KDF-9 Atlas Autocode Compiler

Documentation Vol 1

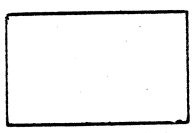
The flowcharts and remarks included in this report are intended to serve as a guide to Edinburgh University, Atlas Autocode, version I. They were prepared from a version written almost completely in Atlas Autocode and therefore do not necessarily reflect the intricacies of the usercode version currently in use on KDF-9. It is suggested that anyone wishing to change the compiler or permanent material use these notes as a guide to the code, rather than drawing conclusions directly from the notes.

TABLE OF CONTENTS

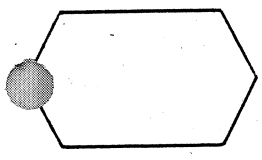
Sections

The flowcharts used in this report are usually flowcharts of routines. The following symbols are used

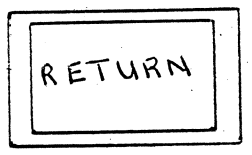
for entry points



for unconditional instructions



for two path branches



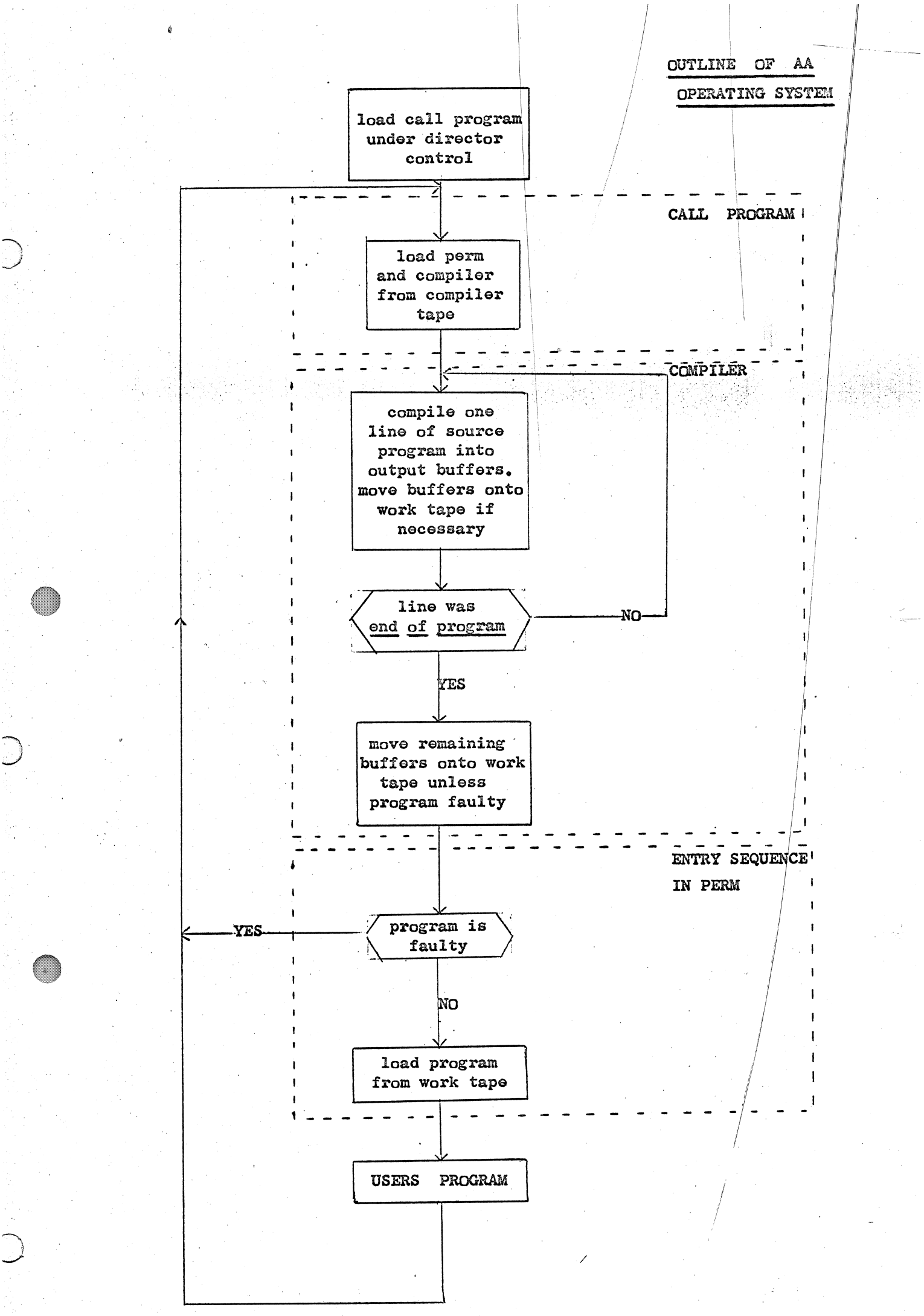
to indicate return from a routine

Small numbers above a box indicate a label (in the code) associated with the instruction in that box.

Two kinds of flowcharts are used, one kind in English, the other in Atlas Autocode. Where both cover the same section of the compiler, they are presented side by side, as much as possible.

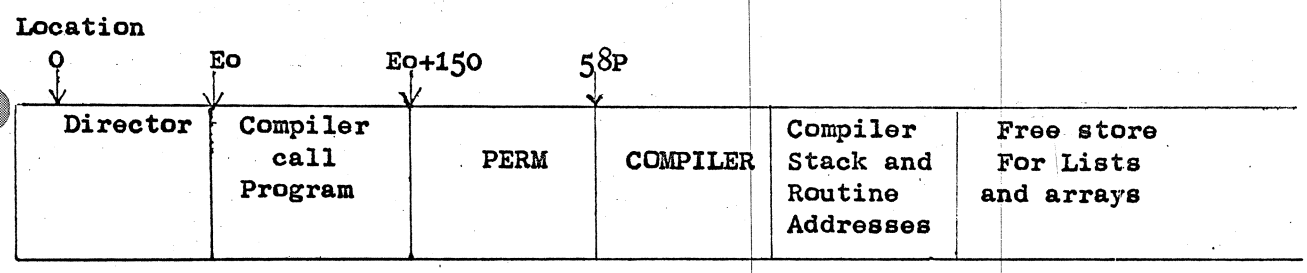
In the notes to the flowcharts, names refering to routines arrays, etc. declared in compiler are enclosed in pointed brackets < >.

PROGRAM MAP OF COMPILER

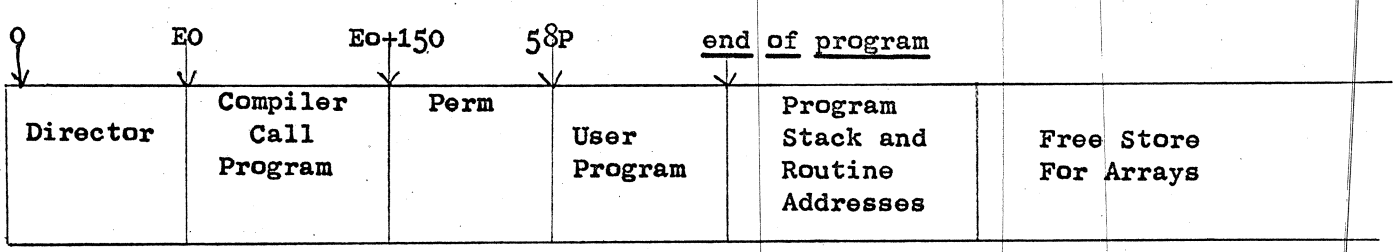

OUTLINE OF AA
OPERATING SYSTEM
load call program under director control
CALL PROGRAM
load perm and compiler from compiler tape
COMPILER
compile one line of source program into output buffers. move buffers onto work tape if necessary
line was end of program
NO
YES
move remaining buffers onto work tape unless program faulty
ENTRY SEQUENCE IN PERM
program is faulty
YES
NO
load program from work tape
USERS PROGRAM

The Atlas Autocode operating system may be thought of as three pieces of code. The first is a call program which will load the other two sections from the (magnetic) compiler tape. The second is a group of routines and sub programs which are permanent material for all Atlas Autocode programs. This permanent material (perm) includes the I/O and math function routines, user program entry and exit sequences, array handling, routine calls,error checking, etc. The third section is the compiler itself, a binary program for compiling AA programs and able to directly reference locations in perm. (In many respects the compiler may be thought of as an ordinary compiled AA program, as it is capable of compiling itself and was originally written in Atlas Autocode.)

The core layout of the system may be pictured as follows:



The compiler compiles a program statement by statement, and at intervals dumps the resulting code onto magnetic tape *(the work tape). When the program is completely compiled, it is loaded into core *, over laying the compiler, by a program entry sequence in perm. When loading is finished, a user program will occupy core as follows:



Control is then transfered to the user program, which executes and upon termination jumps to a stop sequence in perm, which ultimately jumps to the call block where perm and compiler are reloaded.

*Unless, of course, it is faulty.

PROGRAM MAP OF COMPILER

Opposite the block diagram of the compiler are listed the sections which cover the material.

```
begin
    begin
phrase struction  ( routine read string )
read-in           ( routine record      )   not covered
                  ( routine lookup      )
    end
    begin
```

routine initialize — RUN TIME COMPILER INITILIZATION

routine splash

integer fn ca — CODE DUMPING

routine dump stack and routines

routine compare — RECOGNITION PHASE

routine cSS — COMPILATION PHASE

```
    begin
        routine readsym
job     routine read key word        not covered
headings
        routine initial output
    end
```

routine cRSPEC — cRSPEC

routine cUI — cUI

```
expression  ( routine cSEXP          ) cSEXP
compiler    (     routine print orders )
```

```
conditional ( routine cCOND )
Compiler    ( routine cCC   ) cCOND
            ( routine cSC   )
            ( routine cCOMP )
```

```
name handling                routine cNAME          cNAME
                             routine cMOD           not covered
print compile time           routine fault
fault diagnostic
                             routine print name
test whether name            routine test nst       BACKGROUND
set twice                                           ROUTINES
usercode compiler            routine cUCI           not covered

                             routine find label
                             routine copy tag
                             routine replace tag
                             routine From list 2
                             routine pop up 2
                             routine store tag
                             routine push down 2    BACKGROUND
                             routine link           ROUTINES
                             routine more space
                             routine new cell
                             routine return cell
                             routine insert after 2
                             routine skip exp
                             routine store jump
                             routine store name

                             routine p SET
                             routine pSH
                             routine pN             CODE DUMPING
                             routine pQ
                             routine fill label
                             routine fill set
                             routine pJ
                             routine PMS
                        end
                   end
              end
         end
```

FLOWCHARTS OF COMPARE

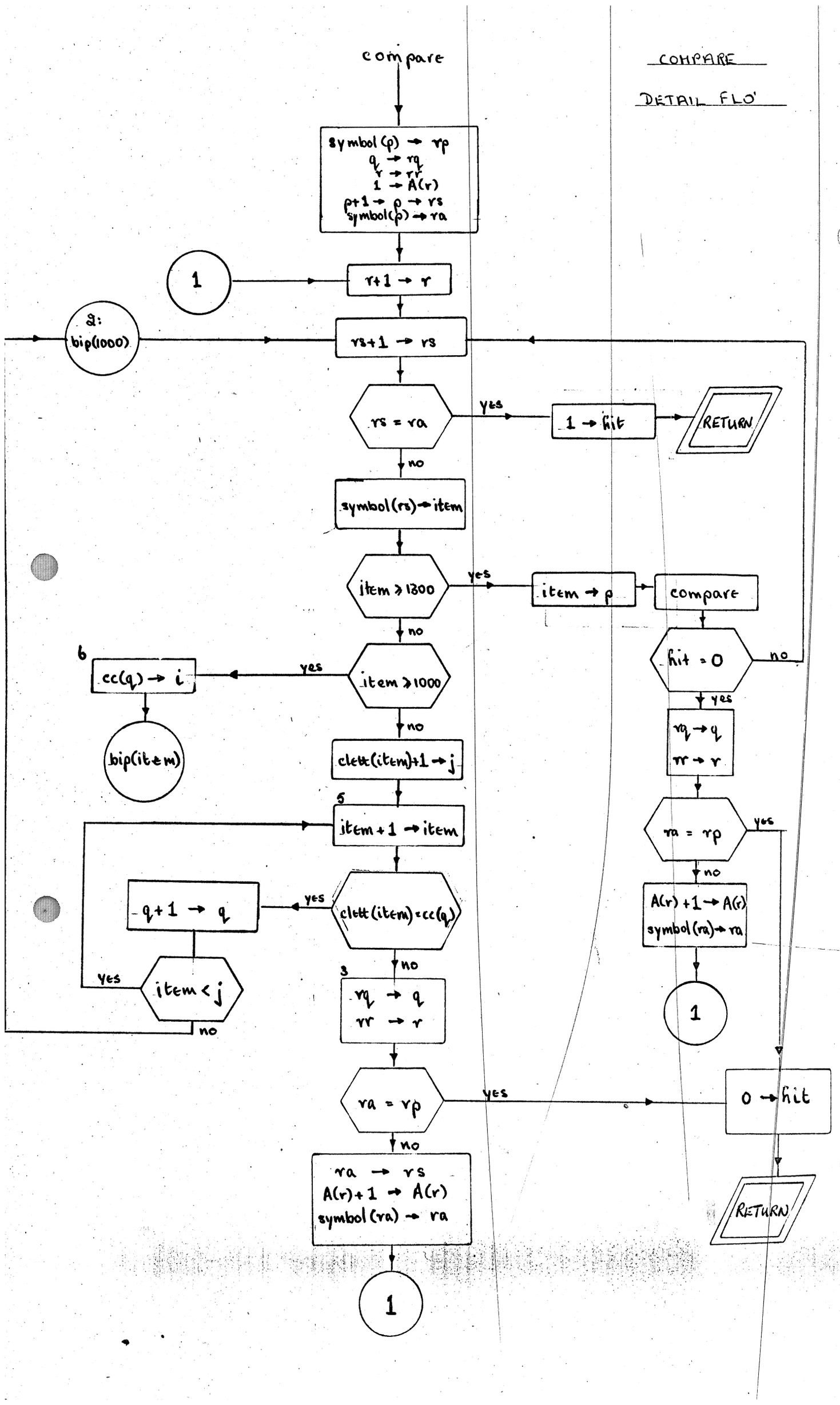
Notes on compare

storage

cc	array containing the source statement, one character in each word
symbol	array containing phrase definitions
clett	array containing text literals
A	array. Analysis record.
p	global pointer to symbol; p points to the entry in symbol for the current definition.
r	global pointer to analysis record; r is used to plant entries in A, and is reset if compare fails.
rr	holds reset value of r
ra	holds pointer to next alternative
rs	holds pointer to next element of current alternative
rp	holds pointer to next definition
q	global pointer to source statement text(cc)
rq	holds reset value of q

COMPARE

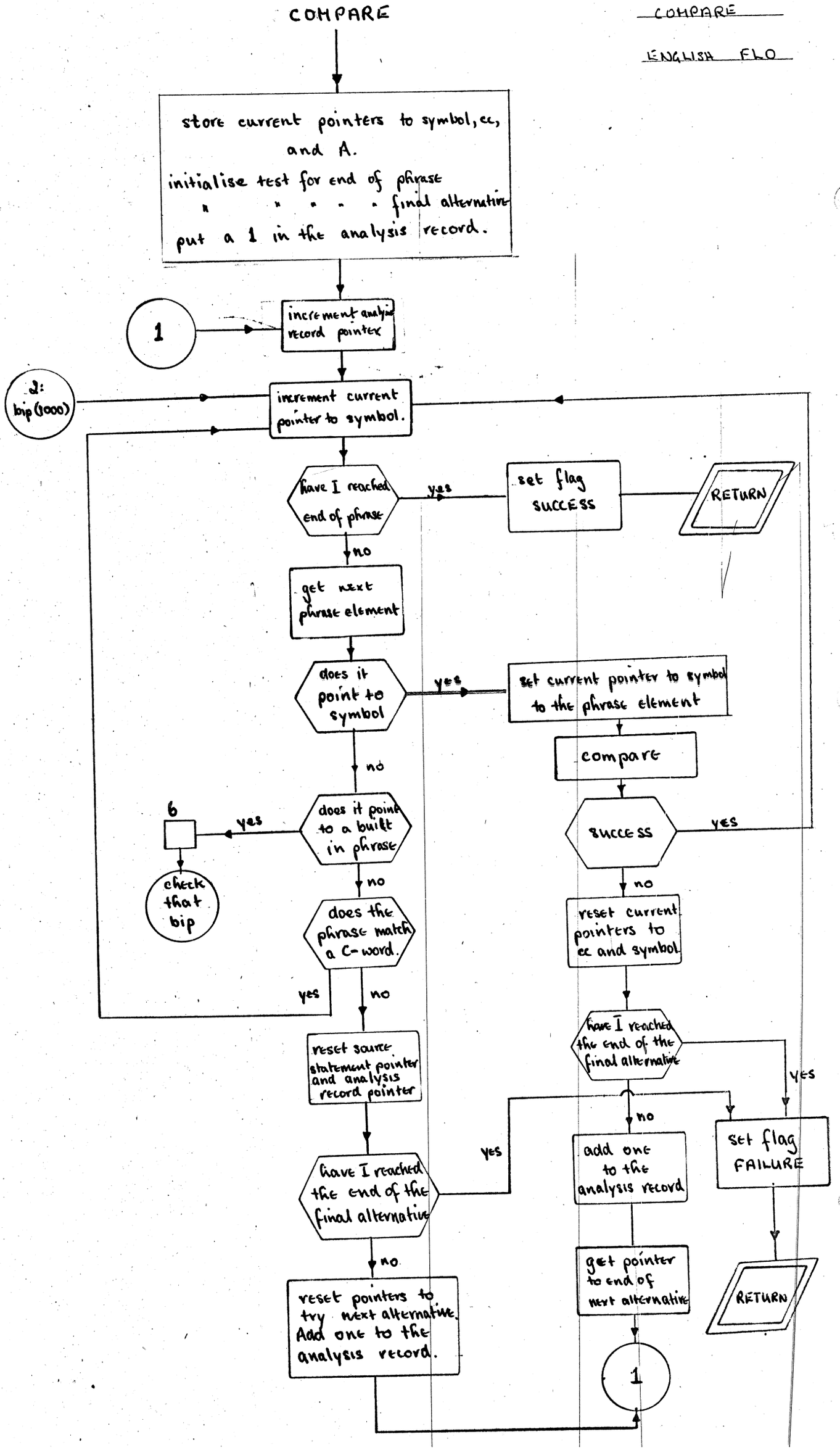
DETAIL FLO'

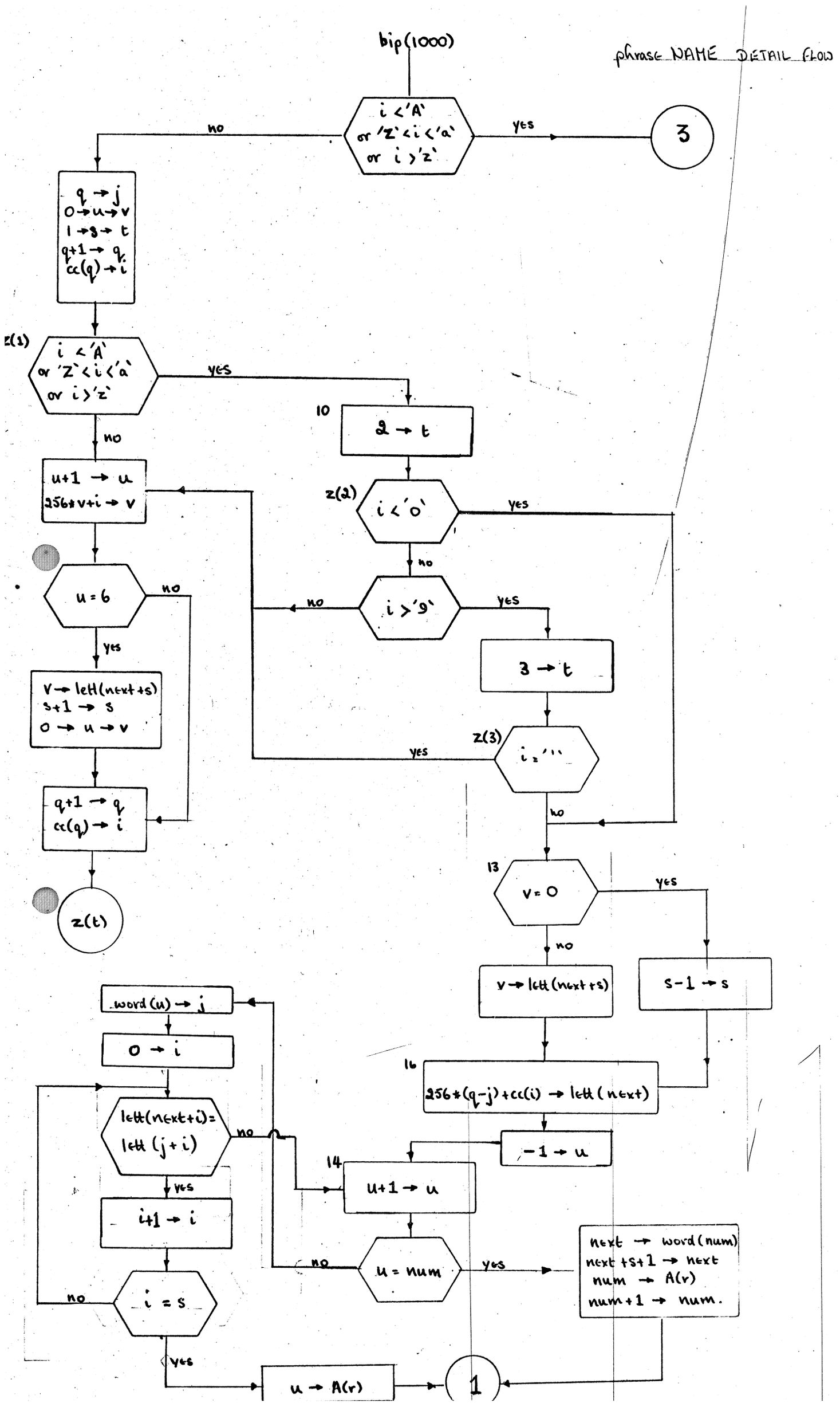


COMPARE

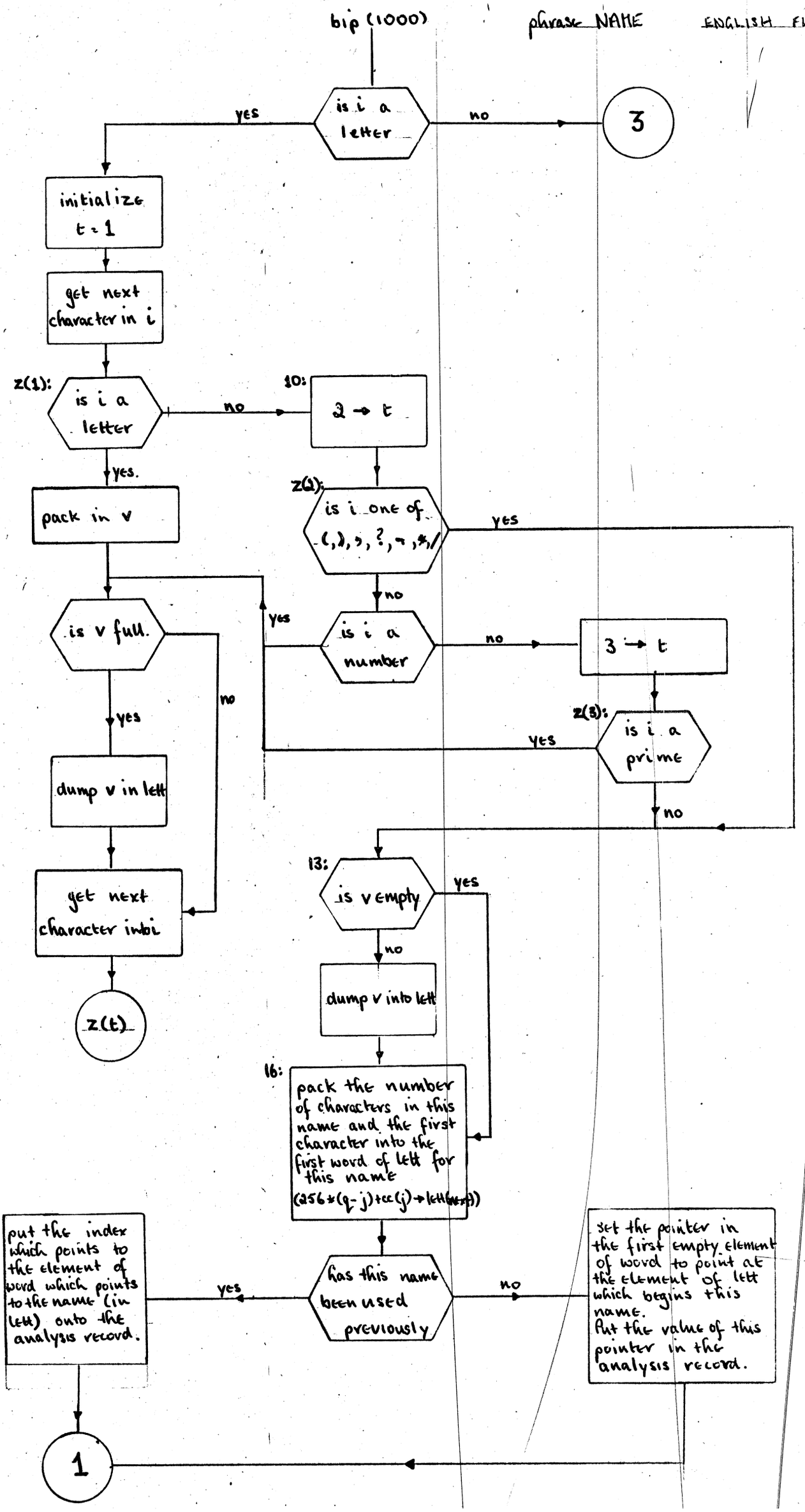
COMPARE

ENGLISH FLO



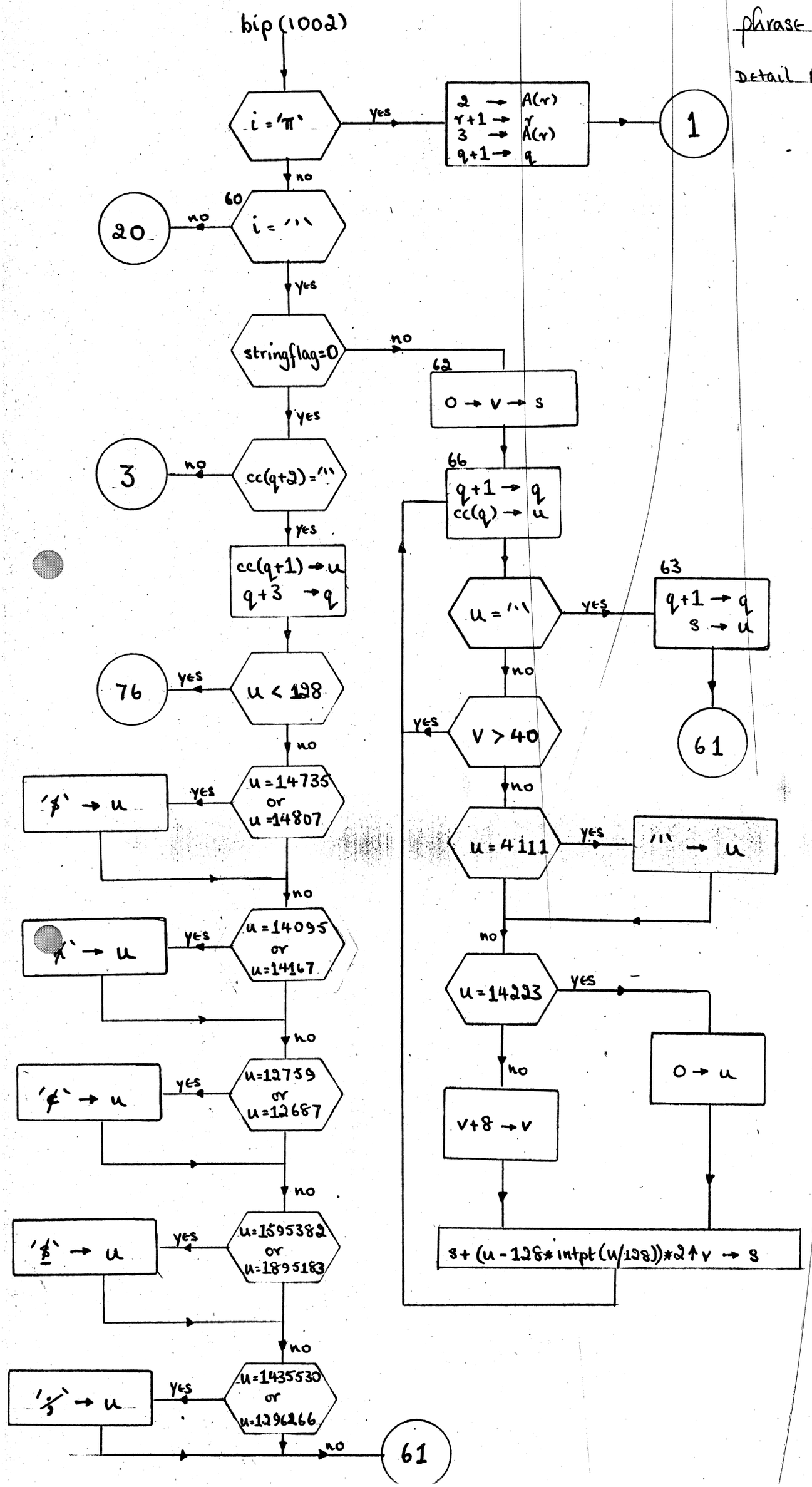

bip(1000)
phrase NAME DETAIL FLOW
i < 'A' or 'Z' < i < 'a' or i > 'z'
no
yes
3
q → j
0 → u → v
1 → s → t
q+1 → q
cc(q) → i
z(1)
i < 'A' or 'Z' < i < 'a' or i > 'z'
yes
no
u+1 → u
256*v+i → v
u = 6
no
yes
v → lett(next+s)
s+1 → s
0 → u → v
q+1 → q
cc(q) → i
z(t)
10
2 → t
z(2)
i < '0'
yes
no
i > '9'
no
yes
3 → t
z(3)
i = ''
yes
no
13
v = 0
yes
no
v → lett(next+s)
s-1 → s
16
256*(q-j)+cc(i) → lett(next)
-1 → u
14
u+1 → u
u = num
no
yes
next → word(num)
next+s+1 → next
num → A(r)
num+1 → num.
word(u) → j
0 → i
lett(next+i) = lett(j+i)
no
yes
i+1 → i
i = s
no
yes
u → A(r)
1

