MEMORANDUM
RM-3731-CC
JUNE 1963

THE LOGIC THEORY MACHINE: A MODEL HEURISTIC PROGRAM

Einar Stefferud

PREPARED FOR:
CARNEGIE CORPORATION

The RAND Corporation
SANTA MONICA • CALIFORNIA

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PREFACE

This Memorandum has been prepared to fill the need for a model program for use in teaching Information Processing Language-V (IPL-V). Experience in teaching IPL programming has shown that class discussion of a good program, developed as a pedagogical tool, is an essential ingredient for comprehending IPL applications and potentialities.

The IPL computer programming language was originally developed at The RAND Corporation, under U. S. Air Force Project RAND, and at Carnegie Institute of Technology, for expressing complex computer programs. IPL is being used to great advantage in dealing with problems requiring flexible memory structures and hierarchies of subroutines and data. IPL is also being applied in the field of artificial intelligence in studies of complex information processing, and by psychologists who are using computer simulation of human cognitive processes.

A number of colleges and universities now offer courses in IPL-V coding, and more such courses appear imminent. IPL coding was taught at the 1962 Summer Heuristic Programming Institute, held at The RAND Corporation and sponsored by the Carnegie Corporation. At that time, several interesting IPL programs were available, but none could serve as a pedagogical model. The Logic Theory Machine (LT) was determined to be the best candidate for such a model, and a new version, documented in this Memorandum, was developed. Bert F. Green and Fred M. Tonge consulted on the development of the program and preparation of the Memorandum.

Use of LT presumes familiarity with the _Information Processing Language-V Manual_[(1)] and particularly with Part Two, "Programmers' Reference Manual." In most cases, LT will be used in conjunction with a study of Part One of the Manual, "The Elements of IPL Programming."[†]

This Memorandum was made possible by funds granted by Carnegie Corporation of New York. The statements made and views expressed are solely the responsibility of the author.

[†] LT may be used by advanced students who have completed Part One of the Manual, or may be used simultaneously with Part One to illustrate the implementation in a complete program of the concepts being developed.

SUMMARY

This Memorandum contains a highly detailed program listing for the Logic Theory Machine (LT), a computer program written in Information Processing Language-V (IPL-V), and developed especially for use as a pedagogical model. The text portions of the Memorandum expand upon the documentation in the listing, tracing program flow, analyzing routines utilized, and providing insight into the structure and the development of the program.

LT was originally programmed in an early version of IPL by Newell, Shaw, and Simon[(2-4)] to derive proofs of logic expressions in the sentential calculus of Whitehead and Russell.[(5)] In rewriting the program for use as a teaching aid, a new method of replacement on subexpressions has been included, and many minor changes effecting improvements in clarity have been incorporated. Features of the code that were unjustifiably hard to explain have been simplified.

The Memorandum defines LT's activity in terms of problem solving, and then a representation of the defined problem is given in terms of IPL-V. Finally, what LT does is discussed in terms of process hierarchies which operate on the list structure representations of logic expressions.

LT can be implemented on any computer for which an IPL-V processor is available.[†]

[†] These include the IBM 650, 704, 709, 7090, 7094, Philco 2000, Bendix G-20, CDC 1604, UNIVAC 1105, and the AN/FSQ-32. A system for the Burroughs 220 is under development. LT, or any IPL-V program written in accordance with the IPL-V Manual, can be executed on any of these machines. In order to facilitate student modification of LT, information on obtaining the program deck can be obtained by writing The RAND Corporation.

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I. INTRODUCTION

Experience in teaching IPL (Information Processing Language)† programming has shown that class discussion of a good model program is an essential ingredient for comprehension of applications and potentialities of the IPL concepts. This documentation of the "Logic Theory Machine,"(2) otherwise known as LT, is specifically aimed at filling the need for such a program.

LT was the best candidate for development as a pedagogical model because 1) it is based in the readily understood context of theorem proving in sentential calculus; 2) literature on theorem proving is readily available;(3,4) and 3) the original LT, written in an early version of IPL by Newell, Shaw, and Simon, established the field of heuristic programming. Because it is a valuable example for students to examine and modify, LT has survived beyond its usefulness as a research tool.

The original version of LT was converted to IPL-V from IPL-II by Fred Tonge, and later converted into the present pedagogical model.‡ The questions originally raised by LT are still valid and interesting, and although conversion has introduced some changes in LT's procedures, its structure remains essentially unchanged and its operating performance is nearly identical to that of the original.

LT does not represent an effort to obtain high machine efficiency. It is rather an effort to take ad-

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†A discussion of the development of the IPL's can be found in the introduction to the IPL-V Manual. (1)

‡The latter conversion was made by the author.

vantage of the powers of symbolization via heuristic symbol manipulation techniques. It is not very successful in comparison with people or even with some computer programs.[6,7] (For an excellent treatment of this topic, see Minsky's discussion of problem solving.)[8]

Since this Manual is designed for class use by students of list processing languages, the discussions and descriptions of LT assume familiarity with IPL-V. Several viewpoints are adopted for discussion purposes: first, what LT does is defined in terms of problem solving; then, representation of the defined problem is described in terms of IPL-V; and finally, what LT does is discussed in terms of process hierarchies which operate on the list structure representations of logic expressions.

The text describing LT is not intended to completely describe the program. Sections XIII through XV contain listings of the entire program along with supporting vocabulary listings. The text and flow diagrams are only intended to introduce the student to the program listing, which provides sufficient annotation to allow him to dissect LT's processes and learn how IPL-V can be used for complex information processing.

To facilitate detailed inspection, the entire program has been carefully and extensively documented in the comment fields. Outlines and flow diagrams have been supplied for some key routines, but others have been left for the student to construct, since learning to write down routine specifications is one of the most important facets of learning to use IPL-V.

II. WHAT LT DOES

THE THEOREM-PROVING PROBLEM

LT derives proofs of logic expressions in the sentential calculus of Whitehead and Russell.(5) To do this, it uses the following entities:

1) Expressions, compounded from:
   a) free variables:†
      A,B,C,D,E,F,G
   b) bound variables:
      P,Q,R,S,T
   c) connectives:

-	intuitive meaning:	NOT
V	intuitive meaning:	OR
I	intuitive meaning:	IMPLIES
*	intuitive meaning:	AND
=	intuitive meaning:	EQUIVALENT TO
.=.	intuitive meaning:	EQUIVALENT TO BY DEFINITION

2) Axioms (expressions given as true):

```
*1.2  [AVA]IA
*1.3  AI[BVA]
*1.4  [AVB]I[BVA]
*1.5  [AV[BVC]]I[BV[AVC]]
*1.6  [AIB]I[[CVA]I[CVB]]
```

3) Definitions (expressions defining connectives):

```
*1.01  [AIB].=.[-AVB]DEF.
*3.01  [A*B].=.-[-AV-B]DEF.
*4.01  [A=B].=.[[AIB]*[BIA]]DEF.
```

---

†The distinction between bound and free variables is needed to distinguish variables of true expressions from variables of unproved expressions.

4) Problems (expressions proposed as provable theorems):

```
*2.08  PIP
*2.14  --PIP
*2.45  -(PVQ)I-P
*3.22  (P*Q)I(Q*P)
*3.24  -(P*-P)
*4.20  P=P
etc.
```

5) Methods based on rules of inference:†

```
Substitution (for free variables)
Replacement (through definitions)
Detachment (A and AIB⇒B)
Chaining (AIB and BIC⇒AIC)
```

PROOF EXAMPLES

```
TO PROVE:  *2.08  PIP
           *1.3   AI[BVA]                 Given
                  PI[PVP]                 Substitution
           *1.2   [AVA]IA                 Given
                  [PVP]IP                 Substitution
           *2.08  PIP                     Chaining
                  Q.E.D.
```

Chaining uses the two expressions PI[PVP] and [PVP]IP to yield PIP.

```
TO PROVE:  *2.14  --PIP
           *2.13  AV---A                  Given
                  PV---P                  Substitution
           *1.4   [AVB]I[BVA]             Given
                  [PV---P]I[---PVP]       Substitution
                  ---PVP                  Detachment
           *1.01  [AIB].=.[-AVB]          Given
                  [--PIP].=.[---PVP]      Substitution
           *2.14  --PIP                   Replacement
                  Q.E.D.
```

This proof requires that *2.13 be previously proved or given as true.

† Chaining is not given as a rule in Whitehead and Russell, but is provable from the axioms. Other such methods might be developed, but chaining is the only one included in LT.

III. REPRESENTATION OF "THE PROBLEM" IN THE IPL-V MACHINE

Expressions, variables, and connectives are represented by IPL-V data list structures. An expression is recursively defined as a single variable or a list of subexpressions with a connective in its head. For example, Axiom *1.5 [AV[BVC]]I[BV[AVC]], looks like this:

Total Expression	*15	9-0		Description list
		9-1	0	Main expression
Description list	9-0	0		
		Q15		Attr. "tree form"
		Q15		
		Q7		Attr. "external name"
		9-2	0	Value is data term containing text
	9-2	21*1.5		
Main Expression	9-1	I0		Main connective
		9-3		Left subexpression
		9-4	0	Right subexpression
Left Expression	9-3	V0		Connective OR
		A0		Variable A
		9-5	0	
Right Expression	9-4	V0		
		B0		Variable B
		9-6	0	
Right of left	9-5	V0		
		B0		
		C0	0	
Right of Right	9-6	V0		
		A0		
		C0	0	Variable C

Variables and connectives look like this:

```
Connective              I0       9-0    0
  IMPLIES               9-0    0
Attr. "type"                     Q14
Value "non-unary"                J4
                                 Q7
                                 9-1    0
                        9-1    21I

Connective OR           V0       9-0    0
                        9-0    0
                                 Q14
                                 J4
                                 Q7
                                 9-1    0
                        9-1    21V

Free Variable "A"       A0       9-0    0
                        9-0    0
Attr. "Variable"                 Q5
                                 Q5
Attr. "Free Var."                Q6
                                 Q6
                                 Q7
                                 9-1    0
                        9-1    21A

Free Variable "B"       B0       9-0    0
                        9-0    0
                                 Q5
                                 Q5
                                 Q6
                                 Q6
                                 Q7
                                 9-1    0
                        9-1    21B

Free Variable "C"       C0       9-0    0
                        9-0      Q5
                                 Q5
                                 Q6
                                 Q6
                                 Q7
                                 9-1    0
                        9-1    21C
```

The rules of inference are embodied in routines called methods:

M11	Detachment
M12	Substitution
M13	Replacement
M14	Forward Chaining
M15	Backward Chaining
M16	Subexpression Replacement I
M17	Subexpression Replacement II

Methods are applied to problems (unproved expressions) by the executive routines:

M1	Single-Problem Executive
M2	Multiple-Problem Executive
M7	Apply Methods (1) to Problem (0)
M8	Create a List of Methods for (0)

Application of methods to a problem results in symbol manipulation on the data list structures representing the problem and will, hopefully, result in finding a proof.

IV. HOW LT WORKS

In LT, the single problem executive uses the methods to find proofs for given problems. The methods are based on rules of inference set forth in Principia Mathematica.[5]

The substitution method tries to directly prove a given problem expression by matching it to an axiom expression or a previously proved theorem expression. The matching procedure tries to effect identity between the two expressions with an appropriate series of substitutions for free variables. If the match succeeds, a proof has been found.

The other methods do not try to find proofs directly. Instead, they try to construct subproblem expressions to serve as surrogates for the given problem. By construction, each new surrogate subproblem, when proved, will imply proof of the given problem from which it was developed. Substitution is immediately tried on each new subproblem in the hope that a proof is at hand.

The replacement methods try to develop subproblem expressions by replacing logical connectives as specified by the definitions. For example:

> "Definition [AIB].=.[-AVB] and problem
> -PVP yield subproblem PIP."

PIP and -PVP are the same assertion in alternate forms as specified by definition *1.01.

The method of detachment is based on the rule of detachment (*1.11), and as in replacement, it tries to develop a surrogate for the problem expression. The rule of detachment:

> "True expressions AIB and A yield new
> true expression B"

is used in a backward sense:

> "True expression AIB and problem B yield
> subproblem A"

so that proof of the subproblem will imply proof of the problem from which it was derived. The substitution method is applied to each new subproblem immediately after it is developed.

Chaining is not set forth as a rule of inference, but its legitimacy as a method is provable from Axiom *1.5 or Theorems *2.05 and *2.06 by detachment. To be strictly legal, chaining should not be used unless *2.05 and *2.06 are in the set of true expressions. Appropriately, LT can prove all theorems through *2.06 without use of chaining.

The methods of chaining also produce subproblem expressions by working backward. For example:

> "Problem AIC and theorem AIB yield sub-
> problem BIC."

In this example, forward chaining works backward to obtain a new subproblem which, if proved, implies proof of the given problem. Backward chaining works backward in a similar manner:

> "Problem AIC and theorem BIC yield sub-
> problem AIB."

The main heuristic† in LT is this procedure of working backward. It is easy to see that the methods could work forward using only true expressions to develop more true expressions, testing each new one to see if it proves the given problem. This procedure would make LT's behavior independent of the given problem, up to the time of proof completion, and it would not perform any better than the British Museum Algorithm.(3)

Working backward gives LT some vital sense of direction by taking advantage of the "heuristic connection"‡ of its problem space. If LT is viewed as a trial solution generator with a solution tester, it is easy to see that the generator should have some sense of how to produce good trial solutions. LT's methods get this necessary sense of direction by working backward.

Substitution is the only method that finds proofs directly; thus, it serves as LT's trial solution tester. It is immediately applied to given problems and is applied as a subprocess to new subproblems as they are developed by the other methods.

The other methods serve as trial solution generators. New subproblems that do not lead directly to a proof are set aside in the untried subproblem list to be selected later for additional application of the other methods.

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†By heuristic, we mean, "Any principle or device that contributes to the reduction in the average search to solution." (9)

‡For an excellent discussion of "heuristic connection," see Marvin Minsky on, "The Problem of Search." (10)

Selection of problems and application of methods is controlled by the single-problem executive routine, M1 (Fig. 1). This routine applies substitution first to avoid wasting effort on a directly provable problem. If substitution fails, the other methods are used to build trial proof sequences by developing subproblems. The method of derivation, the true expression used, and the problem from whence it came, are associated with each new subproblem.

The collection of subproblems develops into a tree of hypothesized proof sequences in which any proved subproblem constitutes proof of the given problem and of all intervening subproblems. Since all new subproblems have been through the substitution method, only subproblems at the outer reaches of the tree are candidates for further effort. These problems are kept on the untried problem list. M1 takes subproblems from the untried problems list, while the methods add new subproblems to it. Figure 2 shows an example of a subproblem tree.

It is interesting to note that while M1 works iteratively, the proof sequence tree grows recursively. This occurs because the context (derivation information) of each subproblem is directly associated with the subproblem itself, while the names of worthwhile candidates for additional effort are kept separately on the untried problems list. This arrangement allows the problem executive to work on whatever part of the tree it decides is most profitable looking.

If M1 worked recursively, LT would attack subproblems in the order of their development, which would involve a

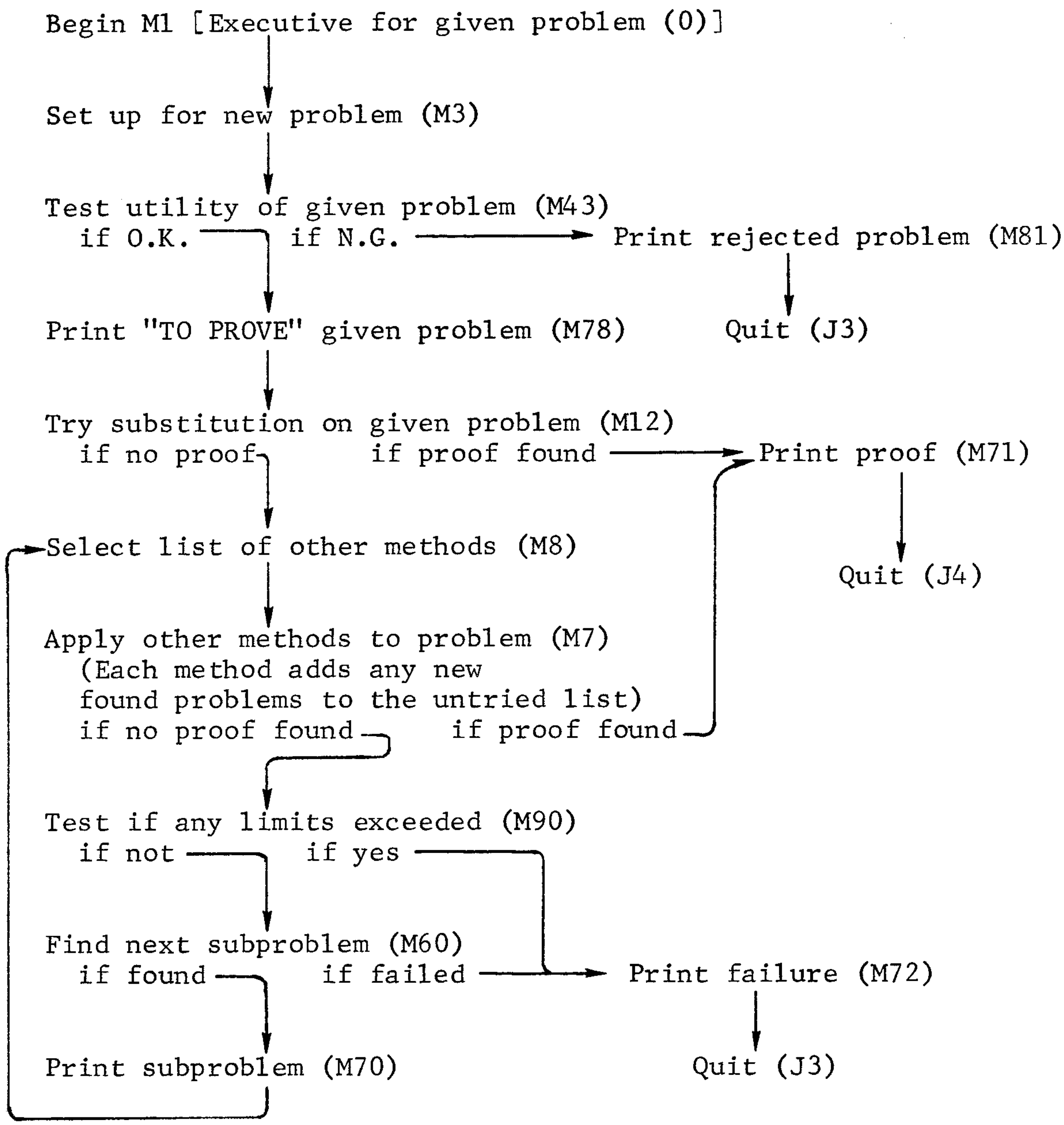

Fig. 1--The Single-Problem Executive

TO PROVE:

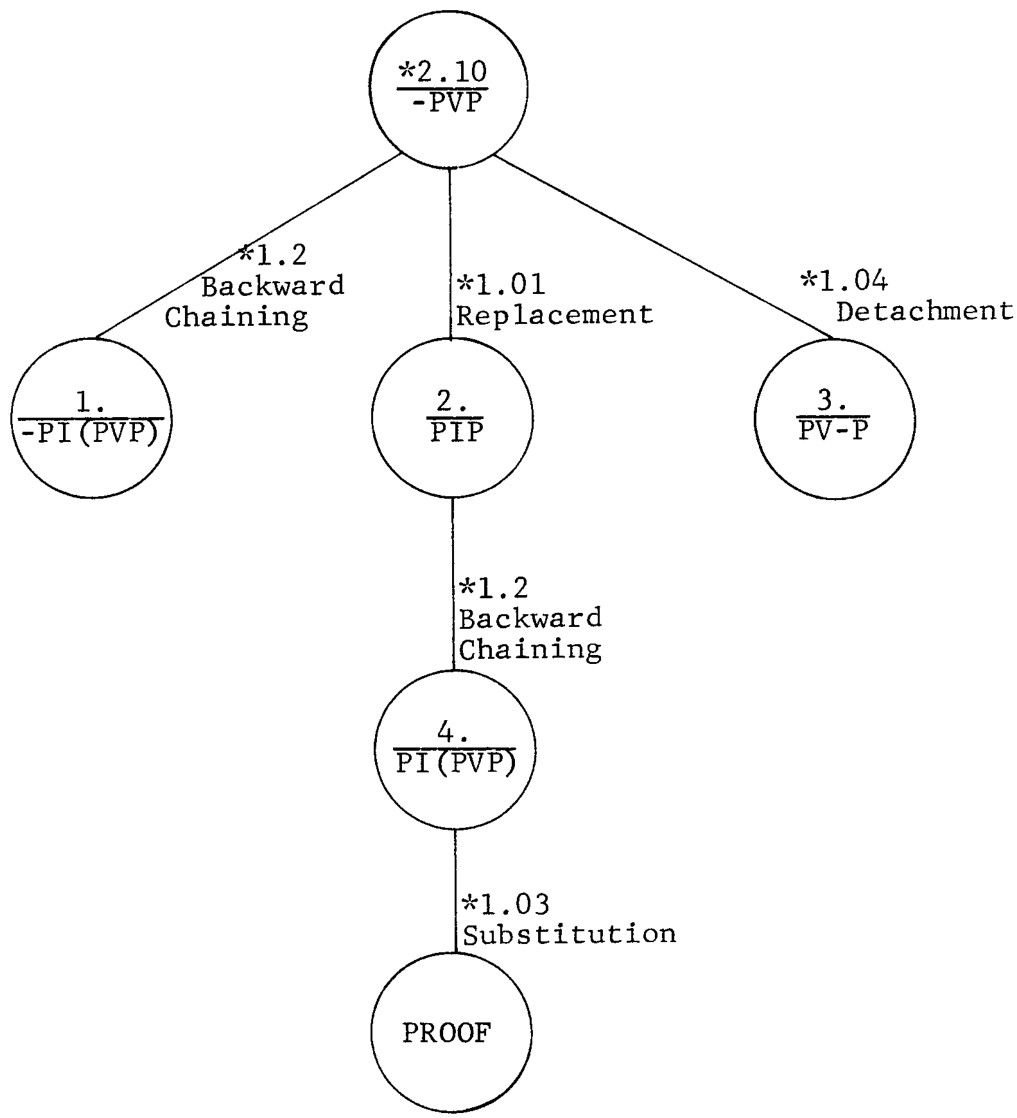

Fig. 2--Sample Subproblem Tree

depth-first attack on the problem, and make it difficult, if not impossible, to temporarily shift attention to more interesting parts of the tree. The subproblem tree in some sense represents what is known about the problem and it seems reasonable that good problem-solving procedures will require some ability to take an overall look at "what can be done" in order to plan future activity.[†]

The procedures embodied in M1 raise a number of questions for which good answers are hard to find. For example, it is unreasonable for each method to try all available theorems, since most of them won't yield any progress. It is easy to answer that a good selection process is needed, but this is not very precise.

This problem is closely connected to the relevancy question in information retrieval research. A more precisely stated answer might be, "Design a theorem storage and retrieval system that will deliver the names of theorems, appropriate parts of which are feasible matches for a given expression." The word "appropriate" takes on a specific meaning for each method using the system.

There are many ways to implement such a system. An interesting one is implemented around routines M54 and M63 of LT. It is discussed in Sec. IX.

There are other interesting questions raised by M1, as enumerated in the following list:

1) What is meant by utility and how can it be measured?
2) How should substitution be implemented?

[†]See Refs. 11 and 12 for recent discussions of the implications of questions raised here.

3) How should the other methods be implemented?
4) How are methods to be selected?
5) What theorems should each method try?
6) How many theorems should each method try?
7) What kind of effort limits are meaningful? Useful?
8) How should the next subproblem be selected?

The remaining sections describe ways in which these questions have been resolved in the current version of LT. They are not the only or the best ways but they do enable LT to do a passable job of theorem proving.

V. SUBSTITUTION AND MATCHING

Matching is the heart of LT. The substitution method, M12 (Fig. 3), uses test for match routine M114 (Fig. 4) to try to effect identity between a problem and a theorem. M114 uses substitution for free variables as appropriate.

It may seem confusing, but substitution method M12 does not actually do any substitution. It only acts as an executive for matching a given problem with a sequence of appropriate theorems until a match is found or the theorem supply is exhausted. Determination of required substitutions is made by the match process.

Test for match routine, M114, is also an executive. It "puts off the work" to match process M111 (Fig. 5). M114's only reason for existence is to discard the output of M111 if a match is successful. Remember, TEST routines should leave no outputs in H0.

M111 does its matching with subprocess 9-100 (Fig. 6) after setting up an empty substitutions list. Since an expression is recursively defined in LT, the match subprocess is recursive. It tests for identity of variables and connectives between expressions, arranges effective substitution for free variables as required, and recursively matches corresponding subexpressions.

Required substitutions are effected through use of the substitution list. The match process adds new required substitutions to the list as they are discovered and looks up previously assigned substitutions when free variables are encountered in expressions. The substitution

Begin M12 [Substitution method for problem (0)]

Define Context (J43)

Find main expression (J81)

Tally substitution counter (J125)

Create list of feasible theorems (M63)

Apply 9-100 to each theorem of the feasible list (J100)

[Subprocess 9-100 of M12]

Make free variables of problem disjoint with theorem (M110)

Find main expression of theorem (J81)
if found → if none → Quit + for generator

Test main expressions for match
with substitution as required (M114, Fig. 4)
if matched → if failed → Quit + for generator

Assign proof (J11)

Output problem and quit - for generator

Erase feasibles list (J71)

Clear context (J33)

Reverse H5 from generator and quit M12 (J5)

Fig. 3--The Substitution Method

Begin M114 [Test if segments (0), (1) match with substitution as required]

↓

Match segments (M111, Fig. 5)
if matched → if failed → Quit -

↓

Erase substitution list (J71), quit +

Fig. 4--Test for Match with Substitution

Begin M111 [Match segments (0), (1) with substitution as required. Output compact substitution list if successful]

↓

Create empty substitution list (J90)

↓

Match with substitution using created list (9-100, Fig. 6)
if matched ↓ if failed ↓

Output created list, quit +

Erase created list (J71), quit -

Fig. 5--The Match Process

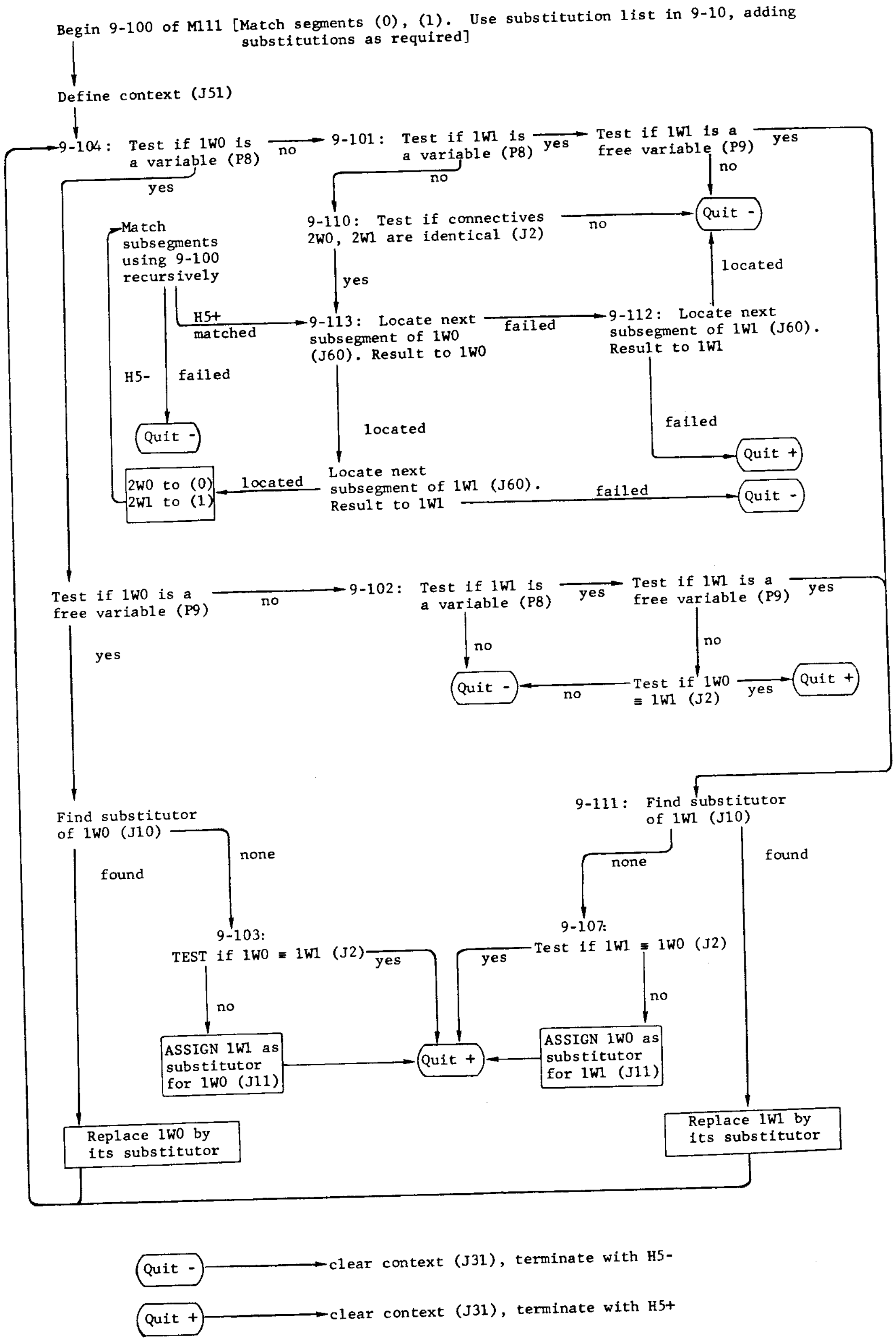

Fig. 6--The Match Subprocess

list is a description list with free variables for attributes and assigned substitutions as values. Because the values are often subsegments of the actual expressions being matched and because they, in turn, may require substitutions within themselves, the substitution list output by M111 is called a compact substitution list.

Figure 6 shows how M111 uses the compact substitution list to effect identity between expressions. The IPL-V symbols in Fig. 6 are taken from the code listed in Sec. XV.

A compact substitution list is not suitable for actual substitution in newly constructed expressions as required by other users of the match process. An expanded form can be obtained by matching with M113 (Fig. 7) which applies M112 (Figs. 8-11) to expand the compact list from M111. The expanded list contains completely substituted locally named copies of the parts and pieces of original expressions that made up the original compact list.

M112 expands the list in one pass by replacing each assigned substitution by its properly substituted locally named copy, using the substitution list itself to look up required substitutions as it goes. The subprocess that constructs properly substituted copies for replacement works recursively and is called delineation (9-100 and 9-200 of M112, Figs. 9, 10). 9-300 of M112 (Fig. 11) is used to replace free variables in expressions.

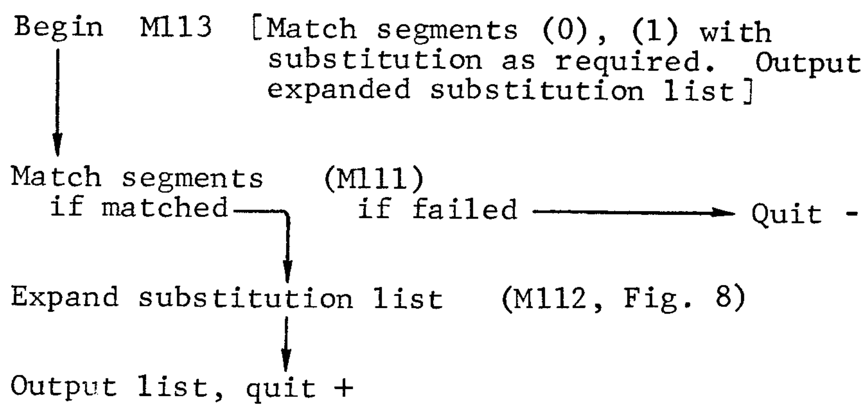

Fig. 7--Match with Substitution and Output Expanded Substitution List

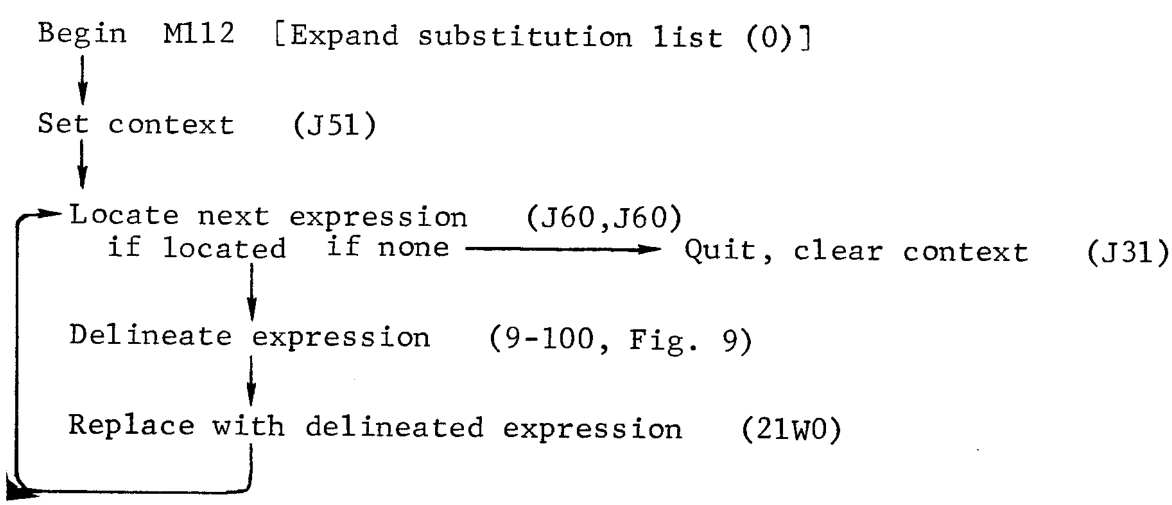

Fig. 8--Expand Substitution List

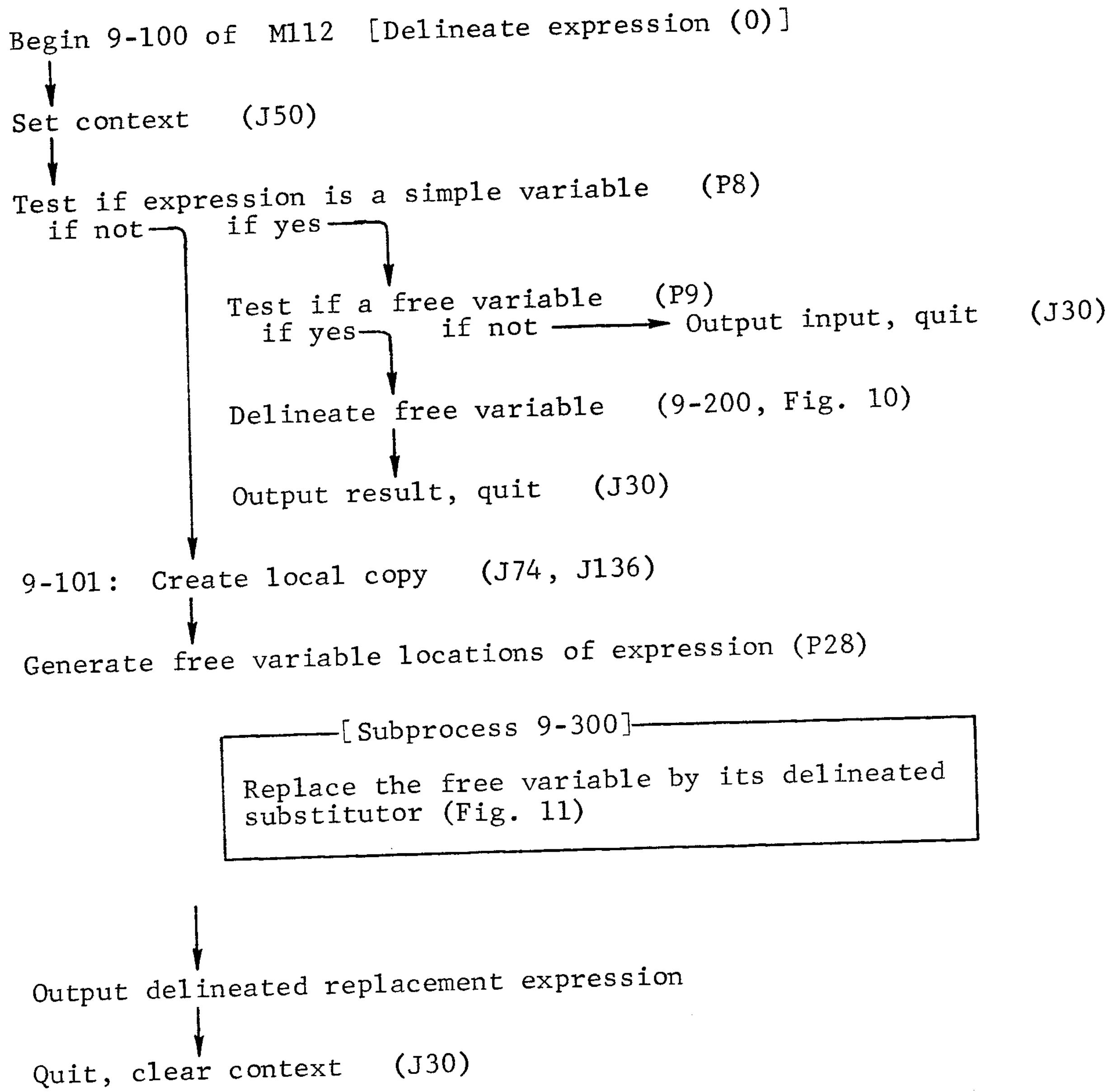

Fig. 9--Delineate Expression

Begin 9-200 of M112 [Delineate free variable (0)]

↓

Set context (J50)

↓

Find corresponding substitutor (J10)
if found ↓ if none → Output input, quit (J30)

Delineate substitutor (9-100, Fig. 9)

↓

Quit, clear context (J30)

Fig. 10--Delineate Free Variable

Begin 9-300 of M112 [Replace free variable 2H0 by its delineated substitutor]

↓

Set context (J50)

↓

Delineate free variable (9-200, Fig. 10)

↓

Replace with delineated expression (21W0)

↓

Clear context, quit + for generator (J4)

Fig. 11--Replace Free Variable by Delineated Substitutor

VI. THE OTHER METHODS

The methods, other than M12, do not detect proofs directly. It is the purpose of the other methods to develop new subproblems, which, if they can be proved, will imply proof of the given problem.

In the detachment method (M11, Figs. 12, 13) this is done by matching the whole problem to the right sides of a sequence of theorems whose main connectives are IMPLIES. For each successful match, a new subproblem is constructed by copying the left side of the theorem and substituting into the copy from the expanded substitution list obtained from the successful match.

> Problem -PVP and axiom [AVB]I[BVA]
> yield subproblem PV-P.

Replacement method M13 works the same way except that it can match expressions to either side of definitions (expressions with main connective .=.).

> Problem PIP and definition [AIB].=.[-AVB]
> yield subproblem -PVP.

> Problem -PVP and definition [AIB].=.[-AVB]
> yield subproblem PIP.

The sublevel replacement method (M16, Figs. 14-16) matches problem subsegments to definitions, proceeding through a problem expression one level at a time. At each level, each subsegment is tried for replacement. A new subproblem is formed if one or more subsegments are replaced at a given level.

Begin M11 [Detachment method for problem (0)]

↓

Define context (J45)

↓

Find main expression of problem (J81)
if found ↓ if none ⟶ Quit -, clear context- (J35)

Find maps of both sides of main connective IMPLIES (J10)
if found ↓ if none ⟶ Quit -, clear context (J35)

Find map of right sides of IMPLIES (J82)
if found ↓ if none ⟶ Quit -, clear context (J35)

Create list of theorems with feasible right side
matches for whole problem (M63)

↓

Generate feasible theorems for process 9-100 (J100)

[Subprocess 9-100]

Match problem to theorem right.
Set H5 for generator (Fig. 13)

↓

Erase feasibles list (J71)

↓

Reverse H5 from generator (J5)
[H5+ means output (0) is a solution,
H5- means no output]

↓

Clear context (J35)

Fig. 12--Detachment Method

Begin 9-100 of M11 [Try detachment with theorem (0)]
↓
Make free variables of problem disjoint
with theorem (M110)
↓
Find right side of theorem (P14)
if found ↓ if none → Quit + for generator (J4)

Match problem to theorem right. (M113)
if matched ↓ if not → Quit + for generator (J4)

Find theorem left side (P13)
if found ↓ if none → Erase substitution list (J72)
↓
Quit + for generator (J4)

Create new total expression from theorem left (P17,P24)
↓
Apply substitution list to new expression (M115)
↓
Erase substitution list (J72)
↓
Finish building new subproblem and test utility (M19)
if O.K. ↓ if N.G. → Quit + for generator

Try substitution. (M12)
if proof ↓ if no proof → Quit + for generator

Output proving subproblem and quit - for generator

Fig. 13--Detachment Method Subprocess

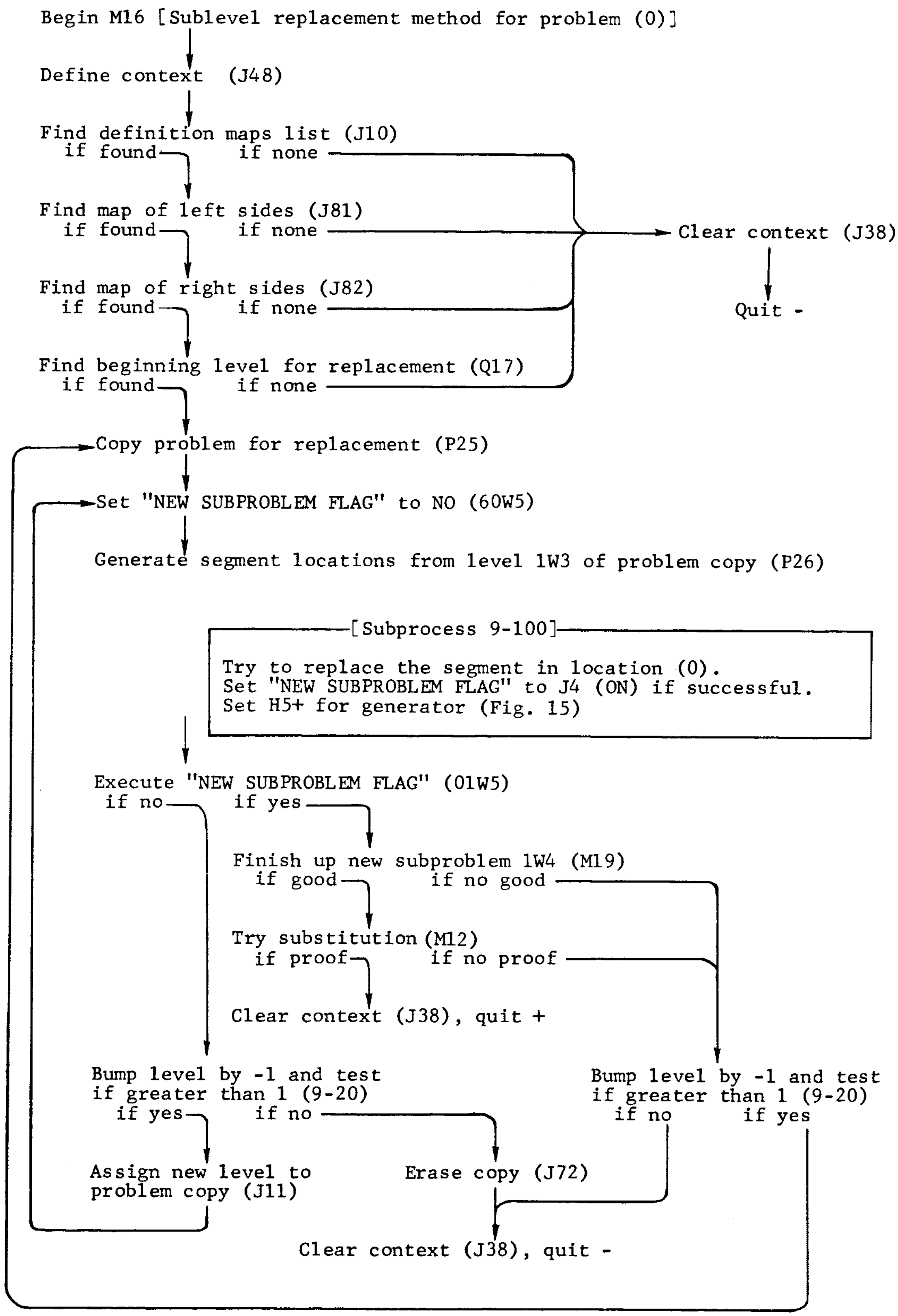

Fig. 14--Sublevel Replacement Method I

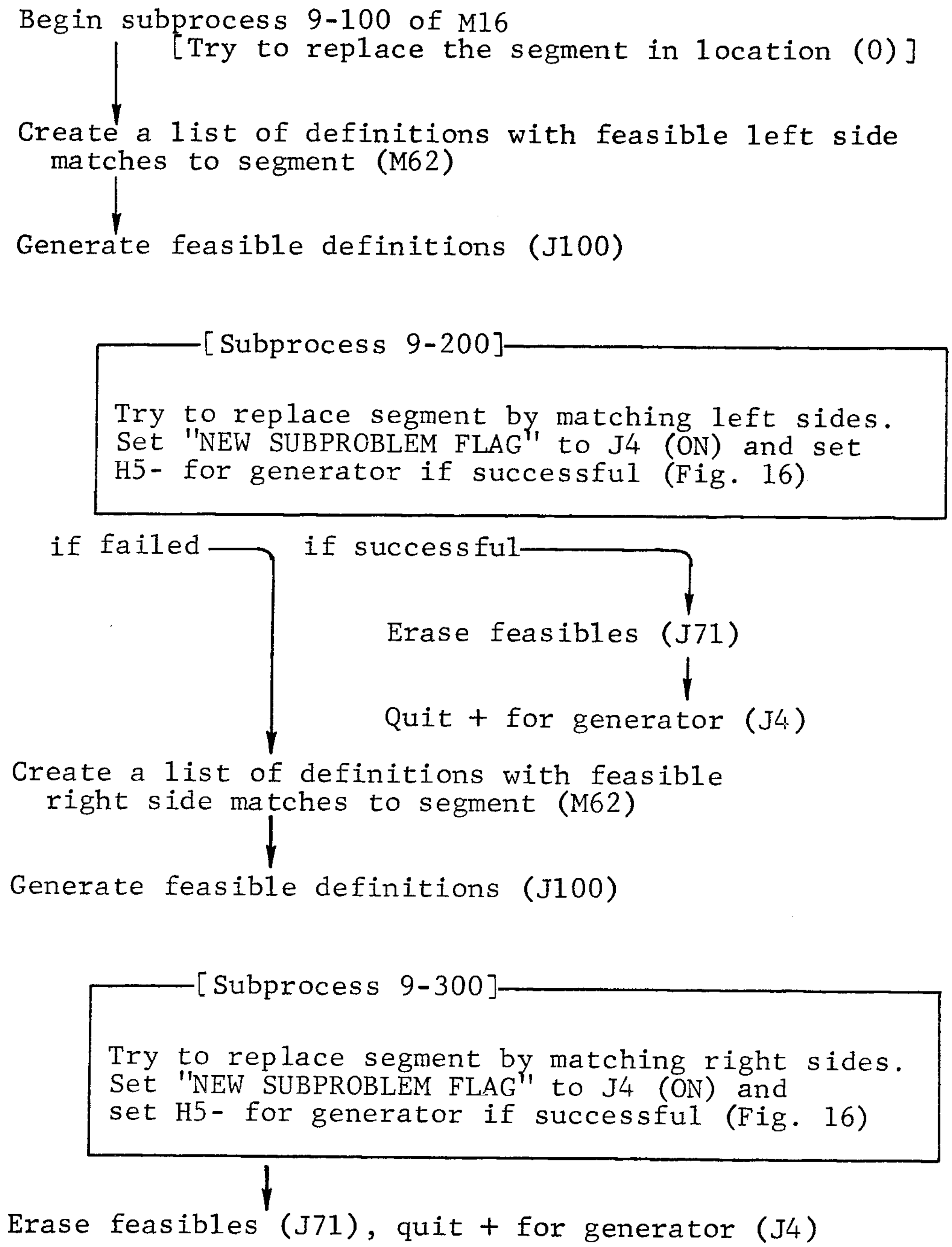

Fig. 15--Try to Replace Located Segment

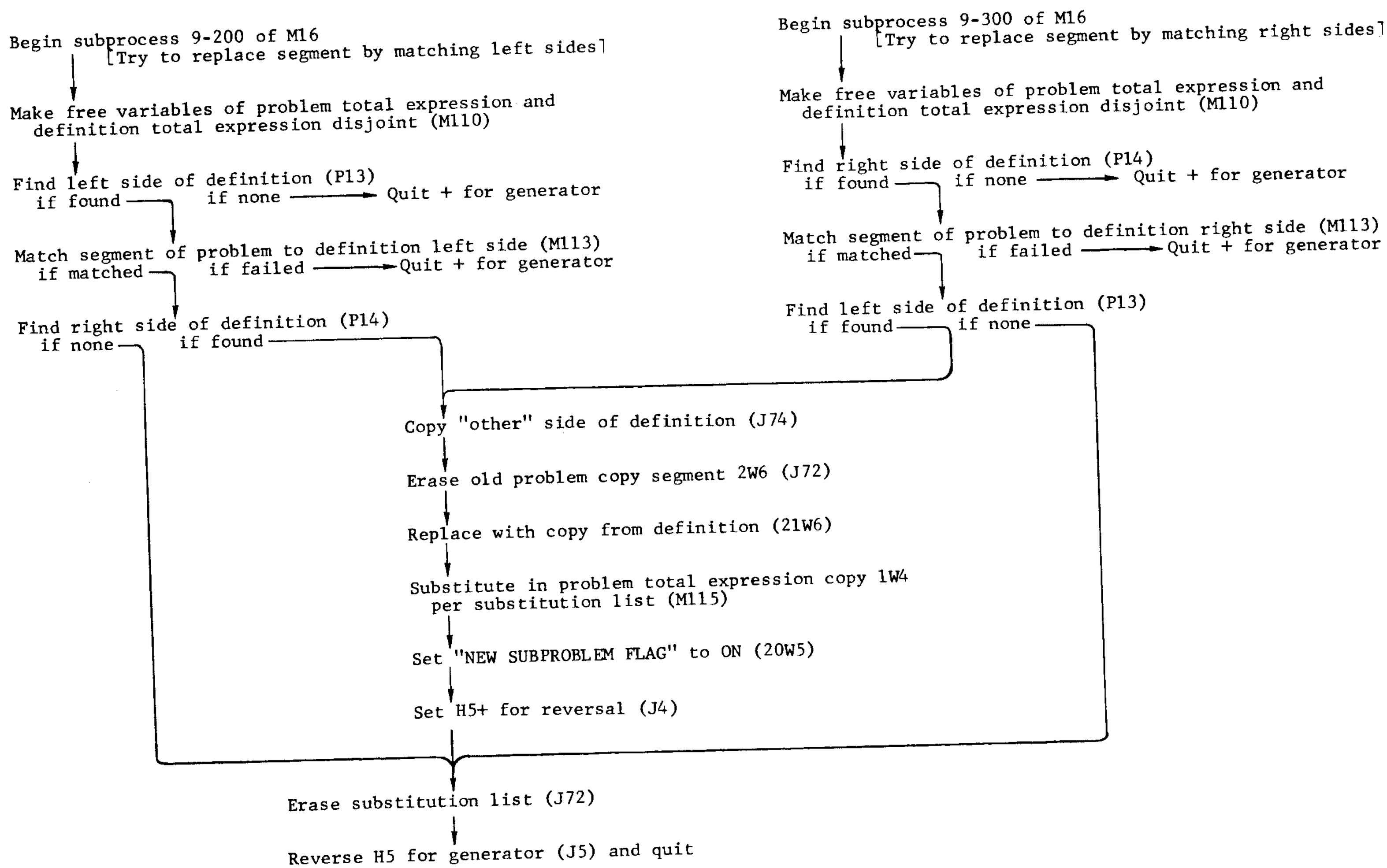

Fig. 16--Try to Replace Segment by Matching Left (Right) Sides

Problem [PI-P]I-P and definition [AIB].=.[-AVB] yield subproblem [-PV-P]I-P.

