NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

DESIGN AND IMPLEMENTATION OF A BASIC CROSS-COMPILER AND VIRTUAL MEMORY MANAGEMENT SYSTEM FOR THE TI-59 PROGRAMMABLE CALCULATOR

by

Mark R. Kindl
and
James H. W. Inskeep, Jr.

June, 1983

Thesis Advisor: Bruce MacLennan

Approved for public release; distribution unlimited

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO. AD-A132 172

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Design and Implementation of a BASIC Cross-Compiler and Virtual Memory Management System for the TI-59 Programmable Calculator

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis
June, 1983

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Mark R. Kindl
James H. W. Inskeep, Jr.

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California

12. REPORT DATE
June, 1983

13. NUMBER OF PAGES
303

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
BAX59, BASIC, Cross-Compiler, linker, TI-59, Segment, Calculator, Compiler, Pascal, Translator

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The instruction set of the TI-59 Programmable Calculator bears a close similarity to that of an assembler. Though most of the calculator instructions perform primitive data movement and/or sequence control, some can do the work of small high level language procedures. Regardless of this fact, to design and debug TI-59 programs of moderate size can be more difficult than doing the computations themselves. Programming in a higher order (Continued)

ABSTRACT (Continued) Block # 20

language such as BASIC offers many advantages over calculator code. This report presents the design and implementation of a cross-compiler which translates correct BASIC programs into equivalent TI-59 programs. This software package includes a linker which maps calculator instructions to a set of magnetic cards. The cards are then used to implement a manually operated virtual memory system for the calculator. This expands program step capacity, and permits more complex programs to be written in BASIC language for translation into TI-59 instructions.

Approved for public release; distribution unlimited.

Design and Implementation of a BASIC Cross-Compiler and Virtual Memory Management System for the TI-59 Programmable Calculator

by

Mark R. Kindl
Captain, United States Army
B.S., United States Military Academy, 1974

and

James H.W. Inskeep, Jr
Captain, United States Army
B.S., United States Military Academy, 1974

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
June 1983

Authors: ______________________________

____

Approved by: ______________________________
Thesis Advisor

____
Second Reader

____
Chairman, Department of Computer Science

____
Dean of Information and Policy Sciences

ABSTRACT

The instruction set of the TI-59 Programmable Calculator bears a close similarity to that of an assembler. Though most of the calculator instructions perform primitive data movement and/or sequence control, some can do the work of small high level language procedures. Regardless of this fact, to design and debug TI-59 programs of moderate size can be more difficult than doing the computations themselves. Programming in a higher order language such as BASIC offers many advantages over calculator code. This report presents the design and implementation of a cross-compiler which translates correct BASIC programs into equivalent TI-59 programs. This software package includes a linker which maps calculator instructions to a set of magnetic cards. The cards are then used to implement a manually operated virtual memory system for the calculator. This expands program step capacity, and permits more complex programs to be written in BASIC language for translation into TI-59 instructions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Hand-held programmable calculators provide an extremely portable means of computation. Designed primarily for small-scale numerical computation, these devices are limited by their small memory capacity, slow processing speed, and inability to perform symbol manipulation. These constraints, however, cannot hide the programmable calculator's usefulness and power as a computational tool. The instruction sets of these machines resemble those of assemblers. Most instruction words are primitive and perform simple data movements or sequence control. Yet, some specialized instructions do the work of small high order language procedures. Typical examples include polar to rectangular coordinate conversion, trigonometric functions, and logarithmic functions. In most assembly languages these operations must be constructed from primitive instructions. Even with these added features, the designing and debugging of calculator programs for non-trivial problems often requires an expenditure of effort which conceals the usefulness of the final product as well as the calculator.

There are a number of reasons for this difficulty. The lack of a sophisticated display mechanism such as a CRT prevents the user from viewing more than a single data item or instruction at any given time. Printing devices can lend assistance, yet most provide little more than a means of dumping memory contents. Furthermore, program debugging can be very difficult if the only error diagnostic is a single flashing display or an incorrect result.

Maximum memory storage capacity constrains even mainframe computers. One solution has been the implementation of virtual memory, whereby a relatively limitless on-call secondary store is used to back up the primary storage. Programmable calculators usually have secondary storage in the form of magnetic cards. Normally, these cards are used as archival rather than on-call storage. The instruction sets of calculators are generally a cross between assembler instructions and a math function library. Compared to an assembler, the calculator instruction set is small and includes only the most basic sequence controls. Though it is possible to build more sophisticated control constructs from the primitives, such endeavors are often constrained by storage capacity. As a result, if complex programs are to fit into memory, it becomes necessary to learn or invent machine dependent "tricks."

The programmer's inability to use meaningful names for variables can create more difficulties during calculator programming. Numerical register indices (a form of absolute addressing) must be used to reference variables. One of the major advantages of assemblers is that they provide for variable naming. While composing his code, the calculator programmer must either remember the register indices of his variables or continuously refer to his own written symbol table while composing code. Both methods become more error prone as the number of variables in use grows. Programs of any substantial computing power usually require large numbers of variables.

The problems associated with calculator programming are many of the same problems which plagued experienced programmers of large scale computers in the past. How can a beginner be expected to design good, sophisticated programs for a pocket calculator if it can be so difficult for someone with experience? One concludes that the majority of users write small, relatively straight forward programs and never fully utilize the power of such calculators.

The Texas Instruments TI-59 Programmable Calculator is one of the more popular models. Its value as a powerful engineering tool is indicated by its use at the U.S. Naval Postgraduate School and in the U.S. Army Field Artillery. Yet, sophisticated programming of the TI-59 suffers from the very weaknesses mentioned earlier. Why, then, should there be such interest in this device? Perhaps, the best answer to this question is provided by Hamming [Ref. 1]. He feels that such a primitive programming machine offers the user valuable experience because it is easy to operate and allows the beginner direct access to very basic computing hardware. But, he warns that attempting mastery of the TI-59 language is a waste of time. One who must do sophisticated or extensive programming for this calculator should, instead, use a cross-compiler to automate and reduce his effort. This report presents the design and implementation of one such cross-compiler for the TI-59.

II. SOFTWARE REQUIREMENTS

A systematic approach to software development begins with the defining of general requirements. In this case, the basic design goal is the production of an effective software tool which will simplify program development and increase memory capacity for the TI-59 Programmable Calculator. Achievement of this goal should result in several enhancements to the utility and capability of the calculator. There will be an increase in its ability to execute larger and more sophisticated software. Most computations which can be programmed in BASIC and some existing BASIC software (which may require minor modifications to be explained later) will become as portable as the TI-59.

Important requirements for a user-oriented language translation system should include that it be easy to use and easy to learn. The BASIC programming language is an obvious choice for the source language; it is popular, simple, and easily learned. More importantly, many BASIC constructs and key words are similar to those of TI-59. This similarity and the fact that both languages are line-oriented and sequential in nature greatly facilitates translation between them.

Many versions of the BASIC language currently exist. Because of its availability at the Naval Postgraduate School and its having many structured control flow constructs, Waterloo BASIC Version 2.0 (WBASIC) [Ref. 2], was chosen as the specific source language to be implemented by this compiler. The power of the TI-59 compared to the WBASIC language places restrictions upon the set of WBASIC commands which can be translated. The specific WBASIC subset implemented is deferred to the discussion of design issues in the next chapter. While WBASIC is easy to learn, it should be apparent that subsetting the language will introduce exceptions and restrictions which will tend to complicate learning for the novice and confuse the veteran. It is desirable to maintain as few exceptions as possible, and to require that restrictions be clean and obvious. A construct should be implemented as completely as possible (within obvious limitations, such as the file handling or alphanumeric features) or not at all.

Provision for error detection and debugging is another important requirement of a language system. The intended use of this initial system will be as a supplement to an existing WBASIC interpreter or compiler. As such, the cross-compiler will assume error-free source program input. The only requirement for error detection will be for the compiler to recognize words/constructs which are not implemented, but which are ordinarily legal WBASIC commands. Debugging of TI-59 programs is so much more difficult than debugging of higher level language programs that it is reasonable to assume that a user would prefer to debug his WBASIC program using the WBASIC interpreter/compiler available. Once the program is logically correct, it may be cross-compiled to TI-59 code, at which time it will be checked for subset and calculator capacity errors.

The TI-59's designers have provided it with capabilities which can be roughly equated to the power of higher level language routines. Interchangeable Solid State Software (trademark of Texas Instruments, Inc.) modules allow on-line access to utility program libraries. Program steps required to call them and the exclusive reservation of particular registers are usually the only storage costs paid for use of these library programs. It is required that the power of these modules be harnessed by the translator under design. Additionally, other sophisticated features of the calculator should be exploited whenever possible in order to maximize and enhance advantages gained by high level language programming.

The linker will statically link the steps of TI-59 programs so that it will not be necessary for a complete program to reside in calculator step storage during execution. Since the swapping in and out of memory modules in the form of magnetic cards can become quite complicated for a running process, it will be necessary to keep this manual system as transparent to the user as can be reasonably expected. The fact that the calculator has a single item display window and associated register will certainly restrict the degree of transparency which might otherwise be possible.

A system must perform static linking if it exceeds program storage available to it during execution. This program will be segmented into overlays according to the size of memory available to it and the portions of code it needs to execute at any given time. That a program be segmented so as to minimize overlay swapping, must be an additional explicit requirement of a linker whose overlay swapping will be supervised manually. It is assumed that we cannot significantly affect the execution speed of the calculator. Thus, the intent of the minimization requirement should be obvious--suppress program segmentation which will tend to involve human thrashing.

The system source code must be portable. In the simplest case, it is desired that the unmodified source code be capable of utilization on any machine which possesses the resources to store, compile, and execute it. Because of operating system variations in such conventions as file naming and handling, transfer and processing of the source code in unmodified form on another machine (with operating system different from that on which it is developed) will be very unlikely. However, the need for changes should be kept to a minimum and should be localized.

Finally, as with most all major software projects, maintanence and readability are considered paramount. Even after its completion, the system will certainly contain undiscovered bugs, areas to improve, and room for additions. Furthermore, development of a large prototype software system requires a great deal of careful planning for addition and modification. Adherence to the programming principles which support both readability and maintenance is absolutely necessary. Additionally, detailed documentation of the source code will supplement and assist in achieving these goals.

III. PRELIMINARY DESIGN

After requirements definition the next step in the software engineering process is the formulation of a preliminary design. Sound software design principles are applied to previously stated requirements to construct the framework for a software solution. It is during this phase of design that many of the most critical decisions are made. These decisions may be based upon a variety of considerations, each of which directly impacts the software organization. These decisions and the resulting organization are explored in this chapter.

A. PRELIMINARY DESIGN DECISIONS

Before a design can be formalized the engineer must investigate all design options and tools available. The following section summarizes the major decisions which strongly influenced and constrained many aspects of the project. With most large software projects, time is an extremely critical resource. As such, its impact upon preliminary design considerations is usually quite strong. Keeping on schedule is generally cost effective. It will be readily apparent that time played a key role in this design also.

