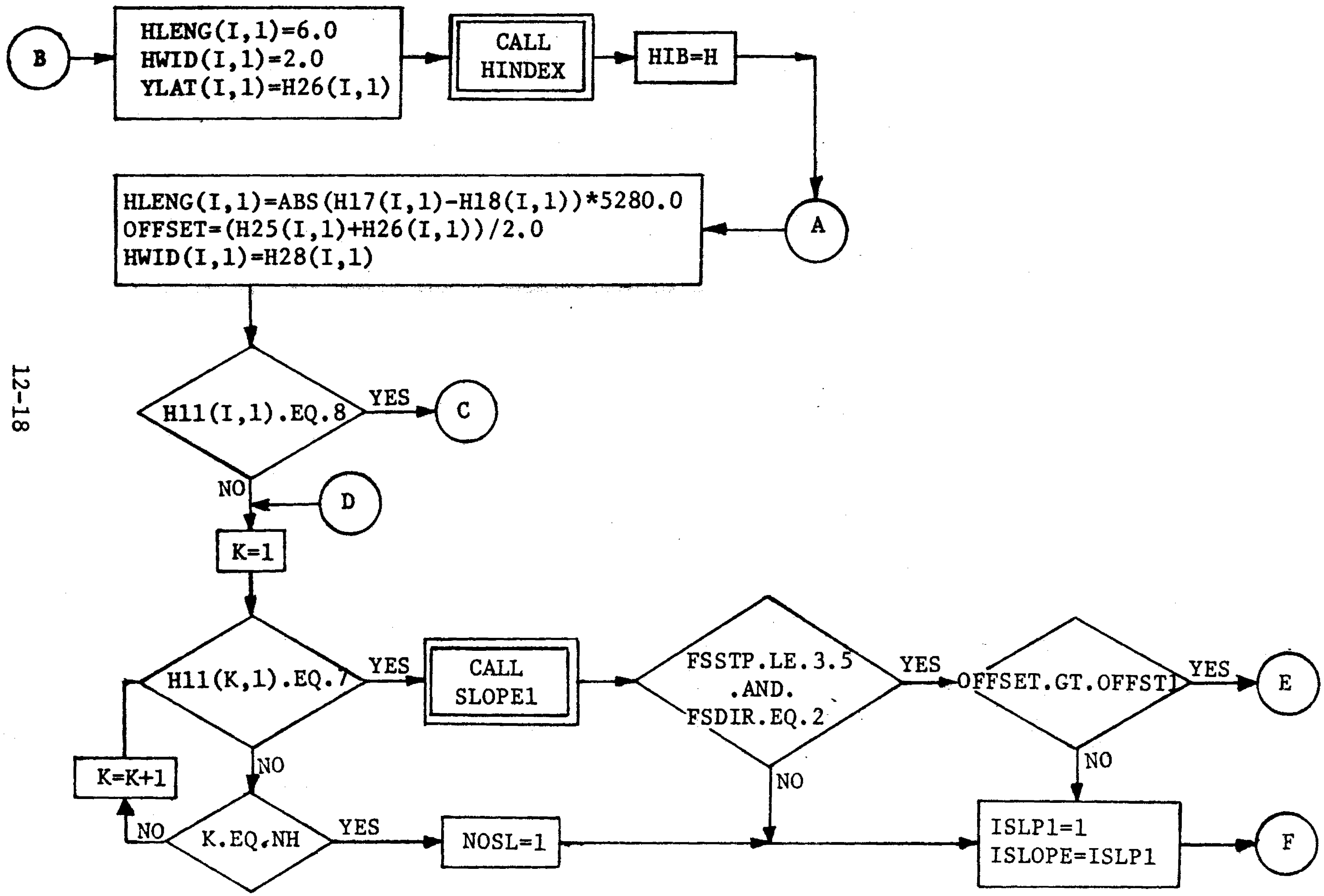


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 2 of 9)

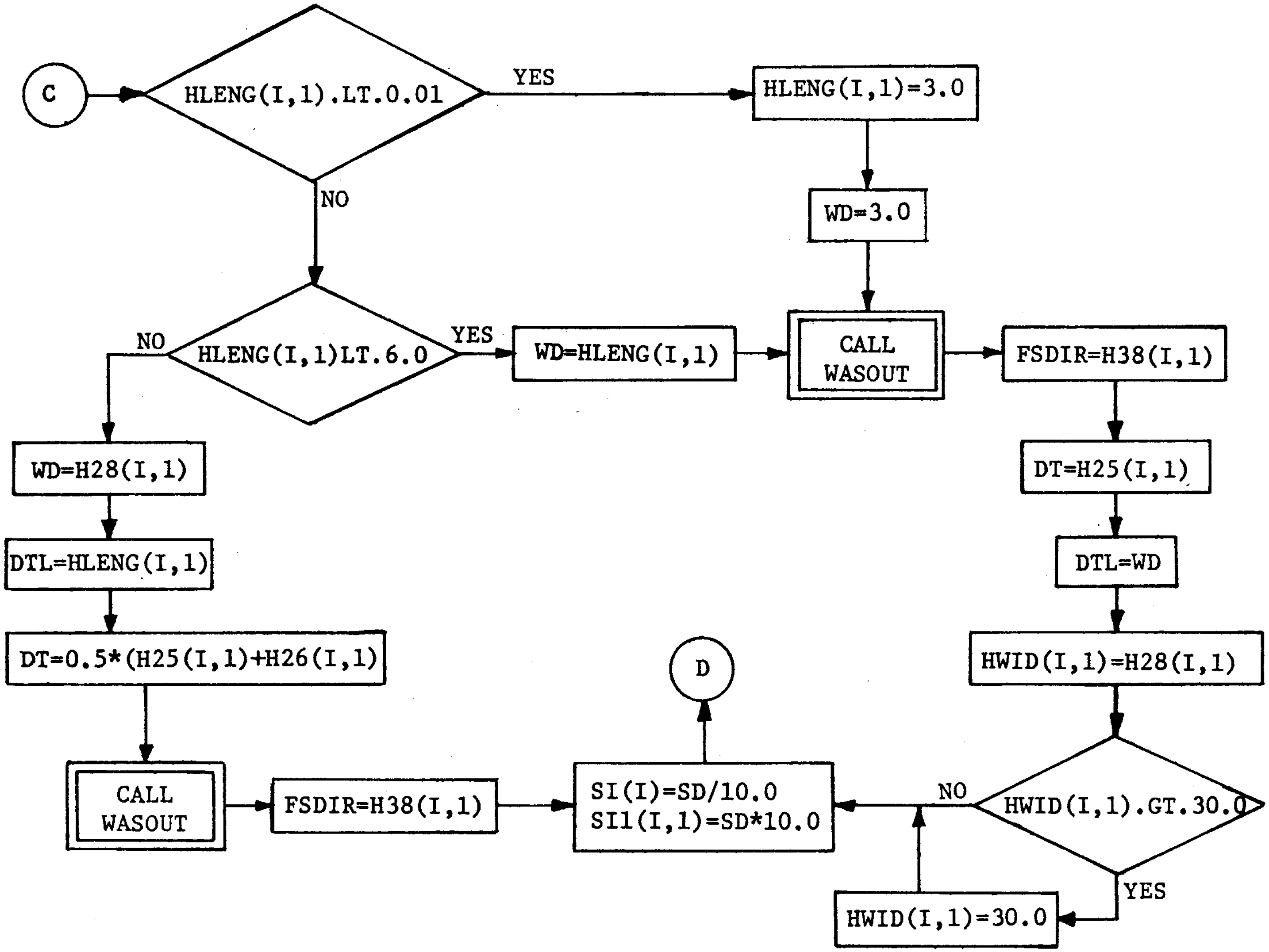


Figure 12-4. Flow Chart — Subroutine LGHAZ (Continued 3 of 9)

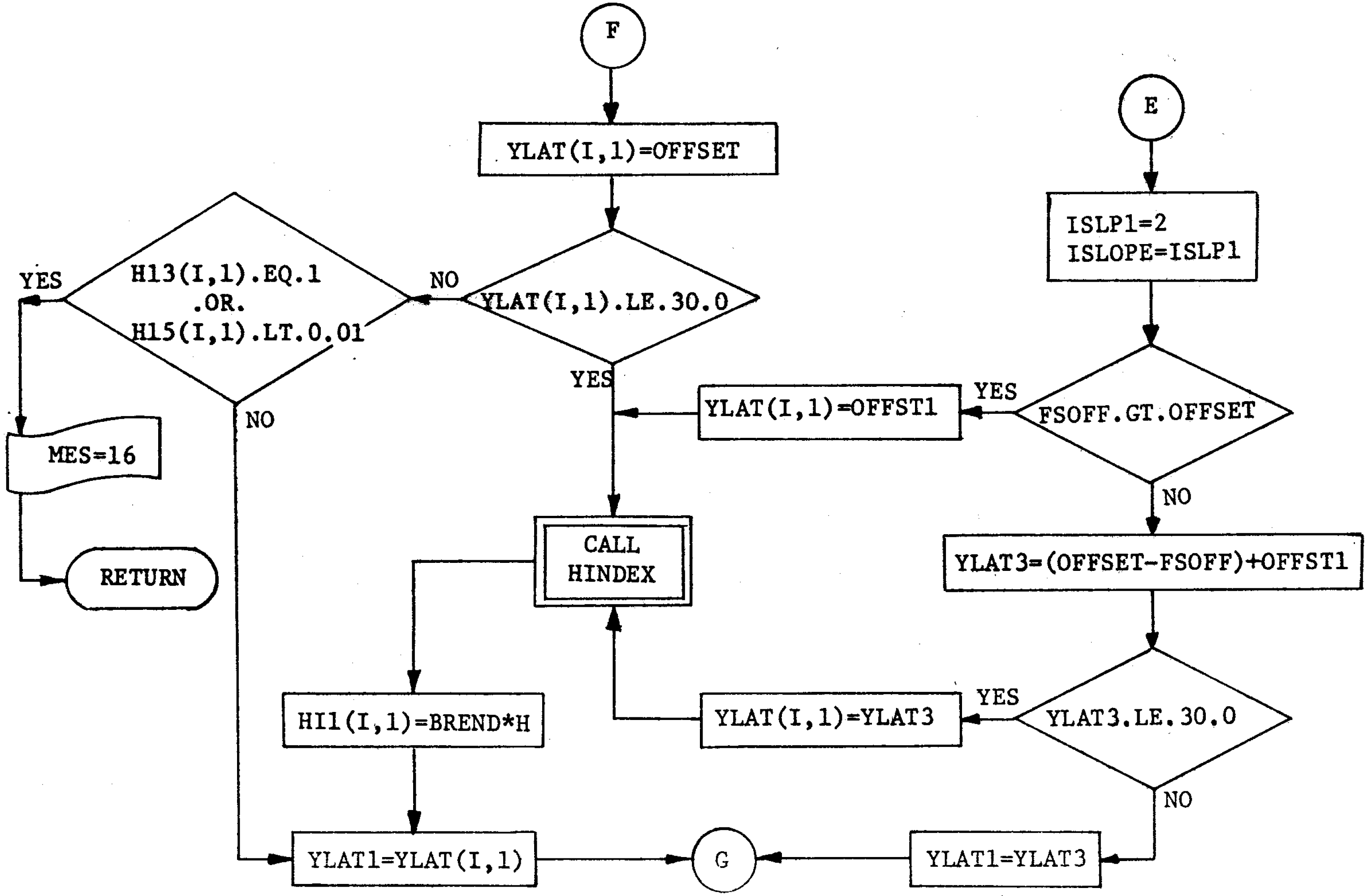


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 4 of 9)

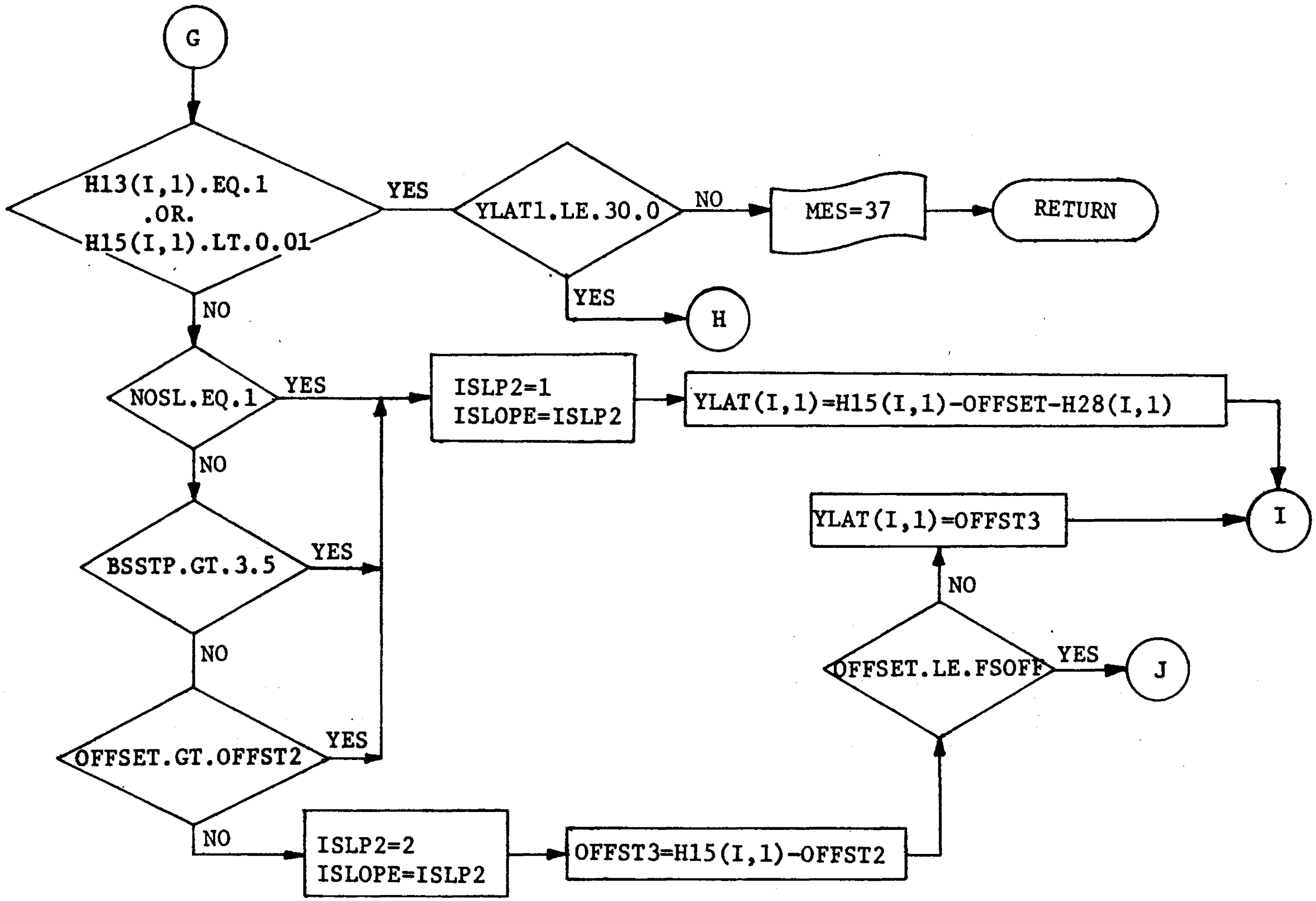


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 5 of 9)

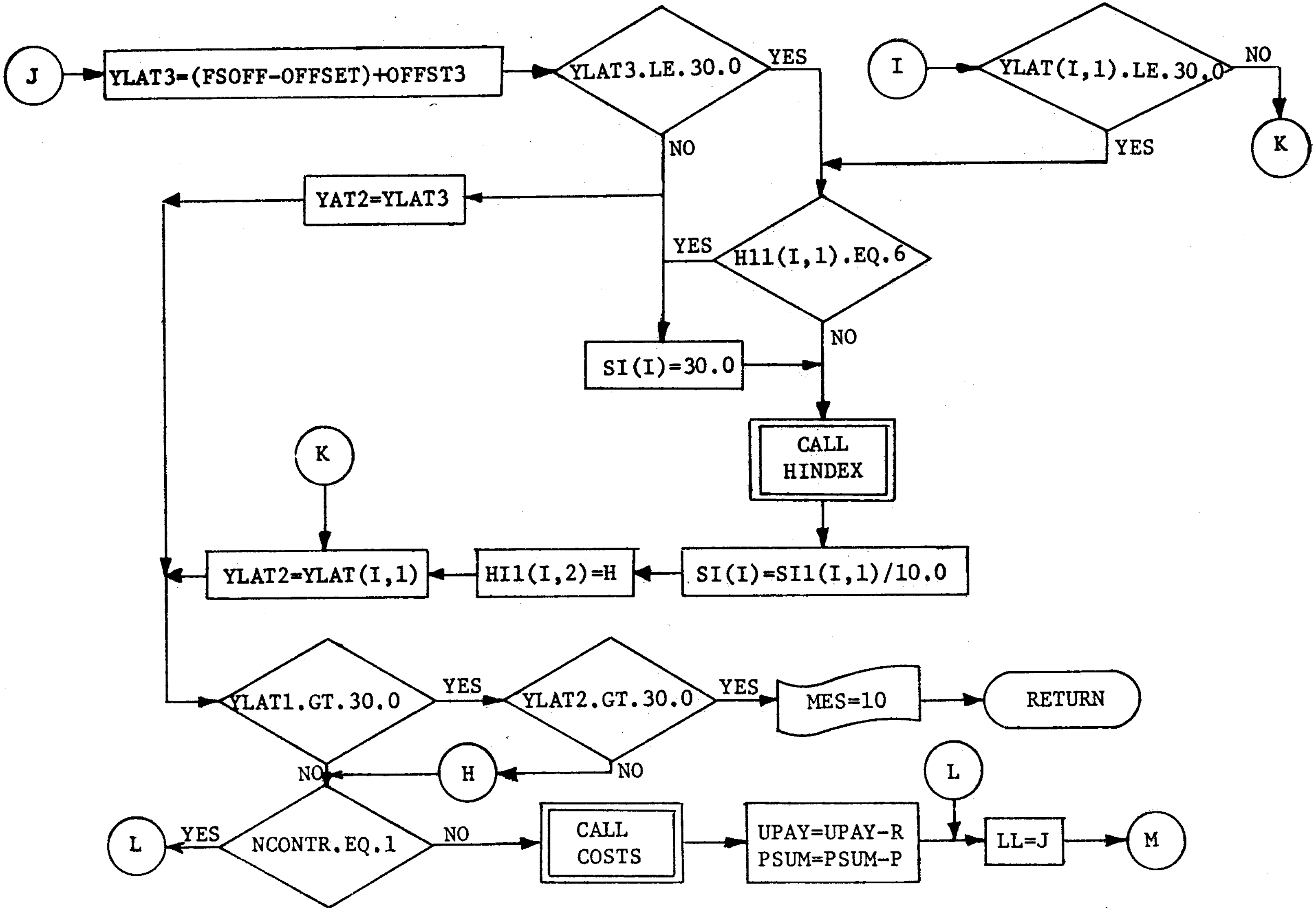


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 6 of 9)

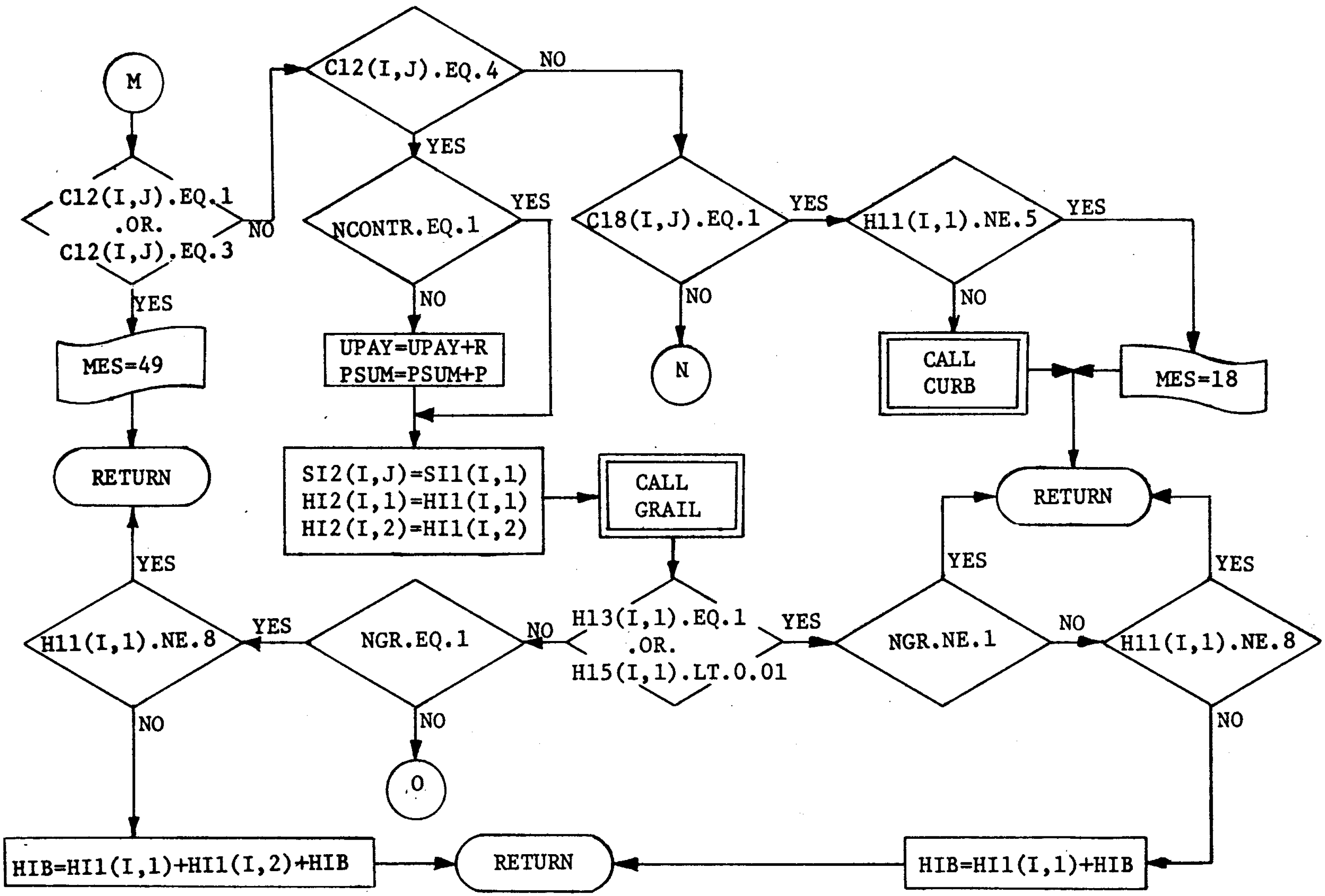


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 7 of 9)

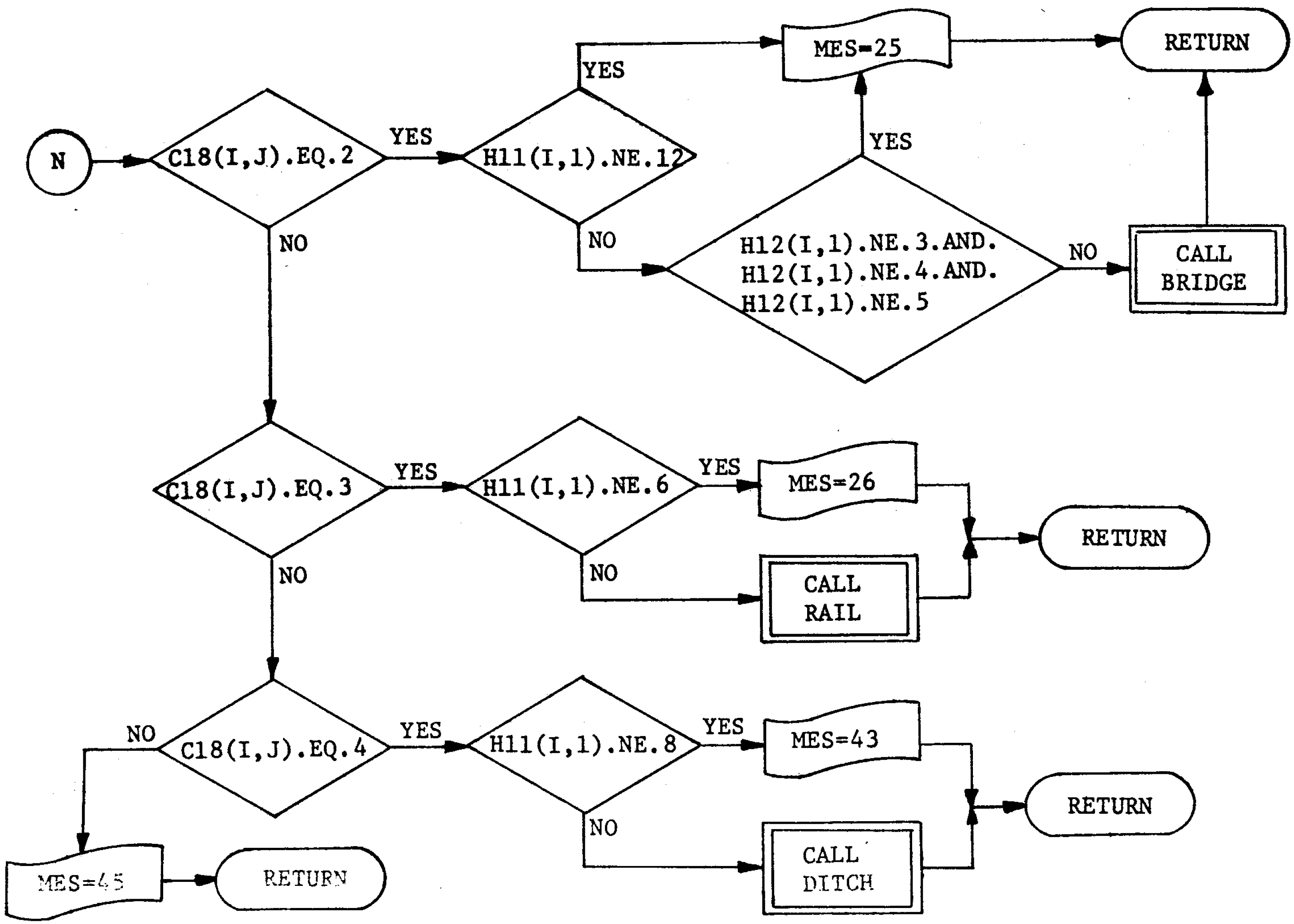


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 8 of 9)

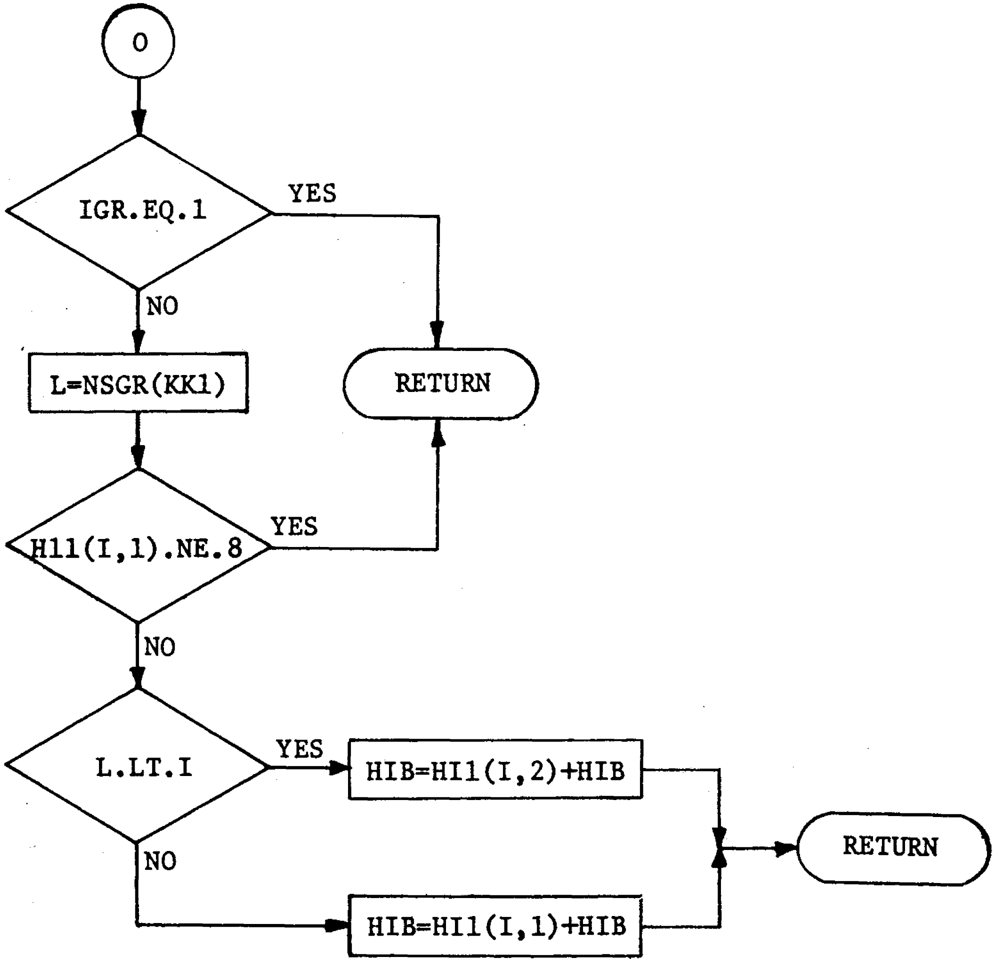


Figure 12-4. Flow Chart -- Subroutine LGHAZ (Continued 9 of 9)

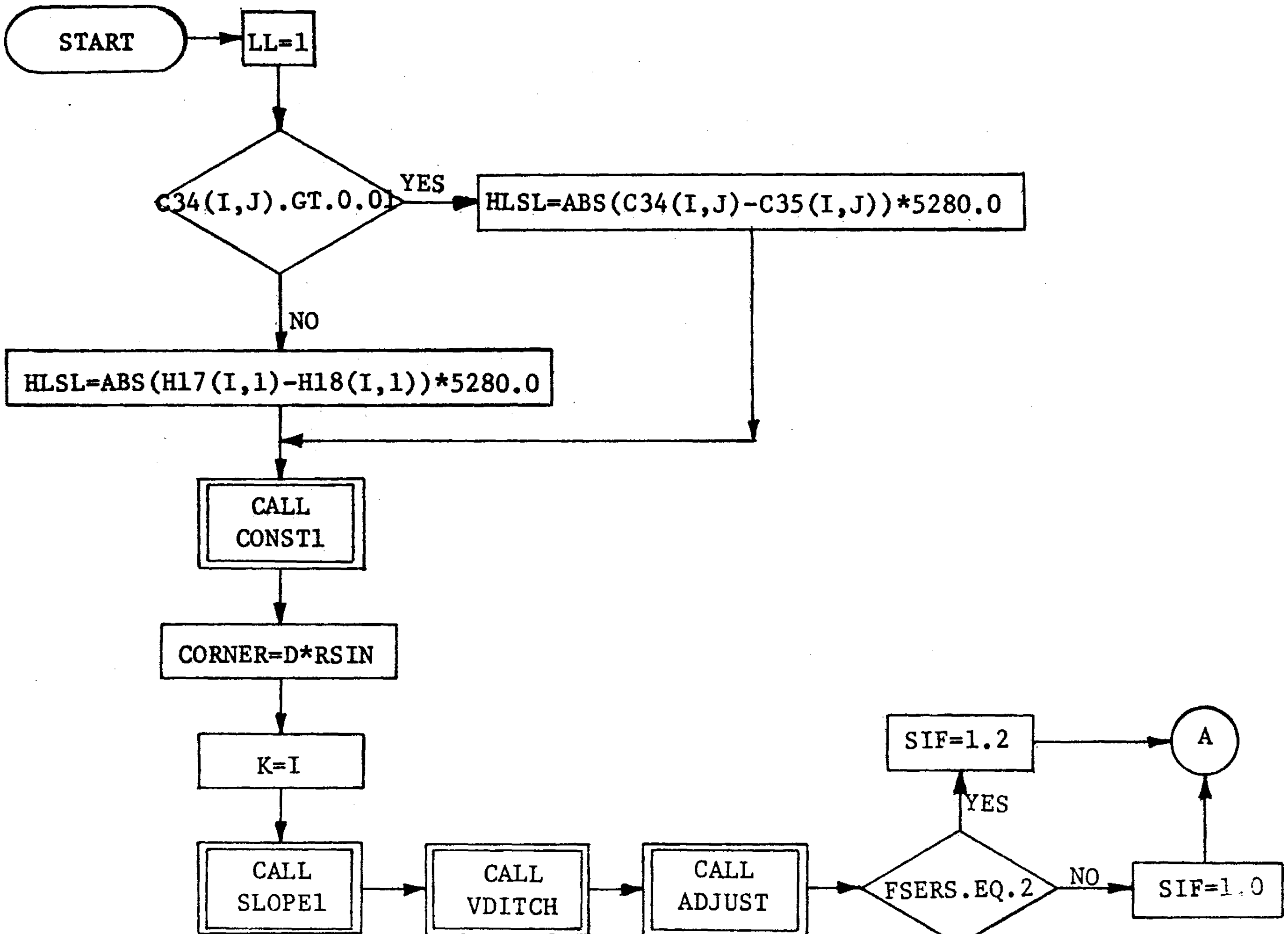


Figure 12-5. Flow Chart -- Subroutine SLHAZ (1 of 6)

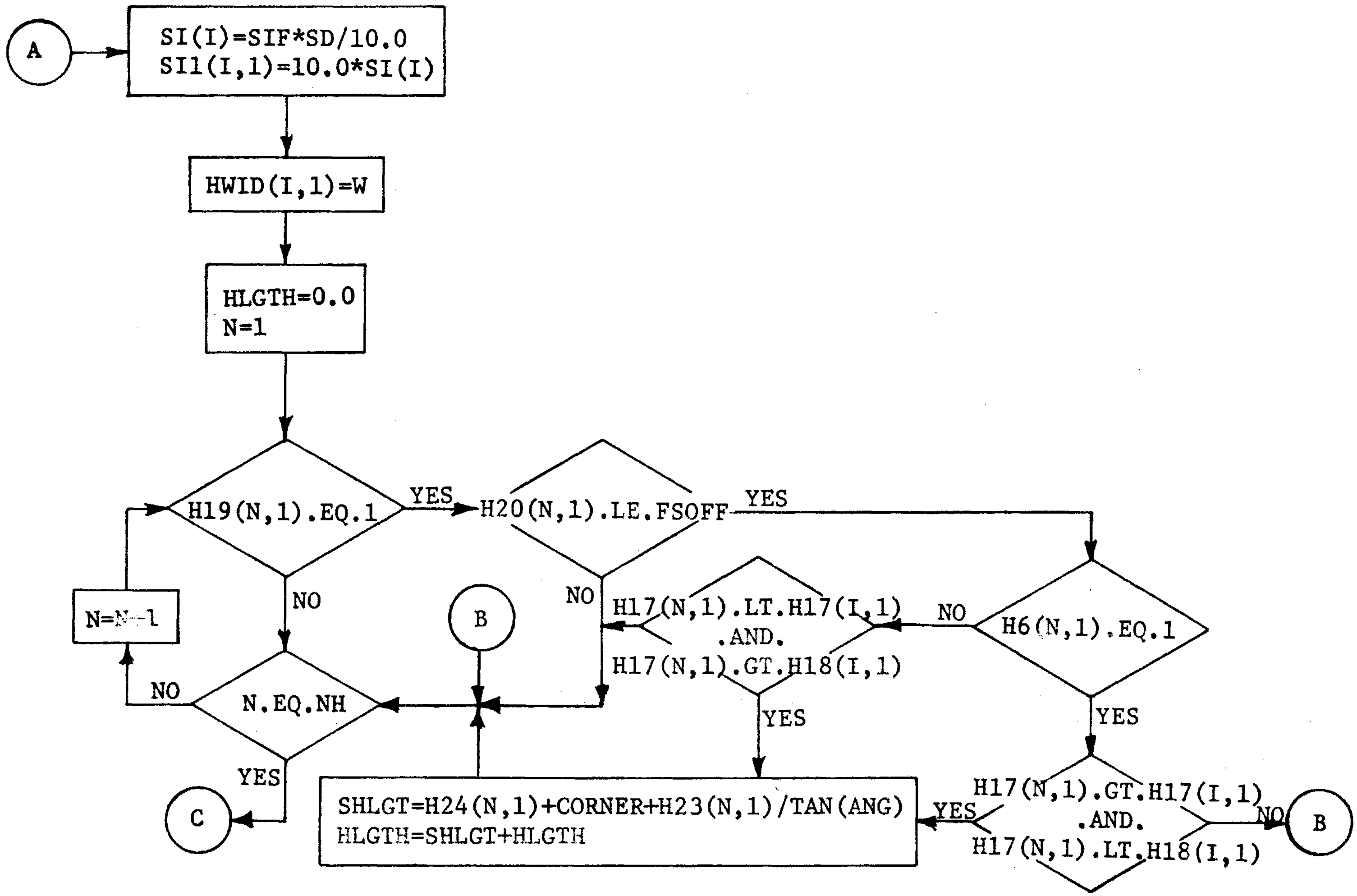


Figure 12-5. Flow Chart -- Subroutine SLHAZ (Continued 2 of 6)

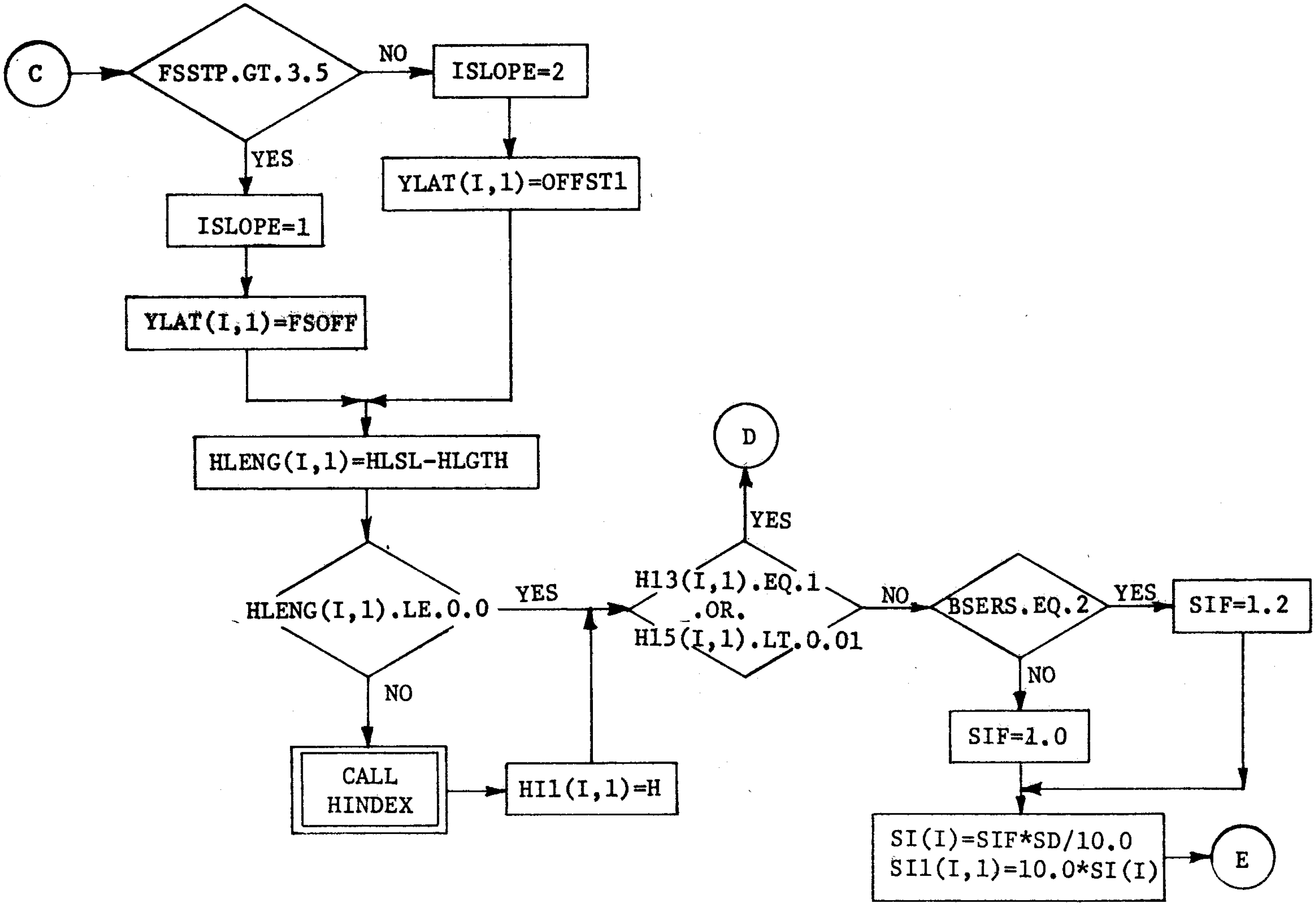


Figure 12-5. Flow Chart -- Subroutine SLHAZ (Continued 3 of 6)