Sublevel replacement method M17 is identical to M16 except that it tries to replace all subsegments starting with those at the lowest level of the problem expression.

The forward chaining method matches the left side of the problem with left sides of a sequence of appropriate theorems. In the event of a match, a new problem is constructed with copies of the right side of the problem and the right side of the theorem. The new subproblem is then substituted into according to the substitution list obtained from M113.

Problem PV---P and theorem AV-A yield new subproblem -PI---P.

Backward chaining is the same except that it matches right sides and uses the left sides to construct new subproblems.

Problem PI[PVQ] and theorem [AVB]I[BVA] yield new subproblem PI[QVP].

Each new subproblem produced by a method needs further processing after appropriate substitution for free variables. Since this is the same for all methods, a separate routine, M19 (Fig. 17), was designed to finish off new subproblems.

M19 connects a new problem into the subproblem tree by assigning values to its derivation attributes. Then, after testing utility, it either quits with H5+ or erases the bad problem and quits with H5-. The utility measures used are discussed in the next section.

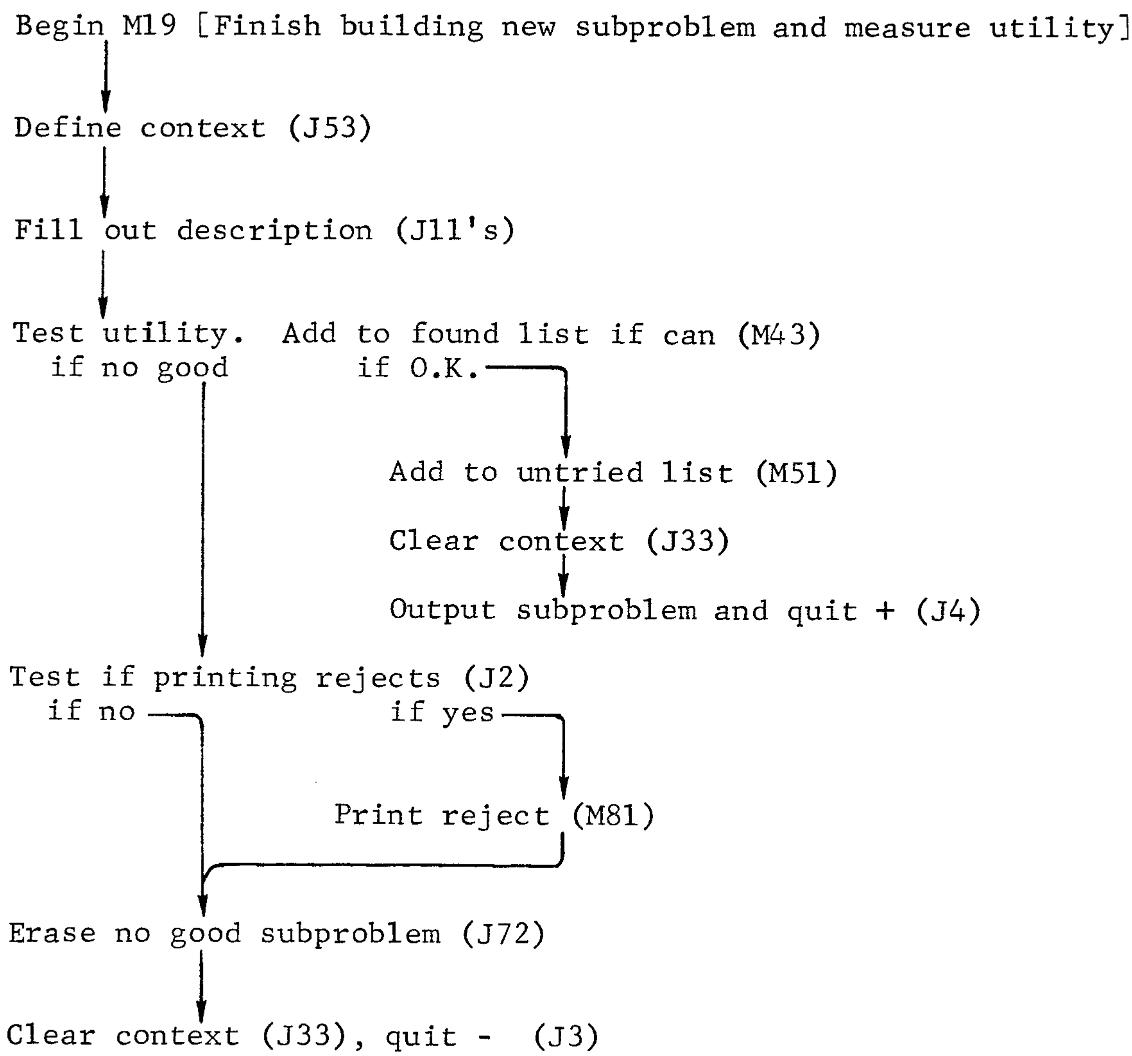

Fig. 17--Finish Building New Subproblem

The last thing each method does to each "good" subproblem is to try substitution in the hope that a proof is at hand.

VII. UTILITY MEASURES

LT considers a problem to have sufficient utility if it has not been previously found and is not clearly unprovable. The newness test adds a new problem to the found problems list if it doesn't match any problems already on the list. The non-provability test rejects single variables (P, -P), problems with matching sub-segments of main connective OR (PVP, [PIQ]V[PIQ]), and problems with faulty structures. Routine M43 (Fig. 18) handles utility measurements.

The test for match across OR uses M114 which uses substitution. The test for newness, M42 (Fig. 19), uses M40 (Fig. 20) which does not match with substitution but does consider any pair of free variables in corresponding positions to be matched.

In order to reduce search time in M42, the found problems list is kept in a structured form. The structure is based on the number of levels (Q2), number of distinct variables (Q3), and the number of variable places (Q4) in the problems stored. Only problems with identical values for Q2, Q3, and Q4 are put through a full match test (M40).

Other more interesting and profitable organization techniques might be developed as student exercises. For example, the found problems might be kept on a map similar to that used for true expressions. This might lead to new ways to organize the untried problems and facilitate new and interesting procedures for the single and multiple problem executives.

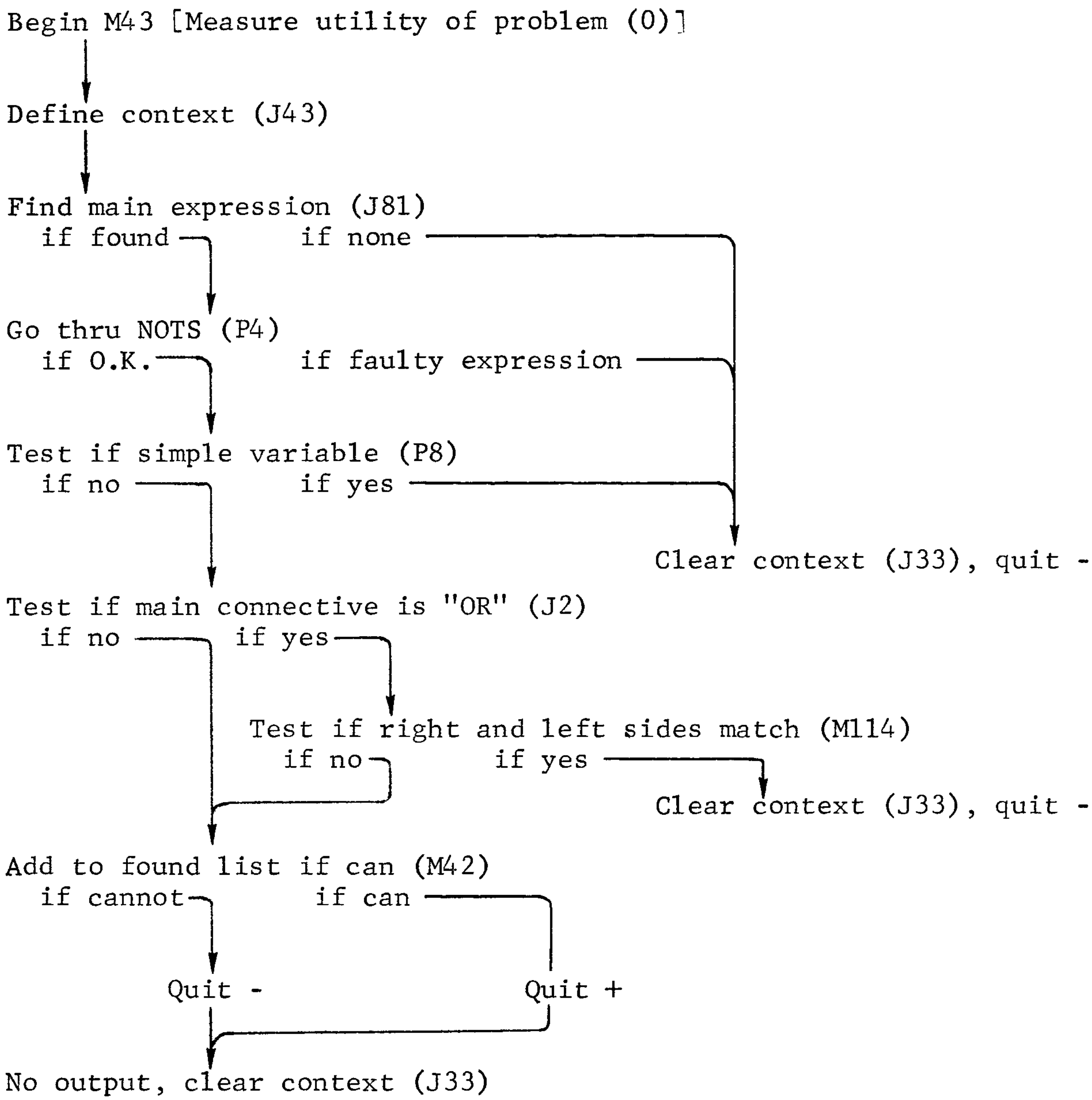

Fig. 18--Measure Utility

Begin M42 [Add to found list if can]

Define context (J42)

Find appropriate sub-sub-sub-list (9-100, 9-100, 9-100)
if found — if failed → Quit - , clear context. (J32)

Generate sub-sub-sub-list for matching subprocess (J100)

[Subprocess]
Compare total expressions (M40), reverse H5 (J5)

if no match — if any match

Quit - , clear context (J32)

Add at end of sub-sub-sub-list (J65)

Quit + , clear context (J32)

Begin 9-100 of M42 [Get sub-list]

Locate sub-list of appropriate level or locate place
to insert a new sub-list (P55)
if to insert — if usable sub-list

Get sub-list and quit (J80)

Create and insert new sub-list (J91, J64)

Create and insert new data term marker (J120, J64)

Output created sublist and quit

Fig. 19--Add to Found List

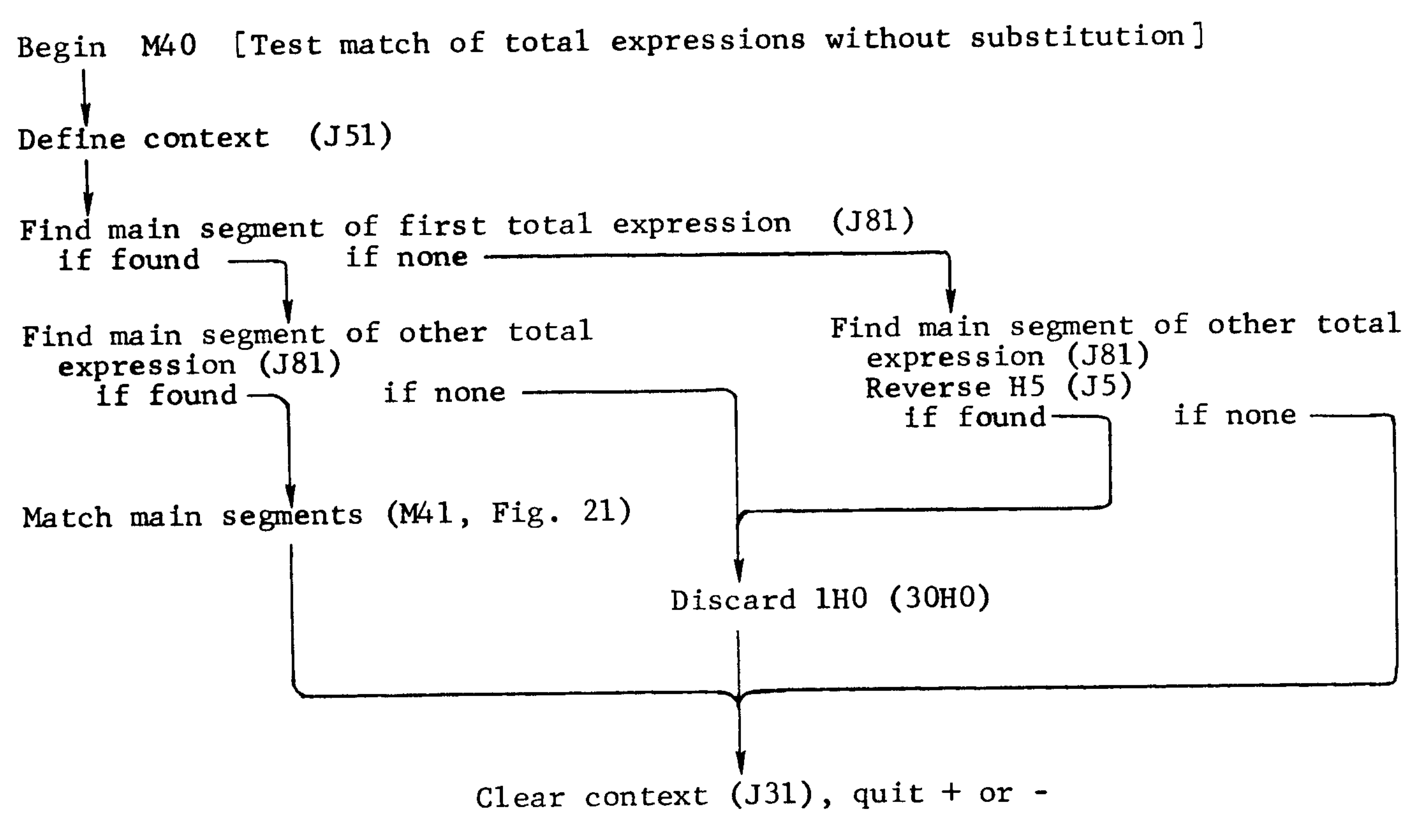

Fig. 20--Test Match of Total Expressions Without Substitution

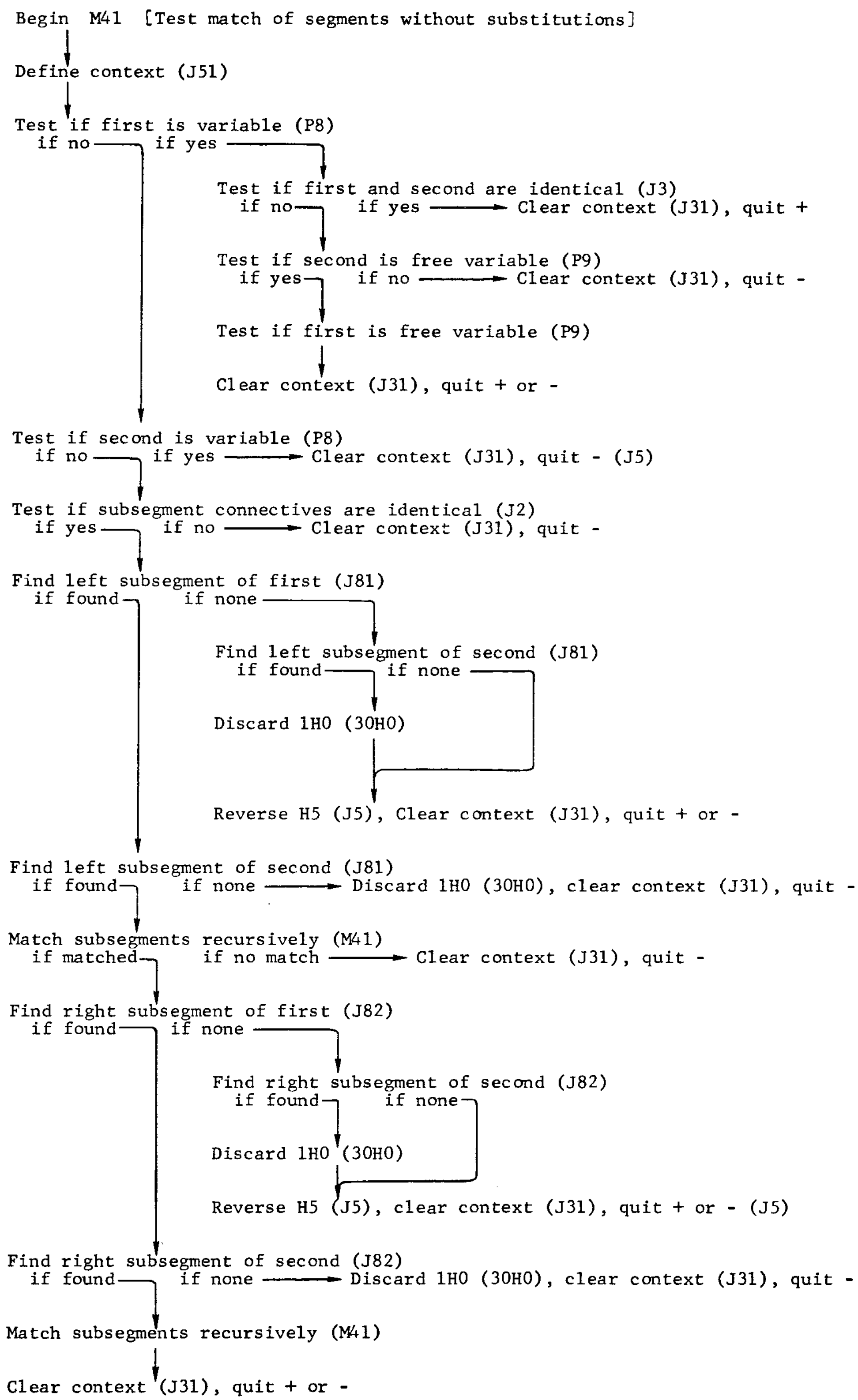

Fig. 21--Test Match of Segments Without Substitution

VIII. INFORMATION STORAGE AND RETRIEVAL

The original version of LT similarity-tested all available axioms and theorems for matching with each problem expression. The similarity test used the number of levels, number of distinct variables, and number of variable places in expressions to measure match feasibility. The purpose of the test was to obtain efficiency by screening out unlikely match candidates.

These measures of match feasibility were not very effective because of the extensive processing required and because of the global nature of the measurements.

Selection of true expressions for matching should take advantage of the fact that successful matching depends on similarity of local structural characteristics. Of course, any cheap elimination of useless true expressions is good, but difficulties arise when relatively scarce useful theorems are eliminated. Use of the original similarity test sometimes made problems unprovable because crucial matches were prevented, thus preventing development of crucial subproblems.

These and other considerations have led to development of better measures of match feasibility. Work involved with extending LT[†] to handle problems involving AND and EQUIVALENCE connectives led to the ideas that an expression is better characterized by its form than by simple counts of its various elements, and that the essence of a form is in its connective structure.

[†] Development of the true expressions map and extension of LT to handle AND and EQUIVALENCE connectives was done by the author as a term project under Fred Tonge, using the Western Data Processing Center's IBM 7090.

New requirements for match feasibility were developed as follows:

> A true expression is considered to be a feasible match if it has the same connective structure as the given problem, viewing the problem as contracted at subsegment places as required.

By "viewing as contracted," we mean viewing a segment as though it were a simple bound variable.[†] This corresponds to the M111 matching procedure of assigning segments as substitutors for free variables as required. For example, under the new feasibility requirement:

[PVQ]I[PV[PVQ]]

is a feasible match for Axioms

*1.2 [AVA]IA
*1.3 AI[BVA]
*1.4 [AVB]I[BVA] ;

but not for Axioms

*1.5 [AV[BVC]]I[BV[AVC]]
*1.6 [AIB]I[[CVA]I[CVB]] .

*1.5 fails because its left side has a segment place corresponding to a bound variable place. *1.6 fails because its subsegments have the wrong connectives.

Implementation of the new requirement was accomplished by mapping all true expressions onto one structure, called "The Map of All True Expressions" (L4). This map serves

---

[†]In LT, bound variables are treated as though they are segments of a particular but unknown form; thus, they can be substituted for free variables but nothing can be substituted for them.

as an index to the true expressions and facilitates selection of feasible matches without individual testing of each true expression.

The structure of the map is similar to that of expressions in that it forms a tree and has nodes corresponding to variable and segment places. Figure 22 shows the map structure when it contains Axioms *1.2 through *1.6. Main map L4 is an IPL-V description list with connectives as attributes and sublists of submaps as values. Each submap has the same form as the main map and each submap place corresponds to a variable or segment place in at least one true expression. The head of each submap holds a list of theorems, each of which has a variable place corresponding to the submap place. Figure 23 shows how the axiom map looks when keypunched.

By examining the map (Figs. 22, 23) it can be seen that Axiom *1.4 has a variable at the left of OR, which is at the left of main connective IMPLIES, etc. Main map L4 in Fig. 23 has only one attribute because all axioms have the same main connective.

Addition of definitions and newly proved theorems will cause additional attributes to appear in the main map. The head of L4 will always remain empty because no true expression can be without at least one connective. The map is constructed and searched by the routines discussed below.

M54 (Fig. 24) adds expressions to the map structure by mapping each new expression over those previously mapped, extending the structure as needed. Since the structure is a tree, M54 does its work with a recursive subprocess (9-100) which adds subsegments to submaps.

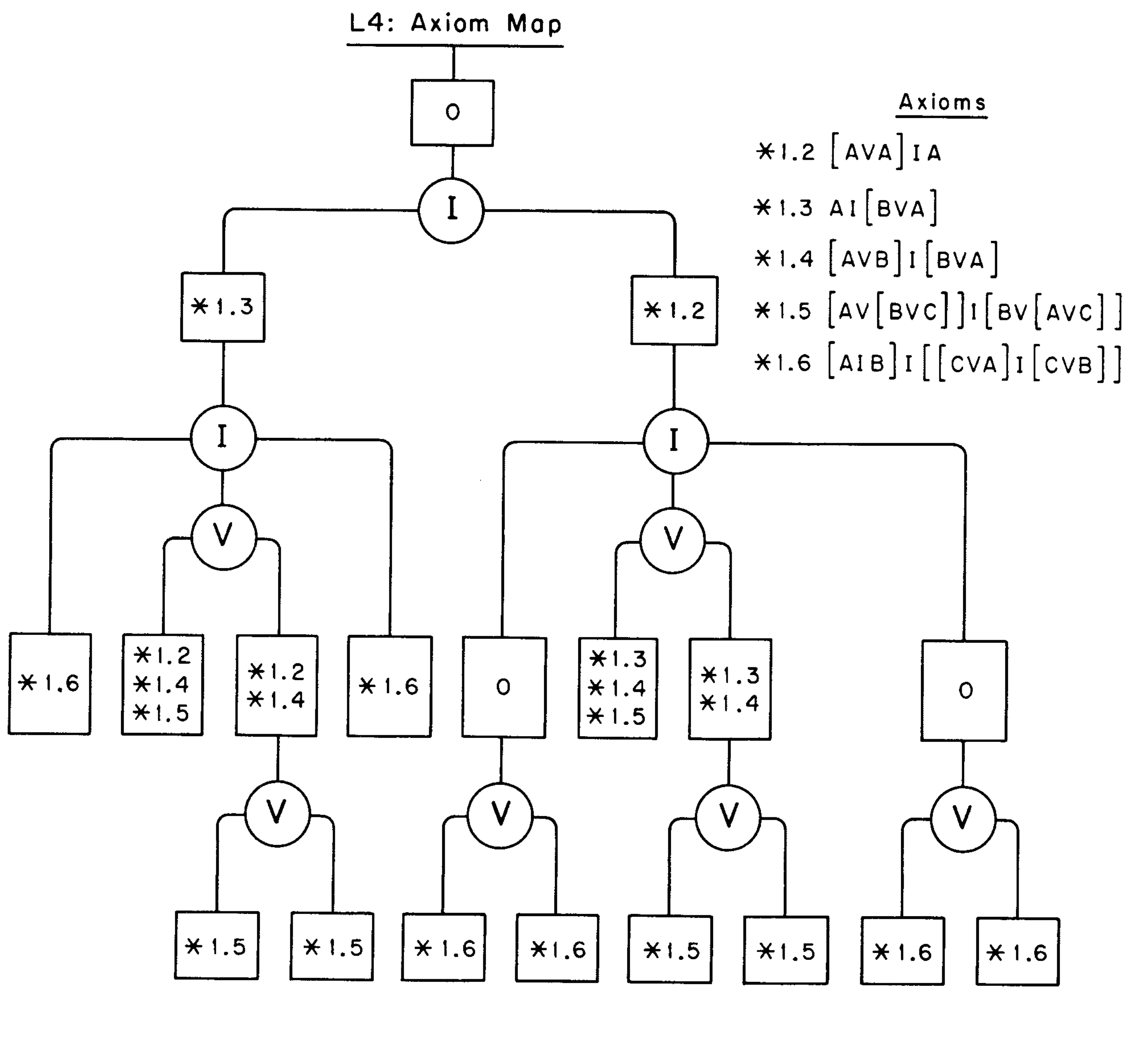

Fig. 22--Axiom Map

```
TRUE EXPRESSIONS MAP HOLDING AXIOMS  L4      0
     *1.2, *1.3, *1.4, *1.5, *1.6.           IO
                                             9-1    0
MAPS LIST FOR MAIN CONNECTIVE I.     9-1     0
                                             9-2
                                             9-3    0
SUBMAP, LEFT SIDES OF I.             9-2     9-4
                                             IO
                                             9-5
                                             VO
                                             9-6    0
SUBMAP, RIGHT SIDES OF I.            9-3     9-7
                                             IO
                                             9-8
                                             VO
                                             9-9    0
AXIOM, VARIABLE ON LEFT OF I.        9-4     0
                                             *13    0
MAPS LIST FOR I ON LEFT OF I.        9-5     0
                                             9-10
                                             9-11   0
MAPS LIST FOR V ON LEFT OF I.        9-6     0
                                             9-12
                                             9-13   0
AXIOM, VARIABLE ON RIGHT OF I.       9-7     0
                                             *12    0
MAPS LIST FOR I ON RIGHT OF I.       9-8     0
                                             9-14
                                             9-15   0
MAPS LIST FOR V ON RIGHT OF I.       9-9     0
                                             9-16
                                             9-17   0
SUBMAP, LEFT OF I ON LEFT OF I.      9-10    9-18   0
SUBMAP, RIGHT OF I ON LEFT OF I.     9-11    9-19   0
SUBMAP, LEFT OF V ON LEFT OF I.      9-12    9-20
                                             VO
                                             9-21   0
SUBMAP, RIGHT OF V ON LEFT OF I.     9-13    9-22   0
SUBMAP, LEFT OF I ON RIGHT OF I.     9-14    0
                                             VO
                                             9-23   0
SUBMAP,RIGHT OF I ON RIGHT OF I.     9-15    0
                                             VO
                                             9-24   0
SUBMAP, LEFT OF V ON RIGHT OF I.     9-16    9-25   0
SUBMAP, RIGHT OF V ON RIGHT OF I.    9-17    9-26
                                             VO
                                             9-27   0
AXIOM, VAR. LEFT OF I, LEFT OF I.    9-18    0
                                             *16    0
AXIOM, VAR. RIGHT OF I, LEFT OF I.   9-19    0
                                             *16    0
```

Fig. 23--Axiom Map in Keypunched Form

```
AXIOMS, VAR. LEFT OF V, LEFT OF I.   9-20    0
                                             *14
                                             *12    0
MAPS LIST, V LEFT OF V, LEFT OF I.   9-21    0
                                             9-28
                                             9-29   0
AXIOMS, VAR. RIGHT OF V, LEFT OF I.  9-22    0
                                             *15
                                             *14
                                             *12    0
MAPS LIST, V LEFT OF V, RIGHT OF I.  9-23    0
                                             9-30
                                             9-31   0
MAPS LIST, V RT. OF I, RT. OF I.     9-24    0
                                             9-32
                                             9-33
AXIOMS, VAR. LT. OF V, RT. OF I.     9-25    0
                                             *15
                                             *14
                                             *13    0
AXIOMS, VAR. RT. OF V, RT. OF I.     9-26    0
                                             *14
                                             *13    0
MAPS LIST, V RT. OF V, RT. OF I.     9-27    0
                                             9-34
                                             9-35   0
MAP, LT. OF V, LT. OF V, LT. OF I.   9-28    9-36   0
MAP, RT. OF V, LT. OF V, LT. OF I.   9-29    9-37   0
MAP, LT. OF V, LT. OF V, RT. OF I.   9-30    9-38   0
MAP, RT. OF V, LT. OF V, RT. OF I.   9-31    9-39   0
MAP, LT. OF V, RT. OF I, RT. OF I.   9-32    9-40   0
MAP, RT. OF V, RT. OF I, RT. OF I.   9-33    9-41   0
MAP, LT. OF V, RT. OF V, RT. OF I.   9-34    9-42   0
MAP, RT. OF V, RT. OF V, RT. OF I.   9-35    9-43   0
AXIOM, VAR. L OF V, L OF V, L OF I.  9-36    0
                                             *15    0
AXIOM, VAR. R OF V, L OF V, L OF I.  9-37    0
                                             *15    0
AXIOM, VAR. L OF V, L OF V, R OF I.  9-38    0
                                             *16    0
AXIOM, VAR. R OF V, L OF V, R OF I.  9-39    0
                                             *16    0
AXIOM, VAR. L OF V, R OF I, R OF I.  9-40    0
                                             *16    0
AXIOM, VAR. R OF V, R OF I, R OF I.  9-41    0
                                             *16    0
AXIOM, VAR. L OF V, R OF V, R OF I.  9-42    0
                                             *15    0
AXIOM, VAR. L OF V, R OF V, R OF I.  9-43    0
                                             *15    0
```

Fig. 23--(Continued)

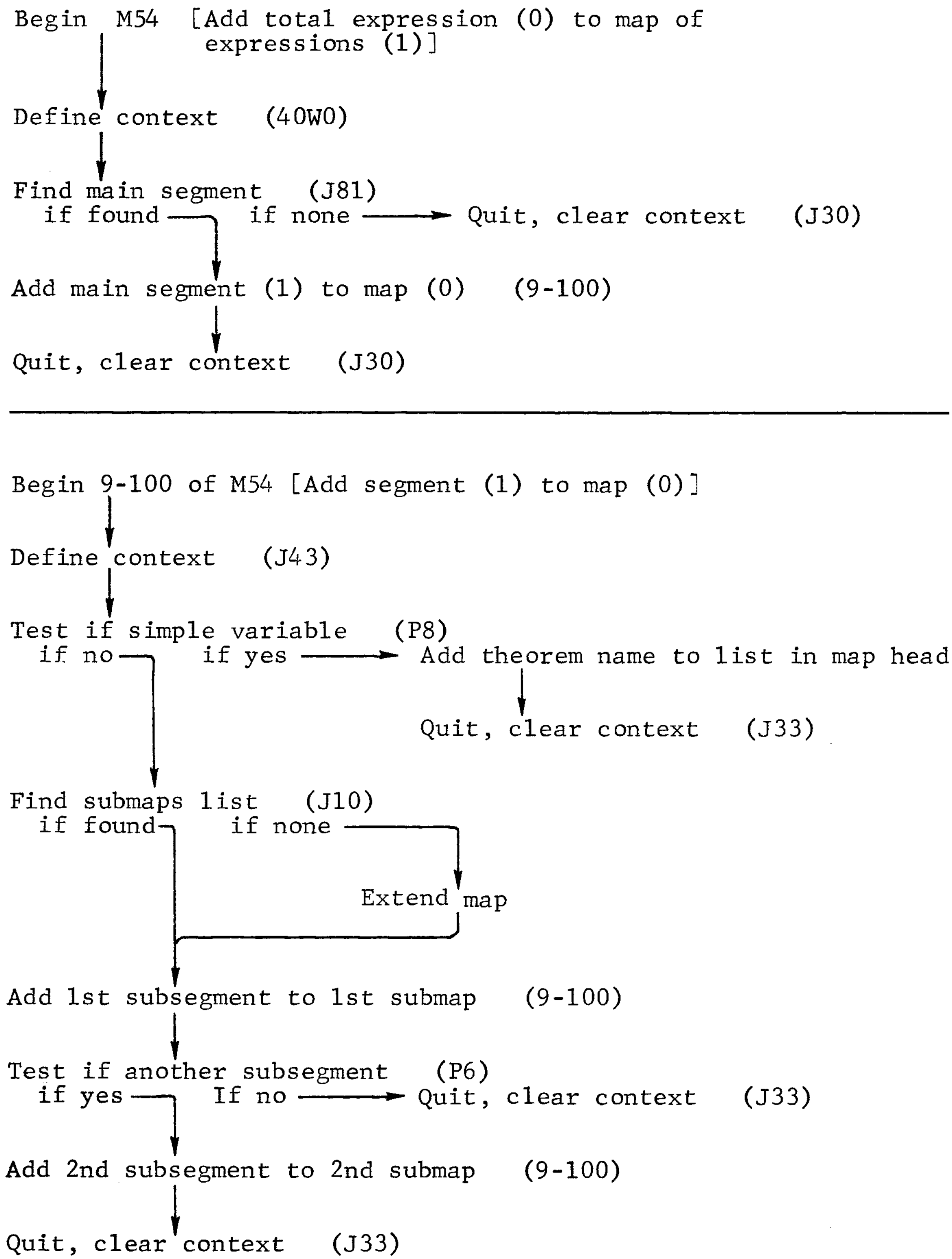

Fig. 24--Add Expression to Map

M63 (Fig. 25) extracts names of feasible match expressions from the map by using a given problem expression as a guide. This is done by laying the problem expression over the map structure and collecting true expression names from overlaid map heads. Figure 26 shows a problem expression [PVQ]I[PV[PVQ]], laid over the map so that Axioms *1.2, *1.3, *1.4, and *1.5 appear in overlaid map heads. Note that *1.5 is not a feasible match for the given problem and that *1.6 is never encountered.

M63 uses recursive processes M62 (Fig. 25) to extract a list of feasible match expressions from the map structure. It uses the following procedure to gather expression names from overlaid map heads and prevent unwanted expressions, such as *1.5 of Fig. 26, from appearing in the output list.

For each map (submap) and corresponding segment (subsegment):

1) Recursively find all feasible matches for all subsegments from corresponding submaps; then

2) If the segment (subsegment) connective is unary (such as NOT), skip to step 3) below, otherwise find the intersection of matches obtained from all submaps; then

3) Append the results of step 2) to a copy of the list of expressions from the head of this map (submap); and

4) Output the result as a list of feasibles from this map (submap).

This procedure meets all requirements set forth previously. When applied to Fig. 26, it shows that Axiom *1.5

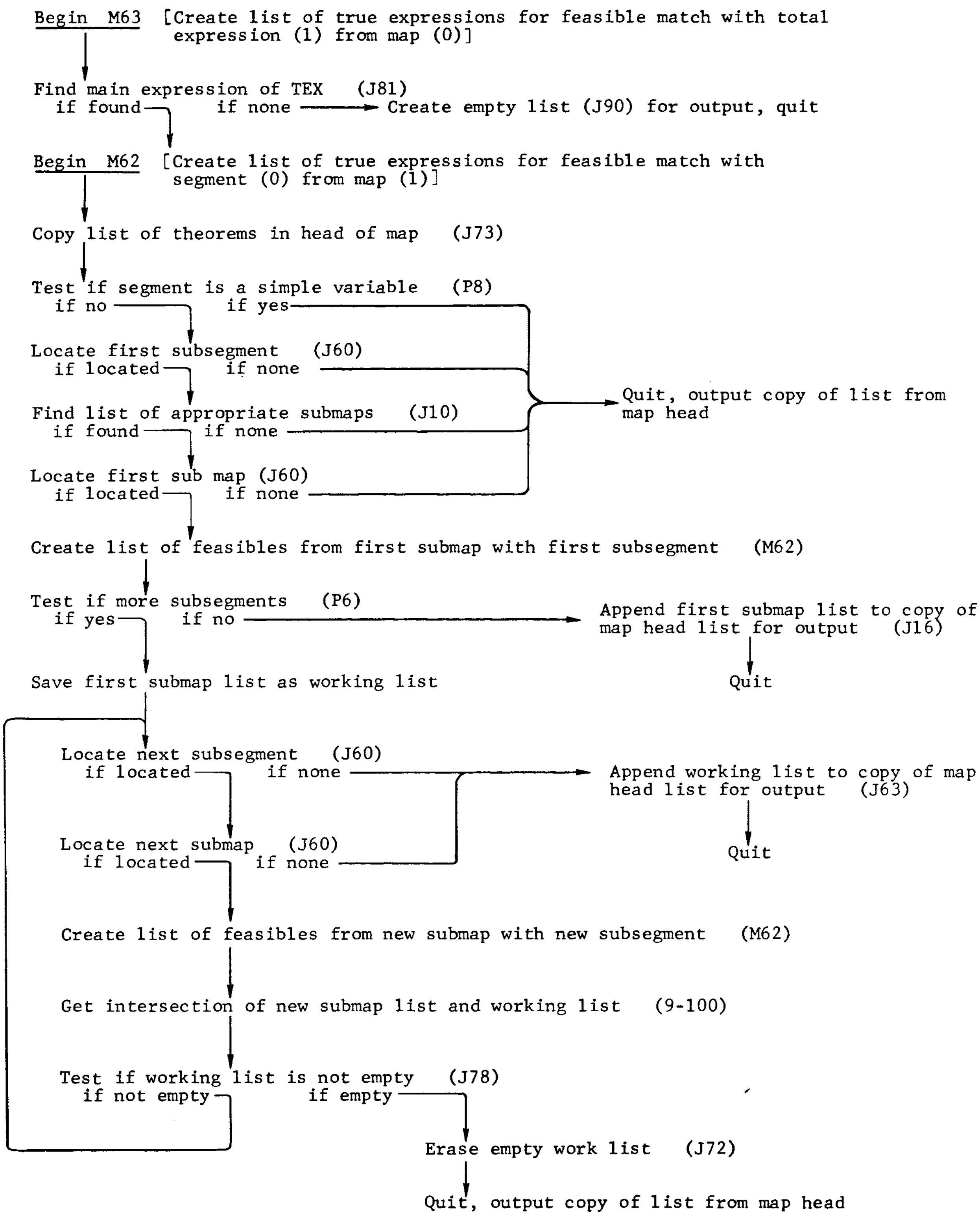

Fig. 25--Create List of Feasible Expressions

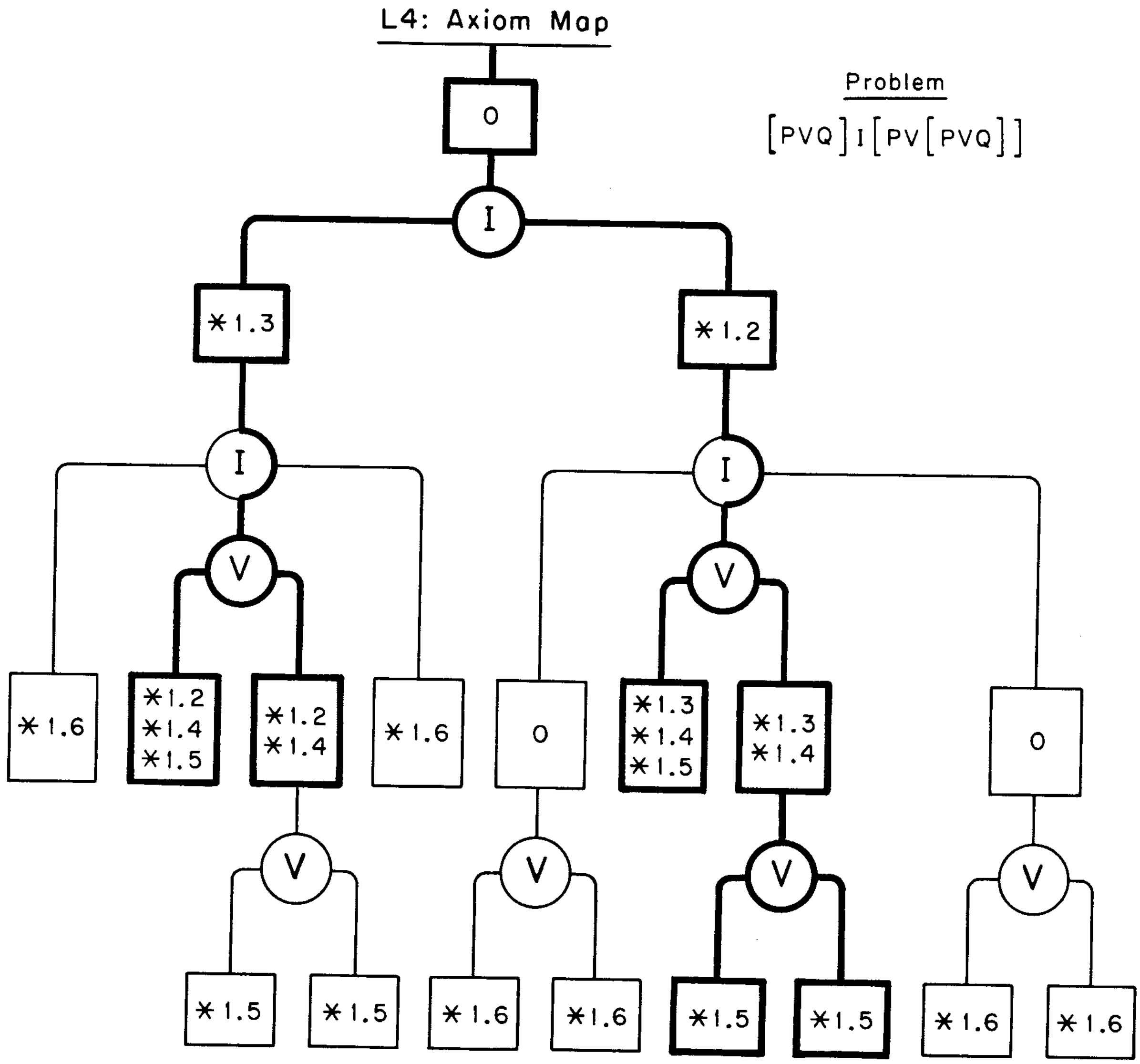

Fig. 26--Axiom Map with Overlaid Problem

is eliminated by step 2) because its name doesn't appear in the map head on the right of OR on the left of main connective IMPLIES. Step 3) provides viewing as contracted at every segment and subsegment place. The procedure completely avoids consideration of *1.6 because *1.6 doesn't have the right subsegment connectives.