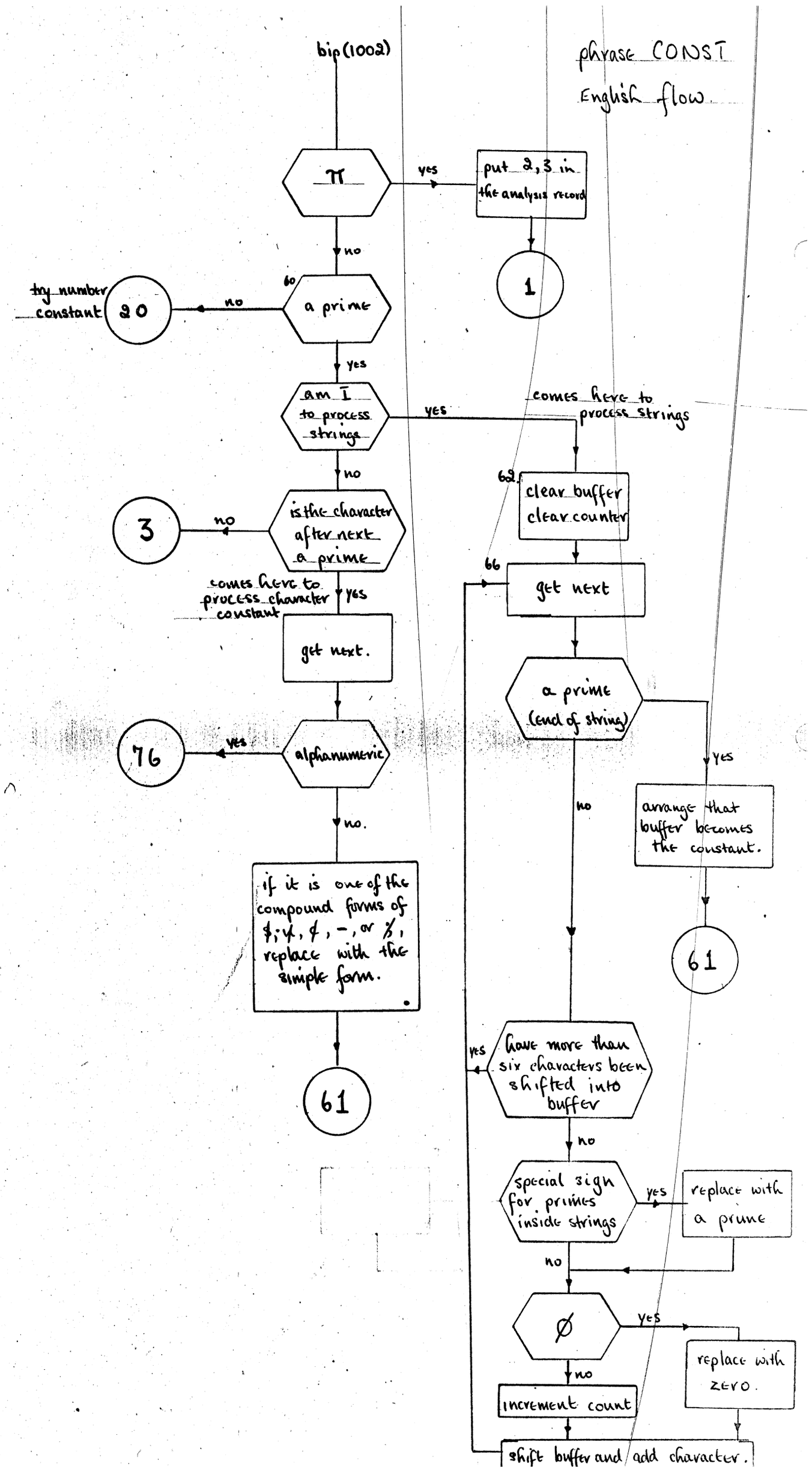
bip (1000) phrase NAME ENGLISH FLOW.



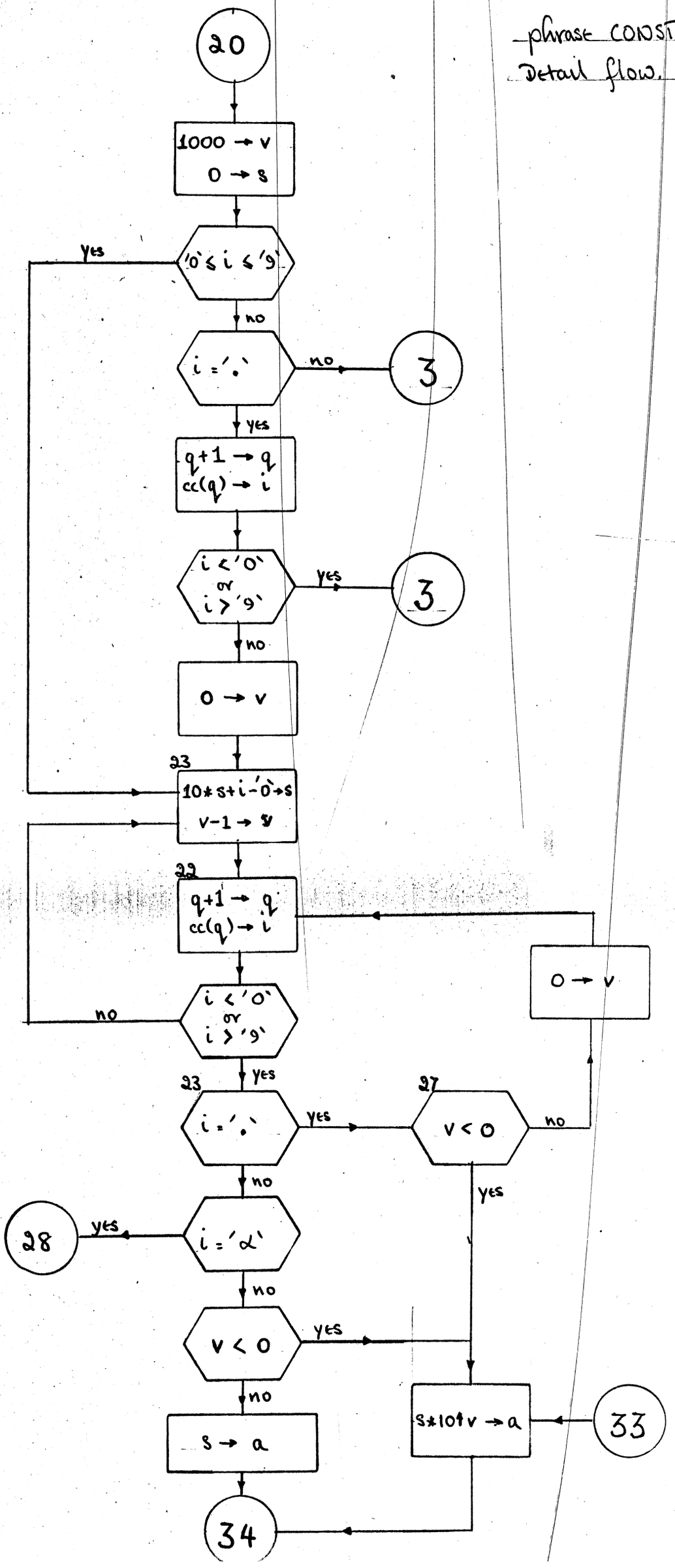
phrase CONST

Detail Flow # 1

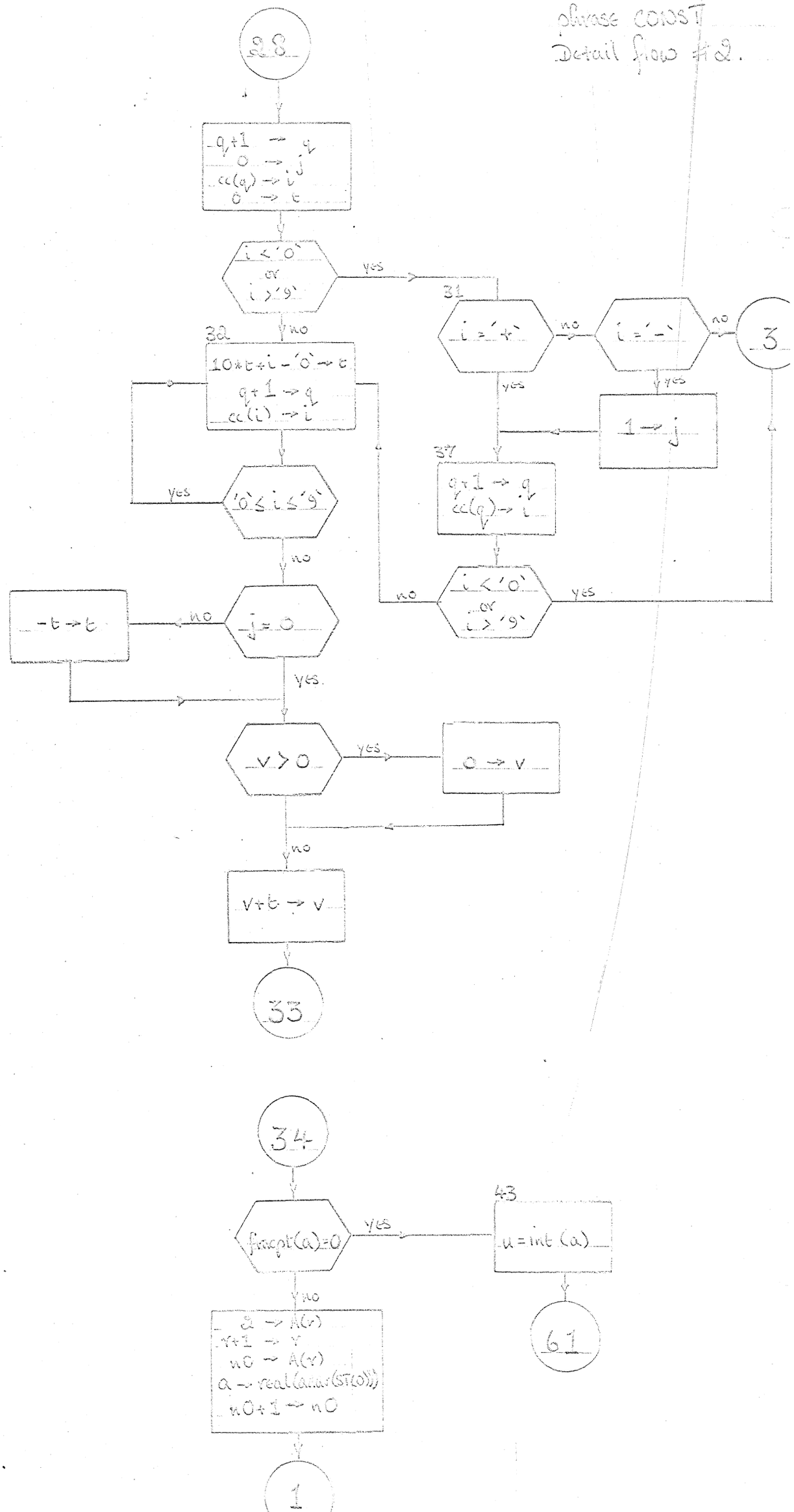



bip(1002)
phrase CONST
English flow
π
yes
put 2,3 in the analysis record
1
no
60
a prime
no
try number constant
20
yes
am I to process strings
yes
comes here to process strings
no
62
clear buffer
clear counter
3
no
is the character after next a prime
66
get next
comes here to process character constant
yes
get next.
a prime (end of string)
yes
arrange that buffer becomes the constant.
61
no
76
yes
alphanumeric
no.
if it is one of the compound forms of $;¢, ¢, -, or %, replace with the simple form.
61
yes
have more than six characters been shifted into buffer
no
special sign for primes inside strings
yes
replace with a prime
no
∅
yes
replace with zero.
no
increment count
shift buffer and add character.

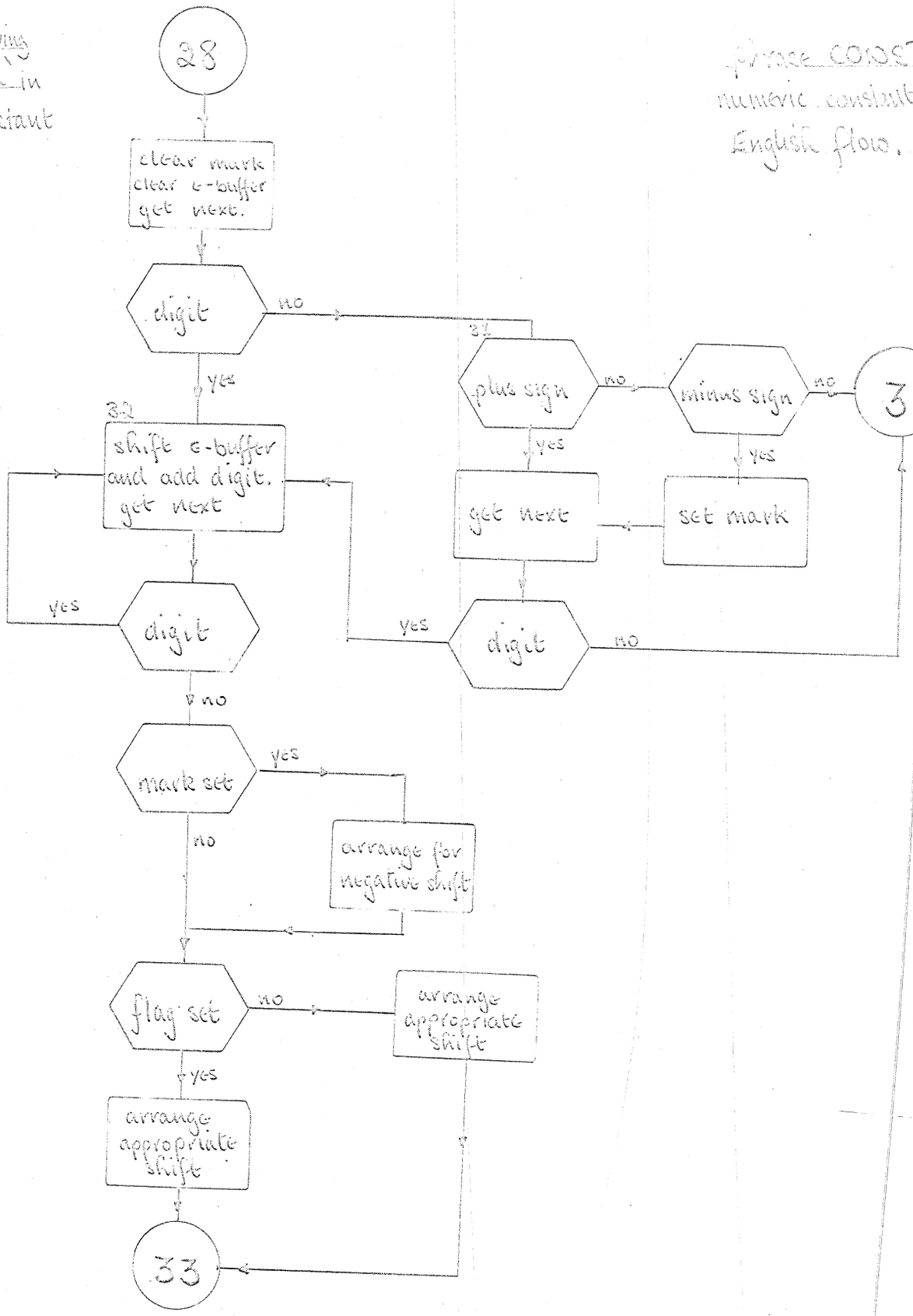
phrase CONST
Detail flow.



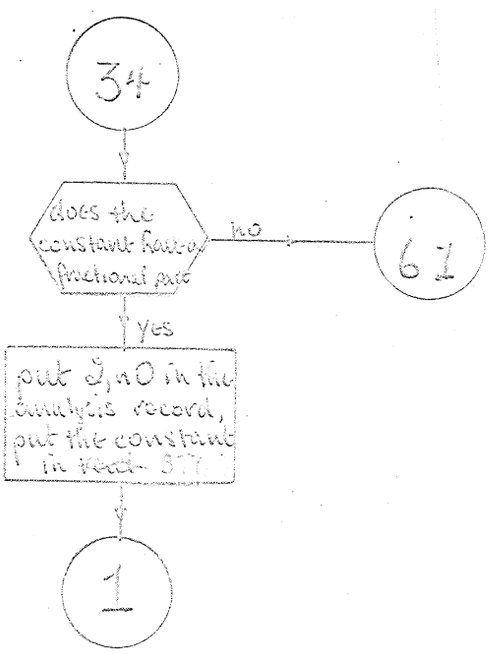
phrase CONST
Detail flow #2.



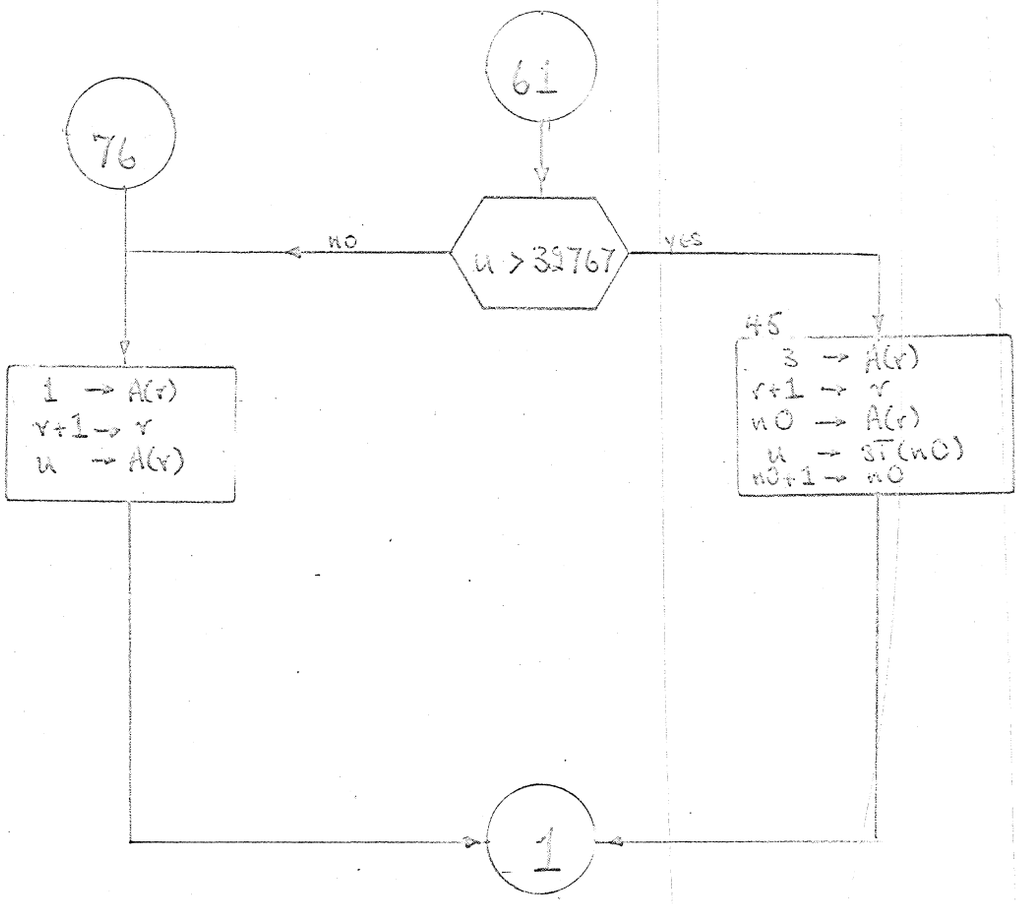
Enter here having just found '&' in numeric constant



Enter here to decide whether integer or floating point

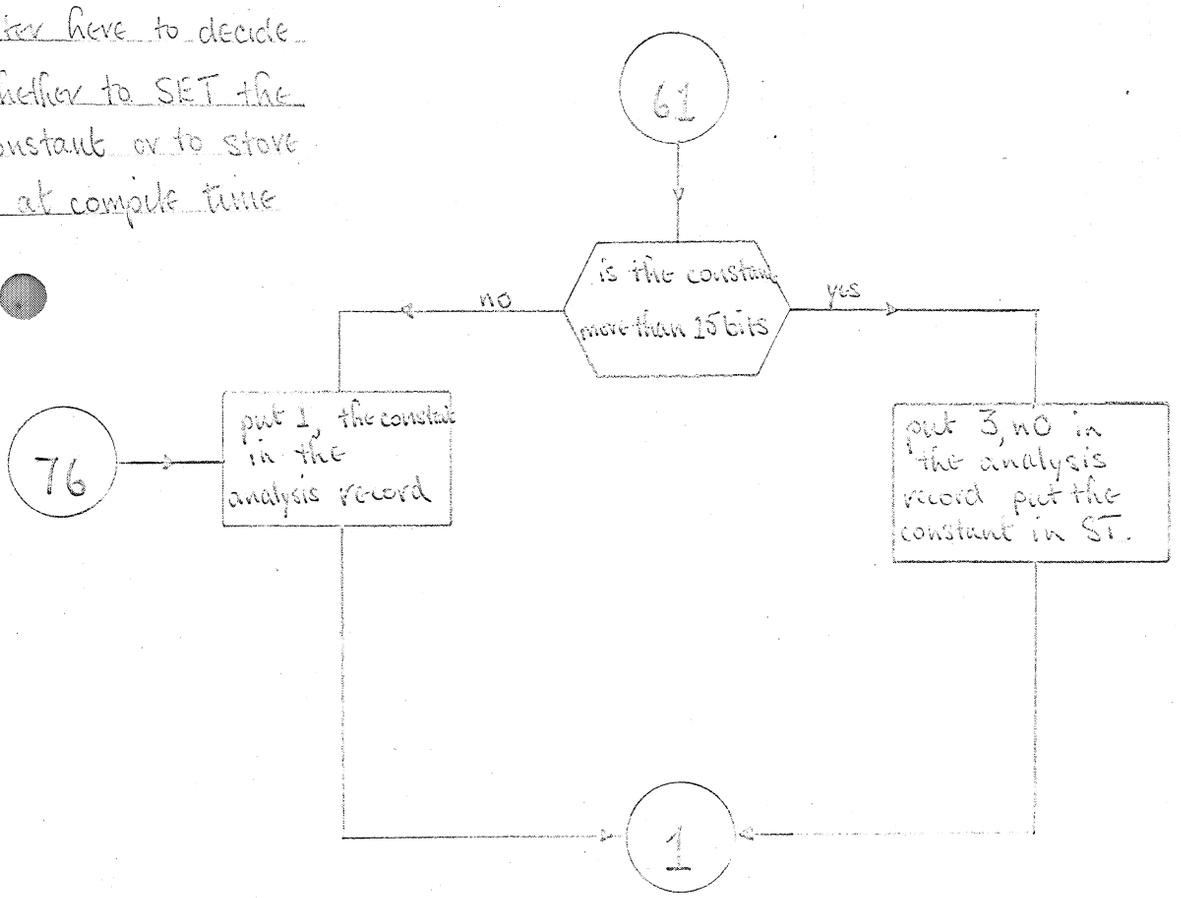


phrase CONST
Detail flow.



Enter here to decide whether to SET the constant or to store it at compile time

English flow.



COMPILATION PHASE cSS

Compilation of an analysis record is accomplished by using certain of its elements as switch indices to jump to particular routines, using others as references to name, constant and label lists, and interrogating others as flags. There is no general way of explaining all the techniques as each analysis record will represent a different tree structure. The following general remarks do apply, however.

The first entry in the analysis record is always interpreted by <cSS> as a switch to code which handles the alternative of [SS] represented. The first command in <cSS> is

```
->sw(A(1))
```

and the rest of the analysis record is dealt with by the code to which control is switched. Briefly these sections are

```
 1      unconditional instructions,conditionals in alternate form
 2      cycles
 3      repeats
 4      labels
 5      conditionals in normal form
 6      ! comments
 7      integer & real declarations
 8      ends
 9      routine specs
10      specs
11      comment comments
12      array declarations
13      job headings
14      begins
15      end of program
16      upper case delimiters
17      switch labels
18      switch declarations
19      compile queries
20      ignore queries
21      machine code permit
22      P-labels
23      machine code instructions
24      fault trap declarations
25      normal delimiters
26      string permit
27      end of perm
28      turn off machine code permit
29      define compiler
```

The most important routines in <cSS> are:

A)<cSEXP(Z)> the expression compiler, which handles phrase types

[±'] [OPERAND] [OP'] [REST OF EXPR].

<cSEXP(Z)>compiles code to evaluate the expression in whatever mode is convenient, and leave the result in the (program) nest in the mode specified by Z.

Z=1	real
Z=2	integer
Z=3	integer if possible,

B)<cNAME (Z)> handles references to names, depending on Z:

Z=0	compile a routine call
Z=1	compile store into cell named
Z=2	compile fetch from cell named
Z=3	compile fetch address of cell named.

C) cCOND and associated routines cSC,cCC,cCOMP, Handle conditionals.

D) cRSPEC handle routine specs

E) cUI handles phrase types [UI]

Separate flowcharts are given for each of these routines.

Generally the analysis record is processed from ''left to right'', and in all of the routines, <p> is a global pointer to the part of the record currently being processed. For example in calls to < cNAME >, the name being referenced is pointed to by <A(p)> upon entry to < cNAME,>

Throughout the compilation phase a number of references are made to list processing routines:

pushdown 2

popup 2

copy tag

store tag

replace tag

find label

link

newcell

return cell

insert after 2

store name

fill label

fill set

store jump.