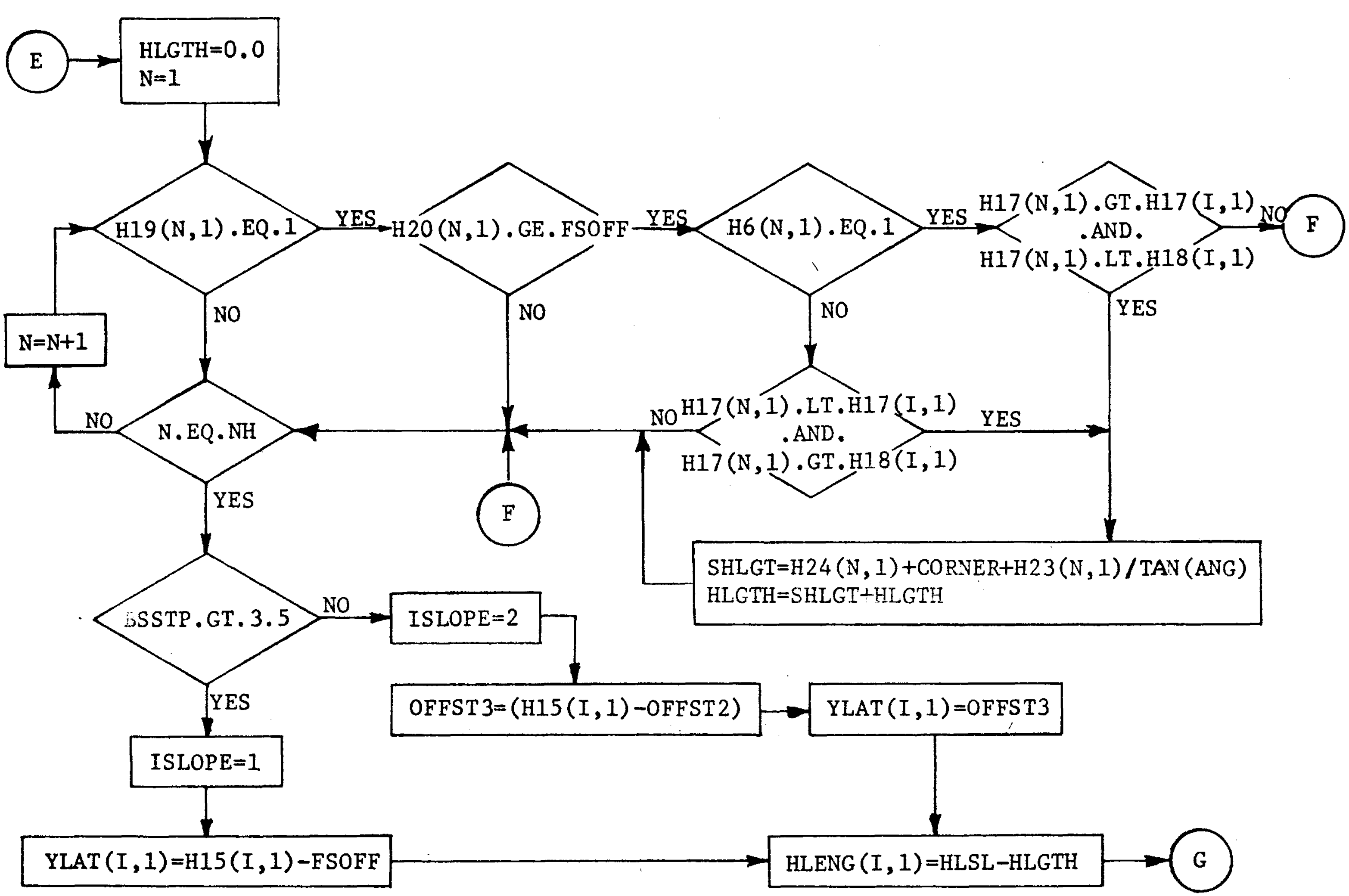


Figure 12-5. Flow Chart -- Subroutine SLHAZ (Continued 4 of 6)

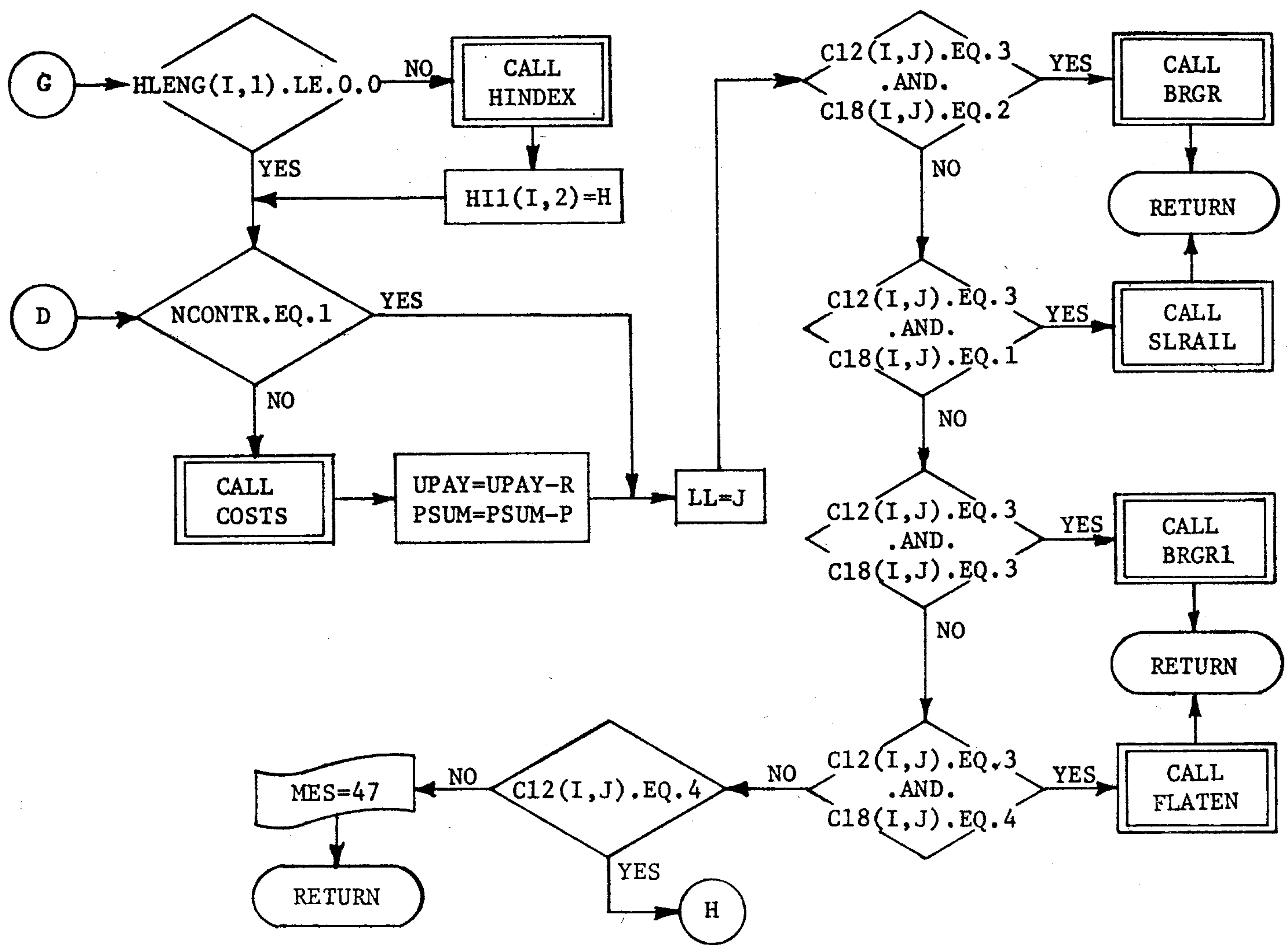


Figure 12-5. Flow Chart -- Subroutine SLHAZ (Continued 5 of 6)

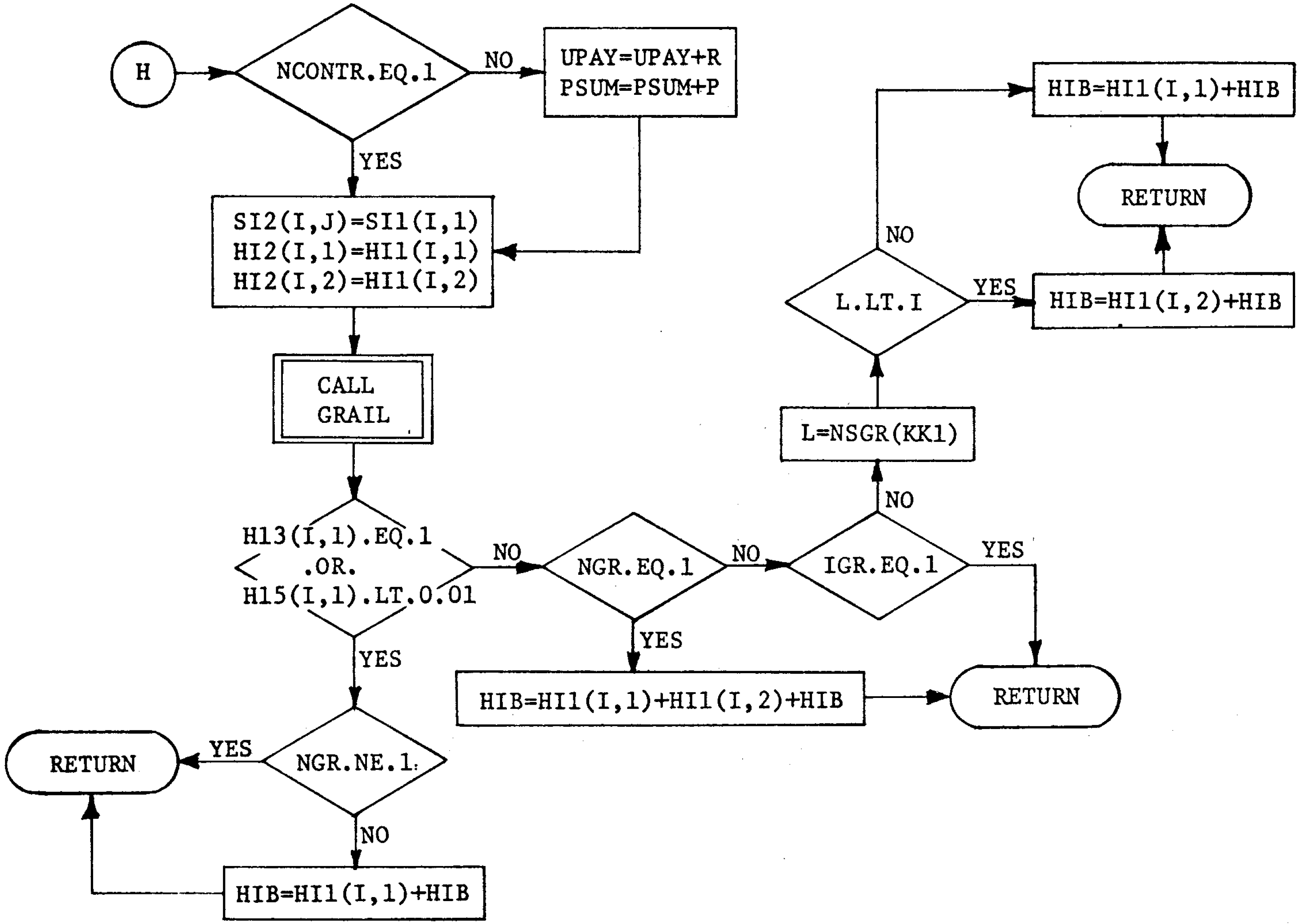


Figure 12-5. Flow Chart -- Subroutine SLHAZ (Continued 6 of 6)

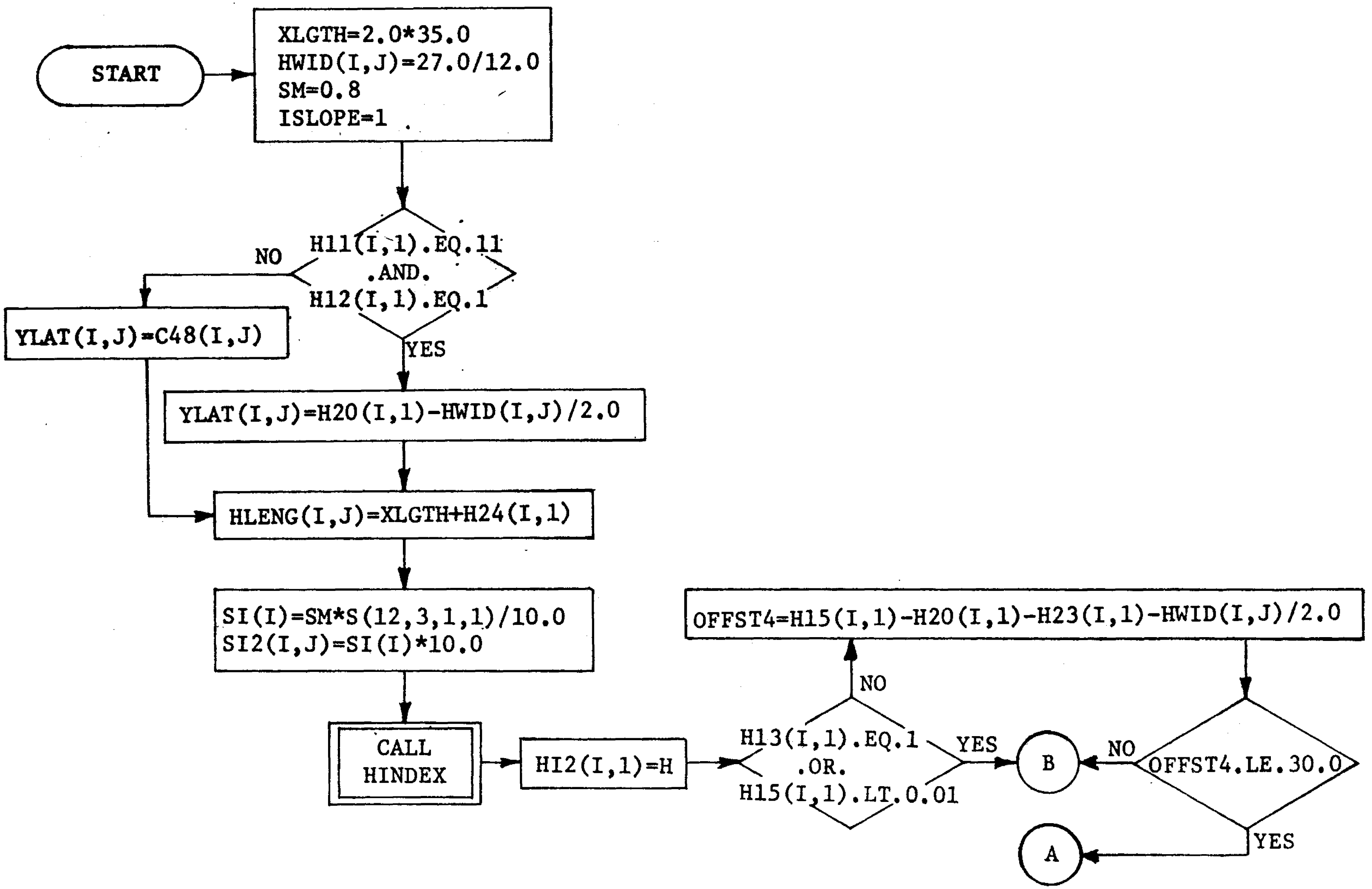


Figure 12-6. Flow Chart -- Subroutine CMBPT (1 of 3)

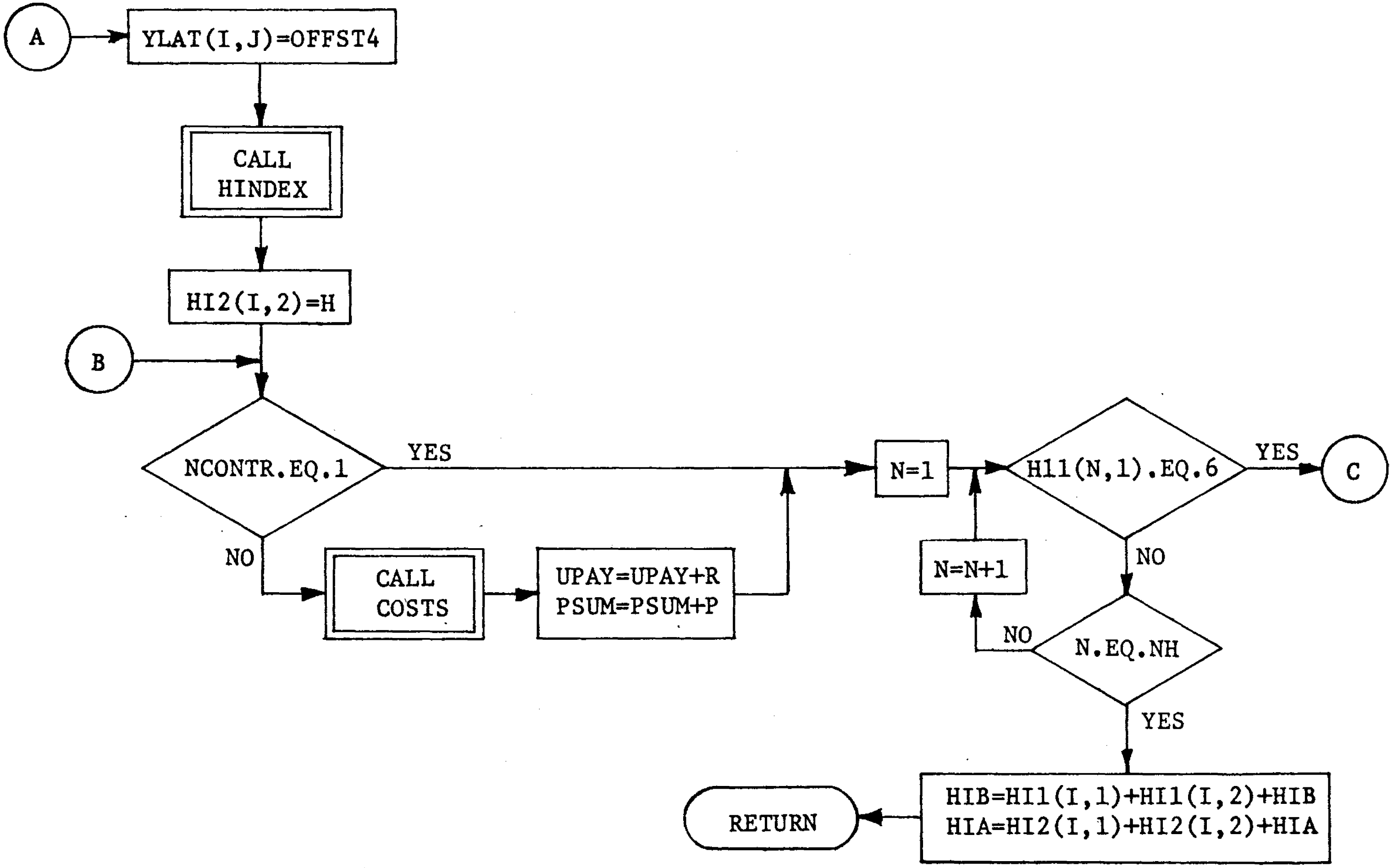


Figure 12-6. Flow Chart -- Subroutine CMBPT (Continued 2 of 3)

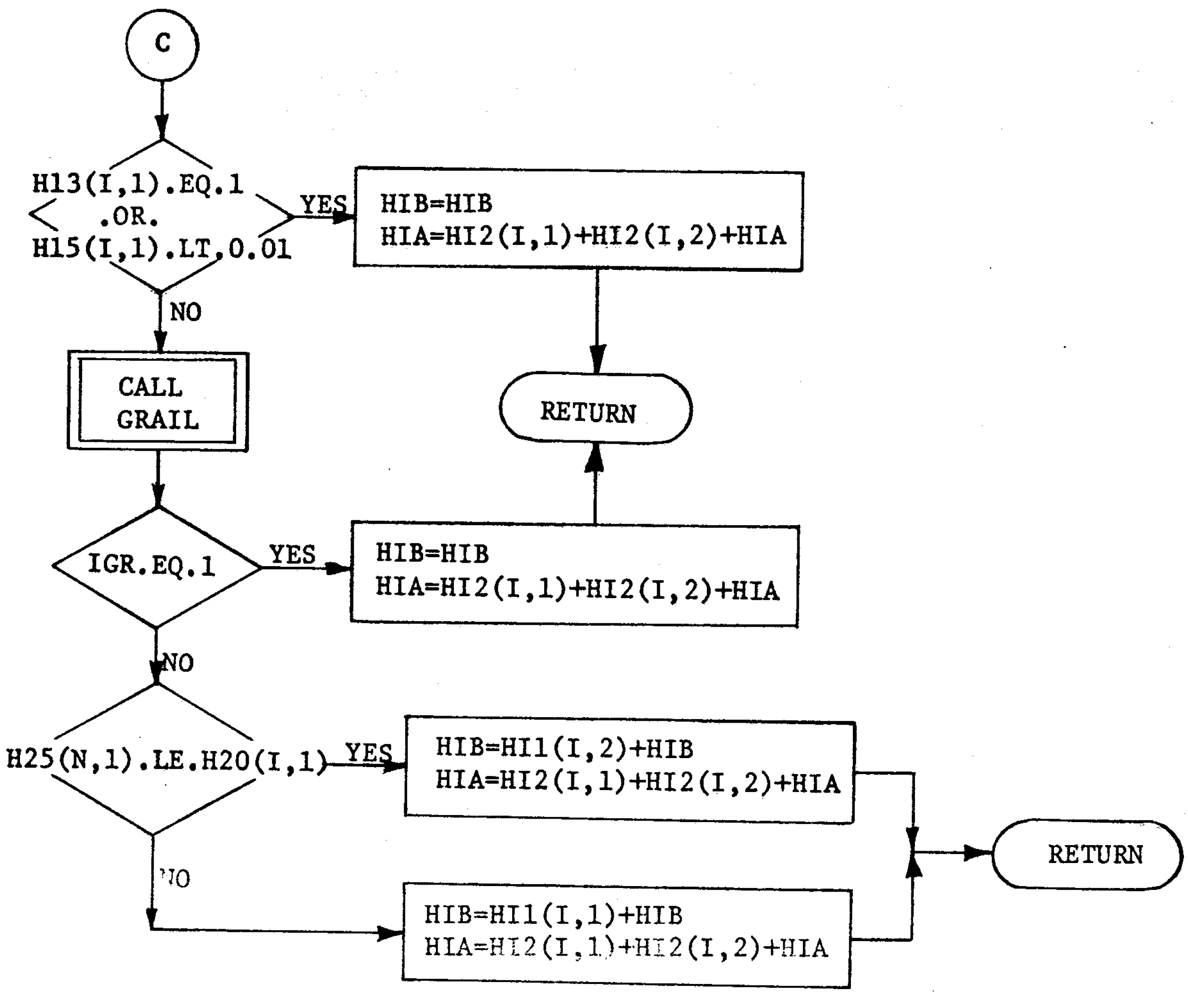


Figure 12-6. Flow Chart -- Subroutine CMBPT (Continued 3 of 3)

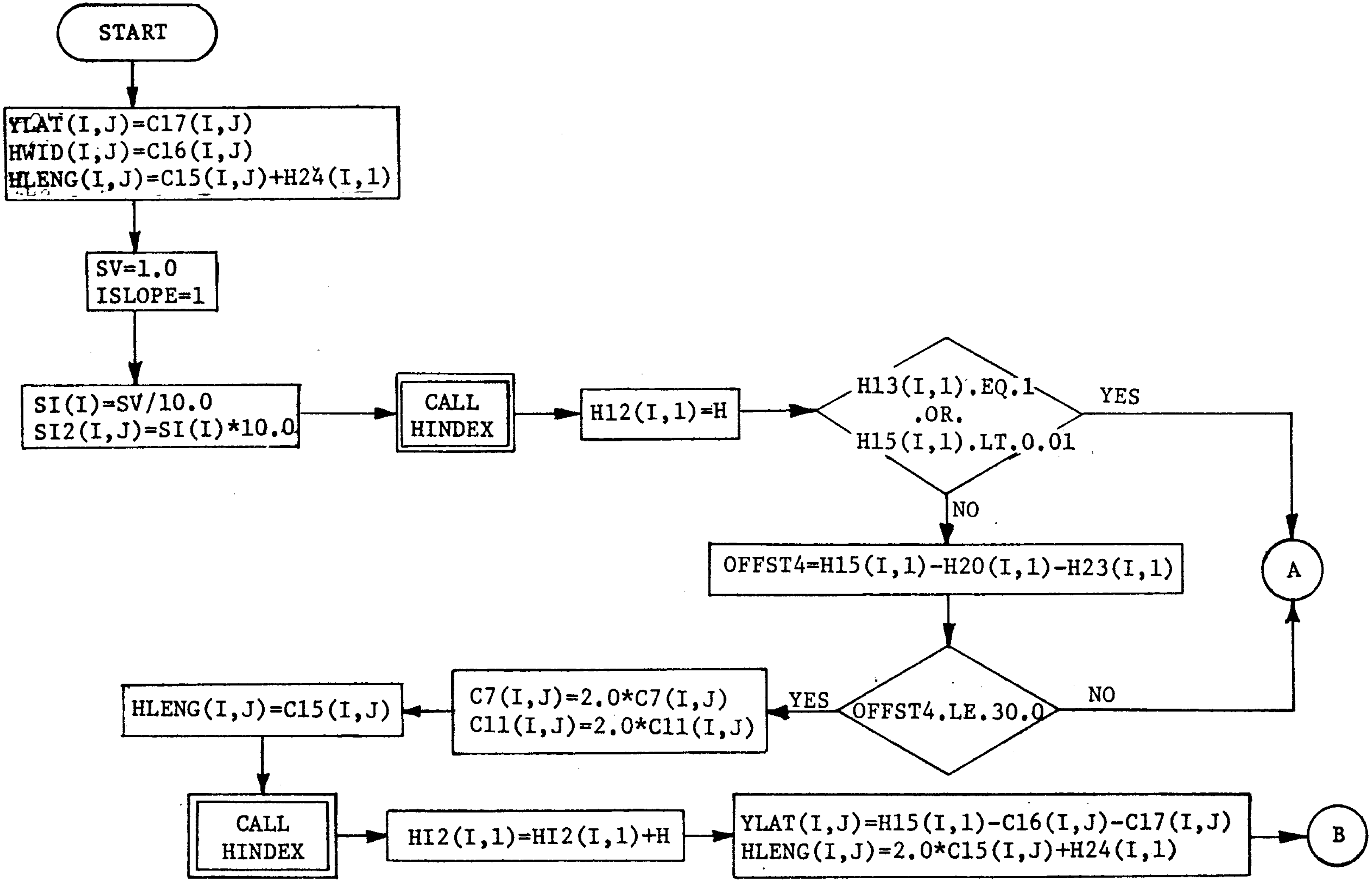


Figure 12-7. Flow Chart -- Subroutine SOFT (1 of 3)

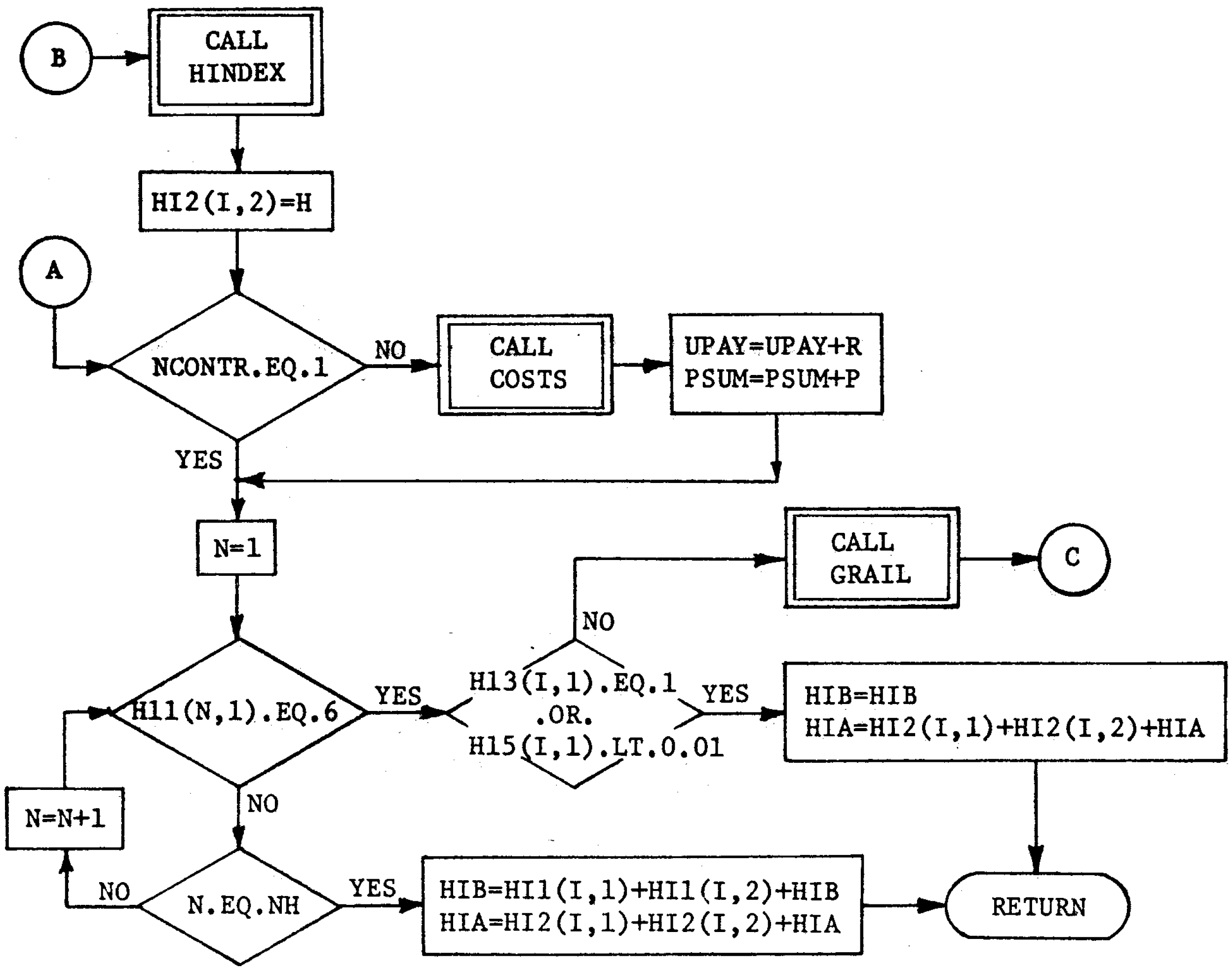


Figure 12-7. Flow Chart -- Subroutine SOFT (Continued 2 of 3)

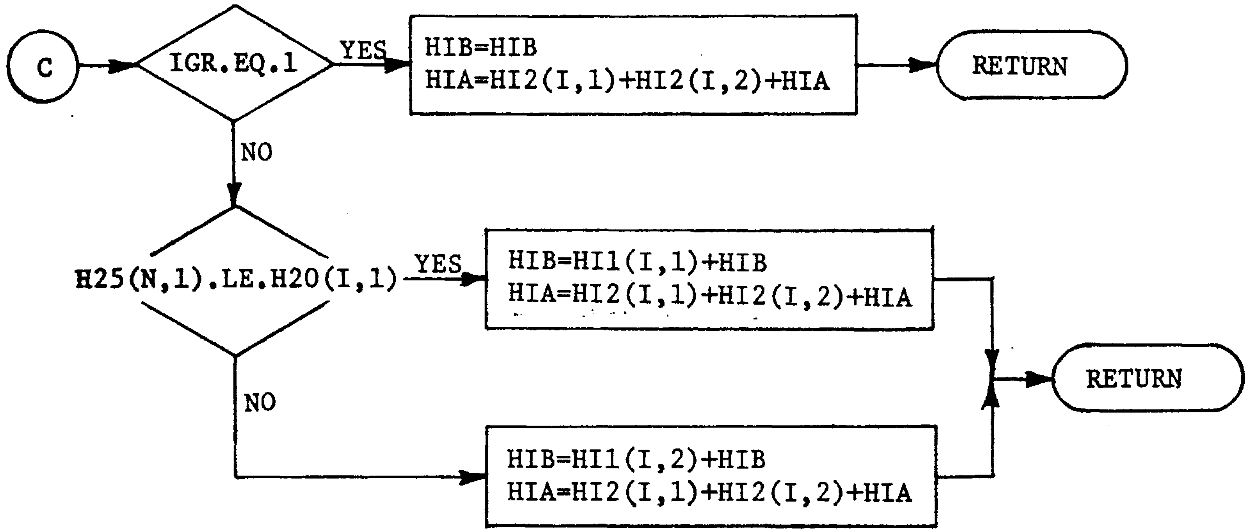


Figure 12-7. Flow Chart -- Subroutine SOFT (Continued 3 of 3)

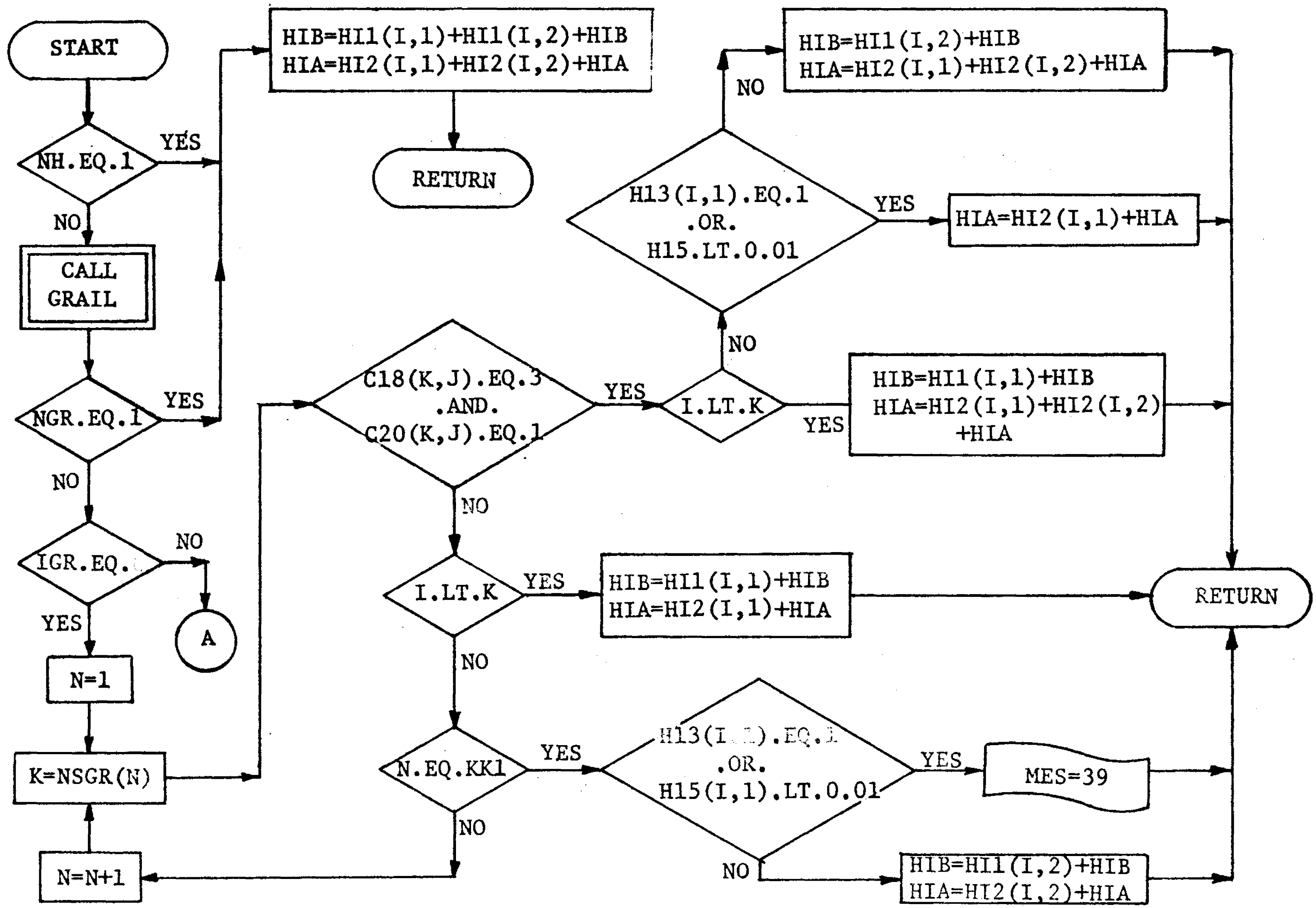


Figure 12-8. Flow Chart -- Subroutine ZERO (1 of 3)

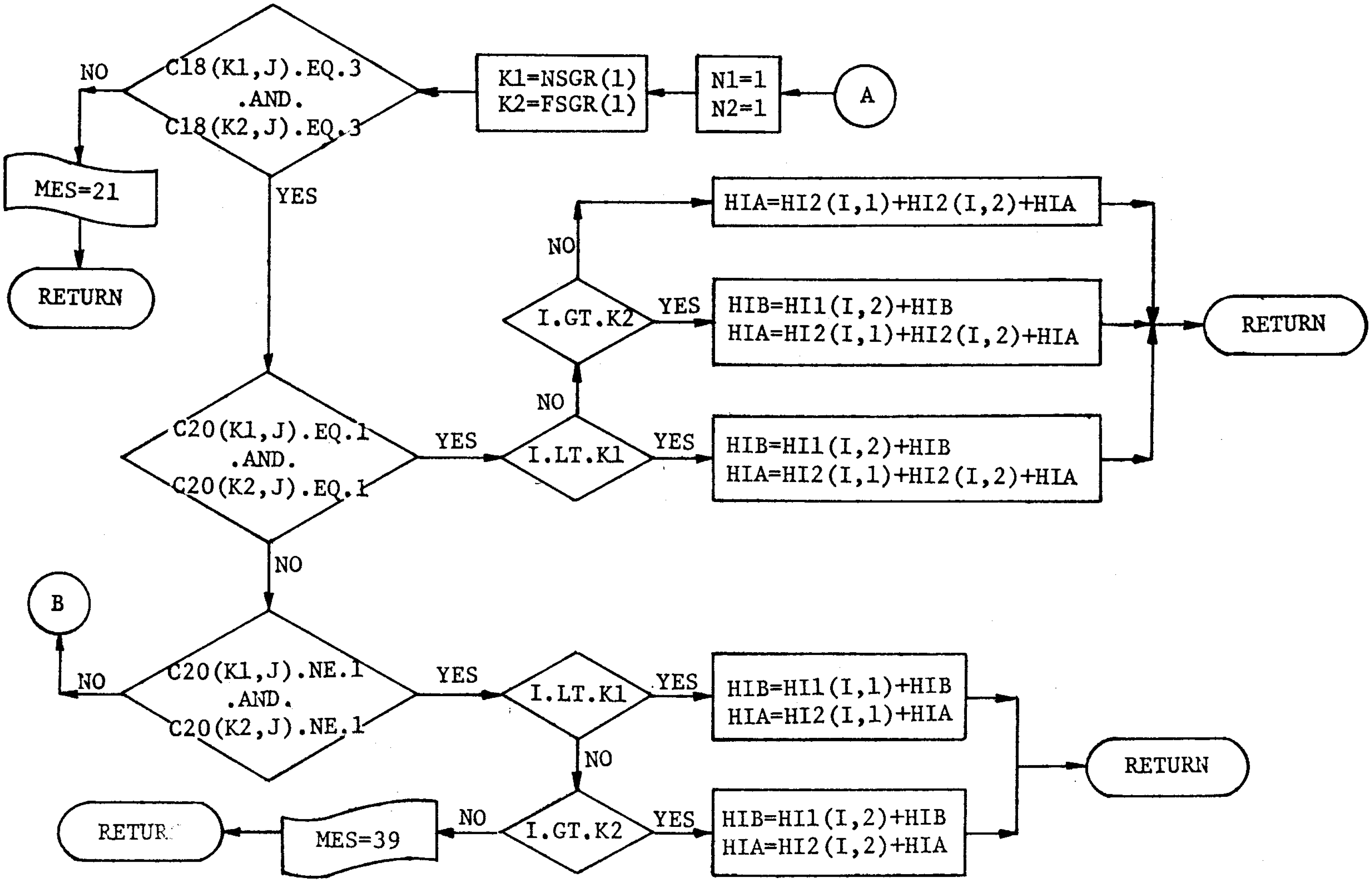


Figure 12-8. Flow Chart -- Subroutine ZERO (Continued 2 of 3)