The ability to completely avoid consideration of certain types of unlikely match candidates is one of the most important features of this retrieval system because each method (M11-M16) deals with a different part of the true expressions it uses. M12 matches whole expressions, so it uses the whole map. M11 matches whole problem expressions to the right sides of true expressions that have main connective IMPLIES, so it uses only the submap of right sides of main connective IMPLIES. M13, M16, and M17 use only the submaps of DEFINITIONAL EQUIVALENCE. M14 and M15 use whatever section of the map is appropriate for the problem at hand.

M14, M15, M16, and M17 use problem subsegments to search appropriate submaps, thus taking full advantage of the ability to ignore all irrelevant parts of the map. This ability becomes more valuable as the number of true expressions becomes large. Thus, this new theorem storage and retrieval system at least partially solves the old problem of what to do with too much information. Obviously irrelevant true expressions no longer get in the way.

Although the expression map technique can be used elsewhere, it is used in this version of LT only to organize true expressions. In particular, it can be applied to the found problems list which is currently organized in terms of number of levels, number of variables, and number of variable places. However, the payoff will be smaller because the found problems match process (M40) doesn't use substitution, so there is no need for viewing as contracted at any level. In fact, a map search routine for a found problems map should specifically avoid viewing as contracted.

Reorganization of the untried problems with a map structure would be more interesting. Some modification of the structure would be required because the viewing as contracted problem is inverted. Once this is done, routines could be devised to search both the true expressions map and the untried problems map at the same time. The result of such a development might enable LT to "see" a larger part of its problem at a time by giving it some ability to scan the problem and its context as a unit.

This sort of thing should lead to more sophisticated ways to select and apply methods to problem theorem pairs. The problem executives (M1, M2) would need expansion to explore problems and plan attacks. The lower-level routines would not need any significant modification.

IX. LOWER-LEVEL ROUTINES

The lower-level routines operate on expression structures and terms. The objective of segregating these processes from the higher-level routines is to generalize the program. In theory, the expression structures that LT handles can be modified by changing only the lower-level routines. In practice, a few changes would also be required in some of the higher-level routines.

Some lower-level routines have interesting characteristics. First among these are the "Q" routines. Each of the IPL-V symbols, Q1-Q19, can take on more than one meaning, depending on the context of its usage. For example, Q7 is the name of a routine (FIND EXTERNAL NAME) and is also the name of an attribute (EXTERNAL NAME) used on the description lists of total expressions, variable terms, and character symbols.

COMMENTS	TYPE	NAME	PQ	SYMB	LINK
ROUTINE HEADER	5		00		
FIND EXTERNAL NAME		Q7	10	Q7	J10
DATA HEADER	5		01		
SYMBOL FOR CHARACTER X		X0		9-1	0
		9-1		0	
ATTRIBUTE-EXTERNAL NAME				Q7	
				9-2	0
VALUE-ALPHANUMERIC DATA TERM		9-2	21	X	

There is no conflict of usage because the description list processes never operate on the contents of cells whose names are used as attributes. If, by private convention, nothing is ever done with the value of an attribute, the attribute symbol may also serve as its own dummy value, as well as for the name of the routine used to find it. Q5, Q6, and Q7 are examples of this usage. (See Sec. XV for code listings.)

There is no reason for "find" routines to be short and simple. Q2, Q3, and Q4 are examples of what is sometimes called an active attribute. Routine Q2 (Figs. 27, 28), when applied to a total expression, tries to find the number of levels in the expression as the value of attribute Q2 on the description list. If it doesn't find a value there, the routine counts levels, assigns the count as the value of attribute Q2, and outputs the value. H5 is set minus if a value cannot be found. This can only happen if the expression structure is faulty so that the number of levels is undefined. Q3 (Fig. 29) and Q4 work in a similar fashion to find the number of distinct variables and number of variable places.

Some interesting generators can be found among the "P" routines. P29 (Fig. 30) is interesting because it uses itself recursively with J18 as a subprocess to search the lower levels of expressions. P29 generates bound variable locations from expressions. P28 is of the same form, but generates free variable locations.

P26 (Figs. 31, 32) has a more difficult task. It is used to generate subsegment locations from a given level of a given expression. To do this, it uses local subgenerator 9-200 (Fig. 32), which counts expression sublevels as it descends into the expression to generate subsegment locations. The most interesting feature of P26 is the way subgenerator 9-200 is executed by subprocesses 9-100, with 9-100 as the subprocess.

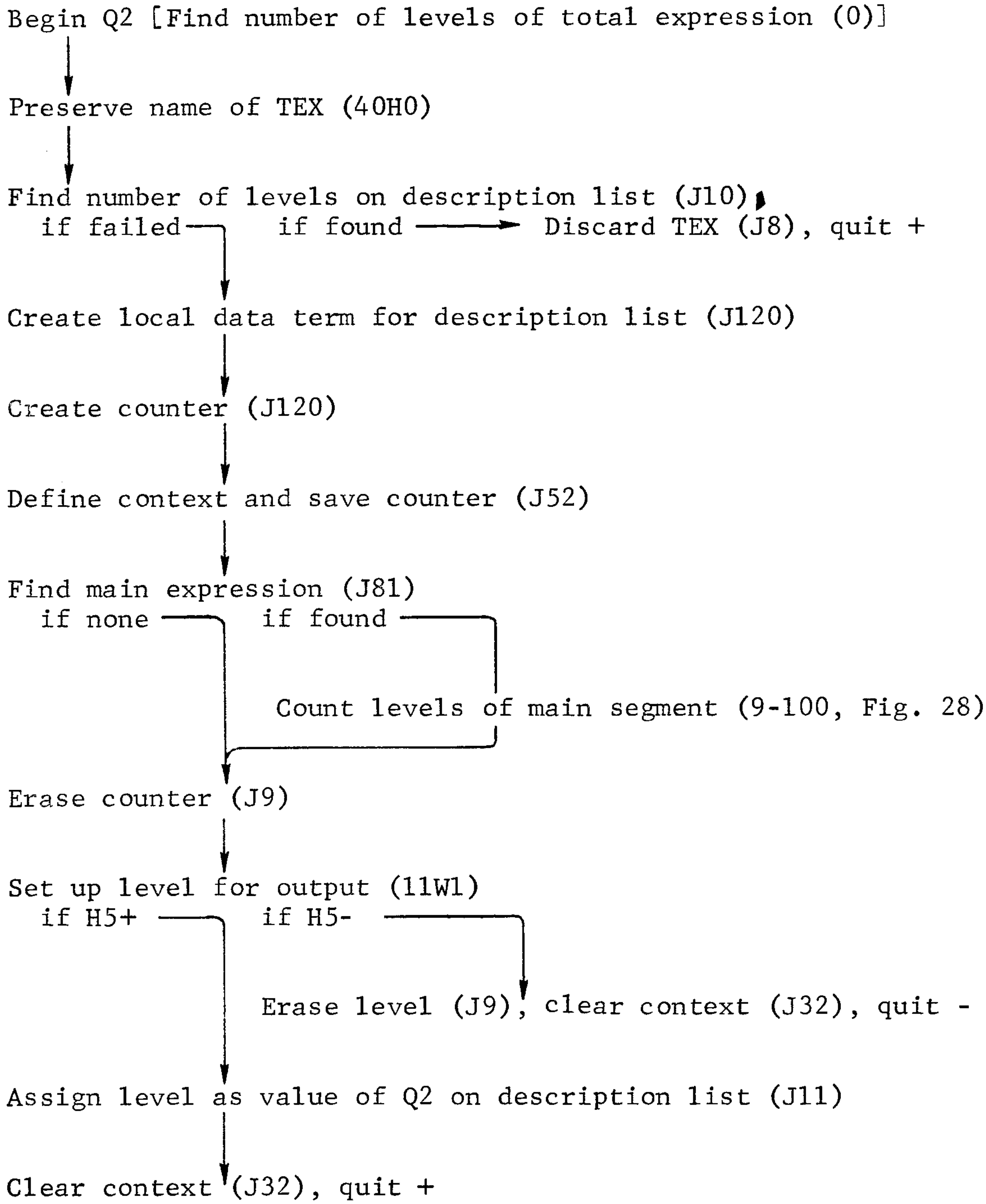

Fig. 27--Find Number of Levels

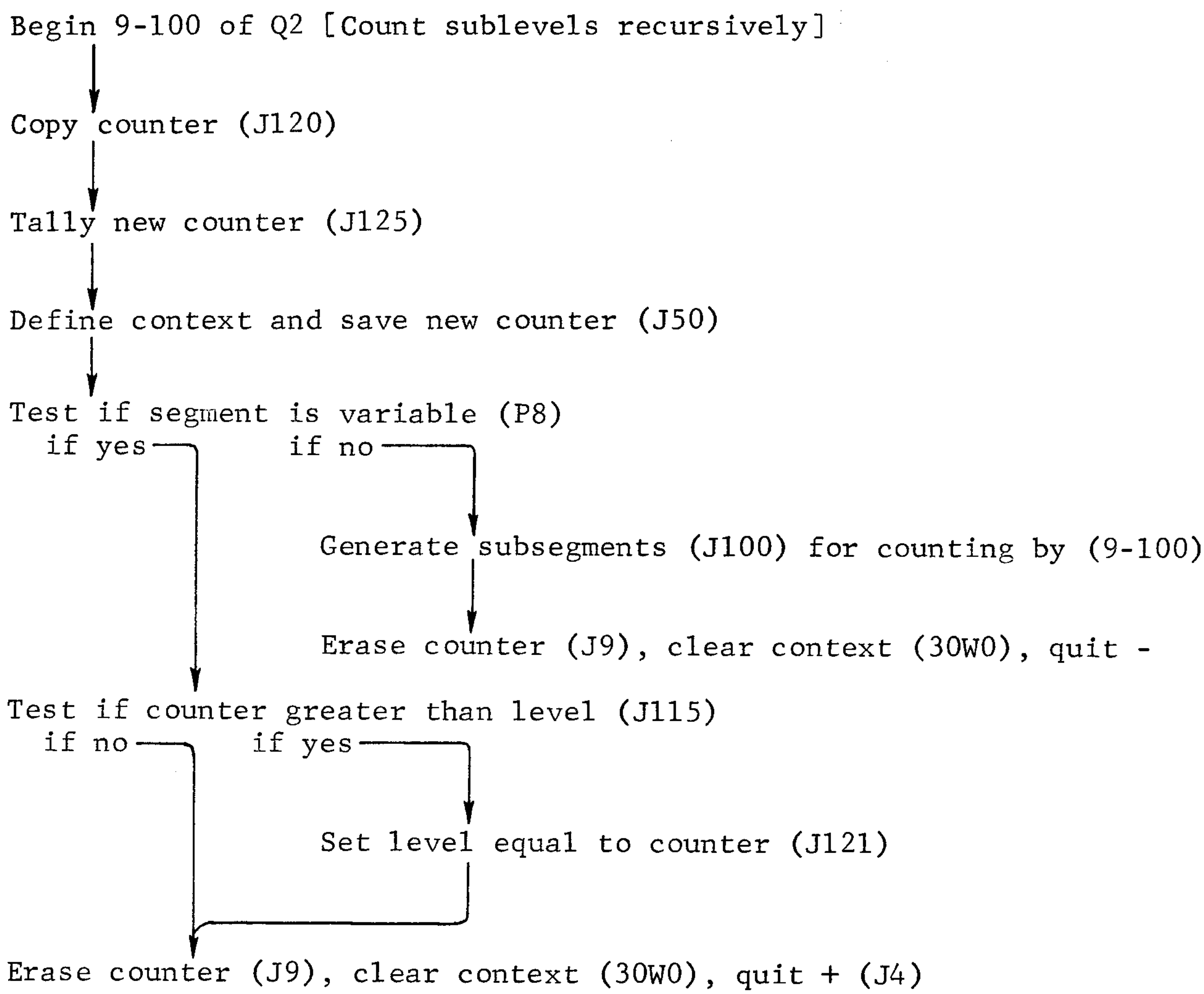

Fig. 28--Count Sublevels Recursively

Begin Q3 [Find number of distinct variables in total expression (0)]

↓

Preserve name of TEX (40H0)

↓

Find number of distinct variables on description list (J10)
if none ↓ if found → Discard TEX (J8), quit +

Define context (J42)

↓

Create list of free variables (P30)

↓

Count free list (J126)

↓

Mark count local for description list (J136)

↓

Erase free list (J71)

↓

Create bound list (P31)

↓

Count bound list (J126)

↓

Add bound count to free count (J110)

↓

Erase bound list (J71)

↓

Erase bound count (J9)

↓

Assign counter as value of Q3 on description list (J11)♦

↓

Clear context (J32), output counter and quit +

Fig. 29--Find Number of Distinct Variables

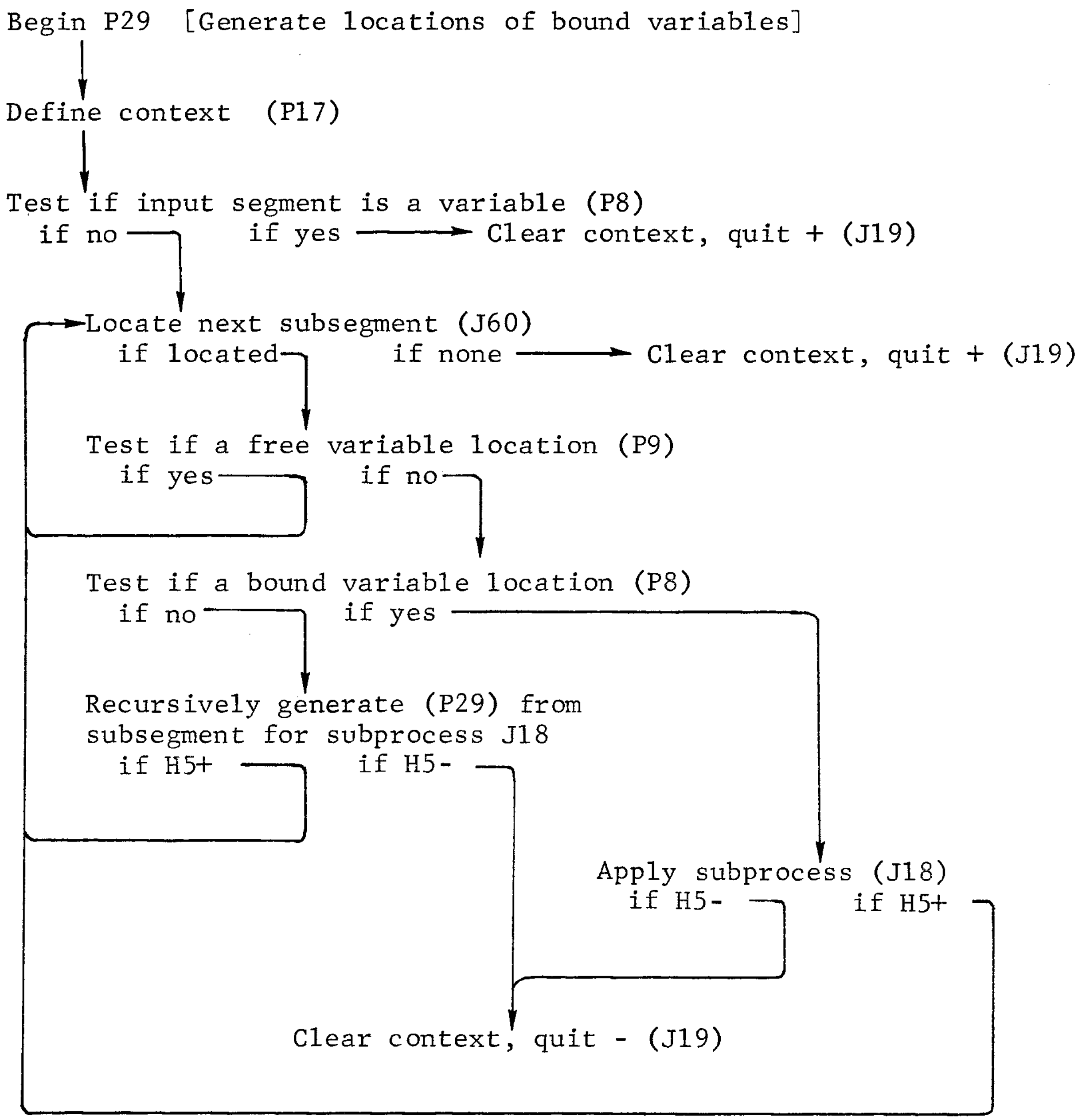

Fig. 30--Generate Locations of Bound Variables

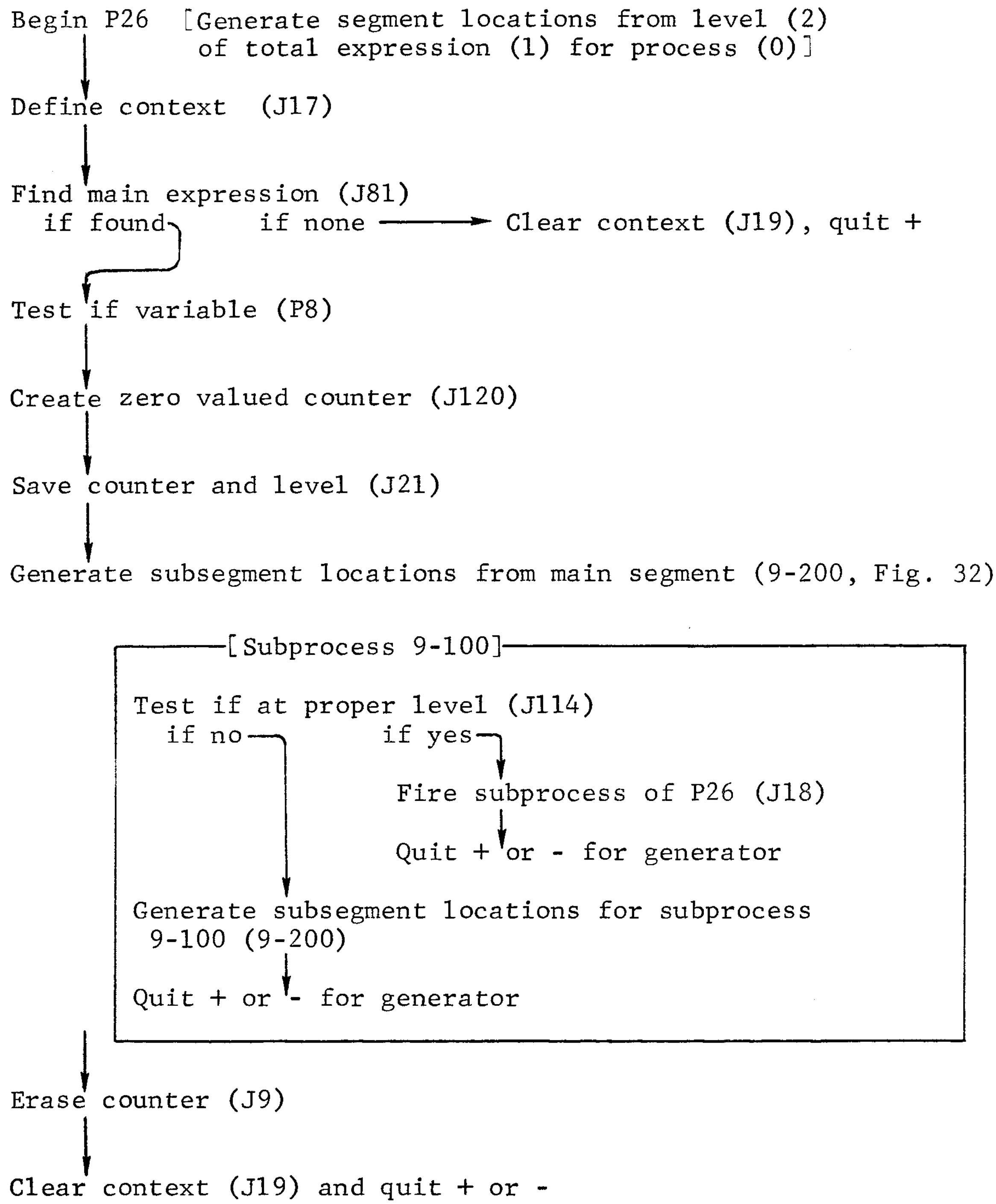

Fig. 31--Generate Segment Locations from Given Level of Expression

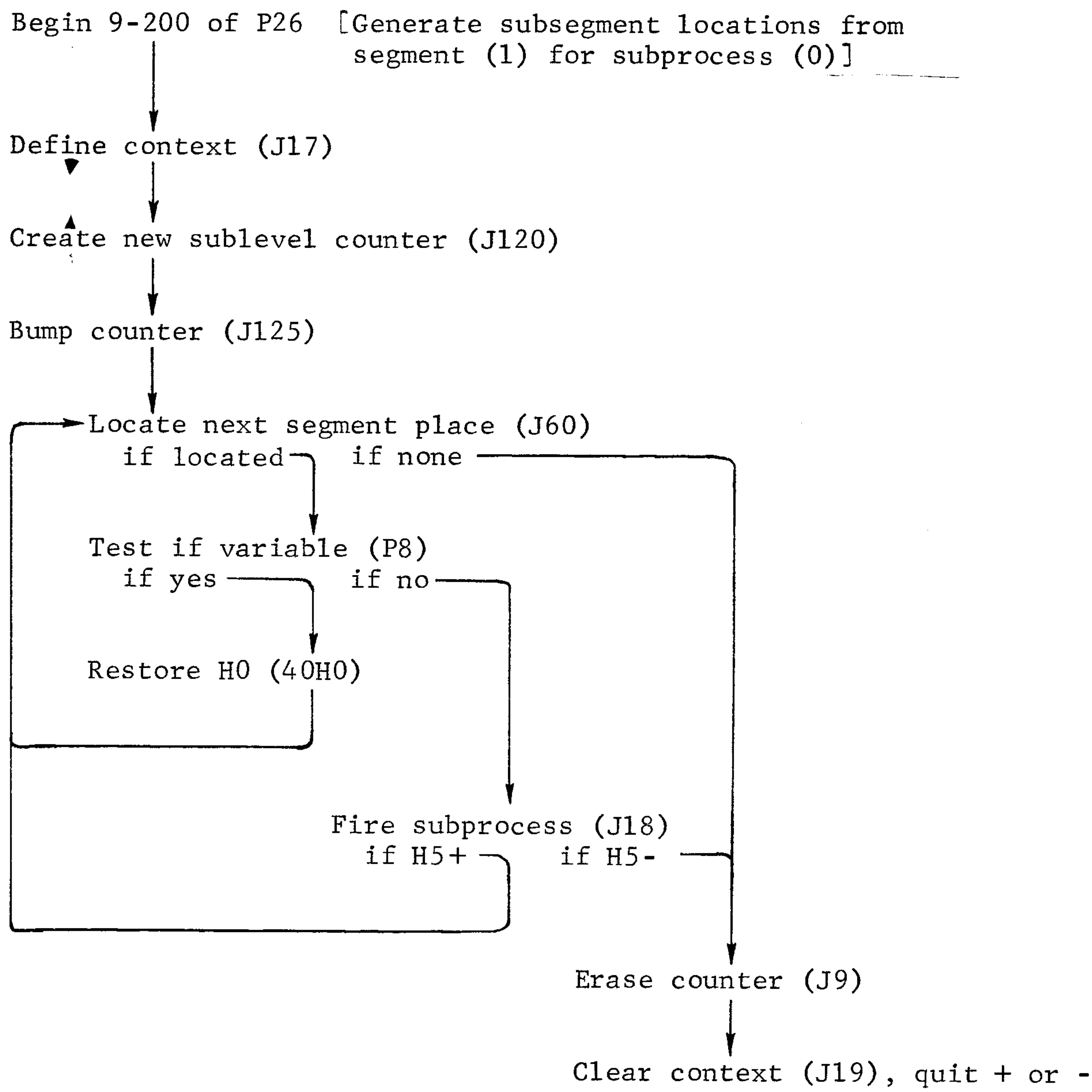

Fig. 32--Generate Subsegment Locations from Segment

P50, P51, and P52 also form an interesting group of routines, They are used to convert expressions from list form to tree form. Previous discussions have dealt only with tree form expressions. LT uses list form expressions to make inputting of expressions easier.

Expressions can be put into LT in any of three different forms. Tree forms and list forms can be directly loaded or M89 may be used to read Hollerith records with the line-read primitives (J180's). M89 will be discussed in the next section.

List form expressions have no tree structure so they are easier to write down on code sheets. The expression is carried as a simple list of character symbols, as shown below. Entire expressions must be parenthesized and redundant parentheses are not allowed.

Head	{*208	9-1	0
List Form Expression		(0	
		P0	
		I0	
		P0	
		)0	0
Description List	9-1	0	
		Q7	
		9-2	0
External Name	{9-2	21*2.08	

P50 converts expressions from list form to tree form only if they are not yet in tree form. Tree form expressions have attribute Q15, while list forms do not.

P50 is a simple routine which first tests for tree form. If the given expression is not in tree form, P50 replaces delimited external connectives (P51); creates a tree form from the list form (P52); discards the old list form, saving its head and description list (J75,J71); inserts the new tree form main expression after the old head (J64); and assigns tree form attribute, Q15, to the expression (J11).

P51 replaces delimited connectives such as .=. by scanning the list form for the delimiter symbol. When one is located, a check is made to be sure there is another delimiter symbol on the other side of the delimited symbol. If there is, all three symbols are replaced by the proper internal symbol obtained from the table of delimitable symbols. K7 holds the delimiter symbol and L8 is the name of the table of delimitable symbols.

P52 (Figs. 33, 34) creates a tree form main segment, complete with subsegments, from a given list expression without destroying the latter. Since a parenthesized list

---

Begin P52 [Create main segment from list (0)]

↓

Define context (J41)

↓

Create first segment from list 1W1 (9-100, Fig. 34)

↓

Clear context and quit + or - (J31)

Fig. 33--Create Main Segment from List Expression

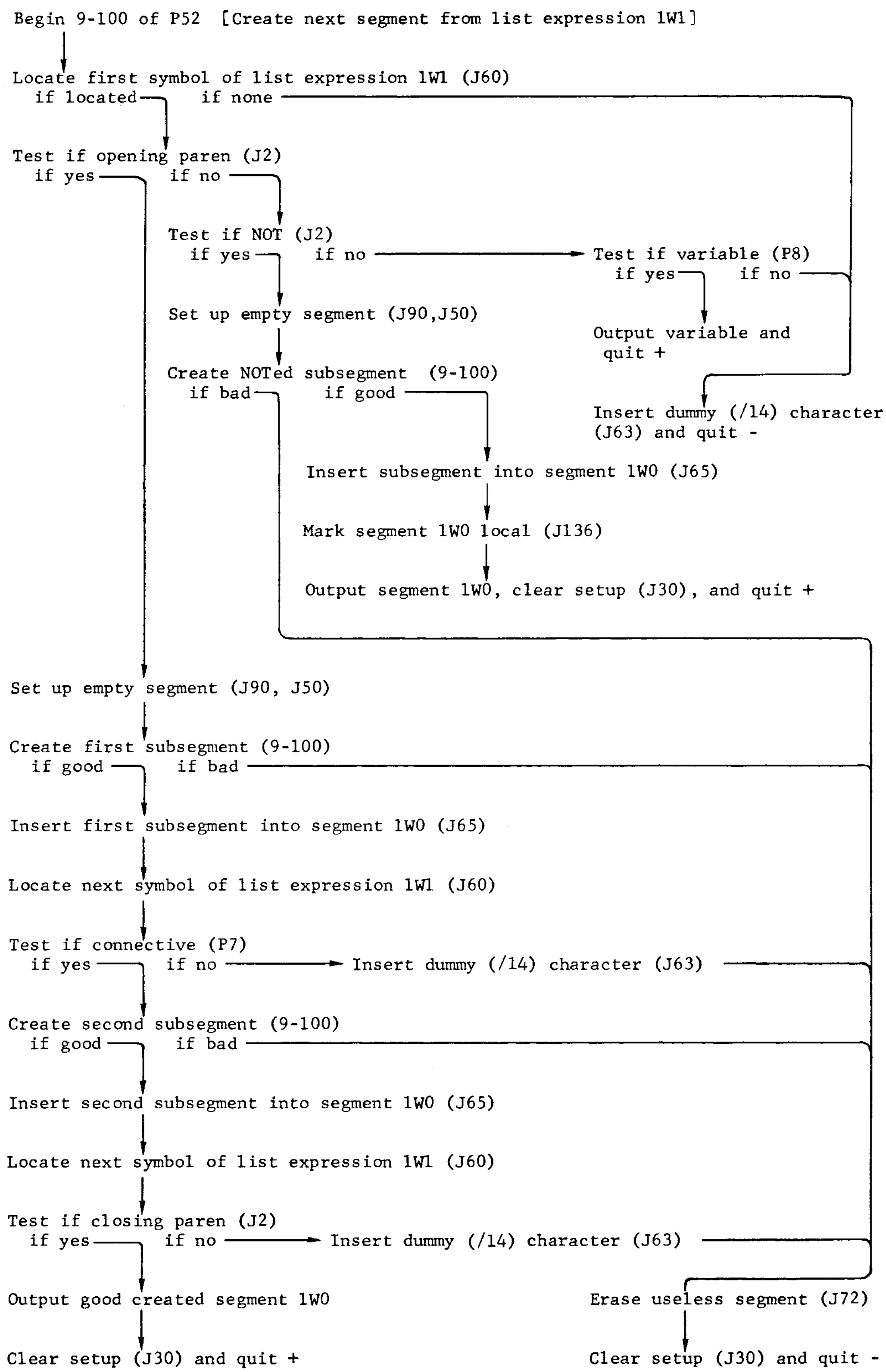

Fig. 34--Create Next Segment from List Expression

expression represents a tree structure, P52 uses a recursive subprocess (9-100) to translate the list expression into its corresponding main expression.

If the list expression is faulty, P52 inserts a dummy character symbol (/14) into the list expression. When the bad list expression is printed by M88, the dummy character appears at the place where trouble was detected.

The remaining lower-level "P" and "Q" routines are relatively trivial and can be studied directly from the code.

X. INPUT-OUTPUT ROUTINES

The input-output routines deal directly with print line primitives (J150's) and read line primitives (J180's).

As mentioned in the preceding section, expressions may be put into LT by loading them with J165 or by reading them with M89. J165 can load tree form expressions or list form expressions, while M89 can read Hollerith records with the following format:

> Beginning in column 1: Any number of blanks (including none); followed by a regional symbol expression name; followed by at least 1 blank; followed by an expression string (enclosed in parentheses with no imbedded blanks); followed by at least 1 blank; followed by an optimal suffix (up to 5 characters); followed by at least 1 blank.
>
> Example: *1.01 ((AIB).=.(-AVB)) DEF.

M89 (Fig. 35) reads one record from unit 1W18 and then scans it in read line buffer 1W24, using the read line primitives. If the record is an End-of-File (E-O-F) or is totally blank, M89 quits with no output and sets H5-. If the record is faulty in some obvious respects, it is skipped and the next record from read unit 1W18 is tried. This procedure continues until an acceptable expression is found or an empty record (or an E-O-F) is found.

In the first part of the scan procedure, the name of the expression is located and checked to see if it is a regional symbol other than a standard character symbol. This is tested with J130 and P18. If the name is okay, the main expression string is located and used to build a list form expression of variables, connectives, and parentheses. If a suffix can be found, it is assigned as the data term value of Q18 on the list expressions' description list.

M88 is the only other input-output routine that deals with list form expressions. It is used to print expressions that fail in the conversion process.

Routines M70-M82 are used to print various tree form expressions on unit 1W19. (See the vocabulary, Sec. XIV, for a list of these routines.) M73 is the central routine in this group because it is used by other routines to enter tree form expressions in the print line buffer. M73 works recursively to build a character string in the print line from a tree form expression. The process is similar to, but opposite from, that of P52. If M73 gets in trouble, it enters the external name of /14 to indicate where the expression is faulty and then continues to enter the rest of the given expression.

M71, which prints whole proof sequences, uses the derivation information associated with each problem (attributes Q10 through Q14) to trace out the successful sequence.

Two other output routines are worth mentioning. M76 is a simple routine which enters data term "text lists" by generating from them for subprocess J157.

M79 is more sophisticated. It can be used to enter the name of anything. First it tries to enter the external name (Q7); if it cannot, it tries to enter the problem number (Q8); if neither can be found, it enters

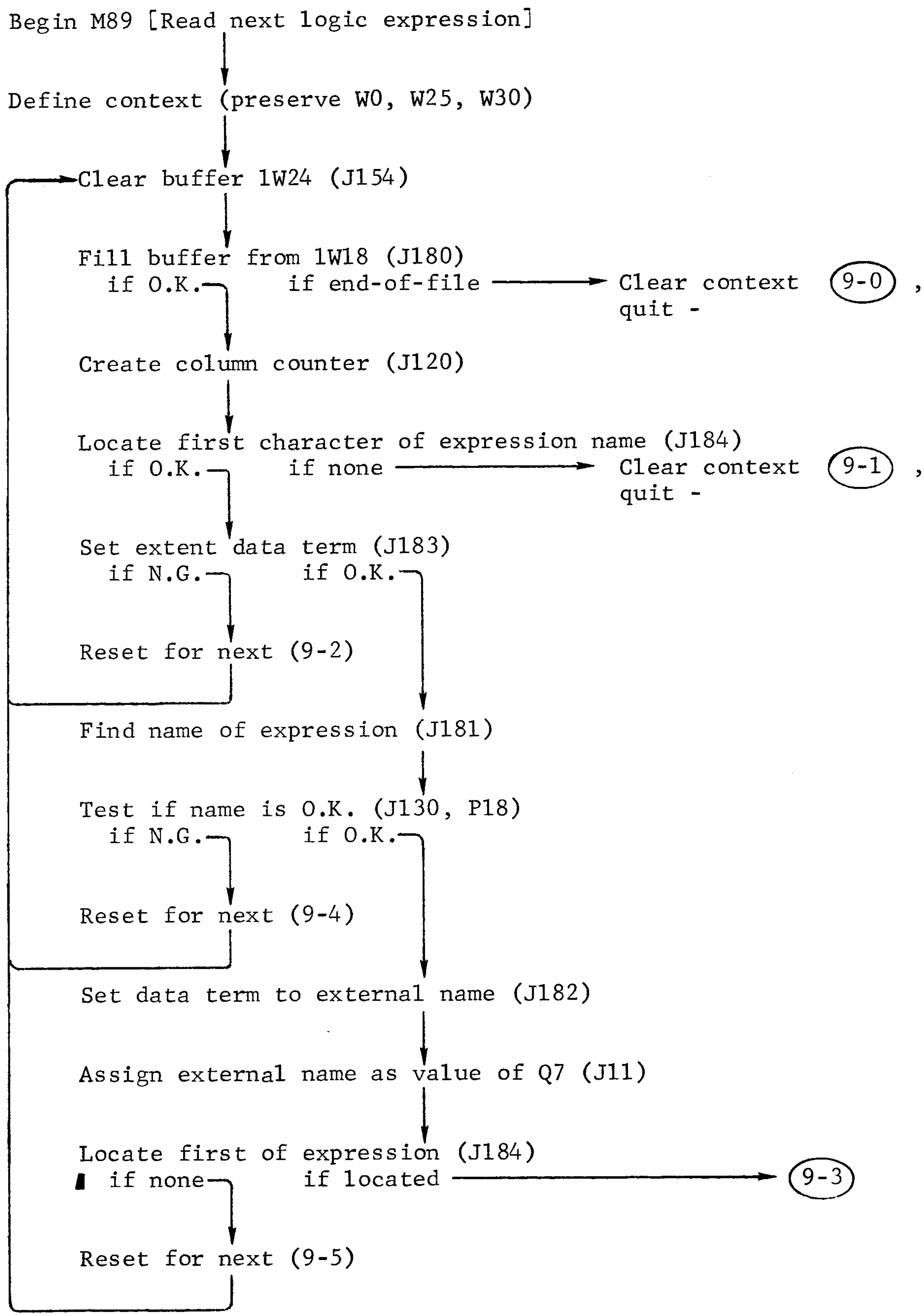

Fig. 35--Read Next Logic Expression

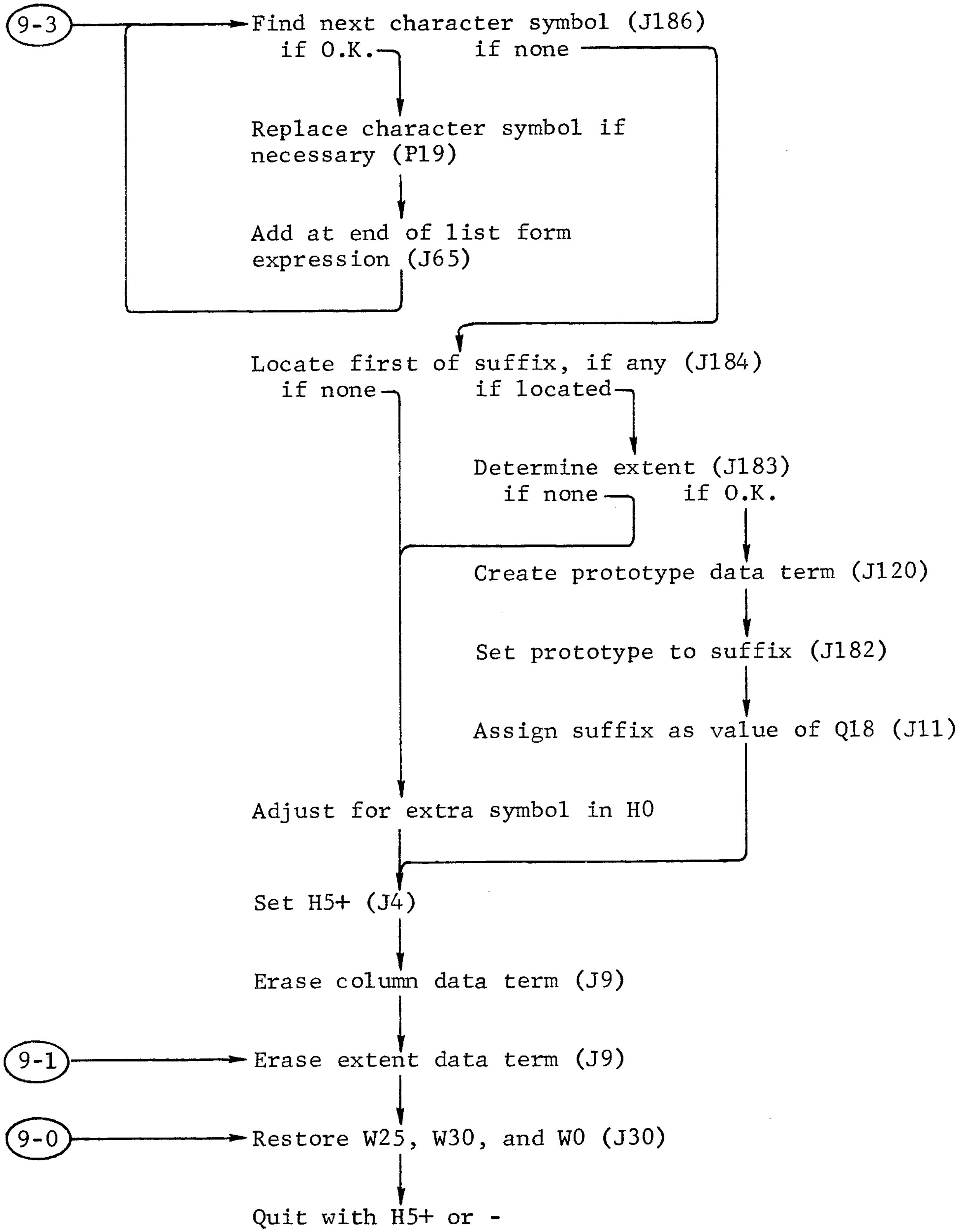

Fig. 35--(Continued)

the given symbol with J156 which enters it in regional or internal form.

The remaining input-output routines are fairly simple examples of how to use the print line primitives. The student should be able to decipher them on his own.

XI. RUN EXECUTIVES AND DEBUGGING ROUTINES

There are two run executives. The first is X9 which creates a restart tape holding the main body of LT's routines and data. X9 terminates with J165 to facilitate loading of additional data and/or routines at run time.

The second run executive is X1. It is the highest-level executive for a theorem-proving run. After initializing some debugging devices, which will be discussed later, X1 reads a set of true expressions for the run converting each expression to tree form and adding it to the map of true expressions. The set of true expressions immediately follows the start card for X1 and ends with the first totally blank card. Any expression that fails in its conversion step (P50) is omitted from the expression set and is printed with M88 to report the difficulty.

Next, X1 reads a set of problem expressions. The problems are converted to tree form and added to the list of unproved expressions (L3). Upon encountering the end of the problem set, X1 links to multiple problem executive M2 which feeds the problems, one at a time, to the single problem executive M1 (Fig. 1).

Executive M2 tries for proofs under two different conditions. If K30 holds "RO," proved theorems are to be added to the set of true expressions, thus retaining results of past efforts for future application.† If K30 does not hold "RO", proved theorems are to be forgotten and each new problem is to be started from scratch.

---

†See Ref. 12.

This procedure for remembering is not the only possible one. Each subproblem in a successful proof sequence is a true theorem in its own right and could be added to the set of true expressions. Modification of LT to incorporate this other kind of remembering might make a good student project. Many experiments might be designed around this part of LT.

Symbols X10 through X19 are used for debugging routines, and X20 through X29 are used for debugging lists.

When X10 is used as the trap value of attribute H3 on the description list of W26, X10 will be executed when the cycle count in H3 becomes equal to W33. X10 sets 1W31 to full trace mode (1W31 = 1) and forces a monitor point with X19 to invoke the change immediately. The trace mode invoked by X10 can be revoked by executing X11 which pops W31 if it has been pushed down and executes X19 to make the change effective immediately.

X10 and X11 are useful when a full trace is desired of a small part of the program that is executed only after a considerable running time. By initially setting W33 to the desired value, the program can run in no-trace mode until W33 equals H3 and then full trace can be invoked for a short time, after which it can again be revoked.

Other similar routines can be designed to meet special needs when they arise. It is difficult to anticipate exactly what will prove useful in all situations.

Routine X13 is used to "snap" (0) at monitor points by loading X13 into W12 and W13. There is some danger in using J150 this way because (0) is not always guaranteed to be a proper list structure. For example, (0) is sometimes a generator subprocess.

Routine X14 is used to obtain a restart tape on an operator signal from the computer console by loading X14 into W14. X14 uses the fact that J166 sets H5+ and the restart mechanism sets H5- in order to stop with a post mortem if just saved or to go on with the program if restarting.

Routine X15 is used to extend the post mortem by loading X15 into W15. The listing in Sec. XV shows that X15 is a simple routine to print L4 (the map of all true expressions).

Routine X19, as mentioned in connection with X10 and X11, is used to force a monitor point in order to make changes in trace mode effective immediately.

The debugging lists (X21-X23) are used by X1 to mark routines for tracing and to set up the trap attribute-value pairs of W26. The technique of marking routines to trace from a given list is simple but effective. The other way to mark for trace is to reload the whole routine with a trace mark (Q = 3 or 4) in its head.

The above mentioned debugging aids were the only ones used to check out the program. Other more sophisticated tools might be designed, but LT's bugs have not required them.

XII. A SAMPLE RUN

This section includes a listing of an input deck for a run and a listing of the resultant output.

INPUT DECK

The input deck includes a modified routine, a modified data structure, and a collection of run parameters and lists. Of particular interest are L6 and L7 which control the order of application of the methods. This run has relatively low limits (K20-K22) and calls for printing of rejected problems (K31) and remembering proved problems (K30).