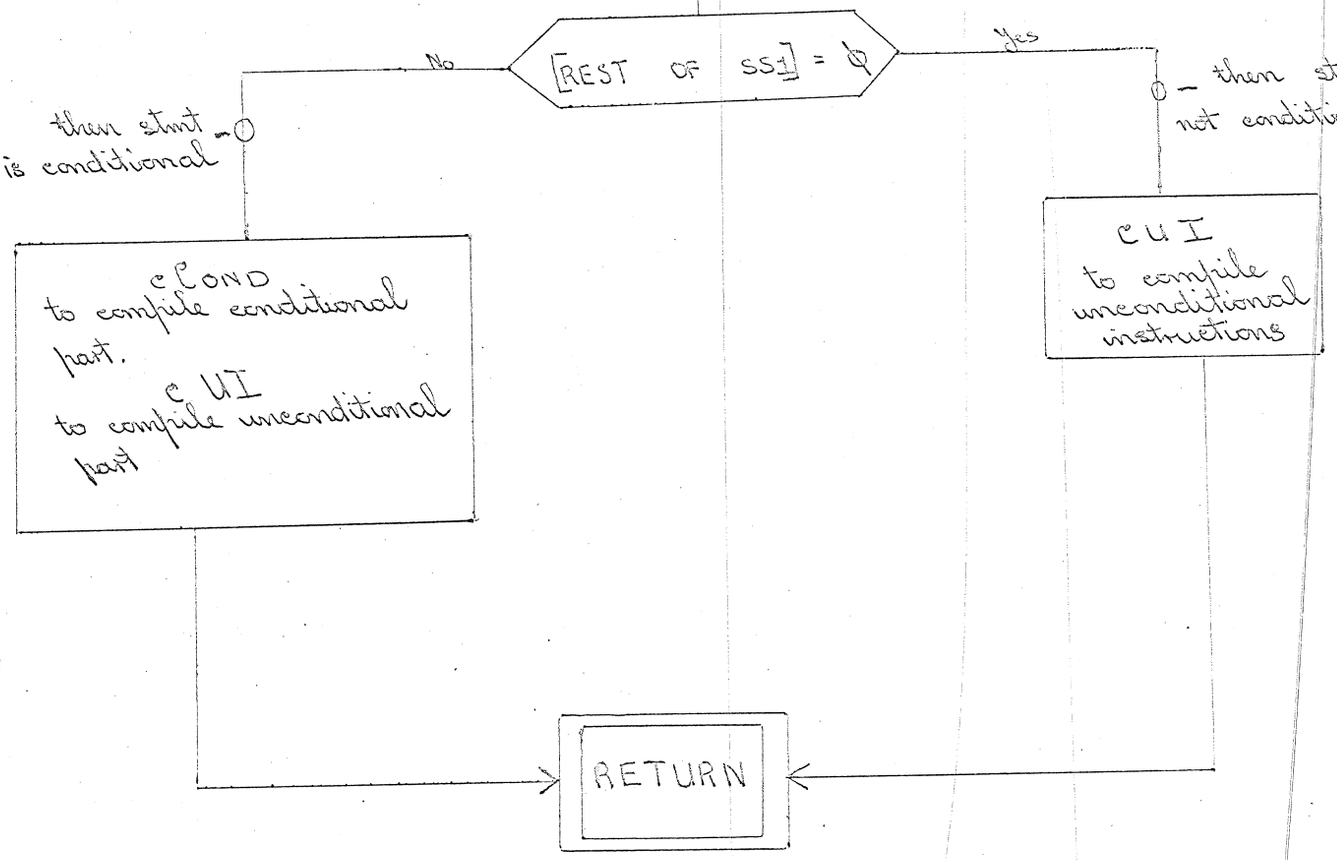
These routines are flowcharted and explained in the section ''Background Routines.''

The actual code planting routines are not explained, but the general nature of the code planting sequence is explained in the section ''Code Dumping.''

[u I] [SET MARKER 2] [REST OF SS 1]

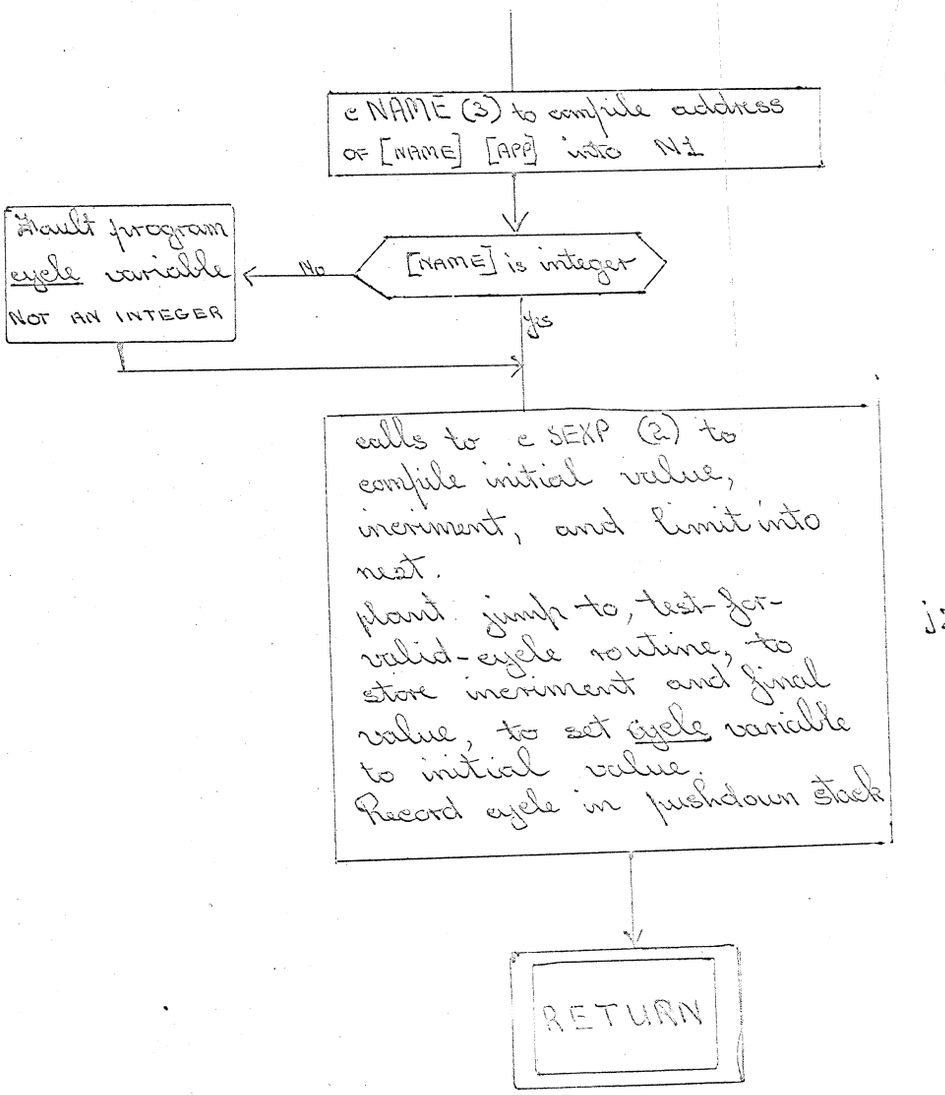
1

Note – marker 2 points to the alternative of [REST OF SS1] which was recognised.



2

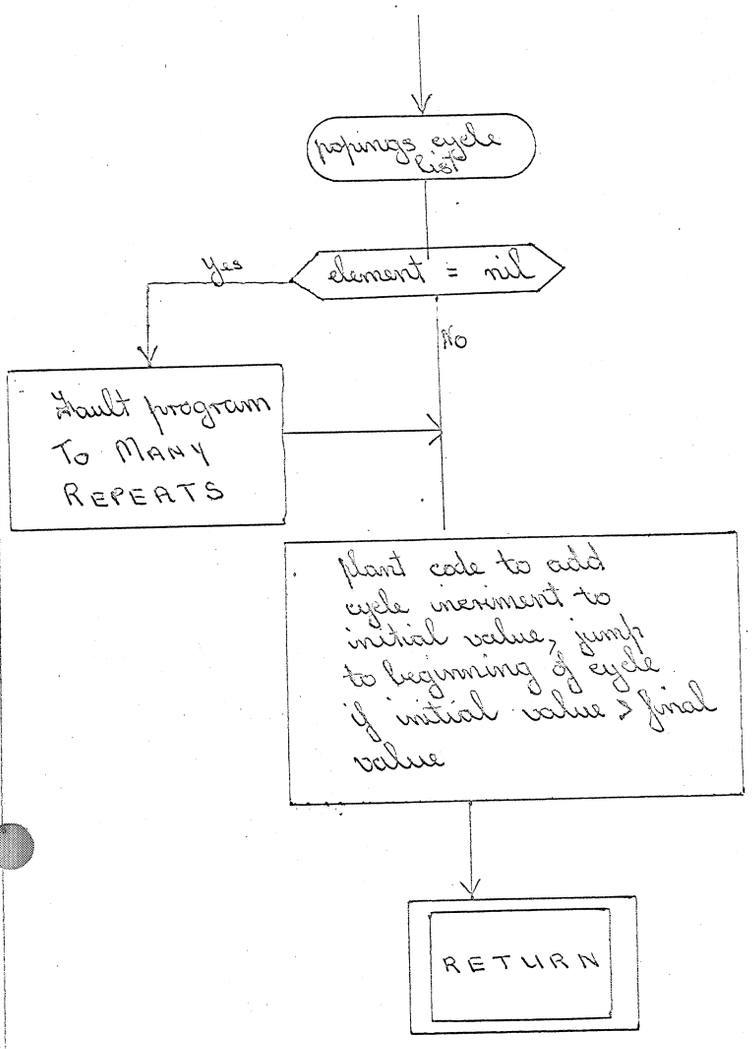
{cycle} [NAME] [APP] { = } [±] [OPERAND] [REST OF EXPR] { , } [±] [OPERAND] [REST OF EXPR] { , } [OPERAND] [REST OF EXPR] [S]



code planted is

(& cycle variable) by c NAME
= En M level
(initial value) by c SEXP
DUP
(increment) by c SEXP
DUP
= E n+1 M level
JS 5P:
En M level
= M13
j: = M0 M13

{repeat} [S]

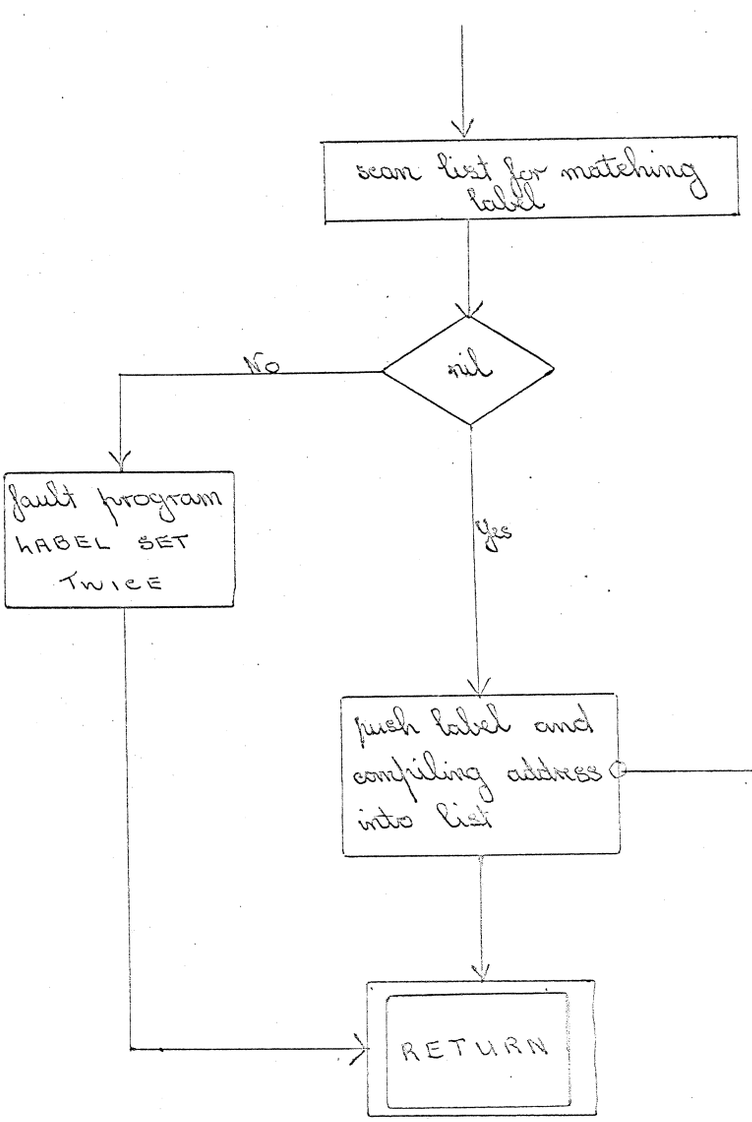


code planted is

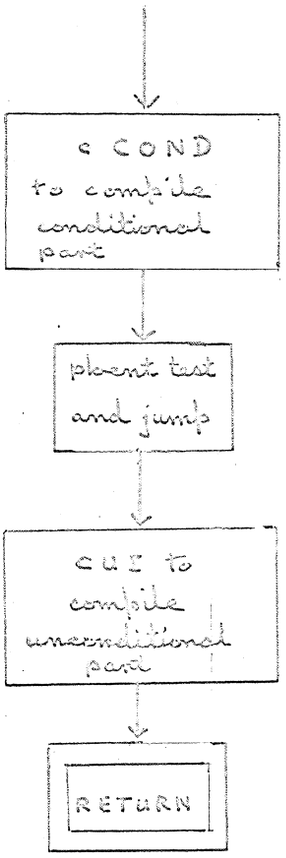
En Mlevel	initial value address
= M13	
M0 M13	initial value
E n+1 Mlevel	increment
+	add
Jj ≠	
ERASE	

Note: cycle variable replaced at j. see c SS for A(1) = 2

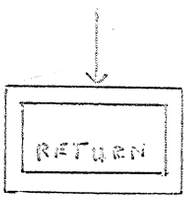
[N] {:}



5 [in] [sc] [REST OF COND] {then} [CLI] [S]



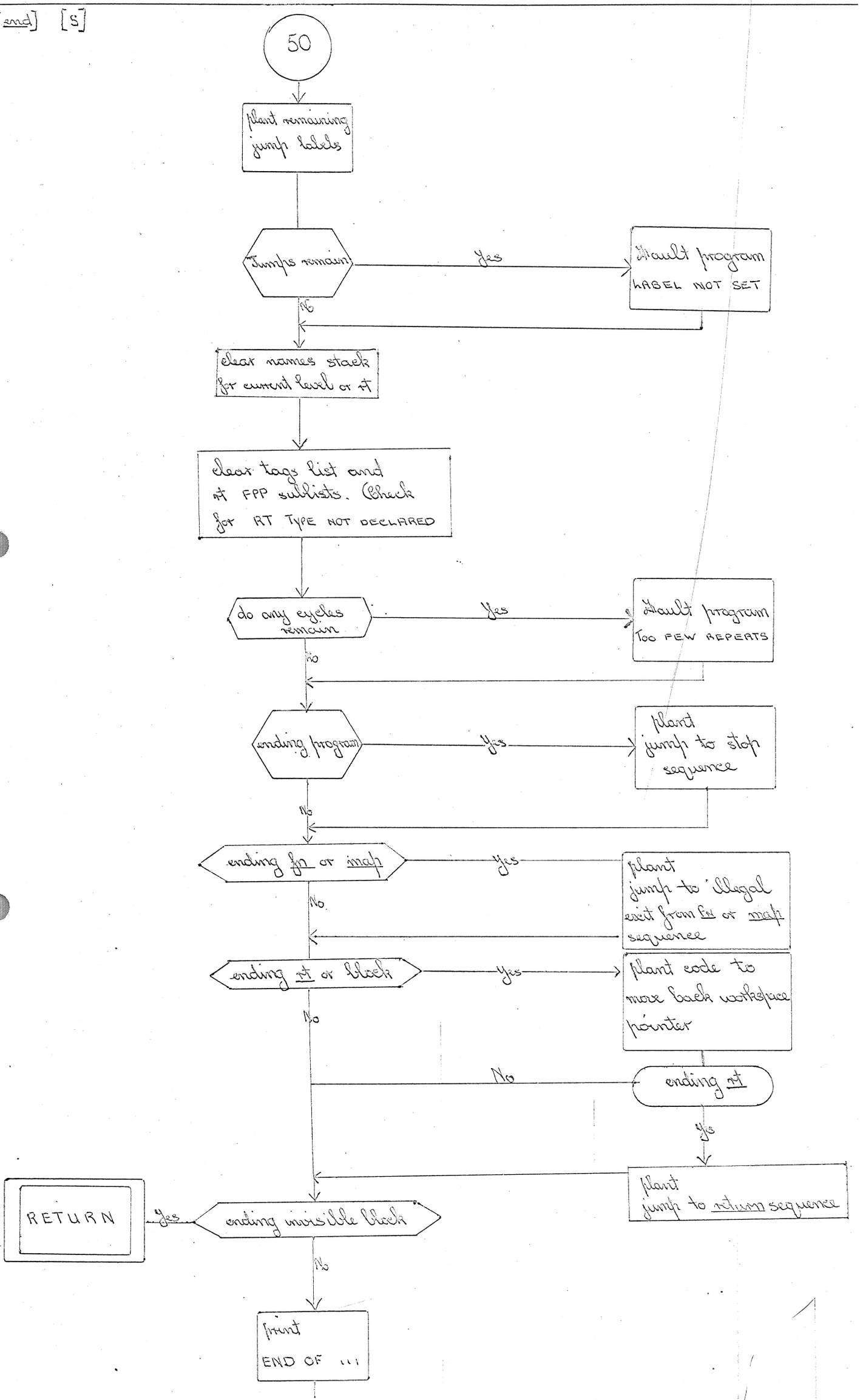
6 {i} [TEXT] [S]

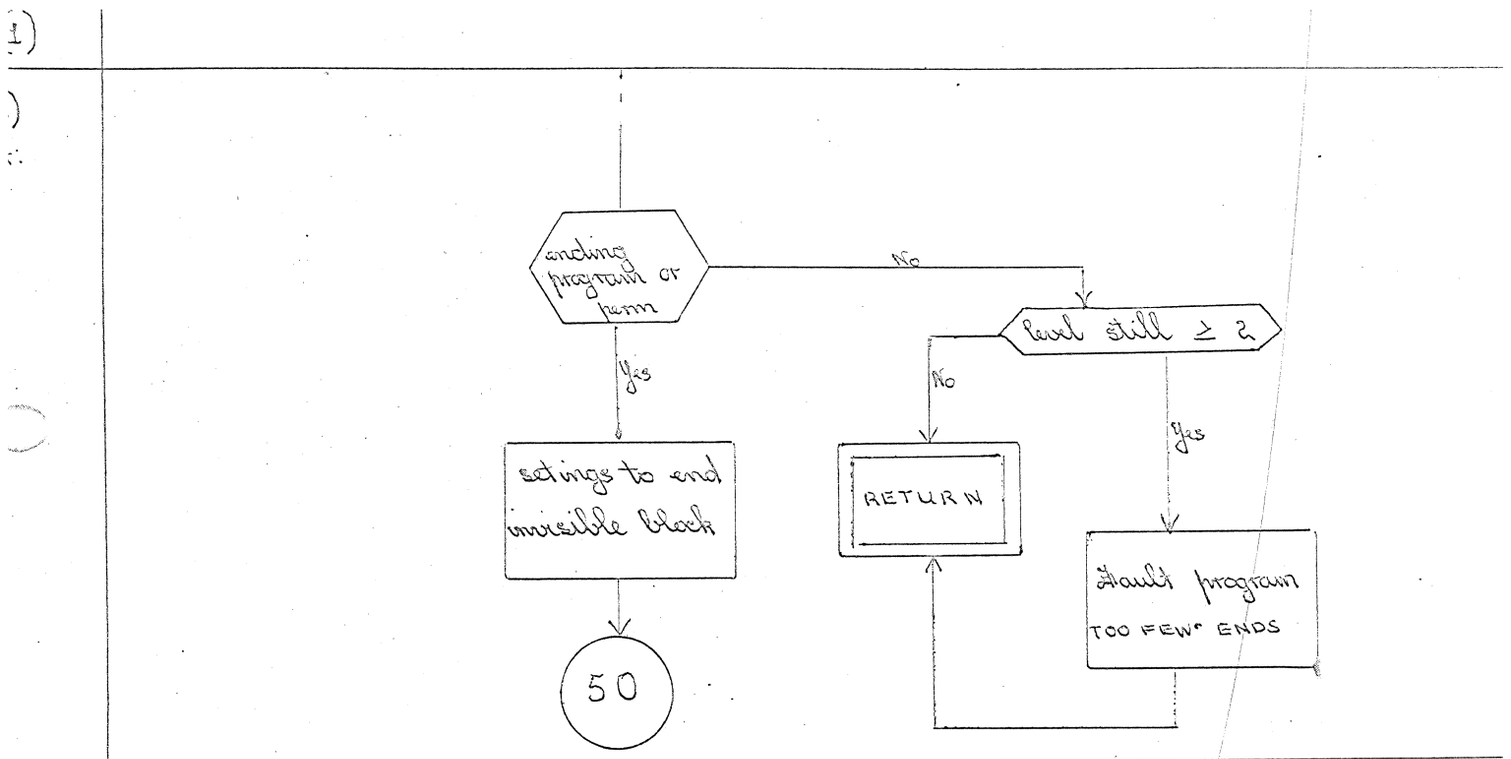


7 [TYPE] [NAME] [REST OF NAME LIST] [S]

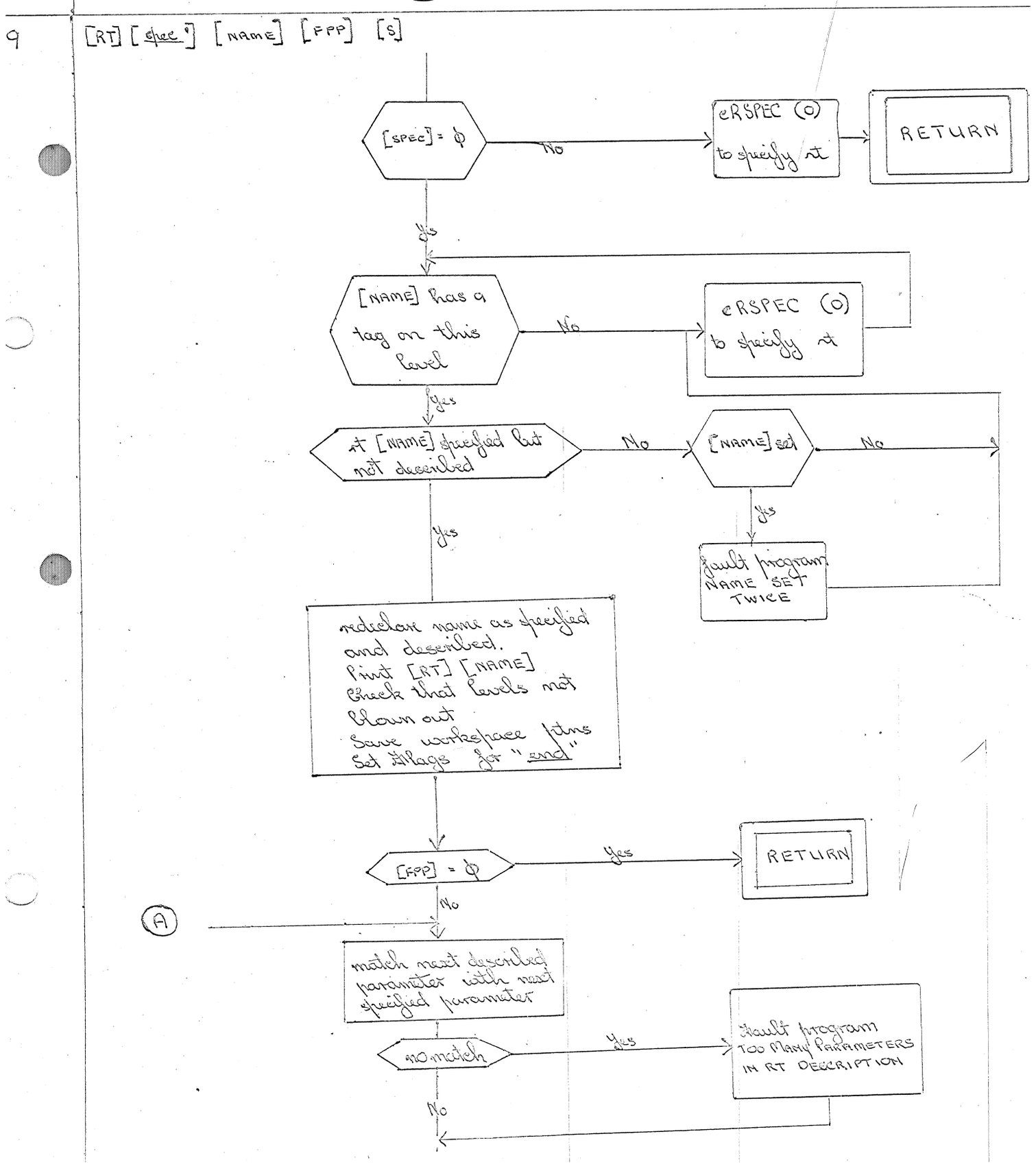
declare names, fault program if name set twice,
set up tags array.

[end] [S]


50
plant remaining jump labels
Jumps remain
Yes
Halt program
LABEL NOT SET
No
clear names stack for current level or it
clear tags list and it FPP sublists. Check for RT TYPE NOT DECLARED
do any cycles remain
Yes
Halt program
Too FEW REPEATS
No
ending program
Yes
plant jump to stop sequence
No
ending fn or inah
Yes
plant jump to 'illegal exit from fn or inah sequence
No
ending it or black
Yes
plant code to move back workspace pointer
No
ending it
Yes
plant jump to return sequence
RETURN
Yes
ending invisible black
No
print
END OF ...