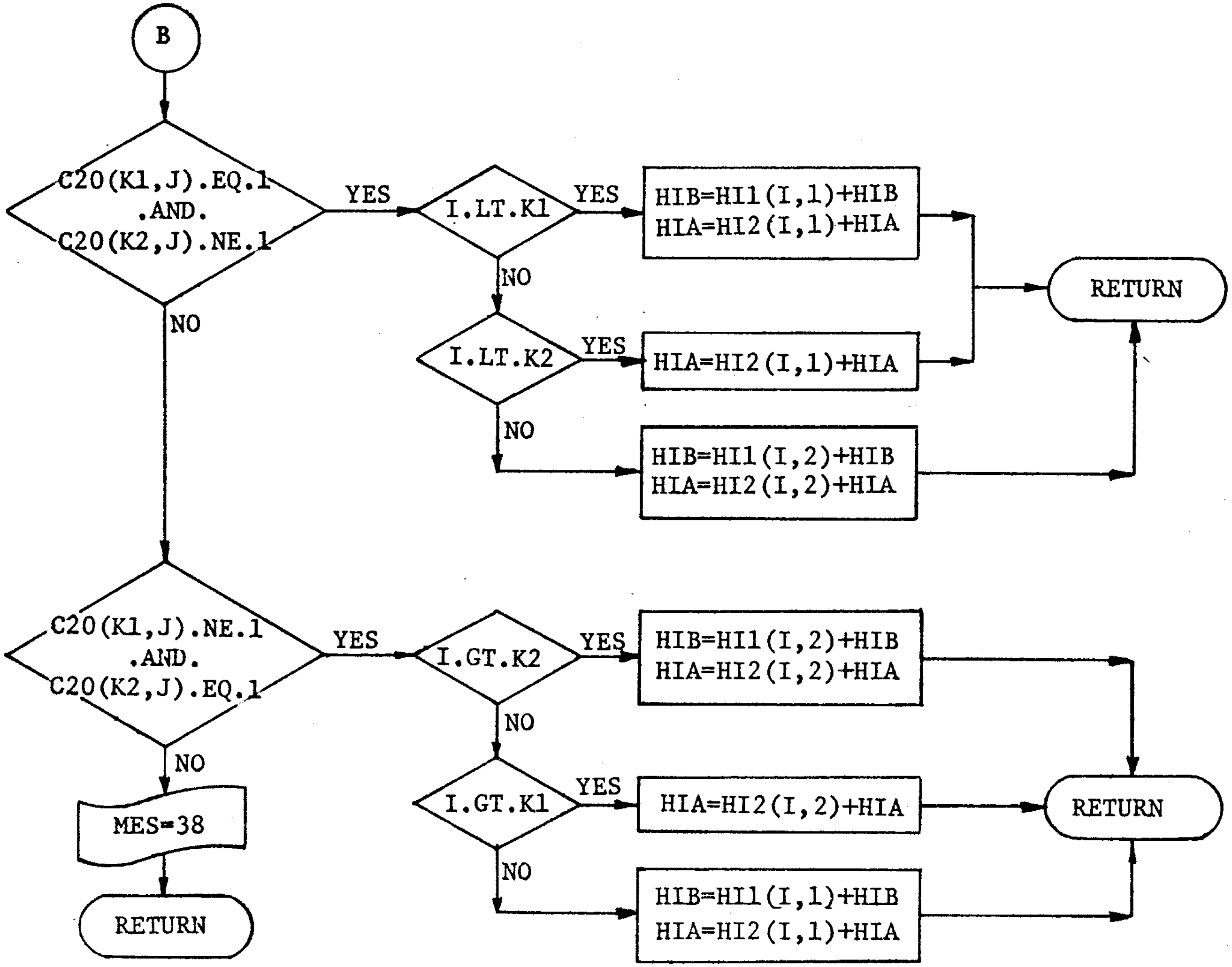


Figure 12-8. Flow Chart -- Subroutine ZERO (Continued 3 of 3)

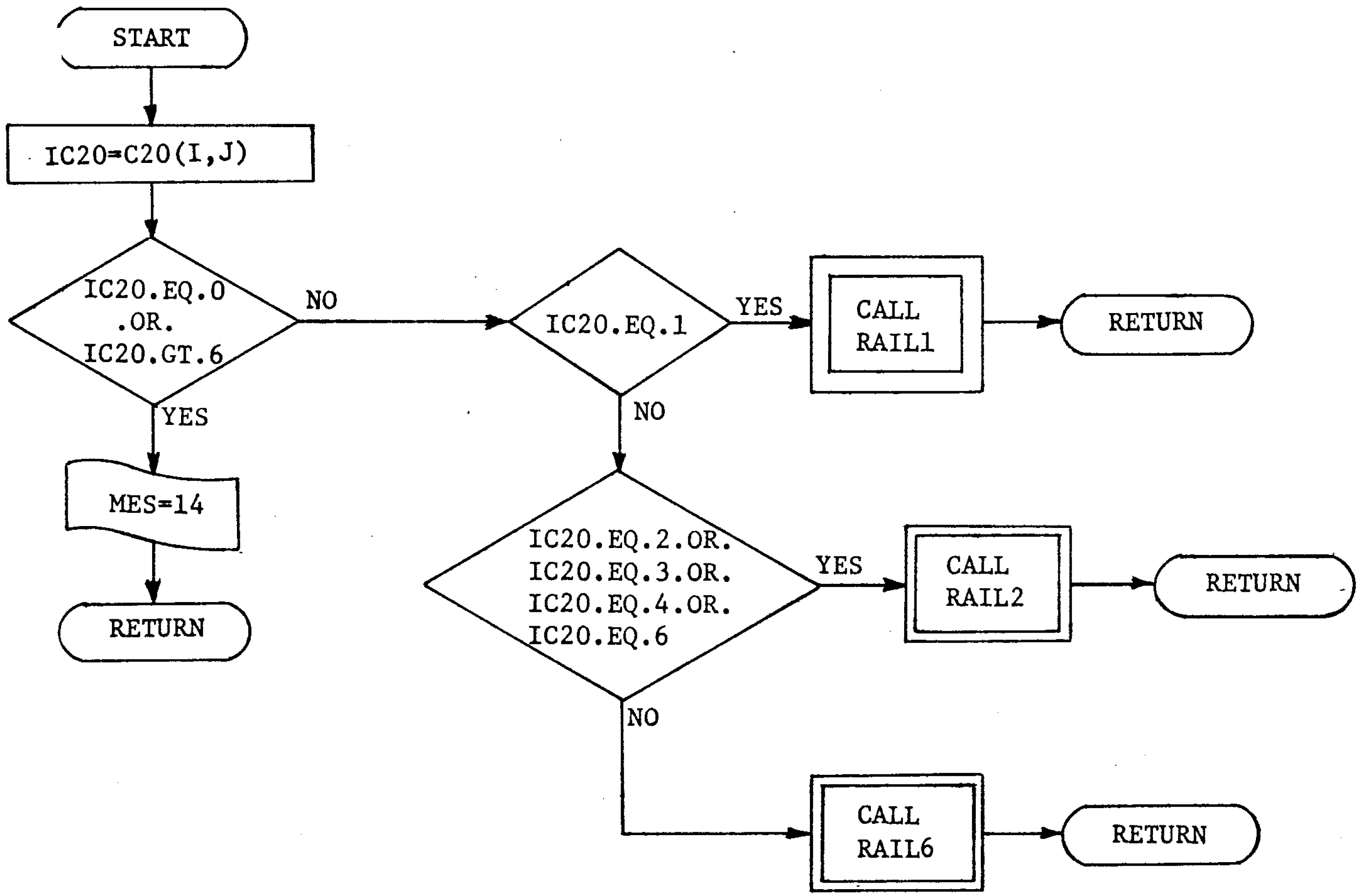


Figure 12-9. Flow Chart -- Subroutine RAIL

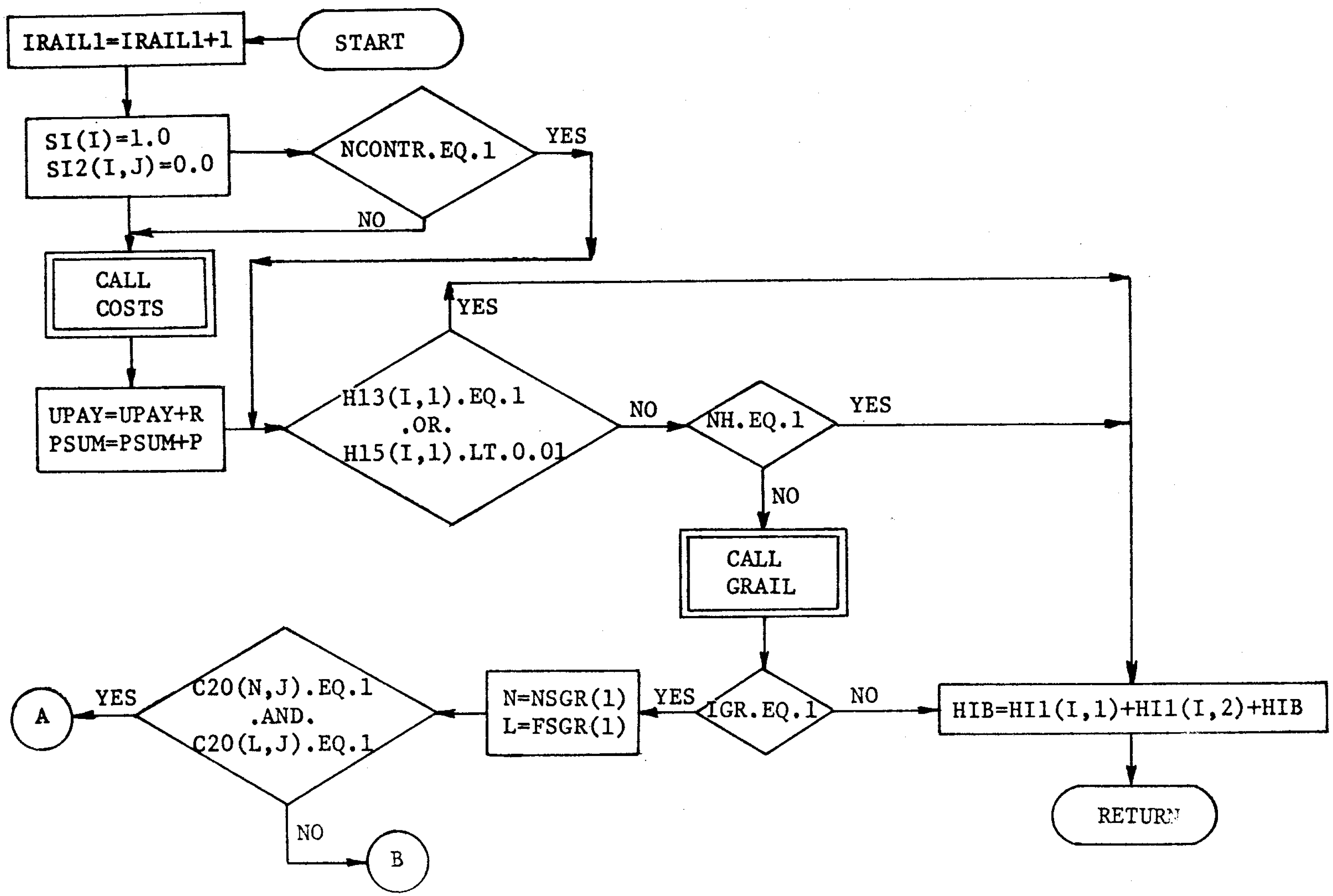


Figure 12-10. Flow Chart -- Subroutine RAIL1 (1 of 3)

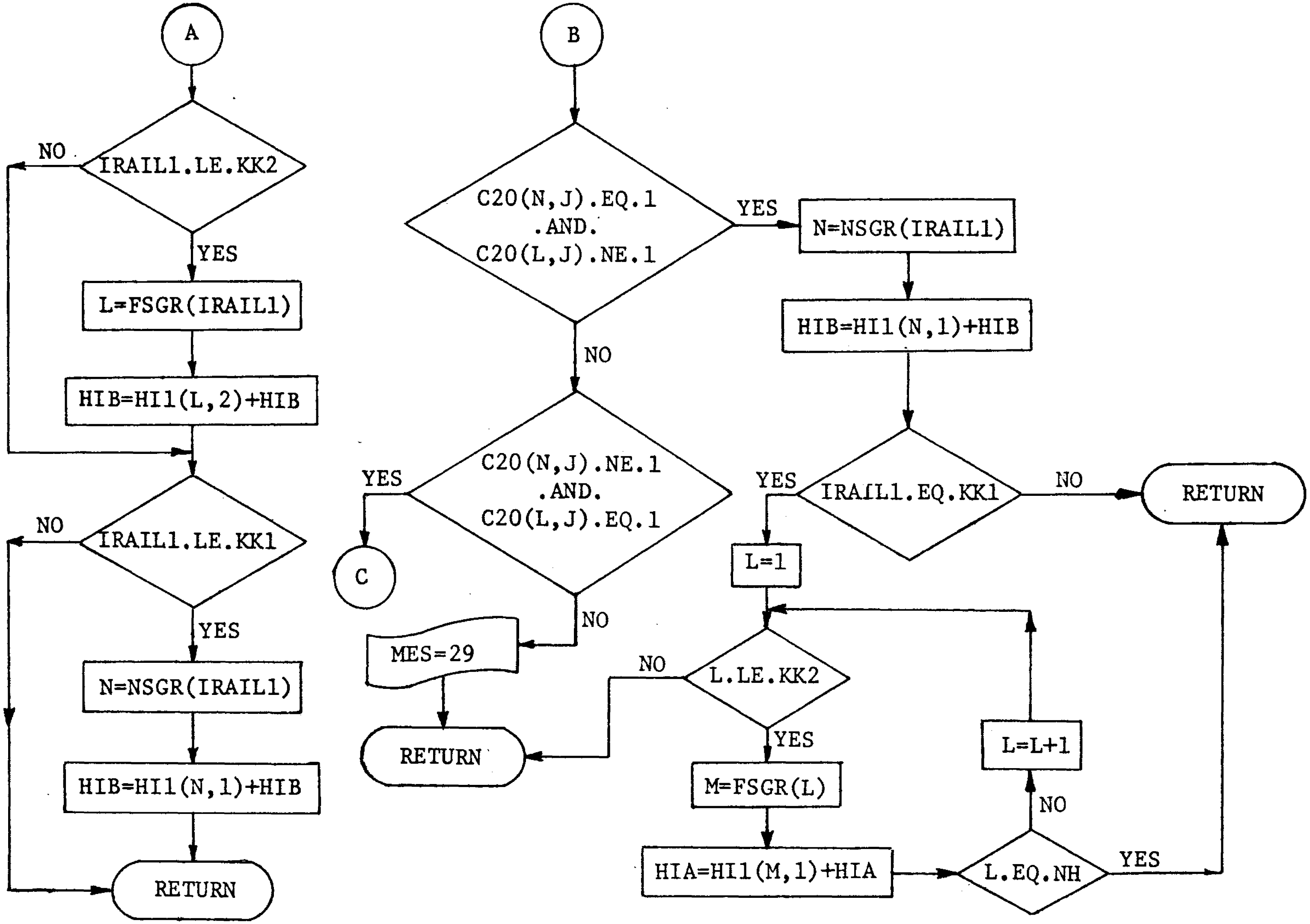


Figure 12-10. Flow Chart -- Subroutine RAIL1 (Continued 2 of 3)

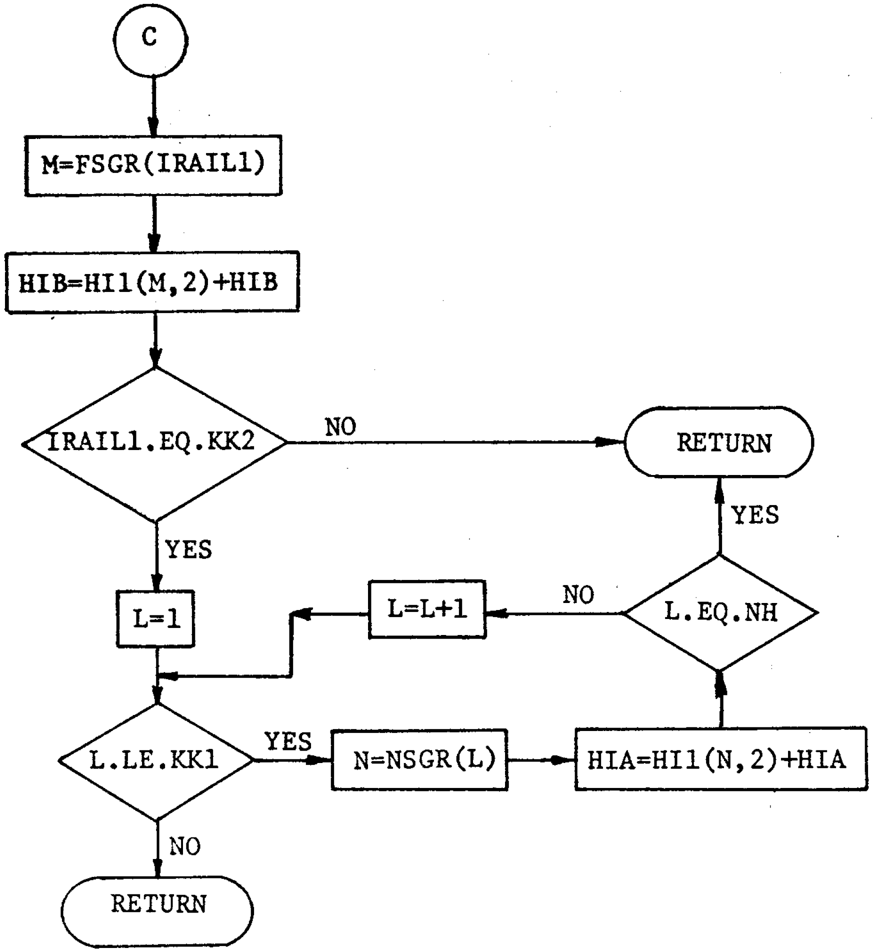


Figure 12-10. Flow Chart -- Subroutine RAIL1 (Continued 3 of 3)

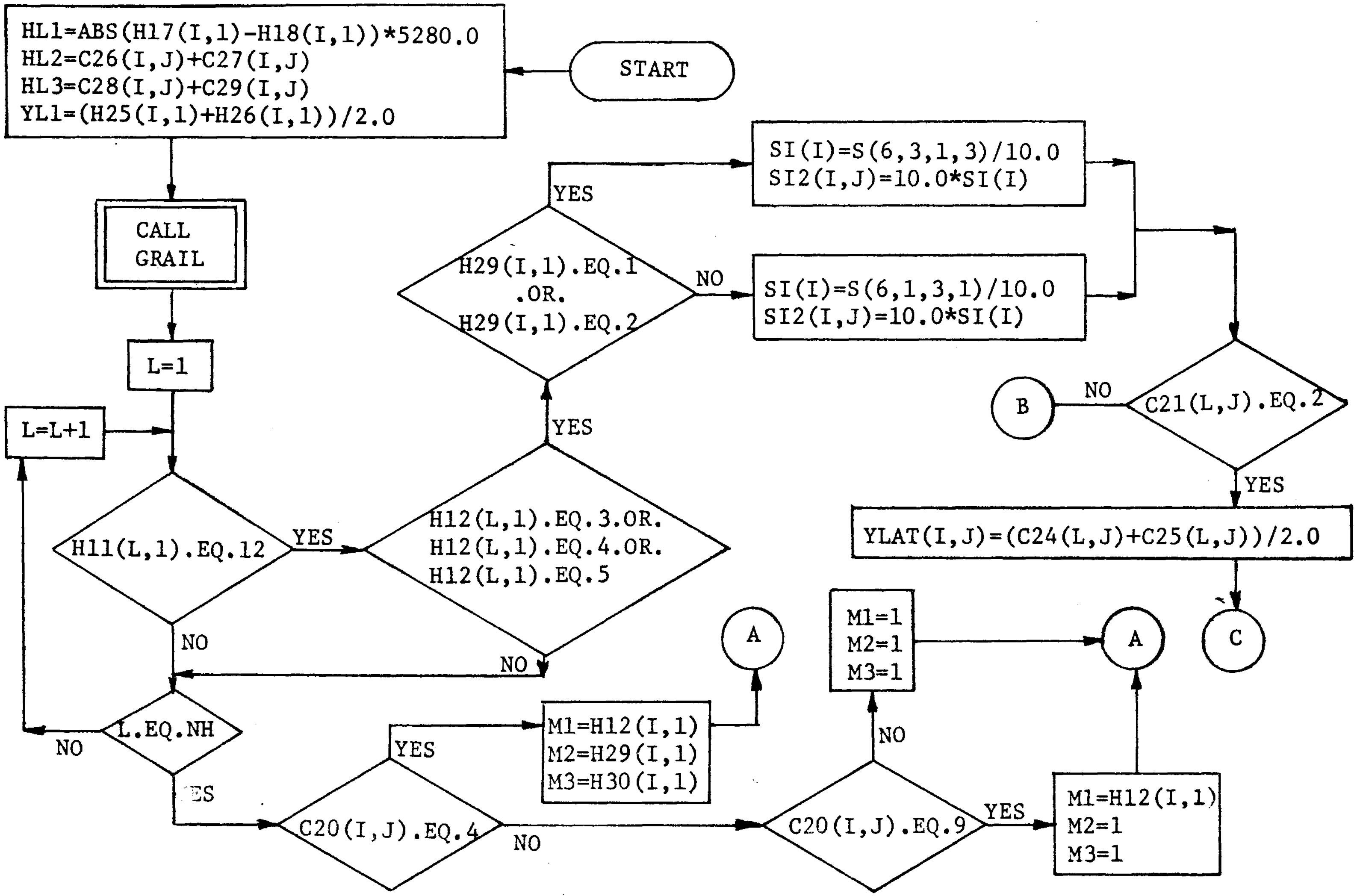


Figure 12-11. Flow Chart -- Subroutine RAIL2 (1 of 3)

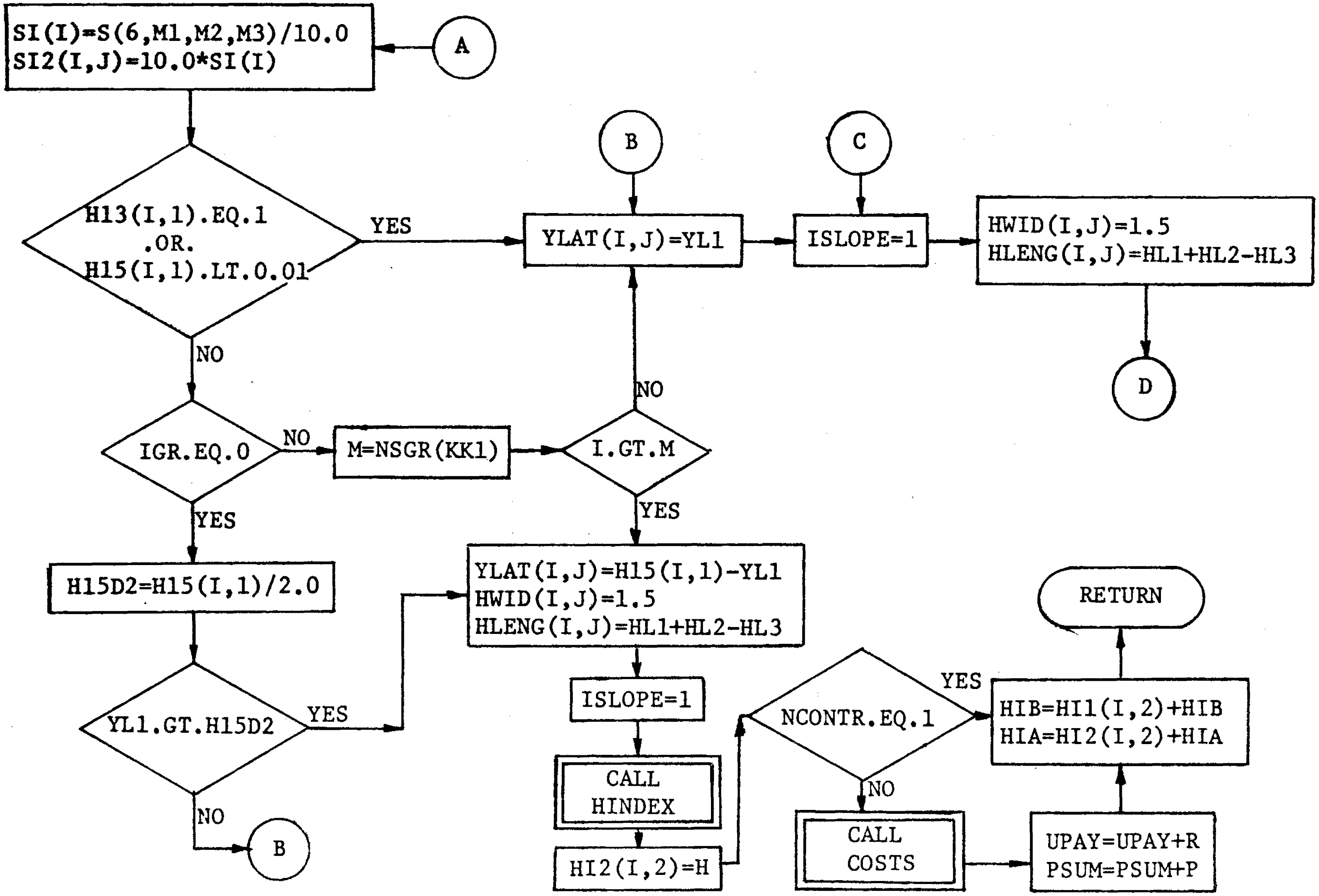


Figure 12-11. Flow Chart -- Subroutine RAIL2 (Continued 2 of 3)

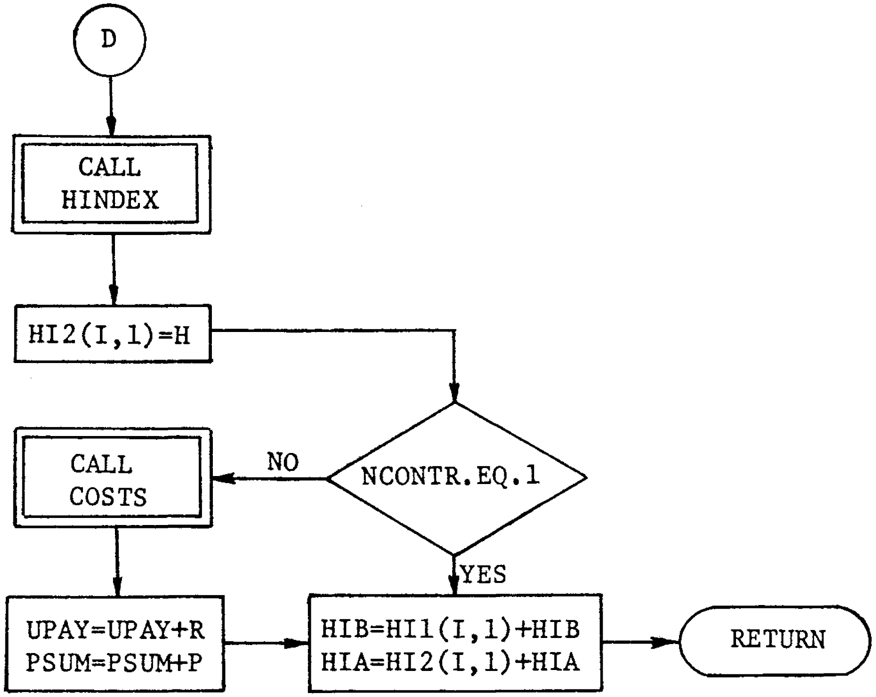


Figure 12-11. Flow Chart -- Subroutine RAIL2 (Continued 3 of 3)

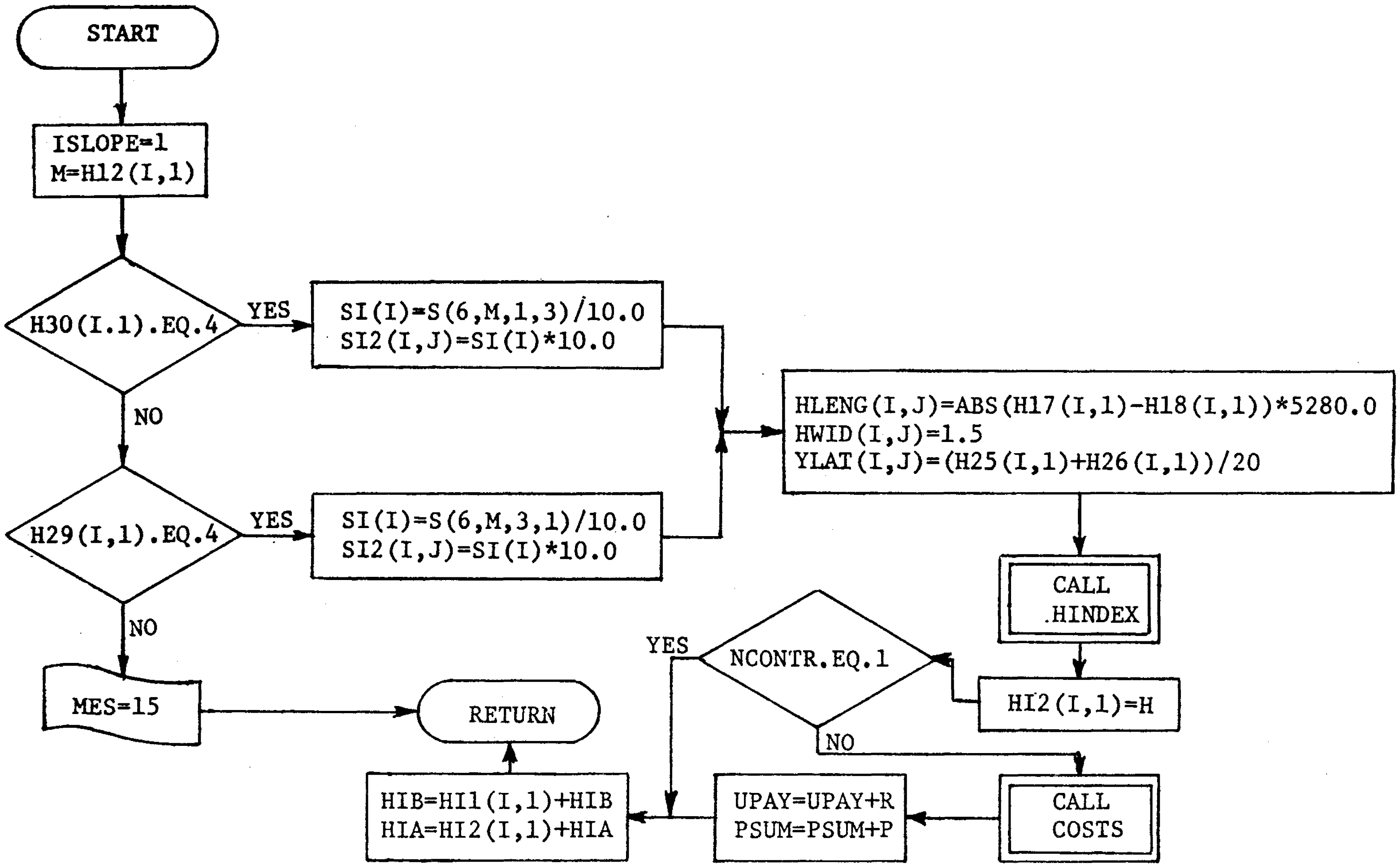


Figure 12-12. Flow Chart -- Subroutine RAIL6

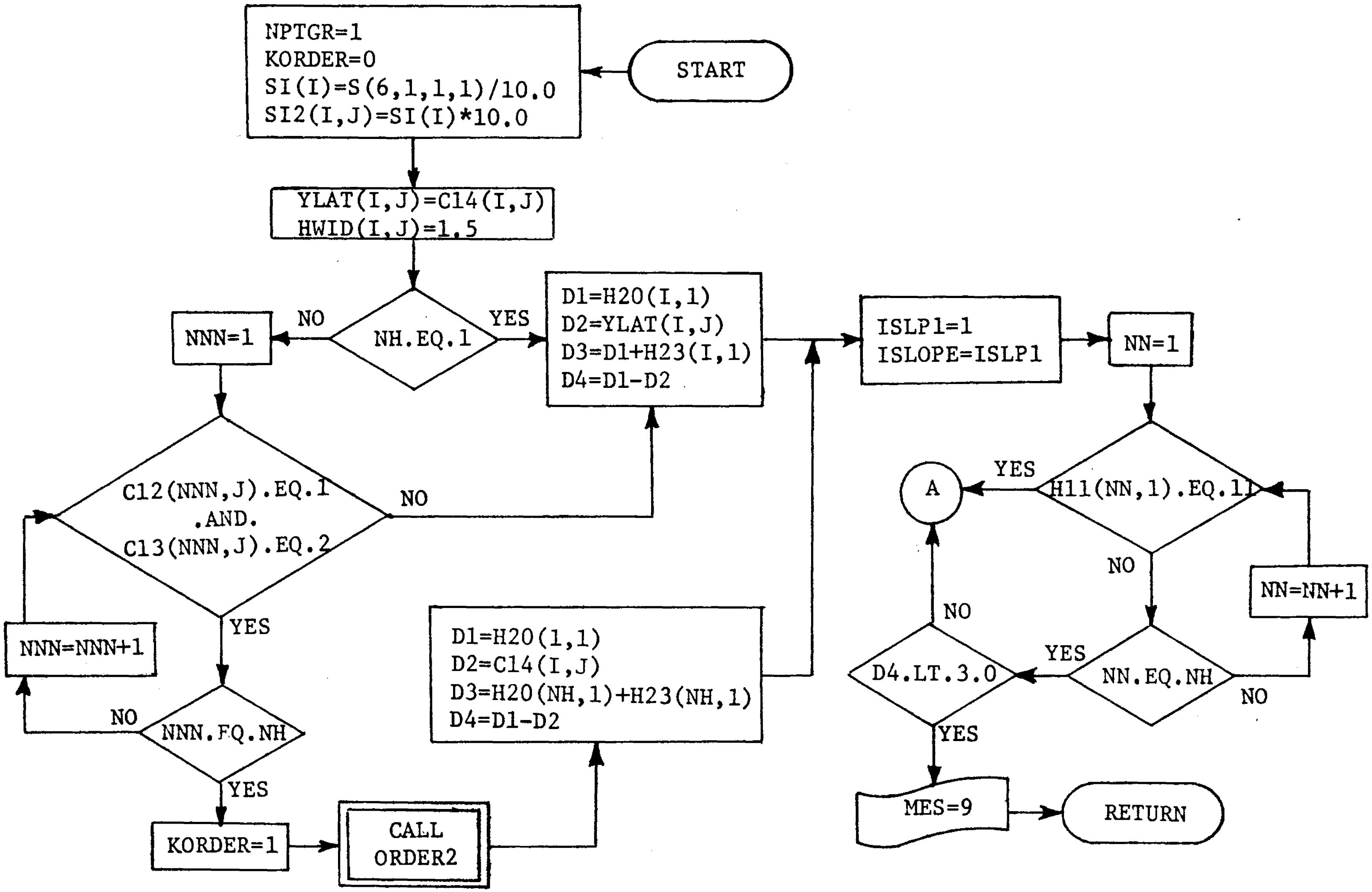


Figure 12-13. Flow Chart -- Subroutine PTRAIL (1 of 4)

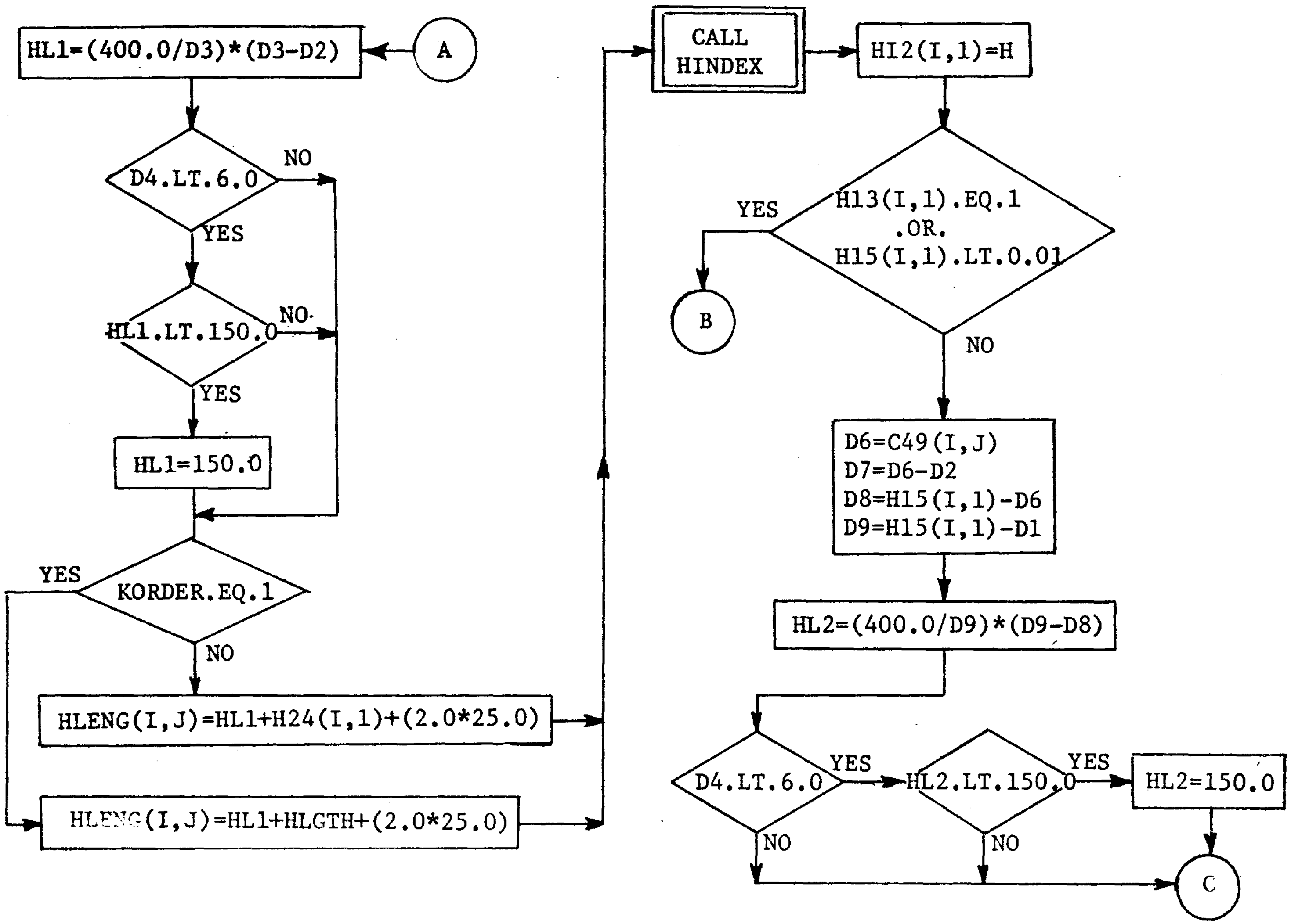


Figure 12-13. Flow Chart -- Subroutine PTRAIL (Continued 2 of 4)