Following the KICK OFF FOR PROVING THEOREMS are three sets of logic expressions. The first set is to be used as true expressions and includes definitions and axioms. Definition *2.33 will fail in conversion because LT cannot handle expressions such as (PVQVR). The second set contains the theorems to be proved (problems) in this run. The third set will be ignored because it follows the second blank card. It was placed here in order to include in this Memorandum all other theorems from *2, *3, *4, and *5 of <u>Principia Mathematica</u>.

```
  JOB      8168,LTNEW1,EAS826,5MIN,0,C99,C        STEFFERUD
  ASSIGN  A6=SYSAR2
  ASSIGN  B6=SYSAR3
  IPL
      LOGIC THEORIST TEST             9
  RELOAD FROM TAPE 2                  5       4 2
MODIFIED ROUTINES                     5       00                           R
                                      1                                    R
Q17 FIND LEVEL OF SUBSEGMENT            Q17   40W0                  Q017R000
    REPLACEMENT IN TEX (0).                   60W0                  Q017R010
                                              10Q17                 Q017R020
FIND CURRENT LEVEL.                             J10                 Q017R030
IF NONE,                                      70        J30         Q017R040
                                              11W0                  Q017R050
FIND NUMBER OF LEVELS,                          Q2                  Q017R060
    IF NONE, QUIT -.                          70J30                 Q017R065
COPY,                                           J120                Q017R070
SAVE ONE FOR OUTPUT,                          40H0                  Q017R080
                                              11W0                  Q017R090
                                                J6                  Q017R100
AND ASSIGN AS CURRENT LEVEL.                  10Q17                 Q017R110
                                              30W0      J11         Q017R120
```

```
MODIFIED DATA                          5       01                               D
/16 DUMMY EXPRESSION --                  /16     9-1                      /016D000
       'DEFINITIONS'.                            9-2     0                /016D010
                                         9-1     0                        /016D020
                                                 Q15                      /016D030
                                                 Q15                      /016D040
                                                 Q7                       /016D050
                                                         0                /016D060
EXTERNAL NAME                                  21                         /016D070
CONNECTIVE 'I'.                          9-2     I0                       /016D080
                                                 9-10                     /016D090
                                                 9-20    0                /016D100
DUMMY VARIABLE 'DEFIN'.                  9-10            0                /016D110
                                                 0                        /016D120
                                                 Q5                       /016D130
                                                 Q5                       /016D140
                                                 Q9                       /016D150
                                                 Q9                       /016D160
                                                 Q7                       /016D170
                                                         0                /016D180
EXTERNAL NAME.                                 21DEFIN                    /016D190
DUMMY VARIABLE 'TIONS'.                  9-20            0                /016D200
                                                 0                        /016D210
                                                 Q5                       /016D220
                                                 Q5                       /016D230
                                                 Q9                       /016D240
                                                 Q9                       /016D250
                                                 Q7                       /016D260
                                                         0                /016D270
EXTERNAL NAME.                                 21TIONS                    /016D280
RUN DATA HEADER                        5       01                               D  -
LIMIT ON NUMBER OF SUBRROBLEMS           K20   + 1             50         K020D000
LIMIT ON NUMBER OF SUBSTITUTIONS         K21   + 1             50         K021D000
LIMIT ON EFFORT                          K22   + 1    20     0000         K022D000
R= ADD PROVED THEOREMS TO THEOREMS       K30     R                        K030D000
Y = PRINT REJECTED SUBPROBLEMS.          K31     YES                      K031D000
L6 LIST OF METHODS FOR ORIG PROBS        L6      0                        L006D000
                                                 M16                      L006D010
                                                 M17                      L006D020
L7   LIST OF METHODS FOR PROBLEMS.       L7      0                        L007D000
     REPLACEMENT.                                M13                      L007D010
     DETACHMENT.                                 M11                      L007D010
     FORWARD CHAINING.                           M14                      L007D010
     BACKWARD CHAINING.                          M15                      L007D010
W12 SET-UP ENTRY SNAP ACTION.            W12     X13     0                W012D000
W13 SET-UP EXIT SNAP ACTION.             W13     X13     0                W013D000
                                         W15     X15     0                W015D000
                                         X21     0                        X021D000
                                         X22     0                        X022D000
DESCRIPTION LIST OF TRAP ACTIONS.        X23     0                        X023D000
```

```
KICK OFF FOR PROVING THEOREMS.      5          X1
  *1.01   ((PIQ).=.(-PVQ))  DEF.
  *2.33   ((PVQVR).=.((PVQ)VR)) DEF.                          X
  *3.01   ((P*Q).=.-(-PV-Q)) DEF.
  *4.01   ((P=Q).=.((PIQ)*(QIP))) DEF.
  *1.2    ((AVA)IA)
  *1.3    (BI(AVB))
  *1.4    ((AVB)I(BVA))
  *1.5    ((AV(BVC))I(BV(AVC)))
  *1.6    ((BIC)I((AVB)I(AVC)))

  *2.01   ((PI-P)I-P)
  *2.02   (QI(PIQ))
  *2.03   ((PI-Q)I(QI-P))
  *2.04   ((PI(QIR))I(QI(PIR)))
  *2.05   ((QIR)I((PIQ)I(PIR)))
  *2.06   ((PIQ)I((QIR)I(PIR)))
  *2.07   (PI(PVP))
  *2.08   (PIP)
  *2.10   (-PVP)
  *2.11   (PV-P)
  *2.12   (PI--P)
  *2.13   (PV---P)
  *2.14   (--PIP)
  *2.15   ((-PIQ)I(-QIP))
  *2.20   (PI(PVQ))
  *2.21   (-PI(PIQ))
  *2.24   (PI(-PIQ))
  *3.13   (-(P*Q)I(-PV-Q))
  *3.14   ((-PV-Q)I-(P*Q))
  *3.24   -(P*-P)
  *4.13   (P=--P)
  *4.20   (P=P)
  *4.24   (P=(P*P))
  *4.25   (P=(PVP))

  *3.02   ((PIQIR).=.((PIQ)*(QIR)))  DEF.
  *4.02   ((P=Q=R).=.((P=Q)*(Q=R))) DEF.                      X
  *4.34   ((P*Q*R).=.((P*Q)*R)) DEF.                          X
  *2.16   ((PIQ)I(-QI-P))
  *2.17   ((-QI-P)I(PIQ))
  *2.18   ((-PIP)IP)
  *2.25   (PV((PVQ)IQ))
  *2.26   (-PV((PIQ)IQ))
  *2.27   (PI((PIQ)IQ))
  *2.30   ((PV(QVR))I(PV(RVQ)))
  *2.31   ((PV(QVR))I((PVQ)VR))
  *2.32   (((PVQ)VR)I(PV(QVR)))
  *2.36   ((QIR)I((PVQ)I(RVP)))
  *2.37   ((QIR)I((QVP)I(PVR)))
  *2.38   ((QIR)I((QVP)I(RVP)))
```

```
*2.40   ((PV(PVQ))I(PVQ))
*2.41   ((QV(PVQ))I(PVQ))
*2.42   ((-PV(PIQ))I(PIQ))
*2.43   ((PI(PIQ))I(PIQ))
*2.45   (-(PVQ)I-P)
*2.46   (-(PVQ)I-Q)
*2.47   (-(PVQ)I(-PVQ))
*2.48   (-(PVQ)I(PV-Q))
*2.49   (-(PVQ)I(-PV-Q))
*2.50   (-(PIQ)I(-PIQ))
*2.51   (-(PIQ)I(PI-Q))
*2.52   (-(PIQ)I(-PI-Q))
*2521   (-(PIQ)I(QIP))
*2.53   ((PVQ)I(-PIQ))
*2.54   ((-PIQ)I(PVQ))
*2.55   (-PI((PVQ)IQ))
*2.56   (-QI((PVQ)IP))
*2.60   ((-PIQ)I((PIQ)IQ))
*2.61   ((PIQ)I((-PIQ)IQ))
*2.62   ((PVQ)I((PIQ)IQ))
*2621   ((PIQ)I((PVQ)IQ))
*2.63   ((PVQ)I((-PVQ)IQ))
*2.64   ((PVQ)I((PV-Q)IP))
*2.65   ((PIQ)I((PI-Q)I-P))
*2.67   (((PVQ)IQ)I(PIQ))
*2.68   (((PIQ)IQ)I(PVQ))
*2.69   (((PIQ)IQ)I((QIP)IP))
*2.73   ((PIQ)I((PVQVR)I(QVR)))                         X
*2.74   ((QIP)I((PVQVR)I(PVR)))                         X
*2.75   ((PVQ)I((PV(QIR))I(PVR)))
*2.76   ((PV(QIR))I((PVQ)I(PVR)))
*2.77   ((PI(QIR))I((PIQ)I(PIR)))
*2.80   ((QVR)I((-RVS)I(QVS)))
*2.81   ((QI(RIS))I((PVQ)I((PVR)I(PVS))))
*2.82   ((PVQVR)I((PV-RVS)I(PVQVS)))                    X
*2.83   ((PI(QIR))I((PI(RIS))I(PI(QIS))))
*2.85   (((PVQ)I(PVR))I(PV(QIR)))
*2.86   (((PIQ)I(PIR))I(PI(QIR)))
*3.10   ((P*Q)I-(-PV-Q))
*3.11   (-(-PV-Q)I(P*Q))
*3.12   ((-PV-Q)V(P*Q))
*3.20   (PI(QI(P*Q)))
*3.21   (QI(PI(P*Q)))
*3.22   ((P*Q)I(Q*P))
*3.26   ((P*Q)IP)
*3.27   ((P*Q)IQ)
*3.30   (((P*Q)IR)I(PI(QIR)))
*3.31   ((PI(QIR))I((P*Q)IR))
*3.33   (((PIQ)*(QIR))I(PIR))
*3.34   (((QIR)*(PIQ))I(PIR))
*3.35   ((P*(PIQ))IQ)
```

```
*3.37   (((P*Q)IR)I((P*-R)I-Q))
*3.40   ((P*Q)I(PIQ))
*3.41   ((PIR)I((P*Q)IR))
*3.42   ((QIR)I((P*Q)IR))
*3.43   (((PIQ)*(PIR))I(PI(Q*R)))
*3.44   (((QIR)*(RIP))I((QVR)IP))
*3.45   ((PIQ)I((P*R)I(Q*R)))
*3.47  (((PIR)*(QIS))I((P*Q)I(R*S)))
*3.48  (((PIR)*(QIS))I((PVQ)I(RVS)))
*4.10   ((PIQ)=(-QI-P))
*4.11   ((P=Q)=(-P=-Q))
*4.12   ((P=-Q)=(Q=-P))
*4.14   (((P*Q)IR)=((P*-R)I-Q))
*4.15   (((P*Q)I-R)=((Q*R)I-P))
*4.21   ((P=Q)=(Q=P))
*4.22   (((P=Q)*(Q=R))I(P=R))
*4.30   ((P*Q)=(Q*P))
*4.31   ((PVQ)=(QVP))
*4.32   (((P*Q)*R)=(P*(Q*R)))
*4.33   (((PVQ)VR)=(PV(QVR)))
*4.36   ((P=Q)I((P*R)=(Q*R)))
*4.37   ((P=Q)I((PVR)=(QVR)))
*4.38   (((P=R)*(Q=S))I((P*Q)=(R*S)))
*4.39   (((P=R)*(Q=S))I((PVQ)=(RVS)))
*4.40   ((P*(QVR))=((P*Q)V(P*R)))
*4.41   ((PV(Q*R))=((PVQ)*(PVR)))
*4.42   (P=((P*Q)V(P*-Q)))
*4.43   (P=((PVQ)*(PV-Q)))
*4.44   (P=(PV(P*Q)))
*4.45   (P=(P*(PVQ)))
*4.50   ((P*Q)=-(-PV-Q))
*4.51   (-(P*Q)=(-PV-Q))
*4.52   ((P*-Q)=-(-PVQ))
*4.53   (-(P*-Q)=-(PVQ))
*4.54   ((-P*Q)=-(PV-Q))
*4.55   (-(-P*Q)=(PV-Q))
*4.56   ((-P*-Q)=-(PVQ))
*4.57   (-(-P*-Q)=(PVQ))
*4.60   ((PIP)=(-PVQ))
*4.61   (-(PIQ)=(P*-Q))
*4.62   ((PI-Q)=(-PV-Q))
*4.63   (-(PI-Q)=(P*Q))
*4.64   ((-PIQ)=(PVQ))
*4.65   (-(-PIQ)=(-P*-Q))
*4.66   ((-P*-Q)=(PV-Q))
*4.67   (-(-PI-Q)=(-P*Q))
*4.70   ((PIQ)=(PI(P*Q)))
*4.71   ((PIQ)=(P=(P*Q)))
*4.72   ((PIQ)=(Q=(PVQ)))
*4.73   (QI(P=(P*Q)))
*4.74   (-PI(Q=(PVQ)))
```

```
*4.76    (((PIQ)*(PIR))=(PI(Q*R)))
*4.77    (((QIP)*(RIP))=((QVR)IP))
*4.78    (((PIQ)V(PIR))=(PI(QVR)))
*4.79    (((QIP)V(RIP))=((Q*R)IP))
*4.80    ((PI-P)=-P)
*4.81    ((-PIP)=P)
*4.82    (((PIQ)*(PI-Q))=-P)
*4.83    (((PIQ)*(-PIQ))=Q)
*4.84    ((P=Q)I((PIR)=(QIR)))
*4.85    ((P=Q)I((RIP)=(RIQ)))
*4.86    ((P=Q)I((P=R)=(Q=R)))
*4.87    (((P*Q)IR)=(PI(QIR))=(QI(PIR)=(Q*P)IR))                X
*5.30    (((P*Q)IR)=((P*Q)I(P*R)))
*5.31    (((R*P)IQ)I(PI(Q*R)))
*5.32    ((PI(Q=R))=((P*Q)=(P*R)))
*5.33    ((P*(QIR))=(P*((P*Q)IR)))
*5.35    (((PIQ)*(PIR))I(PI(Q=R)))
*5.36    ((P*(P=Q))=(Q*(P=Q)))
*5.40    ((PI(PIQ))=(PIQ))
*5.41    (((PIQ)I(PIR))=(PI(QIR)))
*5.42    ((PI(QIR))=(PI(QI(P*R))))
*5.44    ((PIQ)I((PIR)=(PI(Q*R))))
*5.50    (PI((PIQ)=Q))
*5501    (PI(Q=(P=Q)))
*5.53    (((PVQVR)IS)=((PIS)*(QIS)*(RIS)))                      X
*5.54    (((P*Q)=P)V((P*Q)=Q))
*5.55    (((PVQ)=P)V((PVQ)=Q))
*5.60    (((P*-Q)IR)=(PI(QVR)))
*5.61    (((PVQ)*-Q)=(P*-Q))
*5.62    (((P*Q)V-Q)=(PV-Q))
*5.63    ((PVQ)=(PV(-P*Q)))
*5.70    (((PVR)=(QVR))=(RV(P=Q)))
*5.71    ((QI-R)I(((PVQ)*R)=(P*R)))
*5.74    ((PI(Q=R))=((PIQ)=(PIR))
*5.75    (((RI-Q)*(P=(QVR)))I((P*-Q)=R))
```

OUTPUT

The output from the sample run shows that the run commences from a restart. After the loader listings, the true expressions and problems for the run are listed. Note that *2.33 failed and that all true expressions have had their bound variable replaced by free variables.

Next come the proof printouts. First the problem is printed, then the subproblems are printed in the order of generation. Then, if a proof is found, it is printed along with a statement of effort applied. Finally, each proved theorem that is remembered is printed as it appears with its bound variables replaced.

At the end of the run, an IPL-V post mortem printout appears with a printout of the true expressions map as it appeared at the conclusion of the run. At the end of this sample run the map uses approximately 500 cells and holds approximately 30 expressions, which is about 17 cells per expression. With more expressions in the map, it becomes considerably more efficient.

```
     JOB       8168,LTNEW1,EAS826,5MIN,0,099,C         STEFFERUD              1  003650  06/05/63

ASSIGN  A6=SYSAR2
ASSIGN  B6=SYSAR3
IPL

   LOGIC THEORIST TEST            9

      RELOAD FROM TAPE 2                   5        4 ?

MEMORY  RELOADED  FROM  TAPE  A6. 3956     0 0 J166  J165
```

```
    MODIFIED ROUTINES                                5       00                              R
                                                     1                                       R
671     4 0 24587 3976                      Q17      4 0 W0            Q17 FIND LEVEL OF SUBSEGMENT             Q017R000
3976    6 0 24587 3975                               6 0 W0                REPLACEMENT IN TEX (0).              Q017R010
3975    1 0 671   3977                               1 0 Q17                                                    Q017R020
3977    0 0 24770 3978                                   J10           FIND CURRENT LEVEL.                      Q017R030
3978    7 0 3979  24790                              7 0         J30   IF NONE,                                 Q017R040
3979    1 1 24587 3980                               1 1 W0                                                     Q017R050
3980    0 0 656   3981                                   Q2            FIND NUMBER OF LEVELS,                   Q017R060
3981    7 0 24790 3982                               7 0 J30               IF NONE, QUIT -.                     Q017R065
3982    0 0 24880 3983                                   J120          COPY,                                    Q017R070
3983    4 0 24574 3984                               4 0 H0            SAVE ONE FOR OUTPUT,                     Q017R080
3984    1 1 24587 3985                               1 1 W0                                                     Q017R090
3985    0 0 24766 3986                                   J6                                                     Q017R100
3986    1 0 671   3987                               1 0 Q17           AND ASSIGN AS CURRENT LEVEL.             Q017R110
3987    3 0 24587 24771                              3 0 W0      J11                                            Q017R120
```

```
   MODIFIED DATA                          5       01                                D
1540    0 2 3989   3988       /16            9-1        /16 DUMMY EXPRESSION --                /016D000
3988    0 2 3990   0                         9-2    0           'DEFINITIONS'.                 /016D010
3989    0 4 0      3991       9-1            0                                                 /016D020
3991    0 0 669    3992                      Q15                                               /016D030
3992    0 0 669    3993                      Q15                                               /016D040
3993    0 0 661    3994                      Q7                                                /016D050
3994    0 2 3995   0                                0                                          /016D060
3995    2 1                               2 1               EXTERNAL NAME                      /016D070
3990    0 0 134    3996       9-2            I0             CONNECTIVE 'I'.                    /016D080
3996    0 2 3998   3997                      9-10                                              /016D090
3997    0 2 3999   0                         9-20   0                                          /016D100
3998    0 2 4000   0          9-10                  0       DUMMY VARIABLE 'DEFIN'.            /016D110
4000    0 4 0      4001                      0                                                 /016D120
4001    0 0 659    4002                      Q5                                                /016D130
4002    0 0 659    4003                      Q5                                                /016D140
4003    0 0 663    4004                      Q9                                                /016D150
4004    0 0 663    4005                      Q9                                                /016D160
4005    0 0 661    4006                      Q7                                                /016D170
4006    0 2 4007   0                                0                                          /016D180
4007    2 1        DEFIN                  2 1 DEFIN         EXTERNAL NAME.                     /016D190
3999    0 2 4008   0          9-20                  0       DUMMY VARIABLE 'TIONS'.            /016D200
4008    0 4 0      4009                      0                                                 /016D210
4009    0 0 659    4010                      Q5                                                /016D220
4010    0 0 659    4011                      Q5                                                /016D230
4011    0 0 663    4012                      Q9                                                /016D240
4012    0 0 663    4013                      Q9                                                /016D250
4013    0 0 661    4014                      Q7                                                /016D260
4014    0 2 4015   0                                0                                          /016D270
4015    2 1        TIONS                  2 1 TIONS         EXTERNAL NAME.                     /016D280
```

```
    RUN DATA HEADER                              5        01                               D  -
164      0 1              50           K20    +    1            50 LIMIT ON NUMBER OF SUBRROBLEMS                  K020D000
165      0 1              50           K21    +    1            50 LIMIT ON NUMBER OF SUBSTITUTIONS                K021D000
166      0 1          200000           K22    +    1     20   0000 LIMIT ON EFFORT                                 K022D000
174      0 0 704    0                  K30              R             R= ADD PROVED THEOREMS TO THEOREMS           K030D000
175      0 0 834    0                  K31              YES           Y = PRINT REJECTED SUBPROBLEMS.              K031D000
250      0 4 0      4016               L6               0             L6 LIST OF METHODS FOR ORIG PROBS            L006D000
4016     0 0 310    4017                                M16                                                        L006D010
4017     0 0 311    0                                   M17                                                        L006D020
251      0 4 0      4018               L7               0             L7  LIST OF METHODS FOR PROBLEMS.            L007D000
4018     0 0 307    4019                                M13                REPLACEMENT.                            L007D010
4019     0 0 305    4020                                M11                DETACHMENT.                             L007D010
4020     0 0 308    4021                                M14                FORWARD CHAINING.                       L007D010
4021     0 0 309    0                                   M15                BACKWARD CHAINING.                      L007D010
24599    0 0 797    0                  W12              X13    0      W12 SET-UP ENTRY SNAP ACTION.                W012D000
24600    0 0 797    0                  W13              X13    0      W13 SET-UP EXIT SNAP ACTION.                 W013D000
24602    0 0 799    0                  W15              X15    0                                                   W015D000
805      0 4 0      0                  X21              0                                                          X021D000
806      0 4 0      0                  X22              0                                                          X022D000
807      0 4 0      0                  X23              0             DESCRIPTION LIST OF TRAP ACTIONS.            X023D000
    KICK OFF FOR PROVING THEOREMS.               5          X1

END OF LOADING. PROGRAM STARTS AT X1        1 1 W26    3921

NUMBER OF CELLS ON AVAILABLE SPACE=17978
```

```
*1.01   (AIB).=.(-AVB) DEF.
BAD EXPRESSION   ((PVQ/UGH/VR).=.((PVQ)VR))
*3.01   (A*B).=.(-(-AV-B)) DEF.
*4.01   (A=B).=.((AIB)*(BIA)) DEF.
*1.2    (AVA)IA
*1.3    BI(AVB)
*1.4    (AVB)I(BVA)
*1.5    (AV(BVC))I(BV(AVC))
*1.6    (BIC)I((AVB)I(AVC))

*2.01   (PI-P)I-P
*2.02   QI(PIQ)
*2.03   (PI-Q)I(QI-P)
*2.04   (PI(QIR))I(QI(PIR))
*2.05   (QIR)I((PIQ)I(PIR))
*2.06   (PIQ)I((QIR)I(PIR))
*2.07   PI(PVP)
*2.08   PIP
*2.10   -PVP
*2.11   PV-P
*2.12   PI--P
*2.13   PV---P
*2.14   --PIP
*2.15   (-PIQ)I(-QIP)
*2.20   PI(PVQ)
*2.21   -PI(PIQ)
*2.24   PI(-PIQ)
*3.13   (-(P*Q))I(-PV-Q)
*3.14   (-PV-Q)I(-(P*Q))
*3.24   -(P*-P)
*4.13   P=--P
*4.20   P=P
*4.24   P=(P*P)
*4.25   P=(PVP)
```

```
TO PROVE
*2.01   (PI-P)I-P
           1.   (-PV-P)I-P                              , SUBLEVEL REPLACEMENT


 PROOF FOUND.
                                                 *1.2      (AVA)IA
          GIVEN                                  1.        (-PV-P)I-P
          SUBSTITUTION                                     DEFINITIONS
          GIVEN                                  *2.01     (PI-P)I-P
          SUBLEVEL REPLACEMENT
          Q.E.D.

EFFORT                LIMIT 200000           ACTUAL 8062
SUBPROBLEMS           LIMIT 50               ACTUAL 1
SUBSTITUTIONS         LIMIT 50               ACTUAL 2

   REMEMBER PROVED THEOREM

*2.01    (AI-A)I-A
```

```
TO PROVE
*2.02   QI(PIQ)
        1.   QI(-PVQ)                                 , SUBLEVEL REPLACEMENT


 PROOF FOUND.

        GIVEN                              *1.3       BI(AVB)
        SUBSTITUTION                       1.         QI(-PVQ)
        GIVEN                                         DEFINITIONS
        SUBLEVEL REPLACEMENT               *2.02      QI(PIQ)
        Q.E.D.

EFFORT              LIMIT 200000           ACTUAL 6041
SUBPROBLEMS         LIMIT 50               ACTUAL 1
SUBSTITUTIONS       LIMIT 50               ACTUAL 2

   REMEMBER PROVED THEOREM

*2.02   AI(BIA)
```

```
TO PROVE
*2.03    (PI-Q)I(QI-P)
         1.   (-PV-Q)I(-QV-P)                    , SUBLEVEL REPLACEMENT


 PROOF FOUND.

         GIVEN                         *1.4     (AVB)I(BVA)
         SUBSTITUTION                  1.       (-PV-Q)I(-QV-P)
         GIVEN                                  DEFINITIONS
         SUBLEVEL REPLACEMENT          *2.03    (PI-Q)I(QI-P)
         Q.E.D.

EFFORT              LIMIT 200000       ACTUAL 11904
SUBPROBLEMS         LIMIT 50           ACTUAL 1
SUBSTITUTIONS       LIMIT 50           ACTUAL 2

   REMEMBER PROVED THEOREM

*2.03    (AI-B)I(BI-A)
```

```
TO PROVE
*2.04    (PI(QIR))I(QI(PIR))
           1.    (PI(-QVR))I(QI(-PVR))              , SUBLEVEL REPLACEMENT
           2.    (-PV(QIR))I(-QV(PIR))              , SUBLEVEL REPLACEMENT
           3.    (-PV(-QVR))I(-QV(-PVR))            , SUBLEVEL REPLACEMENT

 PROOF FOUND.

          GIVEN                            *1.5     (AV(BVC))I(BV(AVC))
          SUBSTITUTION                     3.       (-PV(-QVR))I(-QV(-PVR))
          GIVEN                                     DEFINITIONS
          SUBLEVEL REPLACEMENT             *2.04    (PI(QIR))I(QI(PIR))
          Q.E.D.

EFFORT              LIMIT 200000          ACTUAL 32262
SUBPROBLEMS         LIMIT 50              ACTUAL 3
SUBSTITUTIONS       LIMIT 50              ACTUAL 4

   REMEMBER PROVED THEOREM

*2.04    (AI(BIC))I(BI(AIC))
```

```
TC PROVE
*2.05   (QIR)I((PIQ)I(PIR))
           1.    (QIR)I((-PVQ)I(-PVR))              , SUBLEVEL REPLACEMENT


 PROOF FOUND.

           GIVEN                             *1.6      (BIC)I((AVB)I(AVC))
           SUBSTITUTION                      1.        (QIR)I((-PVQ)I(-PVR))
           GIVEN                                       DEFINITIONS
           SUBLEVEL REPLACEMENT              *2.05     (QIR)I((PIQ)I(PIR))
           Q.E.D.


EFFORT              LIMIT 200000        ACTUAL 13440
SUBPROBLEMS         LIMIT 50            ACTUAL 1
SUBSTITUTIONS       LIMIT 50            ACTUAL 2


   REMEMBER PROVED THEOREM

*2.05   (AIB)I((CIA)I(CIB))
```

```
TC PROVE
*2.06    (PIQ)I((QIR)I(PIR))
           1.    (PIQ)I((-QVR)I(-PVR))                , SUBLEVEL REPLACEMENT
           2.    (-PVQ)I((-(QIR))V(PIR))              , SUBLEVEL REPLACEMENT
           3.    (-PVQ)I((-(-QVR))V(-PVR))            , SUBLEVEL REPLACEMENT
           4.    (-(PIQ))V((QIR)I(PIR))          *1.01, REPLACEMENT
           5.    (QIR)I((PIQ)I(PIR))             *2.04, DETACHMENT

 PROOF FOUND.

          GIVEN                              *2.05     (AIB)I((CIA)I(CIB))
          SUBSTITUTION                       5.        (QIR)I((PIQ)I(PIR))
          GIVEN                              *2.04     (AI(BIC))I(BI(AIC))
          DETACHMENT                         *2.06     (PIQ)I((QIR)I(PIR))
          Q.E.D.

EFFORT             LIMIT 200000          ACTUAL 46665
SUBPROBLEMS        LIMIT 50              ACTUAL 5
SUBSTITUTIONS      LIMIT 50              ACTUAL 6

   REMEMBER PROVED THEOREM

*2.06    (AIB)I((BIC)I(AIC))
```

```
TO PROVE
*2.07   PI(PVP)


 PROOF FOUND.

          GIVEN                                   *1.3      BI(AVB)
          SUBSTITUTION                            *2.07     PI(PVP)
          Q.E.D.

EFFORT              LIMIT 200000        ACTUAL 2623
SUBPROBLEMS         LIMIT 50            ACTUAL 0
SUBSTITUTIONS       LIMIT 50            ACTUAL 1

   REMEMBER PROVED THEOREM

*2.07   AI(AVA)
```

```
TC PROVE
*2.08   PIP
        1.    -PVP                        *1.01, REPLACEMENT
        5088   P                          *2.02, DETACHMENT.  REJECTED PROBLEM
        5193   (PIP)V(PIP)                *1.2, DETACHMENT.  REJECTED PROBLEM
        2.    (PVP)IP                     *2.07, FORWARD CHAINING

 PROOF FOUND.

        GIVEN                        *1.2       (AVA)IA
        SUBSTITUTION                 2.         (PVP)IP
        GIVEN                        *2.07      AI(AVA)
        FORWARD CHAINING             *2.08      PIP
        Q.E.D.

EFFORT             LIMIT 200000      ACTUAL 8998
SUBPROBLEMS        LIMIT 50          ACTUAL 2
SUBSTITUTIONS      LIMIT 50          ACTUAL 3

  REMEMBER PROVED THEOREM

*2.08   AIA
```

```
TO PROVE
*2.10    -PVP
         1.    PIP                                *1.01, REPLACEMENT


 PROOF FOUND.

         GIVEN                                    *2.08     AIA
         SUBSTITUTION                             1.        PIP
         GIVEN                                    *1.01     (AIB).=.(-AVB) DEF.
         REPLACEMENT                              *2.10     -PVP
         Q.E.D.


EFFORT              LIMIT 200000                  ACTUAL 5150
SUBPROBLEMS         LIMIT 50                      ACTUAL 1
SUBSTITUTIONS       LIMIT 50                      ACTUAL 2

   REMEMBER PROVED THEOREM

*2.10    -AVA
```

```
TO PROVE
*2.11    PV-P
          1.    -PVP                              *1.4, DETACHMENT


 PROOF FOUND.

          GIVEN                                 *2.10     -AVA
          SUBSTITUTION                          1.        -PVP
          GIVEN                                 *1.4      (AVB)I(BVA)
          DETACHMENT                            *2.11     PV-P
          Q.E.D.

EFFORT                LIMIT 200000              ACTUAL 6190
SUBPROBLEMS           LIMIT 50                  ACTUAL 1
SUBSTITUTIONS         LIMIT 50                  ACTUAL 2

   REMEMBER PROVED THEOREM

*2.11    AV-A
```

```
TO PROVE
*2.12   PI--P
          1.    -PV--P                          *1.01, REPLACEMENT


 PROOF FOUND.

          GIVEN                                 *2.11     AV-A
          SUBSTITUTION                          1.        -PV--P
          GIVEN                                 *1.01     (AIB).=.(-AVB) DEF.
          REPLACEMENT                           *2.12     PI--P
          Q.E.D.

EFFORT              LIMIT 200000                ACTUAL 8215
SUBPROBLEMS         LIMIT 50                    ACTUAL 1
SUBSTITUTIONS       LIMIT 50                    ACTUAL 2

   REMEMBER PROVED THEOREM

*2.12   AI--A
```

```
TO PROVE
*2.13   PV---P
          1.    ---PVP                          *1.4, DETACHMENT
          5062   ---P                           *1.3, DETACHMENT.  REJECTED PROBLEM
          5304   PV---P                         *2.08, DETACHMENT.  REJECTED PROBLEM
          5199   (PV---P)V(PV---P)              *1.2, DETACHMENT.  REJECTED PROBLEM
          2.    -PI---P                         *2.11, FORWARD CHAINING

 PROOF FOUND.

          GIVEN                        *2.12      AI--A
          SUBSTITUTION                 2.         -PI---P
          GIVEN                        *2.11      AV-A
          FORWARD CHAINING             *2.13      PV---P
          Q.E.D.

EFFORT               LIMIT 200000      ACTUAL 18263
SUBPROBLEMS          LIMIT 50          ACTUAL 2
SUBSTITUTIONS        LIMIT 50          ACTUAL 3

   REMEMBER PROVED THEOREM

*2.13   AV---A
```

```
TO PROVE
*2.14    --PIP
          1.    ---PVP                         *1.01, REPLACEMENT
          5187   P                             *2.02, DETACHMENT.  REJECTED PROBLEM
          5090   --PIP                         *2.08, DETACHMENT.  REJECTED PROBLEM
          5149   (--PIP)V(--PIP)               *1.2, DETACHMENT.  REJECTED PROBLEM
          2.    ----PIP                        *2.12, FORWARD CHAINING
          5339   --PIP                         *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          3.    (--PV--P)IP                    *2.07, FORWARD CHAINING
          4.    (BI--P)IP                      *2.02, FORWARD CHAINING
          5.    (AV--P)IP                      *1.3, FORWARD CHAINING
          5379   --PIP                         *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
          6.    --PI(PVP)                      *1.2, BACKWARD CHAINING
6.       --PI(PVP)
          7.    ---PV(PVP)                     *1.01, REPLACEMENT
          5051   PVP                           *2.02, DETACHMENT.  REJECTED PROBLEM
          5245   --PI(PVP)                     *2.08, DETACHMENT.  REJECTED PROBLEM
          5552   (--PI(PVP))V(--PI(PVP))       *1.2, DETACHMENT.  REJECTED PROBLEM
          8.    ----PI(PVP)                    *2.12, FORWARD CHAINING
          5612   --PI(PVP)                     *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          9.    (--PV--P)I(PVP)                *2.07, FORWARD CHAINING
          10.    (BI--P)I(PVP)                 *2.02, FORWARD CHAINING
          11.    (AV--P)I(PVP)                 *1.3, FORWARD CHAINING
          5500   --PIP                         *2.07, BACKWARD CHAINING.  REJECTED PROBLEM
          5737   --PI(PVP)                     *1.4, BACKWARD CHAINING.  REJECTED PROBLEM
          5780   --PIP                         *1.3, BACKWARD CHAINING.  REJECTED PROBLEM
          5653   --PI(PVP)                     *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
          12.    --PI((PVP)V(PVP))             *1.2, BACKWARD CHAINING
12.      --PI((PVP)V(PVP))
          13.    ---PV((PVP)V(PVP))            *1.01, REPLACEMENT
          5286   (PVP)V(PVP)                   *2.02, DETACHMENT.  REJECTED PROBLEM
          4842   --PI((PVP)V(PVP))             *2.08, DETACHMENT.  REJECTED PROBLEM
          5854   (--PI((PVP)V(PVP)))V(--PI((PVP)V(PVP)))  *1.2, DETACHMENT.  REJECTED PROBLEM
          14.    ----PI((PVP)V(PVP))           *2.12, FORWARD CHAINING
          5846   --PI((PVP)V(PVP))             *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          15.    (--PV--P)I((PVP)V(PVP))       *2.07, FORWARD CHAINING
          16.    (BI--P)I((PVP)V(PVP))         *2.02, FORWARD CHAINING
          17.    (AV--P)I((PVP)V(PVP))         *1.3, FORWARD CHAINING
          6031   --PI(PVP)                     *2.07, BACKWARD CHAINING.  REJECTED PROBLEM
          18.    --PI(PV((PVP)VP))             *1.5, BACKWARD CHAINING
          6059   --PI((PVP)V(PVP))             *1.4, BACKWARD CHAINING.  REJECTED PROBLEM
          6092   --PI(PVP)                     *1.3, BACKWARD CHAINING.  REJECTED PROBLEM
          5995   --PI((PVP)V(PVP))             *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
          19.    --PI(((PVP)V(PVP))V((PVP)V(PVP)))  *1.2, BACKWARD CHAINING
1.       ---PVP
          6102   --PIP                         *1.01, REPLACEMENT.  REJECTED PROBLEM
          20.    PV---P                        *1.4, DETACHMENT

 PROOF FOUND.

          GIVEN                      *2.13     AV---A
          SUBSTITUTION               20.       PV---P
          GIVEN                      *1.4      (AVB)I(BVA)
          DETACHMENT                 1.        ---PVP
          GIVEN                      *1.01     (AIB).=.(-AVB) DFF.
          REPLACEMENT                *2.14     --PIP
          Q.E.D.
```

```
EFFORT              LIMIT 200000        ACTUAL 181261
SUBPROBLEMS         LIMIT 50            ACTUAL 20
SUBSTITUTIONS       LIMIT 50            ACTUAL 21

   REMEMBER PROVED THEOREM

*2.14    --AIA
```

```
TO PROVE
*2.15    (-PIQ)I(-QIP)
          1.    (--PVQ)I(--QVP)                   , SUBLEVEL REPLACEMENT
          5126    (--PVQ)I(--QVP)                 , SUBLEVEL REPLACEMENT.  REJECTED PROBLEM
          2.    (-(-PIQ))V(-QIP)                  *1.01, REPLACEMENT
          3.    -QI((-PIQ)IP)                     *2.04, DETACHMENT
          4.    -QIP                              *2.02, DETACHMENT
          5.    -(-((-PIQ)I(-QIP)))               *2.14, DETACHMENT
          5539    (-PIQ)I(-QIP)                   *2.08, DETACHMENT.  REJECTED PROBLEM
          5273    ((-PIQ)I(-QIP))V((-PIQ)I(-QIP))  *1.2, DETACHMENT.  REJECTED PROBLEM
          6.    ((QIC)I(-PIC))I(-QIP)             *2.06, FORWARD CHAINING
          7.    ((CI-P)I(CIQ))I(-QIP)             *2.05, FORWARD CHAINING
          8.    ((AV-P)I(AVQ))I(-QIP)             *1.6, FORWARD CHAINING
          9.    (-(-(-PIQ)))I(-QIP)               *2.12, FORWARD CHAINING
          6071    (-PIC)I(-QIP)                   *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          10.    ((-PIQ)V(-PIQ))I(-QIP)           *2.07, FORWARD CHAINING
          11.    (BI(-PIQ))I(-QIP)                *2.02, FORWARD CHAINING
          12.    (AV(-PIQ))I(-QIP)                *1.3, FORWARD CHAINING
          13.    (-PIQ)IP                         *2.02, BACKWARD CHAINING
          14.    (-PIQ)I(-(-(-QIP)))              *2.14, BACKWARD CHAINING
          5757    (-PIQ)I(-QIP)                   *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
          15.    (-PIQ)I((-QIP)V(-QIP))           *1.2, BACKWARD CHAINING
4.      -QIP
          16.    --QVP                            *1.01, REPLACEMENT
          5882    P                               *2.02, DETACHMENT.  REJECTED PROBLEM
          17.    -(-(-QIP))                       *2.14, DETACHMENT
          6171    -QIP                            *2.08, DETACHMENT.  REJECTED PROBLEM
          5396    (-QIP)V(-QIP)                   *1.2, DETACHMENT.  REJECTED PROBLEM
          18.    ---QIP                           *2.12, FORWARD CHAINING
          5396    -CIP                            *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          19.    (-QV-Q)IP                        *2.07, FORWARD CHAINING
          20.    (BI-Q)IP                         *2.02, FORWARD CHAINING
          21.    (AV-Q)IP                         *1.3, FORWARD CHAINING
          22.    -QI--P                           *2.14, BACKWARD CHAINING
          6183    -CIP                            *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
          23.    -QI(PVP)                         *1.2, BACKWARD CHAINING
23.     -QI(PVP)
          24.    --CV(PVP)                        *1.01, REPLACEMENT
          5836    PVP                             *2.02, DETACHMENT.  REJECTED PROBLEM
          25.    -(-(-QI(PVP)))                   *2.14, DETACHMENT
          6364    -QI(PVP)                        *2.08, DETACHMENT.  REJECTED PROBLEM
          6420    (-CI(PVP))V(-QI(PVP))           *1.2, DETACHMENT.  REJECTED PROBLEM
          26.    ---QI(PVP)                       *2.12, FORWARD CHAINING
          6459    -QI(PVP)                        *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          27.    (-QV-C)I(PVP)                    *2.07, FORWARD CHAINING
          28.    (BI-Q)I(PVP)                     *2.02, FORWARD CHAINING
          29.    (AV-Q)I(PVP)                     *1.3, FORWARD CHAINING
          6580    -QIP                            *2.07, BACKWARD CHAINING.  REJECTED PROBLEM
          6601    -QI(PVP)                        *1.4, BACKWARD CHAINING.  REJECTED PROBLEM
          6563    -CIP                            *1.3, BACKWARD CHAINING.  REJECTED PROBLEM
          30.    -QI(-(-(PVP)))                   *2.14, BACKWARD CHAINING
          6627    -QI(PVP)                        *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
          31.    -QI((PVP)V(PVP))                 *1.2, BACKWARD CHAINING
NO PROOF FOUND

EFFORT              LIMIT 200000        ACTUAL 206728
SUBPROBLEMS         LIMIT 50            ACTUAL 31
SUBSTITUTIONS       LIMIT 50            ACTUAL 32
```

```
TO PROVE
*2.20   PI(PVQ)
          1.    -PV(PVQ)                    *1.01, REPLACEMENT
          2.    PVQ                         *2.02, DETACHMENT
          3.    -(-(PI(PVQ)))               *2.14, DETACHMENT
          5676    PI(PVQ)                   *2.08, DETACHMENT.  REJECTED PROBLEM
          5675    (PI(PVQ))V(PI(PVQ))       *1.2, DETACHMENT.  REJECTED PROBLEM
          4.    --PI(PVQ)                   *2.12, FORWARD CHAINING
          6012    PI(PVQ)                   *2.08, FORWARD CHAINING.  REJECTED PROBLEM
          5.    (PVP)I(PVQ)                 *2.07, FORWARD CHAINING
          6.    (BIP)I(PVQ)                 *2.02, FORWARD CHAINING
          7.    (AVP)I(PVQ)                 *1.3, FORWARD CHAINING

 PROOF FOUND.

        GIVEN                       *1.4      (AVB)I(BVA)
        SUBSTITUTION                7.        (CVP)I(PVQ)
        GIVEN                       *1.3      BI(AVB)
        FORWARD CHAINING            *2.20     PI(PVQ)
        Q.E.D.

EFFORT            LIMIT 200000       ACTUAL 38111
SUBPROBLEMS       LIMIT 50           ACTUAL 7
SUBSTITUTIONS     LIMIT 50           ACTUAL 8

  REMEMBER PROVED THEOREM

*2.20   AI(AVB)
```

```
TO PROVE
*2.21    -PI(PIQ)
           1.    -PI(-PVQ)                            , SUBLEVEL REPLACEMENT


 PROOF FOUND.

          GIVEN                             *2.20     AI(AVB)
          SUBSTITUTION                      1.        -PI(-PVQ)
          GIVEN                                       DEFINITIONS
          SUBLEVEL REPLACEMENT              *2.21     -PI(PIQ)
          Q.E.D.

EFFORT              LIMIT 200000            ACTUAL 8021
SUBPROBLEMS         LIMIT 50                ACTUAL 1
SUBSTITUTIONS       LIMIT 50                ACTUAL 2

   REMEMBER PROVED THEOREM

*2.21    -AI(AIB)
```

```
TC PROVE
*2.24   PI(-PIQ)
         1.   PI(--PVQ)                            , SUBLEVEL REPLACEMENT
         4942   PI(--PVQ)                          , SUBLEVEL REPLACEMENT.  REJECTED PROBLEM
         2.   -PV(-PIQ)                        *1.01, REPLACEMENT
         5291   -P                             *2.21, DETACHMENT.  REJECTED PROBLEM
         3.   -PI(PIC)                         *2.04, DETACHMENT

 PROOF FOUND.

         GIVEN                             *2.21      -AI(AIB)
         SUBSTITUTION                      3.         -PI(PIQ)
         GIVEN                             *2.04      (AI(BIC))I(BI(AIC))
         DETACHMENT                        *2.24      PI(-PIQ)
         Q.E.D.

EFFORT              LIMIT 200000           ACTUAL 21521
SUBPROBLEMS         LIMIT 50               ACTUAL 3
SUBSTITUTIONS       LIMIT 50               ACTUAL 4

   REMEMBER PROVED THEOREM

*2.24   AI(-AIB)
```

```
TO PROVE
*3.13    (-(P*Q))I(-PV-Q)
           1.    (-(-(-PV-Q)))I(-PV-Q)                 SUBLEVEL REPLACEMENT


 PROOF FOUND.

           GIVEN                             *2.14     --AIA
           SUBSTITUTION                      1.        (-(-(-PV-Q)))I(-PV-Q)
           GIVEN                                       DEFINITIONS
           SUBLEVEL REPLACEMENT              *3.13     (-(P*Q))I(-PV-Q)
           Q.E.D.

EFFORT               LIMIT 200000            ACTUAL 13293
SUBPROBLEMS          LIMIT 50                ACTUAL 1
SUBSTITUTIONS        LIMIT 50                ACTUAL 2

   REMEMBER PROVED THEOREM

*3.13    (-(A*B))I(-AV-B)
```

```
TO PROVE
*3.14    (-PV-Q)I(-(P*Q))
           1.   (-PV-Q)I(-(-(-PV-Q)))                        SUBLEVEL REPLACEMENT


 PROOF FOUND.

          GIVEN                              *2.12     AI--A
          SUBSTITUTION                       1.        (-PV-Q)I(-(-(-PV-Q)))
          GIVEN                                        DEFINITIONS
          SUBLEVEL REPLACEMENT               *3.14     (-PV-Q)I(-(P*Q))
          Q.E.D.

EFFORT              LIMIT 200000             ACTUAL 12753
SUBPROBLEMS         LIMIT 50                 ACTUAL 1
SUBSTITUTIONS       LIMIT 50                 ACTUAL 2

   REMEMBER PROVED THEOREM

*3.14    (-AV-B)I(-(A*B))
```

```
TO PROVE
*3.24   -(P*-P)
          1.    -(-(-PV--P))                          , SUBLEVEL REPLACEMENT
          5417   -(-(-PV--P))                         , SUBLEVEL REPLACEMENT.  REJECTED PROBLEM
          2.    -PV--P                           *3.14, DETACHMENT

 PROOF FOUND.

          GIVEN                           *2.11     AV-A
          SUBSTITUTION                    2.        -PV--P
          GIVEN                           *3.14     (-AV-B)I(-(A*B))
          DETACHMENT                      *3.24     -(P*-P)
          Q.E.D.

EFFORT              LIMIT 200000          ACTUAL 14541
SUBPROBLEMS         LIMIT 50              ACTUAL 2
SUBSTITUTIONS       LIMIT 50              ACTUAL 3

   REMEMBER PROVED THEOREM

*3.24   -(A*-A)
```

```
TO PROVE
*4.13   P=--P
          1.    (PI--P)*(--PIP)                  *4.01, REPLACEMENT
          2.    -(-(P=--P))                      *2.14, DETACHMENT
          5588    P=--P                          *2.08, DETACHMENT.  REJECTED PROBLEM
          5260    (P=--P)V(P=--P)                *1.2, DETACHMENT.  REJECTED PROBLEM
          3.    PIP                              *2.12, BACKWARD CHAINING

 PROOF FOUND.

          GIVEN                            *2.08      AIA
          SUBSTITUTION                     3.         PIP
          GIVEN                            *2.12      AI--A
          BACKWARD CHAINING                *4.13      P=--P
          Q.E.D.

EFFORT              LIMIT 200000           ACTUAL 15965
SUBPROBLEMS         LIMIT 50               ACTUAL 3
SUBSTITUTIONS       LIMIT 50               ACTUAL 4

   REMEMBER PROVED THEOREM

*4.13   A=--A
```

```
TO PROVE
*4.20    P=P
            1.     (PIP)*(PIP)                  *4.01, REPLACEMENT
            2.     -(-(P=P))                    *2.14, DETACHMENT
            6082     P=P                        *2.08, DETACHMENT.  REJECTED PROBLEM
            5765     (P=P)V(P=P)                *1.2, DETACHMENT.  REJECTED PROBLEM
            3.     --PIP                        *4.13, FORWARD CHAINING

 PROOF FOUND.

            GIVEN                          *2.14      --AIA
            SUBSTITUTION                   3.         --PIP
            GIVEN                          *4.13      A=--A
            FORWARD CHAINING               *4.20      P=P
            Q.E.D.

EFFORT               LIMIT 200000          ACTUAL 12404
SUBPROBLEMS          LIMIT 50              ACTUAL 3
SUBSTITUTIONS        LIMIT 50              ACTUAL 4

   REMEMBER PROVED THEOREM

*4.20    A=A
```

```
TO PROVE
*4.24    P=(P*P)
           1.    P=(-(-PV-P))                     , SUBLEVEL REPLACEMENT
           5377    P=(-(-PV-P))                   , SUBLEVEL REPLACEMENT.  REJECTED PROBLEM
           2.    (PI(P*P))*((P*P)IP)        *4.01, REPLACEMENT
           3.    -(-(P=(P*P)))              *2.14, DETACHMENT
           5457    P=(P*P)                  *2.08, DETACHMENT.  REJECTED PROBLEM
           5321    (P=(P*P))V(P=(P*P))      *1.2, DETACHMENT.  REJECTED PROBLEM
           4.    PI(P*P)                    *4.20, FORWARD CHAINING
           5.    --PI(P*P)                  *4.13, FORWARD CHAINING
           6.    PI(-(-(P*P)))              *2.14, BACKWARD CHAINING
           6563    PI(P*P)                  *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
           7.    PI((P*P)V(P*P))            *1.2, BACKWARD CHAINING
4.       PI(P*P)
           8.    -PV(P*P)                   *1.01, REPLACEMENT
           6597    -P                       *2.21, DETACHMENT.  REJECTED PROBLEM
           9.    P*P                        *2.02, DETACHMENT
           10.    -(-(PI(P*P)))             *2.14, DETACHMENT
           5348    PI(P*P)                  *2.08, DETACHMENT.  REJECTED PROBLEM
           6056    (PI(P*P))V(PI(P*P))      *1.2, DETACHMENT.  REJECTED PROBLEM
           11.    (-PIB)I(P*P)              *2.24, FORWARD CHAINING
           12.    (PVB)I(P*P)               *2.20, FORWARD CHAINING
           6514    --PI(P*P)                *2.12, FORWARD CHAINING.  REJECTED PROBLEM
           6235    PI(P*P)                  *2.08, FORWARD CHAINING.  REJECTED PROBLEM
           13.    (PVP)I(P*P)               *2.07, FORWARD CHAINING
           14.    (BIP)I(P*P)               *2.02, FORWARD CHAINING
           15.    (AVP)I(P*P)               *1.3, FORWARD CHAINING
           5907    PI(-(-(P*P)))            *2.14, BACKWARD CHAINING.  REJECTED PROBLEM
           6607    PI(P*P)                  *2.08, BACKWARD CHAINING.  REJECTED PROBLEM
           5352    PI((P*P)V(P*P))          *1.2, BACKWARD CHAINING.  REJECTED PROBLEM
9.       P*P
           6477    -(-PV-P)                 *3.01, REPLACEMENT.  REJECTED PROBLEM
           16.    -(-(P*P))                 *2.14, DETACHMENT
           5352    P*P                      *2.08, DETACHMENT.  REJECTED PROBLEM
           6484    (P*P)V(P*P)              *1.2, DETACHMENT.  REJECTED PROBLEM
           17.    PI--P                     *2.14, BACKWARD CHAINING

 PROOF FOUND.

           GIVEN                           *2.12      AI--A
           SUBSTITUTION                    17.        PI--P
           GIVEN                           *2.14      --AIA
           BACKWARD CHAINING               9.         P*P
           GIVEN                           *2.02      AI(BIA)
           DETACHMENT                      4.         PI(P*P)
           GIVEN                           *4.20      A=A
           FORWARD CHAINING                *4.24      P=(P*P)
           Q.E.D.

EFFORT              LIMIT 200000           ACTUAL 92331
SUBPROBLEMS         LIMIT 50               ACTUAL 17
SUBSTITUTIONS       LIMIT 50               ACTUAL 18

   REMEMBER PROVED THEOREM

*4.24    A=(A*A)
```

```
TO PROVE
*4.25    P=(PVP)
         1.    (PI(PVP))*((PVP)IP)           *4.01, REPLACEMENT
         2.    -(-(P=(PVP)))                 *2.14, DETACHMENT
         5528   P=(PVP)                      *2.08, DETACHMENT.  REJECTED PROBLEM
         5797   (P=(PVP))V(P=(PVP))          *1.2, DETACHMENT.  REJECTED PROBLEM
         3.    (P*P)I(PVP)                   *4.24, FORWARD CHAINING
         4.    PI(PVP)                       *4.20, FORWARD CHAINING


 PROOF FOUND.

         GIVEN                          *2.20      AI(AVB)
         SUBSTITUTION                   4.         PI(PVP)
         GIVEN                          *4.20      A=A
         FORWARD CHAINING               *4.25      P=(PVP)
         Q.E.D.


EFFORT              LIMIT 200000        ACTUAL 20788
SUBPROBLEMS         LIMIT 50            ACTUAL 4
SUBSTITUTIONS       LIMIT 50            ACTUAL 5

   REMEMBER PROVED THEOREM

*4.25    A=(AVA)
```

```
PROGRAM RAN TO COMPLETION.

IPL-V POST-MORTEM

        H0      *1
                *2
                *3
                *4
        H1      J7
        H2      16207 WORDS
        H3                          879155
        H4      0
        H5      J4
        H6      0
        H7                               0
        H8      0
        H9      0
        H10     0
        H11     0
        H12     0
        W0      0
        W1      0
        W2      0
        W3      0
        W4      0
        W5      0
        W6      0
        W7      0
        W8      0
        W9      0
        W10     24627                    1
        W11                              0
        W12     X13
        W13     X13
        W14     J0
        W15     X15
        W16
        W17
        W18     24628                    0
        W19     24629                    0
        W20     28153                    0
                24630                    0
        W21     28088                    1
                24631                    1
        W22     28088                    1
                24632                    1
        W23     28090
        W24     24633
        W25     24754                   16
        W26     24756
                0
                J0
        W27
        W28
        W29
        W30     24755                    1
        W31     24759                    2
```

```
        W32                              0
        W33
        24153   0
        24152   0
        24150   0
        24151   0
        24156   0
        24145   0
        24154   0
        24155   0
        24160   0
        24157   0
        24159   1
        24158   1
        32531   32548*
*4.25    A=(AVA)

THE FOLLOWING RESULTED FROM EXECUTING 1W15...
        L4      0
                =0
                9-1
                -0
                9-2
                V0
                9-3
                I0
                9-4
                =1
                9-5
5916*   9-1     0
                9-6
                9-7
4849*   9-2     0
                9-8
5095*   9-3     0
                9-9
                9-10
4247*   9-4     0
                9-11
                9-12
4054*   9-5     0
                9-13
                9-14
5707*   9-6     9-15
5719*   9-7     9-16
                V0
                9-17
                *0
                9-18
                -0
                9-19
5398*   9-8     0
                *0
                9-20
5059*   9-9     9-21
                -0
                9-22
5138*   9-10    9-23
                -0
```