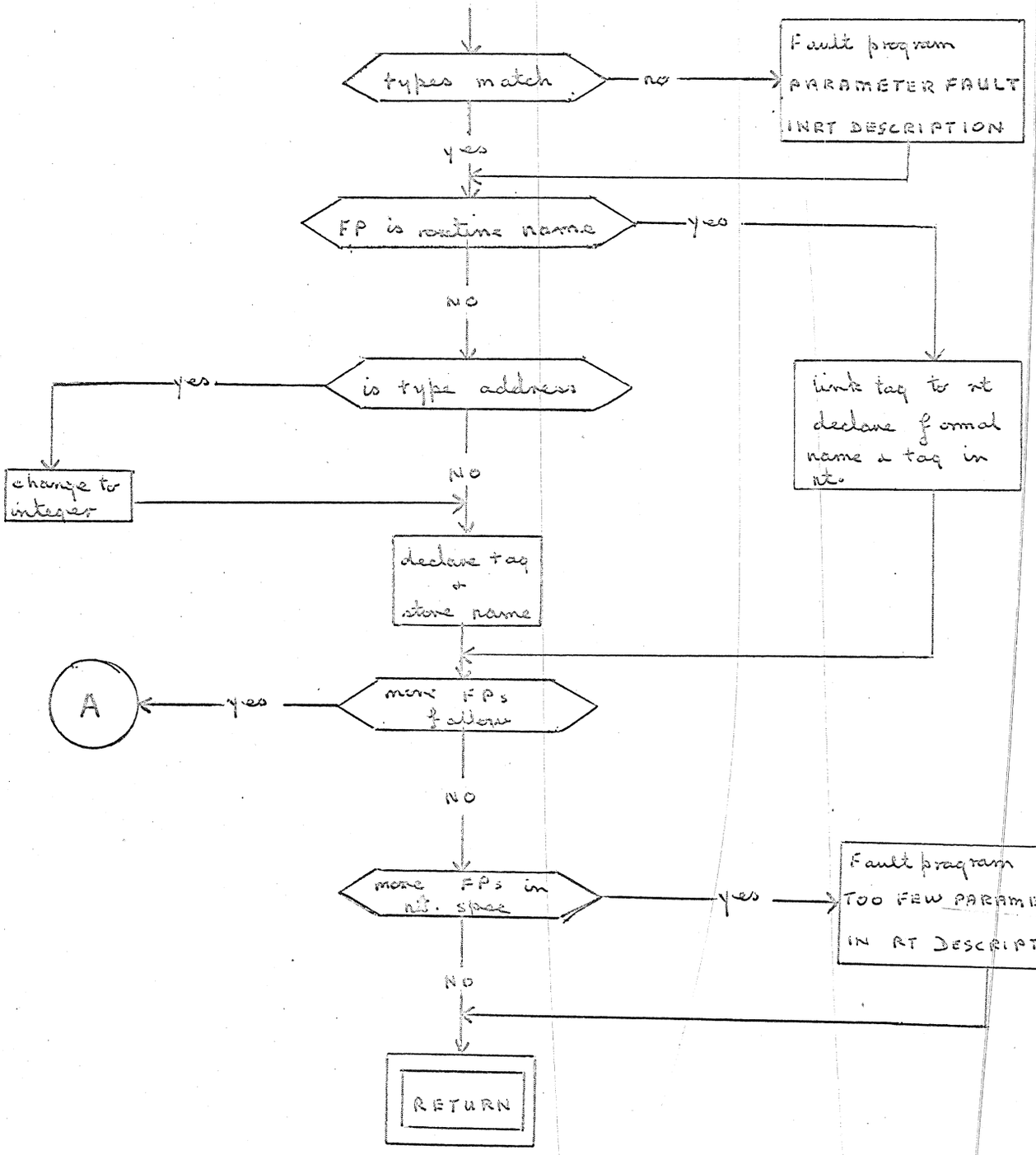


9 [RT] [spec'] [NAME] [FPP] [S]

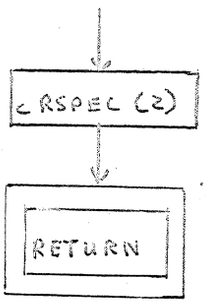


(1)

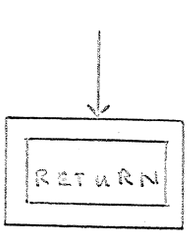
(9) CONT



10 [spec] [NAME] [FPP] [S]

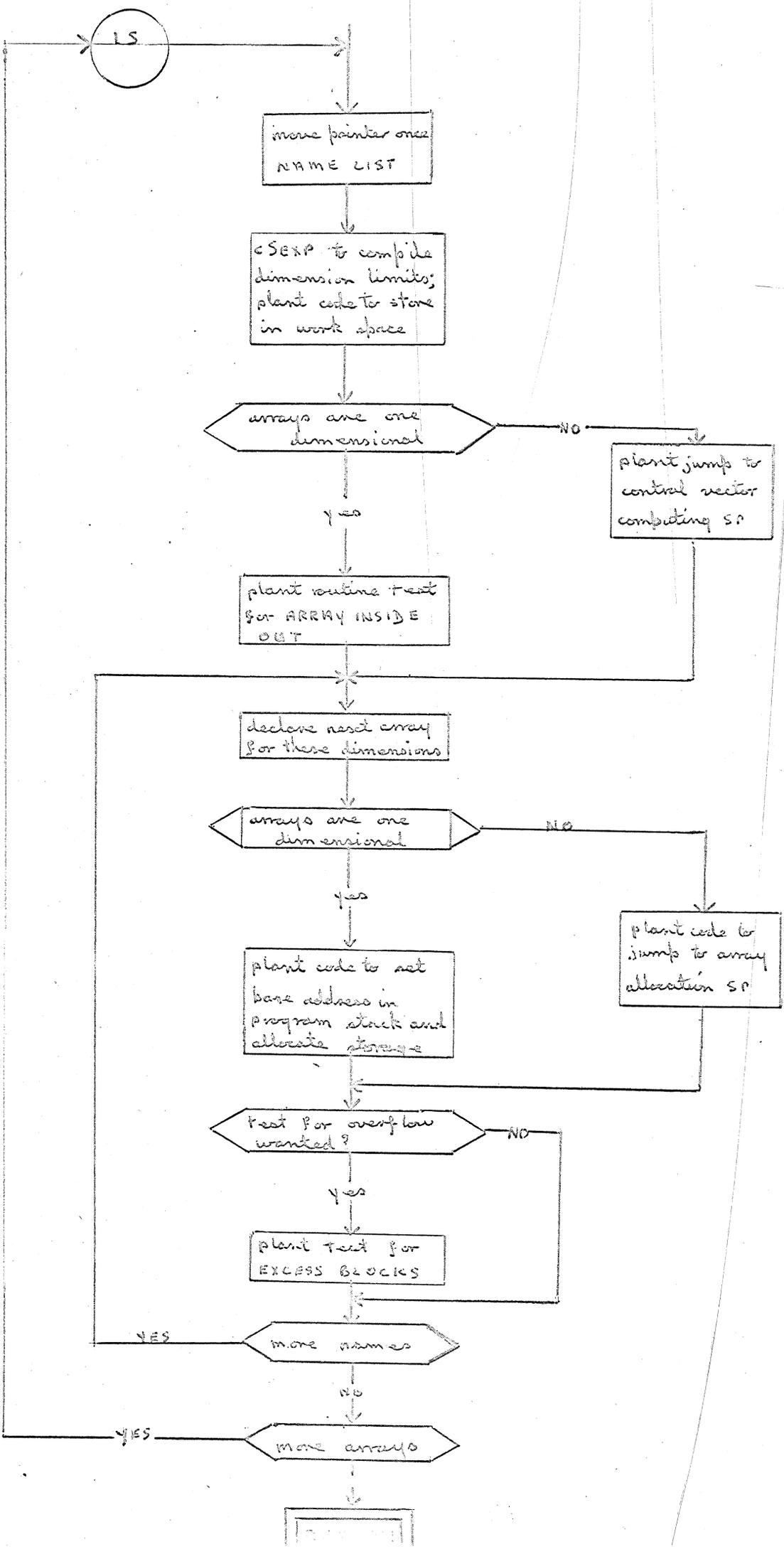


11 {comment} [TEXT] [S]



12

[TYPE'] {array} [NAME] [REST OF NAME LIST] {(} [±'] [OPERAND]
[REST OF EXPR] {:} [±'] [OPERAND] [REST OF EXPR]
[REST OF BP-LIST] {)} [REST OF ARRAY LIST] [S]



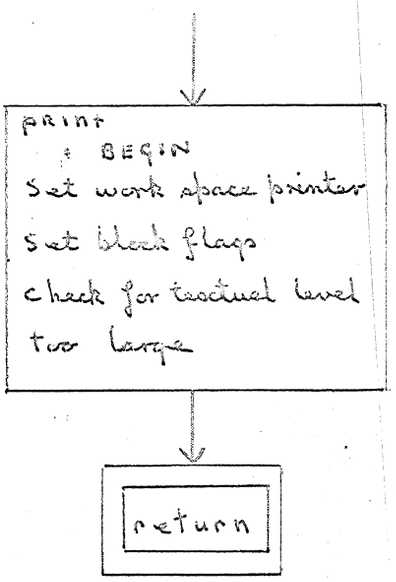
(1)

13 {*} {*} {*} {A} {S}

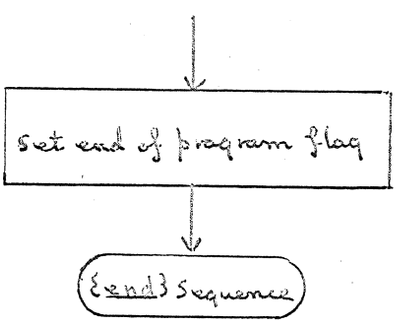
process entire job heading; output devices, magnetic tape allocation, execution times recorded.

(1)

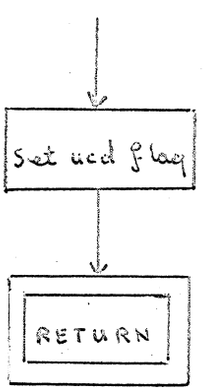
4 {begin} [S]



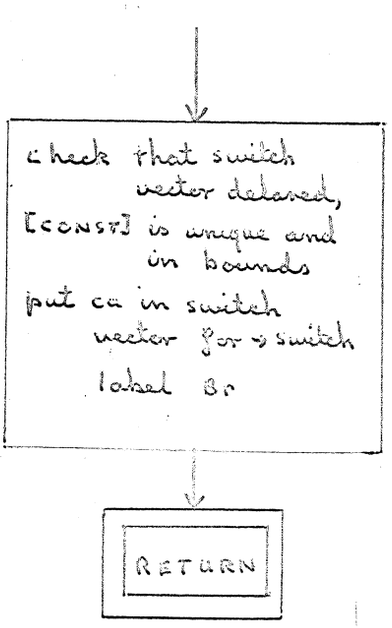
5 {end} {of} {program}



16 {upper} {case} {delimiters}



17 [NAME] {(} [±] [CONST] {)} {:} (switch label)



22 [N] {P} {:}

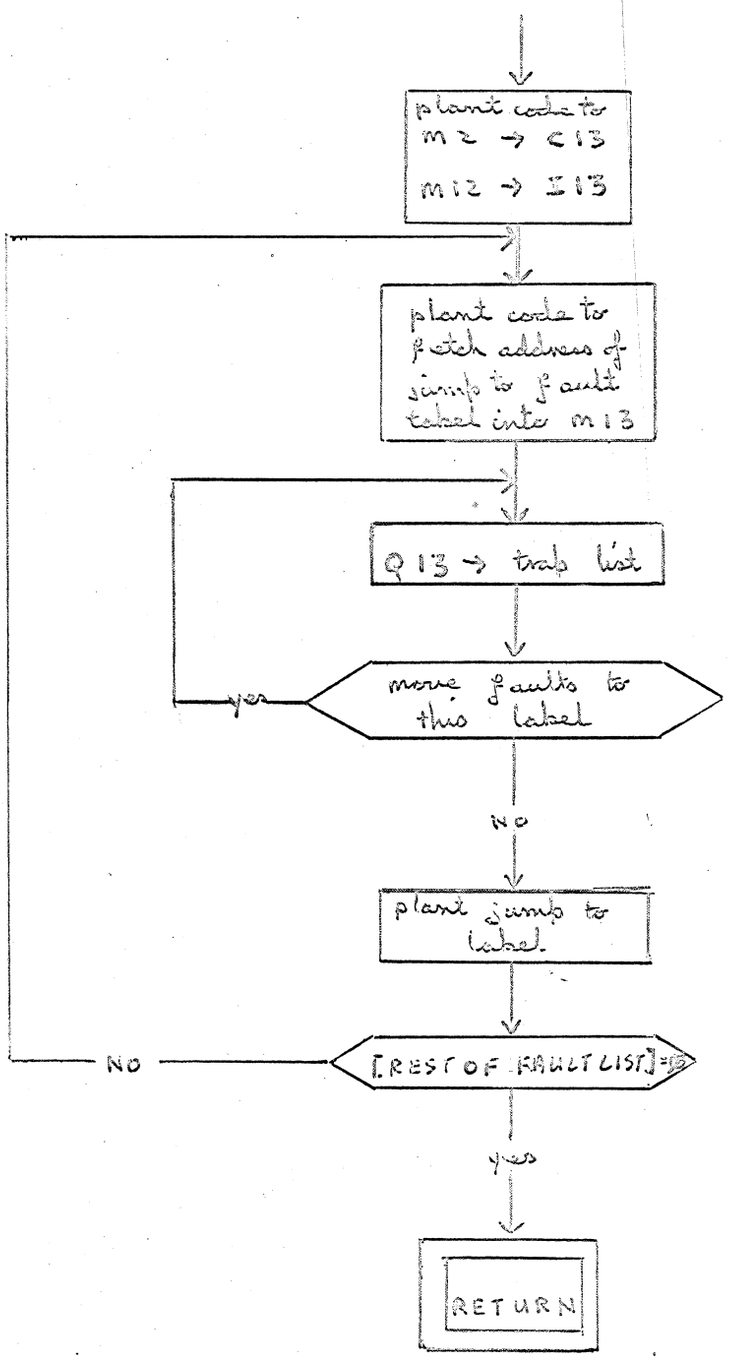
Check that machine code switched on,
that P-label not already set
set label

3 {*} [UCI] [S]

Fault program if machine code not switched on
c UCI to compile user code

4 {Fault} [N] [REST OF NLIST] {→} [N] [REST OF FAULT LIST] [S]

NOTE: When a run time fault occurs in a user program, control transfers to 90P: in perm, where a check is made to see whether the user has trapped the fault or not. If he has, there will be a list element for the fault containing restart information: the values of M12 (stack base address for level 2,) M12 (end of stack pointer for level 2) and the address of a jump instruction to the required label.



25 {normal} {delimiters} [S]

clear acd flag

26 {strings} [S]

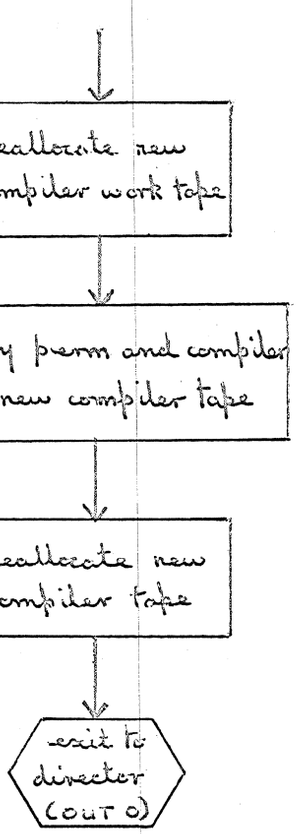
set string flag

27 {end} {of} {perm} [S]

clear perm and machine code flags
reset line count
set overflow test permit

9 {define} {compile} {c} [S]

causes execution of program in compiler which copies the perm and compiler currently in core into a magnetic tape whose device number is in E418.



Note on the meaning of constants

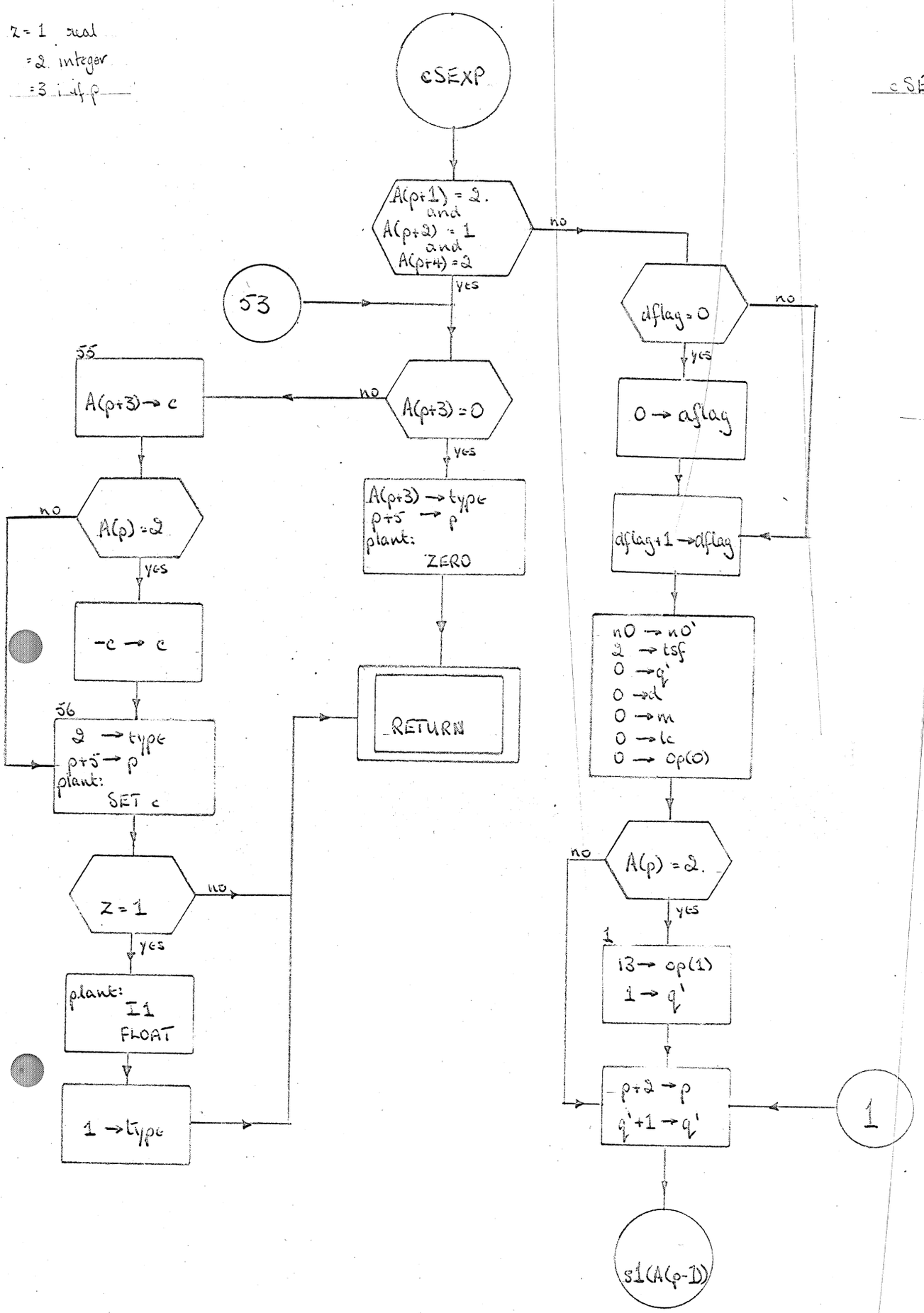
dflag	depth of recursion counter
tsf	represents the current type (integer or real) of the expression being compiled. = 1 for real, = 2 for integer.
lc	long constant flag - set if a long constant is among the current operands.
op( )	array, contains the operators currently being examined.
n0, n0'	stack (ST) pointers.
m	absolute value flag, set if absolute value of an expression is to be taken.

Meaning of call parameter z

1	final value to be real
2	final value to be integer
3	final value to be integer if possible.

z = 1 real
= 2 integer
= 3 if p

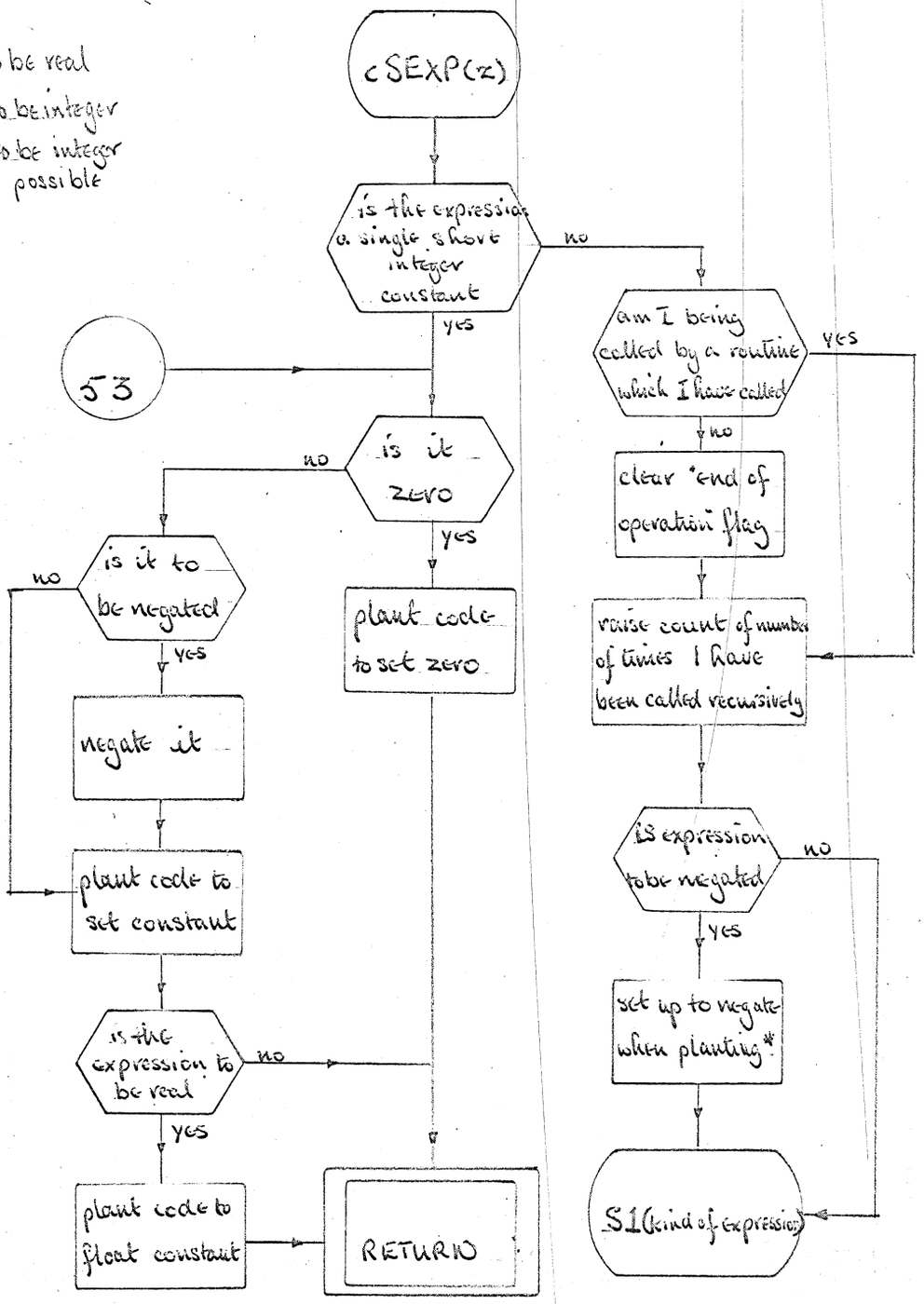
cSEXP



z = 1 if value is to be real
z = 2 if value is to be integer
z = 3 if value is to be integer if possible

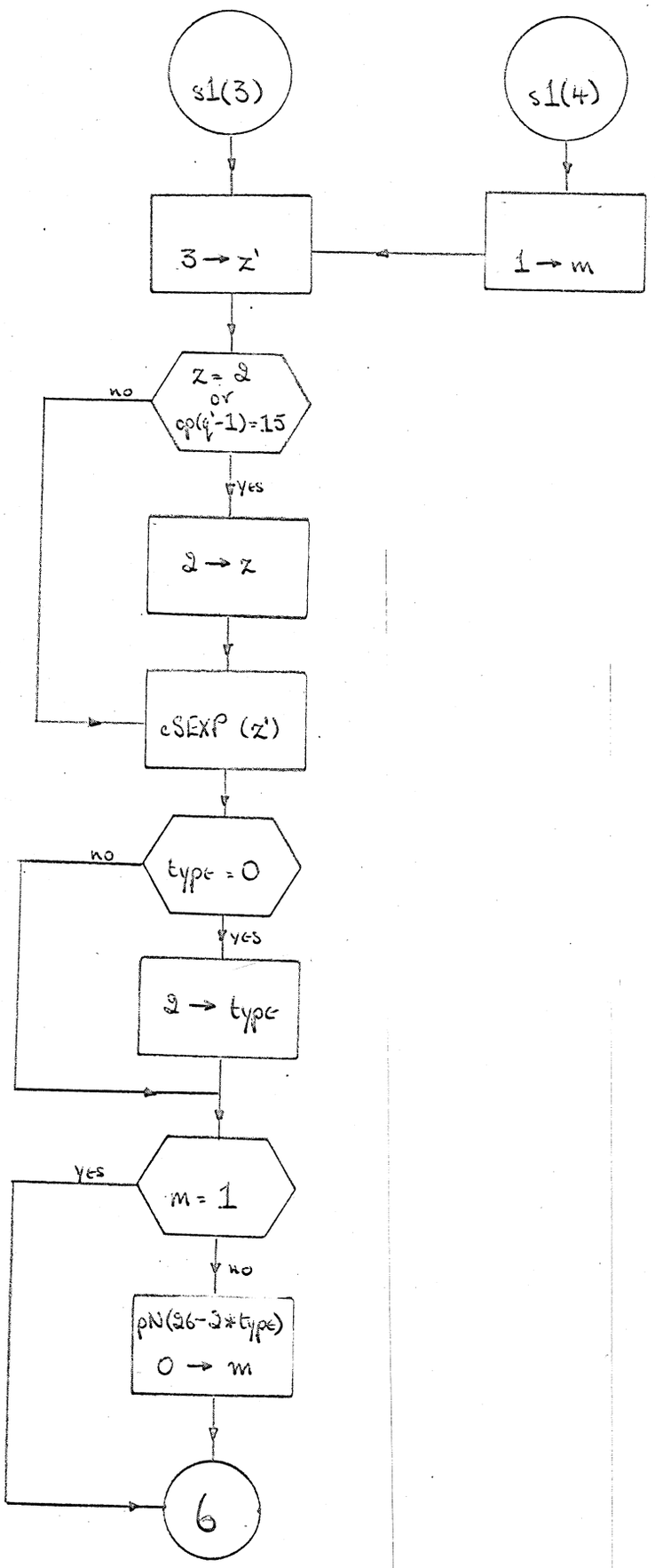
cSEXP

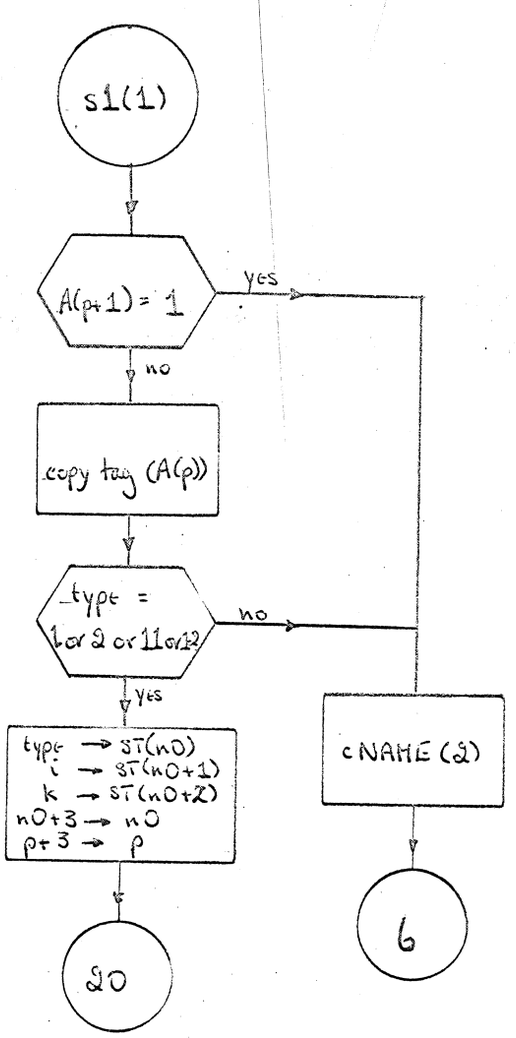
English

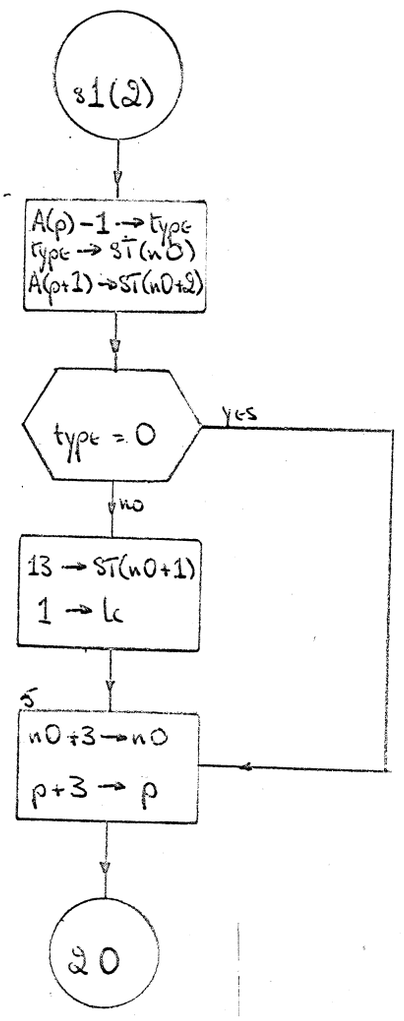


* The "set ups" are finally executed by routine plant orders. See note opposite label (30).

cSEXP

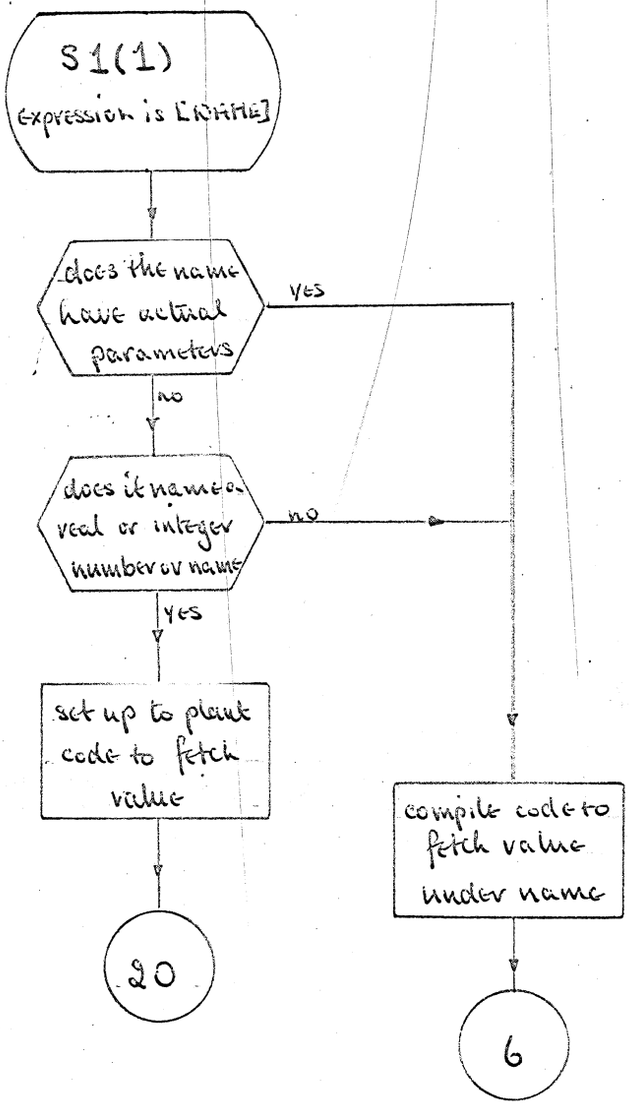

s1(3)
s1(4)
3 → z'
1 → m
z = 2 or φ(z'-1) = 15
no
yes
2 → z
cSEXP (z')
type = 0
no
yes
2 → type
m = 1
yes
no
pN(26-2*type)
0 → m
6