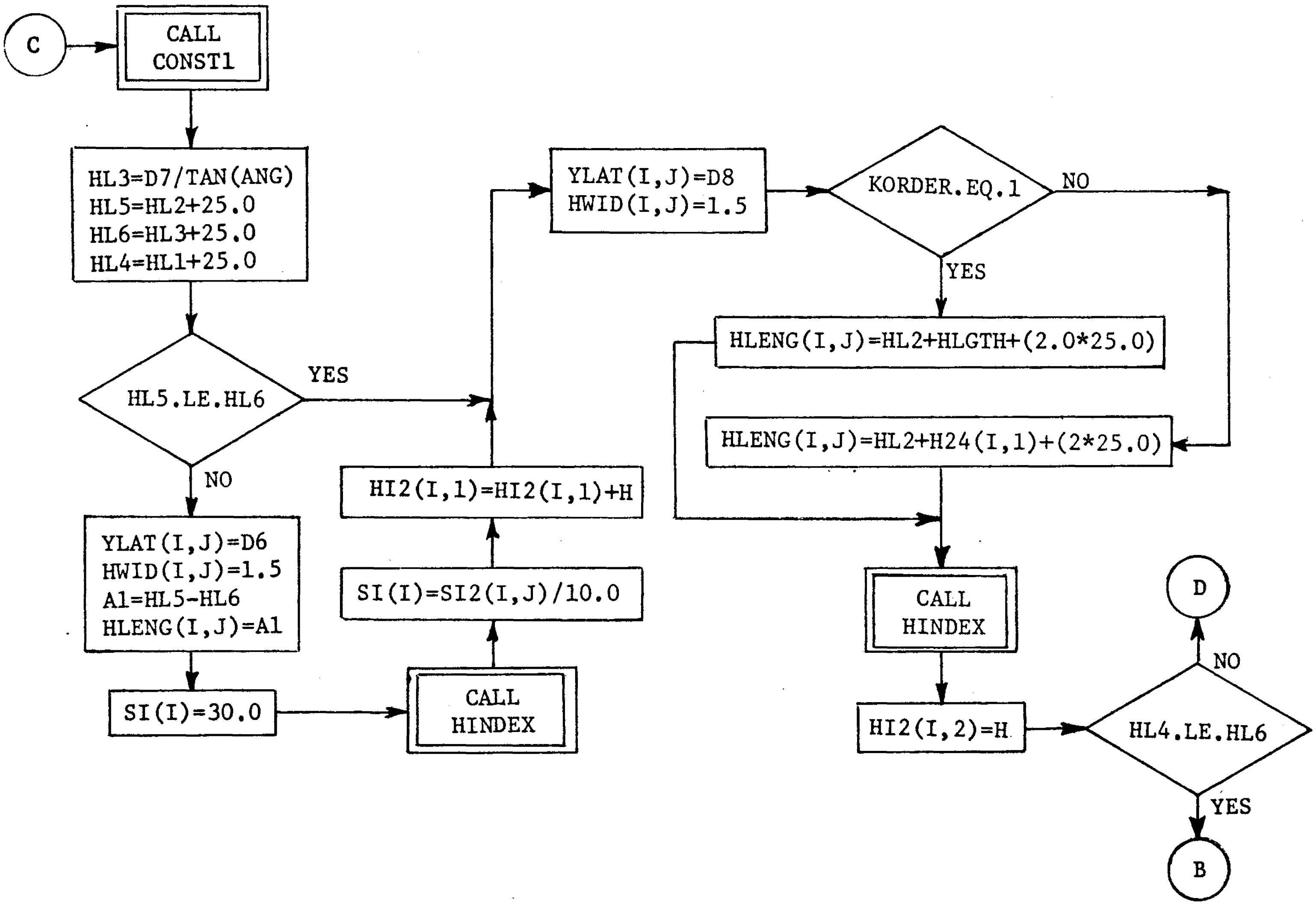


Figure 12-13. Flow Chart -- Subroutine PTRAIL (Continued 3 of 4)

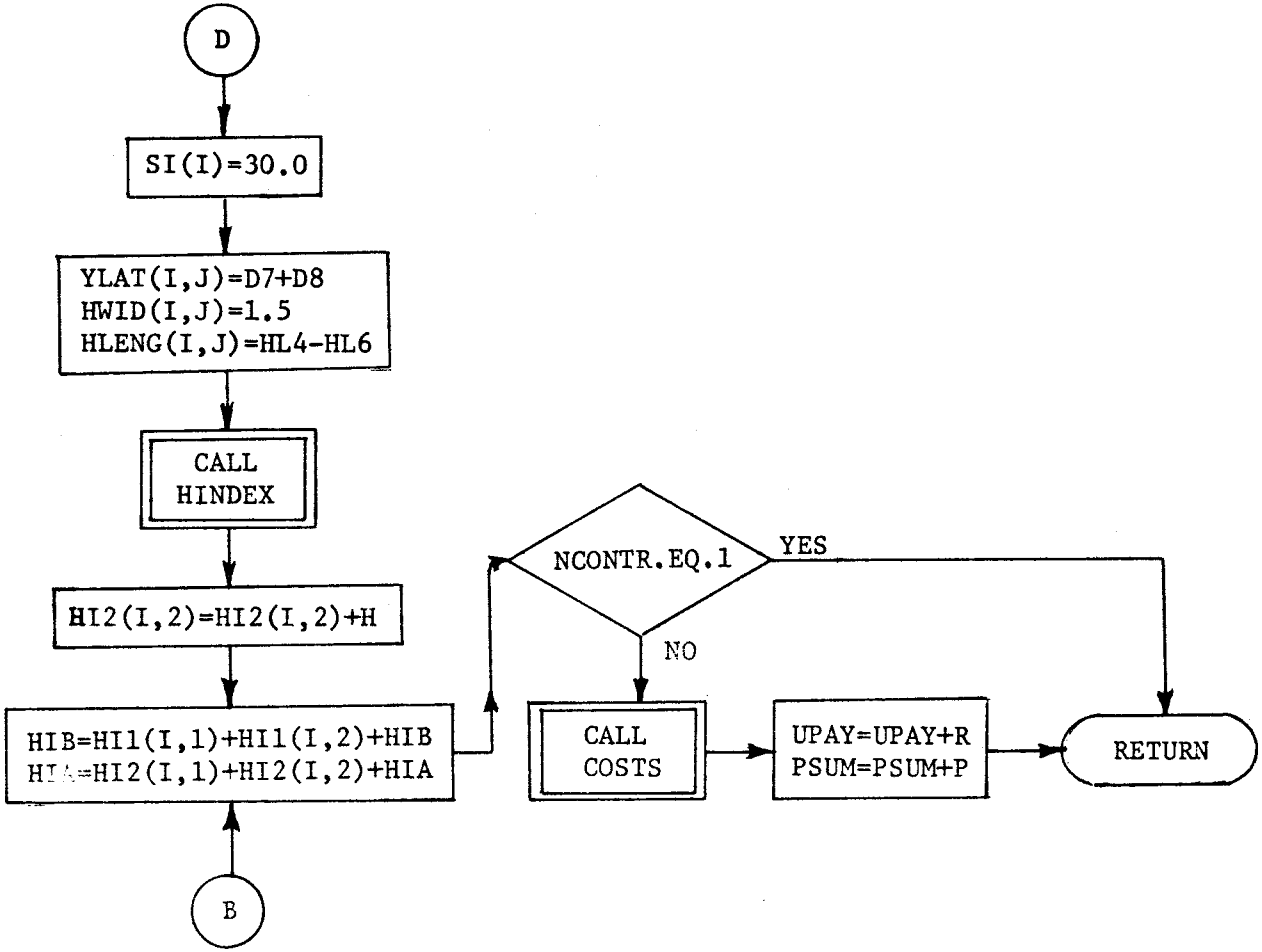


Figure 12-13. Flow Chart -- Subroutine PTRAIL (Continued 4 of 4)

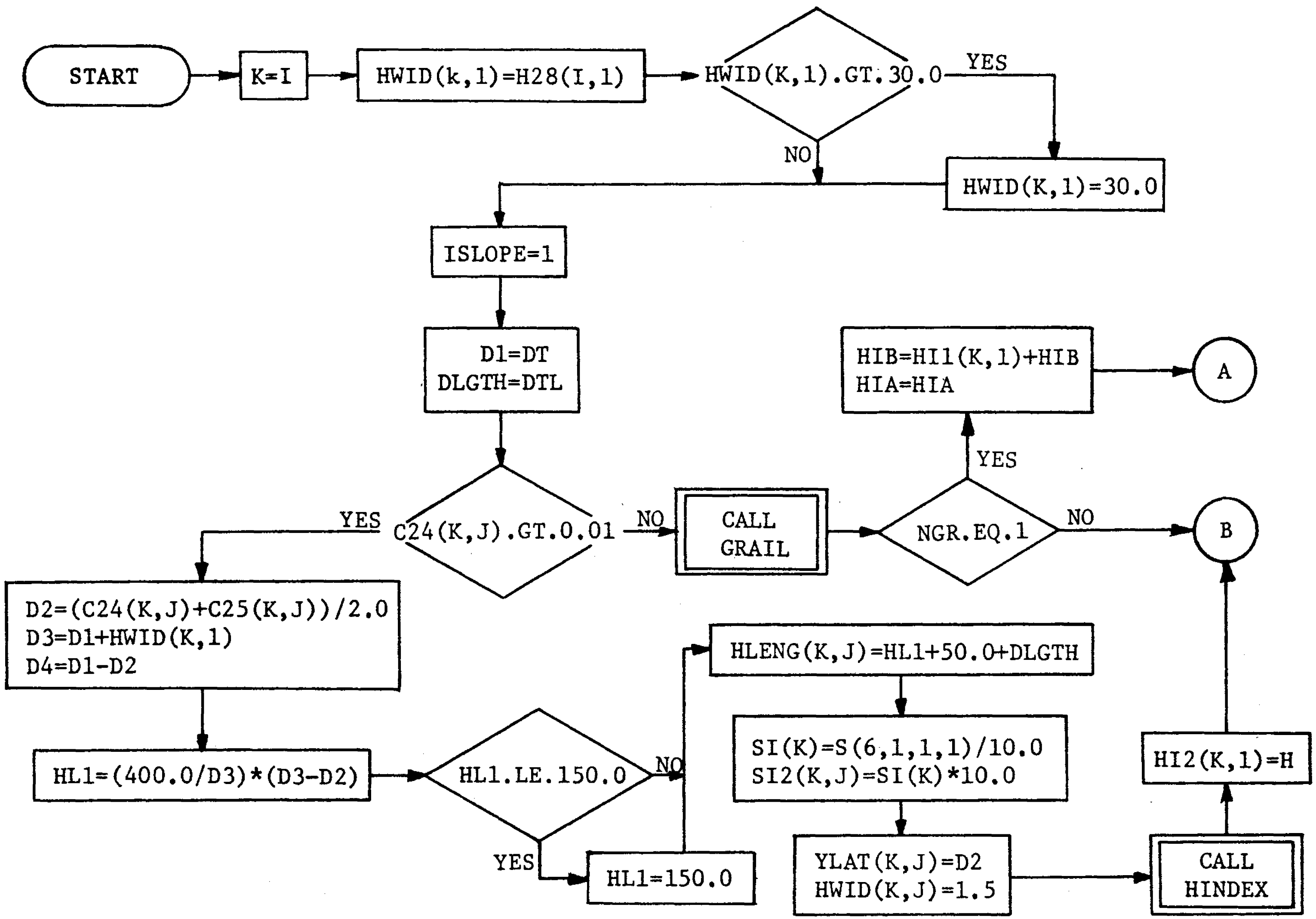


Figure 12-14. Flow Chart -- Subroutine DTRAIL (1 of 3)

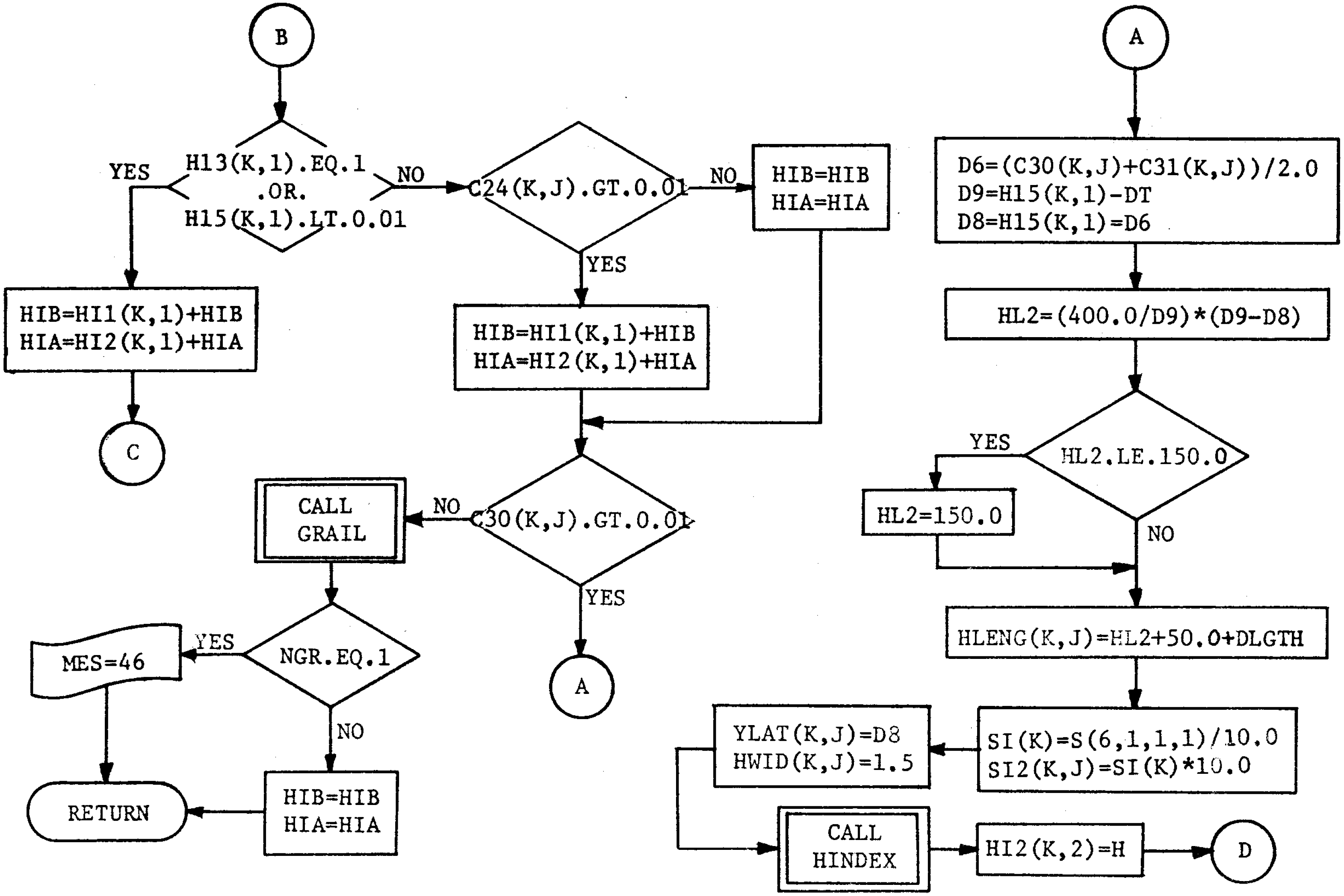


Figure 12-14. Flow Chart -- Subroutine DTRAIL (Continued 2 of 3)

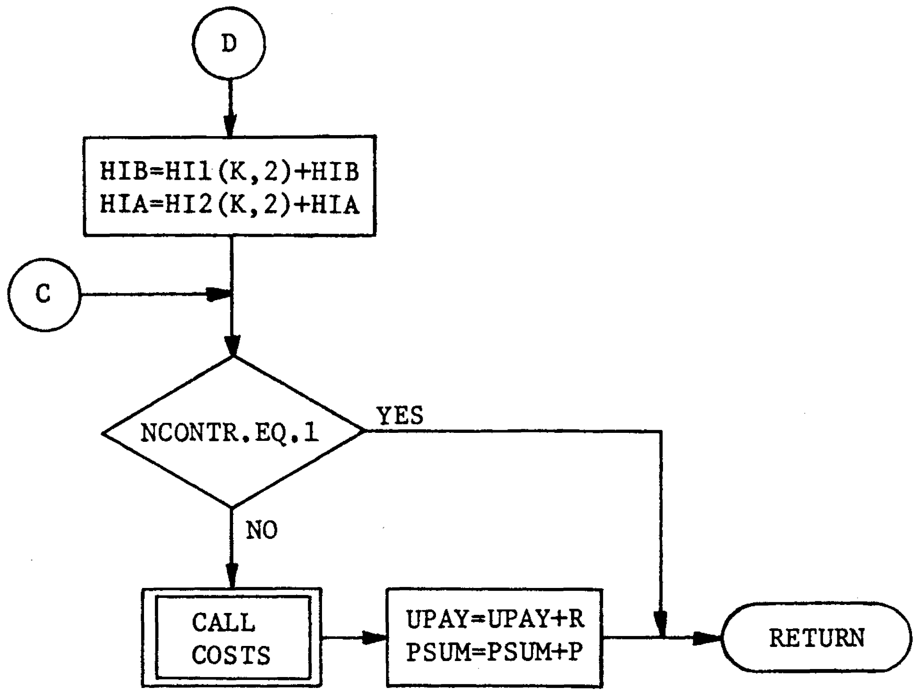


Figure 12-14. Flow Chart -- Subroutine DTRAIL (Continued 3 of 3)

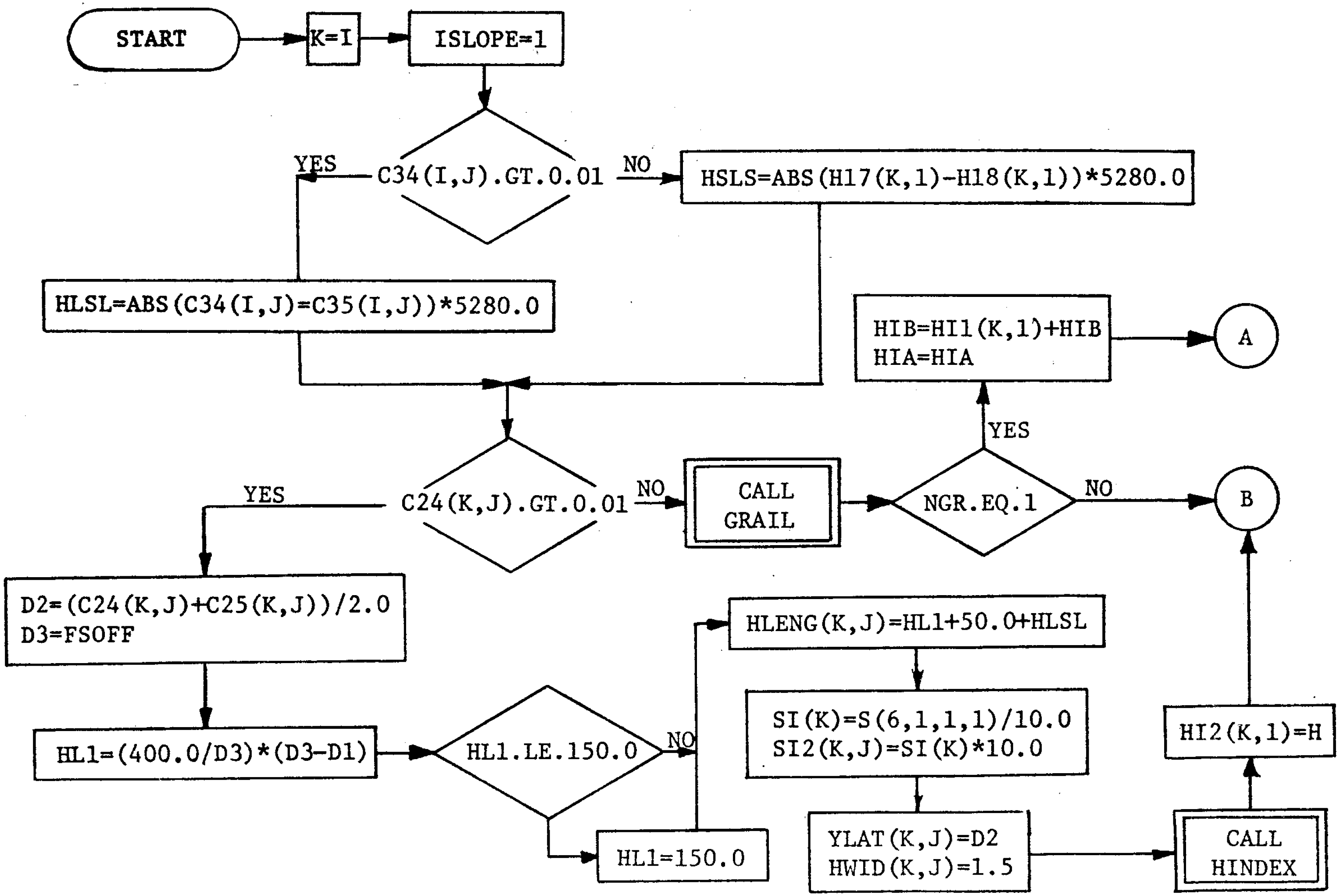


Figure 12-15. Flow Chart -- Subroutine SLRAIL (1 of 3)

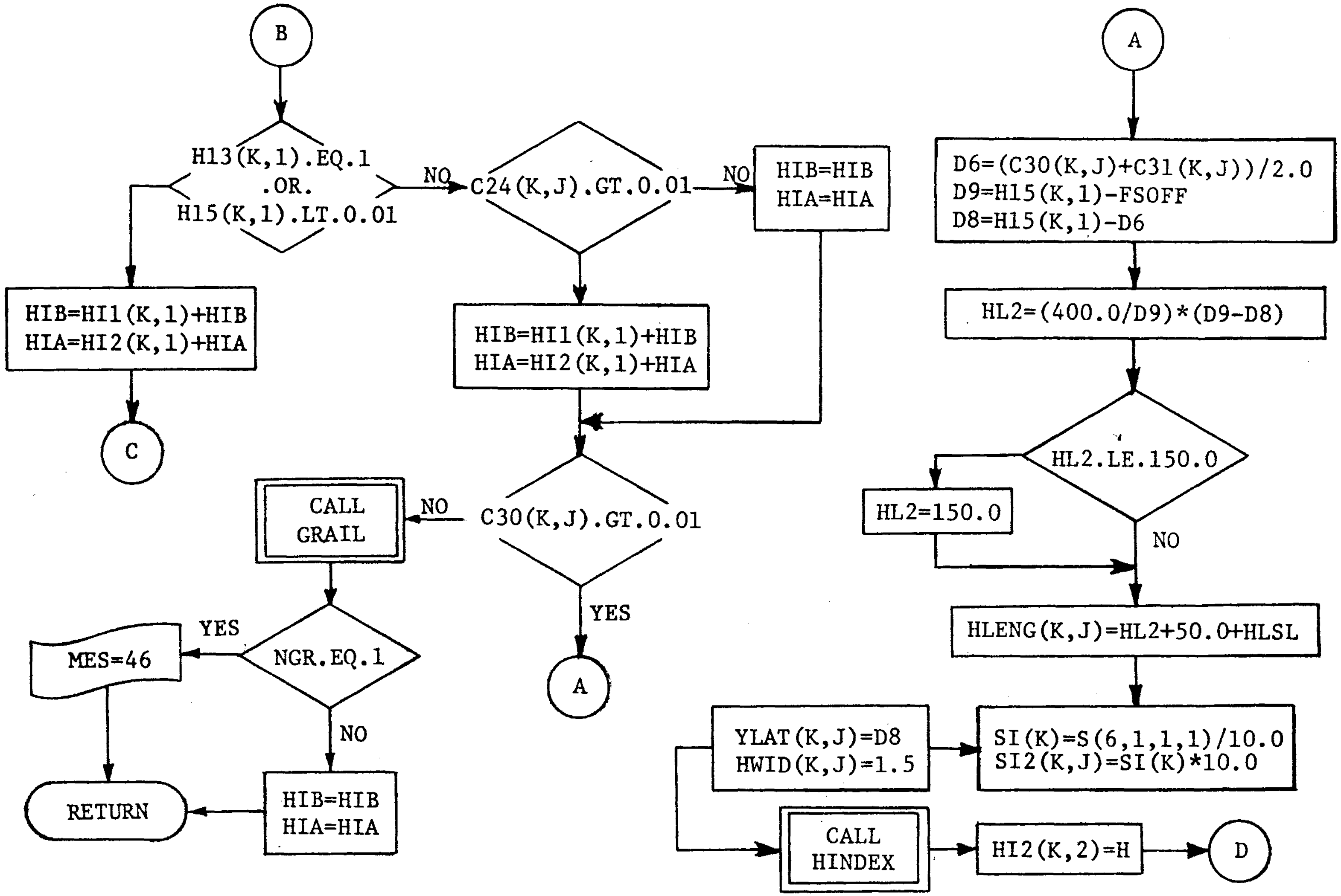


Figure 12-15. Flow Chart -- Subroutine SLRAIL (Continued 2 of 3)

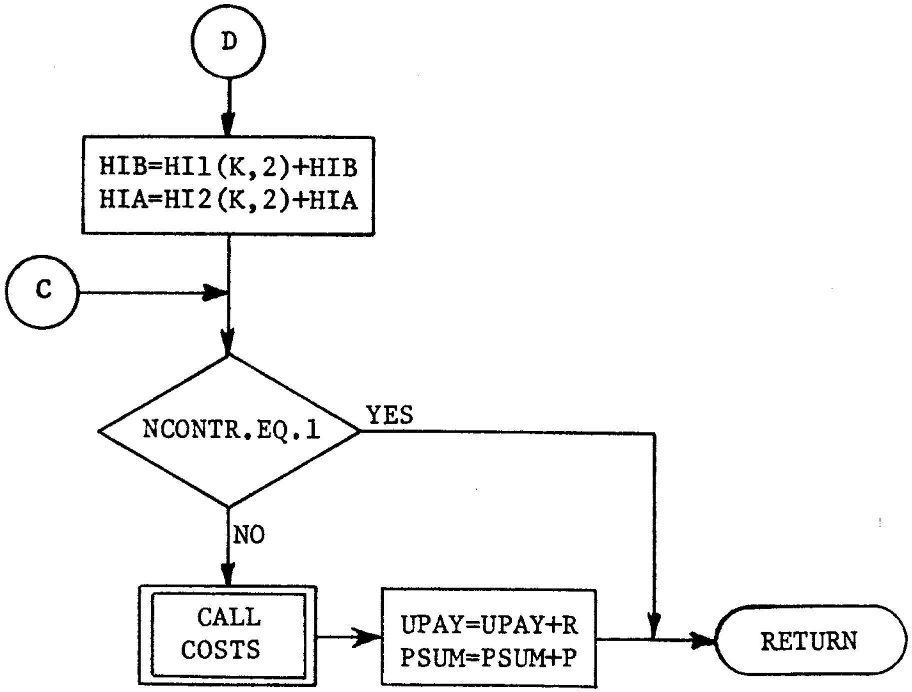


Figure 12-15. Flow Chart -- Subroutine SLRAIL (Continued 3 of 3)

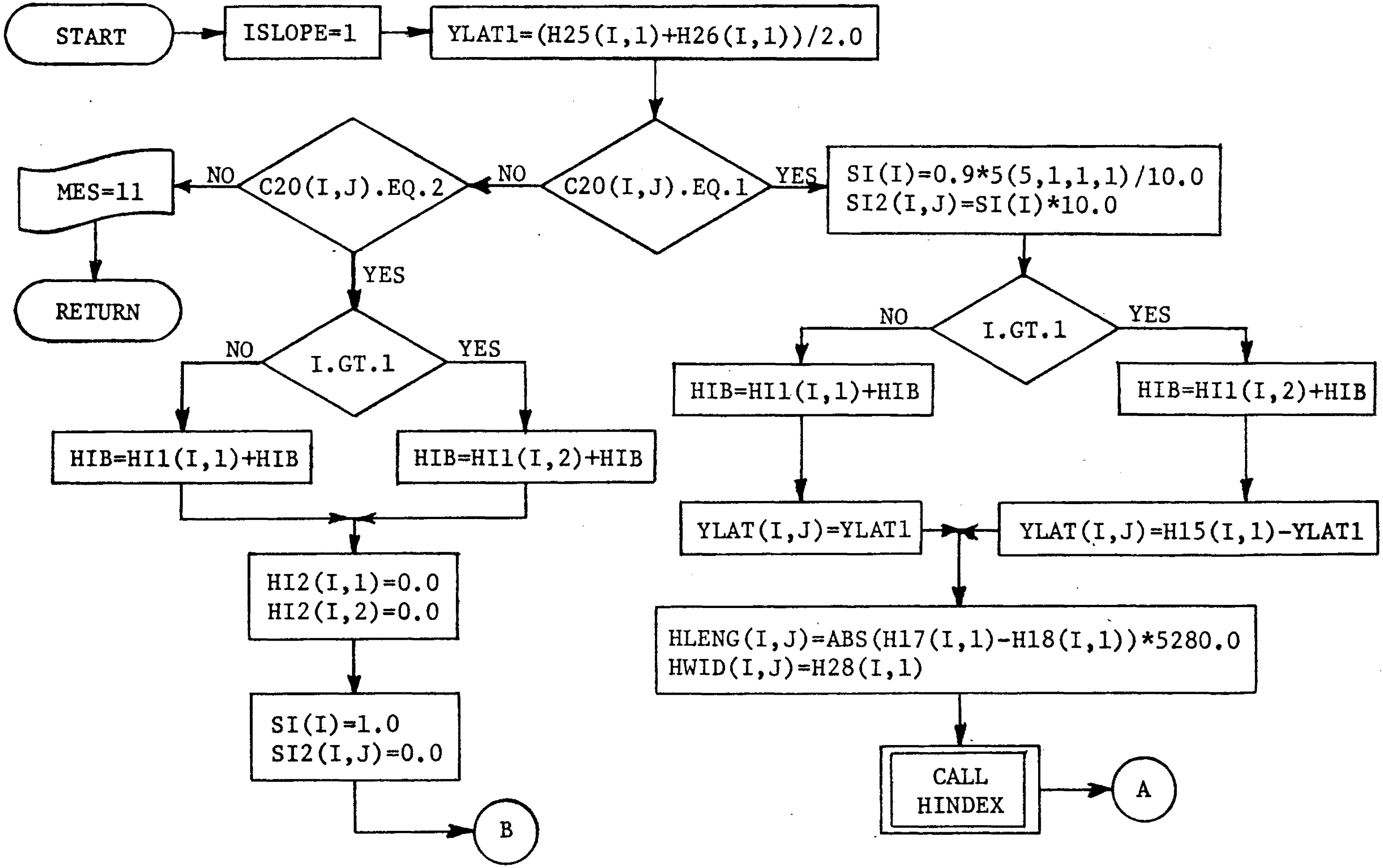


Figure 12-16. Flow Chart -- Subroutine CURB (1 of 2)

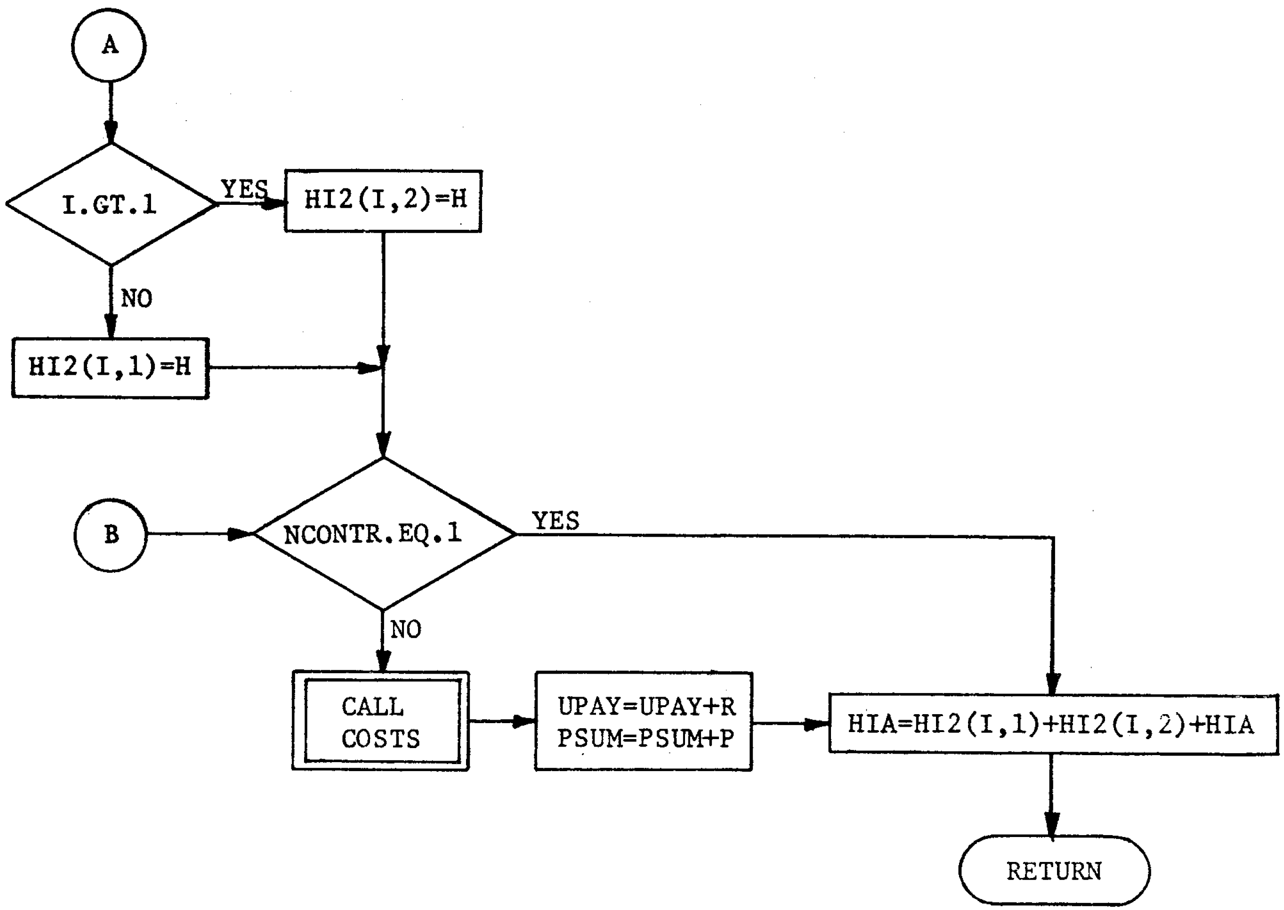


Figure 12-16. Flow Chart -- Subroutine CURB (Continued 2 of 2)

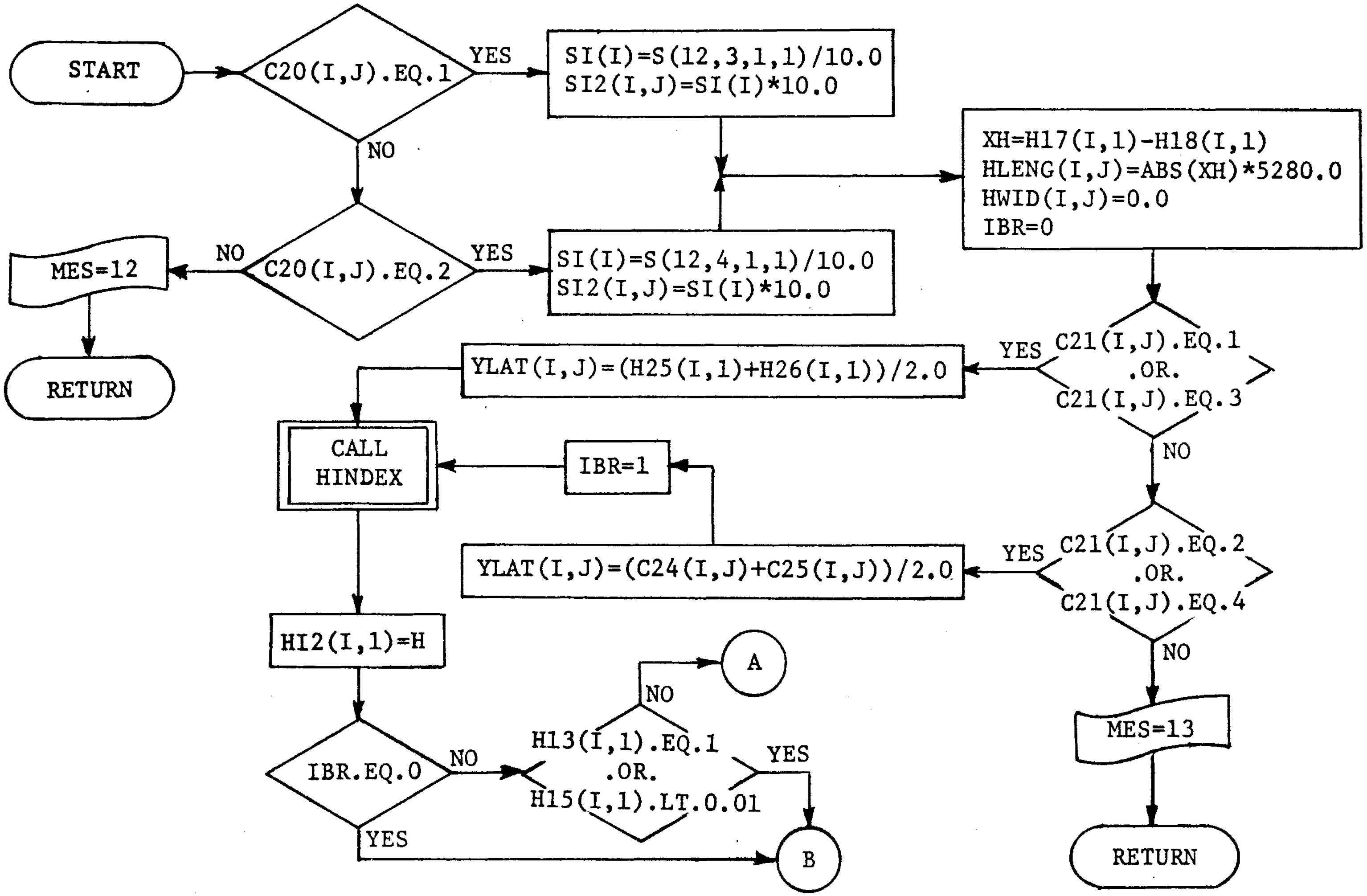


Figure 12-17. Flow Chart -- Subroutine BRIDGE (1 of 2)