		9-24
4239*	9-11	9-25
		-0
		9-26
		IO
		9-27
		VO
		9-28
4209*	9-12	9-29
		-0
		9-30
		IO
		9-31
		VO
		9-32
4077*	9-13	0
		=0
		9-33
		*0
		9-34
		IO
		9-35
4051*	9-14	0
		*0
		9-36
		-0
		9-37
		VO
		9-38
5336*	9-15	0
		*425
		*424
		*420
		*413
5037*	9-16	0
		*420
5789*	9-17	0
		9-39
		9-40
5765*	9-18	0
		9-41
		9-42
5454*	9-19	0
		9-43
6035*	9-20	0
		9-44
		9-45
5173*	9-21	0
		*213
		*211
5262*	9-22	0
		9-46
5013*	9-23	0
		*210
5066*	9-24	0
		9-47
4270*	9-25	0
		*224
		*220

		*212
		*208
		*207
		*202
		*13
5109*	9-26	0
		9-48
4368*	9-27	0
		9-49
		9-50
4250*	9-28	0
		9-51
		9-52
4242*	9-29	0
		*214
		*208
		*12
4875*	9-30	0
		9-53
4371*	9-31	0
		9-54
		9-55
4253*	9-32	0
		9-56
		9-57
4181*	9-33	0
		9-58
		9-59
4131*	9-34	0
		9-60
		9-61
4066*	9-35	0
		9-62
		9-63
4204*	9-36	0
		9-64
		9-65
4113*	9-37	0
		9-66
4069*	9-38	0
		9-67
		9-68
5585*	9-39	9-69
5771*	9-40	9-70
6331*	9-41	9-71
6109*	9-42	9-72
5534*	9-43	0
		-0
		9-73
5819*	9-44	9-74
5411*	9-45	0
		-0
		9-75
5010*	9-46	9-76
4983*	9-47	9-77
		-0
		9-78
5217*	9-48	9-79
		*0

		9-80
		-0
		9-81
4300*	9-49	9-82
4367*	9-50	9-83
		I0
		9-84
		-0
		9-85
4212*	9-51	9-86
		-0
		9-87
4249*	9-52	9-88
		-0
		9-89
		V0
		9-90
4860*	9-53	9-91
		*0
		9-92
		-0
		9-93
4370*	9-54	9-94
		-0
		9-95
		I0
		9-96
		V0
		9-97
4350*	9-55	9-98
		I0
		9-99
		-0
		9-100
		V0
		9-101
4278*	9-56	9-102
		-0
		9-103
4276*	9-57	9-104
		-0
		9-105
		V0
		9-106
4202*	9-58	9-107
4165*	9-59	9-108
4133*	9-60	9-109
4112*	9-61	9-110
4061*	9-62	9-111
4046*	9-63	9-112
4116*	9-64	0
		I0
		9-113
4178*	9-65	0
		I0
		9-114
4109*	9-66	0
		V0
		9-115

4073*	9-67	0
		-0
		9-116
4082*	9-68	9-117
5266*	9-69	0
		*425
5274*	9-70	0
		*425
5609*	9-71	0
		*424
6002*	9-72	0
		*424
6077*	9-73	0
		9-118
6107*	9-74	0
		*324
5417*	9-75	0
		9-119
5136*	9-76	0
		*210
4995*	9-77	0
		*211
5080*	9-78	0
		9-120
5419*	9-79	0
		*221
5608*	9-80	0
		9-121
		9-122
5089*	9-81	0
		9-123
4369*	9-82	0
		*206
		*205
		*204
		*203
		*201
		*16
4257*	9-83	0
		*206
		*205
		*16
5054*	9-84	0
		9-124
		9-125
4956*	9-85	0
		9-126
4254*	9-86	0
		*15
		*14
		*12
5821*	9-87	0
		9-127
4256*	9-88	0
		*14
		*12
4795*	9-89	0
		9-128
4295*	9-90	0

		9-129
		9-130
4871*	9-91	0
		*201
5384*	9-92	0
		9-131
		9-132
5143*	9-93	0
		9-133
4828*	9-94	0
		*221
		*204
		*203
		*202
5950*	9-95	0
		9-134
4979*	9-96	0
		9-135
		9-136
4404*	9-97	0
		9-137
		9-138
4889*	9-98	0
		*224
		*221
		*202
4836*	9-99	0
		9-139
		9-140
4835*	9-100	0
		9-141
4407*	9-101	0
		9-142
		9-143
4283*	9-102	0
		*220
		*207
		*15
		*14
		*13
5549*	9-103	0
		9-144
4285*	9-104	0
		*220
		*207
		*14
		*13
5292*	9-105	0
		9-145
4352*	9-106	0
		9-146
		9-147
4205*	9-107	0
		*401
4176*	9-108	0
		*401
4140*	9-109	0
		*301
4139*	9-110	0

		*301
4050*	9-111	0
		*101
4078*	9-112	0
		*101
4210*	9-113	0
		9-148
		9-149
4215*	9-114	0
		9-150
		9-151
4148*	9-115	0
		9-152
		9-153
4076*	9-116	0
		9-154
4075*	9-117	0
		*101
5854*	9-118	9-155
5579*	9-119	9-156
4910*	9-120	0
		-0
		9-157
5604*	9-121	9-158
5683*	9-122	9-159
6080*	9-123	9-160
4883*	9-124	9-161
4947*	9-125	9-162
4838*	9-126	9-163
6122*	9-127	9-164
5373*	9-128	9-165
4284*	9-129	9-166
4274*	9-130	9-167
5473*	9-131	9-168
5542*	9-132	9-169
5038*	9-133	9-170
6130*	9-134	9-171
5125*	9-135	9-172
5113*	9-136	9-173
4401*	9-137	9-174
4403*	9-138	9-175
5070*	9-139	9-176
4973*	9-140	9-177
4969*	9-141	9-178
4406*	9-142	9-179
4412*	9-143	9-180
5659*	9-144	9-181
5802*	9-145	9-182
4345*	9-146	9-183
4324*	9-147	9-184
4213*	9-148	9-185
4199*	9-149	9-186
4214*	9-150	9-187
4220*	9-151	9-188
4137*	9-152	0
		-0
		9-189
4145*	9-153	0
		-0

		9-190
4092*	9-154	9-191
6091*	9-155	0
		*413
5452*	9-156	0
		*324
5114*	9-157	0
		9-192
5397*	9-158	0
		*313
5428*	9-159	0
		*313
5909*	9-160	0
		*214
4948*	9-161	0
		*204
5058*	9-162	0
		*204
4924*	9-163	0
		*203
		*201
5801*	9-164	0
		*314
6079*	9-165	0
		*314
4323*	9-166	0
		*15
4346*	9-167	0
		*15
5690*	9-168	0
		*314
5599*	9-169	0
		*314
4960*	9-170	0
		*212
6110*	9-171	0
		*224
5166*	9-172	0
		*206
		*205
5133*	9-173	0
		*206
		*205
4408*	9-174	0
		*16
4410*	9-175	0
		*16
5160*	9-176	0
		*206
		*205
		*204
4978*	9-177	0
		*206
		*205
		*204
4903*	9-178	0
		*203
4419*	9-179	0
		*16

4421*	9-180	0
		*16
4807*	9-181	0
		*313
5917*	9-182	0
		*313
4356*	9-183	0
		*15
4358*	9-184	0
		*15
4216*	9-185	0
		*401
4218*	9-186	0
		*401
4227*	9-187	0
		*401
4229*	9-188	0
		*401
4134*	9-189	0
		9-193
4154*	9-190	0
		9-194
4097*	9-191	0
		*101
5207*	9-192	9-195
4158*	9-193	9-196
4163*	9-194	9-197
5261*	9-195	0
		*213
4161*	9-196	0
		*301
4168*	9-197	0
		*301

```
    ACCOUNTING SUMMARY                                                              06/05/63

       JOB      8168,LTNEW1,EAS826,5MIN,0,099,C       STEFFERUD           1  003650

PHASE PROGRAM           TIME
  1   IPL                 04MIN 30SEC
      TOTAL               04MIN 30SEC

MEDIARY OUTPUT COUNT          10 WORDS
       END OF MOCK-DONALD SYSPIT
```

XIII. LEVELS OF VOCABULARY AND USE OF SYMBOLS

The following list summarizes LT's use of symbols for routines and data.

A0,B0,----,G0	Free variables
P0,Q0,----,T0	Bound variables
I0,V0,-0,*0,=0,=1	Connectives
Other zeroth symbols	Character symbols (except H0,J0,W0)
/1,/2,----,/14	Substitute character symbols
N1,N2,----,N10	Integer data terms 1,2,----,0
K1-K99	Constants and parameters
L1-L49	Control and working lists
T1-T39	Text lists
Q1-Q49	Attributes of terms and expressions
P1-P99	Routines to operate on terms and expressions
M1-M199	Logic theorist routines
M1---M9	Executives, setup
M10--M19	Methods
M40--M49	Utility measures
M50--M59	Information recorders
M60--M69	Information retrievers
M70--M89	Input-output routines
M90--M99	Limit testers
M110-M119	Match processes
X1-X49	Run housekeeping and executives
X1---X9	Executives
X10--X19	Debugging routines
X20--X29	Debugging lists

LIST OF IPL-V BASIC PROCESSES

* Indicates processes which set H5

General Processes

J0 No operation
J1 Execute (0) after restoring H0
*J2 TEST (0) ≡ (1)
*J3 Set H5-
*J4 Set H5+
*J5 Reverse sense of H5
J6 Reverse (0) and (1)
J7 Halt, proceed on GO
J8 Restore H0
J9 ERASE cell (0)

Description Processes

*J10 FIND value of attribute (0) of (1)
J11 Assign (1) as value of attribute (0) of (2)
J12 Add (1) at front of value list of attribute (0) of (2)
J13 Add (1) at end of value list of attribute (0) of (2)
J14 ERASE attribute (0) of (1)
J15 ERASE all attributes of (0)
*J16 FIND attribute of (0) randomly

Generator Housekeeping Processes

J17 Gen set up: context (0), subprocess (1)
*J18 Execute subprocess of Gen
*J19 Gen clean up

Working Storage Processes

J2n MOVE (0)-(n) into W0-Wn
J3n Restore W0-Wn
J4n Preserve W0-Wn
J5n Preserve W0-Wn; MOVE (0)-(n) into W0-Wn

List Processes

*J60 LOCATE next symbol after cell (0)
*J61 LOCATE last symbol on list (0)
*J62 LOCATE (0) on list (1) (1st occurrence)
J63 INSERT (0) before symbol in cell (1)
J64 INSERT (0) after symbol in cell (1)
J65 INSERT (0) at end of list (1)
J66 INSERT (0) at end if not on list (1)
J67 Replace (1) by (0) on list (2) (1st occur.)
*J68 DELETE symbol in cell (0)
*J69 DELETE (0) from list (1) (1st occurrence)
*J70 DELETE last symbol from list (0)
J71 ERASE list (0)
J72 ERASE list structure (0)
J73 COPY list (0)
J74 COPY list structure (0)
J75 Divide list after location (0); name of remainder is output (0)
*J76 INSERT list (0) after (1), locate last symbol
*J77 TEST if (0) is on list (1)
*J78 TEST if list (0) is not empty
*J79 TEST if cell (0) is not empty
*J8n FIND the nth symbol on list (0)
J9n Create list of n symbols, (n-1) to (0)
*J100 Gen symbols on list (1) for (0)
*J101 Gen cells of list structure (1) for (0)
*J102 Gen cells of tree (1) for (0)
*J103 Gen cells of block (1) for (0)
J104

Auxiliary Storage Processes

*J105 MOVE list structure (0) in from auxiliary
J106 File list structure (0) in fast-auxiliary
J107 File list structure (0) in slow-auxiliary
*J108 TEST if list structure (0) is on auxiliary
J109 Compact auxiliary data storage system (0)

Arithmetic Processes

J110 (1) + (2) → (0), leave (0)
J111 (1) - (2) → (0), leave (0)
J112 (1) x (2) → (0), leave (0)
J113 (1) / (2) → (0), leave (0)
*J114 TEST if (0) = (1)
*J115 TEST if (0) > (1)
*J116 TEST if (0) < (1)
*J117 TEST if (0) = 0
*J118 TEST if (0) > 0
*J119 TEST if (0) < 0
J120 COPY (0)
J121 Set (0) identical to (1), leave (0)
J122 Take absolute value of (0), leave (0)
J123 Take negative of (0), leave (0)
J124 Clear (0), leave (0)
J125 Tally 1 in (0), leave (0)
J126 Count list (0)
*J127 TEST if data type (0) = data type (1)
J128 Translate (0) to be data type of (1)
J129 Produce random number between 0 and (0)

Data Prefix Processes

*J130 TEST if (0) is regional symbol
*J131 TEST if (0) names data term
*J132 TEST if (0) is local symbol
*J133 TEST if list (0) has been marked processed
*J134 TEST if (0) is internal symbol
J135
J136 Make (0) local, leave (0)
J137 Mark list (0) processed, leave (0)
J138 Make (0) internal, leave (0)
J139

Read and Write Processes

*J140 Read list structure
*J141 Read symbol from console
J142 Write list structure (0)
J143 Rewind tape (0)
J144 Skip to next tape file
J145 Write end-of-file
J146 Write end-of-set

Monitor System

J147 Mark routine (0) to trace
J148 Mark routine (0) to propagate trace
J149 Mark routine (0) to not trace

Print Processes

J150 Print list structure (0)
J151 Print list (0)
J152 Print symbol (0)
J153 Print data term (0) w/o name or type
J154 Clear print line
J155 Print line
*J156 Enter symbol (0) left-justified
*J157 Enter data term (0) left-justified
*J158 Enter symbol (0) right-justified
*J159 Enter data term (0) right-justified
J160 Tab to column (0)
J161 Increment column by (0)
*J162 Enter (0) according to format W43
J163
J164

In-process Loading

J165 Load routines and data

Save for Restart (§ 20.0)

*J166 Save on unit (0) for restart
*J167 Skip list structure
J168
J169

Error Trap

J170 Trap on (0)

Block Handling Processes

J171 Return unused regionals to H2
J172 Make block (0) into a list
*J173 Read into block (0)
*J174 Write block (0)
*J175 FIND region control word of regional symbol (0)
J176 Space (0) blocks on unit 1W19
J177
J178
J179

Line Read Processes

*J180 Read line
*J181 Input line symbol
*J182 Input line data term (0)
*J183 Set (0) to next blank
*J184 Set (0) to next non-blank
*J185 Set (1) to next occurrence of character (0)
*J186 Input line character
J187
J188
*J189 Transfer field to line (0)

Partial Word Processes

J190 Input P of cell (0)
J191 Input Q of cell (0)
J192 Input SYMB of cell (0)
J193 Input LINK of cell (0)
J194 Set (1) to be P of cell (0)
J195 Set (1) to be Q of cell (0)
J196 Set (1) to be SYMB of cell (0)
J197 Set (1) to be LINK of cell (0)
J198
J199

Miscellaneous Processes

*J200 LOCATE (0)th symbol on list (1)
J201 ERASE routine (0)
J202 Print post mortem and continue

IPL INSTRUCTION: PQ SYMB LINK

P is operation code
- P = 0 Execute S
- P = 1 Input S (after preserving H0)
- P = 2 Output to S (then restore H0)
- P = 3 Restore (pop up) S
- P = 4 Preserve (push down) S
- P = 5 Replace (0) by S
- P = 6 Copy (0) in S
- P = 7 Branch to S if H5-

Q is designation code
- Q = 0 S = SYMB
- Q = 1 S = symbol in cell named SYMB
- Q = 2 S = symbol in cell named in cell named SYMB
- Q = 3 S = SYMB; start selective trace
- Q = 4 S = SYMB; continue selective trace
- Q = 5 Machine language routine
- Q = 6 Routine in fast-aux. storage
- Q = 7 Routine in slow-aux. storage

SYMB is symbol operated on by Q
LINK is address of next instruction (0 for end of routine)

SYSTEM STORAGE CELLS

H0	Communication cell
H1	Current instruction address cell
H2	Available space list
H3	Tally of interpretation cycles
H4	Current auxiliary routine cell
H5	Test cell
W0-W9	Common working storage
W10	Random number control cell
W11	Integer division remainder
W12	Monitor start cell (Q = 3)
W13	Monitor end cell (Q = 3)
W14	External interrupt cell
W15	Post mortem routine cell
W16	Input mode cell
W17	Output mode cell
W18	Read unit cell
W19	Write unit cell
W20	Print unit cell
W21	Print column cell
W22	Print spacing cell
W23	Post mortem list cell
W24	Print line cell
W25	Print entry column cell
W26	Error trap cell
W27	Trap address cell
W28	Trap symbol cell
W29	Monitor point address cell
W30	Field length cell
W31	Trace mode cell
W32	Reserved available space cell
W33	Cycle count for trap cell
W34	Current available space cell
W35	Slow-aux. obsolete structure cell
W36	Used slow-auxiliary space cell
W37	Slow-auxiliary storage density cell
W38	Slow-auxiliary storage compacting routine cell
W39	Fast-aux. obsolete structure cell
W40	Used fast-auxiliary space cell
W41	Fast-auxiliary storage density cell
W42	Fast-auxiliary storage compacting routine cell
W43	Format cell

IPL DATA: PQ SYMB LINK

Q = 0 Standard list cell:
- P is irrelevant
- SYMB is symbol
- LINK is address of next list cell (0 for end of list)

Q = 1 Data term:

Data term	±PQ	SYMB	LINK
Decimal integer	1	dddd	dddd
Floating point	11	ddddd	d ±ee
Alphanumeric	21	aaaaa	
Octal	31	ddddd	ddddd

TYPE CARDS

0 (blank) Routines and data
1 Comments
2 Region definition
- NAME = Regional symbol
- SYMB = Origin (if given)
- LINK = Size

3 Block reservation
- NAME = Block control word (if given)
- SYMB = Origin (if given)
- LINK = Size
- Q = 0 Reserve regional symbols
- Q = 1 Reserve print line
- Q = 2 Reserve block
- Q = 3 Reserve auxiliary buffer
- Q = 4 Specify available space

4 Listing cards
5 Main storage header
6 Fast-auxiliary storage header
7 Slow-auxiliary storage header
8 Editing header; inhibits loading
- NAME = Name of storage block
- P = Input mode
  - P = 0 IPL standard
  - P = 1 IPL compressed
  - P = 2 IPL binary
  - P = 3 Machine code
  - P = 4 Restart mode
- Q = Type of input
  - Q = 0 Routines; internals symbolic
  - Q = 1 Data; internals symbolic
  - Q = 2 Routines; internals symbolic; reset internal symbol table
  - Q = 3 Data; internals symbolic; reset internal symbol table
  - Q = 4 Routines; internals absolute
  - Q = 5 Data; internals absolute
- SYMB = Alternate input unit
  - 0 (blank) = controlling unit
  - 1-10 = Internal tapes
  - Regional SYMB names first routine (terminate loading)
- LINK = Output mode: of form bbbcd
  - b = Output unit: blank = unit 1W19; 1-10 = unit 1-10
  - c = 0 (blank) if assembly listing
    - = 1 or any character if no assembly listing
  - d = 0 (blank) if no output
    - = 1 IPL compressed output
    - = 2 IPL binary output
    - = 3 Machine code output
    - = 9 IPL standard output

9 First card
- SYMB = Controlling unit (0 or blank = normal input unit)

XIV. COMPLETE VOCABULARY LISTING

A complete vocabulary listing, as shown in this section, was kept up to date during conversion of LT into its present form.

The vocabulary is intended to serve as an extension of the List of Basic Processes in the IPL-V system.

```
A0    FREE VARIABLE -A-.                                                  A000V000
B0    FREE VARIABLE -B-.                                                  B000V000
C0    FREE VARIABLE -C-.                                                  C000V000
D0    FREE VARIABLE -D-.                                                  D000V000
E0    FREE VARIABLE -E-.                                                  E000V000
F0    FREE VARIABLE -F-.                                                  F000V000
G0    FREE VARIABLE -G-.                                                  G000V000
I0    LOGICAL CONNECTIVE -IMPLIES-                                        I000V000
K0    SYMBOL FOR CHARACTER K.                                             K000V000
K1    HOLDS -OR-.                                                         K001V000
K2    HOLDS -NOT-.                                                        K002V000
K3    HOLDS -AND-                                                         K003V000
K4    HOLDS -PROVEN EQUIVALENCE-                                          K004V000
K5    HOLDS -DEFINITIONAL EQUIVALENCE.                                    K005V000
K6    HOLDS -IMPLIES-                                                     K006V000
K7    HOLDS DELIMIER SYMBOL FOR DELIMITABLE CHARACTERS.                   K007V000
K10   PREVIOUS SUBPROBLEM NUMBER. (DATA TERM)                             K010V000
K11   SUBSTITUTION COUNT.                                                 K011V000
K12   EFFORT BASE (AND TOTAL).                                            K012V000
K20   LIMIT ON NO. OF SUBPROBLEMS.                                        K020V000
K21   LIMIT ON NO. OF SUBSTITUTIONS.                                      K021V000
K22   LIMIT ON EFFORT.                                                    K022V000
K30   HOLDS R0 IF PROVED THEOREMS ARE TO BE REMEMBERED.                   K030V000
K31   HOLDS Y0 IF REJECTED SUBPROBLEMS ARE TO BE PRINTED.                 K031V000
K41   D.T. COLUMN FOR PRINTING METHODS IN PROOF SEQUENCES.                K041V000
K42   D.T. COLUMN FOR PRINTING NAMES IN PROOF SEQUENCES.                  K042V000
K43   D.T. COLUMN FOR PRINTING EXPRESSIONS IN PROOF SEQUENCES.            K043V000
K44   D.T. COLUMN FOR PRINTING 'LIMIT'                                    K044V000
K45   D.T. COLUMN FOR PRINTING 'ACTUAL'                                   K045V000
K46   D.T. COLUMN FOR PRINTING 'REJECTED SUBPROBLEM'.                     K046V000
K47   D.T. COLUMN FOR PRINTING NAME OF NEW SUBPROBLEM.                     K047V000
K48   D.T. COLUMN FOR PRINTING 'THEOREM, METHOD' OF NEW PROBLEMS.         K048V000
K51   DATA TERM '('                                                       K051V000
K52   DATA TERM ')'                                                       K052V000
K53   DATA TERM '.'                                                       K053V000
K54   DATA TERM ','                                                       K054V000
L0    SYMBOL FOR CHARACTER L.                                             L000V000
L1    LIST OF TRUE EXPRESSIONS. (AXIOMS, DEFINITIONS, THEOREMS)           L001V000
L2    LIST OF FREE VARIABLES.                                             L002V000
L3    LIST OF UNPROVED EXPRESSIONS. (PROBLEMS)                            L003V000
L4    LIST STRUCTURE MAP OF ALL TRUE EXPRESSIONS.                         L004V000
L5    HOLDS LIST STRUCTURE MAP OF TRUE EXPRESSIONS.                       L005V000
L6    LIST OF SPECIAL METHODS FOR ORIGINAL PROBLEMS.                      L006V000
L7    LIST OF REGULAR METHODS FOR ALL PROBLEMS.                           L007V000
L8    DESCRIPTION LIST TABLE OF DELIMITABLE CHARACTERS.                   L008V000
L9    DESCRIPTION LIST TABLE OF CHARACTER SYMBOLS FOR READING TEXT.L009V000
L10   LIST OF UNTRIED PROBLEMS.                                           L010V000
L11   LIST OF FOUND PROBLEMS.                                             L011V000
M0    SYMBOL FOR CHARACTER M.                                             M000V000
M1    SINGLE PROBLEM EXEUTIVE FOR PROBLEM (0).                            M001V000
M2    MULTIPLE PROBLEM EXECUTIVE FOR LIST L3.                             M002V000
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M3    SET-UP FOR NEW PROBLEM.                                               M003V000
M7    APPLY METHODS (1) TO PROBLEM (0), ERASE (1) WHEN THRU.                M007V000
M8    CREATE A LIST OF METHODS FOR PROBLEM (0).                             M008V000
M11   DETACHMENT METHOD FOR PROBLEM (0). SETS H5+ AND OUTPUTS               M011V000
      SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND. SETS H5- IF               M011V010
      NO SOLUTION. ADDS GOOD NEW SUBPROBLEMS TO UNTRIED LIST.               M011V020
M12   SUBSTITUTION METHOD FOR PROBLEM (0). SETS H5+ AND OUTPUTS             M012V000
      SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND.                           M012V010
      SETS H5- IF NO OUTPUT.                                                M012V020
M13   REPLACEMENT METHOD FOR SUBPROBLEM (0). SETS H5+ AND OUTPUTS            M013V000
      SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND. SETS H5- IF               M013V010
      NO SOLUTION. ADDS GOOD NEW SUBPROBLEMS TO UNTRIED LIST.               M013V020
M14   FORWARD CHAINING METHOD FOR PROBLEM (0). SETS H5+ AND OUTPUTS         M014V000
      SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND. SETS H5- IF               M014V010
      NO SOLUTION. ADDS GOOD NEW SUBPROBLEMS TO UNTRIED LIST.               M014V020
M15   BACKWARD CHAINING METHOD FOR PROBLEM (0). SETS H5+ AND                M015V000
      OUTPUTS SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND. SETS H5-          M015V010
      IF NO SOLUTION. ADDS GOOD NEW SUBPROBLEMS TO UNTRIED LIST.            M015V020
M16   SUBLEVEL REPLACEMENT METHOD FOR PROBLEM (0).  SETS H5+                M016V000
      AND OUTPUTS SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND.               M016V010
      SETS H5- IF NO SOLUTION.  ADDS GOOD NEW SUBPROBLEMS TO                M016V020
      UNTRIED LIST.  M16 TRIES FOR A SUBPROBLEM AT EACH SUBLEVEL            M016V030
      OF PROBLEM (0).                                                       M016V040
M17   SUBLEVEL REPLACEMENT METHOD FOR PROBLEM (0).  SETS H5+                M017V000
      AND OUTPUTS SUCCESSFUL SUBPROBLEM IF SOLUTION IS FOUND.               M017V010
      SETS H5- IF NO SOLUTION.  ADDS GOOD NEW SUBPROBLEMS TO                M017V020
      UNTRIED LIST.  M17 TRIES FOR ONLY ONE SUBPROBLEM BY TRYING            M017V030
      REPLACEMENT ON ALL SUBLEVELS.                                         M017V040
M19   FINISH BUILDING NEW SUBPROBLEM TEX (3) FROM (2)                       M019V000
      VIA THEOREM (1) BY METHOD(0).                                         M019V010
      H5- MEANS NEW TEX WAS ERASED DUE TO LOW UTILITY.                      M019V020
      H5+ MEANS OUTPUT TEX (0) HAS SATISFACTORY UTILITY.                    M019V030
M40   TEST MATCH OF TOTAL EXPRESSIONS (0),(1) WITHOUT SUBSTITUTION.         M040V000
M41   TEST MATCH OF SEGMENTS (0),(1) WITHOUT SUBSTITUTION.                  M041V000
M42   ADD PROBLEM(0) TO FOUND PROBLEMS LIST IF CAN.                         M042V000
      H5- MEANS THIS PROBLEM WAS PREVIOUSLY FOUND.                          M042V010
M43   MEASURE UTILITY OF (0). H5+ IF GOOD, H5- IF NO GOOD.                  M043V000
M50   ADD TRUE EXPRESSION (0) TO TRUE EXPRESSIONS LIST AND MAP.             M050V000
M51   ADD PROBLEM (0) TO UNTRIED PROBLEMS LIST.                             M051V000
M54   ADD EXPRESSION (0) TO MAP OF TRUE EXPRESSIONS.                        M054V000
M60   FIND AND REMOVE NEXT UNTRIED SUBPROBLEM ON UNTRIED LIST.              M060V000
      H5- MEANS NO SUBPROBLEM ON LIST AND NO OUTPUT.                        M060V010
M62   CREATE A LIST OF FEASIBLE MATCHES FOR SEGMENT (0) FROM MAP (1).M062V000
M63   CREATE A LIST OF FEASIBLE MATCHES FOR TOTAL EXPRESSION (1)            M063V000
      FROM MAP (0).                                                         M063V010
M70   PRINT EXPRESSION (0).                                                 M070V000
M71   PRINT PROOF SEQUENCE WITH SUCCESSFUL SUBPROBLEM (0).                  M071V000
M72   PRINT FAILURE TO FIND PROOF.                                          M072V000
M73   ENTER SEGMENT (0).                                                    M073V000
M74   ENTER TOTAL EXPRESSION (0).                                           M074V000
M75   PRINT NEW SUBPROBLEM (0).                                             M075V000
```

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M76   ENTER LIST OF DATA TERMS (0).                                          M076V000
M77   PRINT CURRENT STATUS OF LIMITS.                                        M077V000
M78   PRINT TO PROVE PROBLEM (0).                                            M078V000
M79   ENTER NAME OF (0). USE EXTERNAL NAME IF CAN.                           M079V000
M80   PRINT PROOF LINE FOR METHOD (0) AND TEX (1).                           M080V000
M81   PRINT REJECTED PROBLEM.                                                M081V000
M82   PRINT 'REMEMBER PROVED THEOREM'                                        M082V000
M88   PRINT LIST FORM EXPRESSION (0).                                        M088V000
M89   READ NEXT LOGIC EXPRESSION FROM UNIT 1W18.                             M089V000
      H5-MEANS NONE THERE.                                                   M089V010
M90   TEST IF A LIMIT HAS BEEN REACHED.                                      M090V000
M110  MAKE FREE VARIABLES OF TOTAL EXPRESSIONS (0),(1) DISJOINT.             M110V000
      SUBSTITUTES NEW VARIABLES IN (1) AS REQUIRED.                          M110V010
M111  MATCH SEGMENTS (0),(1) WITH SUBSTITUTION AS REQUIRED.                  M111V000
      H5+ MEANS OUTPUT (0) IS A SUBSTITUTION LIST OF PAIRS,                  M111V010
          1ST IS A FREE VARIABLE, 2ND IS ITS SUBSTITUTOR.                    M111V020
M112  EXPAND SUBSTITUTION LIST (0).                                          M112V000
      REPLACE EXPRESSIONS WITH COMPLETELY SUBSTITUTED LOCAL COPIES.M112V010
M113  MATCH SEGMENTS (0),(1) WITH SUBSTITUTION AS REQUIRED.                  M113V000
      H5+ MEANS OUTPUT (0) IS EXPANDED SUBSTITUTION LIST.                    M113V010
M114  MATCH SEGMENTS (0),(1) WITH SUBSTITUTION AS REQUIRED.                  M114V000
      NO OUTPUT, H5- MEANS THE MATCH FAILED.                                 M114V010
M115  SUBSTITUTE IN SEGMENT (0) FROM SUBSTITUTION LIST (1).                  M115V000
M116  CREATE LIST OF FREE VARIABLES IN TOTAL EXPRESSION (0).                 M116V000
      H5- MEANS NO OUTPUT.                                                   M116V010
M117  CREATE LIST OF BOUND VARIABLES IN TOTAL EXPRESSION (0).                M117V000
      H5- MEANS NO OUT PUT.                                                  M117V010
N0    SYMBOL FOR CHARACTER N.                                                N000V000
N1    INTEGER DATA TERM = 1                                                  N001V000
N2    INTEGER DATA TERM = 2                                                  N002V000
N3    INTEGER DATA TERM = 3                                                  N003V000
N4    INTEGER DATA TERM = 4                                                  N004V000
N5    INTEGER DATA TERM = 5                                                  N005V000
N6    INTEGER DATA TERM = 6                                                  N006V000
N7    INTEGER DATA TERM = 7                                                  N007V000
N8    INTEGER DATA TERM = 8                                                  N008V000
N9    INTEGER DATA TERM = 9                                                  N009V000
N10   INTEGER DATA TERM = 0                                                  N010V000
O0    SYMBOL FOR CHARACTER O.                                                O000V000
P0    VARIABLE TERM -P-                                                      P000V000
P2    TEST IF (0) IS A BOUND VARIABLE.                                       P002V000
P3    CLEAR DESCRIPTIONS OF EXPRESSION (0).                                  P003V000
P4    GO THRU NOTS OF SEGMENT (0). LEAVE FIRST UNNOTTED SEGMENT.             P004V000
      H5- MEANS NO OUTPUT DUE TO FAULTY EXPRESSION.                          P004V010
P5    TEST IF MAIN CONNECTIVE OF EXPRESSION (0) IS -IMPLIES-.                P005V000
P6    TEST IF CONNECTIVE (0) IS NON-UNARY.                                   P006V000
P7    TEST IF (0) IS A CONNECTIVE.                                           P007V000
P8    TEST IF (0) IS VARIABLE TERM.                                          P008V000
P9    TEST IF (0) IS FREE VARIABLE.                                          P009V000
P12   FIND MAIN EXPRESSION OF TOTAL EXPRESSION (0).                          P012V000
P13   FIND LEFT SEGMENT OF TOTAL EXPRESSION (0).                             P013V000
```

P14	FIND RIGHT SEGMENT OF TOTAL EXPRESSION (0).	P014V000
P15	TEST IF TOTAL EXPRESSION (0) IS IN TREE FORM.	P015V000
P16	FIND MAIN CONNECTIVE OF TOTAL EXPRESSION (0).	P016V000
P17	COPY SEGMENT (0). IF (0) IS A VARIABLE, OUTPUT THE INPUT.	P017V000
P18	TEST IF (0) IS A CHARACTER SYMBOL.	P018V000
P19	GET APPROPRIATE CHARACTER SYMBOL FOR (0).	P019V000
P20	MAKE LEFT SUBEXPRESSION OF EXPRESSION (0) INTO EXPRESSION,	P020V000
	H5- MEANS NO OUTPUT DUE TO FAULTY EXPRESSION.	P020V010
P21	MAKE RIGHT SUBEXPRESSION OF EXPRESSION (0) INTO EXPRESSION,	P021V000
	H5- MEANS NO OUTPUT DUE TO FAULTY EXPRESSION.	P021V010
P22	CREATE NEW PROBLEM WITH SEGMENT (0) AS LEFT SUBEXPRESSION,	P022V000
	SEGMENT (1) AS RIGHT SUBEXPRESSION, IMPLIES AS CONNECTIVE.	P022V010
P23	ERASE MADE EXPRESSION (0).	P023V000
P24	MAKE SEGMENT (0) INTO A NEW TOTAL EXPRESSION.	P024V000
P25	COPY TEX (0) FOR SUBSTITUTION.	P025V000
P26	GENERATE LOCATIONS OF NON-VARIABLE SEGMENTS FROM	P026V000
	TOTAL EXPRESSION (1) AT THE LEVEL OF DATA TERM(2)	P026V010
	FOR PROCESS (0).	P026V020
P27	REPLACE BOUND VARIABLES BY FREE VARIABLES IN TEX (0).	P027V000
P28	GENERATE LOCATIONS OF FREE VARIABLES IN SEGMENT (1) FOR (0).	P028V000
P29	GENERATE LOCATIONS OF BOUND VARIABLES IN SEGMENT (1) FOR (0).	P029V000
P30	CREATE LIST OF FREE VARIABLES IN EXPRESSION (0).	P030V000
P31	CREATE LIST OF BOUND VARIABLES IN EXPRESSION (0).	P031V000
P50	CONVERT LOGIC EXPRESSION (0) TO INTERNAL TREE FORM IF IN	P050V000
	EXTERNAL FORM. NO OUTPUT. H5- MEANS NO CONVERSION.	P050V010
	ENTIRE EXPRESSION MUST BE PARENTHESIZED.	P050V020
P51	REPLACE ALL DELIMITED SYMBOLS IN EXPRESSION (0) IF	P051V000
	(0) IS IN LIST FORM.	P051V010
P52	CREATE A TREE FORM MAIN SEGMENT FROM LIST FORM EXPRESSION (0).	P052V000
	H5- MEANS NO OUTPUT DUE TO A FAULTY INPUT EXPRESSION.	P052V010
P55	LOCATE LIST FOLLOWING DATA TERM (0) ON LIST (1).	P055V000
	H5+ MEANS OUTPUT (0) IS CELL HOLDING SUBLIST.	P055V010
	H5- MEANS OUTPUT (0) IS CELL AFTER WHICH TO INSERT.	P055V020
Q0	VARIABLE TERM -Q-	Q000V000
Q1	FIND CONNECTIVE OF SEGMENT (0).	Q001V000
Q2	FIND NO. OF LEVELS OF EXPRESSION (0).	Q002V000
Q3	FIND NO. OF DISTINCT VARIABLES OF EXPRESSION (0).	Q003V000
Q4	FIND NO. OF VARIABLE PLACES OF EXPRESSION (0).	Q004V000
Q5	ATTRIBUTE--VARIABLE TERM.	Q005V000
Q6	ATTRIBUTE--FREE VARIABLE.	Q006V000
Q7	ATTRIBUTE--EXTERNAL NAME.	Q007V000
Q8	FIND PROBLEM NO. OF EXPRESSION (0).	Q008V000
Q9	ATTRIBUTE--BOUND VARIABLE.	Q009V000
Q10	FIND PROBLEM EXPRESSION (0) DERIVED FROM.	Q010V000
Q11	FIND METHOD OF DERIVATION FOR EXPRESSION (0).	Q011V000
Q12	FIND THEOREM USED TO DERIVE PROBLEM (0).	Q012V000
Q13	FIND PROVING THEOREM FOR PROBLEM (0).	Q013V000
Q14	FIND TYPE OF CONNECTIVE (0).	Q014V000
Q15	ATTRIBUTE--INTERNAL FORM.	Q015V000
Q16	FIND EXTERNAL NAME OF (0) IN TABLE T10.	Q016V000
Q17	FIND CURRENT LEVEL OF SUBSEGMENT REPLACEMENT OF PROBLEM (0).	Q017V000

```
Q18   FIND SUFFIX OF EXPRESSION (0).                               Q018V000
Q19   FIND APPROPRIATE CHARACTER SYMBOL FOR (0).                   Q019V000
R0    VARIABLE TERM -R-                                            R000V000
S0    VARIABLE TERM -S-                                            S000V000
T0    VARIABLE TERM -T-                                            T000V000
T1    TEXT LIST 'GIVEN'                                            T001V000
T2    TEXT LIST 'PROOF FOUND'                                      T002V000
T3    TEXT LIST 'SUBSTITUTION'                                     T003V000
T4    TEXT LIST 'Q.E.D.'                                           T004V000
T5    TEXT LIST OF 5 BLANK CHARACTERS.                             T005V000
T6    TEXT LIST 'NO PROOF FOUND'                                   T006V000
T7    TEXT LIST 'EFFORT'                                           T007V000
T8    TEXT LIST 'SUBPROBLEMS'                                      T008V000
T9    TEXT LIST 'SUBSTITUTIONS'                                    T009V000
T10   DESCRIPTION LIST TABLE OF NAMES.                             T010V000
T12   TEXT LIST 'DETACHMENT'                                       T012V000
T13   TEXT LIST 'REPLACEMENT'                                      T013V000
T14   TEXT LIST 'FORWARD CHAINING'                                 T014V000
T15   TEXT LIST 'BACKWARD CHAINING'                                T015V000
T16   TEXT LIST 'SUBLEVEL REPLACEMENT'                             T016V000
T19   TEXT LIST 'REJECTED PROBLEM'                                 T019V000
T20   TEXT LIST 'ACTUAL'                                           T020V000
T21   TEXT LIST 'LIMIT'                                            T021V000
T22   TEXT LIST 'TO PROVE'                                         T022V000
T23   TEXT LIST 'REMEMBER PROVED THEOREM'                          T023V000
T24   TEXT LIST 'BAD EXPRESSION'                                   T024V000
U0    SYMBOL FOR CHARACTER U.                                      U000V000
V0    LOGICAL CONNECTIVE -OR-                                      V000V000
X0    SYMBOL FOR CHARACTER X.                                      X000V000
X1    RUN EXECUTIVE                                                X001V000
X9    SAVE AND CONTINUE EXECUTIVE.                                 X009V000
X21   LIST OF ROUTINES TO BE MARKED TO TRACE.                      X021V000
X22   LIST OF ROUTINES TO BE MARKED TO PROPAGATE TRACE.            X022V000
X23   DESCRITION LIST OF TRAP ACTIONS. (ATTRIBUTE/VALUE PAIRS)     X023V000
Y0    SYMBOL FOR CHARACTER Y.                                      Y000V000
Z0    SYMBOL FOR CHARACTER Z.                                      Z000V000
=0    LOGICAL CONNECTIVE -PROVEN EQUIVALENCE-                      =000V000
=1    LOGICAL CONNECTIVE -DEFINITIONAL EQUIVALENCE-                =001V000
-0    LOGICAL CONNECTIVE -NOT-                                     -000V000
*0    LOGICAL CONNECTIVE -AND-                                     *000V000
'0    SYMBOL FOR QUOTE MARK.                                       '000V000
.0    SYMBOL FOR PERIOD.                                           .000V000
)0    SYMBOL FOR RIGHT PAREN.                                      )000V000
/0    SYMBOL FOR SLASH.                                            /000V000
/1    SYMBOL FOR DIGIT 1.                                          /001V000
/2    SYMBOL FOR DIGIT 2.                                          /002V000
/3    SYMBOL FOR DIGIT 3.                                          /003V000
/4    SYMBOL FOR DIGIT 4.                                          /004V000
/5    SYMBOL FOR DIGIT 5.                                          /005V000
/6    SYMBOL FOR DIGIT 6.                                          /006V000
/7    SYMBOL FOR DIGIT 7.                                          /007V000
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/8    SYMBOL FOR DIGIT 8.                                                 /008V000
/9    SYMBOL FOR DIGIT 9.                                                 /009V000
/10   SYMBOL FOR DIGIT 0.                                                 /010V000
/11   SYMBOL FOR CHARACTER H.                                             /011V000
/12   SYMBOL FOR CHARACTER J.                                             /012V000
/13   SYMBOL FOR CHARACTER W.                                             /013V000
/14   DUMMY CHARACTER SYMBOL WITH EXTERNAL NAME '/UGH/'                   /014V000
/16   DUMMY EXPRESION TO SUPPLY TEXT 'THE DEFINITIONS'                    /016V000
,0    SYMBOL FOR COMMA.                                                   ,000V000
(0    SYMBOL FOR LEFT PAREN.                                              (000V000
+0    SYMBOL FOR PLUS SIGN.                                               +000V000
$0    SYMBOL FOR DOLLAR SIGN.                                             $000V000
```

XV. COMPLETE PROGRAM LISTING

The program listing has been carefully and extensively documented in the comment fields to enable students to work directly from it.