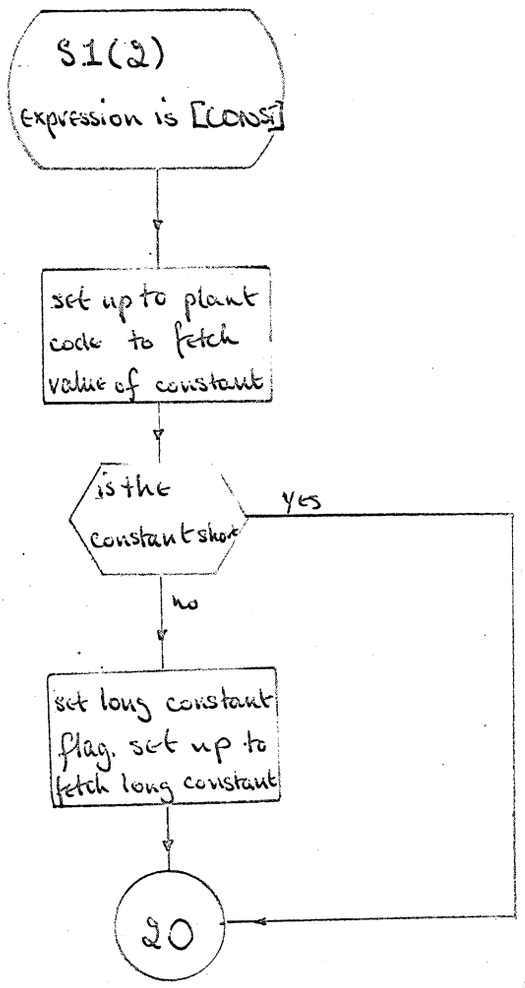

s1(1)
A(p+1) = 1
yes
no
copy tag (A(p))
type =
1 or 2 or 11 or 12
no
yes
type → ST(nO)
i → ST(nO+1)
k → ST(nO+2)
nO+3 → nO
p+3 → p
cNAME (2)
20
6

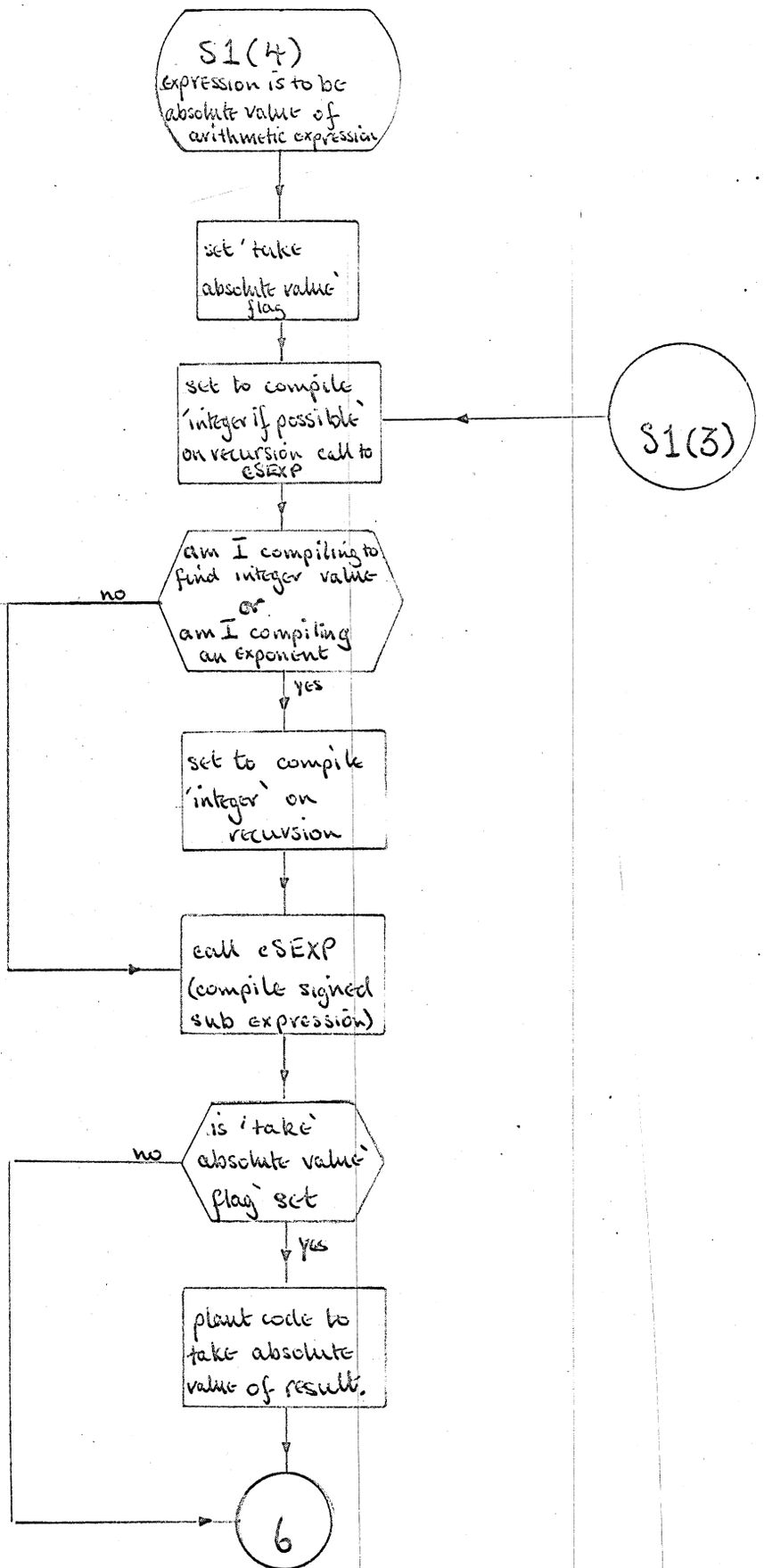

s1(2)
A(p) - 1 → type
type → ST(nO)
A(p+1) → ST(nO+2)
type = 0
yes
no
13 → ST(nO+1)
1 → lc
5
nO+3 → nO
p+3 → p
20

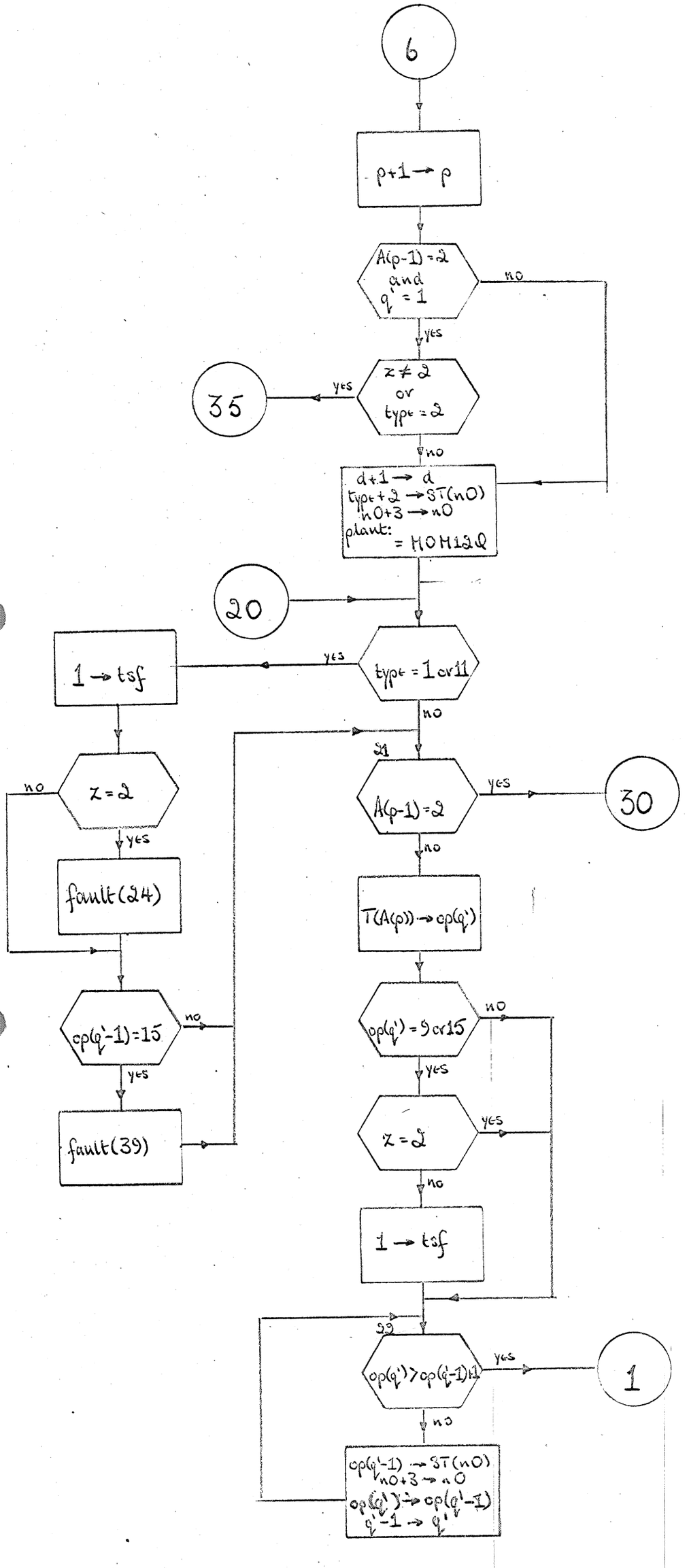
cSEXP

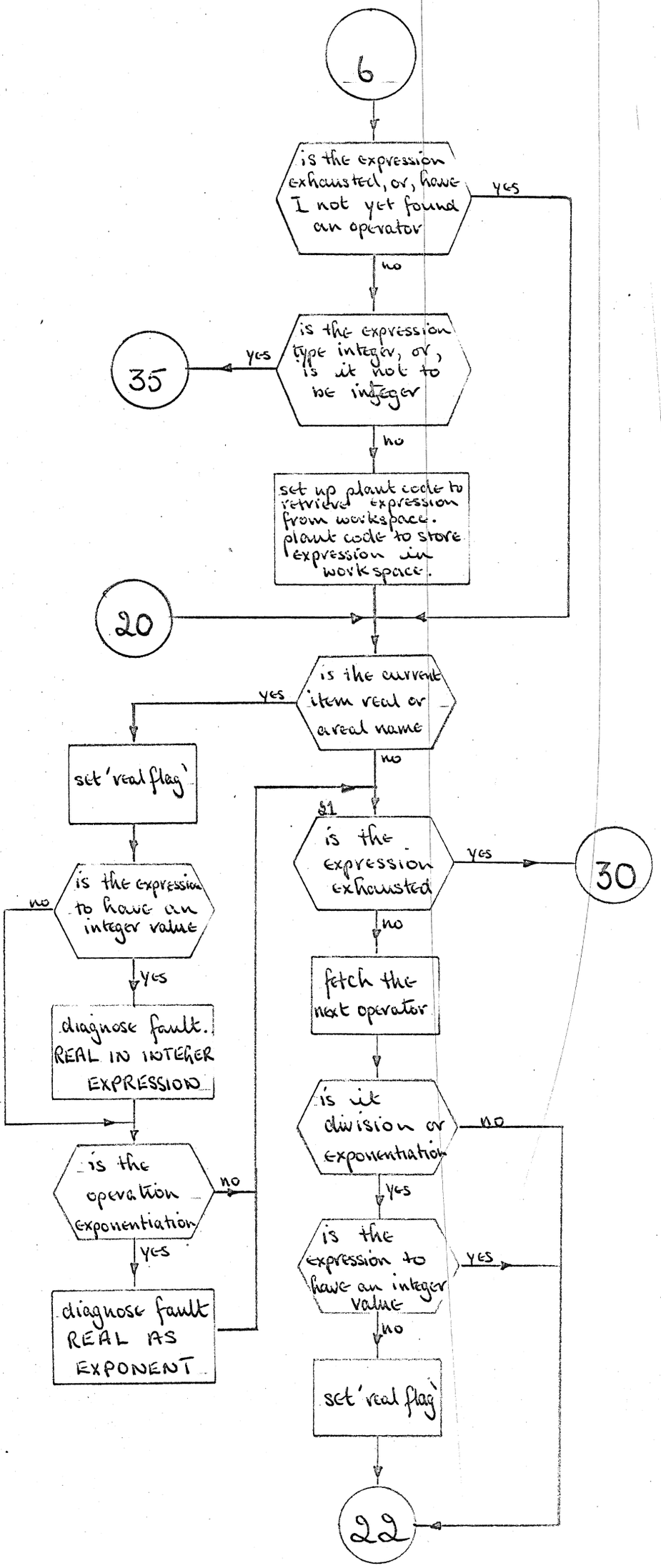
English





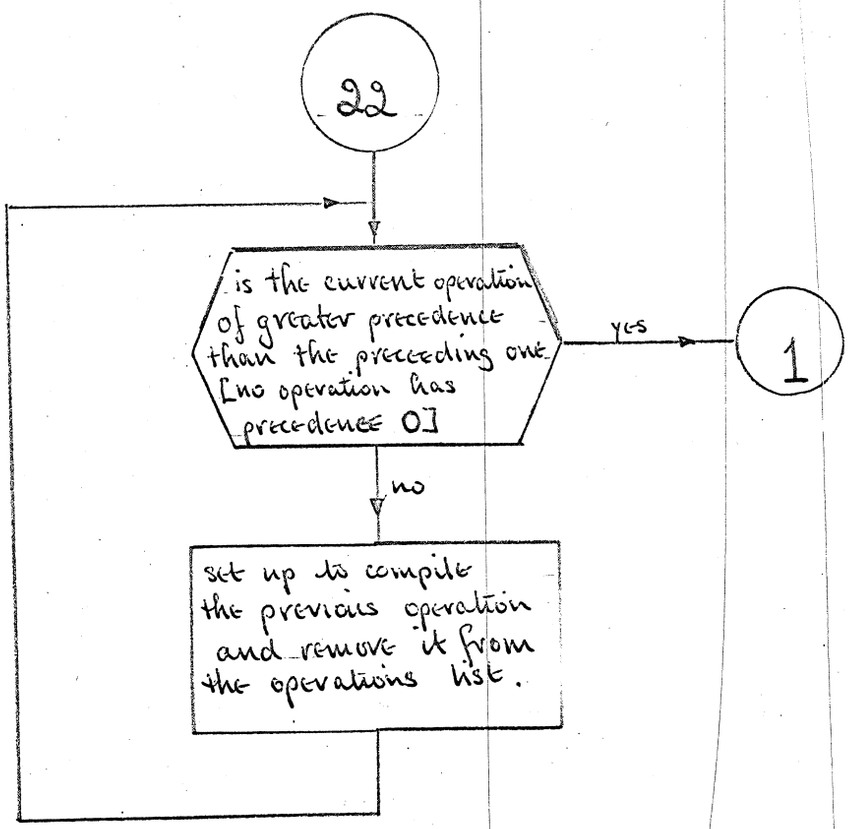

S1(4)
expression is to be absolute value of arithmetic expression
set 'take absolute value' flag
set to compile 'integer if possible' on recursion call to cSEXP
S1(3)
am I compiling to find integer value or am I compiling an exponent
no
yes
set to compile 'integer' on recursion
call cSEXP (compile signed sub expression)
is 'take absolute value' flag' set
no
yes
plant code to take absolute value of result.
6

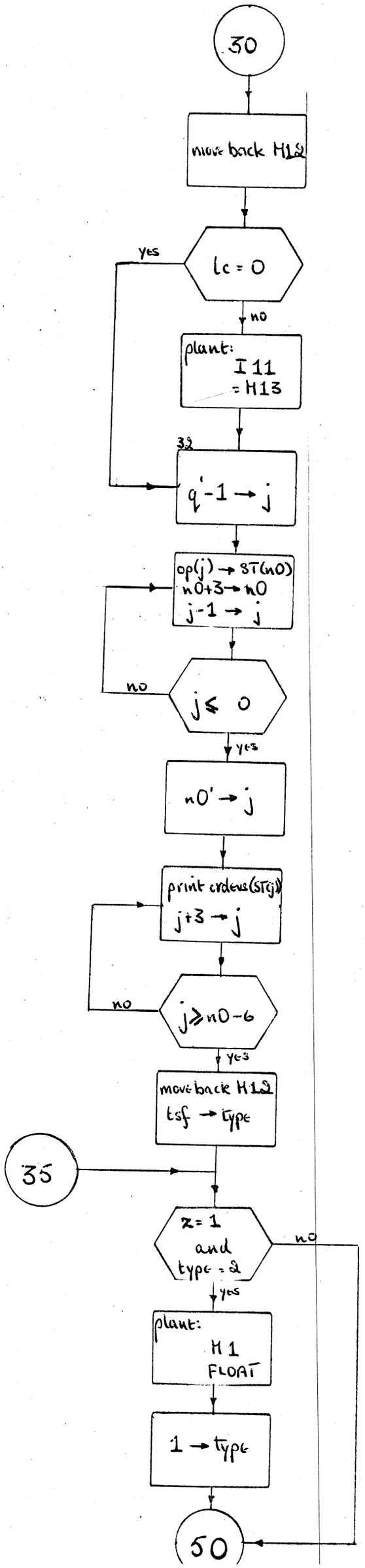

6
p+1 → p
A(p-1) = 2 and q' = 1
no
yes
z ≠ 2 or type = 2
yes
35
no
d+1 → d
type+2 → ST(nO)
nO+3 → nO
plant: = HOH12Q
20
type = 1 or 11
yes
1 → tsf
no
21
A(p-1) = 2
yes
30
no
T(A(p)) → op(q')
op(q') = 9 or 15
no
yes
z = 2
yes
no
1 → tsf
99
op(q') > op(q'-1)+1
yes
1
no
op(q'-1) → ST(nO)
nO+3 → nO
op(q') → op(q'-1)
q'-1 → q'
z = 2
no
yes
fault(24)
op(q'-1) = 15
no
yes
fault(39)


6
is the expression exhausted, or, have I not yet found an operator
yes
no
is the expression type integer, or, is it not to be integer
yes
35
no
set up plant code to retrieve expression from workspace. plant code to store expression in workspace.
20
is the current item real or a real name
yes
set 'real flag'
no
is the expression to have an integer value
no
yes
diagnose fault. REAL IN INTEGER EXPRESSION
is the operation exponentiation
no
yes
diagnose fault REAL AS EXPONENT
21
is the expression exhausted
yes
30
no
fetch the next operator
is it division or exponentiation
no
yes
is the expression to have an integer value
yes
no
set 'real flag'
22

cSEXP

English




30
move back H12
lc = 0
yes
no
plant:
I 11
= H13
32
q'-1 → j
op(j) → ST(n0)
n0+3 → n0
j-1 → j
no
j ≤ 0
yes
n0' → j
print cadena(ST(j))
j+3 → j
no
j ≥ n0-6
yes
move back H12
tsf → type
35
z = 1
and
type = 2
no
yes
plant:
H 1
FLOAT
1 → type
50

'Setting up' an expression for compilation consists in forming a list of operators and operands in the stack. The list is ordered in reverse polish, so that b+c * a † b/e would become

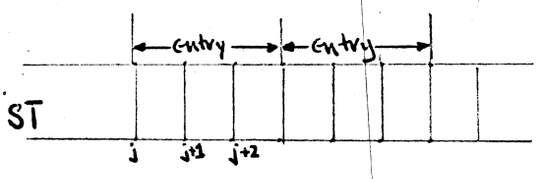
b c a b † * e / +

The following code will be planted (assuming the variables to be integer)

```
**  b
** c
**  a
**  b
*   JS  82P  (exponentiation subroutine)
*   XD
*   CONT
**  e
*   +
*   +
```

Expressions may always be treated in this way since parenthetic sub-expressions are compiled by recursive calls to cSEXP, and the results stored in temporay workspace to be fetched when needed.

The list of operands and operations is kept on part of the ST array. Each entry, whether representing an operand or an operation consists of three words



The first word of each entry identifies the operation or the operand represented by the entry. The next two words give other information about the entry. The entry codes are as follows:

ST(j)	ST(j+1)	ST(j+2)
0 short integer	value	sign: 5 + 6 -
1, 2, real or integer	address of value	...
3, 4, array elements	address of value	...
5 add operator	...	...
6 subtract operator	...	...
8 multiply operator	...	...
9 divide operator	...	...
13 negate operator	...	...
15 exponentiate operator	...	...
11, 12 real or integer name	address of name	...
14 address	...	...

The stack in this form is interpreted by routine print orders, and the corresponding code is planted.

The compiler itself is phrase structure oriented and compiles individual source statements one at a time. Compiler operates in two phases, a recognition phase and a compilation phase.

During the recognition phase, a source statement is compared with a list of permitted statement forms. If the statement matches a particular form, it is said to be syntactically correct and therefore ready for compilation. As a statement is being matched, a list of pointers is made which describe the ''path'' through the phrase structure which resulted in a match. The phrase structure itself is a recursive tree structure whose roots are either text literals or ''built-in-phrases''. Phrase structure components are listed on the next several pages.

Built in phrases (or b.i.p.s) are phrases defined by pieces of compiler program. Recognizing a built in phrase in a source statement involves executing one of these pieces of program. The built in phrases are

[NAME]	all program names
[CONST]	decimal constants
[N]	labels and short decimal constants
[OCTAL]	octal constants
[TEXT]	comment text
[CAPTION TEXT]	
[S]	end-of-statement: semicolon or newline
[SET MARKER 1]	to indicate break between conditional and unconditional statement parts
[SET MARKER 2]	to indicate break between L.H.S. and R.H.S. of expression statements.

Each phrase, or P-word(symbolically 'P[...]') is either defined in terms of P-words and text literals, or is a built in phrase. The definitions, which are actually stored in the compiler, are written

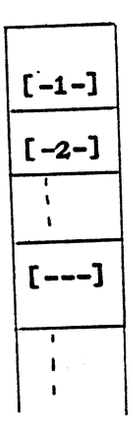
P[---] = ..., ..., ... ;

where '[---]' represents an identifier, and '...' may represent a string of P-word identifiers and text literals. * A phrase definition says that the phrase [---] may consist of ... exclusively, or ... exclusively, or ..., etc. A semicolon terminates the definition. The definition parts separated by commas are called alternatives, and, when a source statement is scanned, a part will be recognised as of the k th alternative of [---] if it matches the kth alternative ....

A null alternative (symbolically 'ø') is possible in many definitions. As A phrase definition is scanned from left to right, as it were, and when a match with the source statement part is found, scanning stops. 'ø' as the kth alternative acts as an instruction, ''match the source statement part as alternative k of this phrase.''

Phrase definitions are stored as a list, in the compiler, each definition occupying a contigmous part of the array < symbol (1300:2320).>

<symbol>



*Text literals are written between spiked brackets '⊢' and '⊣' . The desired text appears between them.