1. Cross-Compiler

The fundamental considerations which most influenced design of the BAX59 (BAsic X-compiler for the TI-59) cross-compiler were the method of parsing it would use, and the language(s) in which it would be written. The availability of several versions of Pascal at the Naval Postgraduate

School and the working experience of the authors of this report with Pascal were, perhaps, the overriding reasons for its early selection as the design language. In addition, the extensibility, strong typing, and block structure of Pascal support modularity, readability, and maintainability. It was at this point that the parsing technique became an issue. The decisions were reduced to a selection between two alternate approaches. Berkeley Pascal was available on a Digital Equipment Corporation VAX-11/780 with Bell Laboratories' Unix operating system. The Unix system included software tools LEX and YACC which are capable of automatically generating a lexical scanner and LALR(1) parser from an input grammar. YACC allows the user to specify code generating actions which will be executed as the productions of the grammar are processed. The alternative system was entirely International Business Machines Corporation. IBM Pascal VS was available on an IBM-3033AP with VM/370 operating system. This system does not have the tools for automatic generation of a compiler front end. Instead, a scanner, recursive descent parser, and code generator would have to be developed from scratch.

While the prospect of automating the development of BAX59 seemed more time efficient and less trouble, it turns out that subtle problems involved are many. A compiler constructed using LEX and YACC is generated in the C language, a kind of structured assembly language. While it is possible to link object code compiled from Berkley Pascal to object code compiled from the C language, the mixing of source code tends to destroy the portability and maintainability required of the system. Modifications or improvements to the finished system could only be made if the programmer were familiar with Pascal, C, and their interface. Likewise, a machine would be required to have both C and Pascal compilers in order to process the source code for use. Thus, a recursive descent compiler in pure Pascal VS was the alternative selected. It quickly became apparent that a recursive descent compiler would be far easier to develop in pure Pascal. Using a block structured language which supports recursion, explicit use of parse tables and stacks is unnecessary. The activation record stack resulting from the recursive procedure calls implicitly holds the same information stored in a parsing stack. The advantage of using Pascal VS is the powerful debugging tools which this language system provides. While BAX59 was written in Pascal VS, to the greatest extent possible only those constructs and features which are standard Pascal [Ref. 3] were used.

Another major consideration involved the identification of the particular WBASIC language subset which could be translated to TI-59. Both feasibility and time constrained this selection. Commands and functions which primarily perform character string and file manipulation were quickly eliminated. The TI-59 is weak in alphanumerics and its storage capacity is too small to consider any concept of file handling.

The WBASIC language is rich with matrix and array functions and constructs. The overhead and difficulty of implementing these operations would outweigh any programming benefits they could provide. As a result, functions and constructs involving all composite data types were ruled out. With only slight overhead , it is possible to implement limited size, single-dimensional arrays. However, time restrictions required that this concept remain a suggested improvement.

In order to simplify the translation of a WBASIC source program, it was decided to allow the BAX59 scanner to recognize all WBASIC keywords as reserved words. This provided a clear distinction between real errors and occurrences of legal keywords which had passed through the WBASIC interpreter but which had not been implemented in the subset. Otherwise, legitimate WBASIC keywords, not implemented in BAX59, would be treated and translated as identifiers. This obvious inconsistency might be very difficult for the user to detect as an error. It should be noted that WBASIC function names are not handled in this way. The reason is that the user can extend the BAX59 built-in function library. Further discussion of this idea is deferred to Chapter IV.

Appendix A is a summary of the WBASIC keywords and functions which have been implemented in BAX59 version 1.0. There are three general categories of keywords recognized by this cross-compiler. Command reserved words are implemented WBASIC keywords which indicate the start of a particular WBASIC construct or statement. Supplemental reserved words are implemented WBASIC keywords which cannot be used to begin a construct or statement, but which can be used (optionally at times) within same to guide the interpreter. Unimplemented reserved words are all WBASIC keywords which have not been implemented in BAX59. The use of this last category of reserved words will result in a fatal subset error during translation.

2. Linker

In designing the linker three major problems arose. This first problem involved the fact that the linker is mainly a postprocessor of compiled data. As such, the linker is highly dependent on the compiler portion of the project. If this dependency were allowed, then most work on the linker would have to be deferred until the compiler was formalized and in the implementation phase of design. The second problem involved settling on a strategy to segment compiled code according to the software requirement to minimize magnetic card reads. Two courses of action were discovered, each of which had advantages over the other. The third problem involved how prompting procedures were to be used to ensure proper execution of the segmented program. Procedures were required to be user-friendly and easily understood.

In the first problem it was decided to make the coupling between the linker and the compiler as loose as possible thereby reducing the dependency. This was achieved by defining a specific "third party" interface between the compiler and linker. This interface was defined to be a text file containing the four coded pieces of information required by the linker to accomplish its task.

This arrangement had several advantages and disadvantages. One advantage was that it allowed for the parallel development of the linker and the compiler. Since the interface was well defined, no other information needed to pass between the linker and the cross-compiler. By using this system, interfacing considerations such a naming conventions were nil since each process was totally independent. Another advantage concerned future implementations. It was envisioned that future versions of the system would be implemented on microcomputers. By having the project divided in half both logically and physically it would be easily adaptable to the more constricting memory requirements of the microcomputer environment. These two advantages alone outweighed the only major disadvantage of the decision. The disadvantage is that the linker needed to be able to regenerate the compiled linked TI-59 code structure which was originally produced by the compiler. As it turned out, this penalty was small when compared to the overall size of the finished linker.

The second problem was a very difficult problem to solve. Due to the limited size of the calculator memory and the cumbersome nature of the magnetic card backing storage system, the software requirements dictate the minimization of magnetic card reads. This requirement mandated the following decision: a code segment-break cannot occur within a backward loop. It would be preposterous to read a magnetic card every time a program encountered a segment break within a thousand iteration backward loop. This lead to the following hierarchy of segmentation rules. First priority, segmentation may not occur within a backward loop. Second priority, maintain invoked subroutines with the invoking code. Third priority, keep adjacent sequential code together. To implement these decisions it became necessary to examine the control flow structure of an input program.

The decision as to how to accomplish this control flow examination is the foundation of linker design. Basically, two options were determined. One dealt with the input program as a whole and the other dealt with it as a series of sequential parts.

In dealing with the input program as a whole, the design algorithm would check to see if the program met the memory limitations. If it did not then the algorithm would examine the control structure and determine where to make an optimal break, that is, a break in a sequential portion of the program. It would then check each new segment to ensure that they complied with the memory restriction. The algorithm would continue until all segments met the memory requirements.

In the other method the program was decomposed into a series of sequential segments (a sequential segment is defined as a segment which does not contain a backward loop reference to any instruction other than possibly to the first instruction of the segment). The algorithm first determined the sequential segments. Next the algorithm combined adjacent segments until the memory limit was encountered. At this point a segmentation occurred. The memory limits were reset and the combining process continued until another limit was encountered or the whole sequentially segmented input program was processed.

The second method was selected for two reasons. The first reason is that the first method eventually required the evaluation of code on a small segment level much like the second to determine a suitable segmentations point. Rather than do this and more, it was decided to just evaluate the small segments and build up rather than down. The second reason was that the second method lent itself to a recursive solution during the recombination process. The recursive solution greatly reduced the length and complexity of the segmentation code.

The third problem involved deciding upon a method for accomplishing the prompting of the user. One method dealt with assigning coded prompt numbers of short length to be built into the code. The other method involved building larger self-explanatory prompts into the the code. The second choice was selected. This was done to reduce the number of instruction references that a user might have to make during the execution of the generated calculator program. This was in keeping with the requirement to make the system user-friendly.

B. PRELIMINARY DESIGN ORGANIZATION

Thus far the system design space has been narrowed to the design language, source language subset, and the general techniques for compilation and linking. Organization of the software into functional categories may now begin. This next phase of development is characterized by a more specialized, yet still preliminary consideration of system components. It should be apparent by now that a natural division into two major functional components, cross-compiler and linker, has been assumed since conception of the system. For a two-man design team, this partitioning appeared to have the greatest potential for success. It allowed the simultaneous development of two independent system components of low coupling [Ref. 4: p. 85] and high cohesion [Ref. 4: p. 106]. The result of this separation was a minimization of programmer interaction, maximization of work time efficiency, and simplification of interfacing. The remainder of this section outlines the preliminary design and organization of the cross-compiler, linker, and the direct interface between them.

1. Cross-Compiler

The common form of all versions of BASIC language can be characterized as imperative, line-oriented, and sequential. The design of BAX59 is based upon this fact. Each WBASIC line is parsed, beginning to end, by recursive descent. Equivalent TI-59 code is generated for each line concurrently with the parsing operation. This means that BAX59 will successfully translate a sequence of syntactically correct yet meaningless WBASIC statements into equivalent TI-59 code. However, the TI-59 code will be as meaningless as the source code. For this reason, it is recommended that the user successfully execute his WBASIC source program using a WBASIC interpreter (or compiler/loader) prior to translation with BAX59.

A line-oriented view of the source code provides several advantages to the design. First, there is a direct sequential correlation between the original source program and the translated TI-59 code. As will be seen later, this allows easy management of the generated code and its associated data. Second, the parse driver routine can be a fairly simple loop, since lines are parsed to end of line one at a time until the end of the source file. Third, viewing the source as a sequence of independent pieces greatly facilitates an iterative enhancement approach [Ref. 5] to the progressive development of BAX59. This approach virtually guarantees a working prototype throughout the coding phase, and supports both reliability and maintainability. Modifications can be quickly tested within the context of the entire compiler system to date. Upon completion, the programmer tends to have greater confidence in his product, because a great deal of testing has already been conducted.

BAX59 was temporally organized into three major functional sections: initialization, translation, and resolution. The primary operations performed by initialization involve setting up data structures and initializing variable values. There are three major data structures manipulated by the translation section: the reserved word table, the symbol table, and the code data structure. Conceptual subdivisions of this section, namely the scanner, the parser, and the code generator, manage each database respectively. While the scanner is a separate routine by itself, the parser and code generator are not as separately defined. These functions are actually performed concurently by a set of mutually recursive procedures under the direction of the main driver. This driver calls the correct subprogram into execution as its corresponding WBASIC construct is recognized. Once translation has been completed, the resolution section processes the generated code into a form suitable for final output. This includes label insertion, peephole optimization, and absolute address resolution.

2. Linker

The linker was organized into three phases. The design of these phases were the direct results of the preceeding design decisions made in the preliminary phase.

The first phase is the direct result of the loose coupling between the linker and compiler and the decision to combine small sequential segments to form memory-size constrained segments. It is the preprocessor phase. This phase processes the interface input file and reconstructs the compiled linked code structure. In addition the preprocessor determines the sequential segments of code and constructs an internal data table called the segment table which is used by the second phase, the segmentation phase. The segmentation phase utilizes the recursive algorithm to recombine sequential code. The postprocessor phase is the result of output design decisions. This phase inserts the prompting code and develops the segmented code lists to be output to the user. It then produces the code in a text format together with specific instructions as to its use.

3. Direct Interface

The design organization is built around the loosely coupled compiler and linker. This coupling is made possible through the rigid definition of the interface text file. The organization of this text file is critical to the design and will be described in more detail.

The text file is the only direct transmittal of data between compiler and linker. Four pieces of data are transmitted. They are the following: a number signifying the next register available for use; generated code list in a numeric formatted form; text containing DATA/READ information; and text containing the mapping of TI-59 registers to BASIC varibles. Each piece of information is preceeded by a

$XXX in the first column where XXX is a number. This simple format enables the linker to easily locate the correct information and process it accordingly. Since this is the only explicit interface, the compiler and linker are not as dependent on each other as they would have been in a closely coupled system.

IV. DETAILED DESIGN

The source code contained in Appendices C and D provides high resolution understanding of the system. However, in order to provide rationale behind design issues for a language system comprised of almost 10,000 lines of code and comment, discussions of some detail are in order.