```
  JOB      8168,LTNEW1,EAS826,5MIN,0,099,C          STEFFERUD
  ASSIGN   A6=SYSAR2
  ASSIGN   B6=SYSAR3
  IPL
LOGIC THEORIST (IPL-V)               9                                        -
                                     2 A              10               0000 000
                                     2 B              10               0000 010
                                     2 C              10               0000 020
                                     2 D              10               0000 030
                                     2 E              10               0000 040
                                     2 F              10               0000 050
                                     2 G              10               0000 060
                                     2 I              10               0000 070
                                     2 K             100               0000 080
                                     2 L              50               0000 090
                                     2 M             200               0000 100
                                     2 N              50               0000 110
                                     2 O              10               0000 120
                                     2 P             100               0000 130
                                     2 Q              50               0000 140
                                     2 R              10               0000 150
                                     2 S              10               0000 160
                                     2 T              40               0000 170
                                     2 U              10               0000 180
                                     2 V              10               0000 190
                                     2 X              50               0000 200
                                     2 Y              10               0000 210
                                     2 Z              50               0000 220
                                     2 -              10               0000 230
                                     2 *             600               0000 240
                                     2 =              10               0000 260
                                     2 ,              10               0000 270
                                     2 /              20               0000 280
                                     2 +              10               0000 290
                                     2 .              10               0000 300
                                     2 (              10               0000 310
                                     2 )              10               0000 320
                                     2 '              10               0000 330
```