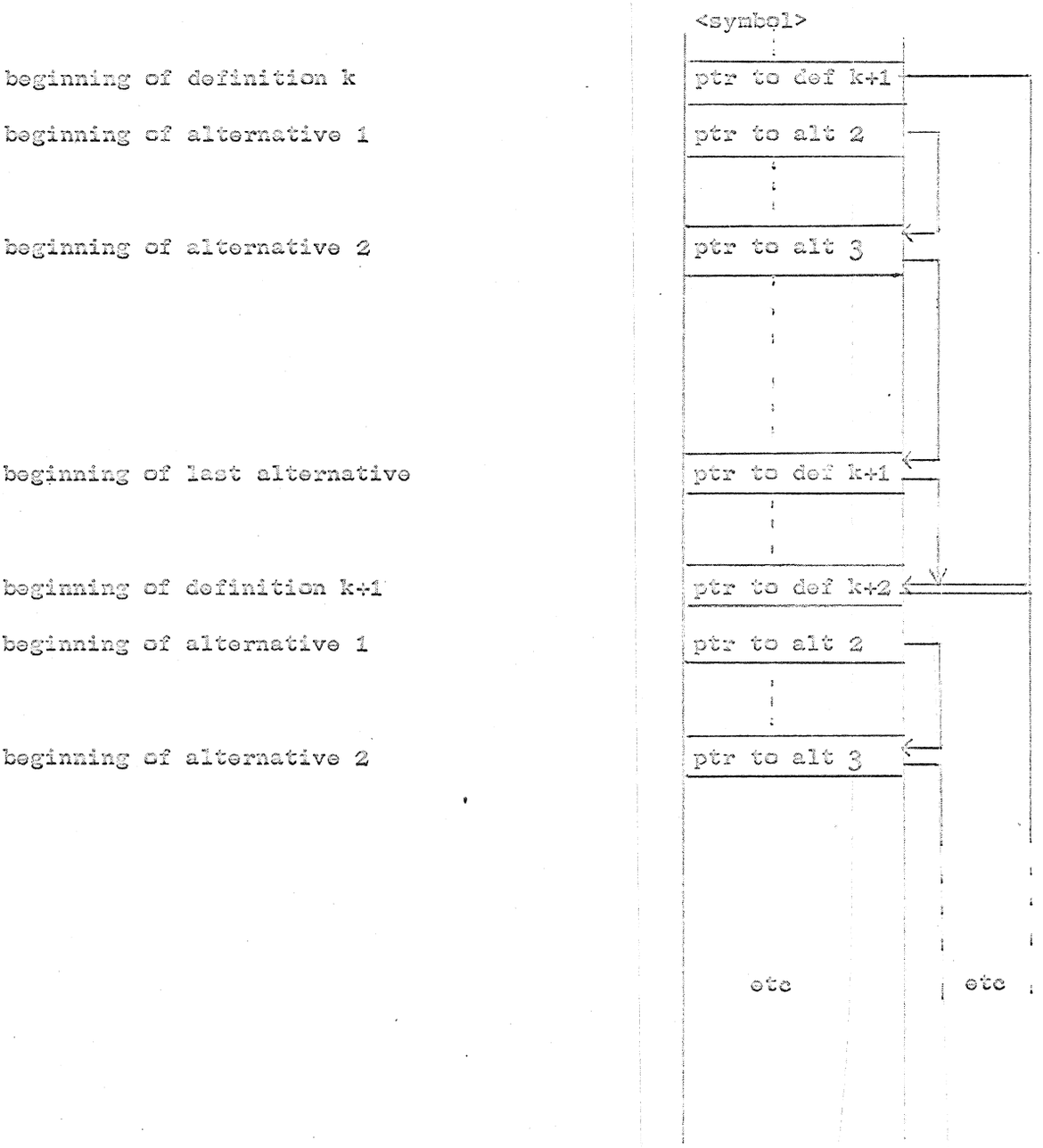
```
P[±']                    =  ⊢+⊣,⊢-⊣,ø;
P[OPERAND]               =  [NAME][APP],[CONST],⊢(⊣[±'][OPERAND][REST OF EXPR]⊢)⊣,
                            ⊢|⊣[±'][OPERAND][REST OF EXPR]⊢|⊣;
P[REST OF EXPR]          =  [OP][OPERAND][REST OF EXPR],ø;
P[APP]                   =  ⊢(⊣[±'][OPERAND][REST OF EXPR][REST OF EXPR-LIST]⊢)⊣,ø;
P[REST OF EXPR-LIST]     =  ⊢,⊣[±'][OPERAND][REST OF EXPR][REST OF EXPR-LIST],ø;
P[OP]                    =  ⊢+⊣⊢-⊣,⊢*⊣,⊢/⊣,⊢↑⊣,ø;
P[QUERY']                =  ⊢?⊣,ø;
P[,']                    =  ⊢,⊣,ø;
P[iu]                    =  ⊢if⊣,⊢unless⊣;
P[real']                 =  ⊢real⊣,ø;
P[TYPE]                  =  ⊢integer⊣,⊢real⊣;
P[TYPE']                 =  ⊢integer⊣,⊢real⊣ø;
P[RT]                    =  ⊢routine⊣,⊢real⊣⊢fn⊣,⊢integer⊣⊢fn⊣,⊢real⊣⊢map⊣,⊢integer⊣
                               ⊢map⊣;
P[FP-DELIMITER]          =  [RT],⊢integer⊣⊢array⊣⊢name⊣,⊢integer⊣⊢name⊣,⊢integer⊣,
                               [real']⊢array⊣⊢name⊣,⊢real⊣⊢name⊣,⊢real⊣,⊢addr⊣;
P[FPP]                   =  ⊢(⊣[FP-DELIMITER][NAME][REST OF NAME LIST][REST OF FP-LIST]
                               ⊢)⊣,ø;
P[REST OF FP-LIST]       =  [,'][FP-DELIMITER][NAME][REST OF NAME LIST][REST OF FP-LIST]
P[REST OF NAME LIST]     =  ⊢,⊣[NAME][REST OF NAME LIST],ø;
P[SC]                    =  [±'][OPERAND][REST OF EXPR][COMP][±'][OPERAND][REST OF EXPR]
                               [REST OF SC],
                               ⊢(⊣[SC][REST OF COND]⊢)⊣;
P[REST OF SC]            =  [COMP][±'][OPERAND][REST OF EXPR],ø;
P[REST OF COND]          =  ⊢and⊣[SC][REST OF AND-C],⊢or⊣[SC][REST OF OR-C],ø;
P[REST OF AND-C]         =  ⊢and⊣[SC][REST OF AND-C],ø;
P[REST OF OR-C]          =  ⊢or⊣[SC][REST OF OR-C],ø;
P[REST OF UI]            =  ⊢=⊣[±'][OPERAND][REST OF EXPR][QUERY'],ø;
P[spce']                 =  ⊢spec⊣,ø;
P[REST OF BP-LIST]       =  ⊢,⊣[+'][OPERAND][REST OF EXPR]⊢:⊣[±'][OPERAND][REST OF EXPR]
                               [REST OF BP-LIST],ø;
P[REST OF ARRAY LIST]    =  ⊢,⊣[NAME][REST OF NAME LIST]⊢(⊣[±'][OPERAND][REST OF EXPR]⊢:
                               [±'][OPERAND][REST OF EXPR][REST OF BP-LIST]⊢)⊣[REST OF
                               ARRAY LIST],ø;
P[REST OF SWITCH LIST] =  ⊢,⊣[NAME][REST OF NAME LIST]⊢(⊣[±'][CONST]⊢:⊣[±'][CONST]⊢:⊣
                               [±'][CONST]⊢)⊣[REST OF SWITCH LIST],ø;
P[COMP]                  =  ⊢=⊣,⊢≥⊣,⊢>⊣,⊢≠⊣,⊢<⊣,⊢≤⊣;
P[REST OF SS1]           =  [S],[iu][SC][REST OF COND][S];
P[REST OF N-LIST]        =  ⊢,⊣[N][REST OF N-LIST],ø;
P[REST OF FAULT LIST]    =  ⊢,⊣[N][REST OF N-LIST]⊢->⊣[N][REST OF FAULT LIST],ø;
```

```
P[UI]          =   [NAME][APP][SET MARKER 1][REST OF UI],
                   ⊢->⊣[N],
                   ⊢caption⊣[CAPTION TEXT],
                   ⊢return⊣,
                   ⊢result=⊣[±'][OPERAND][REST OF EXPR],
                   ⊢stop⊣,
                   ⊢->⊣[NAME]⊢(⊣[±'][OPERAND][REST OF EXPR]⊢)⊣,
                   ⊢monitor⊣[N];

P[SS]          =   [UI][SET MARKER 2][REST OF SS1],
                   ⊢cycle⊣[NAME][APP]⊢=⊣[±'][OPERAND][REST OF EXPR]⊢,⊣
                        [±'][OPERAND]
                       [REST OF EXPR]⊢,⊣[±'][OPERAND][REST OF EXPR][S],
                   ⊢repeat⊣[S],
                   [N]⊢:⊣,
                   [iu][SC][REST OF COND]⊢then⊣[UI][S],
                   ⊢|⊣[TEXT],
                   [TYPE][NAME][REST OF NAME LIST][S],
                   ⊢end⊣[S],
                   [RT][spec'][NAME][FPP][S],
                   ⊢spec⊣[NAME][FPP][S],
                   ⊢comment⊣[TEXT],
                   [TYPE']⊢array⊣[NAME][REST OF NAME LIST]⊢(⊣[±'][OPERANI
                        [REST OF EXPR]⊢:⊣
                        [±'][OPERAND][REST OF EXPR][REST OF BP-LIST]⊢)⊣
                        [REST OF ARRAY LIST][S],
                   ⊢*⊣⊢*⊣⊢*⊣⊢A⊣[S],
                   ⊢begin⊣[S],
                   ⊢end⊣⊢of⊣⊢program⊣,
                   ⊢upper⊣⊢case⊣⊢delimiters⊣[S],
                   [NAME]⊢(⊣[±'][CONST]⊢)⊣⊢:⊣,
                   ⊢switch⊣[NAME][REST OF NAME LIST]⊢(⊣[±'][CONST]⊢:⊣
                        [±'][CONST]⊢)⊣[REST OF SWITCH LIST][S],
                   ⊢compile⊣⊢queries⊣[S],
                   ⊢ignore⊣⊢queries⊣[S],
                   ⊢mcode⊣[S],
                   [N]⊢P⊣⊢:⊣,
                   ⊢*⊣[UCI][S],
                   ⊢fault⊣[N][REST OF N-LIST]⊢->⊣[N][REST OF FAULT LIST][
                   ⊢normal⊣⊢delimiters⊣[S],
                   ⊢strings⊣[S],
                   ⊢end⊣⊢of⊣⊢perm⊣[S],
                   ⊢end⊣⊢of⊣⊢mcode⊣[S],
                   ⊢define⊣⊢compile⊣⊢r⊣[S],
                   [S];
```

built in phrase	action	analysis record entry
[NAME]	File text of name in name list. n=ptr.to entry in name list	n
[CONST]	If constant is a short (≤15bits) integer, j=1, k=value If constant is long integer, j=3,value is stacked, k=address of value If constant is real,j=2,value is stacked k=address of value	j k
[OCTAL] or [N]	v=value	v
[TEXT]	(comment text ignored)	none
[SET MARKER 1] [SET MARKER 2]	internal pointers set to point to next empty element of analysis record; marker 1 if L.H.S. of expression to follow marker 2 if condition for previous part to follow	none
[CAPTION TEXT]	caption text is stacked. k=ptr to text in stack	k
[S]	none	none
ø	recognise this alternative	none

A definition is delimited by means of a pointer stored at the beginning of the array part for that definition. It points to the beginning of the next definition in the array. The alternatives of a definition are treated in the same manner, the first computer word of an alternative being a pointer to the first computer word of the next alternative:



An alternative is composed of a string of phrase identifiers and text literals. These are represented in <symbol> as a string of pointers. There are three kinds of these pointers: (1) to an entry in the dictionary of text literals,(2) to pieces of compiler code for built in phrases, and (3) to phrase definitions in <symbol> for phrases which are defined.

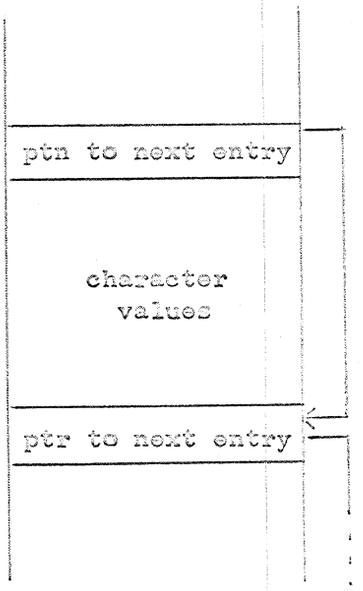
(In fact, the pointers are integer numbers rather than addresses. They are distinguished in the following way. If n is the value of an entry in symbol, then

(1) if $0 \leq n < 1000$, n points to the literal dictionary.

(2) if $1000 \leq n < 1300$, n points to a built in phrase

(3) if $n \geq 1300$, n points to a phrase definition in symbol

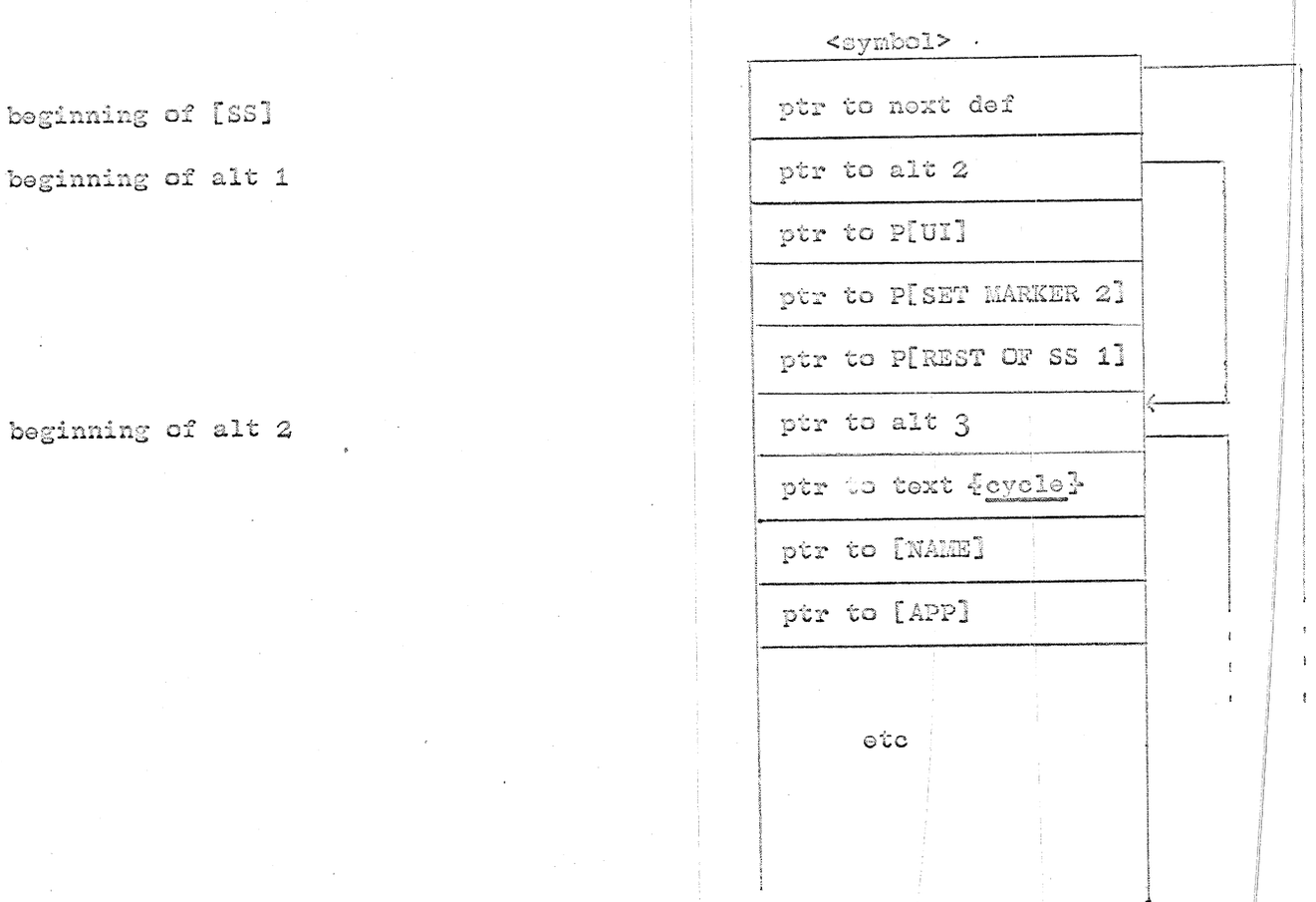
The literal dictionary <clett> is organised so that every entry of a literal begins at a new computer word which contains a pointer to the beginning of the next entry. This enables the



recognition phrase routine <compare> to mechanically test for end-of-literal. The literal dictionary, like the array <symbol> is filled in at compiler-define time described under the section''Compiling a New Compiler''.

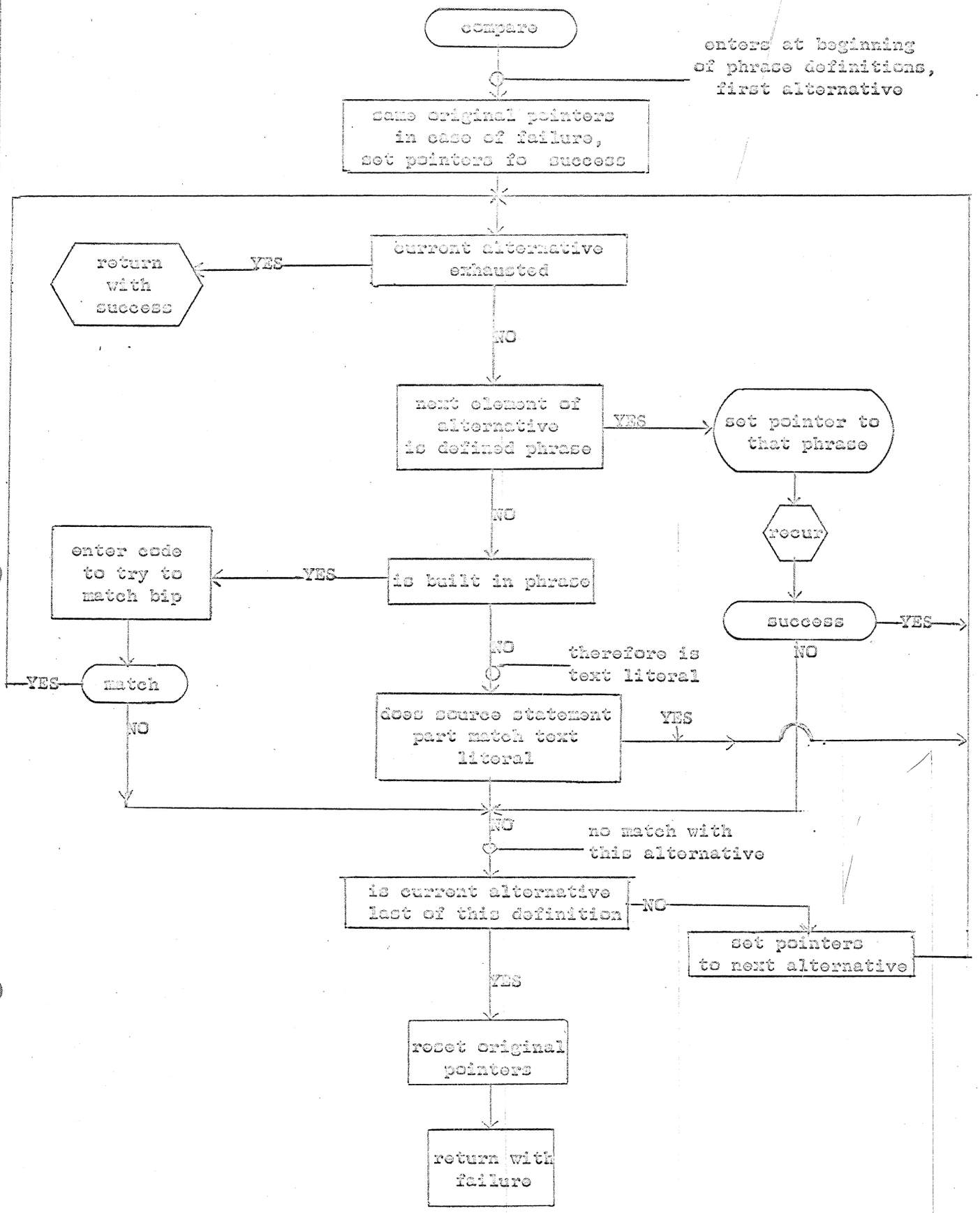
Pointers to built in phrases are used directly as switch indices in <compare> to jump to the coded parts.)

In this fashion, the whole tree of phrase definitions is stored for use by the recognition routine. As a whole, the phrase structure tree (for version I) has thirty ''tips'' and a number of ''roots''. The roots are text literals and the nine built in phrases. The tips are the thirty alternatives of phrase [SS]. Every legal AA source statement corresponds to a path beginning at one of the tips and ending at a prescribed root: ([S] or for labels [:].) Routine compare thus begins scanning from the beginning of the definition of [SS] in <symbol>,



and compares each alternative of [SS] to the source statement until a match is found, or until [SS] is exhausted.

Outline of line recognition routine



The recognition routine is capable of dealing with one phrase definition only. In particular it is capable of processing built in phrases, matching source statement text to text literals, flagging the fact that it has succeeded or failed in matching an alternative and recording the number of the alternative matched.

The method of scanning this involves entering <compare> with <symbol> pointers pointing to the beginning of a phrase definition . <compare> will then try to match the first alternative to the source statement by examining the first entry in the first alternative, trying to match the source statement part if the first entry is a b.i.p. or text literal, or setting pointers for the referenced definition and calling itself if the entry points to a phrase definition.

The object of recognising a source statement is to translate it into a form convenient for compilation. Basically this consists in forming a list of numbers which can be interpreted by the compilation routines as switches to particular routines or as flags. Not surprisingly the compilation routines are organised to reflect the structure of [SS].

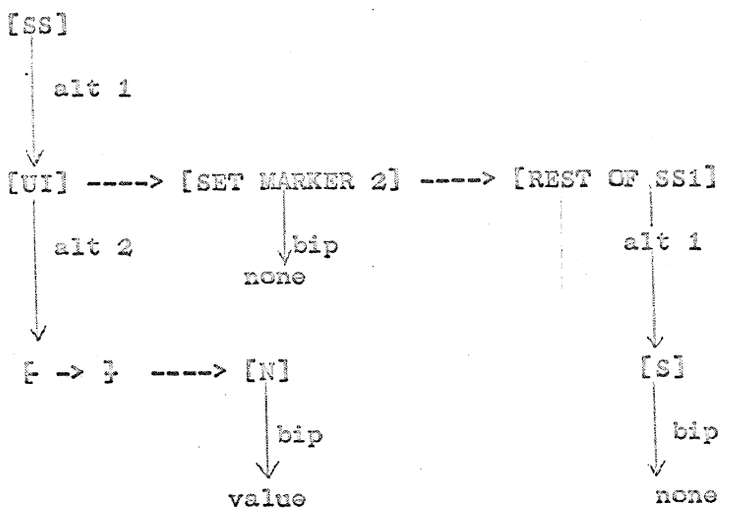
The compilation list or analysis record is written by <compare> as a source statement is matched. The majority of entries consist of alternative numbers of phrase parts matched with source statement parts. Each time compare cannot match an alternative, it goes on to try the next (unless the definition is exhausted, in which case it sets a 'failure' flag and returns.) For details of how the alternative numbers are planted, see the notes accompaning the flowcharts.

Entries in the analysis record other than alternative numbers are deposited for certain built in phrases, as follows;

The formation of an analysis record is illustrated for two examples below. The source statement is presented along with its tree structure, then the corresponding analysis record is given.

Source statement: ->5

Tree:

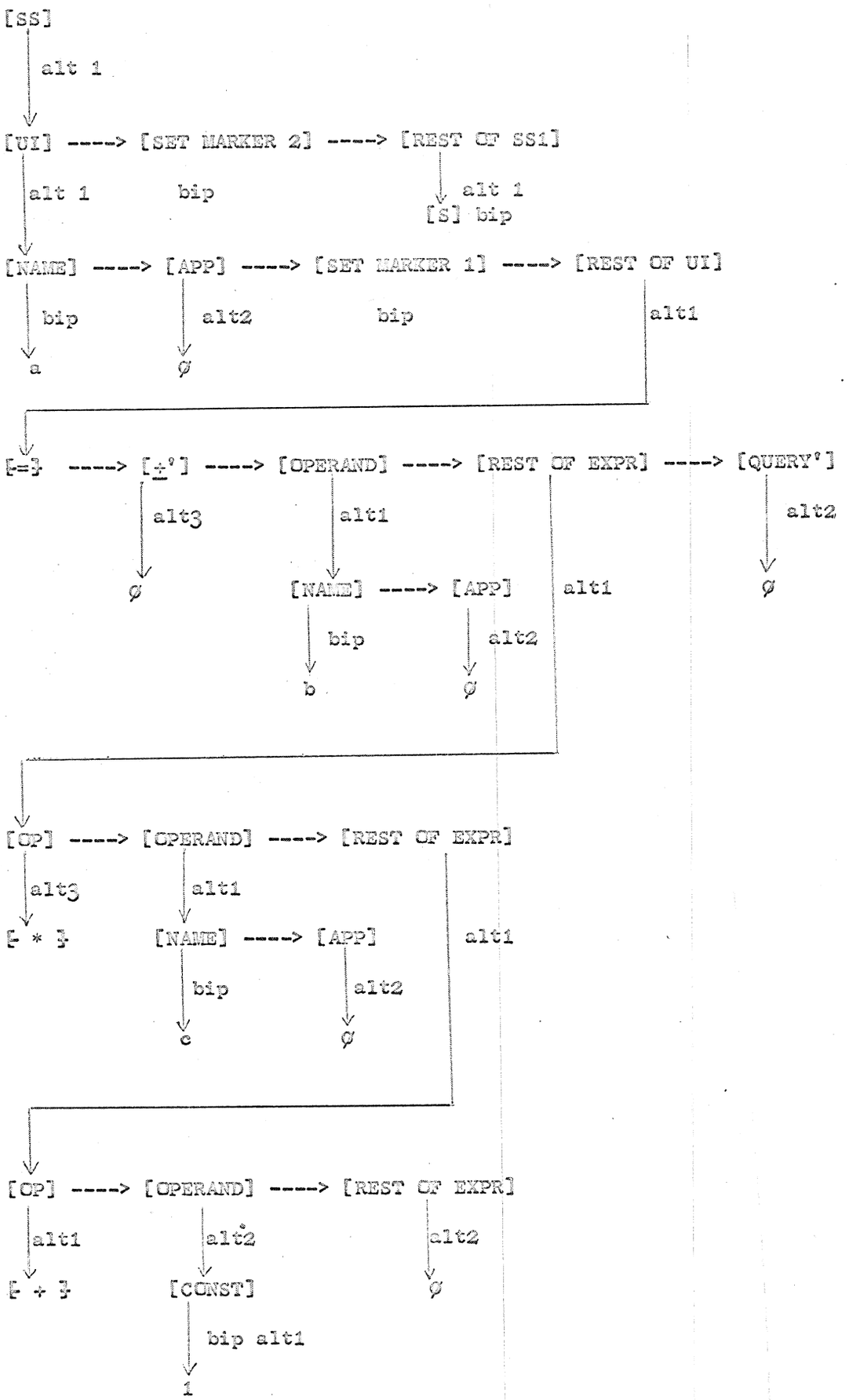


Analysis record A

1	2	5	1
Alt 1	alt 2	value	alt 1
Of	of	of	of
[SS]	[UI]	[N]	[REST OF SS1]

marker 2 points here.

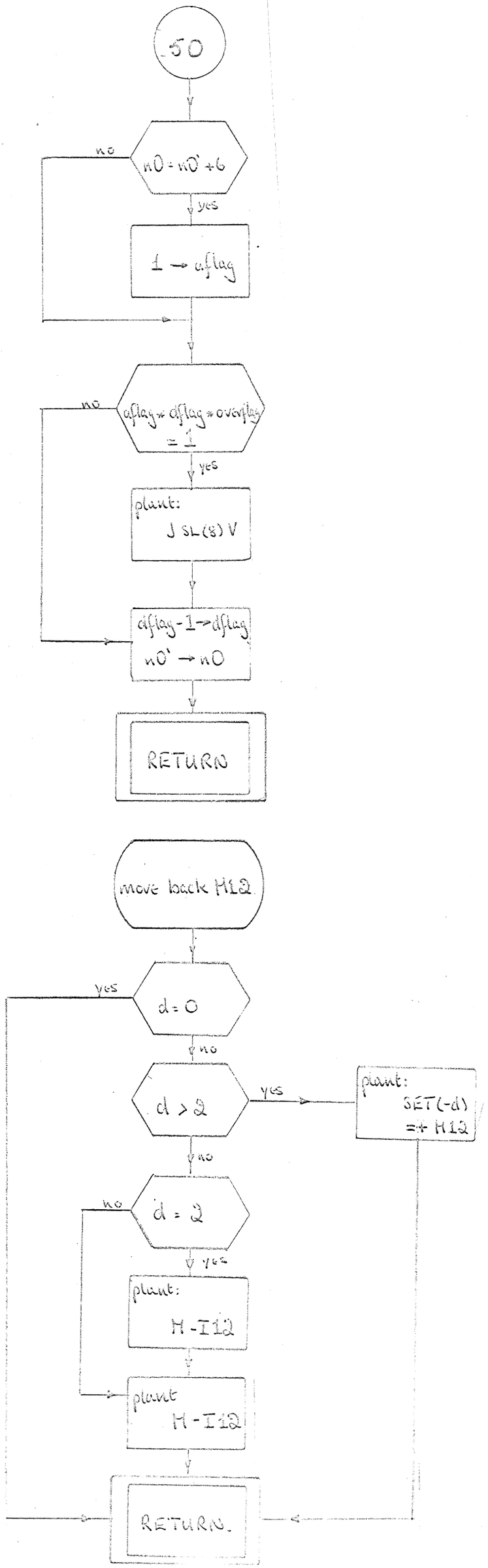
A more complicated example,
Source Statement a=b*c+1
Tree:



The resulting analysis record would be

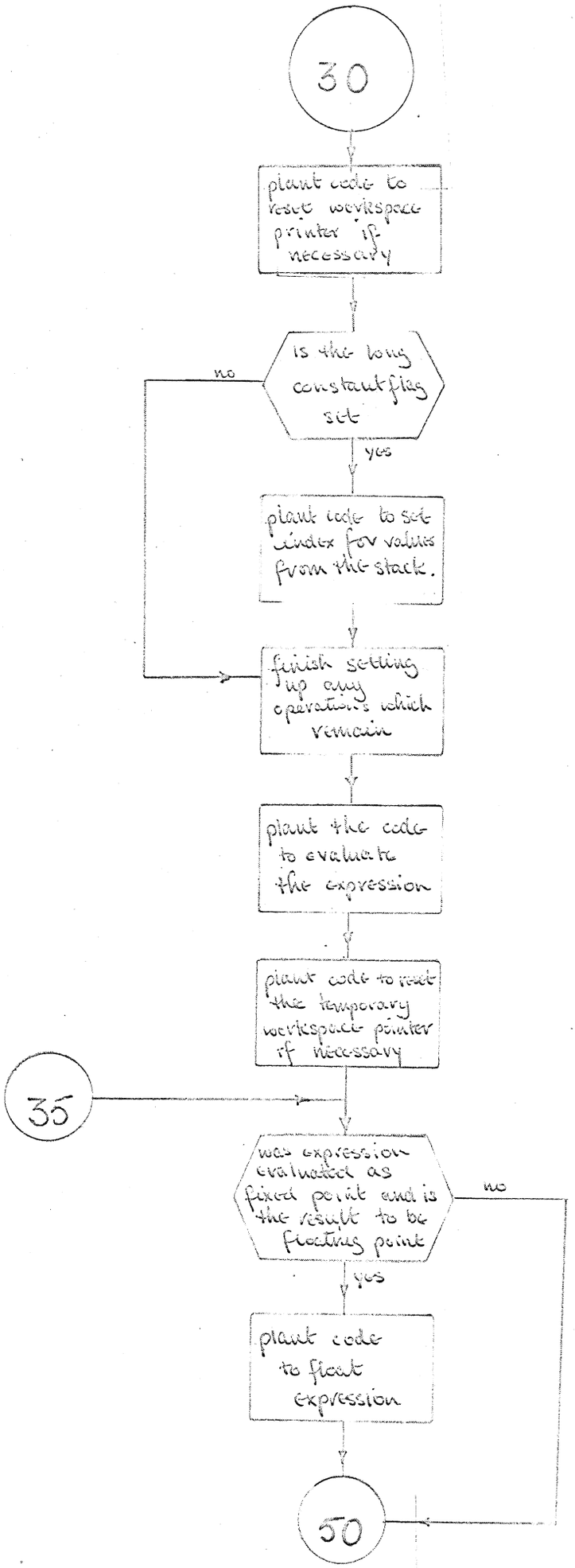
1,1, a,2,1,3,1,b,2,1,3,1,C,2,1,1,2,1,1,2,2,2
= † * + 1 †
marker1 marker 2

cSEXP


50
no
n0 = n0' + 6
yes
1 → aflag
no
aflag * dflag * overflag = 1
yes
plant:
J SL(8) V
dflag - 1 → dflag
n0' → n0
RETURN
move back H12
yes
d = 0
no
d > 2
yes
plant:
SET(-d)
=: H12
no
d = 2
no
yes
plant:
H - I12
plant
H - I12
RETURN.