It is not our intention to explain everything. What we wish to do in this chapter is to introduce design details and strategies of the more important concepts and components in the system. This will serve to illustrate software engineering and how it is used in this project.

Upon the completion of preliminary design, the detailed design is begun. It is during this phase that the actual details of full implementation are defined and laid out prior to coding. Categorized under cross-compiler and linker, the general format for the sub-sections of this chapter will include an informal solution strategy for a specific design problem, followed by a discussion of the major data objects and procedures which manipulate those objects. Where appropriate, inter-procedure interfacing criteria are outlined. In several cases, significant problems, their solutions, and possible system improvements are discussed. The last section presents implicit interface design which impacts greatly on the system.

A. CROSS-COMPILER

The fundamental design of BAX59 is a finite state machine driven by a main loop. Once values and data structures have been initialized, program control enters the main loop which scans, parses, and generates TI-59 code for one

WBASIC source line. At the end of line, the loop checks for end of source file. As long as the end of file is not detected, the main loop repeats its processing of each succeeding line of source code. When end of file is found, control exits the main loop and post-processing begins on the generated TI-59 code. This includes insertion of suspended code data, optimization, address resolution, and final output of code and associated data.

The entire cross-compilation process is broken down into 15 functional areas. These are outlined by the contour diagram in Figure 4.1 Note that solid lines indicate actual procedures (P/) or functions (F/), while dotted lines only indicate logical association. Although these areas often depend upon one another, the particular services performed by each differ enough to allow independent analysis. Were it not for limitations imposed by the Pascal language, many more procedures and functions would have been tightly packaged in order to hide implementation details between functional areas. What follows is a survey of the major functional areas of BAX59 and the design details for each.

1. Initialization

In the interest of execution time efficiency all run-time actions which required completion prior to the start of parsing are incorporated into procedure INITIALIZE. As a result, some variables and databases which would otherwise have been local to their respective procedures, required globalization. One particular example is the reserved word table. This data structure is built of data supplied from outside the program in file RWTBLF. Since the reserved words contained in this file need only be loaded once (at the start of execution), there was no good reason to place them into procedure SCAN, which is called often by parse routines. While it would have been possible to use a

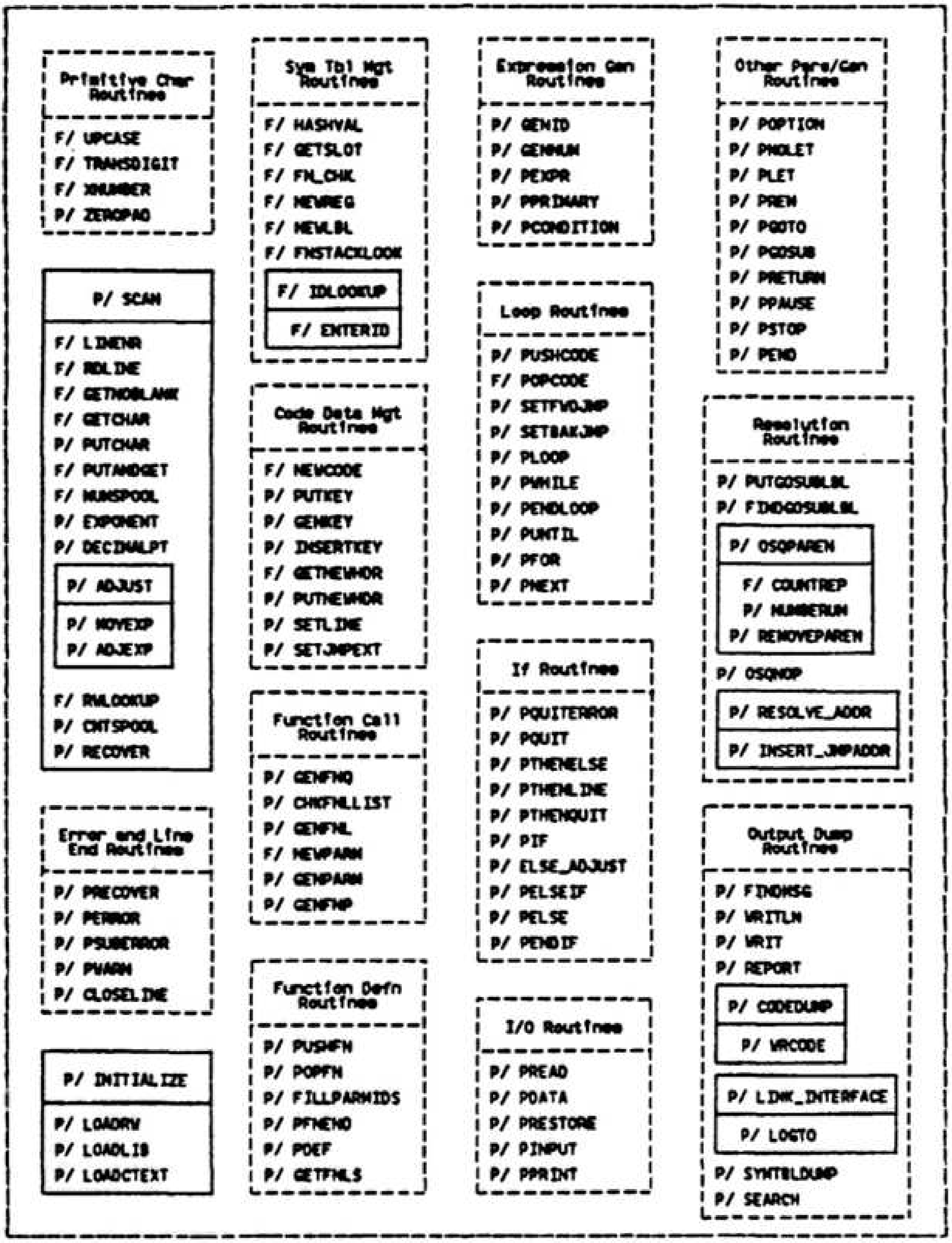

Figure 4.1 Cross-Compiler Contour (PROGRAM BAX59).

boolean switch to detect the initial call to SCAN and subsequently generate the reserved word table at this first call, this would have increased the coupling between modules. Loading the reserved word table from outside the program offers several advantages. First, changes to the reserved word table can be made easily (this process will be discussed when the scanner is considered). Second, the user can check one file (RWTBLF) in order to see the reserved words recognized by EAX59. Third, the loading routine does not need to know the words themselves, only the name and format of the file in which they reside.

Built-in functions are also loaded by procedure INITIALIZE. This operation actually requires two ordered steps. First, the symbol table must be created. Second, function recognition and generation data is read from outside files (BIFNCF and BIFNLF) and the symbol table management routines are used to put this data in the table. Loading the built-in functions by using the same routines which the parser will use to manage the symbol table, ensures table consistency and promotes readability. This approach has been taken as often as possible in designing the cross-compiler.

The complexity of the above initialization processes as well as the the TI-59 keycode text (CTEXTF) loading process required that these operations be abstracted into individual subprograms. However, procedure INITIALIZE performs many other pre-compilation activities which could be performed sequentially. Probably the most important of these activities is the simple initialization of variable values. The importance of this task is elevated by a serious hole in the Pascal VS implementation. The Pascal VS compiler will not detect the failure to initialize a variable value prior to its use. What is worse, random values which exist in pointer references or other variable storage areas will be used as is, whether they were put there by the user or not. As a result, failure to initialize values was a major source of error during development of BAX59. These types of errors tended to be extremely difficult to debug, since they often surfaced late and usually in modules long thought to be robust.

In summary, procedure INITIALIZE loads all information which will be needed by the translation and resolution stages, constructs conveniences data such as character sets, assigns starting values to all variables and pointers.

2. Scanner

At the lowest level of abstraction within the translation component of BAX59 is the scanner, procedure SCAN. This single, self-contained subprogram is basically designed on three important concepts. First, the scanner is itself a finite state machine. Second, with the exception of procedure INITIALIZE and some system constants, its implementation is transparent to the rest of the cross-compiler. Third, the database which it uses for token recognition is simple, time efficient, and general.

The state machine logic of procedure SCAN provides knowledge of token streams in free format and nothing more. Its primary job is to read the source file character by character in order to isolate and recognize single tokens. However, procedure SCAN is designed to do much more. First, it reads and converts line numbers. It also fills as necessary the line buffer and accumulator, the data structures which store the line and token currently being scanned respectively. The scanner also detects the end of a source file which has no explicit WBASIC "END" statement. This allows a more graceful conclusion to what might otherwise be an abrupt exit.

Two other functions performed by the scanner will illustrate its transparency to the rest of the cross-compiler. These are recognition of the end of a line and of continuation lines. Procedure SCAN reads and loads the line buffer (LINBUF) with a new line of source text each time the end of line character ("@") or continuation line character ("&") is found. The only difference is that the end of line token number must be passed up to the parsing routines so that the main loop will know when it has parsed one entire line. On the other hand, the continuation character can remain invisible to the parser, which views only whole source lines.

As mentioned before, the database used by procedure SCAN is the reserved word table. Although referred to as a table, the internal representation of this database is actually three coordinated arrays constructed from the RWTBLF file by procedure INITIALIZE. These arrays are used to compare the characters of a token in the accumulator to the characters of reserved words. The simplicity and efficiency of this comparison is illustrated in Figure 4.2, which depicts a condensed schematic of the arrays. Note that the characters in the RWCHAR array are arranged in order of increasing word length. A reserved word look up is based upon the length of the word in the accumulator. Comparison begins at the first character of the first word in the RWCHAR array which matches the length of the token in the accumulator. Comparison ends when either all characters in the accumulator match a string in the RWCHAR array, or when the characters of all words of a given length have been compared to the accumulator without success.