```
 PROGRAM HEADER                     5                                    R  -
M1 SINGLE PROBLEM EXECUTIVE FOR     M1      M3                     M001R000
   PROBLEM (0). H5 + IF SUCCEEDS.          40W0                    M001R010
                                           60W0        1W0=PROB    M001R020
TEST UTILITY.                               M43                    M001R030
     IF NO GOOD, QUIT.                     709-4                   M001R040
                                           11W0                    M001R050
PRINT 'TO PROVE' PROBLEM 1W0.               M78                    M001R060
                                           11W0                    M001R070
TRY SUBSTITUTION.                           M12                    M001R080
    IF WORKED, PRINT PROOF.                70       9-2            M001R090
                                    9-1    11W0                    M001R100
CREATE LIST OF METHODS FOR PROB.            M8                     M001R110
                                           11W0                    M001R120
APPLY METHODS.                              M7                     M001R130
      IF PROOF FOUND, PRINT  IT.           70       9-2            M001R140
TEST IF ANY LIMITS EXCEEDED.                M90                    M001R150
     IF YES, QUIT.                         70       9-3            M001R160
FIND NEXT SUBPROBLEM.                       M60                    M001R170
     IF NONE, QUIT.                        709-3                   M001R180
     IF ONE,                               60W0                    M001R190
PRINT SUBPROBLEM, TRY METHODS.              M70     9-1            M001R200
PRINT PROOF FROM (0).               9-2     M71                    M001R210
      AND QUIT +.                          30W0     J4             M001R220
PRINT FAILURE, QUIT -.              9-3     M72     9-5            M001R230
                                    9-4    11W0                    M001R240
PRINT REJECTED PROBLEM                      M81                    M001R250
     AND QUIT -.                    9-5    30W0     J3             M001R260
                                   1                                 R
M2 MULTIPLE PROBLEM EXECUTIVE.      M2     10L3                    M002R000
                                           109-100                 M002R010
GENERATE PROBLEMS FOR PROOF.                J100    0              M002R020
                                    9-100   J50                    M002R030
                                           11W0                    M002R040
CONVERT TO INTERNAL (TREE) FORM.            P50                    M002R050
    IF FAILED, TAKE ERROR ACTION.          709-103                 M002R055
                                           11K30                   M002R060
                                           10R                     M002R070
TEST IF REMEMBERING.                        J2                     M002R080
INPUT PROBLEM FOR M1.                      11W0                    M002R090
                                           709-101                 M002R100
TRY FOR PROOF TO BE REMEMBERED,             M1                     M002R110
H5- MEANS NO PROOF FOUND.                  709-102                 M002R120
                                           11W0                    M002R130
PRINT ' REMEMBER PROVED THEOREM'            M82                    M002R135
ADD TO TRUE EXPRESSIONS LIST.               M50     9-102          M002R140
TRY FOR PROOF TO BE FORGOTTEN.      9-101   M1                     M002R150
CLEAN UP W0, H5+ FOR GEN.           9-102  30W0     J4             M002R160
                                    9-103  11W0                    M002R170
                                            M88     9-102          M002R180
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                                           1                                       R
M3 SET UP FOR NEW PROBLEM.                M3     10L10                      M003R000
                                                   J75                      M003R010
CLEAR UNTRIED PROBLEMS LIST.                       J72                      M003R020
                                                 10L11                      M003R030
                                                   J75                      M003R040
CLEAR FOUND PROBLEMS LIST.                         J72                      M003R050
                                                 10K10                      M003R060
CLEAR PREVIOUS PROBLEM NUMBER.                     J124                     M003R070
                                                 50K11                      M003R080
CLEAR SUBSTITUTIONS COUNT.                         J124                     M003R090
                                                 50H3                       M003R100
                                                 10K12                      M003R110
SET EFFORT BASE.                                   J121    J8               M003R120
                                           1                                       R
M7 APPLY METHODS (1) TO PROBLEM           M7       J50                      M007R000
    (0), ERASE LIST (1) WHEN THRU.               40H0                       M007R010
    H5+ MEANS OUTPUT (0) IS SOL'N.               109-100                    M007R020
    H5- MEANS NO OUTPUT, NO SOL'N.                 J100                     M007R030
                                                   J5                       M007R035
                                                 30W0                       M007R040
IF NO PROOF, ERASE METHOD LIST.                  70J71                      M007R045
ELSE SAVE PROOF AND ERASE LIST.                    J6      J71              M007R050
9-100 SUBPROCESS, APPLY METHOD (0)        9-100  11W0                       M007R060
      TO PROBLEM 1W0.                              J6                       M007R070
REVERSE H5 FOR GENERATOR.                          J1      J5               M007R080
                                           1                                       R
M8 CREATE METHOD LIST FOR (0).            M8     10L7                       M008R000
COPY REGULAR LIST.                                 J73                      M008R010
                                                   J50                      M008R020
TEST IF ORIGINAL PROBLEM.                          J130                     M008R030
    IF NOT, NO SPECIAL METHODS.                  709-1                      M008R040
    IF YES,                                      11W0                       M008R050
                                                 10L6                       M008R070
COPY SPECIAL LIST,                                 J73                      M008R080
INSERT AFTER HEAD OF REGULAR LIST.                 J76                      M008R090
SET UP OUTPUT AND QUIT.                          51W0      J30              M008R100
                                          9-1    11W0      J30              M008R110
                                           1                                       R
M11 DETACHMENT METHOD FOR PROB (0).       M11      J45                      M011R000
    ADD NEW SUBPROBLEMS TO UNTRIED               60W1            1W1=PROB   M011R010
    LIST IF CAN.                                   J81                      M011R020
H5+ MEANS OUTPUT (0) IS A                        70J35                      M011R030
    SOLUTION.                                    60W0            1W0=PRBMEXM011R040
    H5- MEANS NO SOLUTION, NO OUTPT              50L5            1L5=L4     M011R050
                                                 11K6            1K6=IMPLY  M011R060
FIND IMPLIES MAPS.                                 J10                      M011R070
                                                 70J35                      M011R080
FIND MAP OF RIGHT SIDES OF MAIN                    J82                      M011R090
CONNECTIVE IMPLIES.                              70J35                      M011R100
                                                 11W1                       M011R110
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                                                 J6                      M011R120
GET LIST OF FEASIBLE THEOREMS.                   M63                     M011R130
SAVE LIST FOR ERASURE.                          60W5                     M011R140
                                                109-100                  M011R150
GENERATE FEASIBLE THEOREMS.                      J100                    M011R160
                                                11W5           1W5=THMLSTM011R170
CLEAN UP AND                                     J71                     M011R180
REVERSE H5 AFTER GENERATOR.                      J5      J35             M011R190
9-100 SUBPROCESS,                        9-100  60W2           1W2=THM   M011R200
      TRY PROOF WITH THEOREM (0).               11W1                     M011R210
                                                11W2                     M011R220
MAKE FREE VARIABLES DISJOINT                     M110                    M011R230
FIND RIGHT SUBSEGMENT OF THM                     P14                     M011R240
                                                70J4                     M011R250
                                                11W0                     M011R260
MATCH, MAKE THM RIGHT LIKE PROB.                 M113          (1)=THMRT M011R270
                                                70J4                     M011R280
                                                60W3           1W3=SUBSTLM011R290
                                                11W2                     M011R300
FIND THM LEFT SUBSEGMENT.                        P13                     M011R310
                                                709-101        (0)=THMLFTM011R320
                                                 P17                     M011R340
MAKE NEW TEX FROM COPY OF THMLFT.                P24                     M011R345
                                                60W4           1W4=NEWTEXM011R350
SUBSTITUTE INTO NEWTEX FROM (1)                  M115                    M011R360
ERASE SUBSTL.                                    9-101                   M011R370
ASSIGN DERIVATION                               11W4           NEWPROBLEMM011R390
                                                11W1           PROBLEM   M011R400
                                                11W2           THEOREM   M011R410
COMPLETE NEW SUBPROBLEM                         10M11                    M011R420
DESCRIPTION AND MEASURE UTILITY.                 M19                     M011R430
H5- MEANS NEW PROBLEM WAS ERASED.               70J4                     M011R440
TRY SUBSTITUTION, OUTPUT SOL'N.                  M12     J5              M011R460
                                         9-101  11W3                     M011R470
                                                 J72     J4              M011R480
                                      1                                         R
M12 SUBSTITUTION METHOD FOR              M12     J43                     M012R000
    PROBLEM (0). H5+ MEANS                      60W1           1W1=PROB  M012R010
    OUTPUT (0) IS A SOLUTION                     J81                     M012R020
    H5- MEANS NO OUTPUT.                        70J33                    M012R030
                                                60W0           1W0=PRBMEXM012R040
                                                50K11                    M012R050
TALLY SUBSTITUTION COUNTER.                      J125                    M012R060
                                                51W1                     M012R070
                                                10L4                     M012R080
GET A LIST OF FEASIBLE THEOREMS.                 M63                     M012R090
SAVE THE LIST FOR ERASURE.                      60W3           1W3=THMLSTM012R100
                                                109-100                  M012R110
GENERATE THEOREMS.                               J100                    M012R120
                                                11W3                     M012R130
ERASE LIST OF THEOREMS,                          J71                     M012R140
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CLEAN-UP AND REVERSE H5.                       J33    J5                   M012R150
9-100 SUBPROCESS, TRY PROBLEM MEX       9-100 60W2            1W2=THM      M012R160
   1WO WITH THEOREM (0).                      11W1                         M012R170
                                              11W2                         M012R180
MAKE FREE VARIABLES DISJOINT.                  M110                        M012R190
FIND MAIN EXPRESSION OF THEOREM.               J81                         M012R200
                                              70J4                         M012R210
                                              11W0                         M012R220
TEST FOR MATCH.                                M114                        M012R230
IF H5-, SET + FOR GENERATOR,                  70J4                         M012R240
                                              11W1                         M012R250
                                              11W2                         M012R260
OTHERWISE ASSIGN PROOF                        10Q13                        M012R270
AND OUTPUT SUCCESSFUL PROBLEM 1W1              J11                         M012R280
AS SOLUTION. QUIT WITH H5- FOR GEN.           11W1    J3                   M012R290
                                        1                                      R
M13 REPLACEMENT METHOD FOR PROB (0)    M13     J46                         M013R000
    ADD NEW SUBPROBLEMS TO UNTRIED            60W1            1W1=PROB     M013R010
    LIST IF CAN.                               J81                         M013R020
    H5+ MEANS OUTPUT (0) IS A                 70J36                        M013R030
    SOLUTION.                                 60W0            1W0=PRBMEXM013R040
    H5- MEANS NO SOL'N, NO OUTPUT.            50L5            1L5=L4       M013R050
                                              11K5            1K5=DEFEQ    M013R060
FIND DEFINITIONAL EQUIVALENCE MAPS.            J10                         M013R070
                                              70J36                        M013R080
                                              60W5            1W5=DEFMPSM013R090
FIND MAP OF LEFT SIDES OF DEFEQ.               J81                         M013R100
                                              709-10                       M013R110
                                              11W1                         M013R120
                                               J6                          M013R130
GET LIST OF FEASIBLE DEFINITIONS.              M63                         M013R140
SAVE LIST FOR ERASURE.                        60W6            1W6=FSBLS    M013R150
TRY LEFT SIDES.                               109-100                      M013R160
GENERATE FEASIBLE DEFINITIONS.                 J100                        M013R170
                                              11W6                         M013R180
ERASE FEASIBLES LIST.                          J71                         M013R190
REVERSE H5 FROM GENERATOR.                     J5                          M013R200
QUIT IF PROOF IN H0, OR TRY RIGHTS.           709-10  J36                  M013R210
                                        9-10  11W5                         M013R220
FIND MAP OF RIGHT SIDES OF DEFEQ.              J82                         M013R230
                                              70J36                        M013R240
                                              11W1                         M013R250
                                               J6                          M013R260
GET LIST OF FEASIBLE DEFINITIONS.              M63                         M013R270
SAVE LIST.                                    60W6            1W6=FSBLS    M013R280
TRY RIGHT SIDES.                              109-200                      M013R290
GENERATE FEASIBLE DEFINITIONS.                 J100                        M013R300
                                              11W6                         M013R310
ERASE FEASIBLES LIST.                          J71                         M013R320
REVERSE H5, CLEAN UP AND QUIT.                 J5     J36                  M013R330
TRY LEFT SIDE OF (0) W/1WO.             9-100 60W2            1W2=DEF      M013R340
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                                               11W1                      M013R350
                                               11W2                      M013R360
MAKE FREE VARIABLES DISJOINT.                    M110                    M013R370
FIND LEFT SUB SEG OF DEF.                        P13                     M013R380
                                               70J4                      M013R390
                                               11W0                      M013R400
MATCH, MAKE DEF LIKE PROB IF CAN.                M113                    M013R410
                                               70J4                      M013R420
                                               60W3            1W3=SUBSTLM013R430
                                               11W2                      M013R440
FIND RIGHT SIDE OF DEFINITION.                   P14                     M013R445
     IF NONE,                                  70      9-300             M013R450
ERASE SUBST. LIST, QUIT + FOR GEN.               J72   J4                M013R455
TRY RIGHT SIDE OF (0) W/1W0.             9-200 60W2            1W2=DEF   M013R460
                                               11W1                      M013R470
                                               11W2                      M013R480
MAKE FREE VARIABLES DISJOINT.                    M110                    M013R490
FIND RIGHT SUB SEG OF DEF.                       P14                     M013R500
                                               70J4                      M013R510
                                               11W0                      M013R520
MATCH, MAKE DEF LIKE PROB IF CAN.                M113                    M013R530
                                               70J4                      M013R540
                                               60W3            1W3=SUBSTLM013R550
                                               11W2                      M013R560
FIND LEFT SIDE OF DEFINITION.                    P13                     M013R565
     IF NONE,                                  70      9-300             M013R570
ERASE SUBST. LIST, QUIT + FOR GEN.               J72   J4                M013R575
MAKE SUBPROB FROM SEGMENT (0)            9-300   P17                     M013R580
     WITH SUBSTITUTION LIST (1)                  P24                     M013R590
                                               60W4            1W4=NEWTEXM013R600
SUBSTITUTE INTO NEWTEX FROM SUBSTL.              M115                    M013R610
                                                 9-301                   M013R620
                                               11W4                      M013R630
                                               11W1                      M013R640
                                               11W2                      M013R650
ASSIGN DERIVATION, ADD FOUND LIST,             10M13                     M013R660
MEASURE UTILITY, ERASE IF NO GOOD.               M19                     M013R670
                                               70J4                      M013R680
TRY SUBSTITUTION, H5+ OUTPUT PROOF.              M12   J5                M013R700
                                         9-301 11W3                      M013R710
ERASE SUBSTITUTION LIST.                         J72   J4                M013R720
                                        1                                    R
M14 FORWARD CHAINING METHOD FOR          M14     J44                     M014R000
    PROBLEM (0). ADDS NEW SUBPROBS             60W1            1W1=PROB  M014R010
    TO UNTRIED LIST IF CAN.                      P13                     M014R020
    H5+ MEANS OUTPUT (0) IS                    70J34                     M014R030
    SOLUTION.                                  609-1                     M014R040
    H5- MEANS NO SOLUTION, NO OUTPT            51W1                      M014R050
FIND MAIN CONNECTIVE OF PROB.                    P16                     M014R060
                                               70J34                     M014R070
                                               10L5                      M014R080
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                                                J6                    M014R090
FIND APPROPRIATE THEOREM MAPS.                  J10                   M014R100
                                              70J34                   M014R110
FIND MAP OF LEFT SIDES.                         J81                   M014R120
                                              70J34                   M014R130
INPUT FAKE TEX.                               109-0                   M014R140
                                                J6                    M014R150
GET FEASIBLE THEOREM LEFT SIDES.                M63                   M014R160
                                              60W0          1W0=FSBLS M014R170
TRY FEASIBLE THM LEFTS WITH                   109-100                 M014R180
PROBLEM LEFT. GENERATE FSBLS.                   J100                  M014R190
                                              11W0                    M014R200
ERASE LIST OF FEASIBLES.                        J71                   M014R210
                                                J5     J34            M014R220
FAKE TEX . . . 9-1 HOLDS MEX.           9-0     0      9-1            M014R230
9-100 SUBPROCESS, TRY LEFT SIDES.       9-100 60W2          1W2=THM   M014R240
                                              11W1          1W1=PROB  M014R250
                                              11W2                    M014R260
MAKE FREE VARIABLES DISJOINT.                   M110                  M014R270
FIND LEFT SEGMENT OF THM TEX.                   P13                   M014R280
                                              70J4                    M014R290
INPUT PROB LEFT                               119-1                   M014R300
MATCH, OUTPUT LIST OF SUBSTITUTIONS             M113                  M014R310
WILL MAKE THM LIKE PROB IF CAN.               70J4                    M014R320
                                              60W3          1W3=SUBSTLM014R330
                                              51W1                    M014R340
FIND RIGHT SIDE OF PROB                         P14                   M014R350
                                              709-101                 M014R360
                                              11W2                    M014R370
FIND RIGHT SIDE OF THEOREM.                     P14                   M014R380
                                              709-102                 M014R390
CREATE NEW TEX WITH COPIES.                     P22                   M014R400
                                              60W4          1W4=NEWTEXM014R405
       THM LEFT, PROB RIGHT.                  11W3                    M014R410
                                                J6                    M014R420
SUBSTITUTE INTO NEW TEX.                        M115                  M014R430
ERASE SUBSTL.                                   9-101                 M014R510
                                              11W4                    M014R520
                                              11W1                    M014R530
                                              11W2                    M014R540
                                              10M14                   M014R550
ASSIGN DERIVATION,ADD TO FOUND LIST             M19                   M014R560
MEASURE UTILITY, ERASE IF NO, GOOD.           70J4                    M014R570
TRY SUBSTITUTION, H5+ OUTPUT PROOF.             M12    J5             M014R590
                                        9-102 30H0                    M014R600
ERASE SUBSTITUTION LIST.                9-101 11W3                    M014R610
                                                J72    J4             M014R620
                                       1                                  R
M15 BACKWARD CHAINING METHOD FOR        M15     J44                   M015R000
    PROBLEM (0). ADDS NEW SUBPROBS            60W1          1W1=PROB  M015R010
    TO UNTRIED LIST IF CAN.                     P14                   M015R020
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    H5+ MEANS OUTPUT (0) IS A                  70J34                  M015R030
    SOLUTION.                                  609-1          9-0=FAKTEXM015R040
    H5- MEANS NO SOLUTION, NO OUTPT            50L5           L5 IS MAP M015R050
                                               11K6           1K6=IMPLY M015R060
FIND APPROPRIATE MAPS.                           J10                    M015R070
                                               70J34                    M015R080
FIND MAP OF RIGHT SIDES.                         J82                    M015R090
                                               70J34                    M015R100
                                               109-0                    M015R110
                                                 J6                     M015R120
GET FEASIBLE THEOREM RIGHT SIDES.                M63                    M015R130
                                               60W0           1W0=FSBLS M015R140
TRY FEASIBLE THM RIGHTS WITH                   109-100                  M015R150
PROBLEM RIGHT. GENERATE FSBLS.                   J100                   M015R160
                                               11W0                     M015R170
ERASE LIST OF FEASIBLES.                         J71                    M015R180
                                                 J5      J34            M015R190
FAKE TEX . . . 9-1 HOLDS MEX.           9-0      0       9-1            M015R200
9-100 SUBPROCESS, TRY RIGHT SIDES.      9-100  60W2           1W2=THM   M015R210
                                               11W1                     M015R220
                                               11W2                     M015R230
MAKE FREE VARIABLES DISJOINT.                    M110                   M015R240
FIND RIGHT SEGMENT OF THM TEX.                   P14                    M015R250
                                               70J4                     M015R260
INPUT PROB RIGHT.                              119-1                    M015R270
MATCH, OUTPUT LIST OF SUBSTITUTIONS              M113                   M015R280
WILL MAKE THM LIKE PROB IF CAN.                70J4                     M015R290
                                               60W3           1W3=SUBSTLM015R300
                                               51W2                     M015R310
FIND LEFT SIDE OF THEOREM.                       P13                    M015R320
                                               709-101                  M015R330
                                               11W1                     M015R340
FIND LEFT SIDE OF PROBLEM.                       P13                    M015R350
                                               709-102                  M015R360
CREATE NEW TEX WITH COPIES.                      P22                    M015R370
                                               60W4           1W4=NEWTEXM015R375
      PROB ON LEFT, THM ON RIGHT.              11W3                     M015R380
                                                 J6                     M015R390
SUBSTITUTE INTO NEW TEX.                         M115                   M015R400
ERASE SUBSTL.                                    9-101                  M015R480
                                               11W4                     M015R490
                                               11W1                     M015R500
                                               11W2                     M015R510
ASSIGN DERIVATION,ADD TO FOUND LIST            10M15                    M015R520
MEASURE UTILITY, ERASE IF NO GOOD.               M19                    M015R530
                                               70J4                     M015R540
TRY SUBSTITUTION, H5+ OUTPUT PROOF.              M12     J5             M015R560
                                        9-102  30H0                     M015R570
ERASE SUBSTITUTION LIST.                9-101  11W3                     M015R580
                                                 J72     J4             M015R590
                                        1                                  R
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M16 SUBLEVEL REPLACEMENT METHOD FOR  M16      J48                         M016R000
    PROBLEM (0). ADD ALL NEW                 60W0               1W0=PROB   M016R010
    SUBPROBLEMS TO UNTRIED LIST.             50L5                          M016R020
    H5-MEANS NO SOL'N, NO OUTPUT.            11K5                          M016R030
    H5+MEANS (0) IS A SOL'N.                  J10                          M016R040
(M16 TRIES ONE LEVEL AT A TIME)              70J38                         M016R050
                                             60W2                          M016R060
FIND MAP OF DEF. LEFT SIDES.                  J81                          M016R070
    IF NONE, QUIT-.                          70J38                         M016R080
                                             60W1               1W1=LFTMAPM016R090
                                             51W2                          M016R100
FIND MAP OF DEF. RIGHT SIDES.                 J82                          M016R110
    IF NONE, QUIT-.                          70J38                         M016R120
                                             60W2               1W2=RTMAP  M016R130
                                             51W0                          M016R140
                                             40H0                          M016R142
                                             10Q17                         M016R145
CLEAR LEVEL                                   J14                          M016R148
FIND LOWEST LEVEL IN PROBLEM.                 Q17                          M016R150
     IF NONE, QUIT-. IF YES,                 70J38                         M016R160
                                             20W3               1W3=CURLEVM016R165
BUMP 1W3, TEST IF GREATER THAN 1.    9-3      9-20                         M016R170
     IF NOT, QUIT-.                          70J38                         M016R175
     IF YES,                         9-10    11W0                          M016R180
COPY PROBLEM FOR REPLACEMENT.                 P25                          M016R190
                                             60W4               1W4=CPROB  M016R200
                                     9-11    10J3                          M016R210
SET'NEW SUBPROBLEM FLAG' TO NO.              60W5               1W5=FLAG   M016R220
                                             509-100                       M016R230
GENERATE SEGMENT LOCATIONS.                   P26                          M016R240
EXECUTE 'NEW SUBPROBLEM FLAG'                01W5                          M016R250
    IF YES, GO FINISH IT UP.                 70        9-1                 M016R260
BUMP 1W3 AND TEST IF GREATER THAN 1           9-20                         M016R270
    IF NOT, GO CLEAN UP, QUIT-.              709-2                         M016R280
    IF GREATER, COPY 1W4 AND                  J120                         M016R290
                                             10Q17                         M016R300
                                             11W4                          M016R310
ASSIGN COPY TO PROBLEM COPY.                  J11                          M016R320
                                             11W3                          M016R330
    LOOP FOR NEXT LEVEL.                     11W4      9-11                M016R340
    ALL DONE,                        9-2     11W4                          M016R350
ERASE LEFTOVER COPY, QUIT.                    J72      J38                 M016R360
SET UP DERIVATION ASSOCIATIONS,      9-1     11W4                          M016R370
                                             11W0                          M016R380
      AND                                    10/16                         M016R390
                                             10M16                         M016R400
FINISH BUILDING THE NEW SUBPROBLEM.           M19                          M016R410
    IF NO GOOD, SET UP TO LOOP.              709-3                         M016R420
    IF GOOD, TRY SUBSTITUTION.                M12                          M016R430
     IF PROOF, QUIT+. IF NOT, LOOP.          709-3     J38                 M016R440
9-20 SUBPROCESS--BUMP AND TEST       9-20    10N2                          M016R470
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    IF 1W3 GREATER THAN 1.                11W3                      M016R480
TEST IF 1W3 GREATER THAN N2.               J115                     M016R490
    IF NO, QUIT SUBPROCESS--.             700            NO OUTPUT  M016R500
    IF YES,                               10N1                      M016R510
                                          11W3                      M016R520
SUBTRACT 1, QUIT SUBPROCESS+.             11W3     J111  OUTPUT 1W3M016R530
9-100 SUBPROCESS FOR SUBSEGMENT     9-100 60W6           1W6=SEGLOCM016R540
    REPLACEMENT IN LOCATION (0).          51W1                      M016R550
                                          12W6                      M016R560
CREATE LIST OF FEASIBLE DEFS.              M62                      M016R570
SAVE LIST FOR LATER ARASURE.              40H0                      M016R580
                                          109-200                   M016R590
GENERATE DEFS FOR LEFT SIDE MATCH.         J100                     M016R600
    IF MATCHED, GO CLEAN UP.              709-101                   M016R610
    IF FAILED, ERASE OLD LIST,             J71                      M016R620
                                          11W2                      M016R630
                                          12W6                      M016R640
CREATE NEW LIST OF FEASIBLE DEFS.          M62                      M016R650
SAVE LIST FOR LATER ERASURE.              40H0                      M016R660
                                          109-300                   M016R670
GENERATE DEFS FOR RIGHT SIDE MATCH.        J100                     M016R680
ERASE LIST AND QUIR + FOR GEN.      9-101  J71     J4               M016R690
9-200 SUBPROCESS, TRY REPLACEMENT   9-200 60W7           1W7=DEF    M016R700
    BY MATCHING SEGMENT TO                11W4           1W4=CPROB  M016R710
    LEFT SIDES.                           11W7                      M016R720
MAKE FREE VARIABLES DISJOINT.              M110                     M016R730
FIND LEFT SEGMENT OF DEF.                  P13                      M016R740
    IF NONE, QUIT + FOR GEN.              70J4                      M016R750
    IF FOUND,                             12W6                      M016R760
MATCH SEGMENT TO LEFT SIDE.                M113                     M016R770
    IF NO MATCH, QUIT + FOR GEN.          70J4                      M016R780
    IF MATCHED, SAVE LIST,                60W8           1W8=SUBST  M016R790
                                          51W7                      M016R800
FIND RIGHT SIDE OF DEF.                    P14     9-301            M016R810
9-300 SUBPROCESS, TRY REPLACEMENT   9-300 60W7           1W7=DEF    M016R820
    BY MATCHING SEGMENT TO                11W4           1W4=CPROB  M016R830
    RIGHT SIDES.                          11W7                      M016R840
MAKE FREE VARIABLES DISJOINT               M110                     M016R850
FIND RIGHT SEGMENT OF DEF.                 P14                      M016R860
    IF NONE, QUIT + FOR GEN.              70J4                      M016R870
    IF FOUND,                             12W6                      M016R880
MATCH SEGMENT TO RIGHT SIDE.               M113                     M016R890
    IF NO MATCH, QUIT + FOR GEN.          70J4                      M016R900
    IF MATCHED, SAVE LIST,                60W8           1W8=SUBST  M016R910
                                          51W7                      M016R920
FIND LEFT SIDE OF DEF.                     P13                      M016R930
    IF NONE, CLEAN UP, QUIT +.      9-301 709-302                   M016R935
    IF FOUND, COPY IT,                     J74                      M016R940
                                          12W6                      M016R945
ERASE OLD SEGMENT, AND                     J72                      M016R950
REPLACE OLD WITH COPY FROM DEF.           21W6                      M016R955
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                                              11W8                  M016R960
                                              11W4                  M016R965
SUBSTITUTE IN PROB TEX PER 1W8.                M115                 M016R970
                                              10J4                  M016R975
SET 'NEW SUBPROBLEM FLAG' TO ON.              20W5                  M016R980
    SET H5 TO QUIT-.                           J4                   M016R985
                                        9-302 11W8                  M016R990
ERASE 1W8, REVERSE H5 FOR GEN.                 J72    J5            M016R995
                                          1                            R
M17 SUBLEVEL REPLACEMENT METHOD FOR     M17    J48                  M017R000
    PROBLEM (0). ADD ALL NEW                  60W0          1W0=PROB  M017R010
    SUBPROBLEMS TO UNTRIED LIST.              50L5                  M017R020
    H5-MEANS NO SOL'N, NO OUTPUT.             11K5                  M017R030
    H5+MEANS (0) IS A SOL'N.                   J10                  M017R040
(M17 TRIES ALL LEVELS A ONCE)                 70J38                 M017R050
                                              60W2                  M017R060
FIND MAP OF DEF. LEFT SIDES.                   J81                  M017R070
    IF NONE, QUIT-.                           70J38                 M017R080
                                              60W1          1W1=LFTMAPM017R090
                                              51W2                  M017R100
FIND MAP OF DEF. RIGHT SIDES.                  J82                  M017R110
    IF NONE, QUIT-.                           70J38                 M017R120
                                              60W2          1W2=RTMAP M017R130
                                              51W0                  M017R140
                                              40H0                  M017R142
                                              10Q17                 M017R145
CLEAR LEVEL                                    J14                  M017R148
FIND LOWEST LEVEL IN PROBLEM.                  Q17                  M017R150
     IF NONE, QUIT-. IF YES,                  70J38                 M017R160
                                              20W3          1W3=CURLEVM017R165
BUMP 1W3, TEST IF GREATER THAN 1.       9-3    9-20                 M017R170
     IF NOT, QUIT-.                           70J38                 M017R175
     IF YES,                            9-10  11W0                  M017R180
COPY PROBLEM FOR REPLACEMENT.                  P25                  M017R190
                                              60W4          1W4=CPROB M017R200
                                        9-11  10J3                  M017R210
SET'NEW SUBPROBLEM FLAG' TO NO.               60W5          1W5=FLAG  M017R220
                                              509-100               M017R230
GENERATE SEGMENT LOCATIONS.                    P26                  M017R240
BUMP 1W3 AND TEST IF GREATER THAN 1            9-20                 M017R250
    IF NOT, GO TEST FLAG.                     709-2                 M017R260
    IF GREATER, COPY 1W4 AND                   J120                 M017R270
                                              10Q17                 M017R280
                                              11W4                  M017R290
ASSIGN COPY TO PROBLEM COPY.                   J11                  M017R300
                                              11W3                  M017R310
    LOOP FOR NEXT LEVEL.                      11W4    9-11          M017R320
EXECUTE 'NEW SUBPROBLEM FLAG'           9-2   01W5                  M017R330
    IF YES, GO FINISH IT UP.                  70      9-1           M017R340
    ALL DONE,                                 11W4                  M017R350
ERASE LEFTOVER COPY, QUIT.                     J72    J38           M017R360
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SET UP DERIVATION ASSOCIATIONS,      9-1   11W4                          M017R370
                                           11W0                          M017R380
      AND                                  10/16                         M017R390
                                           10M16                         M017R400
FINISH BUILDING THE NEW SUBPROBLEM.         M19                          M017R410
    IF NO GOOD, QUIT -.                    70J38                         M017R420
    IF GOOD, TRY SUBSTITUTION.              M12                          M017R430
     IF PROOF, QUIT+. IF NOT, QUIT-         J38    0                     M017R440
9-20 SUBPROCESS--BUMP AND TEST       9-20  10N2                          M017R470
    IF 1W3 GREATER THAN 1.                 11W3                          M017R480
TEST IF 1W3 GREATER THAN N2.                J115                         M017R490
    IF NO, QUIT SUBPROCESS--.              700                NO OUTPUT  M017R500
    IF YES,                                10N1                          M017R510
                                           11W3                          M017R520
SUBTRACT 1, QUIT SUBPROCESS+.              11W3    J111       OUTPUT 1W3M017R530
9-100 SUBPROCESS FOR SUBSEGMENT      9-100 60W6               1W6=SEGLOCM017R540
    REPLACEMENT IN LOCATION (0).           51W1                          M017R550
                                           12W6                          M017R560
CREATE LIST OF FEASIBLE DEFS.               M62                          M017R570
SAVE LIST FOR LATER ARASURE.               40H0                          M017R580
                                           109-200                       M017R590
GENERATE DEFS FOR LEFT SIDE MATCH.          J100                         M017R600
    IF MATCHED, GO CLEAN UP.               709-101                       M017R610
    IF FAILED, ERASE OLD LIST,              J71                          M017R620
                                           11W2                          M017R630
                                           12W6                          M017R640
CREATE NEW LIST OF FEASIBLE DEFS.           M62                          M017R650
SAVE LIST FOR LATER ERASURE.               40H0                          M017R660
                                           109-300                       M017R670
GENERATE DEFS FOR RIGHT SIDE MATCH.         J100                         M017R680
ERASE LIST AND QUIR + FOR GEN.       9-101  J71    J4                    M017R690
9-200 SUBPROCESS, TRY REPLACEMENT    9-200 60W7               1W7=DEF    M017R700
    BY MATCHING SEGMENT TO                 11W4               1W4=CPROB  M017R710
    LEFT SIDES.                            11W7                          M017R720
MAKE FREE VARIABLES DISJOINT.               M110                         M017R730
FIND LEFT SEGMENT OF DEF.                   P13                          M017R740
    IF NONE, QUIT + FOR GEN.               70J4                          M017R750
    IF FOUND,                              12W6                          M017R760
MATCH SEGMENT TO LEFT SIDE.                 M113                         M017R770
    IF NO MATCH, QUIT + FOR GEN.           70J4                          M017R780
    IF MATCHED, SAVE LIST,                 60W8               1W8=SUBST  M017R790
                                           51W7                          M017R800
FIND RIGHT SIDE OF DEF.                     P14    9-301                 M017R810
9-300 SUBPROCESS, TRY REPLACEMENT    9-300 60W7               1W7=DEF    M017R820
    BY MATCHING SEGMENT TO                 11W4               1W4=CPROB  M017R830
    RIGHT SIDES.                           11W7                          M017R840
MAKE FREE VARIABLES DISJOINT                M110                         M017R850
FIND RIGHT SEGMENT OF DEF.                  P14                          M017R860
    IF NONE, QUIT + FOR GEN.               70J4                          M017R870
    IF FOUND,                              12W6                          M017R880
MATCH SEGMENT TO RIGHT SIDE.                M113                         M017R890
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    IF NO MATCH, QUIT + FOR GEN.               70J4                    M017R900
    IF MATCHED, SAVE LIST,                     60W8           1W8=SUBST M017R910
                                               51W7                    M017R920
FIND LEFT SIDE OF DEF.                          P13                    M017R930
    IF NONE, CLEAN UP, QUIT +.          9-301 709-302                  M017R935
    IF FOUND, COPY IT,                          J74                    M017R940
                                               12W6                    M017R945
ERASE OLD SEGMENT, AND                          J72                    M017R950
REPLACE OLD WITH COPY FROM DEF.                21W6                    M017R955
                                               11W8                    M017R960
                                               11W4                    M017R965
SUBSTITUTE IN PROB TEX PER 1W8.                 M115                   M017R970
                                               10J4                    M017R975
SET 'NEW SUBPROBLEM FLAG' TO ON.               20W5                    M017R980
    SET H5 TO QUIT-.                            J4                     M017R985
                                        9-302 11W8                     M017R990
ERASE 1W8, REVERSE H5 FOR GEN.                  J72     J5             M017R995
                                     1                                     R
M19 FINISH BUILDING NEW SUBPROBLEM      M19     J53           1W3=NEWTEXM019R000
   (3) FROM (2) VIA THM(1) BY                  11W3           1W2=PROBLMM019R010
   METHOD (0). MEASURE UTILITY.                11W2           1W1=THM   M019R020
   H5-, NO OUTPUT,TEX ERASED.                  10Q10          1W0=METHODM019R030
   H5+ MEANS OUTPUT (0) IS OK.                  J11                    M019R040
                                               11W3                    M019R050
FILL                                           11W0                    M019R060
QUT                                            10Q11                   M019R070
DESCRIPTION.                                    J11                    M019R080
                                               11W3                    M019R090
                                               11W1                    M019R100
                                               10Q12                   M019R110
                                                J11                    M019R120
                                               11W3                    M019R130
MARK LOCAL FOR FOUND LIST.                      J136                   M019R135
EVALUATE UTILITY.                               M43                    M019R140
                                               11W3                    M019R150
     IF N.G., REJECT IT.                       709-1                   M019R160
     IF O.K., ADD TO UNTRIED LIST.              M51                    M019R170
                                               11W3                    M019R180
QUIT +, OUTPUT NEW PROBLEM.                     J33     J4             M019R190
                                        9-1    11K31                   M019R200
                                               10Y                     M019R210
TEST IF PRINTING REJECTS.                       J2                     M019R220
     IF NO, SKIP IT.                           709-2                   M019R230
     IF YES, PRINT IT.                          M81                    M019R240
                                               11W3                    M019R250
ERASE N. G. SUBPROBLEM.                 9-2     J72                    M019R260
QUIT -.                                         J33     J3             M019R270
                                     1                                     R
M40 TEST IF TOTAL EXPRESSIONS           M40     J51           1W0=TEX1  M040R000
    (0) AND (1) MATCH.                         11W1           1W1=TEX2  M040R010
FIND MAIN SEGMENT.                              J81                    M040R020
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                                              709-0                      M040R030
                                              11W0                       M040R040
FIND MAIN SEGMENT.                              J81                      M040R050
                                              709-1                      M040R060
TEST IF SEGMENTS MATCH.                         M41    J31               M040R070
TEST IF OTHER MAIN SEGMENT             9-0    11W0                       M040R080
EXISTS.                                         J81                      M040R090
                                                J5                       M040R100
NO, QUIT W/H5+ FOR MATCH                      709-1    J31               M040R110
YES, QUIT W/H5- FOR NO MATCH.          9-1    30H0     J31               M040R120
                                     1                                          R
M41 TEST IF SEGMENTS (0) AND (1)       M41      J51            1W0=SEG1  M041R000
    MATCH.                                    11W0             1W1=SEG2  M041R010
TEST IF 1ST IS VARIABLE.                        P8                       M041R020
    IF NOT, EXAMINE SUBSEGMENTS.              709-1                      M041R030
    IF YES,                                   11W0                       M041R040
                                              11W1                       M041R050
TEST IF SAME VARIABLE.                          J2                       M041R060
    IF YES, QUIT, H5+.                        70       J31               M041R070
    IF NO,                                    11W1                       M041R080
TEST IF 2ND IS FREE VARIABLE.                   P9                       M041R090
    IF NO, QUIT, H5-.                         70J31                      M041R100
    IF YES,                                   11W0                       M041R110
TEST IF 1ST IS FREE VARIABLE.                   P9     J31               M041R120
EXAMINE SUBSEGMENTS.                   9-1    11W1                       M041R130
TEST IF NOT SEGMENT.                            P8                       M041R140
    IF NOT, QUIT, H5-                         70       9-2               M041R150
    IF YES,                                   12W0                       M041R160
                                              12W1                       M041R170
TEST IF SAME CONNECTIVES.                       J2                       M041R180
    IF NOT, QUIT, H5-                         70J31                      M041R190
    IF YES,                                   11W0                       M041R200
FIND LEFT SUBSEGMENT.                           J81                      M041R210
    IF NONE, CHECK OTHER SIDE.                709-3                      M041R220
                                              11W1                       M041R230
FIND OTHER LEFT SUBSEGMENT.                     J81                      M041R240
    IF NONE, QUIT, H5-.                       709-7                      M041R250
TEST IF LEFT SEGMENTS MATCH.                    M41                      M041R260
    IF NOT, QUIT, H5-                         70J31                      M041R270
                                              11W0                       M041R280
FIND RIGHT SUBSEGMENT.                          J82                      M041R290
    IF NONE, CHECK OTHER SIDE.                709-4                      M041R300
                                              11W1                       M041R310
FIND OTHER RIGHT SUBSEGMENTS.                   J82                      M041R320
    IF NONE, QUIT, H5-                        709-7                      M041R330
TEST IF RIGHT SEGMENTS MATCH,                   M41    J31   AND QUIT.   M041R340
QUIT, REVERSE H5.                      9-2      J5     J31               M041R350
NO FIRST SEGMENT ON 1W0,               9-3    11W1                       M041R360
FIND FIRST SEGMENT ON 1W1.                      J81                      M041R370
    IF NONE, H5+. ELSE H5-.            9-5    709-2    9-6               M041R380
NO SECOND SEGMENT ON 1W0,              9-4    11W1                       M041R390
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FIND SECOND SEGMENT ON 1W1.                          J82    9-5              M041R400
REVERSE H5 AND                              9-6      J5                      M041R410
QUIT, DISCARD (0).                          9-7     30H0    J31              M041R420
                                         1                                       R
M42 ADD PROBLEM (0) TO FOUND LIST.          M42      J42                     M042R000
    IF CANNOT, SET H5 -.                            60W0            1W0=PROB M042R010
                                                    50L11                    M042R030
                                                    11W0                     M042R040
GET NUMBER OF LEVELS                                 Q2                      M042R050
    IF NONE, QUIT -.                                709-300                  M042R055
GET SUBLIST                                          9-100                   M042R060
                                                    11W0                     M042R070
GET NUMBER OF DISTINCT VARIABLES                     Q3                      M042R080
    IF NONE, QUIT -.                                709-300                  M042R085
GET SUBLIST                                          9-100                   M042R090
                                                    11W0                     M042R100
GET NUMBER OF VARIABLE PLACES                        Q4                      M042R110
    IF NONE, QUIT -.                                709-300                  M042R115
GET SUBLIST                                          9-100                   M042R120
                                                    40H0                     M042R130
                                                    109-200                  M042R140
GENERATE SUBLIST FOR MATCH                           J100                    M042R150
                                                    709-1                    M042R160
INSERT AT END OF LIST                               11W0                     M042R170
                                                     J32    J65              M042R180
                                            9-1     30H0    J32              M042R190
9-200 SUBPROCESS.                           9-200   11W0                     M042R200
COMPARE EXPRESSIONS                                  M40    J5               M042R210
9-100 SUBPROCESS, GET SUBLIST.              9-100   64W1            1W1=D.T. M042R220
LOCATE SUBLIST.                                      P55                     M042R230
                                                    70      J80              M042R240
                                                    40H0                     M042R250
CREATE NEW SUBLIST.                                  J90                     M042R260
                                                     J136                    M042R270
SAVE SUBLIST FOR OUTPUT.                            60W2            1W2=SUBLSTM042R280
INSERT NEW SUBLIST.                                  J64                     M042R290
                                                    11W1                     M042R300
COPY DATA TERM.                                      J120                    M042R310
MARK LOCAL.                                          J136                    M042R320
INSERT BEFORE NEW SUBLIST.                           J64                     M042R330
GET SUBLIST AND QUIT.                               11W2    0                M042R340
                                            9-300   30H0    J32              M042R350
                                         1                                       R
M43 MEASURE UTILITY SUBPROBLEM (0).         M43      J43                     M043R000
    SET H5+ IF GOOD, H5- IF N.G.                    60W0            1W0=PROB M043R010
FIND MEX.                                            J81                     M043R020
                                                    70J33                    M043R030
GO THRU 'NOTS'                                       P4                      M043R040
                                                    70J33                    M043R045
SAVE UNNOTTED MEX.                                  60W1            1W1=MEX  M043R050
TEST IF VARIABLE                                     P8                      M043R060
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                                                    J5                          M043R070
IF H5-, QUIT (VARIABLE ONLY)                        70J33                       M043R080
                                                    12W1             2W1=MCONN  M043R090
                                                    11K1             1K1='OR'   M043R100
TEST IF MAIN CONNECTIVE 'OR'                        J2                          M043R110
IF NOT 'OR', LOOK ON FOUND LIST                     709-10                      M043R120
                                                    11W1                        M043R130
LOCATE RIGHT SIDE                                   J60                         M043R140
                                                    709-0                       M043R150
GET RIGHT SIDE                                      12H0                        M043R160
                                                    J6                          M043R170
LOCATE LEFT SIDE                                    J60                         M043R180
                                                    709-1                       M043R190
GET LEFT SIDE                                       52H0                        M043R200
TEST IF SIDES MATCH.                                M114                        M043R210
                                                    J5                          M043R220
IF SAME QUIT W/H5-                                  70J33                       M043R230
                                            9-10    11W0                        M043R240
ADD TO FOUND LIST IF CAN                            M42      J33                M043R260
                                            9-1     30H0                        M043R270
                                            9-0     30H0     J33                M043R280
                                          1                                     R
M50 ADD TEX(0) TO TRUE EXPRESSIONS          M50     40H0                        M050R000
   LIST AND TRUE EXPRESSIONS MAP.                   J50                         M050R010
   MAKE ALL VARIABLES FREE.                         P27                         M050R020
                                                    10L1                        M050R030
                                                    11W0                        M050R040
ADD TO LIST                                         J65                         M050R050
                                                    10L4                        M050R060
                                                    11W0                        M050R070
ADD TO MAP                                          M54                         M050R080
                                                    11W0                        M050R090
PRINT EXPRESSION AND QUIT.                          M70      J30                M050R100
                                          1                                     R
M51 PRINT NEW SUBPROBLEM (0) AND            M51     J41                         M051R000
    ADD TO UNTRIED SUBPROBLEM LIST.                 60W0             1W0=PROB   M051R010
                                                    10K10                       M051R020
TALLY PREVIOUS SUBPROBLEM NUMBER.                   J125                        M051R030
                                                    J120                        M051R040
                                                    J136                        M051R050
                                                    10Q8                        M051R060
ASSIGN PROBLEM NO.                                  J11                         M051R070
                                                    10L10                       M051R080
                                                    11W0                        M051R110
FIND NO. OF LEVELS                                  Q2                          M051R120
    IF NONE, QUIT -.                                709-3                       M051R125
                                                    60W1             1W1=LEVELSM051R130
LOCATE CORRESPONDING LIST.                          P55                         M051R140
                                                    709-1                       M051R150
GET LIST.                                           52H0                        M051R160
                                                    11W0                        M051R170
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ADD NEW SUBPROBLEM.                          J65     9-2             M051R190
                                     9-1    40H0                     M051R200
                                            11W0                     M051R210
CREATE LIST OF ONE SUBPROBLEM.               J91                     M051R223
                                             J136                    M051R226
INSERT NEW LIST.                             J64                     M051R230
                                            11W1                     M051R240
COPY LEVEL DATA TERM.                        J120                    M051R250
                                             J136                    M051R260
INSERT BEFORE NEW LIST.                      J64     9-2             M051R270
                                     9-2    11W0                     M051R280
PRINT NEW SUBPROBLEM.                        M75     J31             M051R290
                                     9-3    30H0     J31             M051R300
                                   1                                        R
M54 ADD TOTAL EXPRESSION (0) TO      M54    40W0                     M054R000
   MAP OF TRUE EXPRESSIONS (1).             60W0           1W0=THMNAMM054R010
                                             J81                     M054R020
                                            709-0          (0)=MEX   M054R030
                                             J6                      M054R040
ADD MAIN SEGMENT (1) TO MAP (0).             9-100 J30               M054R050
                                     9-0    30H0     J30             M054R060
9-100 SUBPROCESS, ADD SEGMENT (1)    9-100  04J43          1W0=THMNAMM054R070
                  TO MAP (0).               20W1           1W1=MAP   M054R080
                                            60W2           1W2=SEGMNTM054R090
TEST IF SIMPLE VARIABLE.                     P8                      M054R100
   IF NO, CONTINUE DOWN MAP.                709-102                  M054R110
   IF YES, ADD THMNAME.                     11W1                     M054R120
TEST IF NAME LIST IN MAP HEAD.               J79                     M054R130
   IF NO, GO MAKE ONE.                      709-101                  M054R140
   IF YES,                                  12W1                     M054R150
                                            11W0                     M054R160
INSERT NAME AND QUIT.                        J64     J33             M054R170
                                     9-101  11W0                     M054R180
CREATE LIST OF ONE NAME.                     J91                     M054R190
                                             J136                    M054R200
PLACE IN MAP HEAD AND QUIT.                 21W1     J33             M054R210
INPUT MAP HOLDER.                    9-102  10W1                     M054R220
INPUT SEGMENT CONNECTIVE.                   12W2                     M054R230
FIND SUBMAPS LIST.                           J10                     M054R240
   IF FOUND, CONTINUE.                      70       9-110           M054R250
   IF NONE,                                 10W1                     M054R260
                                             J90                     M054R270
CREATE 1ST LOCAL SUBMAP.                     J136                    M054R280
                                            12W2                     M054R290
TEST IF 2ND SUBLIST NEEDED.                  P6                      M054R300
   IF NO, SKIP IT.                          709-111                  M054R310
   IF YES,                                  40H0                     M054R320
CREATE 2ND LOCAL SUBMAP.                     J120                    M054R330
                                             J92     9-112           M054R340
CREATE SUBMAP LIST.                  9-111   J91                     M054R350
                                     9-112   J136                    M054R360
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                                                 60W3             1W3=MAPLSTM054R370
                                                 12W2                       M054R380
ASSIGN AS SUBMAP LIST OF CONNECTIVE               J11                       M054R390
                                                 11W3    9-110              M054R400
                                         9-110   20W3             1W3=MAPLSTM054R410
                                                 11W2                       M054R420
FIND 1ST SUB SEGMENT.                             J81                       M054R430
   IF NONE, QUIT.                                70J33                      M054R440
                                                 11W3                       M054R450
FIND 1ST SUB MAP.                                 J81                       M054R460
   IF NONE, QUIT.                                709-114                    M054R470
ADD SEGMENT (1) TO SUBMAP (0).                    9-100                     M054R480
                                                 12W2                       M054R490
TEST IF MORE SEGMENTS.                            P6                        M054R500
   IF NO, QUIT.                                  70J33                      M054R510
                                                 11W2                       M054R520
FIND 2ND SUBSEGMENT.                              J82                       M054R530
   IF NONE, QUIT.                                70J33                      M054R540
                                                 11W3                       M054R550
FIND 2ND SUBMAP.                                  J82                       M054R560
   IF NONE, QUIT.                                709-114                    M054R570
ADD SEGMENT (1) TO SUBMAP (0).                    9-100  J33                M054R580
                                         9-114   30H0    J33                M054R600
                                       1                                        R
M60 FIND NEXT UNTRIED PROBLEM.           M60     10L10                      M060R000
     H5 - MEANS NONE REMAINING.          9-1      J60                       M060R010
LOCATE NEXT SUBLIST OF PROBLEMS.                  J60                       M060R020
     IF NONE, QUIT -.                            70J8                       M060R030
     IF SOME, GET SUBLIST AND                    12H0                       M060R040
FIND FIRST PROBLEM.                               J81                       M060R050
     IF NONE, LOCATE NEXT LIST.                  709-1                      M060R060
     IF FOUND,GET LOCATION OF LIST,               J6                        M060R070
GET NAME OF LIST, AND                            52H0                       M060R080
LOCATE FIRST PROBLEM.                             J60                       M060R090
     IF NONE, MACHINE ERROR--HALT.               70J7                       M060R100
     IF LOCATED, DELETE FROM LIST,                J68                       M060R110
MARK OUTPUT REGIONAL, QUIT+.                      J138   J4                 M060R120
                                       1                                        R
M62 CREATE A LIST OF TRUE                M62      J45                       M062R000
    EXPRESSIONS FROM MAP (1) FOR                 20W0             1W0=SEG   M062R010
    FEASIBLE MATCH WITH SEGMENT                  60W1             1W1=MAP   M062R020
    (0).  OUTPUT MAY BE EMPTY.                   52W1                       M062R030
                                                  J73                       M062R040
SAVE COPY OF LIST IN MAP HEAD.                   60W2             1W2=THMLSTM062R050
                                                 11W0                       M062R060
TEST IF SEGMENT IS SIMPLE VAR.                    P8                        M062R070
    IF YES, QUIT WITH OUTPUT.                    70      J35                M062R080
    IF NO,                                       51W0                       M062R090
LOCATE 1ST SUBSEGMENT.                            J60                       M062R100
    IF NONE, OUTPUT 1W2, QUIT.                   709-1                      M062R110
                                                 60W3             1W3=SEGLOCM062R120
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                                                 50W1                           M062R130
                                                 12W0                           M062R140
FIND LIST OF APPROPRIATE SUBMAPS.                  J10                          M062R150
    IF NONE, OUTPUT 1W2, QUIT.                   709-0                          M062R160
LOCATE 1ST SUBMAP.                                 J60                          M062R170
    IF NONE, OUTPUT 1W2, QUIT.                   709-1                          M062R180
    IF THERE, SAVE LOCATION,                     60W4                 1W4=MAPLOCM062R190
                                                 52W4                           M062R200
SET UP H0 AND                                    12W3                           M062R210
CREATE LIST FROM MAP (1) FOR (0).                  M62                          M062R220
                                                 12W0                           M062R230
TEST IF CONNECTIVE WAS NON-UNARY.                  P6                           M062R240
    IF UNARY, FIX OUTPUT, QUIT.                  709-2                          M062R250
    IF NON-UNARY, SAVE LIST AND                  60W5                 1W5=ANDLSTM062R260
                                           9-4   51W3                           M062R270
LOCATE NEXT SUBSEGMENT.                            J60                          M062R280
                                                 60W3                           M062R290
    IF NONE, FIX OUTPUT, QUIT.                   709-3                          M062R300
                                                 51W4                           M062R310
LOCATE NEXT SUBMAP.                                J60                          M062R320
                                                 60W4                           M062R330
    IF NONE, FIX OUTPUT, QUIT.                   709-3                          M062R340
                                                 52W4                           M062R350
                                                 12W3                           M062R360
CREATE LIST FROM MAP (1) FOR (0),                  M62                          M062R370
'AND' RESULT WITH LIST 1W5, LOOP.                  9-100 9-4                    M062R380
                                           9-3   51W5                           M062R390
FIX OUTPUT - - -                           9-2   11W2                           M062R400
'OR' W5 WITH 1W2,                                  J6                           M062R410
LEAVE RESULT AS 1W2.                               J76                          M062R420
OUTPUT 1W2, CLEAR CONTEXT.                 9-1   51W2      J35                  M062R430
                                           9-0   11W2      J35                  M062R440
SUBPROCESS - 'AND' (0) WITH 1W5.           9-100 11W5                           M062R450
                                                 109-200                        M062R460
GENERATE 1W5 FOR PROCESS MARKING.                  J100                         M062R470
                                                 40H0                           M062R480
                                                 109-300                        M062R490
GENERATE '(0)' TO UNMARK MARKED.                   J100                         M062R500
ERASE '(0)'                                        J71                          M062R510
                                                 11W5                           M062R520
LOCATE NEXT OF 1W5.                        9-101   J60                          M062R530
    IF NONE, QUIT SUBPROCESS.                    700                            M062R540
                                           9-102 12H0                           M062R550
TEST IF EXPRESSION MARKED.                         J133                         M062R560
    IF NO, LOOP TO NEXT.                         709-101                        M062R570
    IF YES, UNMARK IT,                           32H0                           M062R580
SAVE LOCATION AND DELETE THIS                    40H0                           M062R590
EXPRESSION DUE NOT ON BOTH LISTS.                  J68                          M062R600
    IF MORE, LOOP WITH NEXT.                     700       9-102                M062R610
SUBPROCESS - MARK PROCESSED.               9-200   J137    J8                   M062R620
SUBPROCESS - UNMARK IF MARKED.             9-300 40H0                           M062R630
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                                                      J133                         M062R640
                                                     709-201                       M062R650
                                                     31H0      J8                  M062R660
                                              9-201  30H0      J4                  M062R670
                                          1                                           R
M63 CREATE A LIST OF TRUE                     M63     J6                           M063R000
    EXPRESSIONS FROM MAP (0) FOR                      J81                          M063R010
    FEASIBLE MATCH WITH TEX (1).                     70        M62                 M063R020
    OUTPUT MAY BE AN EMPTY LIST.                     30H0      J90                 M063R030
                                          1                                           R
M70 PRINT EXPRESSION (0), WITH OR             M70     J154                         M070R000
    WITHOUT A SUFFIX.                                40H0                          M070R010
ENTER NAME.                                           M79                          M070R020
                                                     10N8                          M070R030
TAB TO COLUMN (0).                                    J160                         M070R040
                                                     40H0                          M070R050
FIND MEX.                                             J81                          M070R060
     IF NONE, SKIP IT.                               709-1                         M070R070
ENTER MEX.                                            M73                          M070R080
FIND SUFFIX.                                  9-1     Q18                          M070R090
     IF NONE, PRINT WITHOUT IT.                      70J155                        M070R100
                                                     10N1                          M070R110
BUMP COLUMN.                                          J161                         M070R120
ENTER SUFFIX AND PRINT.                               J157     J155                M070R130
                                          1                                           R
M71 PRINT PROOF SEQUENCE FROM (0).            M71     J50              1W0=TEX     M071R000
                                                      J154                         M071R010
                                                      J155                         M071R020
SKIP TWO LINES.                                       J155                         M071R030
                                                     10T2                          M071R040
ENTER 'PROOF FOUND' AND                               M76                          M071R050
PRINT.                                                J155                         M071R060
                                                      J154                         M071R070
SKIP ONE LINE.                                        J155                         M071R080
                                                     11W0                          M071R090
FIND PROVING THEOREM.                                 Q13                          M071R100
                                                     70        9-1                 M071R110
      IF NONE, USE DUMMY CHARACTER.                  10/14                         M071R120
ENTER 'GIVEN'.                                9-1    10T1                          M071R130
PRINT FIRST LINE OF PROOF.                            M80                          M071R140
INPUT TEX AND                                        11W0                          M071R150
'SUBSTITUTION'.                                      10T3                          M071R160
PRINT NEXT EVEN LINE.                         9-6     M80                          M071R170
                                                     11W0                          M071R180
FIND THEOREM USED IN DERIVATION.                      Q12                          M071R190
     IF NONE, FINISH WITH Q.E.D.                     709-2                         M071R200
                                                     10T1                          M071R210
PRINT NEXT ODD LINE.                                  M80                          M071R220
                                                     11W0                          M071R230
FIND METHOD OF DERIVATION                             Q11                          M071R240
                                                     709-3                         M071R250
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FIND EXTERNAL NAME OF METHOD.                    Q16                       M071R260
                                               70        9-4               M071R270
     IF NONE, USE BLANKS.                 9-3  10T5                        M071R280
                                          9-4  11WC                        M071R290
FIND PROBLEM USED IN DERIVATION.                 Q10                       M071R300
                                               70        9-5               M071R310
      IF NONE, USE DUMMY CHARACTER.            10/14                       M071R320
                                          9-5  60WC                        M071R330
LOOP TO PRINT NEXT EVEN LINE.                    J6      9-6               M071R340
                                          9-2    J154                      M071R350
                                               10K41                       M071R360
TAB TO COLUMN K41.                               J160                      M071R370
                                               10T4                        M071R380
ENTER 'Q.E.D. AND                                M76                       M071R390
PRINT.                                           J155                      M071R400
PRINT LIMITS, CLEAR CONTEXT/QUIT.                M77     J30               M071R410
                                        1                                      R
PRINT -NO PROOF FOUND-                    M72    J154                      M072R000
                                               10T6                        M072R010
ENTER MESSAGE                                    M76                       M072R020
PRINT MESSAGE, LIMITS                            J155    M77               M072R030
                                        1                                      R
ENTER SEGMENT (0)                         M73  40H0                        M073R000
TEST IF VARIABLE                                 P8                        M073R010
IF YES, ENTER VARIABLE.                        70        M79               M073R020
                                               12H0                        M073R030
                                               11K2                        M073R040
TEST IF CONNECTIVE NOT                           J2                        M073R050
                                               709-1                       M073R060
                                               12H0                        M073R070
ENTER NOT.                                       M79                       M073R080
                                                 J81                       M073R090
                                               70J7      9-200             M073R095
                                               700       9-200             M073R100
                                          9-1    J41                       M073R110
                                               60WC                1W0=SEG M073R120
LOCAT FIRST SEGMENT.                             J60                       M073R130
                                               20W1                1W1=LOC'N M073R140
IF NONE, QUIT.                                 70J31                       M073R150
                                               12W1                2W1=SUBSEGM073R160
ENTER SEGMENT.                                   9-200                     M073R170
                                               11W1                        M073R180
LOCATE NEXT SUBSEGMENT.                   9-2    J60                       M073R190
                                               20W1                        M073R195
IF NONE, QUIT.                                 70J31                       M073R200
                                               12W0                2W0=CONN M073R205
ENTER CONNECTIVE.                                M79                       M073R210
                                               12W1                        M073R215
ENTER SEGMENT.                                   9-200                     M073R220
                                               11W1      9-2               M073R225
                                          9-200 40H0                       M073R230
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                                             P4                            M073R235
                                            709-201                        M073R238
TEST IF VARIABLE                             P8                            M073R240
                                            70        M73                  M073R250
                                            10K51                          M073R260
ENTER LEFT PAREN.                            J157                          M073R270
ENTER SUBEXPRESSION                          M73                           M073R280
ENTER RIGHT PAREN.                          10K52     J157                 M073R290
                                      9-201 50/14     M79                  M073R300
                                   1                                          R
M74 ENTER TOTAL EXPRESSION (0),       M74   40H0                           M074R000
    WITH OR WITHOUT SUFFIX.                  J81                           M074R010
                                            70J8                           M074R020
ENTER MAIN EXPRESSION.                       M73                           M074R030
FIND SUFFIX.                                 Q18                           M074R040
     IF NONE, QUIT.                         700                            M074R050
     IF ONE,                                10N1                           M074R060
BUMP COLUMN AND ENTER SUFFIX.                J161     J157                 M074R070
                                   1                                          R
M75 PRINT NEW SUBPROBLEM (0).         M75    J154                          M075R000
                                            10K47                          M075R010
TAB TO COLUMN K47.                           J160                          M075R020
                                            40H0             PSV PROB      M075R030
ENTER SUBPROBLEM NAME (NO.).                 M79                           M075R040
                                            10N3                           M075R050
BUMP COLUMN.                                 J161                          M075R060
                                            40H0             PSV PROB      M075R070
ENTER SUBPROBLEM EXPRESSION.                 M74                           M075R080
                                            11W25                          M075R090
                                            10K48                          M075R100
TEST IF EXPRESSION WAS TOO BIG.              J116                          M075R110
     IF YES, DON'T RESET.                   70        9-2                  M075R120
     IF NO, RESET TO K48.                   10K48                          M075R130
                                             J160                          M075R140
                                      9-2   10N2                           M075R160
BUMP COLUMN.                                 J161                          M075R170
                                            40H0                           M075R180
FIND THEOREM.                                Q12                           M075R190
     IF NONE, SKIP IT.                      709-1                          M075R200
                                             M79                           M075R210
ENTER COMMA.                          9-1   10K54                          M075R220
                                             J157                          M075R230
                                            10N1                           M075R240
BUMP COLUMN.                                 J161                          M075R250
FIND METHOD.                                 Q11                           M075R260
     IF NONE, PRINT NOW.                    70J155                         M075R270
FIND EXTERNAL NAME.                          Q16                           M075R280
     IF NONE, PRINT NOW.                    70J155                         M075R290
ENTER TEXT AND PRINT.                        M76      J155                 M075R300
                                   1                                          R
M76 ENTER LIST OF DATA TERMS.         M76   10J157                         M076R000
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                                                J100    0                     M076R010
                                       1                                          R
M77 PRINT LIMITS OF PROOF.               M77    J154                          M077R000
                                                J155                          M077R010
DOUBLE SPACE.                                   J155                          M077R020
                                              10K12                           M077R030
                                              10H3                            M077R040
                                              10K12                           M077R050
SET K12 TO ACTUAL EFFORT.                       J111                          M077R060
                                              10K22                           M077R070
INPUT 'EFFORT'                                10T7                            M077R080
PRINT LINE.                                     9-100                         M077R090
                                              10K10                           M077R100
                                              10K20                           M077R110
INPUT 'SUBPROBLEMS'                           10T8                            M077R120
PRINT LINE.                                     9-100                         M077R130
                                              10K11                           M077R140
                                              10K21                           M077R150
INPUT 'SUBSTITUTIONS'                         10T9      9-100                 M077R160
9-100 SUBPROCESS, PRINT LINE.            9-100  J154                          M077R170
ENTER MESSAGE.                                  M76                           M077R180
                                              10K44                           M077R190
TAB TO COLUMN K44.                              J160                          M077R200
                                              10T21                           M077R210
ENTER 'LIMIT'                                   M76                           M077R220
                                              10N1                            M077R230
BUMP COLUMN.                                    J161                          M077R240
ENTER LIMIT.                                    J157                          M077R250
                                              10K45                           M077R260
TAB TO COLUMN K45.                              J160                          M077R270
                                              10T20                           M077R280
ENTER 'ACTUAL'                                  M76                           M077R290
                                              10N1                            M077R300
BUMP COLUMN.                                    J161                          M077R310
ENTER ACTUAL AND PRINT LINE.                    J157    J155                  M077R320
                                       1                                          R
M78 PRINT 'TO PROVE' PROBLEM (0).        M78    J154            (0)=PROB      M078R000
INPUT TEXT.                                   10T22                           M078R010
ENTER MESSAGE.                                  M76                           M078R020
                                              40W22                           M078R030
                                              10N3                            M078R040
SET UP TO PRINT ON NEW PAGE.                  20W22                           M078R050
                                                J155                          M078R060
RESTORE SPACING AND PRINT (0).                30W22     M70                   M078R070
                                       1                                          R
M79 ENTER NAME OF (0).                   M79  40H0              PSV (0)       M079R000
FIND EXTERNAL NAME.                             Q7                            M079R010
    IF THERE,                                 709-1                           M079R020
        ENTER IT, DISCARD (0).                  J157    J8                    M079R030
    IF NOT THERE,                        9-1  40H0              PSV (0)       M079R040
FIND SUBPROBLEM NUMBER.                         Q8                            M079R050
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    IF NOT THERE, ENTER INTERNAL.                  70J156                  M079R060
    IF THERE, ENTER NO.                              J157                  M079R070
       AND ENTER PERIOD.                           50K53    J157           M079R080
                                      1                                       R
M80 PRINT PROOF LINE.                   M80          J154                  M080R000
    INPUT (0) IS METHOD OR 'GIVEN'                 10K41                   M080R010
    INPUT (1) IS TEX                                 J160                  M080R020
ENTER METHOD                                         M76                   M080R030
                                                   10K42                   M080R040
                                                     J160                  M080R050
                                                   40H0                    M080R060
ENTER NAME                                           M79                   M080R070
                                                   10K43                   M080R080
                                                     J160                  M080R090
ENTER EXPRESSION AND PRINT.                          M74    J155           M080R100
                                      1                                       R
M81 PRINT REJECTED PROBLEM (0).         M81          J154                  M081R000
                                                   10K47                   M081R010
TAB TO COLUMN K47.                                   J160                  M081R020
                                                   40H0                    M081R030
ENTER NAME.                                          M79                   M081R040
                                                   10N3                    M081R050
BUMP COLUMN.                                         J161                  M081R060
                                                   40H0                    M081R070
ENTER TEX.                                           M74                   M081R080
                                                   11W25                   M081R090
                                                   10K48                   M081R100
TEST IF TEX TOO LONG.                                J116                  M081R110
    IF YES, SKIP RESET.                            70       9-2            M081R120
    IF NO,                                         10K48                   M081R130
TAB TO COLUMN K48                                    J160                  M081R140
                                        9-2        10N2                    M081R150
BUMP COLUMN.                                         J161                  M081R160
                                                   40H0                    M081R170
FIND THEOREM.                                        Q12                   M081R180
    IF NONE, SKIP IT.                              709-1                   M081R190
    IF THERE, ENTER NAME.                            M79                   M081R200
                                                   10K54                   M081R210
ENTER COMMA, AND                                     J157                  M081R220
                                                   10N1                    M081R230
BUMP COLUMN.                                         J161                  M081R240
FIND METHOD.                            9-1          Q11                   M081R250
    IF NONE, SKIP IT.                              709-3                   M081R260
    IF THERE, FIND EXTERNAL NAME.                    Q16                   M081R270
    IF NONE, SKIP IT.                              709-3                   M081R280
    IF THERE, ENTER TEXT,                            M76                   M081R290
                                                   10K53                   M081R300
ENTER PERIOD, AND                                    J157                  M081R310
                                                   10N2                    M081R320
BUMP COLUMN.                                         J161                  M081R330
                                        9-3        10T19                   M081R340
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ENTER MESSAGE AND PRINT.                    M76    J155              M081R350
                                  1                                         R
M82 PRINT 'REMEMBER PROVED THEOREM'  M82     J154                    M082R000
                                             J155                    M082R010
                                             J155                    M082R020
                                            10T23                    M082R030
ENTER MESSAGE.                               M76                     M082R040
                                             J155                    M082R050
                                             J154   J155             M082R060
                                  1                                         R
M88 PRINT BAD LIST FORM EXPRESSION.  M88     J154                    M088R000
                                            10T24                    M088R010
ENTER 'BAD EXPRESSION'                       M76                     M088R020
                                            10N3                     M088R030
BUMP COLUMN.                                 J161                    M088R040
                                            10M79                    M088R050
GEN SYMBOLS FOR ENTRY, PRINT.                J100   J155             M088R060
                                  1                                         R
M89 READ NEXT LOGIC EXPRESSION       M89    40W0                     M089R000
    FROM NORMAL INPUT UNIT.                 40W25                    M089R010
    H5- MEANS NONE THERE.                   40W30                    M089R020
CLEAR AND                            9-10    J154                    M089R050
FILL BUFFER.                                 J180                    M089R060
   IF EOF, QUIT, H5-.                       709-0                    M089R070
                                            10N1                     M089R080
                                             J120                    M089R090
LOCATE 1ST OF NAME.                          J184                    M089R110
   IF BLANK CARD, QUIT, H5-.                709-1                    M089R120
                                            20W25       1W25=1ST     M089R125
                                             J90                     M089R130
                                             J124                    M089R140
DETERMINE EXTENT.                            J183                    M089R150
   IF REST OF CARD, RESET, GET NEXT         709-2                    M089R160
                                            20W30       1W30=EXTNTM089R170
INPUT NAME.                                  J181                    M089R180
                                            40H0                     M089R190
TEST IF REGIONAL.                            J130                    M089R200
   IF NOT, RESET, GET NEXT.                 709-4                    M089R210
                                            40H0                     M089R213
TEST IF NAME IS A CHARACTER SYMBOL.          P18                     M089R215
      IF YES, RESET, GET NEXT.              709-4                    M089R217
                                            20W0        1W0=EXPR.    M089R220
   IF OK, GET EXTERNAL NAME.                11W30                    M089R230
                                            11W25                    M089R240
                                            11W25                    M089R250
RESET COLUMN TO 1ST OF NAME.                 J111                    M089R260
                                            50K51                    M089R265
CREATE PROTOTYPE DATA TERM.                  J120                    M089R270
MARK LOCAL.                                  J136                    M089R280
SET D.T. TO HOLD NAME.                       J182                    M089R290
                                            11W0                     M089R300
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                                                J6                  M089R310
                                               10Q7                 M089R320
ASSIGN D.T. AS EXTERNAL NAME.                   J11                 M089R330
                                               11W25                M089R340
LOCATE 1ST OF EXPRESSION.                       J184                M089R350
   IF NONE, RESET, GET NEXT.                   709-5                M089R360
FIND CHARACTER SYMBOL AT 1W25.          9-3     J186                M089R370
      IF NONE, EXPRESSION FINI.                709-6                M089R380
      IF FOUND, GET ALTERNATE,                  P19                 M089R390
                                               11W0                 M089R400
                                                J6                  M089R410
ADD AT END OF LIST EXPRESSION,                  J65                 M089R420
TALLY 1W25 AND LOOP FOR NEXT.                   J125    9-3         M089R430
LOCATE FIRST OF SUFFIX.                 9-6     J184                M089R440
   IF NONE, SKIP IT.                           709-7                M089R480
                                               51W30                M089R490
                                                J124                M089R495
DETERMINE EXTENT.                               J183                M089R500
   IF NONE, SKIP IT.                           709-7                M089R510
                                               50K51                M089R520
CREATE PROTOTYPE.                               J120                M089R530
SET D. T. TO SUFFIX.                            J182                M089R540
                                               11W0                 M089R550
                                                J6                  M089R560
                                               10Q18                M089R570
ASSIGN AS SUFFIX OF 1W0.                        J11                 M089R580
                                               11W0     9-8         M089R590
ADJUST FOR EXTRA IN H0.                 9-7    51W0     9-8         M089R600
SET H5+                                 9-8     J4                  M089R610
                                               11W25                M089R620
DISCARD COLUMN D.T.                             J9                  M089R630
                                               11W30                M089R640
DISCARD EXTENT D.T.                     9-1     J9                  M089R650
                                        9-9    30W25                M089R660
                                               30W30    J30         M089R670
RESET                                   9-5    11W0                 M089R700
AFTER                                           J15                 M089R710
A                                       9-4     J8                  M089R720
BAD                                            11W30                M089R730
EXPRESSION                              9-2     J9                  M089R740
AND                                            11W25                M089R750
GET NEXT CARD.                                  J9      9-10        M089R760
                                      1                                 R
M90 TEST IF PROBLEM LIMITS REACHED.     M90    10K20                M090R000
                                               10K10                M090R010
TEST NO. OF SUBPROBLEMS SET UP                  J116                M090R020
                                               70J5                 M090R030
                                               10K21                M090R040
                                               10K11                M090R050
TEST NO. OF SUBSTITUTIONS                       J116                M090R060
                                               70J5                 M090R070
                                               10K12                M090R080
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                                               10H3                      M090R090
                                                 J90                     M090R100
COMPUTE EFFORT                                   J111                    M090R110
                                               40H0                      M090R120
                                               10K22                     M090R130
                                                 J6                      M090R140
TEST EFFORT.                                     J116                    M090R150
                                                 J9       J5             M090R160
                                         1                                   R
M110 MAKE FREE VARIABLES OF TOTAL    M110        J47                     M110R000
    EXPRESSIONS (0) AND (1)                      J21                     M110R010
    DISJOINT. (SUBSTITUTES IN (1).)            11W1                      M110R020
CREATE FREE VAR. LIST FOR (1)                    M116                    M110R030
                                               70J37                     M110R040
                                               20W3                      M110R050
                                               11W0                      M110R060
CREATE FREE VAR. LIST FOR (0)                    M116                    M110R070
                                               709-1                     M110R080
                                               20W2                      M110R090
CREATE EMPTY SUBSTITUTION LIST.                  J90                     M110R100
                                               20W4                      M110R110
CREATE EMPTY LIST OF MARKED                      J90                     M110R114
PROCESSED                                      20W7                      M110R116
                                               10L2                      M110R120
SET LOCATION ON SYSTEM FREE                    20W5                      M110R130
 VARIABLE LIST                                 11W2                      M110R140
                                               109-100                   M110R150
MARK ALL OF (0)-S FREE VARS.                     J100                    M110R160
                                               11W3                      M110R170
                                               109-200                   M110R180
ADD DUPLICATES TO SUBSTITUTION LIST              J100                    M110R190
                                               11W4                      M110R200
TEST IF ANY DUPLICATES.                          J78                     M110R210
                                               70         9-6            M110R220
UNMARK ALL MARKED VARIABLES                      9-400    9-2            M110R225
                                     9-6       11W4                      M110R230
LOCATE NEXT DUPLICATE                9-5         J60                     M110R240
                                               20W6                      M110R250
                                               709-3                     M110R260
                                     9-4       11W5                      M110R270
LOCATE NEXT SYSTEM FREE VAR.                     J60                     M110R280
                                               20W5                      M110R290
HALT DUE TO NOT ENOUGH FREE VAR.               70J7                      M110R300
                                               12W5                      M110R310
TEST IF USED IN EITHER.                          J133                    M110R320
                                               70         9-4            M110R330
                                               11W6                      M110R340
                                               12W5                      M110R350
INSERT AS SUBSTITUTOR.                           J64                     M110R360
                                               11W6                      M110R370
                                                 J60      9-5            M110R380
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NUMARK ALL MARKED VARIABLES.          9-3     9-400                  M110R390
                                             11W4                    M110R420
                                             11W1                    M110R430
GET MAIN SEGMENT OF (1).                      J81                    M110R440
                                             70J7                    M110R450
SUBSTITUTE.                                   M115                   M110R460
                                      9-2    11W4                    M110R470
                                              J71                    M110R480
                                             11W2                    M110R490
                                              J71                    M110R500
                                      9-1    11W3                    M110R510
                                              J71      J37           M110R520
MARK PROCESSED                        9-100   J137                   M110R525
                                             11W7                    M110R530
                                              J6                     M110R535
ADD TO LIST 1W7 FOR UNMARKING                 J64      J4            M110R540
ADD THOSE MARKED TO SUBST. LIST.      9-200 40H0                     M110R550
MARK THOSE NOT MARKED.                        J133                   M110R560
                                             709-100                 M110R570
                                             11W4                    M110R580
                                              J6       J64           M110R590
UNMARK PROCESSED.                     9-300 31H0                     M110R600
                                             30H0      J4            M110R610
UNMARK PROCESSED ALL VARIABLES        9-400 11W7                     M110R620
ON LIST 1W7                                  109-300                 M110R630
                                              J100     0             M110R640
                                    1                                    R
M111 MATCH SEGMENTS (0) AND (1),      M111    J90                    M111R000
   H5+ MEANS OUTPUT (0) IS LIST              209-10                  M111R010
    OF PAIRS--1ST IS FREE VAR.,               9-100                  M111R020
    2ND IS SUBSTITUTOR.                      119-10                  M111R030
    H5- MEANS NO MATCH, NO OUTPUT.           70J71     0             M111R040
9-100 MATCH SUBPROCESS                9-100 04J51                    M111R050
    (EXPECTS FREE VARIABLES DISJOIN   9-104 11W0                     M111R060
IS (0) A VARIABLE.                            P8                     M111R070
                                             709-101                 M111R080
                                             11W0                    M111R090
IS (0) A FREE VARIABLE.                       P9                     M111R100
                                             709-102                 M111R110
                                             109-10                  M111R120
                                             11W0                    M111R130
IS THERE ALREADY A SUBSTITUTOR                J10                    M111R140
 FOR (0).                                    709-103                 M111R150
SET SUBSTITUTOR AS (0) AND MATCH.            20W0      9-104         M111R160
                                      9-103 109-10                   M111R170
                                             11W1                    M111R180
                                             40H0                    M111R185
TEST IF (1) IS A VARIABLE                     P8                     M111R190
                                             709-105                 M111R195
                                             40H0                    M111R200
                                             11W0                    M111R205
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(1) IS VARIABLE, TEST (1)=(0)                 J2                 M111R210
                                            709-114              M111R215
NO SUBSTITUTOR, QUIT W/H5+            9-116 30H0                 M111R220
                                            30H0      J31        M111R225
IF NOT, MAKE EXPRESSION INTERNAL      9-105   J138               M111R230
ASSIGN (1) AS SUBSTITUTOR FOR (0)     9-114 11W0                 M111R235
                                      9-109   J11                M111R240
                                              J31     J4         M111R250
( (0) IS VARIABLE, NOT FREE. )        9-102 11W1                 M111R260
IS (1) A VARIABLE.                            P8                 M111R270
                                            70J31                M111R280
                                            11W1                 M111R290
IS (1) A FREE VARIABLE.                       P9                 M111R300
                                            709-106              M111R310
                                      9-111 109-10               M111R320
                                            11W1                 M111R330
IS THERE ALREADY A SUBSTITUTOR                J10                M111R340
 FOR (1).                                   709-107              M111R350
SET SUBSTITUTOR AS (1) AND MATCH.           20W1      9-104      M111R360
                                      9-107 109-10               M111R370
                                            11W0                 M111R380
                                            40H0                 M111R390
TEST IF (0) IS A VARIABLE                     P8                 M111R400
                                            709-108              M111R405
                                            40H0                 M111R410
                                            11W1                 M111R415
(0) IS VARIABLE, TEST (0)=(1)                 J2                 M111R420
                                            709-115   9-116      M111R425
IF NOT, MAKE EXPRESSION INTERNAL      9-108   J138               M111R430
ASSIGN (0) AS SUBSTITUTOR FOR (1)     9-115 11W1      9-109      M111R435
(BOTH ARE VARIABLES, NOT FREE)        9-106 11W0                 M111R440
                                            11W1                 M111R450
ARE VARIABLES IDENTICAL.                      J2      J31        M111R460
( (0) IS EXPRESSION. )                9-101 11W1                 M111R470
IS (1) A VARIABLE                             P8                 M111R480
                                            709-110              M111R490
                                            11W1                 M111R500
IS (1) A FREE VARIABLE.                       P9                 M111R510
                                            70J31     9-111      M111R520
( BOTH ARE EXPRESSIONS. )             9-110 12W0                 M111R530
                                            12W1                 M111R540
ARE CONNECTIVES IDENTICAL                     J2                 M111R550
                                            70J31                M111R560
                                      9-113 11W0                 M111R570
LOCATE NEXT SUBSEGMENT ON (0)                 J60                M111R580
                                            20W0                 M111R590
                                            709-112              M111R600
                                            11W1                 M111R610
LOCATE NEXT SUBSEGMENT ON (1)                 J60                M111R620
                                            20W1                 M111R630
                                            70J31                M111R640
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                                                12WO                     M111R650
                                                12W1                     M111R660
MATCH SUBSEGMENTS                                 9-100                  M111R670
                                                70J31     9-113          M111R680
                                          9-112 11W1                     M111R690
LOCATE NEXT SUBSEGMENT ON (1)                     J60                    M111R700
                                                20W1                     M111R710
                                                  J5      J31            M111R720
                                         1                                   R
M112 EXPAND SUBSTITUTION LIST (0).        M112  40HO                     M112R000
     REPLACE EXPRESSIONS WITH                     J51                    M112R010
     COMPLETELY SUBSTITUTED LOCALLY       9-1   11WO                     M112R020
     NAMED COPIES.                                J60                    M112R030
LOCATE NEXT SUBSTATION                            J60                    M112R040
                                                20WO                     M112R050
                                                70J31                    M112R060
                                                12WO                     M112R070
DELINEATE SEGENT AT THIS STATION                  9-100                  M112R080
                                                21WO      9-1            M112R090
SEGMENT DELINEATION SUBPROCESS.           9-100  4J50                    M112R100
                                                11WO                     M112R110
IS INPUT A VARIABLE.                              P8                     M112R120
                                                11WO                     M112R130
                                                709-101                  M112R140
IS INPUT A FREE VARIABLE.                         P9                     M112R150
                                                709-102                  M112R160
                                                11WO                     M112R170
DELINEATE FREE VARIABLE.                          9-200 J30              M112R180
                                          9-102 11WO      J30            M112R190
CREATE SUBSTITUTED LOCAL COPY             9-101   J74                    M112R200
                                                  J136                   M112R210
                                                60WO                     M112R220
                                                109-300                  M112R230
GENERATE FREE VARIABLE LOCATIONS.                 P28     9-102          M112R240
                                          9-300   J50                    M112R250
                                                12WO                     M112R260
DELINEATE FREE VARIABLE                           9-200                  M112R270
                                                21WO                     M112R280
                                                  J30     J4             M112R290
                                          9-200  4J50                    M112R300
                                                10W1                     M112R310
                                                11WO                     M112R320
FIND CORRESPONDING SUBSTITUTOR                    J10                    M112R330
                                                709-201                  M112R340
DELINEATE SUBSTITUTOR                             9-100 J30              M112R350
OUTPUT FREE VARIABLE                      9-201 11WO      J30            M112R360
                                         1                                   R
MATCH SEGMENTS (0) AND (1) FOR            M113    M111                   M113R000
SUBSTITUTION. SETS H5, IF + OUTPUT              700                      M113R010
(0) IS EXPANDED SUBSTITUTION LIST.              40HO                     M113R020
                                                  M112  J4               M113R030
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                                        1                                                R
TEST IF SEGMENT (0) MATCHES               M114    M111                              M114R000
SEGMENT (1).                                      700        J71                    M114R010
                                        1                                                R
M115 SUBSTITUTE IN SEGMENT (0)            M115     J42                              M115R000
    FROM SUBSTITUTION LIST (1).                   20W0                              M115R003
    SUBSTITUTES ONLY FOR VARIABLES.               60W1                              M115R007
SAMPLE SUBST. LIST.                                J81                              M115R010
    IF EMPTY, QUIT.                               70J32                             M115R013
                                                  40H0                              M115R017
TEST IF FREE VARIABLE.                             P9                               M115R020
                                                  709-1                             M115R023
     IF YES,                                      51W0                              M115R027
    GENERATE LOCATIONS OF                         109-100                           M115R030
    FREE VARIABLES.                                P28       J32                    M115R033
TEST IF BOUND VARIABLE.                   9-1      P8                               M115R037
    IF YES,                                       70J32                             M115R040
    GENERATE LOCATIONS OF                         11W0                              M115R043
    BOUND VARIABLES.                              109-100                           M115R047
                                                   P29       J32                    M115R050
9-100 SUBPROCESS, SUBST. IN LOC(0).       9-100   60W2                              M115R055
                                                  50W1                              M115R060
                                                  12W2                              M115R070
FIND SUBSTITUTOR, IF ANY                           J10                              M115R080
                                                  70J4                              M115R090
                                                  40H0                              M115R100
TEST IF A VARIABLE                                 P8                               M115R110
                                                  70         9-101                  M115R120
IF AN EXPRESSION, COPY IT.                         J74                              M115R130
                                                   J136                             M115R140
STORE IN LOCATION                         9-101   21W2       J4                     M115R150
                                        1                                                R
CREATE LIST OF FREE VARIABLES IN          M116     J90                              M116R000
TEX (0). SETS H5, NO OUTPUT IF -.                  J50                              M116R010
GET MAIN SEGMENT.                                  J81                              M116R020
                                                  709-1                             M116R030
                                                  109-100                           M116R040
GENERATE LOCATIONS OF FREE VARS.                   P28                              M116R060
                                          9-1     11W0                              M116R070
                                                  40H0                              M116R080
                                                  30W0                              M116R090
TEST IF ANY FREE VARS.                             J78                              M116R100
                                                  70J71      0                      M116R110
                                          9-100   52H0                              M116R120
                                                  11W0                              M116R130
                                                   J6                               M116R140
ADD TO OUTPUT IF NOT ALREADY ON.                   J66       J4                     M116R150
                                        1                                                R
M117 FIND LIST OF BOUND VARIABLES         M117     P31                              M117R000
    IN TEX (0).                                   40H0                              M117R010
    H5- MEANS NO OUTPUT.                           J78                              M117R020
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                                                   70J9      0                 M117R030
                                           1                                      R
P2 TEST IF (0) IS A BOUND VARIABLE.        P2        Q9                        P002R000
                                                   700       J8                P002R010
                                           1                                      R
CLEAR DESCRIPTIONS OF TOTAL                P3      40H0                        P003R000
EXPRESSION (0)                                     10Q2                        P003R010
                                                     J14                       P003R020
                                                   40H0                        P003R030
                                                   10Q3                        P003R040
                                                     J14                       P003R050
                                                   10Q4      J14               P003R060
                                           1                                      R
P4 GO THRU NOTS OF SEGMENT (0),            P4      12H0                        P004R000
   LEAVE 1ST UNNOTTED SEGMENT.                     11K2                        P004R010
   H5- MEANS NO OUTPUT.                              J2                        P004R020
QUIT, H5+ MEANS NORMAL EXIT.                       70J4                        P004R030
FIND SUBSEGMENT OF NOT.                              J81                       P004R040
IF NONE QUIT -, ELSE LOOP.                         700       P4                P004R050
                                           1                                      R
P5 TEST IF MAIN CONNECTIVE                 P5        P16                       P005R000
     OF TOTAL EXPRESSION (0)                       700                         P005R010
     IS IMPLIES.                                   11K6      J2                P005R020
                                           1                                      R
P6 TEST IF (0) IS NOT UNARY.               P6        Q14                       P006R000
                                                   700       J1                P006R010
                                           1                                      R
 P7-TEST IF (0) IS CONNECTIVE              P7        Q14                       P007R000
                                                   700       J8                P007R010
                                           1                                      R
TEST IF (0) IS VARIABLE                    P8        Q5                        P008R000
                                                   700       J8                P008R010
                                           1                                      R
TEST IF (1) IS FREE VARIABLE               P9        Q6                        P009R000
                                                   700       J8                P009R010
                                           1                                      R
P12 FIND MEX OF TEX (0).                   P12       J81     0                 P012R000
                                           1                                      R
P13 FIND LEFT SIDE OF TEX(0).              P13       J81                       P013R000
                                                   700       J81               P013R030
                                           1                                      R
P14 FIND RIGHT SIDE OF TEX(0).             P14       J81                       P014R000
                                                   700       J82               P014R030
                                           1                                      R
P15 TEST IF (0) IS IN                      P15       Q15                       P015R000
   INTERNAL (TREE) FORM.                           700       J8                P015R010
                                           1                                      R
P16 FIND MAIN CONNECTIVE OF                P16       J81                       P016R000
   TEX (0).                                        700                         P016R010
   GO THRU NOTS.                                     P4                        P016R020
                                                   700       Q1                P016R030
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                                        1                                          R
P17 CREATE COPY OF SEGMENT (0)            P17   40H0                          P017R000
   IF NOT A SIMPLE VARIABLE.                      P8                          P017R010
                                                70         0                  P017R020
COPY AND MARK LOCAL.                              J74      J136               P017R030
                                        1                                          R
P18 TEST IF (0) IS A                      P18     P19                         P018R000
    CHARACTER SYMBOL.                             Q7                          P018R010
                                                  J5                          P018R020
                                                70J8       0                  P018R030
                                        1                                          R
GET APPROPRIATE INTERNAL                  P19   40H0                          P019R000
    CHARACTER SYMBOL (0) FOR                      Q19                         P019R010
    EXTERNAL CHARACTER SYMBOL (0).              700                           P019R020
IF REPLACED, QUIT +.                              J6       J8                 P019R030
                                        1                                          R
P20 MAKE FAKE TEX WITH LEFT SIDE          P20     P13                         P020R000
   OF TEX (0).                                  700        P24                P020R010
                                        1                                          R
P21 MAKE FAKE TEX WITH RIGHT SIDE         P21     P14                         P021R000
  OF TEX (0).                                   700        P24                P021R010
                                        1                                          R
P22 CREATE NEW SUBPROBLEM WITH            P22   40W0                          P022R000
    SEGMENT (0) ON THE LEFT,                      P17                         P022R010
    SEGMENT (1) ON THE RIGHT,                     J6                          P022R020
    AND IMPLIES AS CONNECTIVE.                    P17                         P022R030
CREATE MEX.                                       J92                         P022R040
                                                  J136                        P022R050
                                                60W0                          P022R060
INSERT CONNECTIVE.                              11K6                          P022R070
                                                21W0                          P022R080
CREATE TEX, CLEAN UP, QUIT.                       P24      J30                P022R090
                                        1                                          R
ERASE MADE EXPRESSION (0)                 P23   40H0                          P023R000
                                                  J60                         P023R010
DELETE MAIN SEGMENT                               J68      J72                P023R020
                                        1                                          R
P24 MAKE TEX FROM MEX (0).                P24     J91                         P024R000
                                                40H0                          P024R010
                                                10Q15                         P024R020
DESCRIBE AS IN TREE FORM.                       10Q15      J11                P024R030
                                        1                                          R
P25 COPY TEX (0) FOR SUBSTITUTION.        P25     J74                         P025R000
                                                40H0                          P025R010
                                                10Q7                          P025R020
CLEAR EXTERNAL NAME                               J14                         P025R030
AND CLEAR DESCRIPTIONS.                         40H0       P3                 P025R040
                                        1                                          R
P26 GENERATE SEGMENT LOCATIONS AT         P26   10W1                          P026R000
    LEVEL (2) OF PROBLEM (1) FOR                  J17                         P026R010
    PROCESS (0).                                  J81                         P026R020
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                                                 709-1                    P026R030
                                                 40H0                     P026R060
TEST IF MEX IS A VARIABLE.                         P8                     P026R070
    IF YES, QUIT.                                70       9-2             P026R080
    IF NO, REVERSE,                                J6                     P026R090
                                                 10N1                     P026R100
CREATE COUNTER WITH VALUE 1, AND                   J120                   P026R110
SAVE BOTH LEVEL AND COUNTER.                       J21         1W1=LEVEL P026R120
                                                 109-100       1W0=COUNT P026R130
GENERATE SUBSEGMENT                                9-200                  P026R140
LOCATIONS FOR 9-100.                             11W0                     P026R150
ERASE COUNTER AND QUIT.                            J9     J19             P026R160
POP H0,                                   9-2    30H0                     P026R170
POP H0, AND QUIT.                         9-1    30H0     J19             P026R180
SUBPROCESS 9-100.                         9-100  11W0                     P026R190
                                                 11W1                     P026R200
TEST IF THIS IS THE LEVEL.                         J114                   P026R210
    IF YES, FIRE J18.                            70       J18             P026R220
                                                 52H0                     P026R225
    IF NO, GENERATE                              109-100                  P026R230
       SUBSEGMENTS FOR 9-100.                      9-200 0                P026R240
SUBGENERATOR 9-200.                       9-200  14W0                     P026R250
                                                   J17                    P026R260
                                                 11W0                     P026R270
CREATE NEW SUBLEVEL COUNTER.                       J120                   P026R280
BUMP COUNTER.                                      J125                   P026R290
                                                 20W0                     P026R300
                                                 40W0                     P026R310
LOCATE NEXT SEGMENT PLACE.                9-201    J60                    P026R320
     IF NONE, QUIT.                              709-203                  P026R330
     IF FOUND, PRESERVE LOCATION,                40H0                     P026R340
                                                 12H0                     P026R350
TEST IF SEGMENT IS A VARIABLE.                     P8                     P026R360
     IF NO, FIRE J18.                            709-202                  P026R370
     IF YES, LOOP TO LOCATE.                     30H0     9-201           P026R380
                                          9-202    J18                    P026R390
IF J18 QUIT+, LOOP TO LOCATE,                    70       9-201           P026R400
IF J18 QUIT-,                             9-203  51W0                     P026R410
                                                 30W0                     P026R420
ERASE COUNTER AND QUIT.                            J9     J19             P026R430
                                       1                                      R
P27 REPLACE BOUND BY FREE IN (0).         P27      J43                    P027R000
                                                 60W0          1W0=TEX    P027R010
CREATE LIST OF BOUND OF 1W0.                       P31                    P027R020
                                                 60W1          1W1=BNDLSTP027R030
LOCATE FIRST BOUND.                                J60                    P027R040
                                                 20W2          1W2=BNDLOCP027R050
IF NO BOUND, QUIT.                               709-1                    P027R060
                                                 11W0                     P027R070
CREATE LIST OF FREE OF 1W0.                        P30                    P027R080
                                                 60W3          1W3=FREELSP027R090
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                                                10J137                       P027R100
GEN FREE VAR TO BE MARKED.                        J100                       P027R110
                                                10L2              L2=SYSFREEP027R120
                                                109-100                      P027R130
GEN SYS FREE VAR. TO REPLACE.                     J100                       P027R140
H5+ MEANS NOT ENOUGH FREE VAR.                  70       J7                  P027R150
                                                11W1              1W1=SUBLSTP027R160
                                                11W0                         P027R170
FIND MAIN SEGMENT.                                J81                        P027R175
                                                70       9-2                 P027R180
     IF NONE, SKIP IT.                            J8     9-3                 P027R185
REPLACE IN MEX FROM 1W1.                  9-2     M115                       P027R190
                                          9-3   11W3                         P027R195
                                                109-200                      P027R200
GEN FREE VAR TO BE UNMARKED.                      J100                       P027R210
                                                11W3                         P027R220
ERASE CREATED FREE LIST.                          J71                        P027R230
                                          9-1   11W1                         P027R240
ERASE BOUND LIST.                                 J71    J33                 P027R250
9-100 SUBPROCESS, INSERT (0)              9-100 40H0                         P027R260
    AFTER SYMBOL IN 1W2                           J133                       P027R270
    IF (0) IS UNMARKED.                         70       J8                  P027R280
    THEN ADVANCE TO NEXT                        11W2                         P027R290
    AFTER CELL HOLDING                            J6                         P027R300
    INSERTED SYMBOL.                              J64                        P027R310
                                                11W2                         P027R320
                                                  J60                        P027R330
                                                  J60                        P027R340
QUIT, H5- MEANS QUIT GENERATOR.                 20W2     0                   P027R350
9-200 SUBPROCESS, UNMARK PROCESSED.       9-200 31H0     J8                  P027R360
                                        1                                    R
GENERATE LOCATIONS OF FREE                P28   10W0                         P028R000
VARIABLES WITHIN SEGMENT (1)                      J17                        P028R010
FOR PROCESS (0).                                60W0                         P028R020
                                                  P8                         P028R030
TEST IF INPUT SEGMENT IS VARIABLE.              70       J19                 P028R040
 IF SO, QUIT.                             9-2   11W0                         P028R050
LOCATE NEXT SUBSEGMENT.                           J60                        P028R060
                                                20W0                         P028R070
                                                70J19                        P028R080
                                                12W0                         P028R090
TEST IF SUBSEGMENT IS FREE VAR.                   P9                         P028R100
                                                709-1                        P028R110
                                                11W0                         P028R120
 IF SO, GENERATE LOCATION.                        J18                        P028R130
                                          9-3   70J19    9-2                 P028R140
                                          9-1   12W0                         P028R150
TEST IF SUBSEGMENT IS VARIABLE.                   P8                         P028R160
                                                70       9-2                 P028R170
 IF NOT, GENERATE SUBSEGMENT.                   12W0                         P028R180
                                                10J18                        P028R190
```

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                                              P28    9-3                P028R200
                                      1                                    R
P29 GENERATE LOCATIONS OF BOUND         P29   10W0                      P029R000
    VARIABLES WITHIN SEGMENT (1)                J17                     P029R010
    FOR PROCESS (0).                          60W0                      P029R020
TEST IF INPUT SEGMENT IS VARIABLE.              P8                      P029R030
    IF YES, QUIT H5+.                         70      J19               P029R040
    IF NO,                              9-2   11W0                      P029R050
LOCATE NEXT SEGMENT                             J60                     P029R060
                                              20W0                      P029R070
   IF NONE, QUIT, H5+.                        70J19                     P029R080
                                              12W0                      P029R090
TEST IF FREE VARIABLE.                          P9                      P029R100
    IF YES, GET NEXT.                         70      9-2               P029R110
    IF NO,                                    12W0                      P029R120
TEST IF BOUND VARIABLE.                         P8                      P029R130
    IF NO, GENERATE ON SEGMENT.               709-1                     P029R140
    IF YES, FEED LOCATION                     11W0                      P029R150
        TO PROCESS.                             J18                     P029R160
IF H5-, SUBPROCESS SAID QUIT.           9-3   70J19   9-2               P029R170
INPUT SEGMENT.                          9-1   12W0                      P029R180
INPUT PROCESS.                                10J18                     P029R190
GENERATE LOCATIONS OF BND. VAR.                 P29   9-3               P029R200
                                      1                                    R
P30 CREATE LIST OF FREE VARIABLES       P30     J90                     P030R000
    IN TEX (0).                                 J50         1W0=LIST    P030R010
FIND MAIN SEGMENT                               J81                     P030R020
    IF NONE, CLEAN UP, QUIT.                  709-1                     P030R030
                                              109-100                   P030R040
GEN. LOCATIONS OF FREE VARIABLES.               P28                     P030R050
                                        9-1   11W0    J30               P030R060
SUBPROCESS, ADD FREE VARIABLE           9-100 52H0                      P030R070
2H0 TO LIST 1W0 IF NOT ON.                    11W0                      P030R080
                                                J6                      P030R090
QUIT, H5+ FOR GEN.                              J66   J4                P030R100
                                      1                                    R
P31 CREATE LIST OF BOUND VARIABLES.     P31     J90                     P031R000
    IN TEX (0).                                 J50         1W0=LIST    P031R010
FIND MAIN SEGMENT.                              J81                     P031R020
    IF NONE, CLEAN UP, QUIT.                  709-1                     P031R030
                                              109-100                   P031R040
GENERATE LOCATIONS OF BOUND VAR.                P29                     P031R050
                                        9-1   11W0    J30               P031R060
SUBPROCESS, ADD BOUND VARIABLE          9-100 52H0                      P031R070
2H0 TO LIST 1W0 IF NOT ON.                    11W0                      P031R080
                                                J6                      P031R090
QUIT, H5+ FOR GEN.                              J66   J4                P031R100
                                      1                                    R
P50 CONVERT LOGIC EXPRESSION (0) TO     P50   40H0                      P050R000
   INTERNAL (TREE) FORM IF IN                   P15                     P050R010
   EXTERNAL (LIST) FORM. ENTIRE               70      J8                P050R020
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   EXPRESSION MUST BE ENCLOSED                J41                      P050R030
   IN PARENTHESES. NO  OUTPUT.               60W0                      P050R040
   H5- MEANS FAILURE.                         P51                      P050R050
                                             11W0                      P050R060
CREATE NEW MAIN SEGMENT.                      P52                      P050R070
     IF FAILED, QUIT.                        70J31                     P050R075
SAVE NEW MEX.                                60W1                      P050R080
                                             51W0                      P050R090
SAVE OLD HEAD,                                J75                      P050R100
DISCARD OLD LIST.                             J71                      P050R110
                                             11W0                      P050R120
                                             11W1                      P050R130
INSERT MEX UNDER OLD HEAD.                    J64                      P050R140
                                             11W0                      P050R190
                                             10Q15                     P050R200
                                             10Q15                     P050R210
DESCRIBE AS IN INTERNAL FORM.                 J11     J31              P050R220
                                     1                                        R
P51 REPLACE ALL DELIMITED EXTERNAL   P51     40H0                      P051R000
   CONNECTIVES IN EXPRESSION (0)              P15                      P051R005
   IF (0) IS IN EXTERNAL                     70       J8               P051R010
   LIST FORM.                                 J42                      P051R015
                                             60W0           1W0=LIST   P051R020
                                     9-10    11K7                      P051R025
LOCATE FIRST DELIMITER IN LIST.               J62                      P051R030
                                             709-0                     P051R040
                                             60W1           1W1=LOC1STP051R050
LOCATE CONNECTIVE (EXTERNAL FORM).            J60                      P051R060
                                             60W2           1W2=LOCONNP051R070
LOCATE SECOND DELIMITER IN LIST.              J60                      P051R080
  IF NOT ALL THERE, QUIT.                    709-0                     P051R090
                                             12H0                      P051R100
                                             11K7                      P051R110
TEST IF 2ND IS SAME AS 1ST.                   J2                       P051R120
   IF NOT, TRY ON REMAINDER.                 709-10                    P051R130
  IF YES, DELETE 2ND,                         J68                      P051R140
                                             10L8                      P051R170
                                             12W2                      P051R180
FIND INTERNAL FORM,                           J10                      P051R190
                                             709-1                     P051R200
REPLACE EXTERNAL,                            21W2                      P051R210
                                     9-1     11W1                      P051R220
DELETE FIRST DELIMITER.                       J68                      P051R230
RESET AND DO IT AGAIN.                       11W0     9-10             P051R240
ALL DONE, CLEAN UP AND QUIT.         9-0     30H0     J32              P051R250
                                     1                                        R
P52 CREATE MAIN SEGMENT FROM         P52      J41                      P052R000
    LIST (0). H5- MEANS NO OUTPUT            20W1           1W1=CURLOCP052R020
    DUE TO BAD EXPRESSION.                    9-100 J31                P052R030
9-100 SUBPROCESS CREATE NEXT SGMNT.  9-100 04J0                        P052R040
     H5- MEANS NO OUTPUT.                    11W1           1W1=CURLOCP052R050
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LOCATE FIRST OF EXPRESSION                 J60                      P052R060
                                          20W1                      P052R070
     IF NONE, QUIT.                       709-101                   P052R080
                                          12W1                      P052R090
                                          10(                       P052R100
TEST IF OPENING PAREN.                     J2                       P052R110
    IF YES, BUILD SEGMENT.                70      9-110             P052R120
                                          12W1                      P052R130
                                          11K2           1K2= NOT   P052R140
TEST IF NOT.                               J2                       P052R150
    IF YES, BUILD SEGMENT.                70      9-120             P052R160
                                          12W1                      P052R170
TEST IF VARIABLE.                          P8                       P052R180
     IF NO QUIT.                          709-101                   P052R190
OUTPUT VARIABLE.                          12W1    0                 P052R200
                                    9-101 11W1                      P052R205
                                          10/14   J63               P052R210
TAKE ERROR ACTION, THEN             9-103  9-101                    P052R220
ERASE USELESS SEGMENT.              9-102 11W0                      P052R230
                                           J72    J30               P052R240
OUTPUT SEGMENT.                     9-104 11W0                      P052R250
                                           J136   J30               P052R260
BUILD SEGMENT                       9-110  9-200         1W0=NEWSEGP052R270
CREATE 1ST SUBSEGMENT.                     9-100                    P052R280
     IF NONE, CLEAN UP, QUIT.             709-102                   P052R290
INSERT 1ST SUBSEGMENT.                     9-300                    P052R300
                                          11W1                      P052R310
LOCATE NEXT SYMBOL.                        J60                      P052R320
                                          60W1                      P052R330
                                          52W1                      P052R340
TEST IF CONNECTIVE.                        P7                       P052R350
     IF NOT, CLEAN UP, QUIT.              709-103                   P052R360
                                          12W1                      P052R370
INSERT CONNECTIVE.                        21W0                      P052R380
CREATE 2ND SUBSEGMENT.                     9-100                    P052R390
     IF NONE, CLEAN UP, QUIT.             709-102                   P052R400
INSERT 2ND SUBSEGMENT.                     9-300                    P052R410
                                          11W1                      P052R420
LOCATE NEXT SYMBOL.                        J60                      P052R430
                                          60W1                      P052R440
                                          52W1                      P052R450
                                          10)                       P052R460
TEST IF CLOSING PAREN.                     J2                       P052R470
     IF NO, CLEANUP, QUIT.                709-103 9-104             P052R480
BUILD NOTTED SEGMENT.               9-120  9-200                    P052R490
                                          12W1                      P052R500
NOT THE HEAD.                             21W0                      P052R510
CREATE SUBSEGMENT.                         9-100                    P052R520
     IF NONE, CLEAN UP AND QUIT.          709-102                   P052R530
INSERT                                     9-300  9-104             P052R540
9-200 SUBPROCESS, SET UP EMPTY SEG. 9-200  J90    J50               P052R550
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9-300 SUBPROCESS, INSERT SEGMENT.     9-300 11W0                      P052R560
                                            J6    J65                P052R570
                                    1                                    R
P55 LOCATE SUBLIST FOLLOWING          P55    J41                     P055R000
    DATA TERM (0) ON LIST (1))              20W0                     P055R010
    H5+ MEANS PUTPUT (0) IS           9-3   60W1                     P055R020
        CELL HOLDING SUBLIST.                J60                     P055R030
H5- MEANS OUTPUT (0) IS                     70J31                    P055R040
        CELL AFTER WHICH TO INSERT.         12H0                     P055R050
                                            11W0                     P055R060
TEST IF PAST.                                J116                    P055R070
     IF YES, QUIT, H5-.                     70      9-1              P055R080
                                            12H0                     P055R090
                                            11W0                     P055R100
TEST IF EQUAL.                               J114                    P055R110
     IF YES, QUIT, H5+.                     70      9-2              P055R120
     IF NO, MOVE DOWN THE LIST.              J60                     P055R130
                                            70J7    9-3              P055R140
SET UP CELL TO INSERT AFTER.          9-1   51W1                     P055R150
                                             J3     J31              P055R160
SET UP CELL HOLDING SUBLIST.          9-2    J60                     P055R170
                                            70J7    J31              P055R180
                                    1                                    R
Q1 FIND CONNECTIVE OF SEGMENT (0).    Q1     J80                     Q001R000
                                            700                      Q001R010
                                            40H0                     Q001R020
TEST IF IT IS A CONNECTIVE.                  P7                      Q001R030
                                            70J8    0                Q001R040
                                    1                                    R
Q2 FIND NO. OF LEVELS OF TEX (0).     Q2    40H0                     Q002R000
   H5- MEANS DEFECTIVE EXPRESSION.          10Q2                     Q002R010
FIND VALUE ON DESCRIPTION LIST.              J10                     Q002R020
     IF NONE, GO COUNT LEVELS.              709-0                    Q002R030
     IF THERE, CLEAN UP, QUIT +.             J6     J8               Q002R040
                                      9-0   10N10                    Q002R050
                                             J120                    Q002R060
CREATE LEVEL DATA TERM = ZERO.               J136                    Q002R070
                                            40H0                     Q002R080
CREATE COUNTER.                              J120       1W0=COUNTRQ002R090
SAVE COUNTER, LEVEL, TEX.                    J52        1W1=LEVEL Q002R100
                                            11W2        1W2=TEX   Q002R110
FIND MEX.                                    J81                     Q002R120
       IF NONE, CLEANUP, QUIT-.             709-1                    Q002R130
       IF THERE, COUNT LEVELS.               9-100                   Q002R140
                                      9-1   11W0                     Q002R150
ERASE COUNTER.                               J9                      Q002R160
INPUT LEVEL,                                11W1                     Q002R170
     IF H5-, ERASE LEVEL, QUIT-.            709-2                    Q002R180
    IF H5+,                                 11W2                     Q002R190
ASSIGN LEVEL 1W1 AS VALUE                   11W1                     Q002R200
OF Q2 OF TEX 1W2.                           10Q2                     Q002R210
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QUIT +, OUTPUT (0) IS LEVEL.                  J11     J32                   Q002R220
                                      9-2     J9      J32                   Q002R230
9-100 SUBPROCESS. COUNT SUBLEVELS.    9-100 11W0                            Q002R240
                                              J120                          Q002R250
CREATE COUNTER EQUAL TO THIS LEVEL.           J125                          Q002R260
PRESERVE PREVIOUS COUNTER.                    J50                           Q002R270
                                            40H0                            Q002R300
TEST IF SIMPLE VARIABLE.                      P8                            Q002R310
    IF YES, UPDATE LEVEL.                   70        9-102                 Q002R320
     IF NO, COUNT SUBLEVELS,                109-100                         Q002R330
     THEN QUIT + OR-.                         J100    9-101                 Q002R340
UPDATE LEVEL.                         9-102 51W1                            Q002R350
                                            11W0                            Q002R360
TEST IF COUNTER GREATER THAN LEVEL.           J115                          Q002R370
     IF NO, QUIT +.                         709-103                         Q002R380
                                            11W0                            Q002R390
     IF YES,                                11W1                            Q002R400
SET LEVEL SAME AS COUNTER.                    J121                          Q002R410
                                            30H0                            Q002R420
SET H5+.                              9-103   J4                            Q002R430
ERASE COUNTER OF THIS LEVEL.          9-101 11W0                            Q002R440
RESTORE PREVIOUS COUNTER, QUIT.             30W0      J9                    Q002R450
                                     1                                          R
Q3 FIND NO. OF DISTINCT VARIABLES     Q3    40H0                            Q003R000
   IN TOTAL EXPRESSION (0).                 10Q3                            Q003R010
                                              J10                           Q003R020
FIND AS VALUE IN DESC. LIST.                709-0                           Q003R030
      IF THERE, CLEAN UP, QUIT +.             J6      J8                    Q003R040
      IF NONE, COUNT VARIABLES.       9-0     J42                           Q003R050
                                            60W0               1W0=TEX      Q003R060
CREATE FREE LIST,                             P30                           Q003R070
SAVE IT,                                    60W1               1W1=FREE     Q003R080
COUNT IT,                                     J126                          Q003R090
MARK COUNT LOCAL,                             J136                          Q003R100
AND SAVE FOR OUTPUT.                        60W2               1W2=OUTPUTQ003R110
                                            51W1                            Q003R120
ERASE FREE LIST.                              J71                           Q003R130
                                            11W0                            Q003R140
CREATE BOUND LIST,                            P31                           Q003R150
SAVE IT,                                    60W1               1W1=BOUND Q003R160
COUNT IT,                                     J126                          Q003R170
                                            40H0                            Q003R180
                                            11W2                            Q003R190
                                            11W2                            Q003R200
ADD IT TO OUTPUT DATA TERM.                   J110                          Q003R210
                                            51W1                            Q003R220
ERASE BOUND LIST.                             J71                           Q003R230
ERASE BOUND COUNT.                            J9                            Q003R240
                                            11W0                            Q003R250
                                            11W2                            Q003R260
                                            10Q3                            Q003R270
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ASSIGN AS VALUE OF Q3.                         J11                  Q003R280
                                              11W2                  Q003R290
CLEAN UP AND QUIT.                             J32     J4           Q003R300
                                    1                                   R
Q4 FIND NO. OF VARIABLE PLACES        Q4      40H0                  Q004R000
   IN TEX (0).                                10Q4                  Q004R010
FIND AS VALUE OF DESC. LIST.                   J10                  Q004R020
     IF NONE, GO COUNT PLACES.                709-0                 Q004R030
     IF THERE, CLEAN UP, QUIT, H5+.            J6      J8           Q004R040
                                      9-0     40H0                  Q004R050
SET UP THREE COPIES OF TEX NAME.              40H0                  Q004R060
                                               J90                  Q004R070
                                               J136                 Q004R080
CREATE D.T. WITH VALUE = 0.                    J124                 Q004R090
                                               J6                   Q004R100
                                              109-100               Q004R110
GENERATE FREE LOCATIONS FOR TALLY.             P28                  Q004R120
                                               J6                   Q004R130
                                              109-100               Q004R140
GENERATE BOUND LOCATIONS FOR TALLY.            P29                  Q004R150
                                              40W0                  Q004R160
SAVE OUTPUT D.T.                              60W0         1W0=OUTPUTQ004R170
                                              10Q4                  Q004R180
ASSIGN AS VALUE OF Q4 OF TEX.                  J11                  Q004R190
                                              11W0     J30          Q004R200
DISCARD (0), TALLY (1).               9-100   30H0     J125         Q004R210
                                    1                                   R
ATTRIBUTE--VARIABLE                   Q5      10Q5     J10          Q005R000
                                    1                                   R
ATTRIBUTE--FREE VARIABLE              Q6      10Q6     J10          Q006R000
                                    1                                   R
ATTRIBUTE--EXTERNAL NAME              Q7      10Q7     J10          Q007R000
                                    1                                   R
FIND PROBLEM NUMBER OF (0)            Q8      10Q8     J10          Q008R000
                                    1                                   R
Q9 ATTRIBUTE--BOUND VARIABLE.         Q9      10Q9     J10          Q009R000
                                    1                                   R
FIND PROBLEM (0) DERIVED FROM         Q10     10Q10    J10          Q010R000
                                    1                                   R
FIND METHOD OF DERIVATION FOR (0)     Q11     10Q11    J10          Q011R000
                                    1                                   R
FIND THEOREM USED FOR (0)             Q12     10Q12    J10          Q012R000
                                    1                                   R
FIND PROVING THEOREM FOR (0)          Q13     10Q13    J10          Q013R000
                                    1                                   R
Q14 FIND TYPE OF CONNECTIVE (0).      Q14     10Q14    J10          Q014R000
                                    1                                   R
Q15 ATTRIBUTE -- INTERNAL FORM.       Q15     10Q15    J10          Q015R000
                                    1                                   R
Q16 FIND EXTERNAL NAME OF (0)         Q16     10T10                 Q016R000
    IN TABLE T10.                              J6      J10          Q016R010
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                                       1                                                    R
Q17 FIND LEVEL OF SUBSEGMENT            Q17    40W0                                 Q017R000
    REPLACEMENT IN TEX (0).                    60W0                                 Q017R010
                                               10Q17                                Q017R020
FIND CURRENT LEVEL.                              J10                                Q017R030
IF NONE,                                       70          J30                      Q017R040
                                               11W0                                 Q017R050
FIND NUMBER OF LEVELS,                           Q2                                 Q017R060
    IF NONE, QUIT -.                           70J30                                Q017R065
COPY,                                            J120                               Q017R070
SAVE ONE FOR OUTPUT,                           40H0                                 Q017R080
                                               11W0                                 Q017R090
                                                 J6                                 Q017R100
AND ASSIGN AS CURRENT LEVEL.                   10Q17                                Q017R110
                                               30W0        J11                      Q017R120
                                       1                                                    R
Q18 FIND SUFFIX OF EXPRESSION (0).      Q18    10Q18       J10                      Q018R000
                                       1                                                    R
Q19 FIND CHARACTER SYMBOL FOR '0).      Q19    10L9                                 Q019R000
                                                 J6        J10                      Q019R010
```