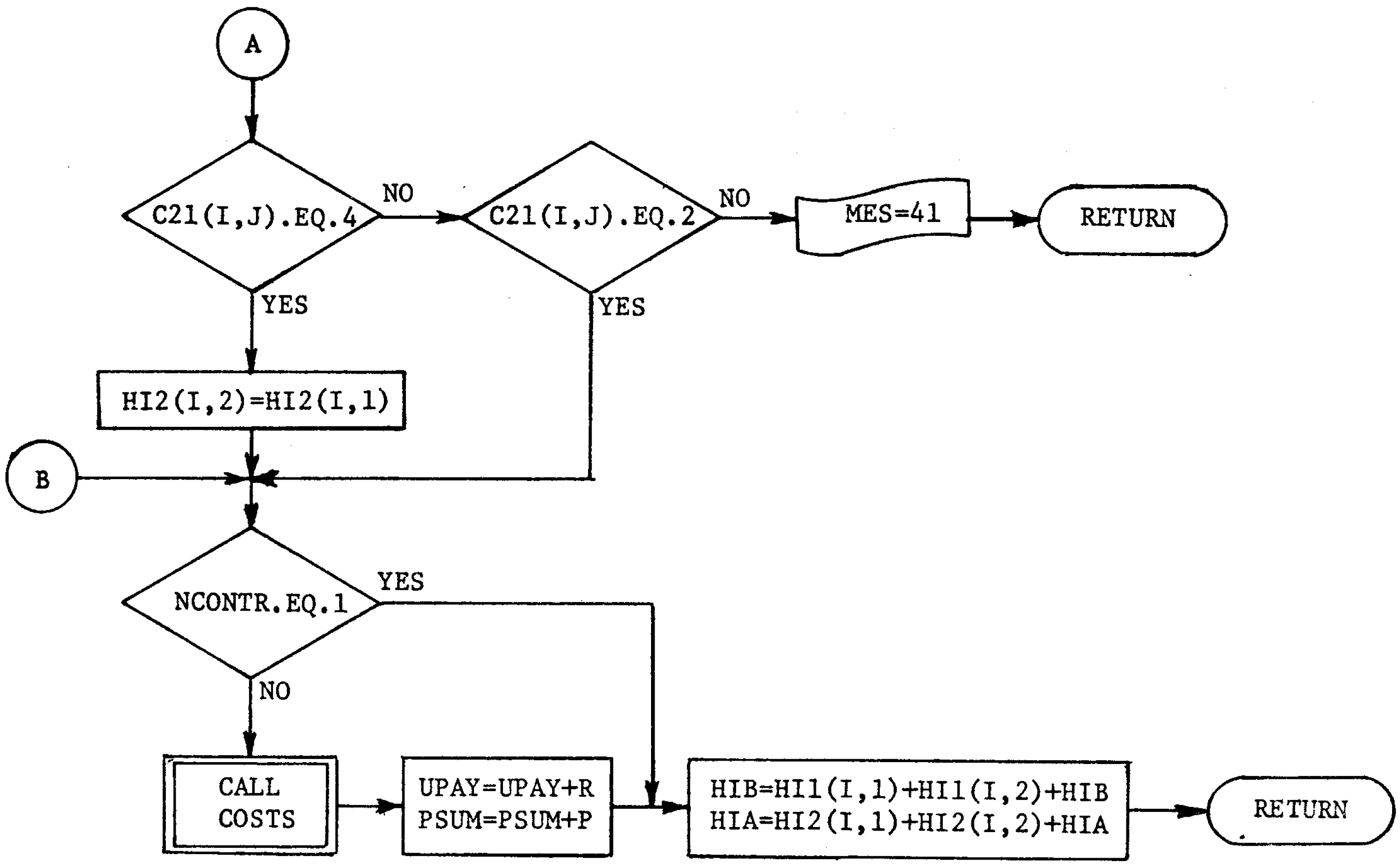


Figure 12-17. Flow Chart -- Subroutine BRIDGE (Continued 2 of 2)

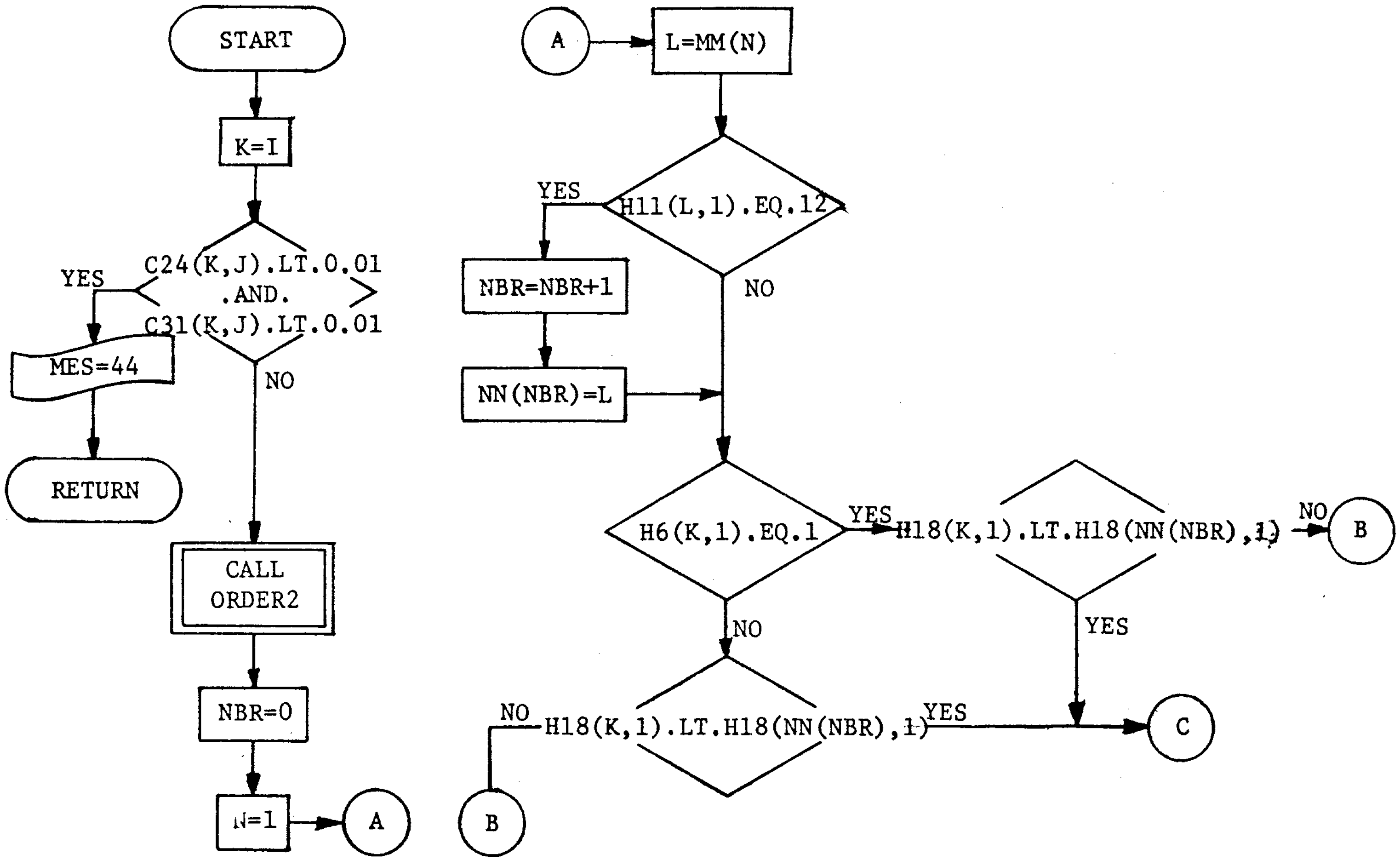


Figure 12-18. Flow Chart -- Subroutine BRGR (1 of 3)

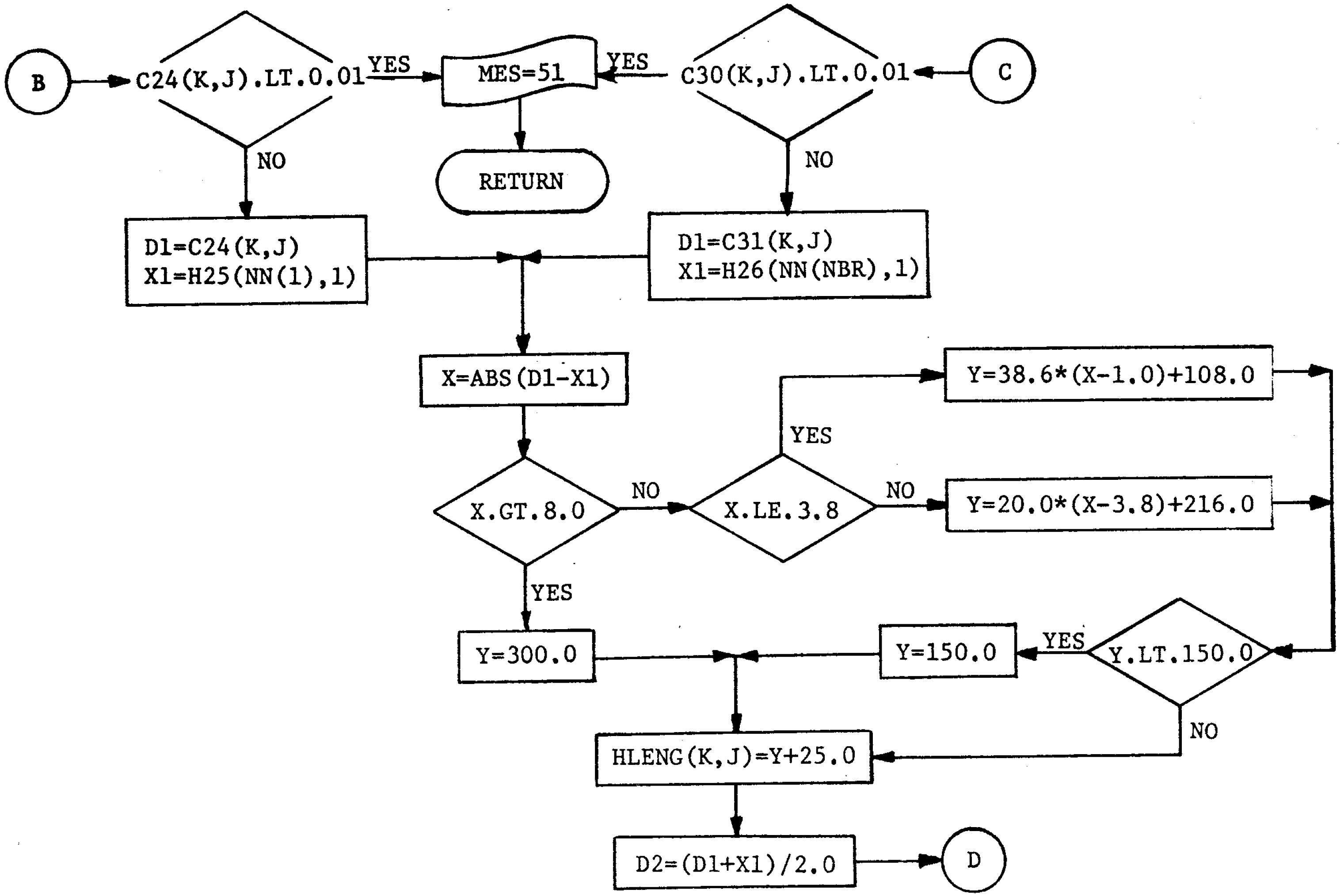


Figure 12-18. Flow Chart -- Subroutine BRGK (Continued 2 of 3)

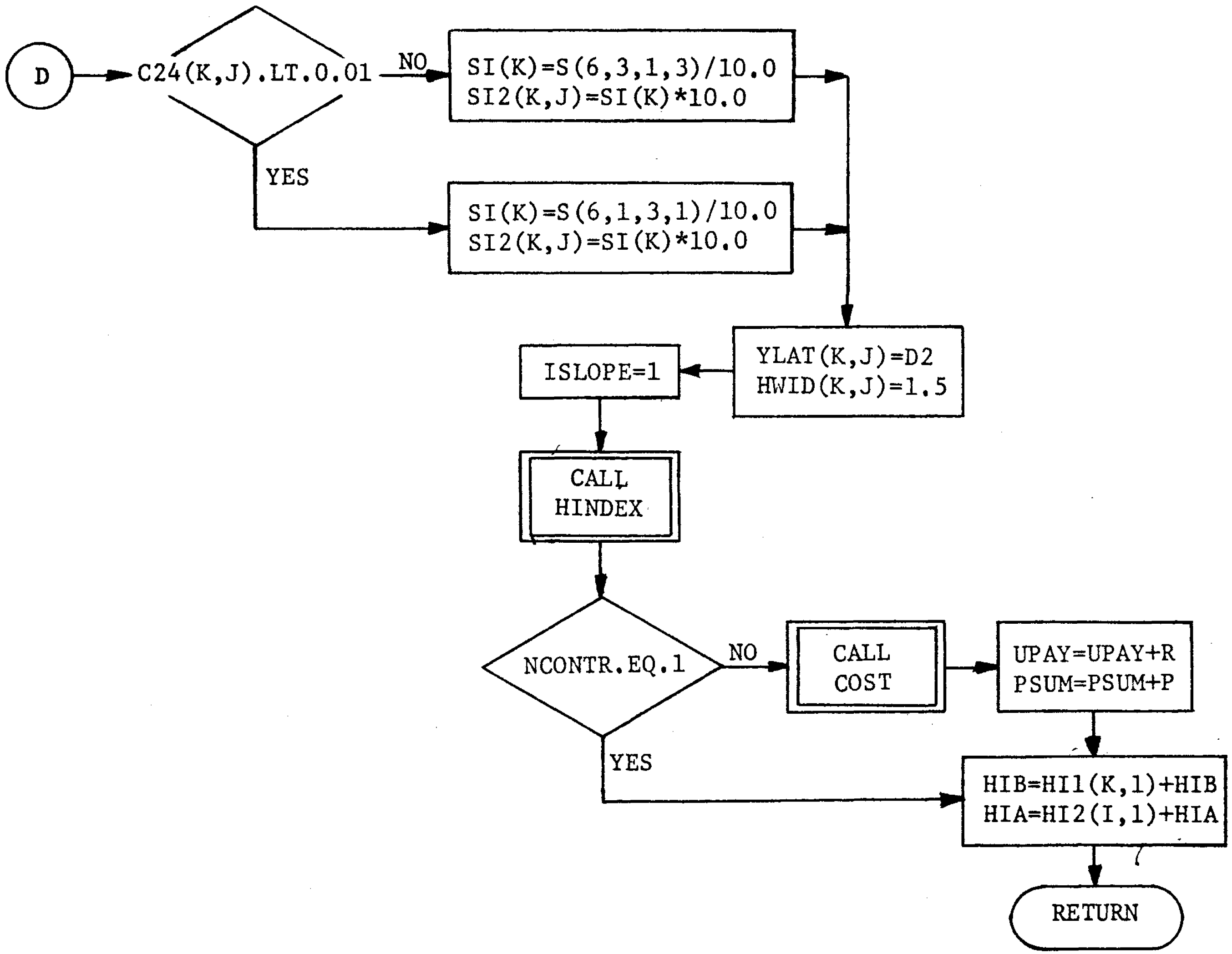


Figure 12-18. Flow Chart -- Subroutine BRGR (Continued 3 of 3)

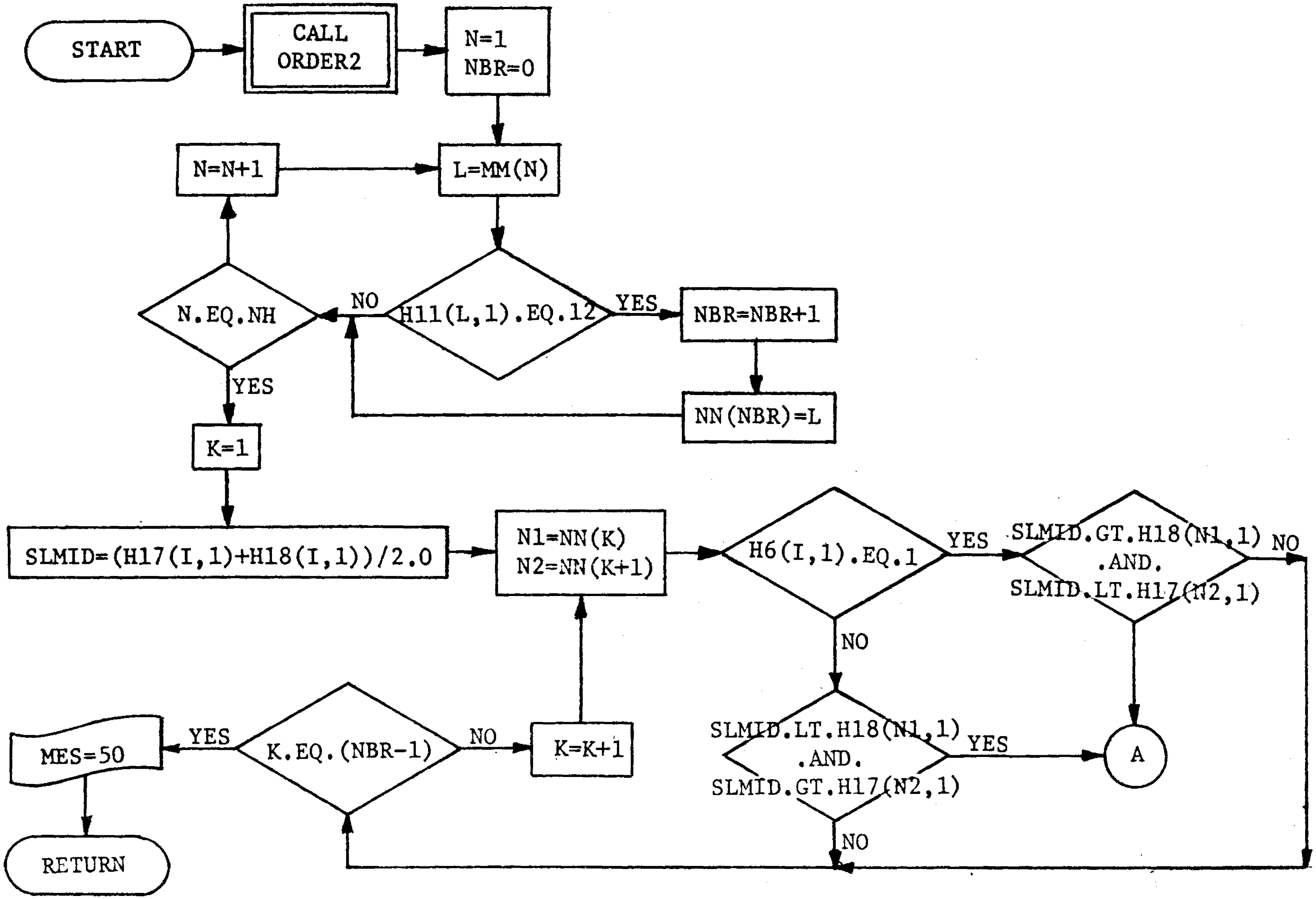


Figure 12-19. Flow Chart -- Subroutine BRGR1 (1 of 2)

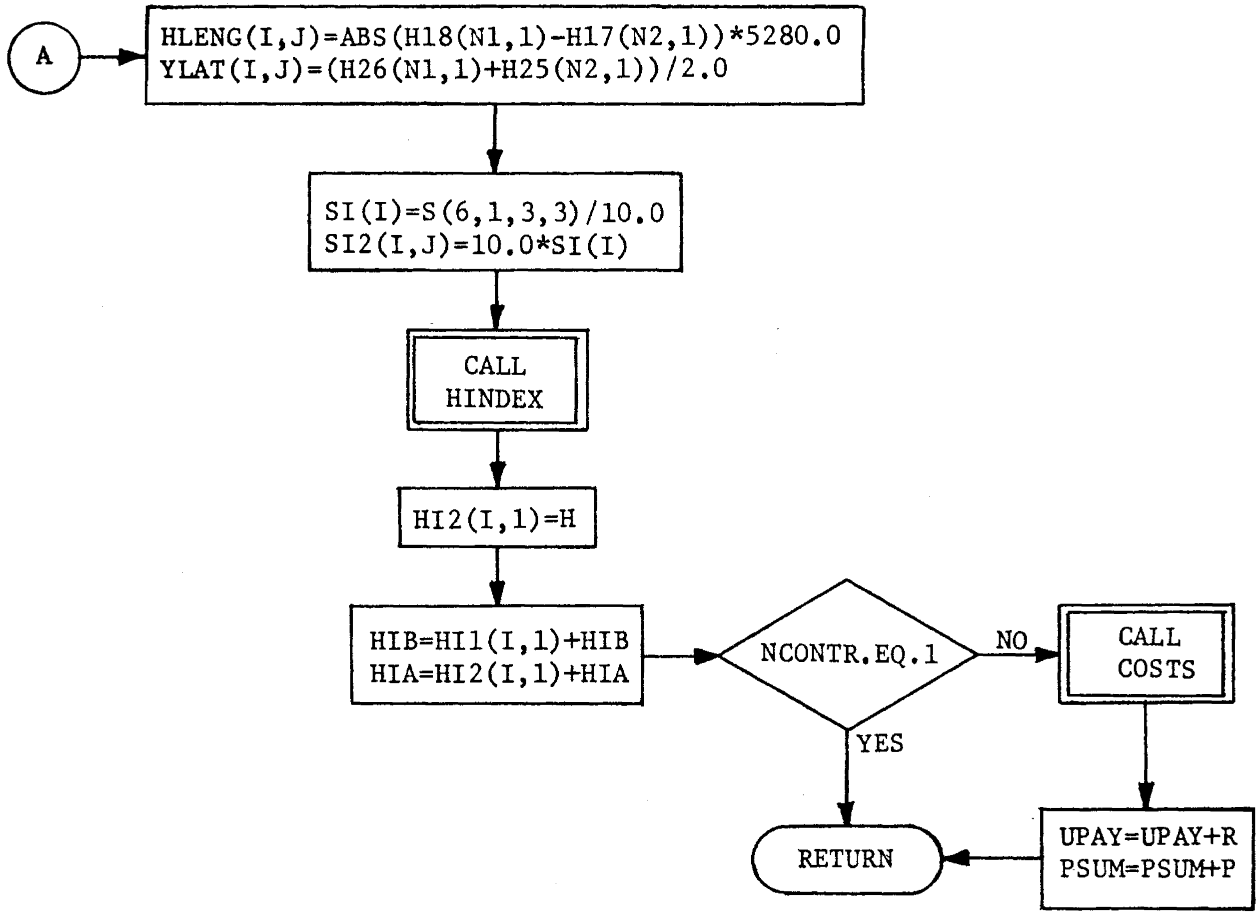


Figure 12-19. Flow Chart -- Subroutine BRGR1 (Continued 2 of 2)

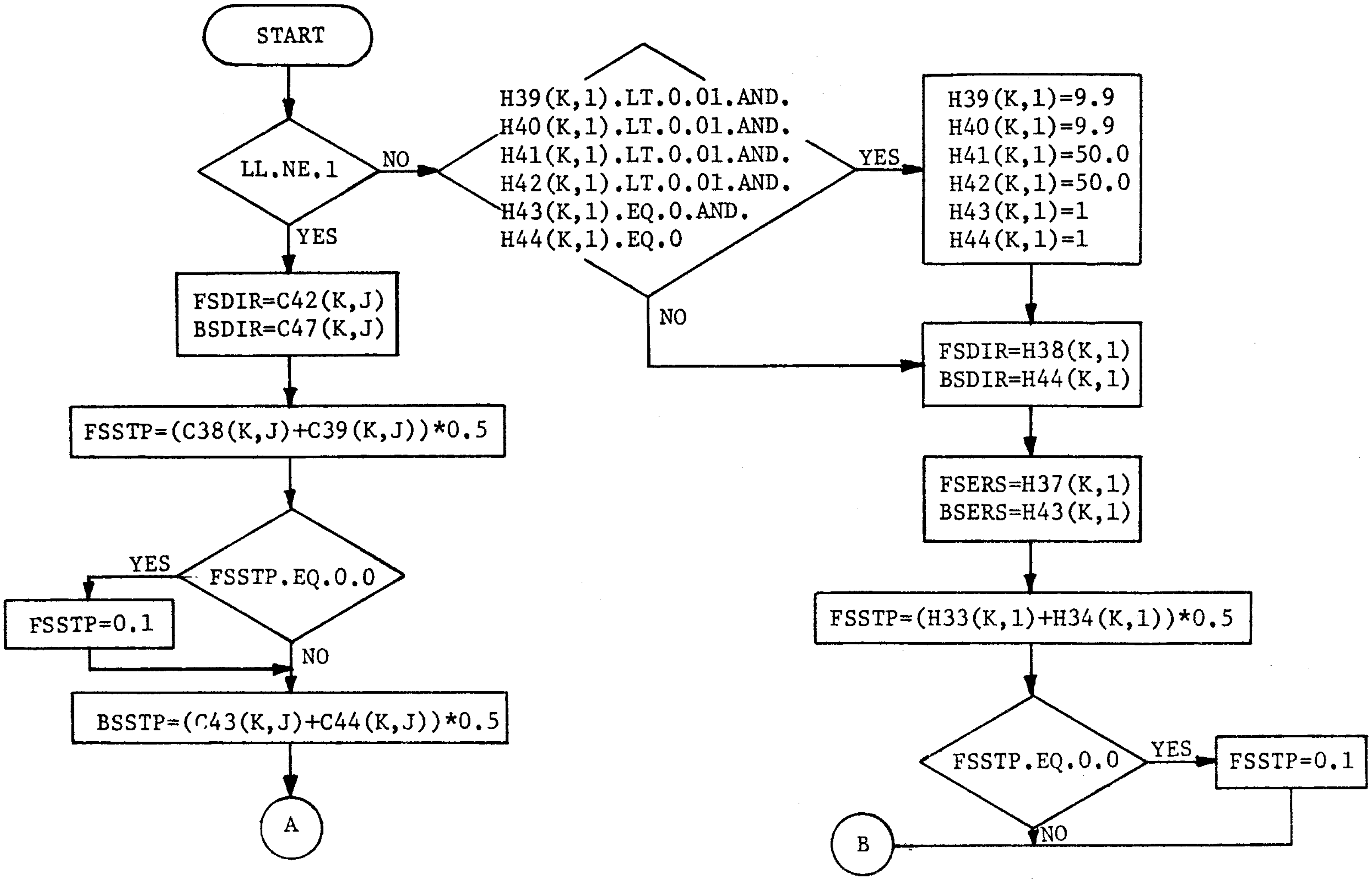


Figure 12-20. Flow Chart -- Subroutine SLOPE1 (1 of 3)

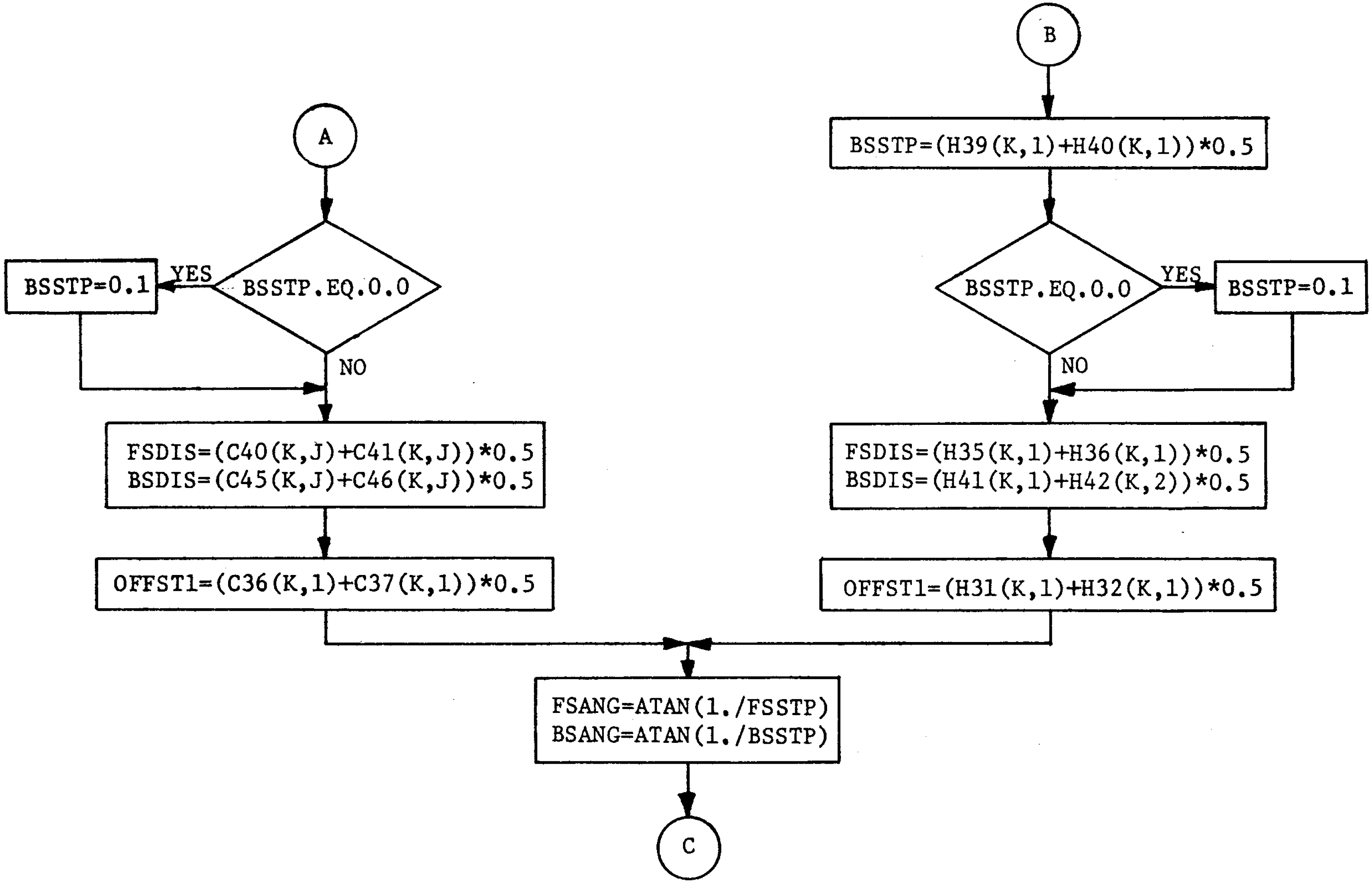


Figure 12-20. Flow Chart -- Subroutine SLOPE1 (Continued 2 of 3)

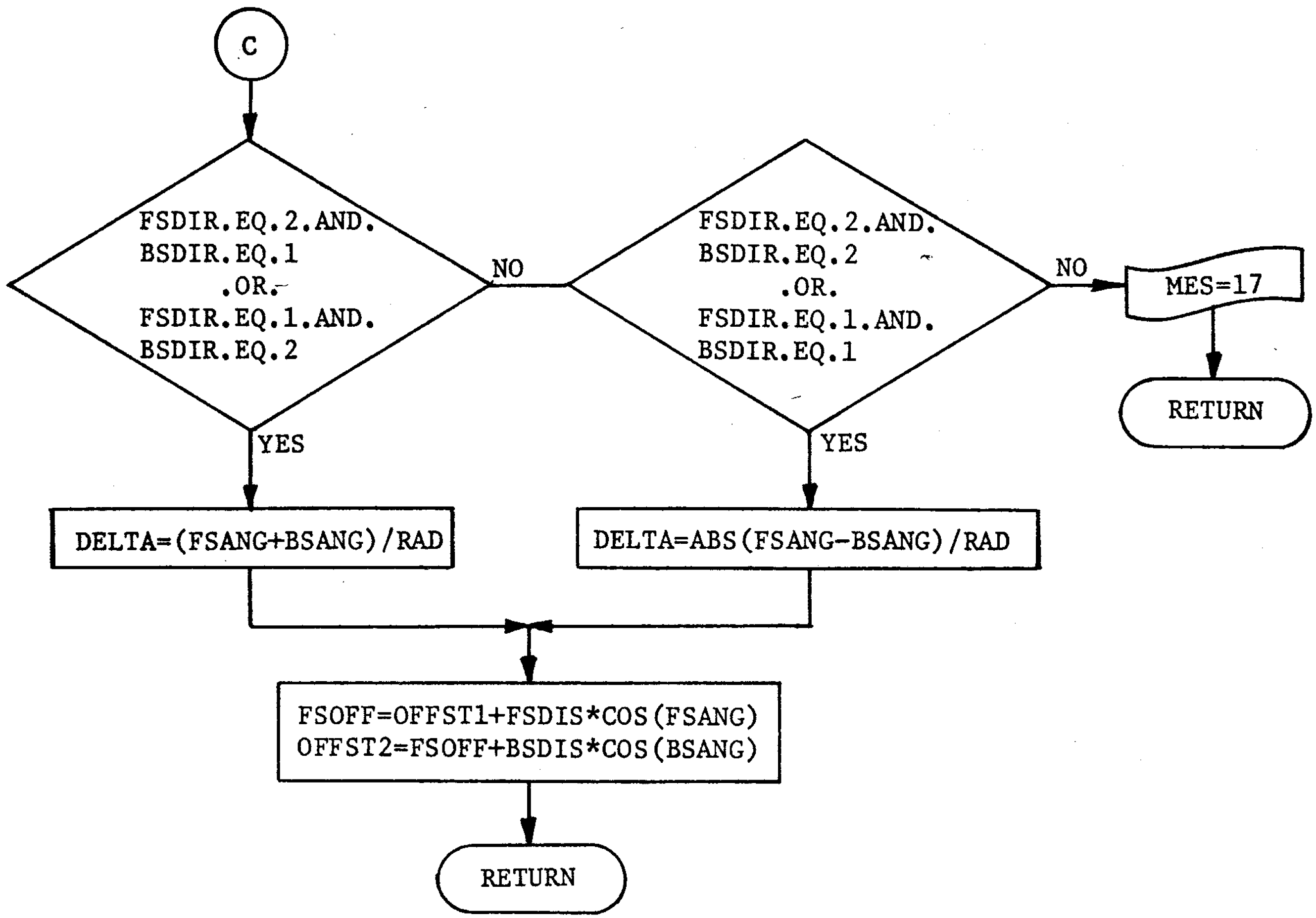


Figure 12-20. Flow Chart -- Subroutine SLOPE1 (Continued 3 of 3)

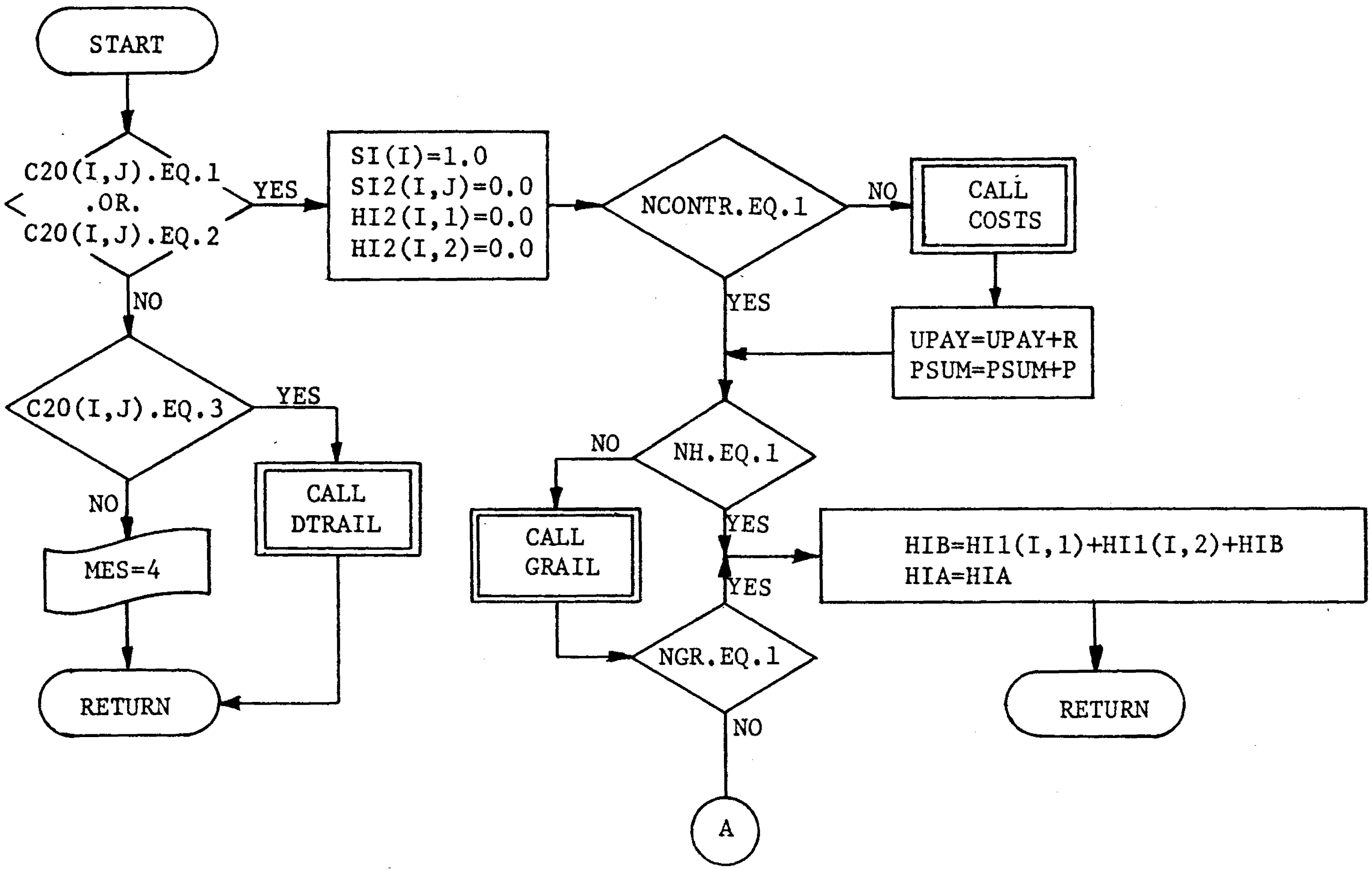


Figure 12-21. Flow Chart -- Subroutine DITCH (1 of 2)

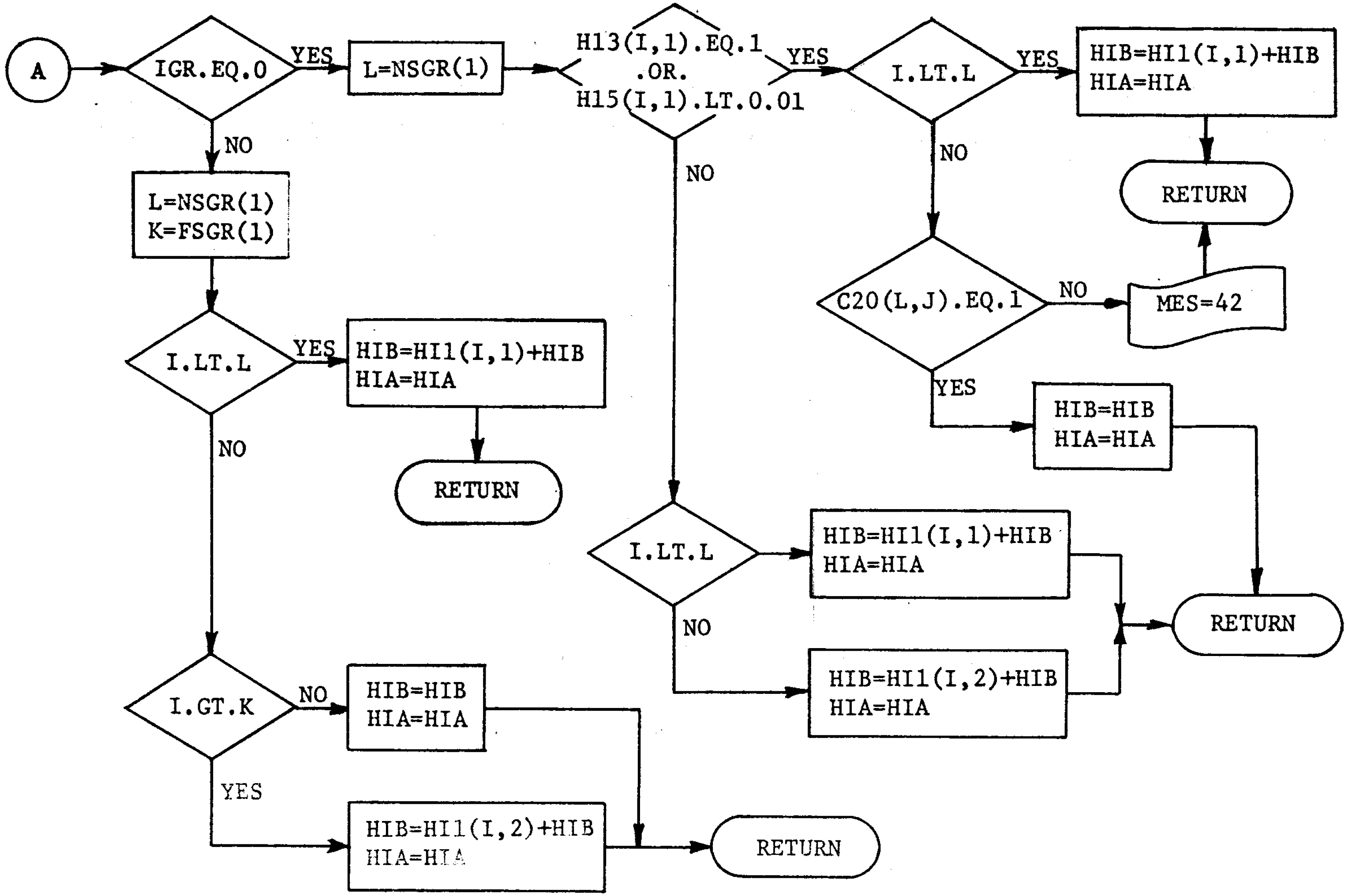


Figure 12-21. Flow Chart -- Subroutine DITCH (Continued 2 of 2)