The RWWORD array references the start index of each word in the RWCHAR array, while the RWLENG array references the start index for the first word in the RWWORD array for that length index. The indexes of the RWWORD array are used

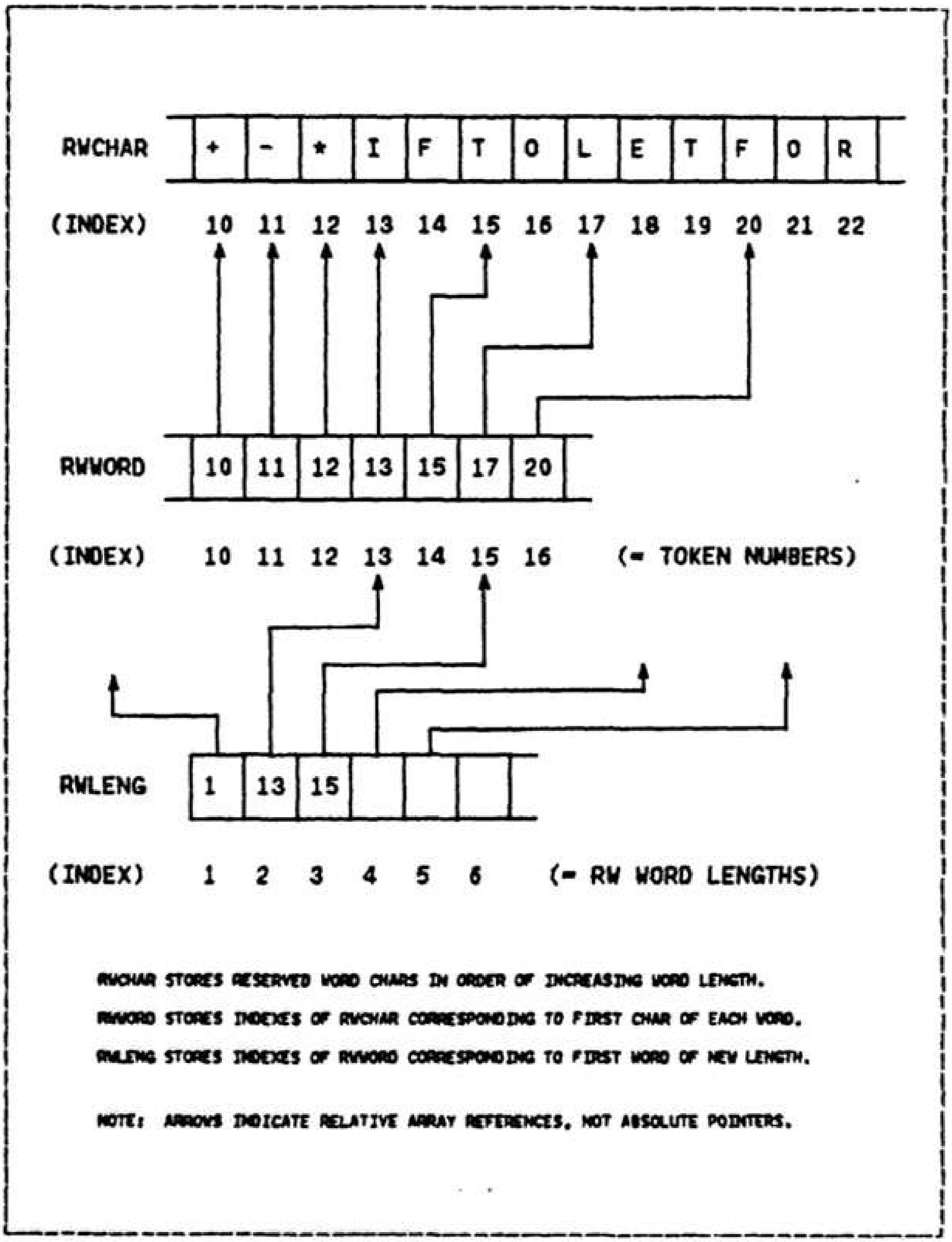

Figure 4.2 Reserved Word Table Arrays.

as the token numbers returned by the scanner after a successful look up. Should a look up operation fail to recognize the accumulator token, then the token is assumed to be a variable identifier. Other token types, such as numerics, are recognized prior to table look up. This mechanism and the fact that the scanner is independent from the parser require that WBASIC keywords be reserved. If keywords were overloaded as variable identifiers, the parser would have to communicate its token type expectation to the scanner. Token overloading would greatly hamper readability.

One scanner related problem which required a relatively complex solution concerned the conversion of WBASIC to TI-59 numeric values. The calculator display window restricts the number of significant figures which can be entered from the keyboard. For numbers without exponents, a maximum of ten digits (with decimal point) can be entered. Numbers with exponents are allowed a maximum of eight digits in the mantissa and two in the exponent. Because of this restriction, a rather complicated procedure was designed to convert WBASIC numeric values to TI-59 compatible values without losing equivalence. Procedure ADJUST performs decimal point shifting and exponent modification on WBASIC numerics which contain too many significant figures for the TI-59. The operation can, of course, reduce significance by truncation of excess digits. Except for this loss of digits, equivalence is maintained.

3. Error Handling

At this point it is appropriate to discuss error recognition and recovery. As implied earlier, the error detection capability in BAX59 is relatively weak and incomplete as compared to full language compilers. The reason is that the system requirements specified error-free input source files. The primary use for this system is as a supplement to an existing BASIC language interpreter or compiler. Debugging of TI-59 programs is a hard enough task without adding the complexity imposed by absence of BASIC language run-time diagnostics. Therefore, users of BAX59 are strongly advised to ensure that a WBASIC program is correct syntactically, semantically, and logically by running it in the WBASIC environment, before translation to TI-59 code. Error handling in BAX59 is restricted to detection of subset related exceptions, calculator capacity limits, and errors of opportunity.

The cross-compiler is designed for recognition of two major types of errors: fatal errors and warning messages. Fatal errors are further categorized as scanner or parser detected.

Warning messages are generally unrelated to WBASIC syntactic or semantic problems. They refer to potential difficulties with the TI-59 run-time environment, most commonly (but not always) calculator capacity. Such conditions as too many registers in use, too many labels in use, or excessively nested subroutine calls, will trigger warnings. Each message is explicit and cautions the user of a situation which is considered abnormal to the calculator. Since these errors are unrelated to the WBASIC source code, warning messages do not halt the parsing or code generation processes. However, TI-59 code generated from a WBASIC source file that produced warnings is not guaranteed to execute properly, if at all.

The warning message is similar to non-fatal errors in full language compilers. The reason for continuation of code generation is slightly different. A user of BAX59 will most likely need to modify and tailor his WBASIC program to fit calculator constraints and capacities. Warnings are a non-fatal means of providing near equivalent code data for use in comparison of efficiencies, capacities, or consistency. Even though the code may not successfully execute on the calculator, it still represents a direct translation from WBASIC and is a fairly accurate indication of program size, register/label use, etc.

Unlike a warning, one fatal error will flag the main loop against further parsing and code generation. However, scanning for tokens continues until the end of the source file is reached. Thus, only a single fatal syntax error can ever be detected in one BAX59 execution, although the scanner will continue to detect any number of lexical errors. Fatal errors are also categorized as subset or non-subset related. Non-subset errors are those previously referred to as errors of opportunity. During the coding phase of development, simple syntax checks were often inserted into the logic of the parsing routines. These were usually one-line IF-THEN-ELSE constructs which cost very little but were highly protective. For example, the main loop calls procedure PGOTO whenever the GOTO command is recognized. Since error-free input is required, this procedure could have been written to assume that the next token must be a numeric line reference. Instead, it was a simple matter to check the next token's type and call a syntax error (PERROR) if it were not numeric. Note, however, that the logic of PGOTO will not call an error for a numeric token which contains a fractional part, clearly a syntax error. In fact, the cross-compiler is not likely to detect an error at all. Execution may result in a Pascal VS run-time error. The reason is that the numeric string will be converted to an integer value based on ordinal values of the characters. The decimal point will appear to BAX59 as any other character. However, its ordinal value will be added during conversion resulting in an inconsistent integer value for the line reference. The routine used to set jump pointers will probably not be able to find the line number since it is already in error.

Although often incomplete, these error traps provided much assistance in tracking system bugs. The technique used was to translate simple source programs known to be correct. Errors, tripped at these check points by system bugs, usually indicated the likely trouble spots. The faulty routine had helped in parsing either the statement which caused the error or the statement which immediately preceded it. Since the token which tripped the error was also known, the exact routine and the specific bug were easily found.

Subset related errors were defined in the software requirements. The user must be told where and how he has misused the system. BAX59 incorporates all WBASIC keywords (Version 2.0) in its reserved word table. The main loop logic contains the information to distinguish between implemented keywords and unimplemented keywords. This technique allows the reserved word table and implemented subset to be easily expanded (or contracted). Such a technique strongly supports the requirement for maintainable source code.

There is more room for improvement in the area of error detection and handling than in any other aspect of the cross-compiler. The capability could certainly be extended to protect against all possible syntactic and semantic errors so that prior compilation or interpretation would be unnecessary. However, the benefits to be gained are questionable, since run-time and logical debugging of TI-59 programs is no easy task. A special file to hold error message text might help to reduce some of the awkwardness in portions of the code which issue these messages. Within this file the messages could be indexed by number, thereby allowing more verbose and possibly clearer explanations of errors. Generally speaking, the critical resource of time forced the design of error handling to be barely adequate.

4. Symbol Table Management

One of the more important duties of the parser is to manage the symbol table. The BAX59 symbol table is a variable bucket hash table similar to one described by Aho and Ullman [Ref. 6]. The data structure used is an array of pointers. The indices to this array of base pointers are hash values computed by taking the modulo 99 sum of the ordinal values of identifier characters. This operation is performed by procedure HASHVAL. Figure 4.3 depicts the structure of the table itself and its four types of identifier entries. Three of the four types of identifiers are functions. These will be discussed later in this chapter. The important structural feature to notice now is that each node has a SLOTP field regardless of variant tag. The SLOTP field is each entry's link in the variable length chain which forms a bucket. In order to insure that no uninitialized pointer references or variables occur, new nodes are created as needed by the separate function GETSLOT. The job of this function is to create the node and to insure that all of its fields have been initialized to default values. This same approach to data structure construction is used throughout BAX59 in order to protect against random initialization by the Pascal VS compiler.

The look up operation of procedure IDLOOKUP is simply to hash the characters of the identifier token in the accumulator to the correct base pointer bucket in the symbol table. The IDENT field of each slot node is compared to the accumulator token until either a match or a nil pointer is found. If a match is found, a pointer to that slot is returned. If no match is found, then a slot for the accumulator identifier token is automatically added to the symbol table in the bucket just searched. A pointer to this new slot is then returned. This is in accordance with the

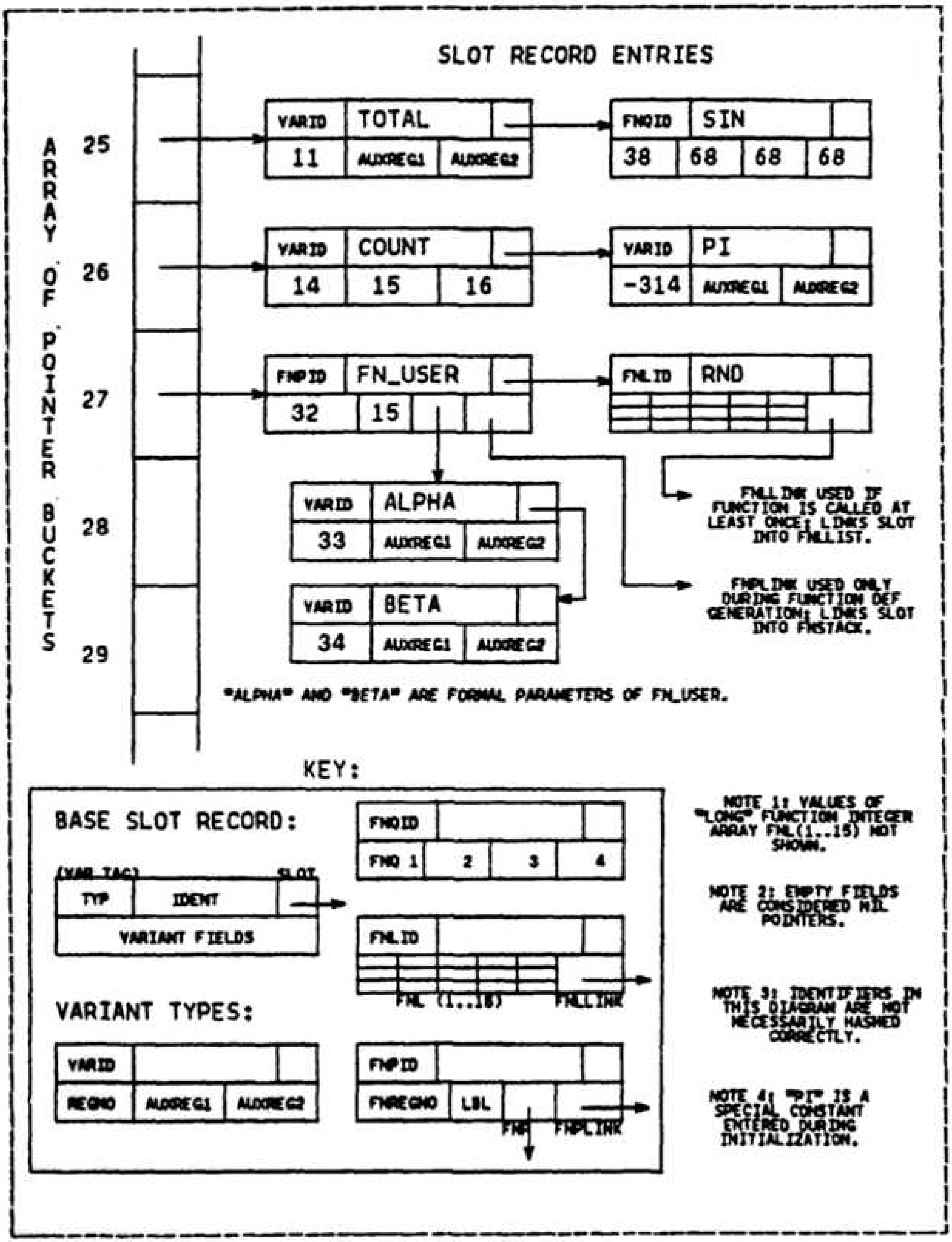

Figure 4.3 Symbol Table.

semantic rules of the BASIC language which allows implicit declaration of variable names by using them in statements.