DATA HEADER	5	1		D -
FREE VARIABLE A	A		0	A000D000
		0		A000D010
		Q5		A000D020
		Q5		A000D030
		Q6		A000D040
		Q6		A000D050
		Q7		A000D060
			0	A000D070
		+21A		A000D080
FREE VARIABLE B	B		0	B000D000
		0		B000D010
		Q5		B000D020
		Q5		B000D030
		Q6		B000D040
		Q6		B000D050
		Q7		B000D060
			0	B000D070
		+21B		B000D080
FREE VARIABLE C	C		0	C000D000
		0		C000D010
		Q5		C000D020
		Q5		C000D030
		Q6		C000D040
		Q6		C000D050
		Q7		C000D060
			0	C000D070
		+21C		C000D080
FREE VARIABLE D	D		0	D000D000
		0		D000D010
		Q5		D000D020
		Q5		D000D030
		Q6		D000D040
		Q6		D000D050
		Q7		D000D060
			0	D000D070
		+21D		D000D080
FREE VARIABLE E	E		0	E000D000
		0		E000D010
		Q5		E000D020
		Q5		E000D030
		Q6		E000D040
		Q6		E000D050
		Q7		E000D060
			0	E000D070
		+21E		E000D080
FREE VARIABLE F	F		0	F000D000
		0		F000D010
		Q5		F000D020
		Q5		F000D030

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                                                  Q6                       F000D040
                                                  Q6                       F000D050
                                                  Q7                       F000D060
                                                        0                  F000D070
                                               +21F                        F000D080
FREE VARIABLE G                          G              0                  G000D000
                                                  0                        G000D010
                                                  Q5                       G000D020
                                                  Q5                       G000D030
                                                  Q6                       G000D040
                                                  Q6                       G000D050
                                                  Q7                       G000D060
                                                        0                  G000D070
                                               +21G                        G000D080
HO LUBRICATION.                          H0       *1                       H000D000
                                                  *2                       H000D010
                                                  *3                       H000D020
                                                  *4    0                  H000D030
 IMPLIES                                 I              0                  I000D000
                                                  0                        I000D010
                                                  Q14                      I000D020
                                                  J4                       I000D030
                                                  Q7                       I000D040
                                                        0                  I000D050
                                               +21I                        I000D060
KO SYMBOL FOR CHARACTER K.               K              0                  K000D000
                                                  0                        K000D010
                                                  Q7                       K000D020
                                                        0                  K000D030
                                               +21K                        K000D040
HOLDS  'OR'                              K1       V0    0                  K001D000
HOLDS  'NOT'                             K2       -0    0                  K002D000
HOLDS  'AND'                             K3       *0    0                  K003D000
HOLDS  'PROVEN EQUIVALENCE'              K4       =0    0                  K004D000
HOLDS 'DEFINITIONAL EQUIVALENCE'         K5       =1    0                  K005D000
HOLDS  'IMPLIES'                         K6       I0    0                  K006D000
K7 HOLDS CONNECTIVE DELIMITER.           K7       .     0                  K007D000
K10 PREVIOUS PROBLEM NUMBER.             K10  01               0           K010D000
SUBSTITUTION COUNT                       K11  + 1              0           K011D000
EFFORT BASE (AND TOTAL).                 K12  + 1              0           K012D000
LIMIT ON NO. OF SUBPROBLEMS              K20  + 1            100           K020D000
LIMIT ON NO. OF SUBSTITUTIONS            K21  + 1            100           K021D000
LIMIT ON EFFORT                          K22  + 1  100      0000           K022D000
                                         K30      F                        K030D000
K31 DON'T PRINT REJECTS IF HOLDS NO      K31      NO                       K031D000
K41 VALUE = METHOD COLUMN.               K41  01              10           K041D000
K42 VALUE = NAME COLUMN.                 K42  01              40           K042D000
K43 VALUE = EXPRESSION COLUMN.           K43  01              50           K043D000
K44 VALUE = 'LIMIT' COLUMN.              K44  01              20           K044D000
K45 VALUE = 'ACTUAL' COLUMN.             K45  01              40           K045D000
K46 VALUE = 'REJECTED' COLUMN.           K46  01              20           K046D000
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K47 VALUE = NAME OF NEW SUBPROBLEM   K47   01              11 COLUMN.   K047D000
K48 VALUE = THM, METHOD COLUMN.      K48   01              43           K048D000
K51 DATA TERM '('                    K51   21(                          K051D000
K52 DATA TERM ')'                    K52   21)                          K052D000
K53 DATA TERM '.'                    K53   21.                          K053D000
K54 DATA TERM ','                    K54   21,                          K054D000
L0 SYMBOL FOR CHARACTER L.           L              0                   L000D000
                                            0                           L000D010
                                            Q7                          L000D020
                                                    0                   L000D030
                                          +21L                          L000D040
L1 TRUE THEOREMS AXIOMS DEFINITIONS  L1     0       0                   L001D000
LIST OF FREE VARIABLES               L2     0                           L002D000
                                            A0                          L002D010
                                            B0                          L002D020
                                            C0                          L002D030
                                            D0                          L002D040
                                            E0                          L002D050
                                            F0                          L002D060
                                            G0      0                   L002D080
L3 PROBLEM LIST FOR MULTI PROB EXEC  L3     0       0       (M2)        L003D000
TRUE EXPRESSIONS MAPS                L4     0       0                   L004D000
LIST DESCRIBED BY L4                 L5     L4      0                   L005D000
L6 LIST OF METHODS FOR ORIG PROBS    L6     0                           L006D000
                                            M16                         L006D010
                                            M17                         L006D020
L7  LIST OF METHODS FOR PROBLEMS.    L7     0                           L007D000
    DETACHMENT.                             M11                         L007D010
    REPLACEMENT.                            M13                         L007D010
    FORWARD CHAINING.                       M14                         L007D010
    BACKWARD CHAINING.                      M15                         L007D010
L8 DESCRIPTION LIST TABLE OF         L8             0                   L008D000
    DELIMITABLE EXTERNL CONNECTIVES         0                           L008D010
                                            =                           L008D020
                                            =1                          L008D030
L9 DESCRIPTION LIST TABLE OF         L9             0                   L009D000
     CHARACTER SYMBOLS FOR                  0                           L009D010
     READING TEXT.                          0                           L009D020
                                            /10                         L009D025
                                            1                           L009D030
                                            /1                          L009D040
                                            2                           L009D050
                                            /2                          L009D060
                                            3                           L009D070
                                            /3                          L009D080
                                            4                           L009D090
                                            /4                          L009D100
                                            5                           L009D110
                                            /5                          L009D120
                                            6                           L009D130
                                            /6                          L009D140
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                                                  7                        L009D150
                                                  /7                       L009D160
                                                  8                        L009D170
                                                  /8                       L009D180
                                                  9                        L009D190
                                                  /9                       L009D200
                                                  H                        L009D210
                                                  /11                      L009D220
                                                  J                        L009D230
                                                  /12                      L009D240
                                                  W                        L009D250
                                                  /13                      L009D260
UNTRIED PROBLEMS LIST                     L10     0      0                 L010D000
L11 FOUND PROBLEMS LIST.                  L11     0      0                 L011D000
M0 SYMBOL FOR CHARACTER M.                M              0                 M000D000
                                                  0                        M000D010
                                                  Q7                       M000D020
                                                         0                 M000D030
                                              +21M                         M000D040
N0 SYMBOL FOR CHARACTER N.                N              0                 N000D000
                                                  0                        N000D010
                                                  Q7                       N000D020
                                                         0                 N000D030
                                              +21N                         N000D040
 1 INTEGER CONSTANTS.                     N1  +01            1             N001D000
                                          N2  +01            2             N002D000
                                          N3  +01            3             N003D000
                                          N4  +01            4             N004D000
                                          N5  +01            5             N005D000
                                          N6  +01            6             N006D000
                                          N7  +01            7             N007D000
                                          N8  +01            8             N008D000
                                          N9  +01            9             N009D000
 0                                        N10 +01            0             N010D000
O0 SYMBOL FOR CHARACTER O.                O              0                 O000D000
                                                  0                        O000D010
                                                  Q7                       O000D020
                                                         0                 O000D030
                                              +21O                         O000D040
VARIABLE P                                P              0                 P000D000
                                                  0                        P000D010
                                                  Q5                       P000D020
                                                  Q5                       P000D030
                                                  Q9                       P000D033
                                                  Q9                       P000D037
                                                  Q7                       P000D040
                                                         0                 P000D050
                                              +21P                         P000D060
VARIABLE Q                                Q              0                 Q000D000
                                                  0                        Q000D010
                                                  Q5                       Q000D020
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                                      Q5                     Q000D030
                                      Q9                     Q000D033
                                      Q9                     Q000D037
                                      Q7                     Q000D040
                                           0                 Q000D050
                                    +21Q                     Q000D060
VARIABLE R                      R          0                 R000D000
                                      0                      R000D010
                                      Q5                     R000D020
                                      Q5                     R000D030
                                      Q9                     R000D033
                                      Q9                     R000D037
                                      Q7                     R000D040
                                           0                 R000D050
                                    +21R                     R000D060
VARIABLE S                      S          0                 S000D000
                                      0                      S000D010
                                      Q5                     S000D020
                                      Q5                     S000D030
                                      Q9                     S000D033
                                      Q9                     S000D037
                                      Q7                     S000D040
                                           0                 S000D050
                                    +21S                     S000D060
VARIABLE T                      T          0                 T000D000
                                      0                      T000D010
                                      Q5                     T000D020
                                      Q5                     T000D030
                                      Q9                     T000D033
                                      Q9                     T000D037
                                      Q7                     T000D040
                                           0                 T000D050
                                    +21T                     T000D060
T1 'GIVEN'                      T1    0                      T001D000
                                           0                 T001D010
                                     21GIVEN                 T001D020
T2 'PROOF FOUND.'               T2    0                      T002D000
                                      9-1                    T002D010
                                      9-2                    T002D020
                                      9-3  0                 T002D030
                                9-1  21 PROO                 T002D040
                                9-2  21F FOU                 T002D050
                                9-3  21ND.                   T002D060
T3 'SUBSTITUTION'               T3    0                      T003D000
                                      9-1                    T003D010
                                      9-2                    T003D020
                                      9-3  0                 T003D030
                                9-1  21SUBST                 T003D040
                                9-2  21ITUTI                 T003D050
                                9-3  21ON                    T003D060
T4 'Q.E.D.'                     T4    0                      T004D000
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                                              9-1                 T004D010
                                              9-2   0             T004D020
                                        9-1  21Q.E.D              T004D030
                                        9-2  21.                  T004D040
T5 LIST OF ONE BLANK D.T.               T5     0                  T005D000
                                                    0             T005D010
                                             21                   T005D020
T6 'NO PROOF FOUND'                     T6     0                  T006D000
                                              9-1                 T006D010
                                              9-2                 T006D020
                                              9-3   0             T006D030
                                        9-1  21NO PR              T006D040
                                        9-2  21OOF F              T006D050
                                        9-3  21OUND               T006D060
T7 'EFFORT'                             T7     0                  T007D000
                                              9-1                 T007D010
                                              9-2   0             T007D020
                                        9-1  21EFFOR              T007D030
                                        9-2  21T                  T007D040
T8 'SUBPROBLEMS'                        T8     0                  T008D000
                                              9-1                 T008D010
                                              9-2                 T008D020
                                              9-3   0             T008D030
                                        9-1  21SUBPR              T008D040
                                        9-2  21OBLEM              T008D050
                                        9-3  21S                  T008D060
T9 'SUBSTITUTIONS'                      T9     0                  T009D000
                                              9-1                 T009D010
                                              9-2                 T009D020
                                              9-3   0             T009D030
                                        9-1  21SUBST              T009D040
                                        9-2  21ITUTI              T009D050
                                        9-3  21ONS                T009D060
T10 DESC. LIST TABLE OF NAMES.          T10   9-0   0             T010D000
                                        9-0    0                  T010D010
                                              M11                 T010D020
                                              T12                 T010D030
                                              M12                 T010D040
                                              T3                  T010D050
                                              M13                 T010D060
                                              T13                 T010D070
                                              M14                 T010D080
                                              T14                 T010D090
                                              M15                 T010D100
                                              T15                 T010D110
                                              M16                 T010D120
                                              T16   0             T010D130
T12 'DETACHMENT'                        T12    0                  T012D000
                                              9-1                 T012D010
                                              9-2   0             T012D020
                                        9-1  21DETAC              T012D030
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                                        9-2   21HMENT                  T012D040
T13 'REPLACEMENT'                       T13     0                      T013D000
                                               9-1                     T013D010
                                               9-2                     T013D020
                                               9-3    0                T013D030
                                        9-1   21REPLA                  T013D040
                                        9-2   21CEMEN                  T013D050
                                        9-3   21T                      T013D060
T14 'FORWARD CHAINING'                  T14     0                      T014D000
                                               9-1                     T014D010
                                               9-2                     T014D020
                                               9-3                     T014D030
                                               9-4    0                T014D040
                                        9-1   21FORWA                  T014D050
                                        9-2   21RD CH                  T014D060
                                        9-3   21AININ                  T014D070
                                        9-4   21G                      T014D080
T15 'BACKWARD CHAINING'                 T15     0                      T015D000
                                               9-1                     T015D010
                                               9-2                     T015D020
                                               9-3                     T015D030
                                               9-4    0                T015D040
                                        9-1   21BACKW                  T015D050
                                        9-2   21ARD C                  T015D060
                                        9-3   21HAINI                  T015D070
                                        9-4   21NG                     T015D080
T16 'SUBLEVEL REPLACEMENT'              T16     0                      T016D000
                                               9-1                     T016D010
                                               9-2                     T016D020
                                               9-3                     T016D030
                                               9-4    0                T016D040
                                        9-1   21SUBLE                  T016D050
                                        9-2   21VEL R                  T016D060
                                        9-3   21EPLAC                  T016D070
                                        9-4   21EMENT                  T016D080
T19 'REJECTED PROBLEM'                  T19     0                      T019D000
                                               9-1                     T019D010
                                               9-2                     T019D020
                                               9-3                     T019D030
                                               9-4    0                T019D040
                                        9-1   21REJEC                  T019D050
                                        9-2   21TED P                  T019D060
                                        9-3   21ROBLE                  T019D070
                                        9-4   21M                      T019D080
T20 'ACTUAL'                            T20     0                      T020D000
                                               9-1                     T020D010
                                               9-2    0                T020D020
                                        9-1   21ACTUA                  T020D030
                                        9-2   21L                      T020D040
T21 'LIMIT'                             T21     0                      T021D000
                                                      0                T021D010
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                                          21LIMIT                    T021D020
T22 'TO PROVE'                      T22     0                        T022D000
                                            9-1                      T022D010
                                            9-2    0                 T022D020
                                    9-1   21TO PR                    T022D030
                                    9-2   21OVE                      T022D040
T23 'REMEMBER PROVED THEOREM'       T23     0                        T023D000
                                            9-1                      T023D010
                                            9-2                      T023D020
                                            9-3                      T023D030
                                            9-4                      T023D040
                                            9-5                      T023D050
                                            9-6    0                 T023D060
                                    9-1   21    RE                   T023D070
                                    9-2   21MEMBE                    T023D080
                                    9-3   21R PRO                    T023D090
                                    9-4   21VED T                    T023D100
                                    9-5   21HEORE                    T023D110
                                    9-6   21M                        T023D120
T24 'BAD EXPRESSION'                T24     0                        T024D000
                                            9-1                      T024D010
                                            9-2                      T024D020
                                            9-3    0                 T024D030
                                    9-1   21BAD E                    T024D040
                                    9-2   21XPRES                    T024D050
                                    9-3   21SION                     T024D060
U0 SYMBOL FOR CHARACTER U.          U              0                 U000D000
                                            0                        U000D010
                                            Q7                       U000D020
                                                   0                 U000D030
                                         +21U                        U000D040
 OR                                 V              0                 V000D000
                                            0                        V000D010
                                            Q14                      V000D020
                                            J4                       V000D030
                                            Q7                       V000D040
                                                   0                 V000D050
                                         +21V                        V000D060
X0 SYMBOL FOR CHARACTER X.          X              0                 X000D000
                                            0                        X000D010
                                            Q7                       X000D020
                                                   0                 X000D030
                                         +21X                        X000D040
Y0 SYMBOL FOR CHARACTER Y.          Y              0                 Y000D000
                                            0                        Y000D010
                                            Q7                       Y000D020
                                                   0                 Y000D030
                                         +21Y                        Y000D040
Z0 SYMBOL FOR CHARACTER Z.          Z              0                 Z000D000
                                            0                        Z000D010
                                            Q7                       Z000D020
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                                                         0           Z000D030
                                                 +21Z                Z000D040
 NOT                                         -           0           -000D000
                                                    0                -000D010
                                                    Q14              -000D020
                                                    J3               -000D030
                                                    Q7               -000D040
                                                         0           -000D050
                                                 +21-                -000D060
 AND                                         *           0           *000D000
                                                    0                *000D010
                                                    Q14              *000D020
                                                    J4               *000D030
                                                    Q7               *000D050
                                                         0           *000D050
                                                 +21*                *000D060
PROVEN EQUIVALENCE                           =           0           =000D000
                                                    0                =000D010
                                                    Q14              =000D020
                                                    J4               =000D030
                                                    Q7               =000D040
                                                         0           =000D050
                                                 +21=                =000D060
=1 DEFINITIONAL EQUIVALENCE                  =1          0           =001D000
                                                    0                =001D010
                                                    Q14              =001D020
                                                    J4               =001D030
                                                    Q7               =001D040
                                                         0           =001D050
                                                 +21.=.              =001D060
+0 SYMBOL FOR PLUS SIGN.                     +           0           +000D000
                                                    0                +000D010
                                                    Q7               +000D020
                                                         0           +000D030
                                                 +21+                +000D040
/0 SYMBOL FOR SLASH.                         /           0           /000D000
                                                    0                /000D010
                                                    Q7               /000D020
                                                         0           /000D030
                                                 +21/                /000D040
/1 SYMBOL FOR DIGIT 1.                       /1          0           /001D000
                                                    0                /001D010
                                                    Q7               /001D020
                                                         0           /001D030
                                                 +211                /001D040
/2 SYMBOL FOR DIGIT 2.                       /2          0           /002D000
                                                    0                /002D010
                                                    Q7               /002D020
                                                         0           /002D030
                                                 +212                /002D040
/3 SYMBOL FOR DIGIT 3.                       /3          0           /003D000
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                                        0                       /003D010
                                         Q7                     /003D020
                                                  0             /003D030
                                     +213                       /003D040
/4 SYMBOL FOR DIGIT 4.            /4              0             /004D000
                                        0                       /004D010
                                         Q7                     /004D020
                                                  0             /004D030
                                     +214                       /004D040
/5 SYMBOL FOR DIGIT 5.            /5              0             /005D000
                                        0                       /005D010
                                         Q7                     /005D020
                                                  0             /005D030
                                     +215                       /005D040
/6 SYMBOL FOR DIGIT 6.            /6              0             /006D000
                                        0                       /006D010
                                         Q7                     /006D020
                                                  0             /006D030
                                     +216                       /006D040
/7 SYMBOL FOR DIGIT 7.            /7              0             /007D000
                                        0                       /007D010
                                         Q7                     /007D020
                                                  0             /007D030
                                     +217                       /007D040
/8 SYMBOL FOR DIGIT 8.            /8              0             /008D000
                                        0                       /008D010
                                         Q7                     /008D020
                                                  0             /008D030
                                     +218                       /008D040
/9 SYMBOL FOR DIGIT 9.            /9              0             /009D000
                                        0                       /009D010
                                         Q7                     /009D020
                                                  0             /009D030
                                     +219                       /009D040
/10 SYMBOL FOR DIGIT 0.           /10             0             /010D000
                                        0                       /010D010
                                         Q7                     /010D020
                                                  0             /010D030
                                     +210                       /010D040
/11 SYMBOL FOR CHARACTER J.       /11             0             /011D000
                                        0                       /011D010
                                         Q7                     /011D020
                                                  0             /011D030
                                     +21H                       /011D040
/12 SYMBOL FOR CHARACTER W.       /12             0             /012D000
                                        0                       /012D010
                                         Q7                     /012D020
                                                  0             /012D030
                                     +21J                       /012D040
/13 SYMBOL FOR CHARACTER H.       /13             0             /013D000
                                        0                       /013D010
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                                                Q7                              /013D020
                                                      0                         /013D030
                                             +21W                               /013D040
/14 DUMMY CHARACTER SYMBOL             /14            0                         /014D000
                                                0                               /014D010
                                                Q7                              /014D020
                                                      0                         /014D030
                                             +21/UGH/                           /014D040
/16 DUMMY EXPRESSION --                /16      9-1                             /016D000
       'DEFINITIONS'.                           9-2   0                         /016D010
                                       9-1      0                               /016D020
                                                Q15                             /016D030
                                                Q15                             /016D040
                                                Q7                              /016D050
                                                      0                         /016D060
EXTERNAL NAME                                    21                             /016D070
CONNECTIVE 'I'.                        9-2      I0                              /016D080
                                                9-10                            /016D090
                                                9-20  0                         /016D100
DUMMY VARIABLE 'DEFIN'.                9-10           0                         /016D110
                                                0                               /016D120
                                                Q5                              /016D130
                                                Q5                              /016D140
                                                Q9                              /016D150
                                                Q9                              /016D160
                                                Q7                              /016D170
                                                      0                         /016D180
EXTERNAL NAME.                                   21DEFIN                        /016D190
DUMMY VARIABLE 'TIONS'.                9-20           0                         /016D200
                                                0                               /016D210
                                                Q5                              /016D220
                                                Q5                              /016D230
                                                Q9                              /016D240
                                                Q9                              /016D250
                                                Q7                              /016D260
                                                      0                         /016D270
EXTERNAL NAME.                                   21TIONS                        /016D280
(0 SYMBOL FOR LEFT PAREN.              (              0                         (000D000
                                                0                               (000D010
                                                Q7                              (000D020
                                                K51   0                         (000D030
'0 SYMBOL FOR QUOTE MARK.              '              0                         '000D000
                                                0                               '000D010
                                                Q7                              '000D020
                                                      0                         '000D030
                                             +21'                               '000D040
)0 SYMBOL FOR RIGHT PAREN.             )              0                         )000D000
                                                0                               )000D010
                                                Q7                              )000D020
                                                K52   0                         )000D030
,0 SYMBOL FOR COMMA.                   ,              0                         ,000D000
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                                                 0                          ,000D010
                                                 Q7                         ,000D020
                                                 K54    0                   ,000D030
.0 SYMBOL FOR PERIOD                 .                  0                   .000D000
                                                 0                          .000D010
                                                 Q7                         .000D020
                                                 K53    0                   .000D030
$0 SYMBOL FOR DOLLAR SIGN.           $                  0                   $000D000
                                                 0                          $000D010
                                                 Q7                         $000D020
                                                        0                   $000D030
                                             +21$                           $000D040
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EXECUTIVE HEADER                        5                                       R  -
                                        1                                       R
                                          X1     11W26                   X001R000
                                                 10X23                   X001R010
                                                   J73                   X001R020
SET UP TRAPS.                                      J76                   X001R030
                                                 50X21                   X001R040
                                                 10J147                  X001R050
MARK TO TRACE.                                     J100                  X001R060
                                                 10X22                   X001R070
                                                 10J148                  X001R080
MARK TO PROPAGATE TRACE.                           J100                  X001R090
GET NEXT TRUE TEX FROM                    9-1      M89                   X001R100
INPUT UNIT IF ANY LEFT.                          709-10                  X001R110
                                                 40H0                    X001R120
CONVERT TO TREE FORM.                              P50                   X001R130
                                                 709-2                   X001R140
ADD TO SET OF TRUE EXPRESSION.                     M50    9-1            X001R150
TAKE ACTION, TRY FOR ANOTHER              9-2      9-100  9-1            X001R160
                                          9-10     J154                  X001R170
SKIP TWO LINES.                                    J155                  X001R180
                                                   J155                  X001R190
GET NEXT PROBLEM TEX.                     9-11     M89                   X001R200
IF NO MORE, GO TRY PROOFS.                       70M2                    X001R210
                                                 40H0                    X001R215
CONVERT TO INTERNAL.                               P50                   X001R220
                                                 709-12                  X001R230
                                                 40H0                    X001R240
PRINT EXPRESSION.                                  M70                   X001R250
                                                 10L3                    X001R260
                                                   J6                    X001R270
ADD TO LIST OF PROBLEMS.                           J65    9-11           X001R280
                                          9-12     9-100  9-11           X001R290
BAD INPUT ACTION.                         9-100  40H0                    X001R300
                                                   M88                   X001R310
                                                 40H0                    X001R320
                                                   J15                   X001R330
                                                   J75    J72            X001R340
                                        1                                       R
                                          X9     10N2                    X009R000
                                                   J166   J165           X009R010
                                        1                                       R
X10 INVOKE FULL TRACE.                    X10    10N1                    X010R000
                                                   J120                  X010R010
                                                 40W31                   X010R020
                                                 20W31                   X010R030
                                                   X19    0              X010R040
                                        1                                       R
X11 REVOKE CURRENT TRACE MODE             X11    40H5                    X011R000
    IF ANOTHER EXISTS.                           10W31                   X011R010
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                                                J78                      X011R020
                                               709-0                     X011R030
                                               11W31                     X011R040
                                               30W31                     X011R050
                                                X19                      X011R060
                                               30H5    J9                X011R070
                                         9-0   30H5    0                 X011R080
                                       1                                     R
                                         X13   40H0    J150              X013R000
                                       1                                     R
X14 SAVE FOR RESTART ON INTERUPT         X14   40H5                      X014R000
    USING UNIT 3.                              10N3                      X014R010
                                                J3                       X014R020
SAVE AND SET H5+.                               J166                     X014R020
     IF H5+, HALT.                             70      J7                X014R030
     IF H5-, CONTINUE.                         30H5    0                 X014R040
                                       1                                     R
                                         X15   10L4    J150              X015R000
                                       1                                     R
X19  MONITOR POINT FORCER.               X19   03J0    0                 X019R000
SAVE FOR RESTART                       5        X9
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COMMENTS	TYPE		NAME	SIGN	PQ	SYMB		LINK		COMMENTS	I.D.
06–40	41	42	43–47	48	49–50	51–55	56	57–61	62	63–72	73–80