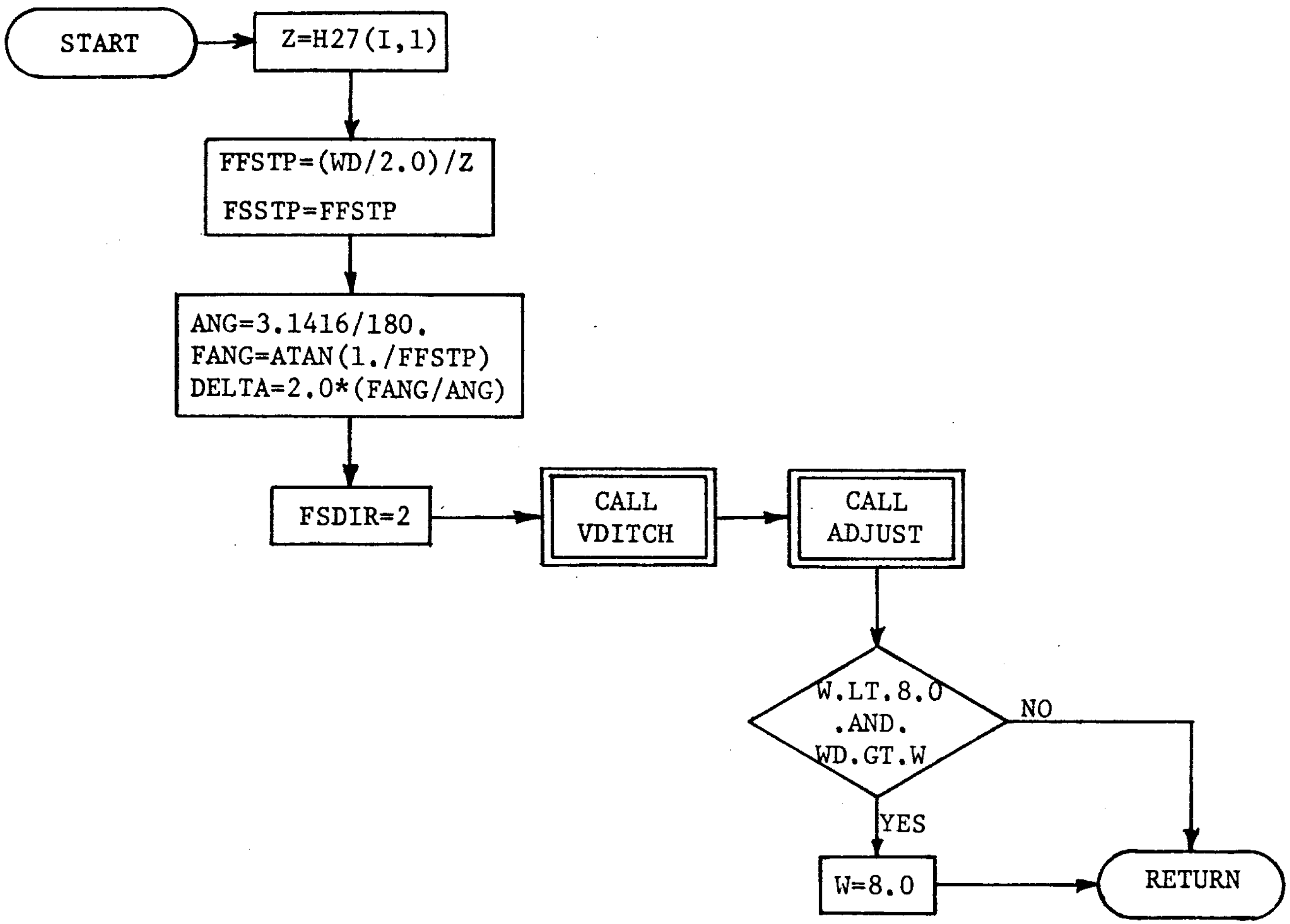


Figure 12-22. Flow Chart -- Subroutine WASOUT

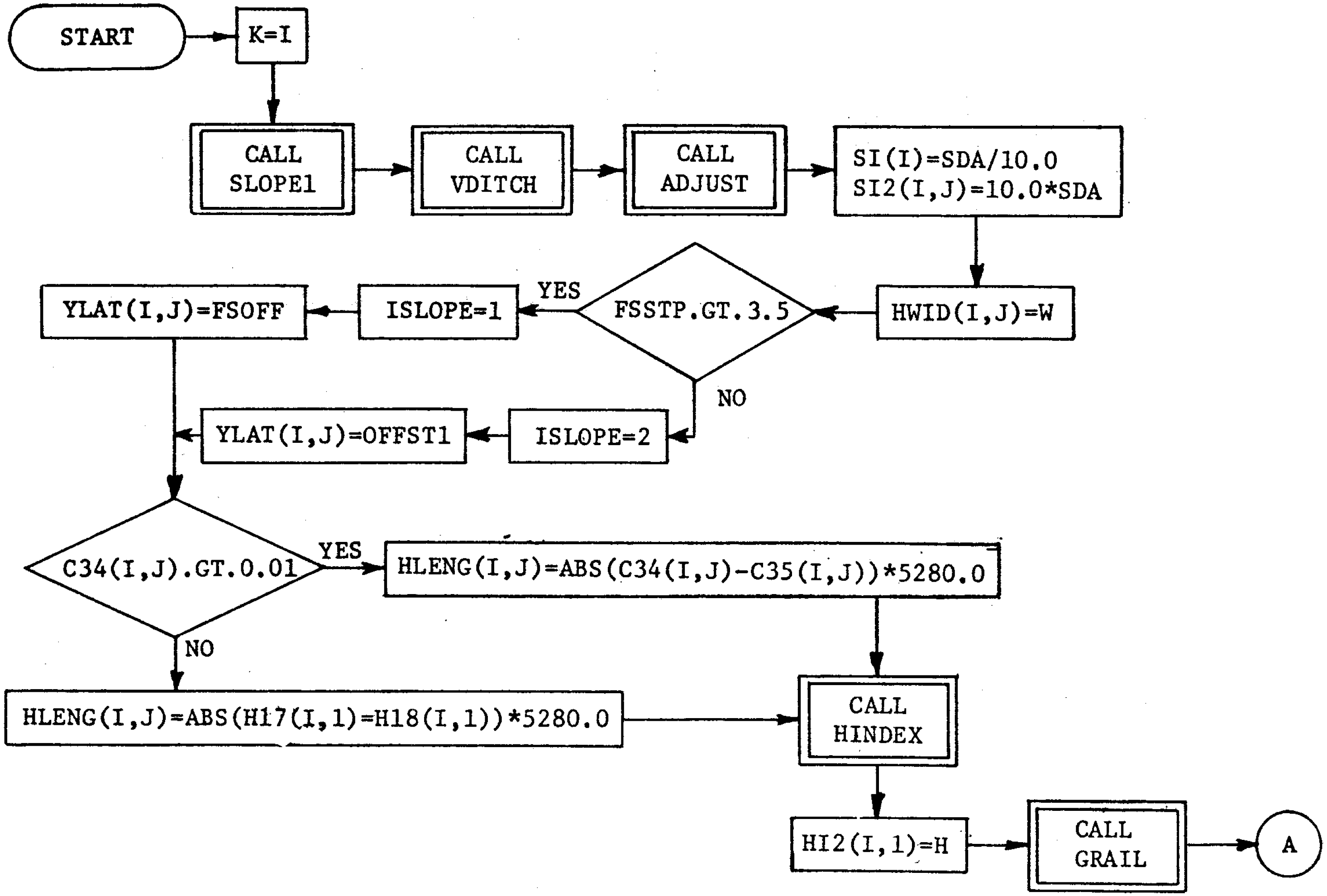


Figure 12-23. Flow Chart -- Subroutine FLATEN (1 of 4)

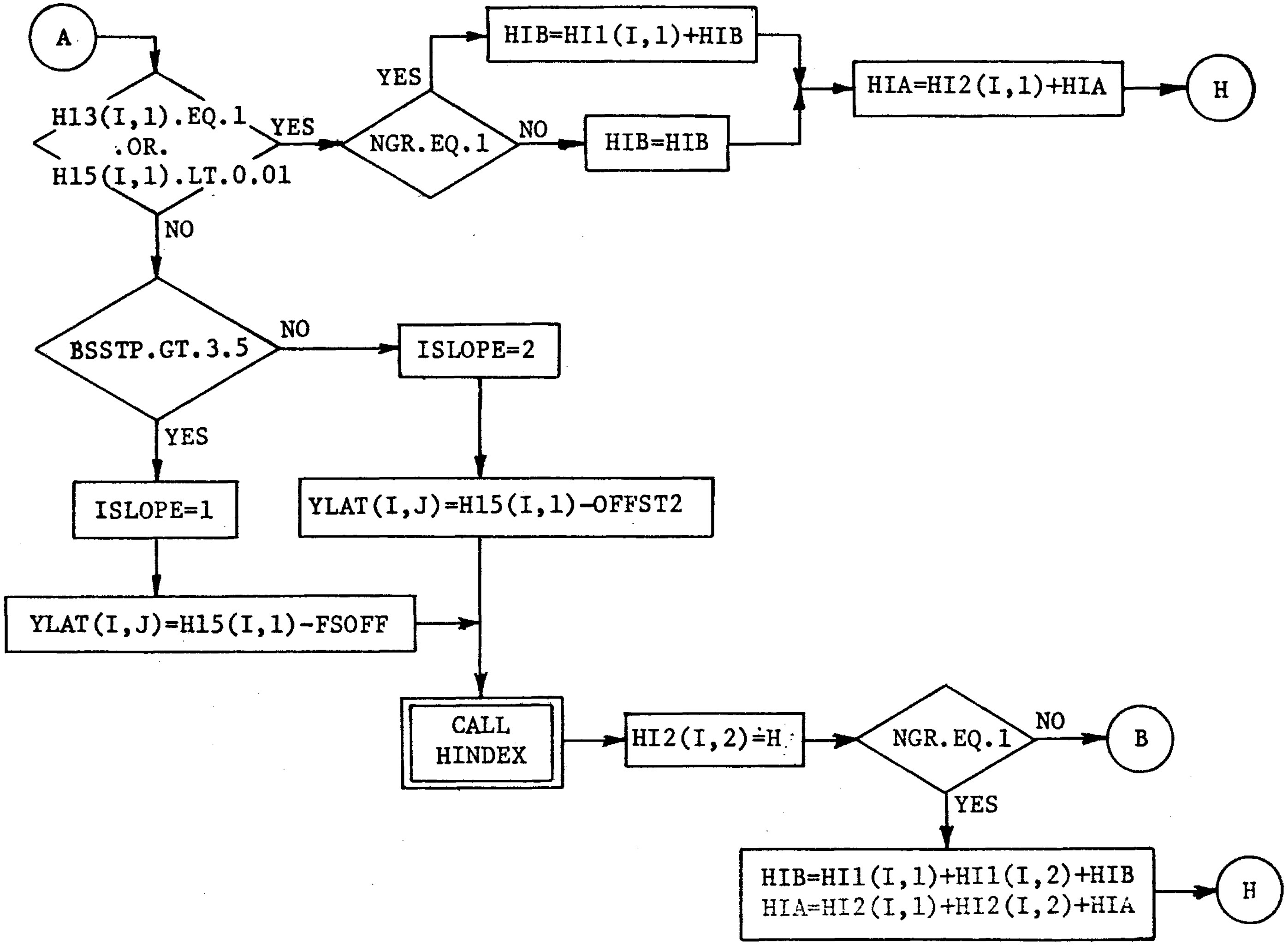


Figure 12-23. Flow Chart -- Subroutine FLATEN (Continued 2 of 4)

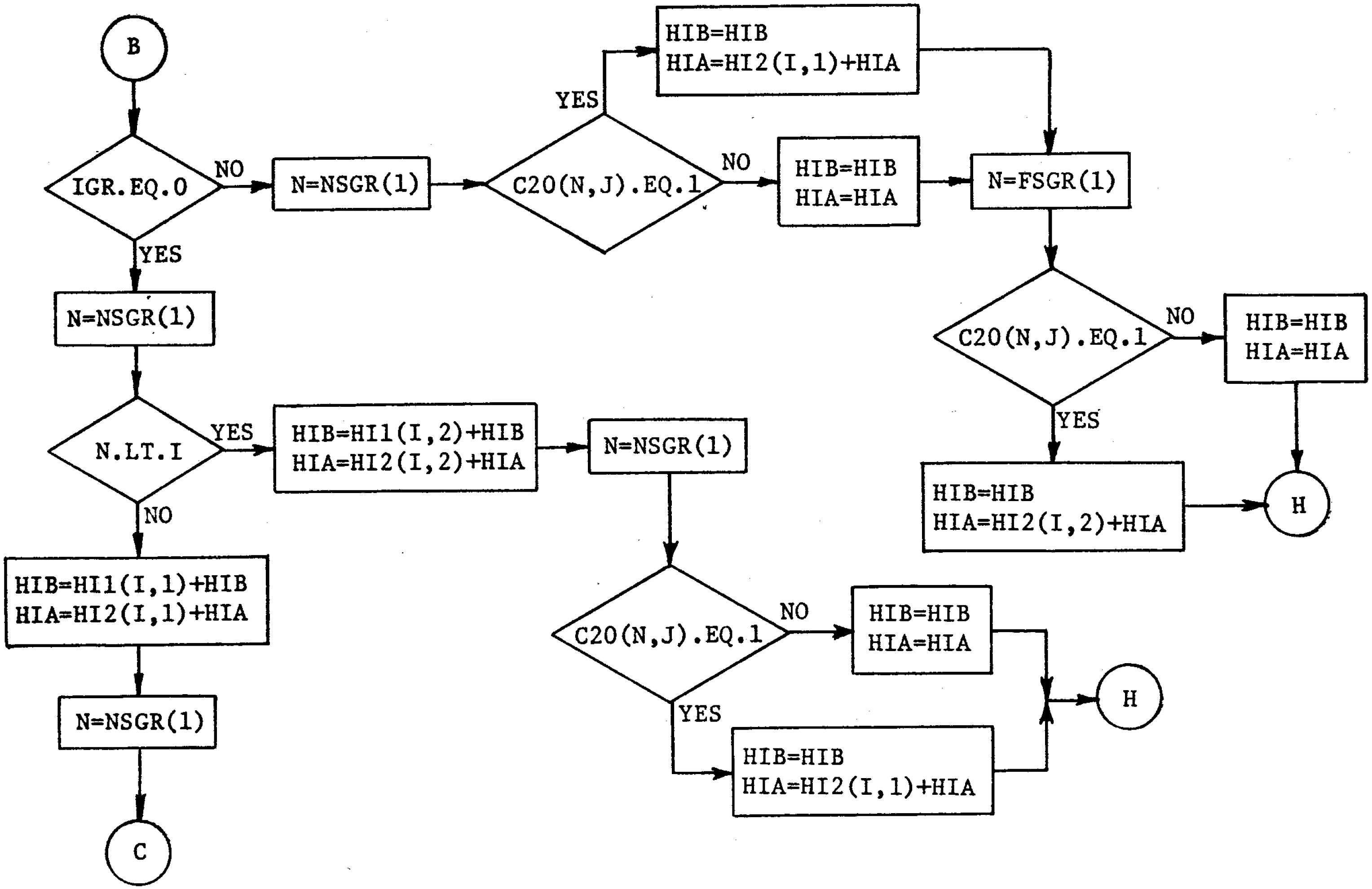


Figure 12-23. Flow Chart -- Subroutine FLATEN (Continued 3 of 4)

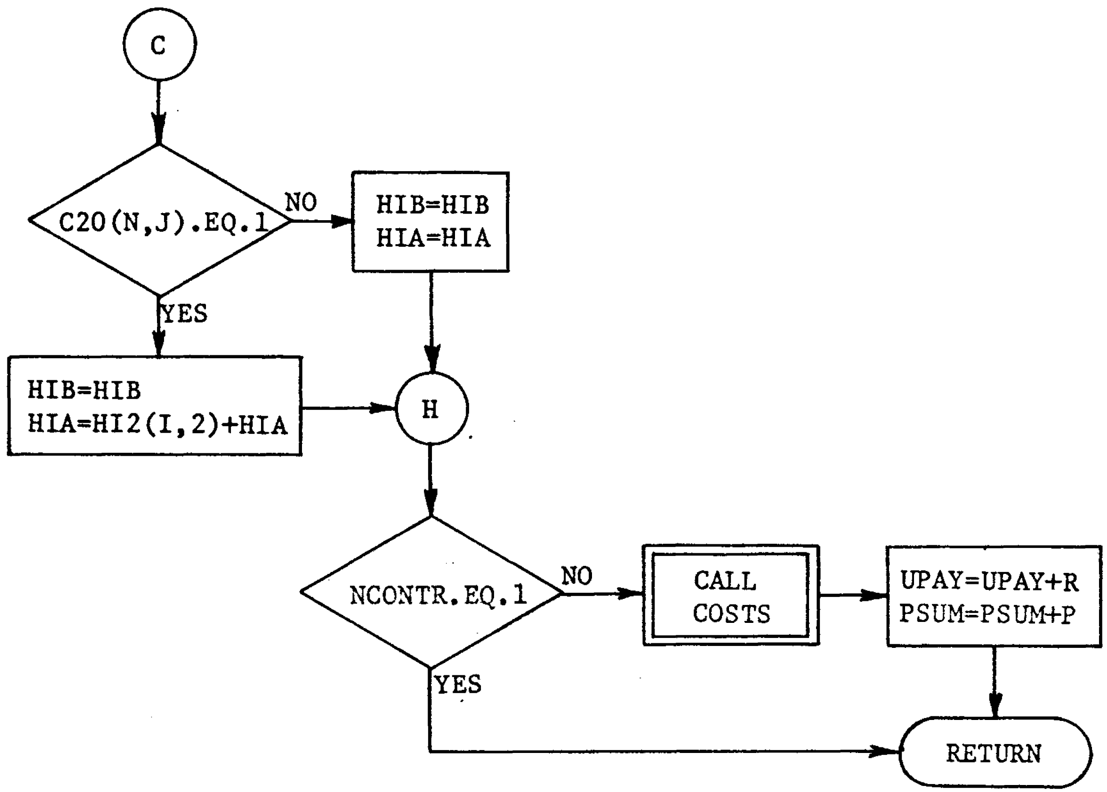


Figure 12-23. Flow Chart -- Subroutine FLATEN (Continued 4 of 4)

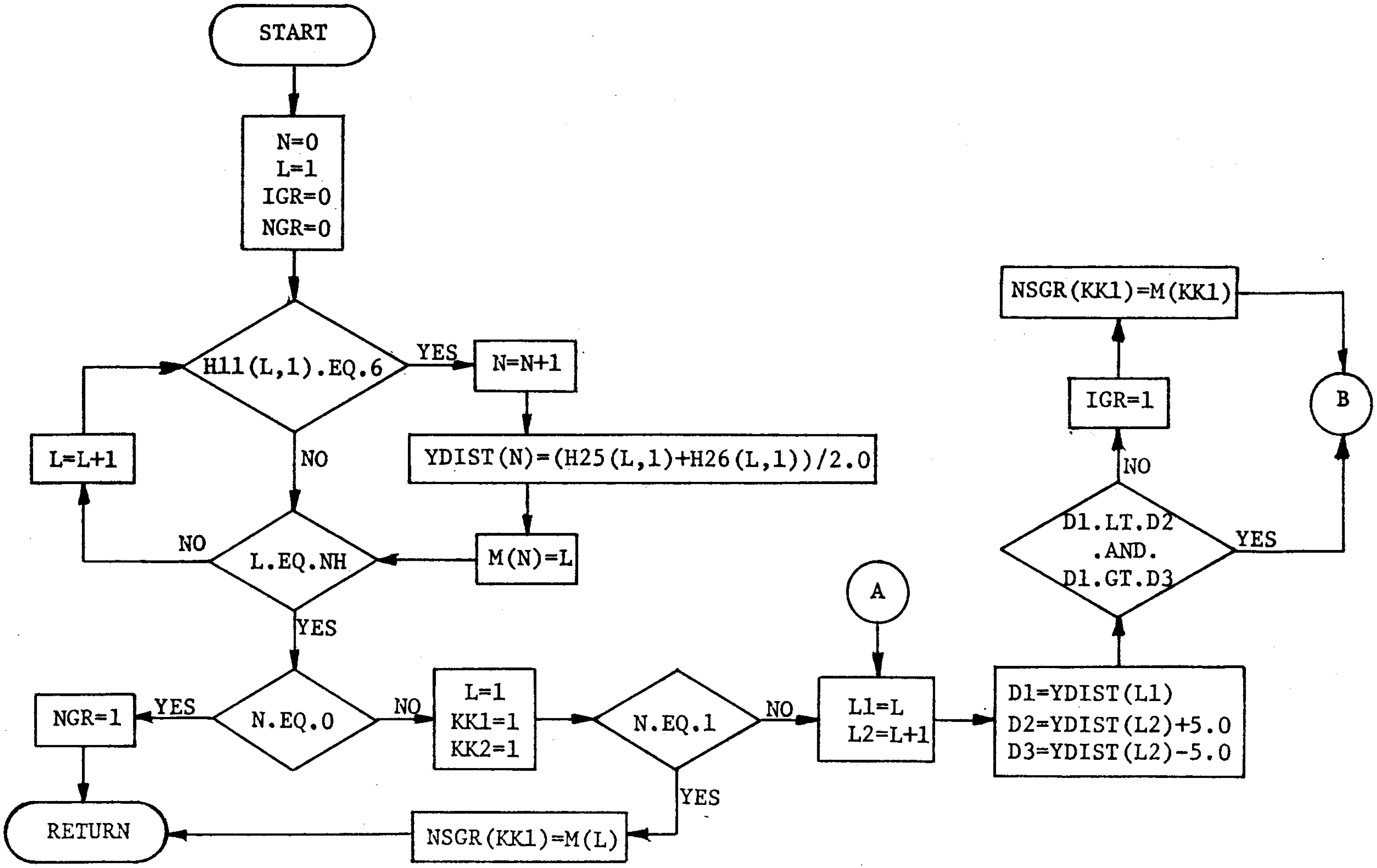


Figure 12-24. Flow Chart -- Subroutine GRAIL (1 of 2)

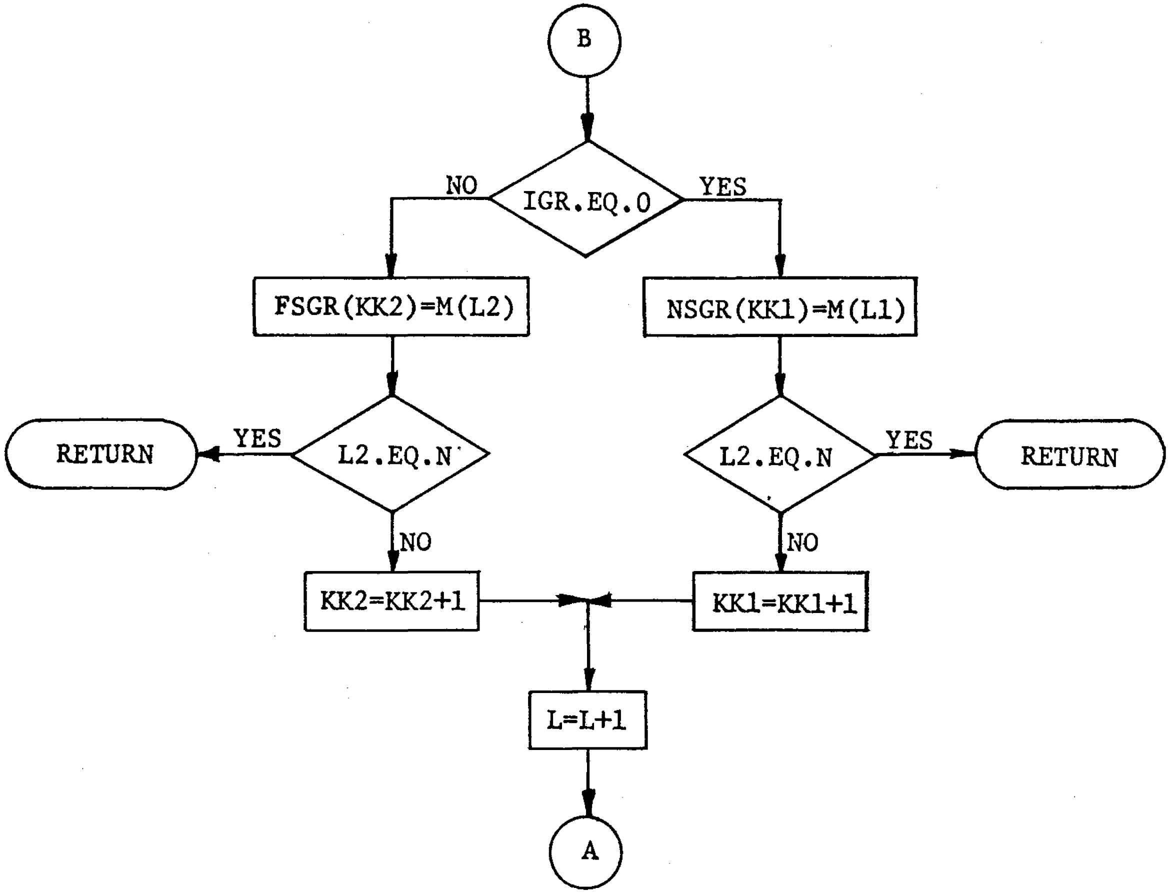


Figure 12-24. Flow Chart -- Subroutine GRAIL (Continued 2 of 2)

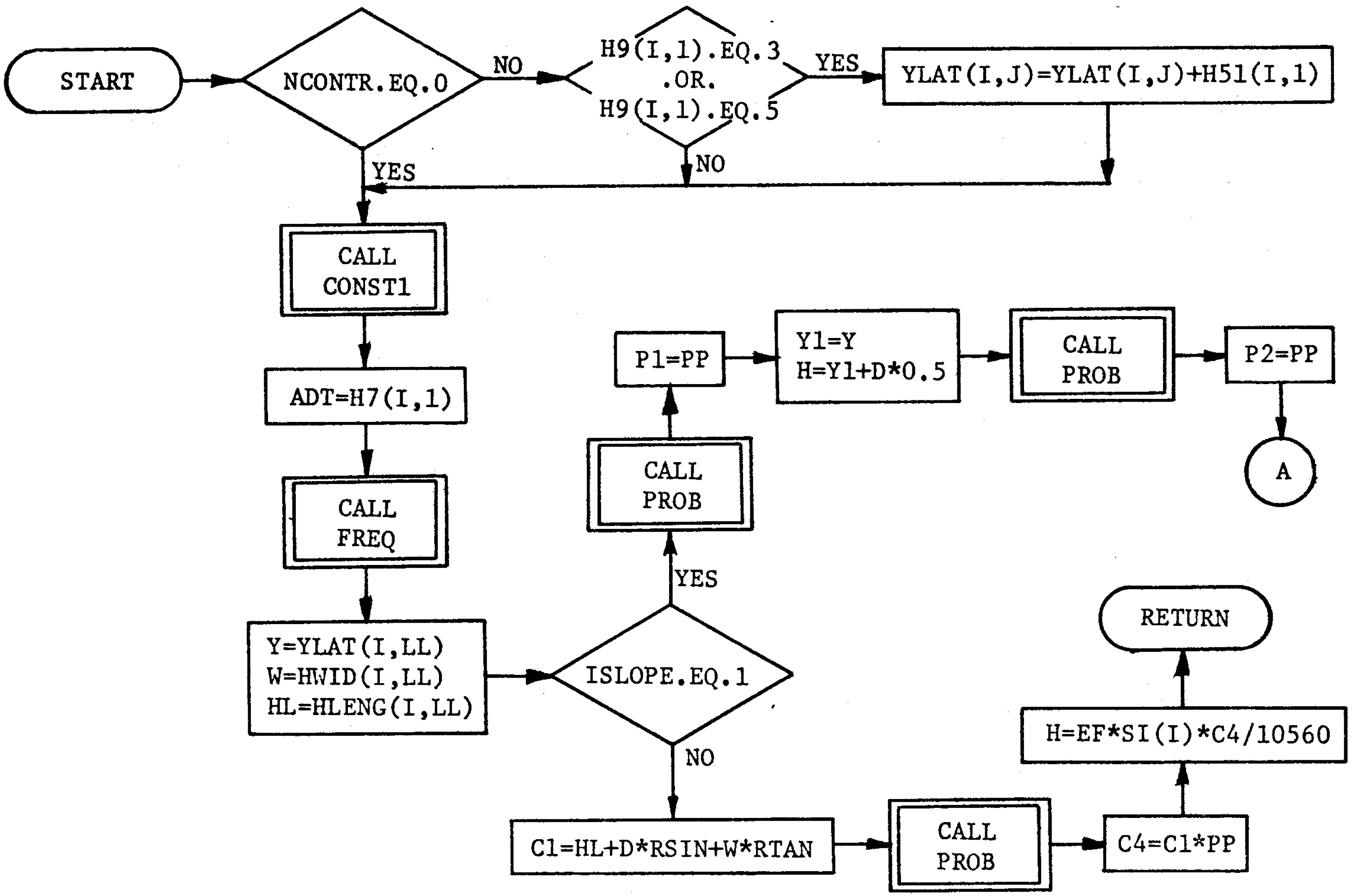


Figure 12-25. Flow Chart -- Subroutine HINDEX (1 of 2)

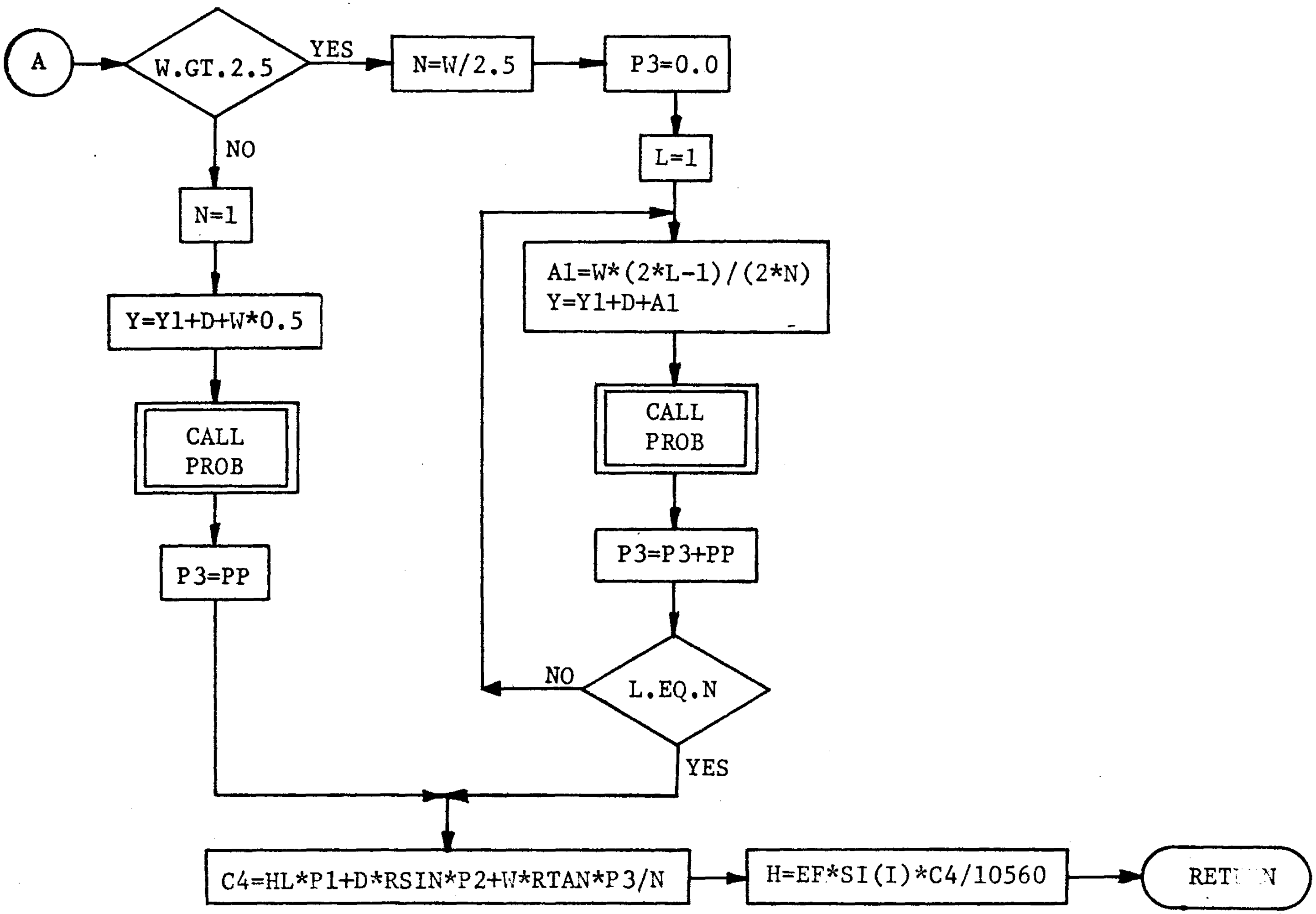


Figure 12-25. Flow Chart -- Subroutine HINDEX (Continued 2 of 2)

```
C     ************************************************************************
C
        SUBROUTINE SLIST
C
C     ************************************************************************
C
C     SUBROUTINE PRINTS OUT A LISTING OF SUBROUTINE NAMES AND DESCRIPTIONS
C
C
        DIMENSION NAME(40,2), IDESC(40,19), NC(40)
C
C
        WRITE(6,95)
        NSUB=39
        WRITE(6,96)
        DO 2 I=1,NSUB
        READ(5,99) (NAME(I,J), J=1,2)
      2 CONTINUE
C
        K=1
        DO 15 I=1,NSUB
      8 CONTINUE
        READ(5,100)(IDESC(I,N), N=1,19), J
        IF(K .EQ. 1) GO TO 25
        GO TO 26
     25 CONTINUE
        WRITE(6,105)I,(NAME(I,MM),MM=1,2),(IDESC(I,N),N=1,19)
        GO TO 20
     26 CONTINUE
        WRITE(6,106) (IDESC(I,N),N=1,19)
     20 CONTINUE
        IF(J .EQ. 1) GO TO 16
        K=K+1
        GO TO 8
     16 CONTINUE
        K=1
        WRITE(6,107)
     15 CONTINUE
C
C     FORMAT STATEMENTS
C
     95 FORMAT( 1H1 )
     96  FORMAT(///, T46, 'L I S T  O F  S U B R O U T I N E S',///,
       * T15, 'NUMBER', T25, 'SUBROUTINE', T63, 'DESCRIPTION OF SUBROUTI
       *',/, T28, 'NAME', //)
     99 FORMAT( 2A4 )
    100 FORMAT(19A4, I4)
    105 FORMAT(T17,I2,T26,2A4,T39,19A4 )
    106 FORMAT(T39,19A4)
    107 FORMAT( /)
        RETURN
C
        END
```

Figure 12-26. Subroutine SLIST (1 of 1)

```
*************************************************************************

      SUBROUTINE HWY

*************************************************************************

 SUBROUTINE CONTAINS DESCRIPTION OF HIGHWAY (TYPE AND CLASSIFICATION)


      COMMON / INFO / TYPE, CLASS

      DIMENSION  TYPE(10,20), CLASS(10,20)


      DO 10 L=1,8
      READ(5,100)(TYPE(L,M),M=1,20)
   10 CONTINUE

      DO 12 L=1,5
      READ(5,100)(CLASS(L,M),M=1,20)
   12 CONTINUE

  100 FORMAT(20A4)

      RETURN
      END
```

Figure 12-27. Subroutine HWY (1 of 1)

```
C     ***********************************************************************
C
         SUBROUTINE DIST
C
C     ***********************************************************************
C
C     SUBROUTINE READS AND STORES INFORMATION ON THE RELATIONSHIP
C     BETWEEN COUNTY AND DISTRICT NUMBERS.
C
C
         COMMON / DIST1 / IDIST
C
         DIMENSION IDIST(255)
C
C
         READ ( 5,999 )  ( IDIST(I), I=1,255 )
     999 FORMAT ( 20I4 )
         RETURN
C
         END
```

Figure 12-28. Subroutine DIST (1 of 1)

```
C    ********************************************************************
C
      SUBROUTINE ERROR
C
C    ********************************************************************
C
C  SUBROUTINE CONTAINS ERROR OR FLAG MESSAGES THAT ARE BUILT INTO THE
C  COMPUTER PROGRAM.  A LIST OF THESE MESSAGES IS PRESENTED LATER.
C
C
      COMMON / ERROR1 / MG, NMES
C
      DIMENSION  MG(60,20), NAME(60,4)
C
C
      WRITE(6,95)
      WRITE(6,100)
      NMES=51
      DO 2 I=1,NMES
      READ(5,99) (NAME(I,J),J=1,4)
    2 CONTINUE
      DO 150 I=1,NMES
      READ(5,340) (MG(I,J),J=1,20)
      WRITE(6,350) I,(NAME(I,N),N=1,4),(MG(I,J),J=1,20)
  150 CONTINUE
C
C  FORMAT STATEMENTS
C
   95 FORMAT(1H1)
   99 FORMAT(4A4)
  100 FORMAT(///, T41, 'L I S T   O F   E R R O R   O R   F L A G   M E
     *S S A G E S',///,T15, 'MESSAGE', T26, 'SUBROUTINES', T63,
     * 'DESCRIPTION OF MESSAGE', /, T16, 'NAME', // )
  340 FORMAT(20A4)
  350 FORMAT( T17, I2, T25, 4A4, T42, 20A4, / )
C
      RETURN
      END
```

Figure 12-29. Subroutine ERROR (1 of 1)

```
C     *********************************************************************
C
         SUBROUTINE   SEVRTY
C
C     *********************************************************************
C
C     SUBROUTINE TO READ AND STORE SEVERITY-INCICIES OBTAINED FROM THD.
C     THESE INDICIES ARE ADJUSTED TO TAKE INTO CONSIDERATION THE HIGHER
C     DAMAGE COSTS ASSOCIATED WITH FIXED HAZARDS SUCH AS A BRIDGE PIER.
C
         COMMON / SEVERE / S
C
         DIMENSION  S(13,7,4,4)
C
C
         WRITE (6,100)
C
         J=0
         K=0
         L=0
         IJ=1
         IK=1
         IL=1
C
         DO 500 I=1,13
         GO TO ( 515, 515, 505, 515, 503, 520, 506, 515, 504, 503, 502,
        *          506, 507 ),   I
C
C     IDENTIFICATION
C
C       I=01   UTILITY POLES
C       I=02   TREES
C       I=03   RIGID SIGNPOST
C       I=04   RIGID BASE LUMINAIRE SUPPORT
C       I=05   CURBS
C       I=06   GUARDRAIL OR MEDIAN BARRIER
C       I=07   ROADSIDE SLOPE
C       I=08   WASHOUT
C       I=09   CULVERTS
C       I=10   INLETS
C       I=11   ROADWAY UNDER BRIDGE STRUCTURE
C       I=12   ROADWAY OVER BRIDGE STRUCTURE
C       I=13   RETAINING WALL
C
C
  501 JJ=1
         GO TO 516
  502 JJ=3
         GO TO 516
  503 JJ=3
```