*SEXP

English



* Special codes are:

NOT; NEG	to add one to N1
NEG; NOT	to subtract one from N1

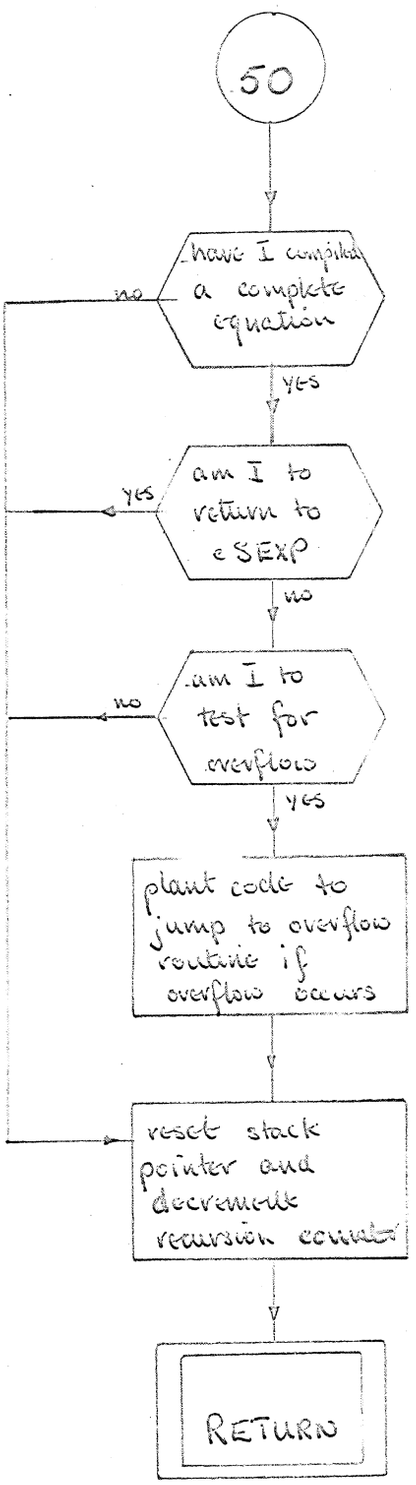
This is a bit of optimisation and the reason for it lies in the comparative execution times of the following code sequences

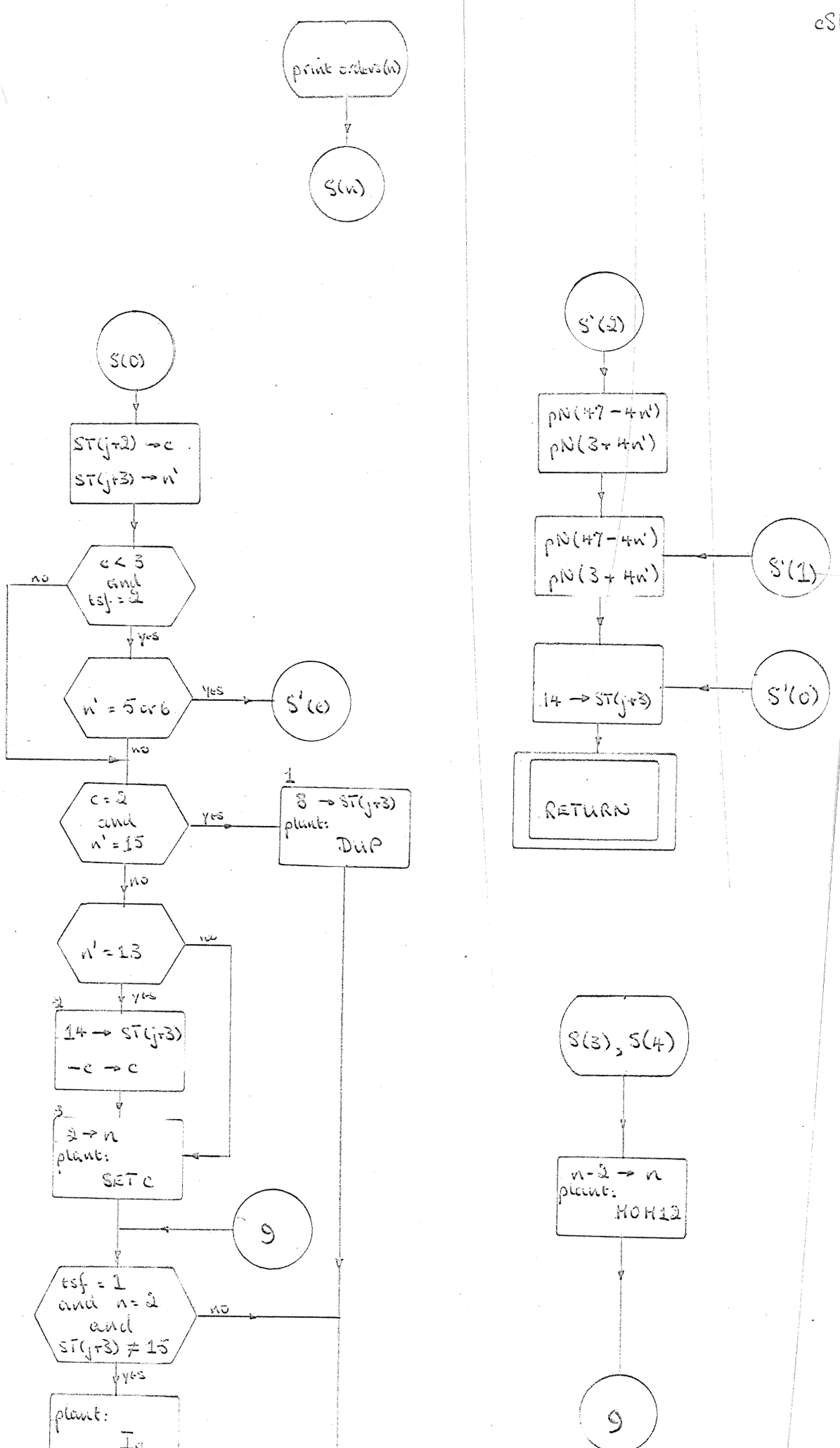
SET 1		NOT	
+	= 6 μsec	NEG	= 2 μsec

SET 2		NOT	
+	= 6 μsec	NEG	
		NOT	= 4 μsec
		NEG	

and the fact that the statement forms x = y + 1 and x = y $\pm$ 2 are quite common.

eSEXP
English




print c.rdevs(n)
S(n)
S(0)
ST(j+2) → c
ST(j+3) → n'
c < 3 and tsf = 2
no
yes
n' = 5 or 6
yes
S'(c)
no
c = 2 and n' = 15
yes
1
8 → ST(j+3)
plant: DUP
no
n' = 13
no
yes
2
14 → ST(j+3)
-c → c
3
2 → n
plant: SET c
9
tsf = 1 and n = 2 and ST(j+3) ≠ 15
no
yes
plant: I4 FLOAT
RETURN
S'(2)
pN(47-4n')
pN(3+4n')
pN(47-4n')
pN(3+4n')
S'(1)
14 → ST(j+3)
S'(0)
RETURN
S(3), S(4)
n-2 → n
plant: HOH12
9

cSEXP

English

n = ST(j)

print orders(n)

S(n)

S(0)
short constant

value < 3 and expression is integer

no

yes

the next stack entry says add or subtract

yes

S'(value of constant)

value is 2 and next entry says exponentiate

yes

set next entry to multiply plant code to duplicate N1

no

constant is negative

no

yes

put no operation into next entry, negate value

3

plant SET value

S(3), S(4)
array element values, already put in temp. workspace

plant code to fetch temporary workspace value

9

is the value in N1 integer, and the expression of which it is a part, real

no

yes

plant code to float it.

RETURN

S'(2)
add or subtract 2

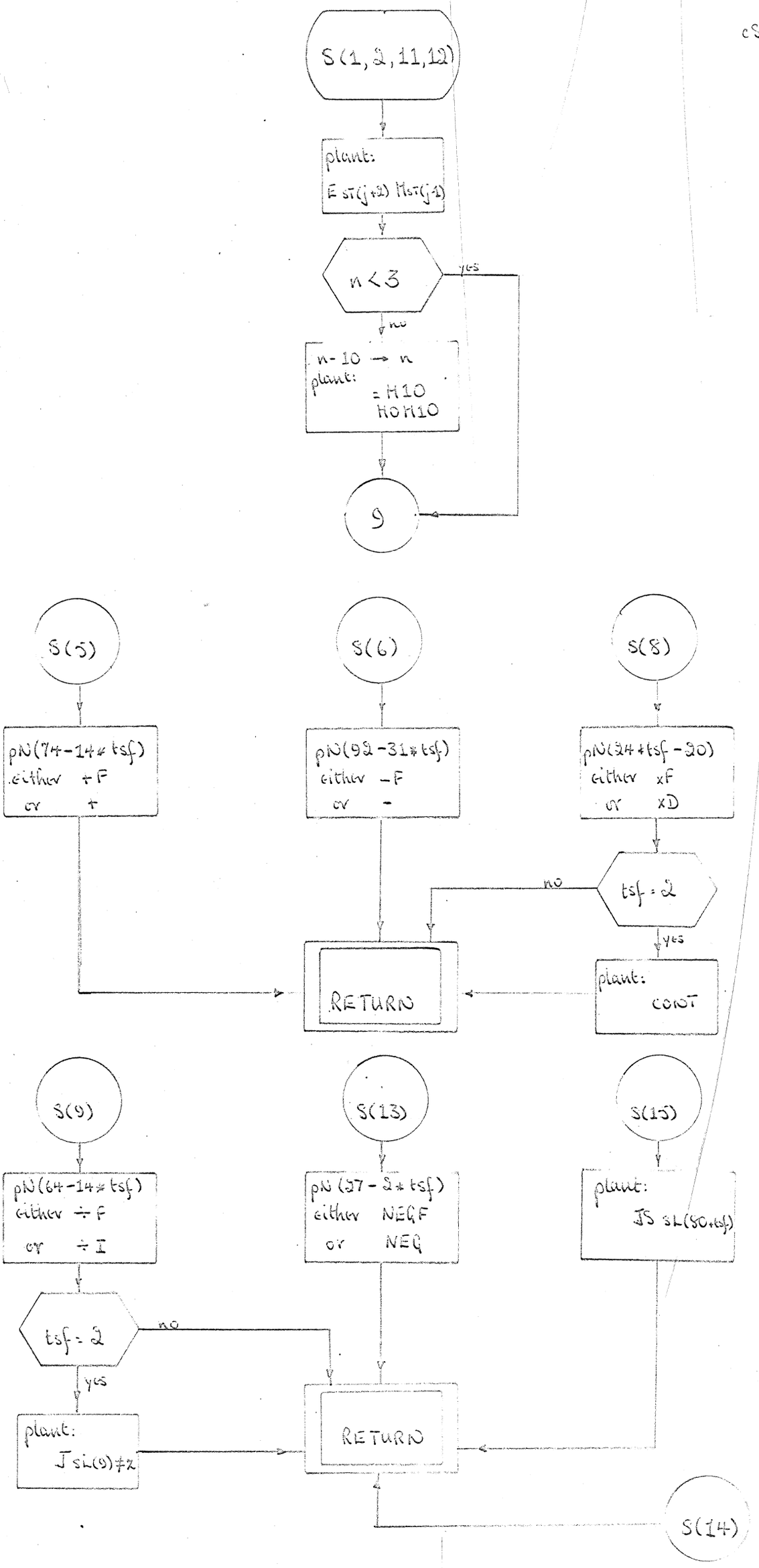
plant special code to add or subtract 1

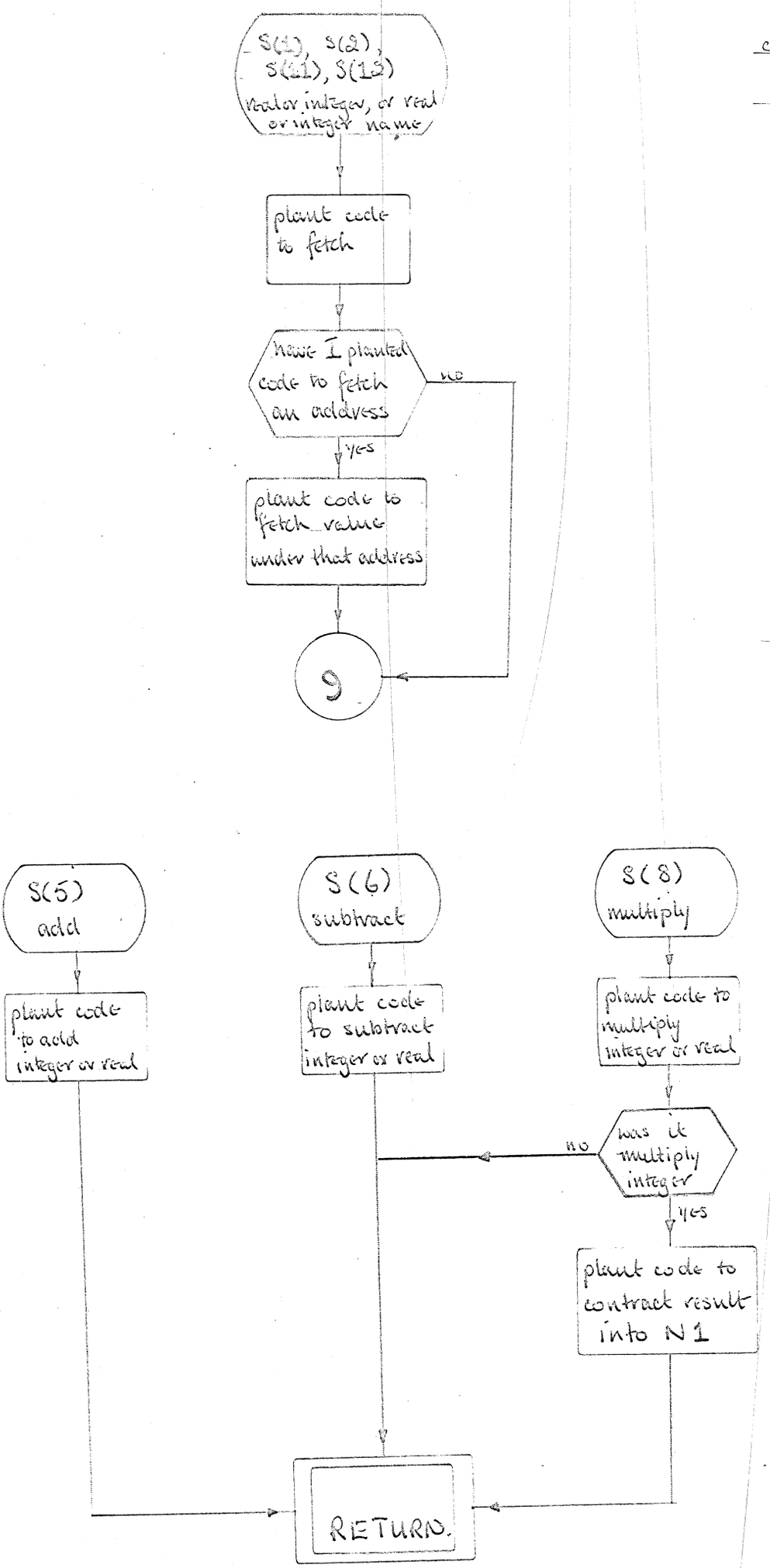
plant special code to add or subtract 1

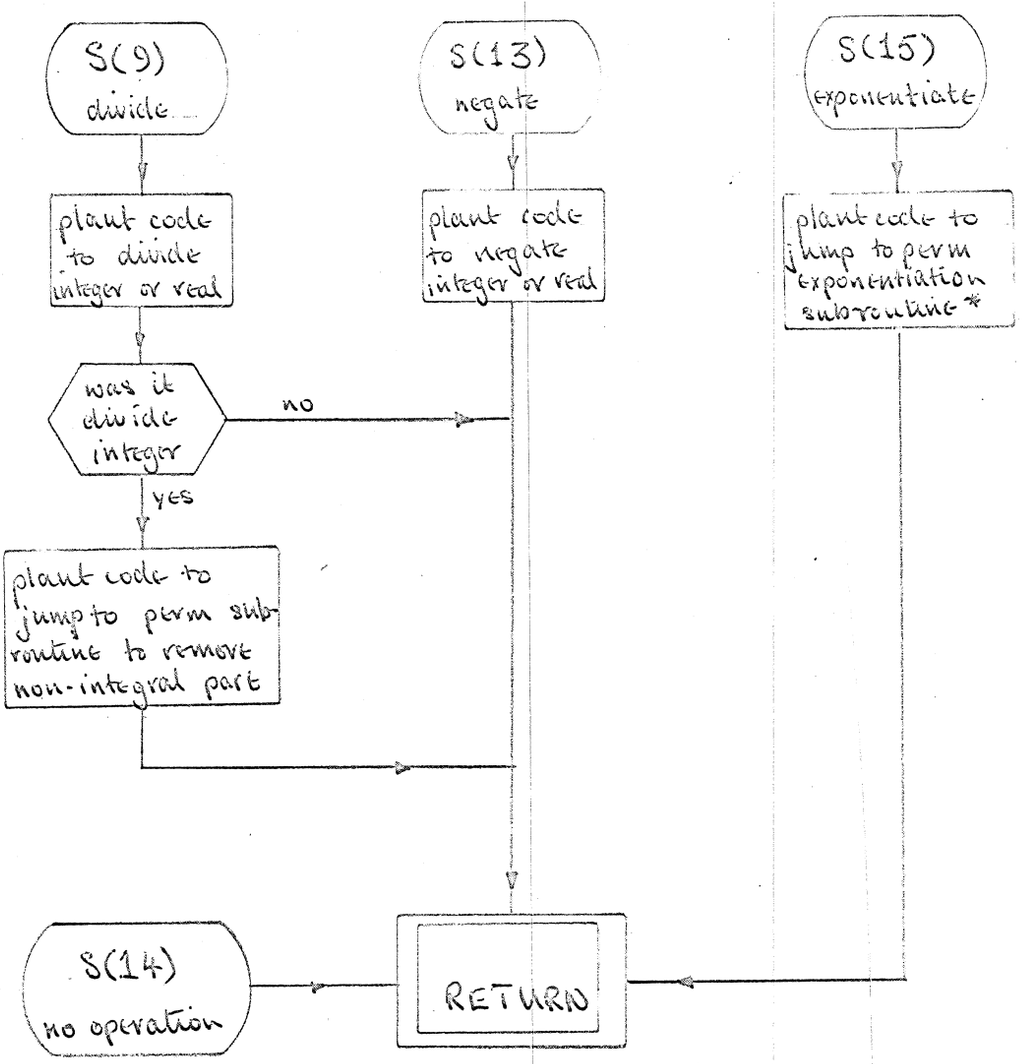
S'(1)
add or subtract 1

set next entry to no operation

S'(0)
value is 0


S(1,2,11,12)
plant:
E ST(j+2) HST(j-1)
n<3
yes
no
n-10 → n
plant:
=H10
HOH10
9
S(5)
pN(74-14*tsf)
either +F
or +
S(6)
pN(92-31*tsf)
either -F
or -
S(8)
pN(24+tsf-20)
either xF
or xD
tsf=2
no
yes
RETURN
plant:
CONJT
S(9)
pN(64-14*tsf)
either ÷F
or ÷I
tsf=2
no
yes
plant:
J SL(9)≠z
S(13)
pN(37-2*tsf)
either NEGF
or NEG
RETURN
S(15)
plant:
JS SL(50.tsf)
S(14)


S(1), S(2), S(11), S(12)
read or integer, or real or integer name
plant code to fetch
have I planted code to fetch an address
no
yes
plant code to fetch value under that address
9
S(5) add
plant code to add integer or real
S(6) subtract
plant code to subtract integer or real
S(8) multiply
plant code to multiply integer or real
was it multiply integer
no
yes
plant code to contract result into N1
RETURN



* Note, for a^b, N1 = b, N2 = a has been compiled at this point.

The following pages list the steps in the recognition and compilation of

if (p=q and q > r) then p=r

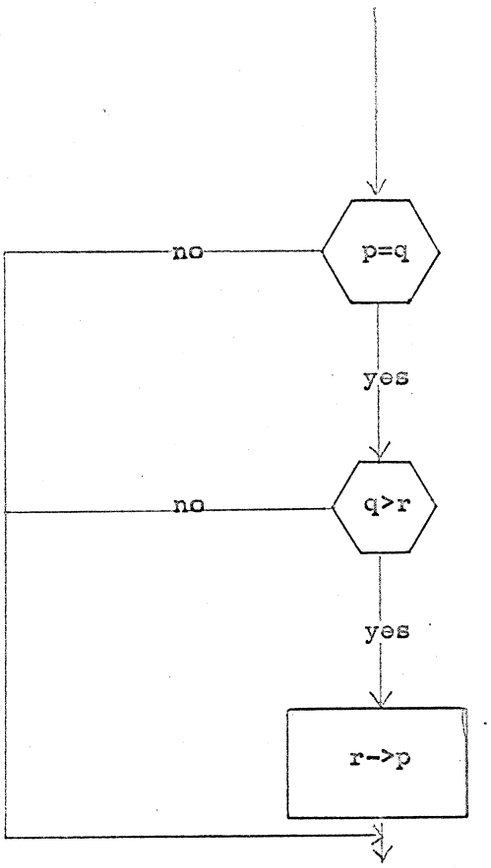
(P[SS]alt=[iu][SC][REST OF COND] then [UI][S].)

The left hand pages show the phrases recognised, in order downwards, with indenting to show the logical structure. On the right hand pages, the routines called in compiling the statement are listed in order downwards with the logical and recursive structure shown by indenting. The analysis record and its pointer <p> are listed in the middle.

The machine code finally planted is as follows

```
SET line no.
=I2                          ;|update line count
p
q
SIGN                         ;|N1=0 if P=Q,=1 if p>q,=-1 if p<q
DUP
J a ≠ Z                      ;| go to a if p≠ q
ERASE
q
r
SIGN                         ;|N1=0 if q=r, =1 if q>r, =-1 if q<r
NEG
NOT                          ;|N1=0 if q>r, ≠0 otherwise
a:  Jb≠Z                     ;|go to b if p≠q or q≤r
r
=p
b:  ...
```

Notice that this is extraordinarily efficient code.



The compilation of this example is completely listed below.

Broadly speaking, the four routines do the following.

<cCOND> simply calls <cCC>, and plants overflow checks if required.

<cCC> (''compile compound condition'') deals with

conditional and/or ...

using <cSC> to compile the simple conditional, planting a test,

and calling <cCC> to handle the right conditional part ... .

<cSC> (''compile simple condition'')

deals with X condition y, by compiling x and y

into the nest, and calling <cCOMP> to make the comparison

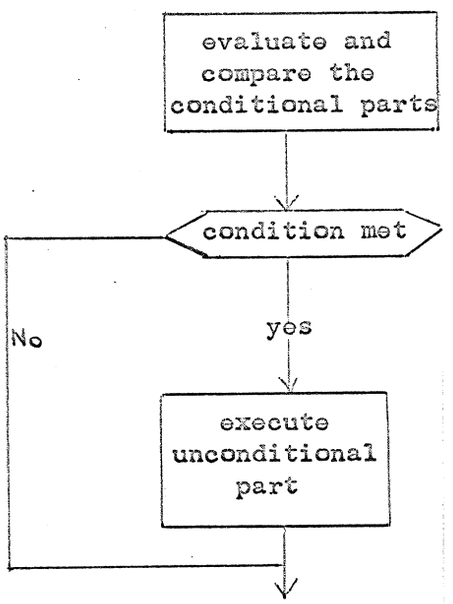
<cCOMP> plants code to compare N1 and N2 and set N1=0 if the condition is met.

All legal conditionals have one of two forms.

if or unless conditional part then execute unconditional part

execute unconditional part if or unless conditional part.

A conditional source statement is compiled by five routines controled by <cSS.> <cUI> compiles the unconditional part, and <cCOND,cCC,cSC,cCOMP> compile the conditional part. <cSS> first moves the analysis pointer to point at the conditional part of the statement, and calls <cCOND>. Upon return, <cSS> moves the pointer to the unconditional part and calls <cUI>. The resulting code will accomplish



This flow diagram is deceptive, though, because the code is heavily ""optimised"" to test whether the conditional parts are met every time failing such a test would mean skipping the unconditional part. For example,

if (p=q and q>r) then p=r

compiles as

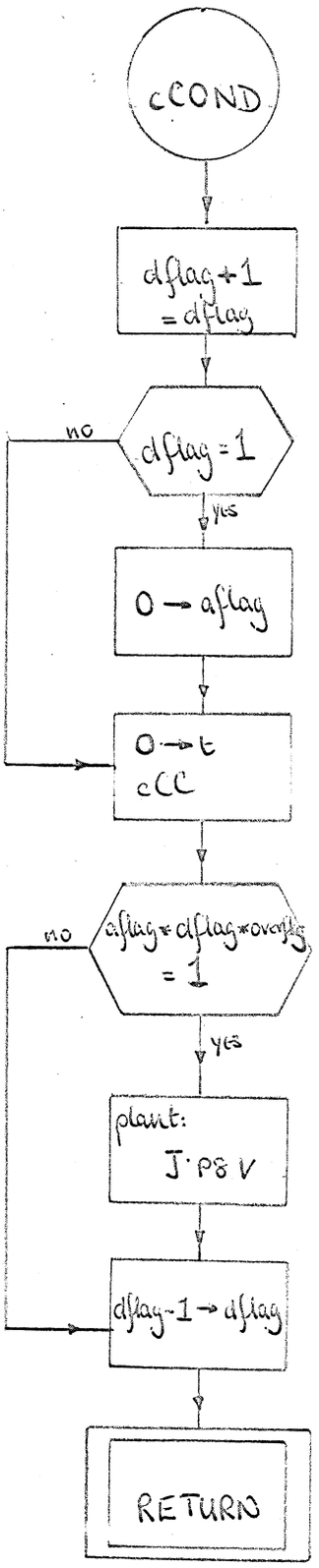
PHRASE PART	ALTERNATIVE
[ss]	5
[iu]	if
[SC]	PARENTHETIC
[(]	
[SC]	NON-PARENTHETIC
[±']	ø
[OPERAND]	NAME
[NAME]	P
[APP]	ø
[REST OF EXPR]	ø
[COMP]	=
[±']	ø
[OPERAND]	NAME
[NAME]	q
[APP]	ø
[REST OF EXPR]	ø
[REST OF SC]	ø
[REST OF COND]	and
[and]	
[SC]	NON-PARENTHETIC
[±']	ø
[OPERAND]	NAME
[NAME]	q
[APP]	ø
[REST OF EXPR]	ø

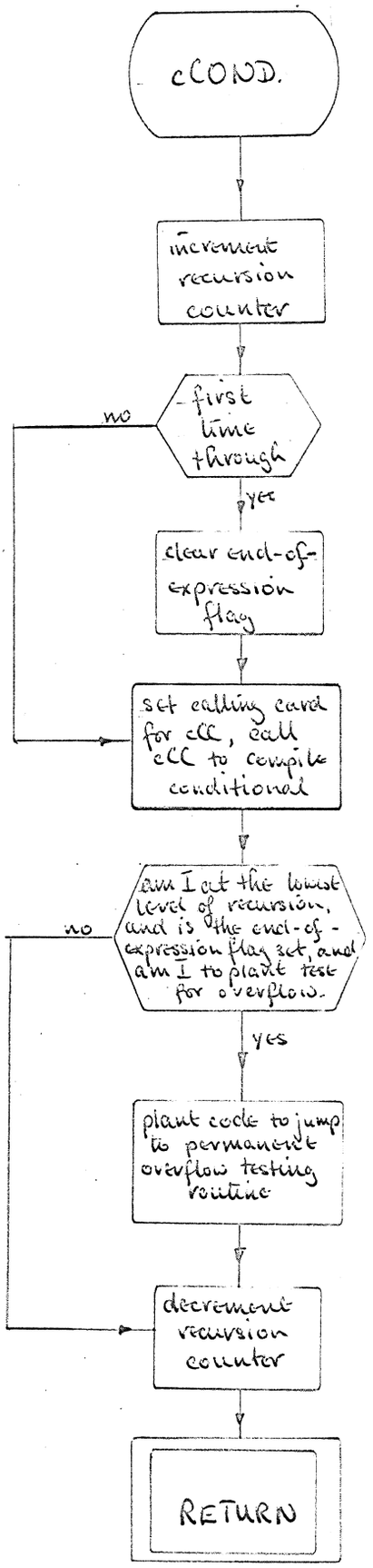
PHRASE PART	ALTERNATIVE
[ss]	5
[iu]	if
[sc]	PARENTHETIC
[(]	
[sc]	NON-PARENTHETIC
[±']	ø
[OPERAND]	NAME
[NAME]	P
[APP]	ø
[REST OF EXPR]	ø
[COMP]	=
[±']	ø
[OPERAND]	NAME
[NAME]	q
[APP]	ø
[REST OF EXPR]	ø
[REST OF SC]	ø
[REST OF COND]	and
[and]	
[sc]	NON-PARENTHETIC
[±']	ø
[OPERAND]	NAME
[NAME]	q
[APP]	ø
[REST OF EXPR]	ø