The insertion of new identifiers into the symbol table is performed by procedure ENTERID. This procedure creates the new slot, fills all fields which are known, and links the slot into the symbol table. It is also during this process that identifiers are assigned TI-59 registers for code generation purposes. Function NEWREG handles the register pool, which is actually nothing more than an implicit stack of integers. An important feature regarding the assignment of registers to variable names is that the user has some control over these assignments from outside the program. Included in the LABELF file is a place to list register numbers which the user wants to reserve for his own use. Function NEWREG will not assign these numbers to WBASIC variable names. The significance and power of this control feature becomes more apparent during the discussion of functions. The user is cautioned against reserving the last assignable register number (system parameter in constant declaration block: REGBASE). Reserving this register will short circuit the logic which reports a TI-59 memory overflow warning message, the situation in which too many registers are in use.

As a final note, there are two forms of output which are closely associated with the symbol table. One is the WBASIC variable name to TI-59 register mapping which correlates variables to register assignments. The other is an optionally available symbol table image, which lists each table entry in bucket order with type and register assignment. Both outputs are discussed in the last section of this chapter.

5. Expressions

The most fundamental and most common construct seen by the parse routines is the arithmetic expression. The many similarities between BASIC language expressions and TI-59 expressions make them relatively easy to parse and generate. However, a few subtle differences cause abnormal situations requiring careful design. If there is one lesson to learn from this discussion, it is this: in compiler design, when in doubt revert to the grammar specification.

TABLE I

Production Rules for Expressions

```
<EXPRESSION> ::= <PRIMARY> {<BINARYOP> <PRIMARY>}

   <PRIMARY> ::= {+|-} <PRIMARY>        |
                 <UNSIGNED NUMBER>      |
                 <IDENTIFIER>           |
                 ( <EXPRESSION> )
```

Table I lists the grammatical specification for a WBASIC expression. The two production rules in Table I are abstracted by the two BAX59 parse procedures PEXPR and PPRIMARY. They are designed to parse and generate code through mutual recursion. Careful examination of the case statements within these procedures will reveal the differences between WBASIC and TI-59 expressions. While both use infix notation for binary operators, unlike WBASIC, TI-59 unary operators and function applications are postfix. This minor twist in notation adds a little complexity to the logic of the expression parsing routines. However, once designed, the code for translation of expressions became the fundamental base upon which assignment statements, conditional expressions, functions, and many other contructs could be built.

6. Unstructured Jumps

Some of the easiest constructs to understand and implement were the unstructured control statements GOTO and GOSUB. To realize their simplicity it is necessary at this point to introduce the code data structure which is constructed by the generation routines.

Illustrated by Figure 4.4, the code data structure is, perhaps, the most unique design concept of this cross-compiler. There are two types of nodes: WBASIC line number nodes and TI-59 keycode nodes. Since unstructured constructs in WBASIC are dependent upon source line numbers, there had to be a method of associating the TI-59 code with those same line numbers. Figure 4.4 shows how line nodes and code nodes are linked to duplicate this association. It is important to note that the TI-59 code chain is completely independent (and may be traversed as such) of the WBASIC line number chain. The line nodes merely provide a frame of reference for the TI-59 code.

Procedure SETLINE, called at the beginning of the main driving loop, is responsible for insuring that new line nodes are created and inserted into proper order. As each line is parsed, special holding pointers (FIRSTLP, LASTLP, BEGINCP, ENDCP, LPLEAD, LPTRAIL, LPCUR, CPCUR) keep track of all key locations in the structure. As Figure 4.4 indicates, it is possible to have line nodes created and linked prior to their encounter in the source code. This occurs whenever a forward jump (GOTO) is parsed. Since the line reference of a forward jump has not been parsed, its line node would not exist. However, the jump pointer (JMPP) must be anchored to a node. So the line node and an anchoring

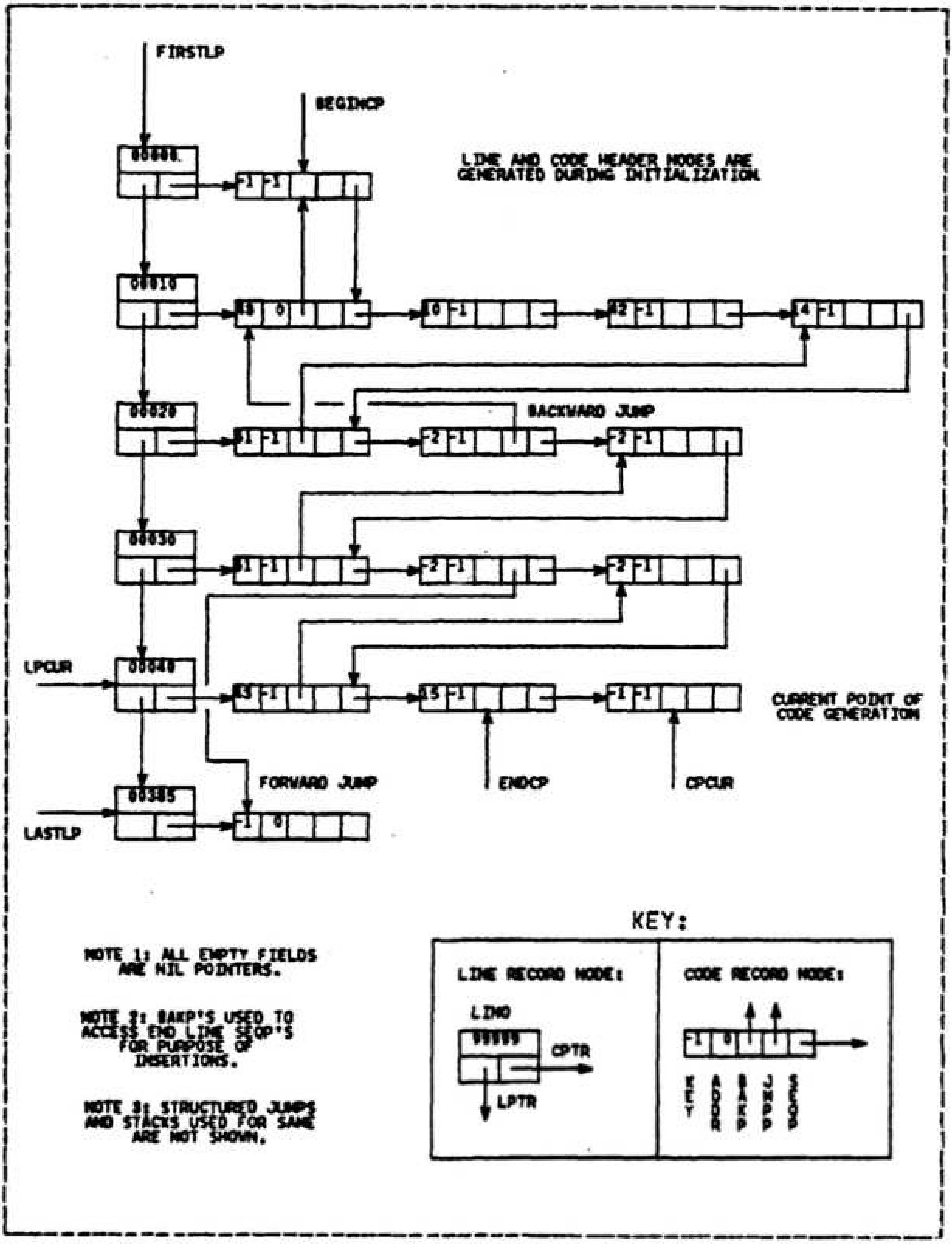

Figure 4.4 Code Data Structure.

code node are inserted in correct order ahead of the current line. Procedure SETJMPEXT sets forward as well as backward jump references. Of course, setting backward jumps is easier because the line number node has already been created and is in place. It should be noted that procedure SETLINE always checks its forward line number chain before creating a new line node. If a line node exists whose line number field (LINO) is equal to the next WBASIC line number, then it will be used instead.

The technique for handling GOSUB statements is similar to but slightly more involved than the GOTO. Since the GOSUB is actually an unstructured subroutine call, it was necessary to maintain consistency in code generation so that the linker could recognize the difference between subroutines and unconditional jumps. All TI-59 subroutines are prefaced with and called by a label name. Therefore, while initially the GOSUB can be treated as a GOTO, at some time later a label must be inserted at the head of the subroutine body, which is the node referenced by the jump pointer. This is done during the resolution phase of compilation by procedure FINDGOSUBLBL. This fairly tricky insertion is one reason for the existence of the back pointer field (BAKP) in code nodes. This operation will be explored in the sub-section on resolution.

7. Looping and Branching

Users of BAX59 are strongly urged to practice structured programming when writing WBASIC code. Translation to and execution on the TI-59 are far more regular and predictable when the input source code is structured and readable. Much of the design of the entire system is based upon the assumption that the source program will be structured. You will understand why more thoroughly in the section describing linker design.

We begin discussion of structured looping and branching by introducing procedure PCONDITION. This procedure is fundamental to the parsing and code generation for simple boolean expressions (compound boolean expressions have not been implemented). While WBASIC has a fairly common set of boolean operators, the TI-59 does not. There was a need to construct efficient sequences of TI-59 code which are equivalent to the WBASIC boolean operators. These equivalances, shown in Table II, are implemented in

TABLE II

TI-59 Keycode Sequences Equivalent to Boolean Operators

A = B	A <> B	A >= B	A <= B	A > B	A < B
RCL A	RCL A	RCL A	RCL A	RCL A	RCL A
X->T	X->T	X->T	X->T	X->T	X->T
RCL B	RCL B	RCL B	RCL B	RCL B	RCL B
INV	X=T	X->T	INV	X>=T	X->T
X=T		INV	X>=T		X>=T
		X>=T			

procedure PCONDITION. While it would have been possible to implement compound boolean expressions (AND and OR), the lack of time and the fact that their logic could be duplicated using IF statements prevented this enhancement. It was, however, a very simple extension of logic to recognize and translate a negation (NOT).