Figure 12-30. Subroutine SEVRTY (1 of 3)

```
      GO TO 516
 504  JJ=4
      GO TO 516
 505  JJ=5


 300  FORMAT (16F5.1)
 100  FORMAT(1H1, //, T44, 'S E V E R I T Y   I N D I C E S',
     *                                    ///, T18, 'IDENTIFICATION
     * CODE', T42, 'DESCRIPTOR CODE', T62, 'END TREATMENT CODE', T87,
     *'SEVERITY-INDEX', /, T60, 'BEGINNING', T76, 'ENDING',
     *T85,'SURVEY',T95,'ADJUSTED',//)
 102  FORMAT(T27,I2,T48,I2,T64,I1,T78,I1,T86,F4.1,T96,F5.1)
      GO TO 516
 506  JJ=6
      GO TO 516
 507  JJ = 2
      GO TO 516

 515  CONTINUE
      READ (5,300)  S(I,IJ,IK,IL)
      X=S(I,IJ,IK,IL)
      IF(X .LE. 4.0) GO TO 299
      IF(X .GT. 4.0 .AND. X .LE. 7.0) GO TO 301
      GO TO 302
 301  S(I,IJ,IK,IL)=7.0*X-24.0
      GO TO 299
 302  S(I,IJ,IK,IL)=25.0*X-150.0
 299  CONTINUE
      WRITE(6,102) I,J,K,L,X,S(I,IJ,IK,IL)
      GO TO 525
 516  CONTINUE
      READ (5,300)  (S(I,J,IK,IL), J=1,JJ)
      DO 518 J=1,JJ
      X=S(I,J,IK,IL)
      IF(X .LE. 4.0) GO TO 304
      IF(X .GT. 4.0 .AND. X .LE. 7.0) GO TO 305
      GO TO 306
 305  S(I,J,IK,IL)=7.0*X-24.0
      GO TO 304
 306  S(I,J,IK,IL)=25.0*X-150.0
 304  CONTINUE
 518  WRITE(6,102) I,J,K,L,X,S(I,J,IK,IL)
      GO TO 525
 520  CONTINUE
      DO 522 J=1,7
      DO 522 K=1,4
 522  READ (5,300)  (S(I,J,K,L), L=1,4)
```

Figure 12-30. Subroutine SEVRTY (2 of 3)

```
      DO 523 J=1,7
      DO 523 K=1,4
      DO 523 L=1,4
      X=S(I,J,K,L)
      IF(X .LE. 4.0) GO TO 308
      IF(X .GT. 4.0 .AND. X .LE. 7.0) GO TO 309
      GO TO 310
  309 S(I,J,K,L)=7.0*X-24.0
      GO TO 308
  310 S(I,J,K,L)=25.0*X-150.0
  308 CONTINUE
  523 WRITE(6,102) I,J,K,L,X,S(I,J,K,L)
  525 CONTINUE
      WRITE (6,103)
      J=0
      K=0
      L=0
  500 CONTINUE
  103 FORMAT (//)
      RETURN
C
      END
```

Figure 12-30. Subroutine SEVRTY (3 of 3)

```
C   **************************************************************
C
      SUBROUTINE ADJUST
C
C   **************************************************************
C
C       SUBROUTINE TO ADJUST SEVERITY-INDICIES
C       CALCULATED IN SUBROUTINE VDITCH
C
      COMMON / HDITCH / SD, W, WD, SDA
      SD=SD*10.0
      IF( SD .LE. 4.0 )GO TO 50
      IF( SD .GT. 4.0 .AND. SD .LT. 7.0 )GO TO 51
      SD=25.0 * SD - 150.0
      GO TO 50
   51 CONTINUE
      SD= 7.0 * SD - 24.0
   50 CONTINUE
      SDA=SD
      RETURN
      END
```

Figure 12-31. Subroutine ADJUST (1 of 1)

```
C     ******************************************************************
C
      SUBROUTINE  INVTRY
C
C     ******************************************************************
C
C     SUBROUTINE READS AND STORES HAZARD AND IMPROVEMENT DATA OBTAINED
C     FIELD.  MAXIMUM NUMBER OF HAZARDS PER GROUP IS 15.  MAXIMUM NUMBER
C     OF IMPROVEMENT ALTERNATIVES PER GROUP IS 4.
C
C
      COMMON / INVENT / I, J, NH, LP1, LL, MES
      COMMON / COUNT / NC
      COMMON / HINVNT / H1, H2, H3, H4, H5, H6, H7, H8, H9, H11, H12
     *                  H13, H15, H16, H17, H18, H19, H20, H21, H22,
     *                  H23, H24, H25, H26, H27, H28, H29, H30, H31,
     *                  H32, H33, H34, H35, H36, H37, H38, H39, H40,
     *                  H41, H42, H43, H44, H50, H51
      COMMON / CINVNT / C1, C2, C3, C4, C5, C7, C8, C9, C10, C11, C1
     *                  C13, C14, C15, C16, C17, C18, C20, C21, C24,
     *                  C25, C26, C27, C28, C29, C34, C35, C36, C37,
     *                  C38, C39, C40, C41, C42, C43, C44, C45, C46,
     *                  , C30, C31, C48, C49
      COMMON / SAVCRD / ISAVE, ISTART, IEND
C
      INTEGER   H1, H2, H3, H4, H5, H6, H8, H9, H11, H12, H13, H16, H
     *          H29, H30, H37, H38, H43, H44
      INTEGER   C1, C2, C3, C4, C5, C12, C13, C18, C20, C21, C42, C47
      INTEGER   NC, X80, Y80
C
      DIMENSION  H1(15,1), H2(15,1), H3(15,1), H4(15,1), H5(15,1),
     *           H6(15,1), H7(15,1), H8(15,1), H9(15,1), H11(15,1),
     *           H12(15,1), H13(15,1), H15(15,1), H16(15,1), H17(15,
     *           H18(15,1), H19(15,1), H20(15,1), H21(15,1), H22(15,
     *           H23(15,1), H24(15,1), H25(15,1), H26(15,1), H27(15,
     *           H28(15,1), H29(15,1), H30(15,1), H31(15,1), H32(15,
      DIMENSION  H33(15,1), H34(15,1), H35(15,1), H36(15,1), H37(15,
     *           H38(15,1), H39(15,1), H40(15,1), H41(15,1), H42(15,
     *           H43(15,1), H44(15,1), H50(15,1), H51(15,1)
      DIMENSION  C1(15,5), C2(15,5), C3(15,5), C4(15,5), C5(15,5),
     *           C7(15,5), C8(15,5), C9(15,5), C10(15,5), C11(15,5)
     *           C12(15,5), C13(15,5), C14(15,5), C15(15,5), C16(15
     *           C17(15,5), C18(15,5), C20(15,5), C21(15,5), C24(15
     *           C25(15,5), C26(15,5), C27(15,5), C28(15,5), C29(15
     *           C34(15,5), C35(15,5), C36(15,5), C37(15,5), C38(15
      DIMENSION  C39(15,5), C40(15,5), C41(15,5), C42(15,5), C43(15
     *           C44(15,5), C45(15,5), C46(15,5), C47(15,5)
     *           , C30(15,5), C31(15,5), C48(15,5), C49(15,5)
      DIMENSION  NC(15), X(79), Y(79), PART(20)
```

Figure 12-32. Subroutine INVTRY (1 of 8)

```
C   INITIALIZE ARRAYS
C
      N=1
      DO 25 M=1,15
       H1(M,N) = 0.0
       H2(M,N) = 0.0
       H3(M,N) = 0.0
       H4(M,N) = 0.0
       H5(M,N) = 0.0
       H6(M,N) = 0.0
       H7(M,N) = 0.0
       H8(M,N) = 0.0
       H9(M,N) = 0.0
      H11(M,N) = 0.0
      H12(M,N) = 0.0
      H13(M,N) = 0.0
      H15(M,N) = 0.0
      H16(M,N) = 0.0
      H17(M,N) = 0.0
      H18(M,N) = 0.0
      H19(M,N) = 0.0
      H20(M,N) = 0.0
      H21(M,N) = 0.0
      H22(M,N) = 0.0
      H23(M,N) = 0.0
      H24(M,N) = 0.0
      H25(M,N) = 0.0
      H26(M,N) = 0.0
      H27(M,N) = 0.0
      H28(M,N) = 0.0
      H29(M,N) = 0.0
      H30(M,N) = 0.0
      H31(M,N) = 0.0
      H32(M,N) = 0.0
      H33(M,N) = 0.0
      H34(M,N) = 0.0
      H35(M,N) = 0.0
      H36(M,N) = 0.0
      H37(M,N) = 0.0
      H38(M,N) = 0.0
      H39(M,N) = 0.0
      H40(M,N) = 0.0
      H41(M,N) = 0.0
      H42(M,N) = 0.0
      H43(M,N) = 0.0
      H44(M,N) = 0.0
      H50(M,N)=0.0
      H51(M,N)=0.0
   25 CONTINUE
C
```

Figure 12-32. Subroutine INVTRY (2 of 8)

```
      DO 20 M=1,15
      DO 20 N=1,5
       C1(M,N) = 0.0
       C2(M,N) = 0.0
       C3(M,N) = 0.0
       C4(M,N) = 0.0
       C5(M,N) = 0.0
       C7(M,N) = 0.0
       C8(M,N) = 0.0
       C9(M,N) = 0.0
      C10(M,N) = 0.0
      C11(M,N) = 0.0
      C12(M,N) = 0.0
      C13(M,N) = 0.0
      C14(M,N) = 0.0
      C15(M,N) = 0.0
      C16(M,N) = 0.0
      C17(M,N) = 0.0
      C18(M,N) = 0.0
      C20(M,N) = 0.0
      C21(M,N) = 0.0
      C24(M,N) = 0.0
      C25(M,N) = 0.0
      C26(M,N) = 0.0
      C27(M,N) = 0.0
      C28(M,N) = 0.0
      C29(M,N) = 0.0
      C30(M,N) = 0.0
      C31(M,N) = 0.0
      C34(M,N) = 0.0
      C35(M,N) = 0.0
      C36(M,N) = 0.0
      C37(M,N) = 0.0
      C38(M,N) = 0.0
      C39(M,N) = 0.0
      C40(M,N) = 0.0
      C41(M,N) = 0.0
      C42(M,N) = 0.0
      C43(M,N) = 0.0
      C44(M,N) = 0.0
      C45(M,N) = 0.0
      C46(M,N) = 0.0
      C47(M,N) = 0.0
      C48(M,N)=0.0
      C49(M,N)=0.0
C
   20 CONTINUE
C
C
```

Figure 12-32. Subroutine INVTRY (3 of 8)

```
      I=0
      J=1
      NH=1
      IFINDO = 0
      IFINDG = 0
C
  559 CONTINUE
      IF ( ISAVE .EQ. 0 ) GO TO 120
      DO 315 II = 1,79
315   X(II) = Y(II)
      X80 = Y80
      ISAVE = 0
      GO TO 140
120   IF ( IEND .EQ. 99 ) GO TO 606
      READ (5,306,END=505) ( X(L),L=1,79 ), X80
140   IF ((X(77) .GT. .9) .AND. (X(77) .LT. 1.1)) GO TO 160
      IF ((X(77) .GT. 1.9) .AND. (X(77) .LT. 2.1)) GO TO 551
      IF ( ( ( X80.GT.0.9 ).AND.( X80.LT.1.1 ) ) .OR.
     1     ( ( X80.GT.1.9 ).AND.( X80.LT.2.1 ) ) .OR.
     2     ( ( X80.GT.2.9 ).AND.( X80.LT.3.1 ) ) ) GO TO 120
      WRITE (6,190)
190   FORMAT (//,' *****PRECEDING CARD UNRECOGNIZABLE - CHECK COLS 77 AN
     1D 80****')
      GO TO 120
160   YGRPNO  =  XGRPNO
      XGRPNO = 1000.*X(35) + 100.*X(36) + 10.*X(37) + X(38) + 0.01
      IF ( XGRPNO .LT. 0.1 ) GO TO 549
      IF ( IFINDO .EQ. 99) GO TO 317
      IFINDO = 0
      IFINDG = 99
      IF ( ISTART .EQ. 0 ) GO TO 209
      IF (   ABS(XGRPNO-YGRPNO) .LT. 0.1   )  GO TO 210
312   DO 313 II = 1,79
313   Y(II) = X(II)
      Y80 = X80
      ISAVE = 1
      GO TO 500
317   IFINDO = 0
      IFINDG = 99
      GO TO 312
505   IEND = 99
      GO TO 500
209   ISTART = 1
210   I = I + 1
      NH = I
      J = 1
      GO TO 551
C
549   IF ( (IFINDO .EQ. 99) .OR.  (IFINDG .EQ. 99) ) GO TO 499
      IFINDO = 99
      IFINDG = 0
```

Figure 12-32. Subroutine INVTRY (4 of 8)

```
      GO TO 210
499   IFINDG = 0
      IFINDO = 99
      GO TO 312
  551 CONTINUE
      IF (J .NE. 1)  GO TO 552
C
      H1(I,J)=1000.*X(23)+100.*X(24)+10.*X(25)+X(26)+.1
      H2(I,J)=1000.*X(3)+100.*X(4)+10.*X(5)+X(6)+.1
      H3(I,J)=100.*X(8)+10.*X(9)+X(10)+.1
      H4(I,J)=1000.*X(11)+100.*X(12)+10.*X(13)+X(14)+.1
      H5(I,J)=10.*X(15)+X(16)+.1
      H6(I,J)=X(22)+.1
      H7(I,J)=100.*X(19)+10.*X(20)+X(21)
      H8(I,J)=10.*X(1)+X(2)+.1
      H9(I,J)=X(7)+.1
      H11(I,J)=10.*X(27)+X(28)+.1
      H12(I,J)=10.*X(29)+X(30)+.1
      H13(I,J)=X(31)+.1
      H15(I,J)=100.*X(32)+10.*X(33)+X(34)
      H16(I,J)=1000.*X(35)+100.*X(36)+10.*X(37)+X(38)+.1
      H17(I,J)=100.*X(39)+10.*X(40)+X(41)+.1*X(42)+.01*X(43)+.001*X(4
      H18(I,J)=100.*X(45)+10.*X(46)+X(47)+.1*X(48)+.01*X(49)+.001*X(5
      H51(I,J)=10.*X(17)+X(18)
      H19(I,J)=X(51)+.1
C
      IH19=H19(I,J)
      GO TO ( 553, 554, 555 ),  IH19
C
C  IDENTIFICATION
C
C  IH19 = 1   POINT HAZARDS
C  IH19 = 2   LONGITUDINAL HAZARDS
C  IH19 = 3   SLOPES
C
  553 CONTINUE
      H20(I,J)=10.*X(52)+X(53)
      H21(I,J)=10.*X(60)+X(61)+.1*X(62)
      H22(I,J)=10.*X(63)+X(64)+.1*X(65)
      H23(I,J)=100.0*X(54)+10.0*X(55)+X(56)
      H24(I,J)=100.0*X(57)+10.0*X(58)+X(59)
      J=2
      GO TO 559
C
  554 CONTINUE
      H25(I,J)=10.*X(52)+X(53)
      H26(I,J)=10.*X(54)+X(55)
      H27(I,J)=10.*X(56)+X(57)+.1*X(58)
      H28(I,J)=10.*X(59)+X(60)
      H29(I,J)=X(61)+.1
      H30(I,J)=X(62)+.1
```

Figure 12-32. Subroutine INVTRY (5 of 8)

```
      J=2
      GO TO 559
C
  555 CONTINUE
      H31(I,J)=10.*X(52)+X(53)
      H32(I,J)=10.*X(54)+X(55)
      H33(I,J)=X(56)+.1*X(57)
      H34(I,J)=X(58)+.1*X(59)
      H35(I,J)=10.*X(60)+X(61)
      H36(I,J)=10.*X(62)+X(63)
      H37(I,J)=X(64)+.1
      H38(I,J)=X(65)+.1
      H39(I,J)=X(66)+.1*X(67)
      H40(I,J)=X(68)+.1*X(69)
      H41(I,J)=10.*X(70)+X(71)
      H42(I,J)=10.*X(72)+X(73)
      H43(I,J)=X(74)+.1
      H44(I,J)=X(75)+.1
      J=2
      GO TO 559
C
  552 CONTINUE
      C1(I,J)=1000.*X(1)+100.*X(2)+10.*X(3)+X(4)+.1
      C2(I,J)=1000.*X(5)+100.*X(6)+10.*X(7)+X(8)+.1
      C3(I,J)=100.*X(9)+10.*X(10)+X(11)+.1
      C4(I,J)=1000.*X(12)+100.*X(13)+10.*X(14)+X(15)+.1
      C5(I,J)=10.*X(16)+X(17)+.1
      C7(I,J)=100000.*X(18)+10000.*X(19)+1000.*X(20)+100.*X(21)+
     *           10.*X(22)+X(23)
      C8(I,J)=1000.*X(24)+100.*X(25)+10.*X(26)+X(27)
      C9(I,J)=1000.*X(28)+100.*X(29)+10.*X(30)+X(31)
      C10(I,J)=1000.*X(32)+100.*X(33)+10.*X(34)+X(35)
      C11(I,J)=1000.*X(36)+100.*X(37)+10.*X(38)+X(39)
      C12(I,J)=X(40)+.1
C
      IC12=C12(I,J)
      GO TO (556,557,558,580),IC12
C
C   IDENTIFICATION
C
C   IC12 = 1   POINT HAZARD IMPROVEMENT
C   IC12 = 2   LONGITUDINAL HAZARD IMPROVEMENT
C   IC12 = 3   SLOPE IMPROVEMENT
C   IC12 = 4   NO IMPROVEMENT
C
  580 CONTINUE
      NC(I)=J-1
      J=J+1
      GO TO 559
```

Figure 12-32. Subroutine INVTRY (6 of 8)

```
  556 CONTINUE
      C13(I,J)=X(41)+.1
      C14(I,J)=10.*X(42)+X(43)
      C15(I,J)=100.*X(42)+10.*X(43)+X(44)
      C16(I,J)=10.*X(45)+X(46)
      C17(I,J)=10.*X(47)+X(48)
      C20(I,J)=X(42)+0.1
      C48(I,J)=10.*X(42)+X(43)
      C49(I,J)=10.*X(44)+X(45)
      NC(I)=J-1
      J=J+1
      GO TO 559
C
  557 CONTINUE
      C18(I,J)=X(41)+0.1
      C20(I,J)=X(42)+.1
      C21(I,J)=X(43)+.1
      C24(I,J)=10.*X(44)+X(45)
      C25(I,J)=10.*X(46)+X(47)
      C26(I,J)=1000.*X(43)+100.*X(44)+10.*X(45)+X(46)
      C27(I,J)=1000.*X(47)+100.*X(48)+10.*X(49)+X(50)
      C28(I,J)=1000.*X(51)+100.*X(52)+10.*X(53)+X(54)
      C29(I,J)=1000.*X(55)+100.*X(56)+10.*X(57)+X(58)
      C30(I,J)=10.*X(48)+X(49)
      C31(I,J)=10.*X(50)+X(51)
      NC(I)=J-1
      J=J+1
      GO TO 559
C
  558 CONTINUE
      C18(I,J)=X(41)+0.1
      C24(I,J)=10.*X(44)+X(45)
      C25(I,J)=10.*X(46)+X(47)
      C30(I,J)=10.*X(48)+X(49)
      C31(I,J)=10.*X(50)+X(51)
      C34(I,J)=100.*X(64)+10.*X(65)+X(66)+.1*X(67)+
     *          .01*X(68)+.001*X(69)
      C35(I,J)=100.*X(70)+10.*X(71)+X(72)+.1*X(73)+
     *          .01*X(74)+.001*X(75)
      C36(I,J)=10.*X(42)+X(43)
      C37(I,J)=10.*X(44)+X(45)
      C38(I,J)=X(46)+.1*X(47)
      C39(I,J)=X(48)+.1*X(49)
      C40(I,J)=10.*X(50)+X(51)
      C41(I,J)=10.*X(52)+X(53)
      C42(I,J)=X(54)+.1
      C43(I,J)=X(55)+.1*X(56)
      C44(I,J)=X(57)+.1*X(58)
      C45(I,J)=10.*X(59)+X(60)
      C46(I,J)=10.*X(61)+X(62)
```

Figure 12-32. Subroutine INVTRY (7 of 8)

```
      C47(I,J)=X(63)+.1
      NC(I)=J-1
      J=J+1
      GO TO 559
C
  500 CONTINUE
      LP1=NC(1)
      RETURN
C
  606 CONTINUE


      MES = 27
      RETURN
C
  306 FORMAT (79F1.0, I1)
C
      END
```

Figure 12-32. Subroutine INVTRY (8 of 8)

```
C     ****************************************************************************
C
          SUBRCUTINE   ORDERI
C
C     ****************************************************************************
C
C     SUBROUTINE TO RE-ARRANGE THE HAZARDS IN ASCENDING ORDER BASED ON LATE
C     OFFSET DISTANCE FROM EDGE OF TRAVELLED LANE
C
C
          COMMON / INVENT / I, J, NH, LP1, LL, MES
          COMMON / HINVNT / H1, H2, H3, H4, H5, H6, H7, H8, H9, H11, H12,
         *                  H13, H15, H16, H17, H18, H19, H20, H21, H22,
         *                  H23, H24, H25, H26, H27, H28, H29, H30, H31,
         *                  H32, H33, H34, H35, H36, H37, H38, H39, H40,
         *                  H41, H42, H43, H44, H50, H51
          COMMON / CINVNT / C1, C2, C3, C4, C5, C7, C8, C9, C10, C11, C12,
         *                  C13, C14, C15, C16, C17, C18, C20, C21, C24,
         *                  C25, C26, C27, C28, C29, C34, C35, C36, C37,
         *                  C38, C39, C40, C41, C42, C43, C44, C45, C46, C4
         *                  , C30, C31, C48, C49
          COMMON / SLOPES / K, FSDIR, BSDIR, FSERS, BSERS, FSSTP, BSSTP,
         *                  FSANG, BSANG, OFFST1, OFFST2, FSOFF, DELTA,
         *                  FSDIS, BSDIS
          COMMON / HASCND / NORDER
          INTEGER   A1,A2,A3,A4,A5,A6,A8,A9,A11,A12,A13,A16,A19,A29,A30,A37,
         *          A38,A43,A44
          INTEGER   B1,B2,B3,B4,B5,B12,B13,B18,B20,B21,B42,B47
C
          INTEGER   H1, H2, H3, H4, H5, H6, H8, H9, H11, H12, H13, H16, H19,
         *          H29, H30, H37, H38, H43, H44
          INTEGER   C1, C2, C3, C4, C5, C12, C13, C18, C20, C21, C42, C47
          INTEGER FSDIR, BSDIR, FSERS, BSERS
C
          DIMENSION   NC(15)
          DIMENSION   H1(15,1), H2(15,1), H3(15,1), H4(15,1), H5(15,1),
         *            H6(15,1), H7(15,1), H8(15,1), H9(15,1), H11(15,1),
         *            H12(15,1), H13(15,1), H15(15,1), H16(15,1), H17(15,1),
         *            H18(15,1), H19(15,1), H20(15,1), H21(15,1), H22(15,1),
         *            H23(15,1), H24(15,1), H25(15,1), H26(15,1), H27(15,1),
         *            H28(15,1), H29(15,1), H30(15,1), H31(15,1), H32(15,1)
          DIMENSICN   H33(15,1), H34(15,1), H35(15,1), H36(15,1), H37(15,1),
         *            H38(15,1), H39(15,1), H40(15,1), H41(15,1), H42(15,1),
         *            H43(15,1), H44(15,1), H50(15,1), H51(15,1)
          DIMENSICN   C1(15,5), C2(15,5), C3(15,5), C4(15,5), C5(15,5),
         *            C7(15,5), C8(15,5), C9(15,5), C10(15,5), C11(15,5),
         *            C12(15,5), C13(15,5), C14(15,5), C15(15,5), C16(15,5),
         *            C17(15,5), C18(15,5), C20(15,5), C21(15,5), C24(15,5),
         *            C25(15,5), C26(15,5), C27(15,5), C28(15,5), C29(15,5),
         *            C34(15,5), C35(15,5), C36(15,5), C37(15,5), C38(15,5),
          DIMENSION   C39(15,5), C40(15,5), C41(15,5), C42(15,5), C43(15,5),
```

Figure 12-33. Subroutine ORDERI (1 of 8)

```
*            C44(15,5), C45(15,5), C46(15,5), C47(15,5)
*            , C30(15,5), C31(15,5), C48(15,5), C49(15,5)
 DIMENSION   A1(15,5), A2(15,5), A3(15,5), A4(15,5), A5(15,5),
*            A7(15,5), A8(15,5), A9(15,5), A10(15,5), A11(15,5),
*            A12(15,5), A13(15,5), A14(15,5), A15(15,5), A16(15,5),
*            A17(15,5), A18(15,5), A20(15,5), A21(15,5), A24(15,5),
*            A25(15,5), A26(15,5), A27(15,5), A28(15,5), A29(15,5),
*            A34(15,5), A35(15,5), A36(15,5), A37(15,5), A38(15,5)
 DIMENSION   A39(15,5), A40(15,5), A41(15,5), A42(15,5), A43(15,5),
*            A44(15,5), A45(15,5), A46(15,5), A47(15,5),
*            A50(15,5), A51(15,5)
 DIMENSION A6(15,5), A19(15,5), A22(15,5), A23(15,5), A30(15,5),
*          A31(15,5), A32(15,5), A33(15,5)
 DIMENSION   B1(15,5),B2(15,5),B3(15,5),B4(15,5),B5(15,5),B7(15,5),
*            B8(15,5),B9(15,5),B10(15,5),B11(15,5),B12(15,5),
*            B13(15,5),B14(15,5),B15(15,5),B16(15,5),B17(15,5),
*            B18(15,5),B20(15,5),B21(15,5),B24(15,5),B25(15,5),
*            B26(15,5),B27(15,5),B28(15,5),B29(15,5),B34(15,5)
 DIMENSION   B35(15,5), B36(15,5),B37(15,5),B38(15,5),B39(15,5),
*            B40(15,5),B41(15,5),B42(15,5),B43(15,5),B44(15,5),
*            B45(15,5),B46(15,5),B47(15,5),B30(15,5),
*            B31(15,5),B48(15,5), B49(15,5)
 DIMENSION   NORDER(15)
 DIMENSION   HOFF(15,1), NCOUNT(15), MM(15)

 IF(NH.EQ.1) GO TO 14
 DO 10 L=1,NH
 NCOUNT(L)=1
 IH19=H19(L,1)
 GO TO ( 100, 101, 102 ),  IH19

00 CONTINUE
 HOFF(L,1)=H20(L,1)
 MM(L)=L
 GO TO 10

01 CONTINUE
 HOFF(L,1)=.5*(H25(L,1)+H26(L,1))
 MM(L)=L
 GO TO 10

02 CONTINUE
 K = L
 LL=1

 CALL SLOPE1

 HOFF(L,1)=FSOFF
 MM(L)=L
10 CONTINUE
```

Figure 12-33. Subroutine ORDER1 (2 of 8)

```
C
      N1=NH-1
      DO 12 N=1,N1
      IP1=N+1
      DO 12 K=IP1,NH
      IF(HOFF(N,1).LE.HOFF(K,1)) GO TO 12
      TEMP = HOFF(N,1)
      HOFF(N,1)=HOFF(K,1)
      HOFF(K,1)=TEMP
      ITEMP=MM(N)
      MM(N)=MM(K)
      MM(K)=ITEMP
   12 CONTINUE
C
C
      DO 55 M=1,NH
      K=MM(M)
       A1(M,1) =  H1(K,1)
       A2(M,1) =  H2(K,1)
       A3(M,1) =  H3(K,1)
       A4(M,1) =  H4(K,1)
       A5(M,1) =  H5(K,1)
       A6(M,1) =  H6(K,1)
       A7(M,1) =  H7(K,1)
       A8(M,1) =  H8(K,1)
       A9(M,1) =  H9(K,1)
      A11(M,1) = H11(K,1)
      A12(M,1) = H12(K,1)
      A13(M,1) = H13(K,1)
      A15(M,1) = H15(K,1)
      A16(M,1) = H16(K,1)
      A17(M,1) = H17(K,1)
      A18(M,1) = H18(K,1)
      A19(M,1) = H19(K,1)
      A50(M,1) = H50(K,1)
      A51(M,1) = H51(K,1)
C
      IH19=H19(K,1)
      GO TO(50,51,52),IH19
C
   50 CONTINUE
      A20(M,1) = H20(K,1)
      A21(M,1) = H21(K,1)
      A22(M,1) = H22(K,1)
      A23(M,1) = H23(K,1)
      A24(M,1) = H24(K,1)
      GO TO 55
C
   51 CONTINUE
      A25(M,1) = H25(K,1)
      A26(M,1) = H26(K,1)
      A27(M,1) = H27(K,1)
```

Figure 12-33. Subroutine ORDER1 (3 of 8)

```
      A28(M,1) = H28(K,1)
      A29(M,1) = H29(K,1)
      A30(M,1) = H30(K,1)
      GO TO 55
C
   52 CONTINUE
      A31(M,1) = H31(K,1)
      A32(M,1) = H32(K,1)
      A33(M,1) = H33(K,1)
      A34(M,1) = H34(K,1)
      A35(M,1) = H35(K,1)
      A36(M,1) = H36(K,1)
      A37(M,1) = H37(K,1)
      A38(M,1) = H38(K,1)
      A39(M,1) = H39(K,1)
      A40(M,1) = H40(K,1)
      A41(M,1) = H41(K,1)
      A42(M,1) = H42(K,1)
      A43(M,1) = H43(K,1)
      A44(M,1) = H44(K,1)
   55 CONTINUE
C
      DO 35 M=1,NH
      K=M
       H1(M,1) =  A1(K,1)
       H2(M,1) =  A2(K,1)
       H3(M,1) =  A3(K,1)
       H4(M,1) =  A4(K,1)
       H5(M,1) =  A5(K,1)
       H6(M,1) =  A6(K,1)
       H7(M,1) =  A7(K,1)
       H8(M,1) =  A8(K,1)
       H9(M,1) =  A9(K,1)
      H11(M,1) = A11(K,1)
      H12(M,1) = A12(K,1)
      H13(M,1) = A13(K,1)
      H15(M,1) = A15(K,1)
      H16(M,1) = A16(K,1)
      H17(M,1) = A17(K,1)
      H18(M,1) = A18(K,1)
      H19(M,1) = A19(K,1)
      H50(M,1) = A50(K,1)
      H51(M,1) = A51(K,1)
C
      IH19=A19(K,1)
      GO TO(40,41,42),IH19
C
   40 CONTINUE
      H20(M,1) = A20(K,1)
      H21(M,1) = A21(K,1)
      H22(M,1) = A22(K,1)
```

Figure 12-33. Subroutine ORDERI (4 of 8)

```
      H23(M,1) = A23(K,1)
      H24(M,1) = A24(K,1)
      GO TO 35
C
   41 CONTINUE
      H25(M,1) = A25(K,1)
      H26(M,1) = A26(K,1)
      H27(M,1) = A27(K,1)
      H28(M,1) = A28(K,1)
      H29(M,1) = A29(K,1)
      H30(M,1) = A30(K,1)
      GO TO 35
C
   42 CONTINUE
      H31(M,1) = A31(K,1)
      H32(M,1) = A32(K,1)
      H33(M,1) = A33(K,1)
      H34(M,1) = A34(K,1)
      H35(M,1) = A35(K,1)
      H36(M,1) = A36(K,1)
      H37(M,1) = A37(K,1)
      H38(M,1) = A38(K,1)
      H39(M,1) = A39(K,1)
      H40(M,1) = A40(K,1)
      H41(M,1) = A41(K,1)
      H42(M,1) = A42(K,1)
      H43(M,1) = A43(K,1)
      H44(M,1) = A44(K,1)
   35 CONTINUE
C
C
      N1 = LP1 + 1
      DO 60 M=1,NH
      DO 60 N=2,N1
      K=MM(M)
       B1(M,N) =  C1(K,N)
       B2(M,N) =  C2(K,N)
       B3(M,N) =  C3(K,N)
       B4(M,N) =  C4(K,N)
       B5(M,N) =  C5(K,N)
       B7(M,N) =  C7(K,N)
       B8(M,N) =  C8(K,N)
       B9(M,N) =  C9(K,N)
       B10(M,N) =  C10(K,N)
       B11(M,N) =  C11(K,N)
       B12(M,N) =  C12(K,N)
C
      IB12=B12(M,N)
      GO TO(64,65,66,60),IB12
C
   64 CONTINUE
```

Figure 12-33. Subroutine ORDER1 (5 of 8)

```
      B13(M,N) =  C13(K,N)
      B14(M,N) =  C14(K,N)
      B15(M,N) =  C15(K,N)
      B16(M,N) =  C16(K,N)
      B17(M,N) =  C17(K,N)
      B20(M,N) =  C20(K,N)
      B48(M,N) =  C48(K,N)
      B49(M,N) =  C49(K,N)
     GO TO 60
C
   65 CONTINUE
      B18(M,N) =  C18(K,N)
      B20(M,N) =  C20(K,N)
      B21(M,N) =  C21(K,N)
      B24(M,N) =  C24(K,N)
      B25(M,N) =  C25(K,N)
      B26(M,N) =  C26(K,N)
      B27(M,N) =  C27(K,N)
      B28(M,N) =  C28(K,N)
      B29(M,N) =  C29(K,N)
      B30(M,N) =  C30(K,N)
      B31(M,N) =  C31(K,N)
     GO TO 60
C
   66 CONTINUE
      B18(M,N) =  C18(K,N)
      B24(M,N) =  C24(K,N)
      B25(M,N) =  C25(K,N)
      B30(M,N) =  C30(K,N)
      B31(M,N) =  C31(K,N)
      B34(M,N) =  C34(K,N)
      B35(M,N) =  C35(K,N)
      B36(M,N) =  C36(K,N)
      B37(M,N) =  C37(K,N)
      B38(M,N) =  C38(K,N)
      B39(M,N) =  C39(K,N)
      B40(M,N) =  C40(K,N)
      B41(M,N) =  C41(K,N)
      B42(M,N) =  C42(K,N)
      B43(M,N) =  C43(K,N)
      B44(M,N) =  C44(K,N)
      B45(M,N) =  C45(K,N)
      B46(M,N) =  C46(K,N)
      B47(M,N) =  C47(K,N)
   60 CONTINUE
      N1 = LP1 + 1
      DO 30 M=1,NH
      DO 30 N=2,N1
      K=M
       C1(M,N) =  B1(K,N)
       C2(M,N) =  B2(K,N)
```

Figure 12-33. Subroutine ORDER1 (6 of 8)

```
      C3(M,N) =  B3(K,N)
      C4(M,N) =  B4(K,N)
      C5(M,N) =  B5(K,N)
      C7(M,N) =  B7(K,N)
      C8(M,N) =  B8(K,N)
      C9(M,N) = B9(K,N)
      C10(M,N) = B10(K,N)
      C11(M,N) = B11(K,N)
      C12(M,N) =  B12(K,N)
C
      IC12=C12(M,N)
      GO TO(44,45,46,30),IC12
C
   44 CONTINUE
      C13(M,N) =  B13(K,N)
      C14(M,N) = B14(K,N)
      C15(M,N) = B15(K,N)
      C16(M,N) = B16(K,N)
      C17(M,N) = B17(K,N)
      C20(M,N) = B20(K,N)
      C48(M,N) = B48(K,N)
      C49(M,N) = B49(K,N)
      GO TO 30
C
   45 CONTINUE
      C18(M,N) =  B18(K,N)
      C20(M,N) =  B20(K,N)
      C21(M,N) =  B21(K,N)
      C24(M,N) = B24(K,N)
      C25(M,N) = B25(K,N)
      C26(M,N) = B26(K,N)
      C27(M,N) = B27(K,N)
      C28(M,N) = B28(K,N)
      C29(M,N) = B29(K,N)
      C30(M,N) = B30(K,N)
      C31(M,N) = B31(K,N)
      GO TO 30
C
   46 CONTINUE
      C18(M,N) = B18(K,N)
      C24(M,N) = B24(K,N)
      C25(M,N) = B25(K,N)
      C30(M,N) = B30(K,N)
      C31(M,N) = B31(K,N)
      C34(M,N) = B34(K,N)
      C35(M,N) = B35(K,N)
      C36(M,N) = B36(K,N)
      C37(M,N) = B37(K,N)
      C38(M,N) = B38(K,N)
      C39(M,N) = B39(K,N)
      C40(M,N) = B40(K,N)
      C41(M,N) = B41(K,N)
      C42(M,N) = B42(K,N)
      C43(M,N) = B43(K,N)
```

Figure 12-33. Subroutine ORDERI (7 of 8)

```
      C44(M,N) = B44(K,N)
      C45(M,N) = B45(K,N)
      C46(M,N) = B46(K,N)
      C47(M,N) = B47(K,N)
   30 CONTINUE
   14 CONTINUE
      RETURN
C
      END
```

Figure 12-33. Subroutine ORDER1 (8 of 8)

```
C    ************************************************************************
C
        SUBROUTINE  ORDER2
C
C    ************************************************************************
C
C    SUBROUTINE REARRANGES HAZARDS LONGITUDINALLY WITHIN A GROUP
C    FOR INSTALLATION OF A SINGLE LENGTH OF GUARDRAIL TO PROTECT THE GROUP
C
C
        COMMON / INVENT / I, J, NH, LP1, LL, MES
        COMMON / HINVNT / H1, H2, H3, H4, H5, H6, H7, H8, H9, H11, H12,
       *                  H13, H15, H16, H17, H18, H19, H20, H21, H22,
       *                  H23, H24, H25, H26, H27, H28, H29, H30, H31,
       *                  H32, H33, H34, H35, H36, H37, H38, H39, H40,
       *                  H41, H42, H43, H44, H50, H51
        COMMON / PTHZGR / NPTGR, HLGTH
        COMMON / BRGR2 / MM
C
        INTEGER  H1, H2, H3, H4, H5, H6, H8, H9, H11, H12, H13, H16, H19,
       *         H29, H30, H37, H38, H43, H44
C
        DIMENSION  H1(15,1), H2(15,1), H3(15,1), H4(15,1), H5(15,1),
       *           H6(15,1), H7(15,1), H8(15,1), H9(15,1), H11(15,1),
       *           H12(15,1), H13(15,1), H15(15,1), H16(15,1), H17(15,1),
       *           H18(15,1), H19(15,1), H20(15,1), H21(15,1), H22(15,1),
       *           H23(15,1), H24(15,1), H25(15,1), H26(15,1), H27(15,1),
       *           H28(15,1), H29(15,1), H30(15,1), H31(15,1), H32(15,1)
        DIMENSION  H33(15,1), H34(15,1), H35(15,1), H36(15,1), H37(15,1),
       *           H38(15,1), H39(15,1), H40(15,1), H41(15,1), H42(15,1),
       *           H43(15,1), H44(15,1), H50(15,1), H51(15,1)
        DIMENSION  MM(15)
C
C
        DO 5 N=1,NH
        MM(N)=N
      5 CONTINUE
        IH6=H6(I,1)
        GO TO ( 10, 12 ), IH6
C
     10 CONTINUE
        N1=NH-1
        DO 14 N=1,N1
        IP1=N+1
        DO 14 K=IP1,NH
        IF ( H17(N,1) .LE. H17(K,1) )  GO TO 14
        ITEMP=MM(N)
        MM(N)=MM(K)
        MM(K)=ITEMP
     14 CONTINUE
        II=MM(1)
```