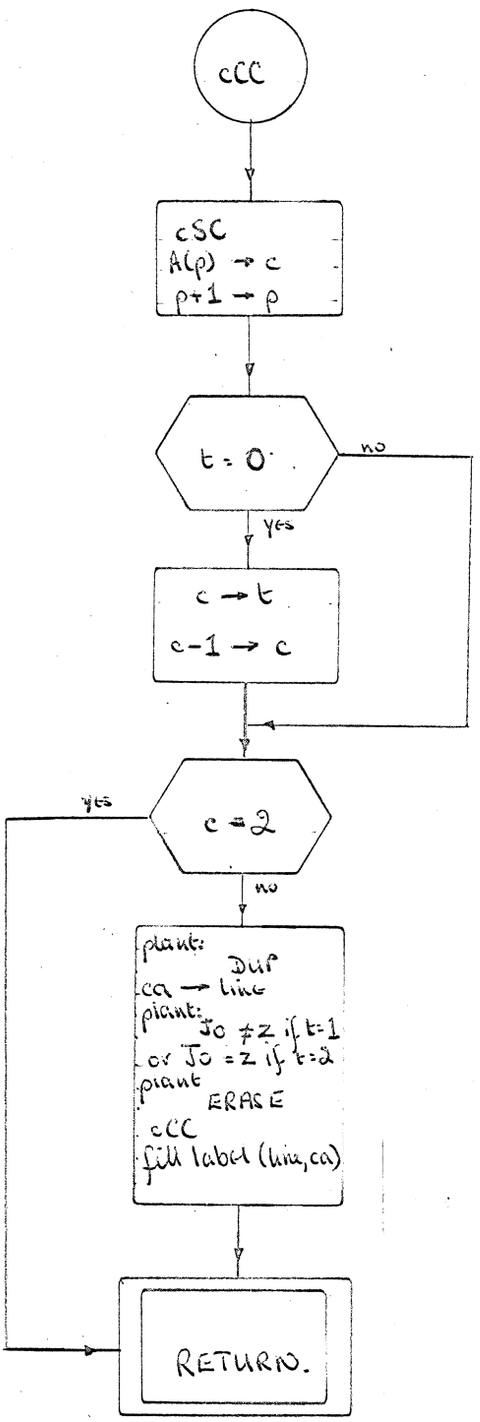
A(p)	P	ROUTINE EXAMING A(.)	CODE COMPILED
5	1	cSS	SET LINE
1	2		=I2
2	3	cCOND	
		cCC	
		cSC	
1	4	cCOND	
		cCC	
		cSC	
3	5	cSEXP(3)	fetch p
1	6		
P	7		
2	8		
2	9		
1	10	cCOMP(1)	
3	11	cSEXP(3)	fetch q
1	12		
q	13		
2	14		
2	15		
2	16	(cCOMP)	SIGN
1	17	(cSC)	
		(cCC)	DUP
1	18		ja≠Z
			ERASE
		cCC	
		cSC	
3	19	cSEXP(3)	fetch q
1	20		
q	21		
2	22		
2	23		

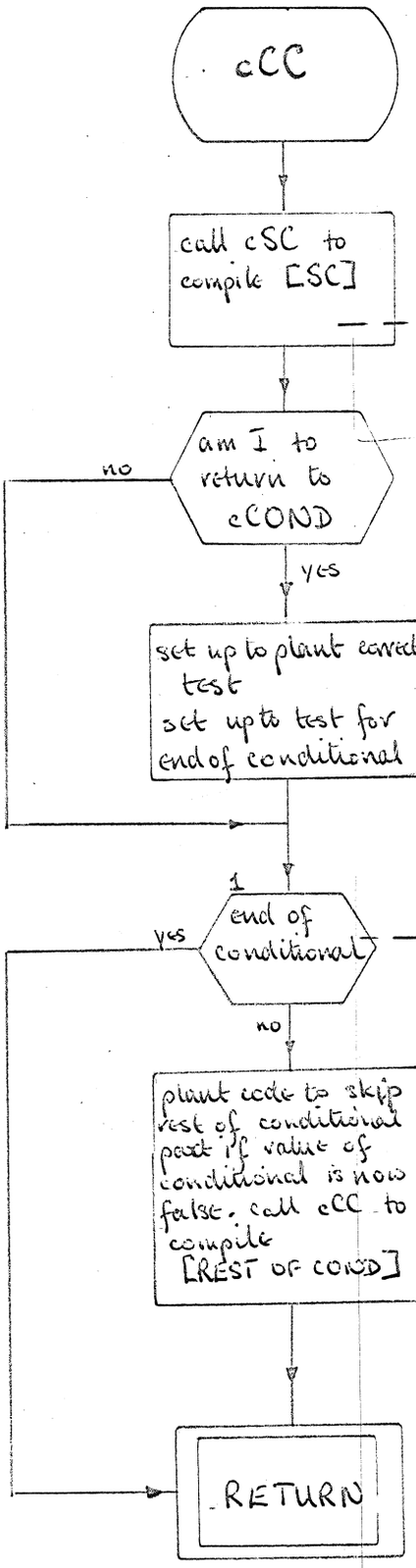
PHRASE PART		ALTERNATIVE
	[COMP]	>
	[±']	ø
	[OPERAND]	NAME
	[NAME]	r
	[APP]	ø
	[REST OF EXPR]	ø
	[REST OF SC]	ø
	[REST OF AND-C]	ø
[)]		
[REST OF COND]		ø
[Then]		
[UI]		1
[NAME]		P
[APP]		ø
[SET MARKER 1]		
[REST OF UI]	→	not ø
[=]		
[±']		ø
[OPERAND]		NAME
[NAME]		+
[APP]		ø
[REST OF EXPR]		ø
[QUERY']		ø
[S]		

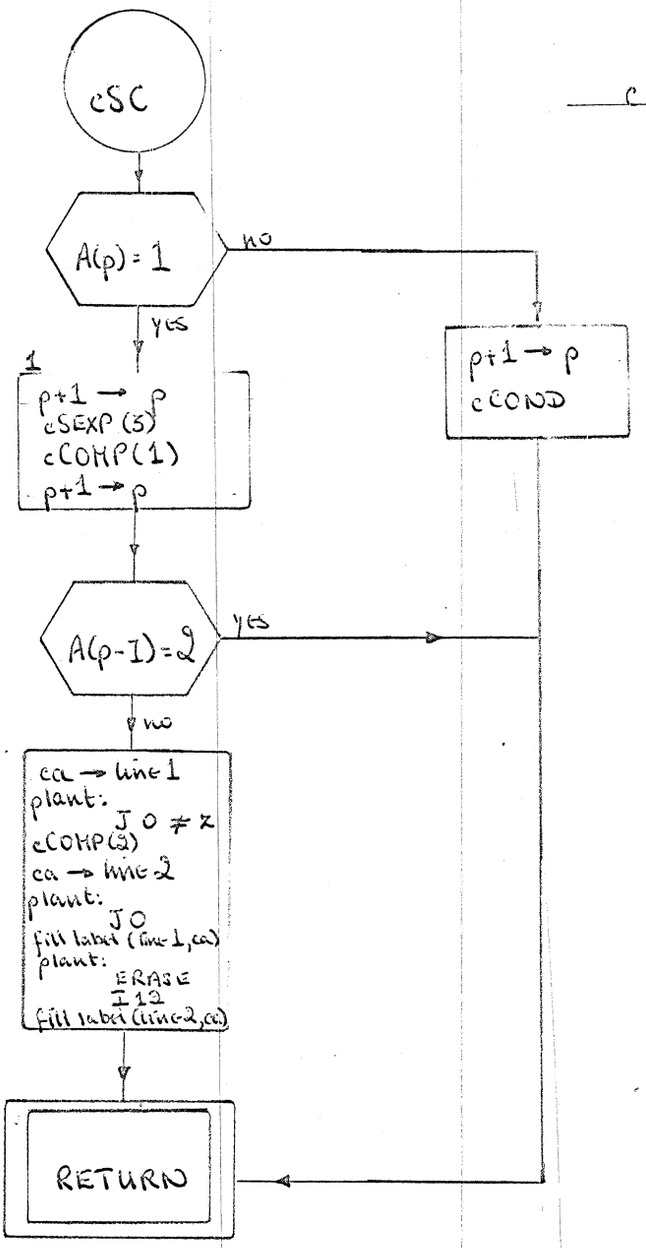
A(p)	P	ROUTINE EXAMINING A(.)	CODE COMPILED
3	24	cCOMP(1)	
3	25	cSEXP(3)	fetch r
1	26		
r	27		
2	28		
2	29	(cCOMP)	SIGN NEG NOT
2	30	(cSC)	
		(cCC)	
2	31	(cCC)	a:
		(cCOND)	
		(cCC)	
3	32	(cCOND)	
1	33	(cSS)	Jb ≠ Z
	34	cUI	
	35	{ cSEXP / cNAME }	fetch r =p
1	36		
3	37		
1	38		
r	39		
2	40		
2	41		
2	42		
		(cSS)	
			(b:)


cCOND
dflag+1
=dflag
dflag=1
no
yes
0→aflag
0→t
cCC
aflag*dflag*overflg
=1
no
yes
plant:
J·P8V
dflag-1→dflag
RETURN

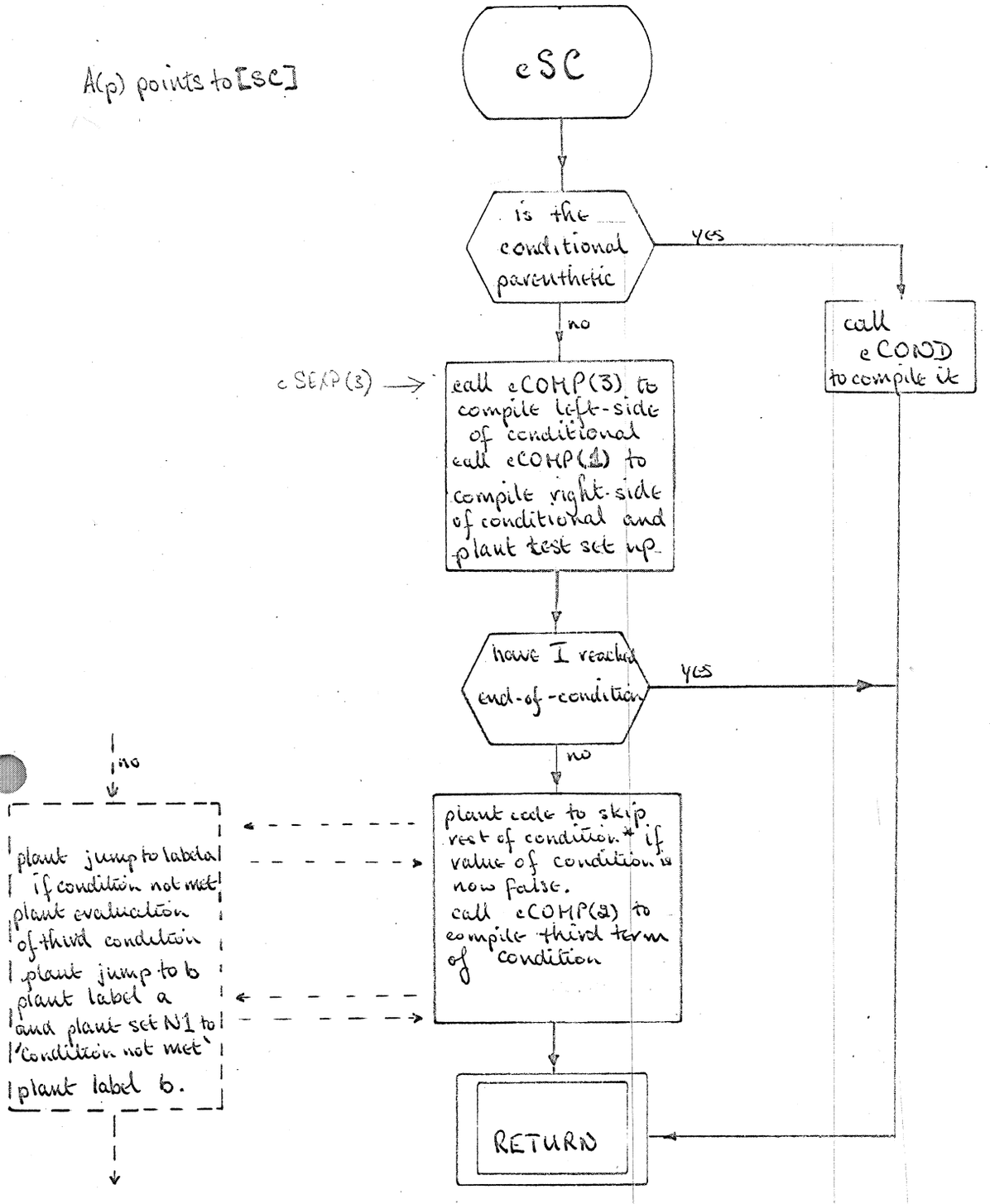

cCOND.
increment recursion counter
first time through
no
yes
clear end-of-expression flag
set calling card for cCC, call cCC to compile conditional
am I at the lowest level of recursion, and is the end-of-expression flag set, and am I to plant test for overflow.
no
yes
plant code to jump to permanent overflow testing routine
decrement recursion counter
RETURN


cCC
cSC
A(p) → c
p+1 → p
t = 0
no
yes
c → t
c-1 → c
c = 2
yes
no
plant: Dup
ca → line
plant: Jo ≠ z if t=1
or Jo = z if t=2
plant ERASE
cCC
fill label (lin, ca)
RETURN.


cCC
call cSC to compile [SC]
Note: A(p) points to [REST OF CO
am I to return to cCOND
no
yes
set up to plant correct test
set up to test for end of conditional
1
end of conditional
yes
i.e., A(p) = ∅
no
plant code to skip rest of conditional pack if value of conditional is now false. call cCC to compile [REST OF COND]
RETURN

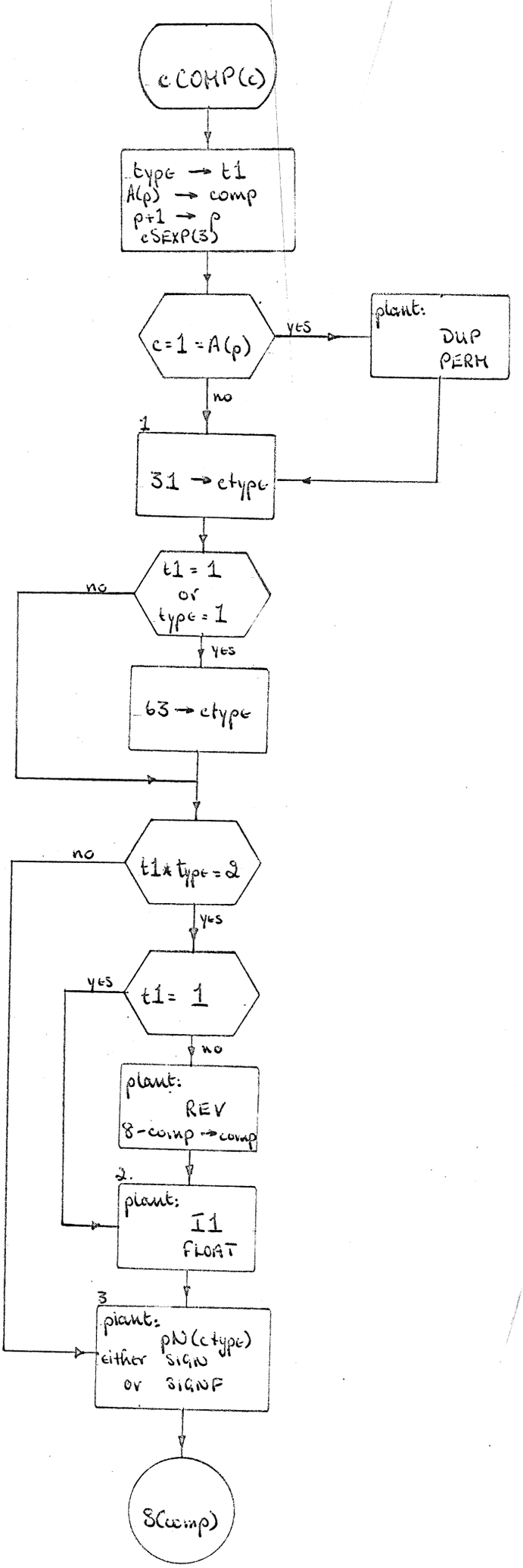

cSC
A(p) = 1
no
yes
p+1 → p
cCOND
1
p+1 → p
cSEXP (5)
cCOMP (1)
p+1 → p
A(p-1) = 2
yes
no
cα → line 1
plant:
J 0 ≠ z
cCOMP (3)
cα → line 2
plant:
J 0
fill label (line 1, cα)
plant:
ERASE
I 12
fill label (line 2, cα)
RETURN

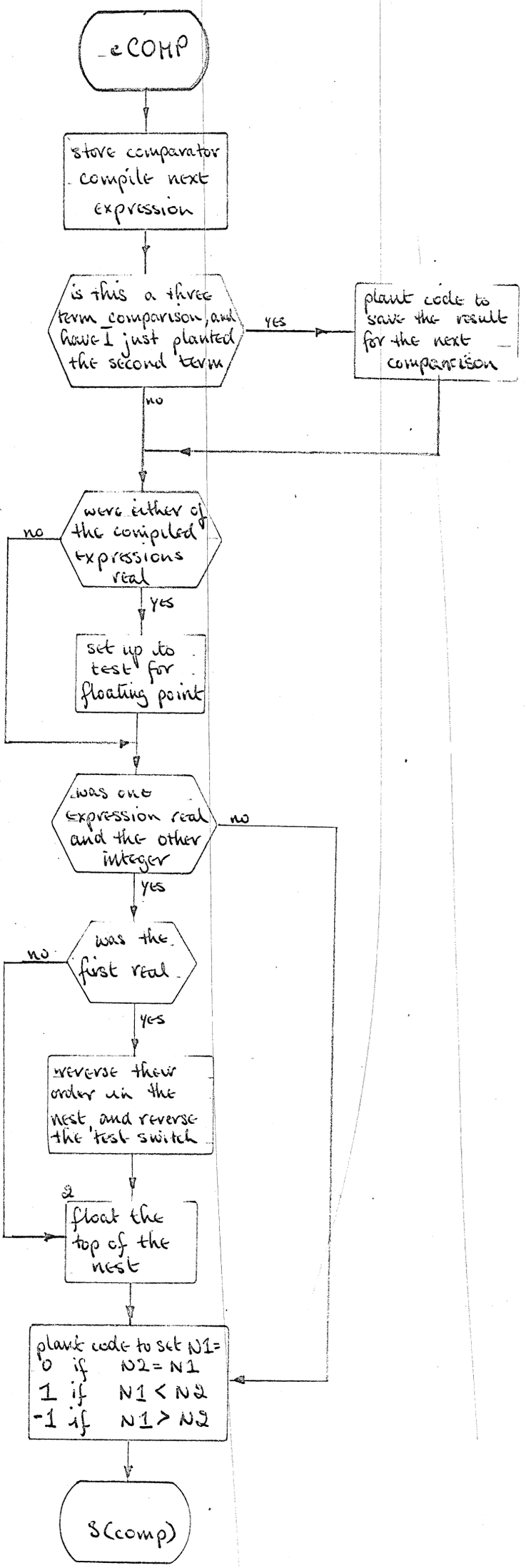
A(p) points to [SC]

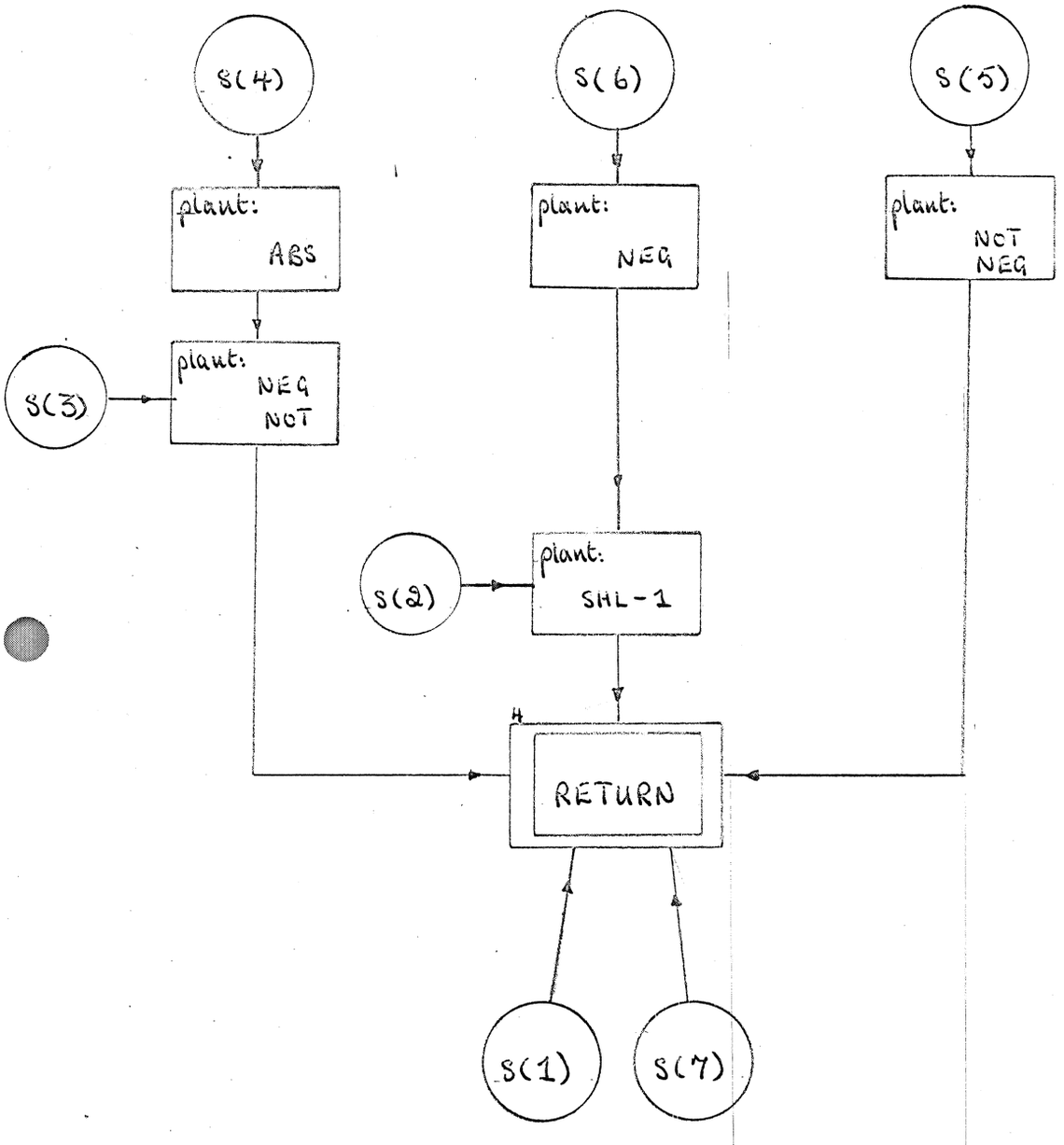


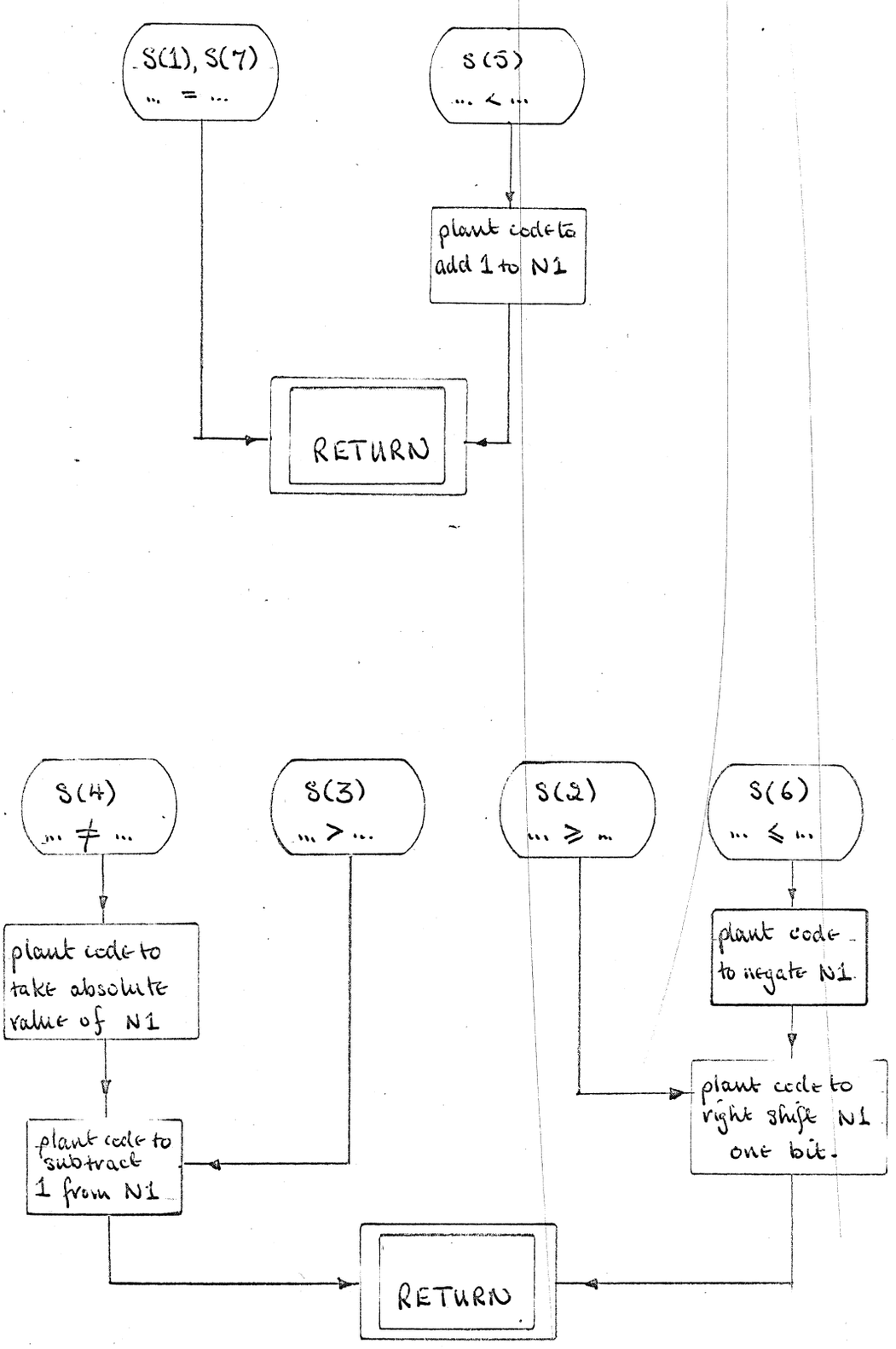
* This is to handle three termed conditionals (e.g. $x > y > z$)

c = 1 on first call
= 2 on second call.




_cCOMP
store comparator
compile next
expression
is this a three
term comparison, and
have I just planted
the second term
yes
plant code to
save the result
for the next
comparison
no
were either of
the compiled
expressions
real
no
yes
set up to
test for
floating point
was one
expression real
and the other
integer
no
yes
was the
first real
no
yes
reverse their
order in the
nest and reverse
the test switch
2
float the
top of the
nest
plant code to set N1=
0 if N2 = N1
1 if N1 < N2
-1 if N1 > N2
S(comp)


S(4)
S(6)
S(5)
plant:
ABS
plant:
NEG
plant:
NOT
NEG
S(3)
plant:
NEG
NOT
S(2)
plant:
SHL-1
4
RETURN
S(1)
S(7)



These codes set N1=0 if condition met, ≠0 if condition not met.