In the implementation of a block structured language which allows nesting, the use of stacks is an important technique. And so it was with looping in BAX59. By nature loops involve backward jumps. As with unstructured jumps, there existed a need to anchor pointers on code nodes whose source code had yet to be translated. In the case of loops, the inverse of this concept is also true. There was a need to create pointers from code nodes whose source code had yet to be translated. Since structured nesting of loops is checked by the WBASIC interpreter, it was possible to pre-create these nodes and push them onto a stack until their place of insertion is encountered. This is exactly how loops are translated using LOOPSTACK and ENDLOOPSTACK. When the LOOP statement is encountered, a NOP keycode node is created and pushed onto the ENDLOOPSTACK. In the case of the WHILE statement, a boolean expression is processed, a forward reference node is created, a jump pointer is set to the node (for the false branch to end of loop), and this node is pushed onto the LOOPSTACK. When the ENDLOOP or UNTIL is found, the stacks are popped and the NOP nodes are inserted. The nature of correct nesting guarantees that NOP code nodes popped from the stack will have jump pointers referencing or will be referenced by the appropriate code nodes.

Iterative loops are written by using the FOR-NEXT construct. The stack implementation is similar to that described above. The main difference is in the additional calculator resources required for such a loop. Unlike ordinary variable names, the FOR loop variable requires from two to three register assignments. The fields AUXREG1 and AUXREG2 in the VARID tagged slot record are used for this purpose. AUXREG1 holds the TI-59 register number which will store the upper (lower) limit of the FOR index variable. The FOR index variable increment will always default to +1 unless the STEP option is used. If STEP is used, then AUXREG2 will hold the register number which stores the increment value. The user should understand that use of a FOR loop carries a fairly heavy overhead in terms of both register and program step use. A single simple FOR statement in WBASIC translates to use of two registers and over 20 program steps. Most of this overhead is caused by the run-time checking of the FOR index variable value against its limit for each iteration through the loop.

Branching is another construct implemented with stacks. There are actually two forms of branching: the unstructured or line-oriented IF statement and the block structured IF statement. The unstructured IF is actually only partially implemented. WBASIC allows either a jump to a line number or execution of any single statement within each of the IF branches. Because the structured IF can be written to perform the same way, it was decided to restrict the unstructured IF to allow line jumps or the QUIT statement. The implementation of line-oriented jumps has already been discussed. An IF-THEN-QUIT or IF-THEN-ELSE-QUIT is handled by setting a jump pointer to the ENDLOOPSTACK. The effect is to force program control to exit the current loop. If control is not within a loop (i.e. ENDLOOPSTACK is nil), then an error condition is raised. FOR loops are not considered loops in this context.

The more powerful of the two IF statements is the block structured IF-ELSEIF-ELSE-ENDIF. This form disallows the use of keyword THEN, since it is implied. Once again, stacks are used to implement the structured IF. The logic and its correspondence to the manipulation of stacks is roughly similar to that of looping. Instead of directing jump pointers to the end of loops, they are directed to the next ELSEIF or ELSE. An unusual situation occurs, however, in the case of the IF statement. Stack manipulation for the IF-ENDIF is slightly different from that for the IF-ELSE-ENDIF or the IF-ELSEIF-ELSE-ENDIF. To understand the problem, assume the viewpoint of a parser which has just evaluated the condition of a structured IF. At this point you do not know whether or not an ELSE/ELSEIF or an immediate ENDIF will follow the true branch. To which stack will the jump pointer of the false branch be set? In order to cover both possibilities, a pointer to a node pushed onto each stack is required. However, there is only one jump pointer field (JMPP) for the code node which represents the jump address to the false branch. Our solution uses the back pointer field (BAKP) to refernce a node in the IFSTACK, while the jump pointer field (JMPP) references a node in the ENDIFSTACK. Procedure ELSEADJUST performs the resetting of pointers required when an ELSE/ELSEIF is encountered. When the ENDIF is encountered, the BAKP is tested for a nil pointer. A nil BAKP at the top of the ENDIFSTACK indicates that an ELSE/ELSEIF has been seen. This is because procedure ELSEADJUST is the only routine which can clear the BAKP reference before the ENDIF is encountered.

The cause for all the foregoing complexity is the fact that IF-ENDIF has a single false branch which must be a jump past the ENDIF. The tail of the true branch merely falls through the ENDIF. On the other hand, IF-ELSEIF-ELSE-ENDIF can have several false branches, only one of which may jump to the ENDIF. The tails of the all true branches must be jumps to the ENDIF. The logic of BAX59 is designed to recognize and generate equivalent TI-59 code for any of these possibilites.

8. Functions

The most powerful feature of the BAX59 cross-compiler is the translation of functions. Both built-in and user-defined functions are handled. In order to take full advantage of the calculator's capabilities, it was necessary to design three distinctly different types of functions. The first type, referred to as "quick" functions, are the common arithmetic/trignometric functions such as LOG, SIN, COS. The second type of function harnesses the power of the

Solid State Software module. These are referred to as "long" functions. Both of these first two types are built-in functions. The third type is user-defined "parameter" functions, which are translated from WBASIC source code specifications.

The difference between "quick" and "long" functions is basically the number of TI-59 program steps generated for each. "Quick" functions generally translate to a one or two step TI-59 keycode sequence. However, they may have as many as four steps. Because they are short, "quick" functions are inserted as in-line macros. On the other hand, "long" functions may translate to as many as 15 steps. Therefore, their length requires that they be called as subroutines rather than translated in-line.

Read from the BIFNQF and BIFNLF files respectively, the code for both "quick" and "long" functions is entered into the symbol table during initialization. BIFNQF and BIFNLF may be revised by the user from outside the cross-compiler. By knowing the TI-59 key stroke sequence, a user may add his own functions to either file. As a special user note, the format for additions to these files is critical. The number of key strokes in a function sequence may not exceed the maximum limit for the type of function. If less than that limit, then the end of the sequence must be padded with NOP (68) key strokes to the maximum limit. These limits may be altered by adjusting the system parameters FNQLEN and FNLLEN in the constant declaration block of the BAX59 source code.

Most all functions that could be implemented as "quick" have been and are listed in the BIFNQF file. However, only the RND(X) (random number generator) function has been implemented as "long." To illustrate the concept of "long" function, we will walk through the design of RND(X).

Suppose you desire to write a TI-59 program which uses a random number generator. You might write your own pseudo-random number generator subroutine, but the TI-59 has such a routine built into its read-only Solid State Software module. Use of this built-in facility would clearly be more space efficient. WBASIC also has such a function, RND(X). If it had not, it would be possible to write one in WBASIC using the DEF FN_RND(X) statement. Before translation it would be necessary to remove the function definition block and replace the FN_RND(X) calls with RND(X). However, this is not required in our example. You must ensure that the TI-59 registers used by the Solid State Software module to run the RND(X) function are reserved in the LABELF file. This information can be found in the Master Library Manual [Ref. 7], which is the Master Solid State Software module reference guide. RND(X) uses registers 01, 02, 03, 04, 05, 06, and 09. "Long" functions always take a single parameter (even if it is a dummy). Register number 10 has been designated to store this parameter and should also appear on the reserved list. This parameter register assignment may be changed in system parameters of the BAX59 source code if desired. Each time it is encountered within the WBASIC source program, RND(X) will translate as a call to a subroutine whose single parameter is stored in register 10. The first time seen, the RND symbol table node will be linked to a special list (FNLLIST). At the conclusion of code generation, FNLLIST will be traversed and the key sequence which executes RND(X) as well as any other "long" functions on the list, will be added to the code data structure as subroutine bodies.

The real power of this facility lies in its user-controlled flexibility. The user may convert almost any program function in the Solid State Software module into a single parameter "long" function. All he must do is reserve the correct registers in the LABELF file, list the key sequence in the BIFNLF file, and, if necessary, fix the values of all but one of the function input parameters (or create a dummy). If the function does not exist in WBASIC, then he must write the DEF block for it in order to check program correctness prior to translation.

Having strayed from implementation design toward system utility, we now return to implementation discussion of so-called "parameter" functions. The name given these user-defined functions applies more to how they are implemented rather than to their nature. The parsing routines always expect parameters but do not require them. Parameterless functions are, indeed, recognized.

Although the cross-compiler will correctly translate a function definition (DEF statement or block) whether it occurs before or after its respective call, the linker requires that all subroutine/function bodies be placed after the main program.

When a new function identifier is recognized (by the "FN_" prefix), a new FNPID tagged slot is created for the symbol table. Procedure GENPARM is then called upon to parse actual parameter expressions, generate code which performs their run-time evaluation, and construct the formal parameter list. Parameters, if found, are linked in order to the FNP field of the symbol table slot for the function. While registers are assigned to these parameters, the corresponding formal parameter names cannot yet be entered since they are not known until the function DEF statement is found. Note that formals are assumed to match actual parameters by both order and quantity. There are no checks in BAX59 to insure this correctness. Only a run through the WBASIC interpreter will verify parameter correspondence.

When the function definition is found in the DEF statement, a process similar to parsing the call takes place. The formal parameter names are now inserted into the parameter list attached to the function slot in the symbol table. Before the function body is processed, the slot is pushed onto the FNSTACK. This stack simulates an activation record stack. Each identifier look up that is performed by procedure IDLOOKUP requires that the FNSTACK be examined for active functions. If a formal parameter name is found in an active function parameter list which matches the identifier being sought, then its register assignment is used for code generation. As a result, standard rules of variable visibility and scoping apply. When the end of a function body (FNEND statement) is encountered, the function slot is popped from the FNSTACK and its formal parameters are no longer visible to the run-time environment.

As a final note, the user should know that "parameter" function names receive their own register assignment. This register is the place in which the final value of the function is returned. This register is zeroed during run-time just prior to the execution of the function call. However, after execution the value in this register persists until the next call on the function. This corresponds to an identical situation in the WBASIC run-time environment.

9. Code Resolution

If the physical end of the WBASIC source program is reached, or if a WBASIC END statement is found, parsing is stopped, the bodies for any "long" functions used are generated, and the code data structure is closed out with nil pointers. At this point, the code resolution phase of compilation begins.

The first step in resolution is to locate and insert labels at the destinations of all unstructured subroutine (SBR) calls. These, of course, were generated by GOSUB statements. Since GOSUB is a line-oriented jump, then there is a pointer in the code data structure referencing the destination of that jump. Procedure FINDGOSUBLBL traverses the code data nodes searching for SBR keycodes which are followed by a node with a non-nil jump pointer (JMPP). A very complicated check is made to ensure that the SBR label has not already been inserted by an identical SBR call. If not, then the back pointer (BAKP) is used by procedure PUTGOSUBLBL to assist in the insertion of the label at the jump destination. Once the insertion has been completed, the address field (ADDR) of the JMPP target is set from zero to negative one and the jump pointer (JMPP) is set to nil. This signifies to other routines that this jump has been resolved. The process continues until the end of the code data is reached.

The next step in resolution is to perform a special brand of TI-59 "peephole" optimization. The most common forms of excess parentheses pairs are removed. Such forms as "(RCL nn)" and "(2.333E-12)" will have been generated as a result of parsing even simple assignment statements and expressions. Since the parentheses in these expressions are unnecessary and use up valuable program steps, they are removed, provided they are not referenced by a jump pointer. If referenced by a jump pointer, the node's address field (ADDR) value will be 0 instead of -1 or -2. Removal of these will cause dangling jump references.