Figure 12-34. Subroutine ORDER2 (1 of 2)

```
      JJ=MM(NH)
      HLGTH=ABS(H17(II,1)-H17(JJ,1))+H24(JJ,1)
      GO TO 16
C
   12 CONTINUE
      N1=NH-1
      DO 18 N=1,N1
      IP1=N+1
      DO 18 K=IP1,NH
      IF ( H17(N,1) .GE. H17(K,1) )  GO TO 18
      ITEMP=MM(N)
      MM(N)=MM(K)
      MM(K)=ITEMP
   18 CONTINUE
      II=MM(1)
      JJ=MM(NH)
      HLGTH=ABS(H17(II,1)-H17(JJ,1))+H24(JJ,1)
   16 CONTINUE
      RETURN
C
      END
```

Figure 12-34. Subroutine ORDER2 (2 of 2)

```
C     ***********************************************************************
C
         SUBROUTINE  CCNST1
C
C     ***********************************************************************
C
C     SUBROUTINE TO COMPUTE CONSTANT VALUES
C
C
         COMMON / CCNSNT / D, THETA, RAD, ANG, RSIN, RTAN, LIFE, RI
C
C
         D=6.
         RAD=3.1416/180.
         THETA=11.
         ANG=THETA*RAD
         RSIN=1./SIN(ANG)
         RTAN=1./TAN(ANG)
         LIFE=20
         RI=8.
         RETURN
         END
```

Figure 12-35. Subroutine CONST1 (1 of 1)

```
*************************************************************************

   SUBROUTINE  HAZARD

*************************************************************************

SUBROUTINE CALLS UP THE APPROPRIATE MAIN SUBROUTINE FOR ONE OF
THE THREE DEFINED TYPE HAZARDS (POINT, LONGITUDINAL, AND SLOPE).
EXCEPT FOR SEVERAL SPECIAL CASES, THE SEVERITY-INDICIES FOR THE
HAZARD ARE OBTAINED FROM STORAGE ARRAYS.


   COMMON / INVENT / I, J, NH, LP1, LL, MES
   COMMON / COUNT / NC
   COMMON / SEVERE / S
   COMMON / HINVNT / H1, H2, H3, H4, H5, H6, H7, H8, H9, H11, H12,
  *                  H13, H15, H16, H17, H18, H19, H20, H21, H22,
  *                  H23, H24, H25, H26, H27, H28, H29, H30, H31,
  *                  H32, H33, H34, H35, H36, H37, H38, H39, H40,
  *                  H41, H42, H43, H44, H50, H51
   COMMON / CINVNT / C1, C2, C3, C4, C5, C7, C8, C9, C10, C11, C12,
  *                  C13, C14, C15, C16, C17, C18, C20, C21, C24,
  *                  C25, C26, C27, C28, C29, C34, C35, C36, C37,
  *                  C38, C39, C40, C41, C42, C43, C44, C45, C46, C47
  *                  , C30, C31, C48, C49
   COMMON / HAZRDS / HI1, HI2, SI, SI1, SI2, R, P, UPAY, PSUM, HIB,
  *                  HIA
   COMMON / NCNHWY / NCONTR, MONTH, NYEAR

   INTEGER  H1, H2, H3, H4, H5, H6, H8, H9, H11, H12, H13, H16, H19,
  *         H29, H30, H37, H38, H43, H44
   INTEGER  C1, C2, C3, C4, C5, C12, C13, C18, C20, C21, C42, C47

   DIMENSION  NC(15)
   DIMENSION  S(13,7,4,4)
   DIMENSION  H1(15,1), H2(15,1), H3(15,1), H4(15,1), H5(15,1),
  *           H6(15,1), H7(15,1), H8(15,1), H9(15,1), H11(15,1),
  *           H12(15,1), H13(15,1), H15(15,1), H16(15,1), H17(15,1),
  *           H18(15,1), H19(15,1), H20(15,1), H21(15,1), H22(15,1),
  *           H23(15,1), H24(15,1), H25(15,1), H26(15,1), H27(15,1),
  *           H28(15,1), H29(15,1), H30(15,1), H31(15,1), H32(15,1)
   DIMENSION  H33(15,1), H34(15,1), H35(15,1), H36(15,1), H37(15,1),
  *           H38(15,1), H39(15,1), H40(15,1), H41(15,1), H42(15,1),
  *           H43(15,1), H44(15,1), H50(15,1), H51(15,1)
   DIMENSION  C1(15,5), C2(15,5), C3(15,5), C4(15,5), C5(15,5),
  *           C7(15,5), C8(15,5), C9(15,5), C10(15,5), C11(15,5),
  *           C12(15,5), C13(15,5), C14(15,5), C15(15,5), C16(15,5),
  *           C17(15,5), C18(15,5), C20(15,5), C21(15,5), C24(15,5),
  *           C25(15,5), C26(15,5), C27(15,5), C28(15,5), C29(15,5),
  *           C34(15,5), C35(15,5), C36(15,5), C37(15,5), C38(15,5)
   DIMENSION  C39(15,5), C40(15,5), C41(15,5), C42(15,5), C43(15,5),
  *           C44(15,5), C45(15,5), C46(15,5), C47(15,5)
  *           , C30(15,5), C31(15,5), C48(15,5), C49(15,5)
```

Figure 12-36. Subroutine HAZARD (1 of 4)

```
      DIMENSION  SI(15), HI1(15,2), HI2(15,2), SI2(15,5), SI1(15,1)
C
C
      IF ( NH .EQ. 1 )  GO TO 604
      IF (H1(I,1) .NE. C1(I,J) .OR. H2(I,1) .NE. C2(I,J) .OR. H3(I,1)
     *    .NE. C3(I,J) .OR. H4(I,1) .NE. C4(I,J) .OR. H5(I,1) .NE.
     *    C5(I,J)) GO TO 607
      DO 602 L=2,NH
      M1=L-1
      IF ( NC(L) .NE. NC(M1)) GO TO 605
      IF(H13(L,1) .NE. H13(M1,1)) GO TO 606
  602 CONTINUE
      GO TO 604
  605 CONTINUE
      MES=28
      RETURN
C
  606 CONTINUE
      MES=31
      RETURN
C
  607 CONTINUE
      MES=24
      RETURN
C
  604 CONTINUE
C
      IF(C7(I,J) .GT. 0.0) GO TO 60
      IF(C12(I,J) .EQ. 4) GO TO 60
      MES=34
      RETURN
C
   60 CONTINUE
C
      IF(H11(I,1) .NE. 6) GO TO 50
      IF(C12(I,J) .EQ. 4) GO TO 50
      IF(C8(I,J) .EQ. 0.0 .OR. C10(I,J) .EQ. 0.0) GO TO 51
      IF(C9(I,J) .EQ. 0.0 .OR. C11(I,J) .EQ. 0.0) GO TO 52
      GO TO 50
   51 CONTINUE
      MES=35
      RETURN
C
   52 CONTINUE
      IF(C18(I,J) .EQ. 3 .AND. C20(I,J) .EQ. 1) GO TO 50
      MES=36
      RETURN
C
   50 CONTINUE
      IF(H19(I,1) .EQ. 1) GO TO 40
      IF(H18(I,1) .EQ. 0.0) GO TO 41
```

Figure 12-36. Subroutine HAZARD (2 of 4)

```
      GO TO 40
   41 CONTINUE
      MES=1
      RETURN
C
   40 CONTINUE
C
C  HAZARD SEVERITY-INDEX COMPUTATIONS  ( GENERAL )
C
      I1=H11(I,1)
      IF ( H12(I,1) .EQ. 0 )  GO TO 5
      IF ( H11(I,1) .EQ. 6 )  GO TO 6
C
      I2=H12(I,1)
      I3=1
      I4=1
      GO TO 7
C
    5 CONTINUE
      I2=1
      I3=1
      I4=1
      GO TO 7
C
    6 CONTINUE
      IF(H29(I,1) .EQ. 0 .OR. H30(I,1) .EQ. 0) GO TO 31
      IF(H29(I,1) .GT. 4 .OR. H30(I,1) .GT. 4) GO TO 32
      GO TO 30
   31 CONTINUE
      MES=32
      RETURN
C
   32 CONTINUE
      MES=33
      RETURN
C
   30 CONTINUE
      I2=H12(I,1)
      I3=H29(I,1)
      I4=H30(I,1)
C
    7 CONTINUE
      SI(I)=S(I1,I2,I3,I4)/10.
      SI1(I,1)=10.*SI(I)
C
C  SPECIAL CASE -- SEVERITY INDEX OF DROP INLETS WITH A RAISED HEIGHT OR
C                  DEPRESSED DEPTH GREATER THAN 1.0 FT
C
      IF ( H11(I,1) .NE. 10 )  GO TO 10
      IF ( H21(I,1) .GT. 1. )  GO TO 12
      IF ( H22(I,1) .LE. 1. )  GO TO 10
```

Figure 12-36. Subroutine HAZARD (3 of 4)

```
C
      SI(I)=11.0/10.0
      SI1(I,1)=10.*SI(I)
      GO TO 10
C
C   SEVERITY INDEX FOR RAISED DROP INLET ASSUMED EQUAL TO THAT OF A BRIDG
C
   12 CONTINUE
      SI(I)=S(11,1,1,1)/10.
      SI1(I,1)=10.*SI(I)
   10 CONTINUE
      IH19=H19(I,1)
      IF ( IH19 .NE. 1 .AND. IH19 .NE. 2 .AND. IH19 .NE. 3 )  GO TO 14
      GO TO ( 16, 18, 20 ), IH19
C
   16 CONTINUE
C
      CALL PTHAZ
      RETURN
   18 CONTINUE
C
      CALL LGHAZ
      RETURN
C
   20 CONTINUE
C
      CALL SLHAZ
      RETURN
C
   14 CONTINUE
      MES=6
      RETURN
C
      END
```

Figure 12-36. Subroutine **HAZARD** (4 of 4)

```
C     **********************************************************************
C
      SUBROUTINE  VDITCH
C
C     **********************************************************************
C
C     THIS PROGRAM IS DESIGNED TO CALCULATE THE SEVERITY INDEX, SI, FOR
C     THE V-DITCH OR INTERSECTION OF THE FRONT AND BACK SLOPES LOCATED
C     WITHIN 30 FEET OF THE TRAVELED WAY.   IN ADDITION, THE WIDTH, W,
C     OF THE IMAGINARY LONGITUDINAL HAZARD IS ASSIGNED.
C
C
      COMMON / SLOPES / K, FSDIR, BSDIR, FSERS, BSERS, FSSTP, BSSTP,
     *                  FSANG, BSANG, OFFST1, OFFST2, FSOFF, DELTA,
     *                  FSDIS, BSDIS
      COMMON / HDITCH / SD, W, WD, SDA
C
      INTEGER FSDIR, BSDIR, FSERS, BSERS
C
C     MAXIMUM V-DITCH SEVERITY ASSIGNED FIRST THEN CHECKED
C
      SI=.80
C
C     FRONT SLOPE CHECKED FOR DIRECTION
C
      IF(FSDIR-1) 10,10,20
10    IF(FSSTP.GE.6.) GO TO 600
      IF(FSSTP.GE.4.) GO TO 610
      IF(FSSTP.LT.4.)  GO TO 620
20    IF(FSSTP.GE.6.) GO TO 100
      IF(FSSTP.GE.5.)  GO TO 200
      IF(FSSTP.GE.4.) GO TO 300
      IF(FSSTP.GE.3.6)  GO TO 400
      IF(FSSTP.GE.3.)  GO TO 500
      IF(FSSTP.LT.3.)  GO TO 800
C
C     100 SERIES FOR SLOPES FLATTER THAN 6 TO 1
C
100   IF(DELTA.LT.19.)  SI=.22
      IF(DELTA.GE.19.0.AND.DELTA.LT.23.6)  SI=.24
      IF(DELTA.GE.23.6.AND.DELTA.LT.27.9)  SI=.30
      GO TO 800
C
C     200 SERIES FOR SLOPES FLATTER THAN 5 TO 1
C
200   IF(DELTA.LT.21.9)  SI=.24
      IF(DELTA.GE.21.9.AND.DELTA.LT.28.5)  SI=.27
      IF(DELTA.GE.28.5.AND.DELTA.LT.30.8)  SI=.32
      GO TO 800
```

Figure 12-37. Subroutine VDITCH (1 of 2)

```
C
C     300 SERIES FOR SLOPES FLATTER THAN 4 TO 1
C
300   IF(DELTA.LT.23.6)  SI=.26
      IF(DELTA.GE.23.6.AND.DELTA.LT.28.2)  SI=.30
      IF(DELTA.GE.28.2.AND.DELTA.LT.32.5)  SI=.40
      GO TO 800
C
C     400 SERIES FOR SLOPES FLATTER THAN 3.6 TO 1
C
400   IF(DELTA.LT.25.1)  SI=.35
      IF(DELTA.GE.25.1.AND.DELTA.LT.29.7)  SI=.38
      IF(DELTA.GE.29.7.AND.DELTA.LT.34.0)  SI=.45
      GO TO 800
C
C     500 SERIES FOR SLOPES FLATTER THAN 3 TO 1
C
500   IF(DELTA.LT.27.9)  SI=.36
      IF(DELTA.GE.27.9.AND.DELTA.LT.32.5)  SI=.42
      IF(DELTA.GE.32.5.AND.DELTA.LT.36.8)  SI=.48
      GO TO 800
C
C
C     600 SERIES DETERMINES THE SEVERITY FOR A + FRONT SLOPE CONDITION
C
C     THE FOLLOWING THREE STATEMENTS ARE FOR A FRONT SLOPE OF 6 TO 1 OR
C     FLATTER
C
600   IF(DELTA.LE.3.0) SI=.10
      IF(DELTA.LE.4.7) SI=.15
      IF(DELTA.LE.9.0) SI=.20
      GO TO 800
C
C     STATEMENT 610 IS FOR A FRONT SLOPE OF 4 TO 1 OR FLATTER
C
610   IF(DELTA.LE.2.0) SI=.30
      GO TO 800
C
C     STATEMENTS 620 ARE FOR FRONT SLOPES STEEPER THAN 4 TO 1
C
620   IF(DELTA.LE.1.0) SI=.36
      IF(DELTA.GT.1.0) SI=.80
C
C     800 SERIES IS FOR DETERMINING THE WIDTH OF OBSTACLE
C
800   W=4.
      IF(FSDIR.EQ.1.AND.FSSTP.LE.3.5)  W=8.
      IF(FSDIR.EQ.2.AND.FSSTP.LT.3.0)  W=8.
      IF(FSOFF.LT.15.)  W=8.
      SD = SI
      RETURN
C
      END
```

Figure 12-37. Subroutine VDITCH (2 of 2)

```
C     ******************************************************************
C
       SUBROUTINE  PROB
C
C     ******************************************************************
C
C  SUBROUTINE TO COMPUTE PROBALITY OF A VEHICLE LATERAL DISPLACEMENT
C  GREATER THAN SOME OFFSET DISTANCE.  ENCROACHMENT ANGLE EQUAL TO
C  11 DEG.  (FIGURE 4 IN NCHRP 20-7).
C
C
       COMMON / PROBTY / Y, PP
C
C  Y  LATERAL OFFSET DISTANCE TO OBSTACLE (FT)
C
       IF ( Y .LE. 6. )  GO TO 400
       IF ( Y .GE. 44. )  GO TO 402
C
C  Y LESS OR EQUAL 6.   PP=1
C
C  Y GREATER 44.        PP=0
C
       Y2=Y**2
       Y3=Y**3
C
       PP=99.0826+.74597*Y-.161676*Y2+.0021346*Y3
       GO TO 404
C
  400 PP = 100.0
       GO TO 404
C
  402 PP = 0.0
C
  404 CONTINUE
       PP = 0.01 * PP
C
       RETURN
       END
```

Figure 12-38. Subroutine PROB (1 of 1)

```
C      ***********************************************************************
C
        SUBROUTINE  FREQ
C
C      ***********************************************************************
C
C   SUBROUTINE TO COMPUTE THE ENCROACHMENT FREQUENCY EXPRESSED AS THE NUM
C   OF ROADSIDE ENCROACHMENTS PER MILE PER YEAR.  ( FIGUTR 2 IN NCHRP 20-
C
C
        COMMON / FRQNCY / ADT, EF
C
C
C   AVERAGE DAILY TRAFFIC FOR BOTH DIRECTIONS OF TRAFFIC
C
        ADT=ADT*1000.
        IF (ADT .LE. 3200.0) GO TO 400
        IF ( ADT .GT. 3200.0 .AND. ADT .LE. 5500.0) GO TO 402
        GO TO 404
C
    400 FF = 0.001625 * ADT
        GO TO 406
    402 EF = 5.2 - (0.001739 * (ADT - 3200.0))
        GO TO 406
    404 EF = 1.2 + (0.0004113 * (ADT - 5500.0))
C
    406 CONTINUE
C
        RETURN
        END
```

Figure 12-39. Subroutine FREQ (1 of 1)

```
C    ***********************************************************************
C
       SUBROUTINE  COSTS
C
C    ***********************************************************************
C
C   SUBROUTINE TO COMPUTF ANNUALIZED COSTS TAKING INTO CONSIDERATION (1)
C   COSTS OF IMPROVEMENT, (2) NORMAL MAINTENANCE COSTS OF HAZARD AND IMPR
C   AND (3) REPAIR COSTS OF HAZARD AND IMPROVEMENT FOLLOWING A COLLISION.
C   COMPOUND INTEREST IS USED WITH AN ASSUMED INTEREST RATE OF 6 PERCENT
C   AND A 20 YEAR LIFE.  REFER TO EQUATION ON PAGES 49 AND 50 IN NCHRP PR
C   20-7 BY MR. J.C. GLENNON FORMERLY OF TTI.
C
C
      COMMON / INVENT / I, J, NH, LP1, LL, MES
      COMMON / CINVNT / C1, C2, C3, C4, C5, C7, C8, C9, C10, C11, C12,
     *                  C13, C14, C15, C16, C17, C18, C20, C21, C24,
     *                  C25, C26, C27, C28, C29, C34, C35, C36, C37,
     *                  C38, C39, C40, C41, C42, C43, C44, C45, C46, C47
     *                  , C30, C31, C48, C49
      COMMON / CONSNT / D, THETA, RAD, ANG, RSIN, RTAN, LIFE, RI
      COMMON / HAZRDS / HI1, HI2, SI, SI1, SI2, R, P, UPAY, PSUM, HIB,
     *                  HIA
C
      INTEGER  C1, C2, C3, C4, C5, C12, C13, C18, C20, C21, C42, C47
C
      DIMENSION  C1(15,5), C2(15,5), C3(15,5), C4(15,5), C5(15,5),
     *           C7(15,5), C8(15,5), C9(15,5), C10(15,5), C11(15,5),
     *           C12(15,5), C13(15,5), C14(15,5), C15(15,5), C16(15,5),
     *           C17(15,5), C18(15,5), C20(15,5), C21(15,5), C24(15,5),
     *           C25(15,5), C26(15,5), C27(15,5), C28(15,5), C29(15,5),
     *           C34(15,5), C35(15,5), C36(15,5), C37(15,5), C38(15,5)
      DIMENSION  C39(15,5), C40(15,5), C41(15,5), C42(15,5), C43(15,5),
     *           C44(15,5), C45(15,5), C46(15,5), C47(15,5)
     *           , C30(15,5), C31(15,5), C48(15,5), C49(15,5)
      DIMENSION  SI(15), HI1(15,2), HI2(15,2), SI2(15,5), SI1(15,1)
C
C
C   INTEREST FACTOR
C
      A1=(1.+RI*.01)**LIFE
      A3=RI*A1*.01
      A4=(A1-1.)/A3
      A5=1./A4
C
      IF ( LL .EQ. 1 )  GO TO 100
C
C   ANNUALIZED COST OF IMPROVEMENT
```

Figure 12-40. Subroutine COSTS (1 of 2)

```
C
      IF ( HI2(I,1) .GE. HI2(I,2) )  GO TO 102
      HINDX=HI2(I,2)
      GO TO 104
  102 CONTINUE
      HINDX=HI2(I,1)
  104 CONTINUE
      CI=C9(I,J)*A5*HINDX/SI(I)
      CF=C7(I,J)*A5
      R=CI+CF+C11(I,J)
      P=R*A4
      RETURN
C
C  ANNUALIZED COST OF HAZARD
C
  100 CONTINUE
      IF ( HI1(I,1) .GE. HI1(I,2) )  GO TO 106
      HINDX=HI1(I,2)
      GO TO 108
  106 CONTINUE
      HINDX=HI1(I,1)
C
  108 CONTINUE
      CO=C8(I,LL+1)*A5*HINDX/SI(I)
      R=CO+C10(I,LL+1)
      P=R*A4
      RETURN
C
      END
```

Figure 12-40. Subroutine COSTS (2 of 2)

```
C ***********************************************************************
C
C    SUBROUTINE OUTPUT
C
C ***********************************************************************
C
C SUBROUTINE TO PRINT THE OUTPUT FROM THE COMPUTER PROGRAM.
C
C
      COMMON / TITLE / LIST
      COMMON / INVENT / I, J, NH, LP1, LL, MES
      COMMON / DIST1 / IDIST
      COMMON / ERROR1 / MG, NMES
      COMMON / HINVNT / H1, H2, H3, H4, H5, H6, H7, H8, H9, H11, H12,
     *                  H13, H15, H16, H17, H18, H19, H20, H21, H22,
     *                  H23, H24, H25, H26, H27, H28, H29, H30, H31,
     *                  H32, H33, H34, H35, H36, H37, H38, H39, H40,
     *                  H41, H42, H43, H44, H50, H51
      COMMON / CINVNT / C1, C2, C3, C4, C5, C7, C8, C9, C10, C11, C12,
     *                  C13, C14, C15, C16, C17, C18, C20, C21, C24,
     *                  C25, C26, C27, C28, C29, C34, C35, C36, C37,
     *                  C38, C39, C40, C41, C42, C43, C44, C45, C46, C47
     *                  , C30, C31, C48, C49
      COMMON / CONSNT / D, THETA, RAD, ANG, RSIN, RTAN, LIFE, RI
      COMMON / HAZRDS / HI1, HI2, SI, SI1, SI2, R, P, UPAY, PSUM, HIB,
     *                  HIA
      COMMON / OUTPT1 / UPMT, PVAL, CE, LC1, IPRINT
      COMMON / NCNHWY / NCONTR, MONTH, NYEAR
      COMMON / INFO / TYPE, CLASS
C
      INTEGER  H1, H2, H3, H4, H5, H6, H8, H9, H11, H12, H13, H16, H19,
     *         H29, H30, H37, H38, H43, H44
      INTEGER  C1, C2, C3, C4, C5, C12, C13, C18, C20, C21, C42, C47
      INTEGER UPMT, PVAL, CE
      INTEGER DISTRT, DIST
C
      DIMENSION  H1(15,1), H2(15,1), H3(15,1), H4(15,1), H5(15,1),
     *           H6(15,1), H7(15,1), H8(15,1), H9(15,1), H11(15,1),
     *           H12(15,1), H13(15,1), H15(15,1), H16(15,1), H17(15,1),
     *           H18(15,1), H19(15,1), H20(15,1), H21(15,1), H22(15,1),
     *           H23(15,1), H24(15,1), H25(15,1), H26(15,1), H27(15,1),
     *           H28(15,1), H29(15,1), H30(15,1), H31(15,1), H32(15,1)
      DIMENSION  H33(15,1), H34(15,1), H35(15,1), H36(15,1), H37(15,1),
     *           H38(15,1), H39(15,1), H40(15,1), H41(15,1), H42(15,1),
     *           H43(15,1), H44(15,1), H50(15,1), H51(15,1)
      DIMENSION  C1(15,5), C2(15,5), C3(15,5), C4(15,5), C5(15,5),
     *           C7(15,5), C8(15,5), C9(15,5), C10(15,5), C11(15,5),
     *           C12(15,5), C13(15,5), C14(15,5), C15(15,5), C16(15,5),
     *           C17(15,5), C18(15,5), C20(15,5), C21(15,5), C24(15,5),
     *           C25(15,5), C26(15,5), C27(15,5), C28(15,5), C29(15,5),
     *           C34(15,5), C35(15,5), C36(15,5), C37(15,5), C38(15,5)
```

Figure 12-41. Subroutine OUTPUT (1 of 7)

```
      DIMENSION  C39(15,5), C40(15,5), C41(15,5), C42(15,5), C43(15,5),
     *           C44(15,5), C45(15,5), C46(15,5), C47(15,5)
     *           , C30(15,5), C31(15,5), C48(15,5), C49(15,5)
      DIMENSION  SI(15), HI1(15,2), HI2(15,2), SI2(15,5), SI1(15,1)
      DIMENSION  MG(60,20), IDIST(255)
      DIMENSION IH1(999), IH2(999), IH3(999), IH4(999), IH5(999),
     *          IH6(999), IGRP(999)
      DIMENSION IC1(15,5), IC2(15,5), IC3(15,5), IC4(15,5)
      DIMENSION  UPMT(15,5), PVAL(15,5), CE(15,5)
      DIMENSION  DISTRT(15,1)
      DIMENSION  TYPE(10,20), CLASS(10,20)
C
C
C   REDEFINE HEADING OUTPUT VARIABLES FOR PRINT CONTROL USING LC1 AS
C   A COUNTER
C
      IF(LIST .EQ. 0) GO TO 2
      GO TO 4
    2 CONTINUE
      WRITE(6,99)
      WRITE(6,98)
      WRITE(6,97)
      MESAGE=0
      IERROR=100
      RETURN
C
    4 CONTINUE
      KEY=0
      IF(MES.EQ.27) GO TO 210
      IF(MES.EQ.23) GO TO 210
      IF(MES.EQ.0 .OR. MES.EQ.30) GO TO 5
      MESAGE=MESAGE+1
      IF(MESAGE.NE.IERROR) GO TO 5
      MES=23
    5 CONTINUE
      M = LC1
      N = LC1 - 1
      IGRP(M) = H16(I,1)
      IH2(M) = H2(I,1)
      IH3(M) = H3(I,1)
      NH3=H3(I,1)
      DIST=IDIST(NH3)
      IH1(M) = DIST
      IH4(M) = H4(I,1)
      IH5(M) = H5(I,1)
      IH6(M) = H6(I,1)
      DISTRT(I,1) = DIST
```

Figure 12-41. Subroutine OUTPUT (2 of 7)

```
      IF ( LC1 .EQ. 1 ) GO TO 10
      IF ( IH2(M) .EQ. IH2(N) .AND. IH3(M) .EQ. IH3(N) .AND.
     *     IH1(M) .EQ. IH1(N) .AND. IH4(M) .EQ. IH4(N) .AND.
     *     IH5(M) .EQ. IH5(N) .AND. IH6(M) .EQ. IH6(N)) GO TO 12
      IF(MES.EQ.24 .AND. NH.NE.1)  GO TO 12
   10 CONTINUE
      KEY=1
      IH7 = H7(I,1)
      IH8=H8(I,1)
      IH9=H9(I,1)
      WRITE(6,100)  (TYPE(IH8,K),K=1,13), (CLASS(IH9,K),K=1,13),
     *                  H51(I,1), H2(I,1), H3(I,1), DISTRT(I,1),
     *              H4(I,1), H5(I,1), H6(I,1), IH7, LIFE, RI, MONTH,
     *              NYEAR
      WRITE(6,101)
      WRITE(6,102)
   12 CONTINUE
C  IMPROVEMENT CODING
C
      ICODE1 = C12(I,J)
      GO TO ( 14, 15, 16, 17 ), ICODE1
   14 CONTINUE
      ICODE2 = C13(I,J)
      GO TO ( 18, 19, 19, 19 ),ICODE2
   18 ICODE3=C20(I,J)
      ICODE4 = 0
      GO TO 22
   19 ICODE3 = 0
      ICODE4 = 0
      GO TO 22
   15 CONTINUE
      ICODE2 = C18(I,J)
      ICODE3 = C20(I,J)
      GO TO ( 20, 21, 20, 20 ),ICODE2
   20 ICODE4 = 0
      GO TO 22
   21 ICODE4 = C21(I,J)
      GO TO 22
   16 CONTINUE
      ICODE2=C18(I,J)
      ICODE3 = 0
      ICODE4 = 0
      GO TO 22
   17 ICODE2=0
      ICODE3=0
      ICODE4=0
   22 CONTINUE
      IC1(I,J) = ICODE1
      IC2(I,J) = ICODE2
      IC3(I,J) = ICODE3
      IC4(I,J) = ICODE4
```

Figure 12-41. Subroutine OUTPUT (3 of 7)

```
      IF ( H6(I,1) .EQ. 1 ) GO TO 24
      IF ( H18(I,1) .EQ. 0.0 ) H18(I,1) = H17(I,1) - ( H24(I,1)/5280.)
      GO TO 25
   24 IF ( H18(I,1) .EQ. 0.0 ) H18(I,1) = H17(I,1) + ( H24(I,1)/5280.)
   25 UPMT(I,J) = UPAY
      PVAL(I,J) = PSUM
      IH16=H16(I,1)
      IF(LC1 .EQ. 1) GO TO 28
      IF(NH .EQ. 1 .AND. KEY .EQ. 0 .AND. LP1 .EQ. 1) GO TO 26
      IF(IGRP(M) .NE. IGRP(N) .AND. KEY .EQ. 0) GO TO 26
      GO TO 28
   26 CONTINUE
      WRITE (6,103)
   28 CONTINUE
      IF ( H19(I,1) .EQ. 2 )  GO TO 40
      H29(I,1)=0
      H30(I,1)=0
   40 CONTINUE
      DO 50 L=1,NH
      IF(C12(L,J) .NE. 4) GO TO 51
   50 CONTINUE
      IF(I .EQ. NH) GO TO 206
   51 CONTINUE
      IF(MES .EQ. 30) GO TO 202
      DO 200 IN = 1,NMES
      IF ( MES .EQ. IN )  GO TO 204
  200 CONTINUE
      IF ( IPRINT .EQ. 0 )  GO TO 203
      IF ( IPRINT .EQ. 1 )  GO TO 201
      IF(IPRINT .EQ. 2) GO TO 205
  201 CONTINUE
      IC7=C7(I,J)
      M=J-1
      WRITE (6,106)  H1(I,1), H11(I,1), H12(I,1), H29(I,1), H30(I,1),
     * SI1(I,1), H13(I,1), H16(I,1), H17(I,1), H18(I,1), M, IC1(I,J),
     * IC2(I,J), IC3(I,J), IC4(I,J), SI2(I,J), IC7,            PVAL(I,J),
     * UPMT(I,J), CE(I,J)
      LC1=LC1+1
      RETURN
C
  202 CONTINUE
      IN=30
      M=J-1
      WRITE(6,107) H1(I,1), H11(I,1), H12(I,1), H29(I,1), H30(I,1),
     * SI1(I,1), H13(I,1), H16(I,1), H17(I,1), H18(I,1), M, IC1(I,J),
     * IC2(I,J), IC3(I,J), IC4(I,J), (MG(IN,IM),IM=1,20)
      LC1=LC1+1
      RETURN
```

Figure 12-41. Subroutine OUTPUT (4 of 7)

```
  203 CONTINUE
      IC7=C7(I,J)
      M=J-1
      WRITE (6,108)  H1(I,1), H11(I,1), H12(I,1), H29(I,1), H30(I,1),
     * SI1(I,1), H13(I,1), H16(I,1), H17(I,1), H18(I,1), M, IC1(I,J),
     * IC2(I,J), IC3(I,J), IC4(I,J), SI2(I,J), IC7, PVAL(I,J), UPMT(I,J)
      LC1=LC1+1
      RETURN
C
  204 CONTINUE
      M=J-1
C  PRINT ****** ON ERROR MSG
      IF( SI1(I,1).LT.0.1 ) SI1(I,1)=99999.9
      WRITE (6,109)  H1(I,1), H11(I,1), H12(I,1), H29(I,1), H30(I,1),
     * SI1(I,1), H13(I,1), H16(I,1), H17(I,1), H18(I,1), M, IC1(I,J),
     * IC2(I,J), IC3(I,J), IC4(I,J), IN
      LC1=LC1+1
      IF(I .EQ. NH) WRITE(6,103)
      RETURN
C
  205 CONTINUE
      IC7=C7(I,J)
      M=J-1
      WRITE (6,112)  H1(I,1), H11(I,1), H12(I,1), H29(I,1), H30(I,1),
     * SI1(I,1), H13(I,1), H16(I,1), H17(I,1), H18(I,1), M, IC1(I,J),
     * IC2(I,J), IC3(I,J), IC4(I,J), SI2(I,J), IC7, PVAL(I,J), UPMT(I,J)
      LC1=LC1+1
      RETURN
C
  206 CONTINUE
      M=J-1
      WRITE(6,113) H1(I,1), H11(I,1), H12(I,1), H29(I,1), H30(I,1),
     * SI1(I,1), H13(I,1), H16(I,1), H17(I,1), H18(I,1), M, IC1(I,J),
     * IC2(I,J), IC3(I,J), IC4(I,J)
      LC1 = LC1+1
      RETURN
  210 CONTINUE
      WRITE ( 6,110 )  (MG(MES,IM), IM=1,20 )
      RETURN
C
C  FORMAT STATEMENTS
C
   99 FORMAT(1H1, ////////,T46, 'A COST-EFFECTIVENESS PRIORITY APPROACH'
     *,/,T64, 'FOR',/,T41, 'ROADSIDE SAFETY IMPROVEMENT PROGRAMS ON FREE
     *WAYS',///,T60,'AUGUST 1973',////,T25,'RESEARCH SPONSOR AGENCIES--
     *TEXAS HIGHWAY DEPARTMENT (PROJECT 011)',/, T53, 'FEDERAL HIGHWAY A
     *DMINISTRATION (PROJECT 1-12)',            //,T41, 'PROJECT MANAGERS
     *-- MR. PAUL TUTT,P.E.', /, T60, 'MR. ED SMITH,P.E.',
     * /, T60,  'MR. ED KRISTAPONIS,P.E. (FHWA)'           ,//,T25,'RESEAR
     *CH CONDUCTED BY-- TEXAS TRANSPORTATION INSTITUTE (PROJECT 2011)',
     * / )
```

Figure 12-41. Subroutine OUTPUT (5 of 7)

```
98 FORMAT(T35,'PRINCIPAL INVESTIGATOR-- DR. DONALD WOODS,P.E.'/,
  * T41,           'STUDY SUPERVISOR-- MR. GRAEME WEAVER,P.E.',
  * / , T35,     'COMPUTER PROGRAM LOGIC-- DR. EDWARD POST,P.E.',//,
  * T37, 'COMPUTER PROGRAMMERS-- MR. SHING-TAK CHEUNG (C.E. GRADUATE
  *STUDENT)',/,T60, 'MR. CHARLES HETHCOAT (C.E. GRADUATE STUDENT)',/,
  * T60, 'MR. RICHARD PETERSON (C.E. GRADUATE STUDENT)',/)
 97 FORMAT( T25, 'COMPUTER FACILITIES AND PROGRAM', //, T35, 'LOCATION
  *-- TEXAS A&M UNIVERSITY', /, T35, 'TYPE-- IBM 360/65',
  * /, T35, 'CORE REQUIRED-- 380K (OS WATFIV)',
  *                                  /, T35,'COMPILE TIME (APPROX)',
  * T59, '= 0.5 MINUTES',
  *                    /, T35,'EXECUTION TIME (APPROX)', T59,
  * '= 0.01 MINUTES/HAZARD',
  *  /, T35, 'NUMBER OF SUBROUTINES', T59, '= 37'          )
C
100 FORMAT( 1H1,   T50, 'C O S T   E F F E C T I V E N E S S   P R O G
  * R A M', //, T64, 'TYPE HIGHWAY =', T79, 13A4, /, T54,
  * 'HIGHWAY CLASSIFICATION =', T79, 13A4, /, T55,
  * 'WIDTH TO FAR SHOULDER =',T79,F4.1,T83,'(FT)', //,
  * T65, 'HIGHWAY NO  =', I5, /, T66, 'COUNTY NO  =', I5,
  */,T64, 'DISTRICT NO  =', I5, /, T65, 'CONTROL NO  =', I5, /,
  * T65, 'SECTION NO  =', I5, //, T56, 'RECORDING DIRECTION  =', I5,
  * /, T65, 'ADT (1000)  =', I5,   /, T71, 'LIFE  =', I5, '(YRS)',
  * /,T67,'INTEREST  =',F5.1,'(PERCENT)',/,T71,'DATE  =',I3,
  * T81, '-', T82, I2, /    )
C
101 FORMAT ( T26, 'H   A   Z   A   R   D', T82, 'I   M   P   R   O   V
  *   E   M   E   N   T' // T2, 'HAZARD', T10, 'IDENT', T17, 'DESC',
  * T26, 'END', T33, 'SEVERITY', T43, 'OFFSET', T51, 'GROUP', T60,
  * 'MILE-POST', T78, 'IMPR', T84, 'IMPR', T90, 'SEVERITY', T100,
  * 'FIRST', T107, 'PRESENT', T116, 'ANNUAL', T126, 'COST' )
C
102 FORMAT ( T4, 'NO', T11, 'CODE', T17, 'CODE', T23, 'TREATMENT',
  * T34, 'INDEX', T44, 'CODE', T52, 'NO', T59, 'BEG', T67, 'END',
  * T79, 'ALT', T84, 'CODE', T91, 'INDEX', T101, 'COST', T108,
  * 'WORTH', T117, 'COST', T124, 'EFFECTIVE' / T23, 'BEG', T29,
  * 'END', T126, 'VALUE' /,T101, '($)', T109, '($)', T116, '($/YR)'
  * ,/)
C
103 FORMAT(/)
C
106 FORMAT ( T3, I4, T11, I2, T18, I2, T24, I1, T30, I1, T35, F5.1,
  * T45, I1, T51, I4, T57, F7.3, T65, F7.3, T80, I1, T83, I1, '-',
  * I1, '-', I1, '-', I1, T92, F4.1, T99, I6, T107, I7, T116, I6,
  * T124, I9,/ )
```

Figure 12-41. Subroutine OUTPUT (6 of 7)

```
107 FORMAT ( T3, I4, T11, I2, T18, I2, T24, I1, T30, I1, T35, F5.1,
   * T45, I1, T51, I4, T57, F7.3, T65, F7.3, T80, I1, T83, I1, '-',
   * I1, '-', I1, '-', I1, T92, 10A4,/,T92,10A4,/)
C
108 FORMAT ( T3, I4, T11, I2, T18, I2, T24, I1, T30, I1, T35, F5.1,
   * T45, I1, T51, I4, T57, F7.3, T65, F7.3, T80, I1, T83, I1, '-',
   * I1, '-', I1, '-', I1, T92, F4.1, T99, I6, T107, I7, T116, I6,
   * T126,'GROUP')
C
109 FORMAT ( T3, I4, T11, I2, T18, I2, T24, I1, T30, I1, T35, F5.1,
   * T45, I1, T51, I4, T57, F7.3, T65, F7.3, T80, I1, T83, I1, '-',
   * I1, '-', I1, '-', I1, T92, '*****ERROR***** SEE ERROR MESSAGE NO.
   *', I2 )
C
110 FORMAT( ///, T50, 20A4,///)
C
112 FORMAT ( T3, I4, T11, I2, T18, I2, T24, I1, T30, I1, T35, F5.1,
   * T45, I1, T51, I4, T57, F7.3, T65, F7.3, T80, I1, T83, I1, '-',
   * I1, '-', I1, '-', I1, T92, F4.1, T99, I6, T107, I7, T116, I6,
   * T124, 'END GROUP', / )
C
113 FORMAT ( T3, I4, T11, I2, T18, I2, T24, I1, T30, I1, T35, F5.1,
   * T45, I1, T51, I4, T57, F7.3, T65, F7.3, T80, I1, T83, I1, '-',
   * I1, '-', I1, '-', I1, T92, '*****NO IMPROVEMENTS RECOMMENDED*****
   *', / )
C
    END
```

Figure 12-41. Subroutine OUTPUT (7 of 7)

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4. Hutchinson, John W., and Kennedy, Thomas W. "Medians of Divided Highways--Frequency and Nature of Vehicle Encroachment," University of Illinois Engineering Experiment Station Bulletin 487, 1966.

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