Looping and branching generate many place holding NOP keycodes. These are also an unnecessary use of program steps. However, remember that almost all of these were generated to anchor or project jump pointers. Thus, before removal their jump pointers must be reset. Procedure OSQNOP passes over the code data twice, once to reset all jumps to and from NOP's, and the second to locate and remove the NOP's. It is important to realize that there is a distinction between a useless NOP and one which is acting as a label identifier or a jump address place holder. Because the TI-59 requires that particular keycodes be followed by labels, register numbers, or addresses it is easy to check keycode usage. This information is actually loaded during initialization into the UNIT field of the CODETEXT record. It is an integer 0..3 which indicates whether the TI-59 code node is a one, two, three, or four keystroke instruction. This information is used to pass over keycodes which are required parts of a larger instruction.

The final stage of resolution is to convert relative jump (pointer referenced) addresses into absolute (numerical) addresses. This must be the last step because previous code insertion/deletion routines constantly change absolute addresses. At this point no code insertion or deletion occurs. Procedure RESOLVE_ADDR passes over the code data twice. The first pass fills the address fields (ADDR) of all code nodes in sequential order starting at 000. Now that each exact absolute address is known, all jump pointers which are still marking address space and referencing a destination node can be resolved. A TI-59 coded address consists of two parts. During the second pass procedure INSERT_JMPADDR is called at non-nil jump pointers to read the destination address, split it into its two integer parts, and insert the parts into the address space nodes. Once all jumps have been resolved, the code data structure is ready for output and linking.

10. Input/Output

In this subsection we discuss two input/output related issues: Implementation of I/O constructs and OPTION messages to the compiler. The limited capabilities of the calculator required that file handling and string handling aspects of WBASIC be eliminated from our subset. For similar reasons the I/O constructs which could be translated from WBASIC required restrictions.

While the WBASIC I/O statements INPUT and PRINT normally provide for file management, the BAX59 implementation cannot. The cross-compiler recognizes PRINT followed by any number of simple expressions separated by commas. The TI-59 code generated will evaluate these expressions and print their values (to either the display register or the Texas Instruments PC-100 Printer Cradle). On the other hand, the INPUT statement takes any number of variable identifiers separated by commas. For each identifier in the INPUT list, the TI-59 program halts execution, displays the register assignment for that identifier, and stores the input value entered by the user in the register assigned.

Many programs require the reading of large amounts of data, often at the start of execution. In this situation the INPUT statement tends to generate an excessive amount of program step overhead. Unless the program is designed to be interactive, this overhead unnecessarily increases TI-59 program size. In order to provide a more space efficient means of data entry, a limited translation of the WBASIC DATA and READ statements was designed. In some sense, these statements provide a substitute for file handling. The DATA statements are placed at the beginning of the WBASIC source program. Each statement may be followed by numeric data items separated by commas. The total number of data items in one program is limited to the number of unreserved registers available in the calculator (based upon the system parameter REGBASE). If this limit is exceeded, a warning message will be issued. READ statements take variable identifiers and may be written with the DATA statements, however, the number of variables input to READ statements should never exceed the number of data items provided by DATA statements. This condition will also cause a warning message and further DATA/READ statements will be ignored. The parse routines make register assignments to the variables in the READ statements, and concurrently build a list which maps the data items to their respective registers and variable names. This list is one form of compiler output. Using the list the user can pre-load TI-59 registers with numeric values and be assured that they will be in correspondence with the translation of variable names. More importantly, no TI-59 program steps are used for this initial input. In fact, the data could be read from a magnetic card into a memory bank prior to execution.

As we have previously implied, there are many forms of output which can be generated by the cross-compiler. Additionally, the user will probably have to do some debugging. We have chosen to provide a primitive set of tools and options which can be toggled on or off from outside the BAX59 source program. The toggles are set or reset by using the OPTION statement in the WBASIC program. Caution! Do not confuse this statement, which is unique to the BAX59 cross-compiler, with the WBASIC OPTION statement. They are not the same. BAX59 does not recognize WBASIC OPTION parameters and WBASIC does not recognize BAX59 OPTION parameters. Table III lists the possible options available to BAX59 users. To toggle the options, simply include an OPTION statement as the first line of the program to be translated. Desired parameter settings should follow the OPTION reserved word separated by spaces. Positive parameters set the

TABLE III

BAX59 OPTION Statement Parameters

Parameter	Option	Default
±0	Generate linker interface file	false
±1	Generate code for PC-100 printer	true
±2	Optimize out unnecessary parentheses	true
±3	Optimize out unnecessary NOP's	true
±4	Translated TI-59 code to list file	true
±5	Image of symbol table to list file	false
±6	Contents of code structure to list file	false
±7	Each lexical token to terminal	false
±8	Each lexical token to list file	false

toggle true; negative parameters reset the toggle false. In the case of the zero parameter, the sign has no effect.

As a final note, an OPTION statement may not be placed in the WBASIC source program until it is ready for translation. Also, placing an OPTION statement in any line but the first may produce unpredictable results.

B. LINKER

The linker's purpose is to produce a segmented version of the compiled code and present the code in a format that is user friendly. The informal strategy used to accomplish this was discussed in the preliminary design phase of Chapter III. The detailed design that supported the solution strategy called for the linker to operate sequentially through three major phases. In Figure 4.5, the contour diagram for the linker is presented. The preprocessor phase of the linker includes actions from some of the SYSTEM UTILITY procedures and the BLD_SEGTBL procedure. The remaining two procedures, COALESCE and INSTRUCTIONS, accomplish the segmenting and postprocessing activities.

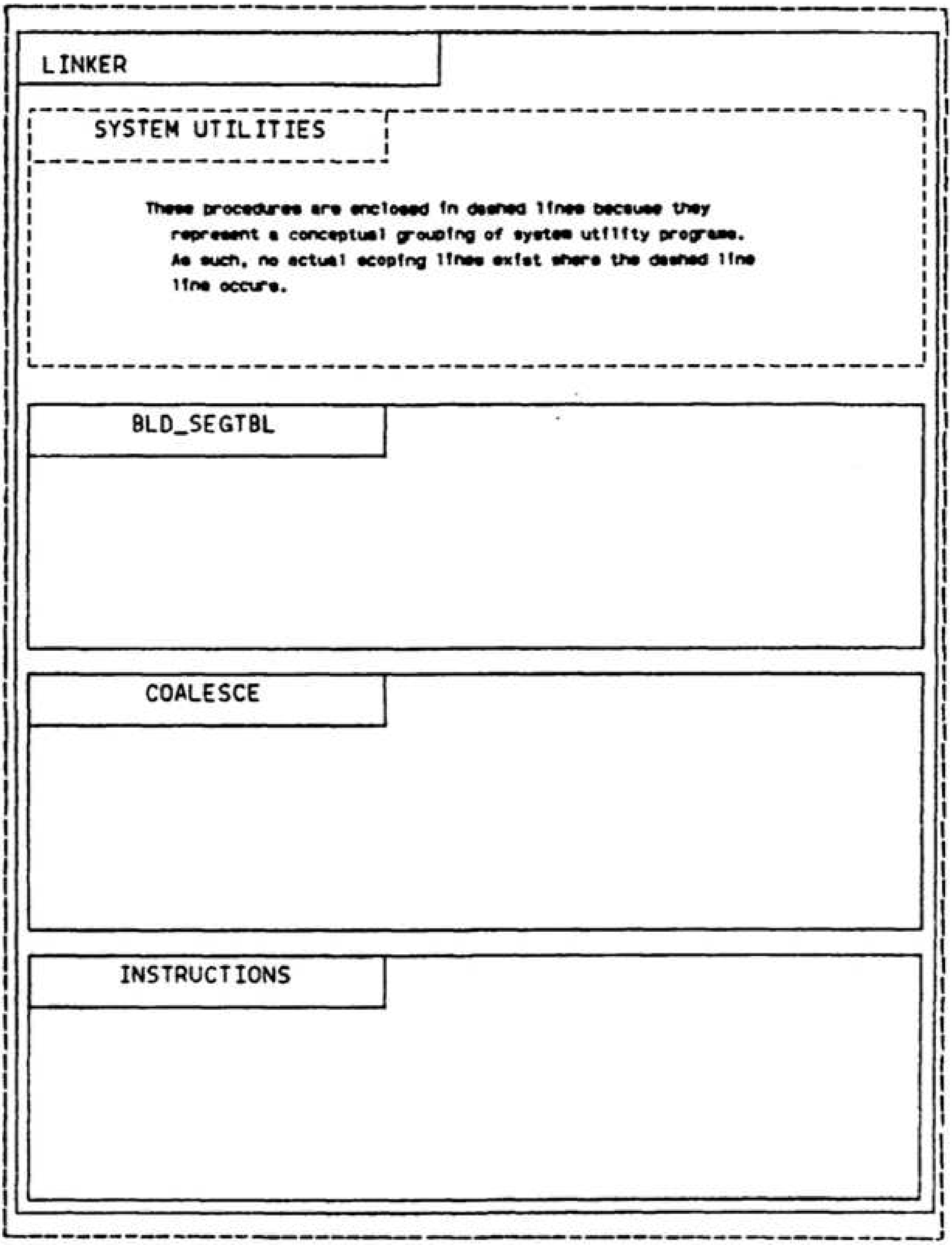

Figure 4.5 Linker Contour.

Each of these major actions were described in the preliminary design phase in Chapter III. The detailed design of these specific operations will be presented in the next sections. Only those major design considerations required for understanding the operation of the major operative phases will be presented.

1. Preprocessor

As was mentioned in the preliminary design, the primary purpose of the preprocessor is to reproduce the compiled linked code list and generate a table that represents the sequential segments of the compiled code.

The informal strategy called for a two step operation. In the first step, textual integer pairs are read from an input file into a data record. Each record is linked to the preceding record forming a linked list which reproduces the linked list of code generated by the compiler. The next step evaluates the linked list to determine where the sequential segments are located. Information concerning each sequential segment is stored in another record and linked to the preceding sequential segment record, thus forming a linked list of sequential segment description records. Evaluation for sequential segments would occur by TI-59 labeled subroutines. Each list of sequential segment records would be pointed to by a header record which contains the subroutine name. Each of these subroutine name header records would be linked to other subroutine name header records in the same order in which they were detected in the generated code.

Two data structures were needed to support this strategy. The first structure comprises a linked list of records. Each record contains all the information that is contained in one program step in the TI-59 calculator, including the address of the instruction and the instruction integer code. Each record is linked to the following record by a dynamic pointer, which captures the sequential nature of the compiled code. Another dynamic link is provided for those records containing keycodes that may cause the flow of control to change from a sequential flow. The generated linked list of records is a complete internal representation of the compiled code.

A second data structure is needed to represent a sequential segment of code. Vital program control flow information must be captured by the structure so that segmentation rules may be applied during linker processing. To accomplish this a sequential segment table was developed utilizing a record format to describe each segment. This table record holds data such as segment start address, stop address, whether the segment is covered by an iterative backloop, a list of forward jumps and a list of subroutine invocations that originate within the segment. Each one of these records is linked to the following sequential segment's record. In addition, the sequential segment records are grouped according to subroutine. That is to say, only those sequential segments residing within one TI-59 subroutine definition are connected together in sequential order.

The linked sequential segments are tied together by other records of the same basic type but different variants. Each subroutine grouping of sequential segment records is pointed to by a linked list of header nodes. These nodes contain the name of the subroutine and the subroutine definition address. Each header is linked to another subroutine header in the same order in which subroutine definitions occur within the generated TI-59 code.

To capture information relating to forward jumps, a variant of the sequential segment record is used to build a forward jump list. This list contains the originating address of the forward jump and the address of the instruction to which control is transferred. Because the actual jump address is used, the link to the jump location is termed relative. Each jump node is dynamically linked to following jump nodes to form a jump list. This list is, in turn, dynamically pointed to by the sequential segment in which the jumps originate.

To capture information regarding subroutine invocations, the same type of structures is used as for the jump node lists. The only difference is that the subroutine lists point to the invoked subroutine in a dynamic manner. That is to say, that a dynamic pointer is set to the first sequential segment of the invoked routine in the sequential segment table. This is basically the only difference between the subroutine invoke list and the forward jump list.

Figure 4.6 is the contour diagram of a conceptual grouping of procedures referred to as the SYSTEM UTILITIES group. These procedures are not explicitly grouped together by code; rather, the grouping is to facilitate discussion and understanding. There are several operations within this group which manipulate the data objects.

In creating the linked compiled code list of records two separate procedures are used. The first procedure is called INPUT. This procedure builds the initial linked structure. It utilizes an input file containing the integer pairs representing TI-59 code steps. Essentially it creates one record for each pair and links the previous record to the new record. The only thing not done is the setting of pointers to represent an indirection in the flow of control.

This is the job of the procedure SET_JMPS. In this procedure, the major activity is the detection in the actual keycode portion of the compiled code of an instruction that represents a possible change in control flow. When one is

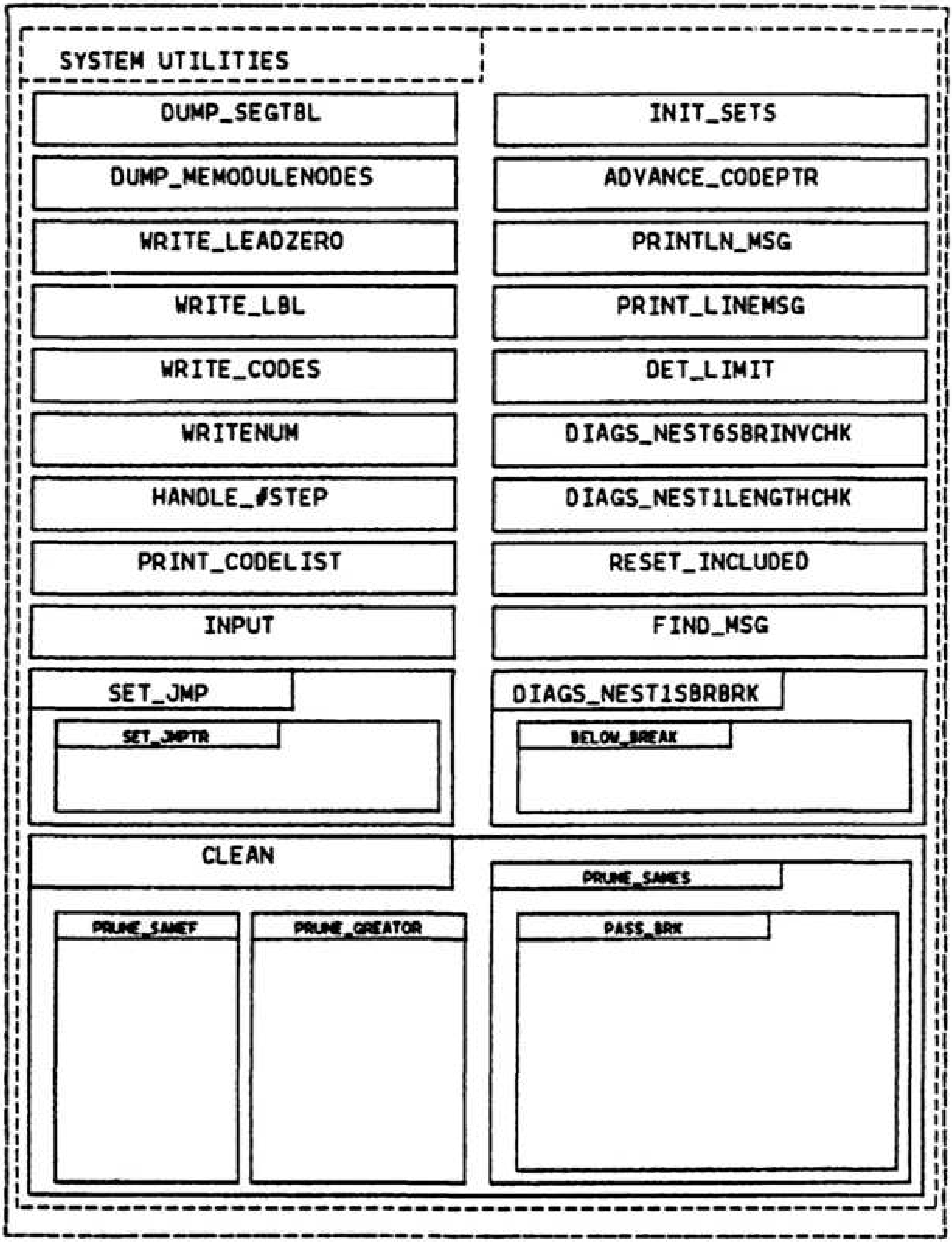

Figure 4.6 System Utilities Contour.

detected, a jump pointer (the indirection pointer) is set pointing to the record containing the next TI-59 program step to be executed.

The operations which create the second data object are a little more complicated and are contained in Figure 4.7 The action of building the sequential segment table data structure is broken down into three steps. The first step begins the formation of the table while the second step completes segment detection. The last step captures other information and ensures that internal interfacing requirements are met.

The first part of this procedure is accomplished through the BLD_PRIMSEGTBL procedure. This operation passes over the compiled codelist structure and determines where a subroutine starts, stops, or issues a back jump command, and locates the terminal points of the back jump commands. Each of these points is called a critical point. When detected, each critical point is inserted in the segment table data structure under the header node containing the TI-59 subroutine code name which is being processed. In addition, each of the jump commands with their initiation and termination points are inserted into the structure. This completes the first major step.

The second operation is accomplished through the BLD_ADVSEGTBL procedure. In this procedure the initialized data structure is fleshed out. Up to now only critical points have been inserted. As these are points and are not double ended, segments have not been delineated. This procedure examines the segment data structure and adds points to delineate where a segment starts and ends. It does this by subtracting one from the point following it and taking this to be its end point. This results in a series of records which are all covered by an iterative backloop, with the exception of the first record. This is noted in

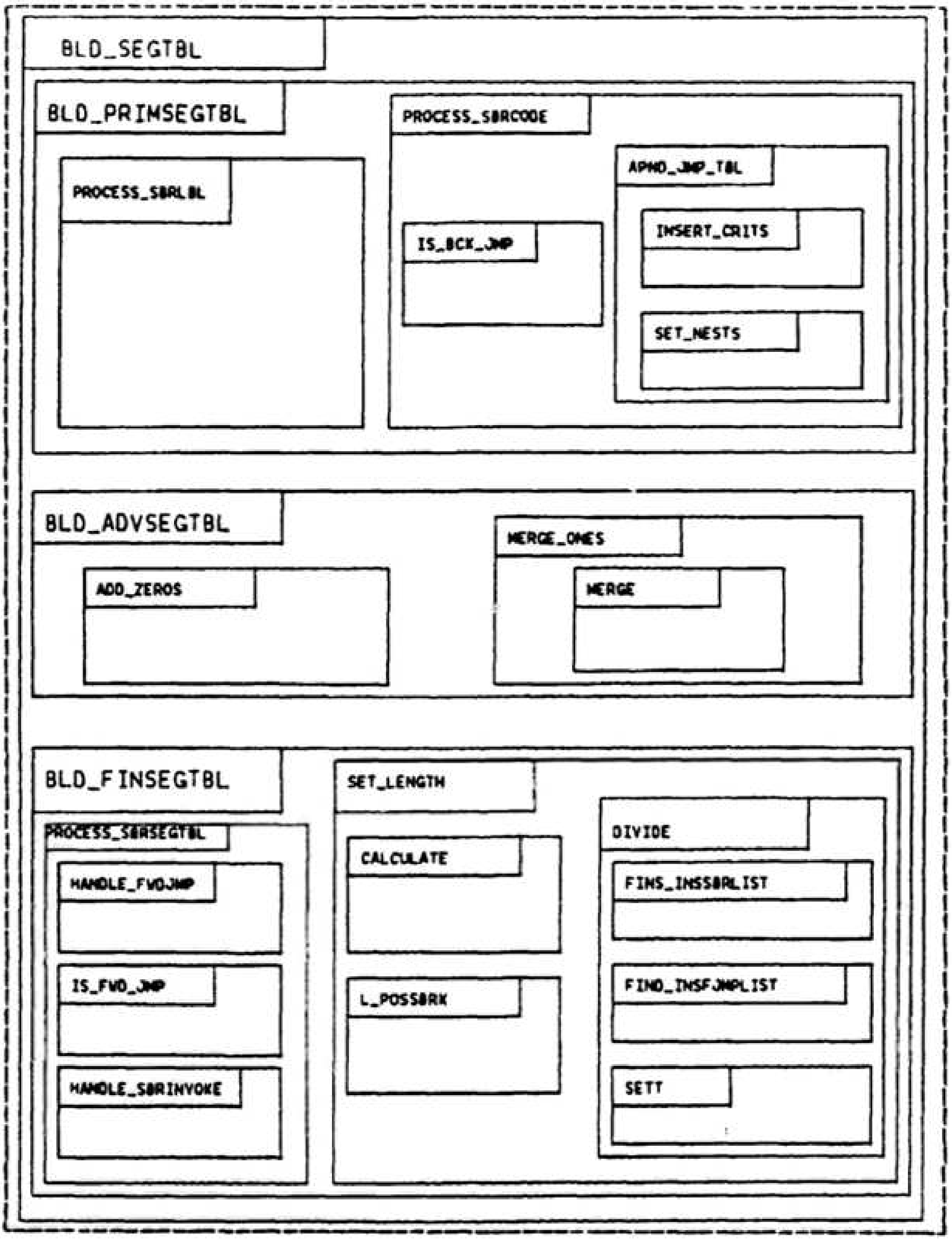

Figure 4.7 BLD_SEGTBL Contour.

the record. Next, the procedure examines the modified structure and determines by examining the addresses where there are holes in the table. These holes correspond to sequential segments that are not covered by an iterative backloop. These records are then inserted into the structure. Lastly, adjacent segments that are covered are merged to form one record representing a sequential segment that is covered by the largest iterative backloop.

The segment table structure is completed in the last procedure, called BLD_FINSEGTBL. In this operation two primary things happen. First, PROCESS_SBRSEGTBL evaluates the compiled code list and determines where forward jumps and subroutine invocations occur. It inserts these locations into the proper sequential segment that covers the area where the call or invocation occurs. Second, SETT_LENGTH checks that each sequential segment does not violate the memory size limit of the calculator. It does this by checking each sequential segment record and calculating a size. If the size is too great, then the segment is divided in half and a new segment is inserted into the table. This is not done for segments that are covered by an iterative loop as this would represent a break of an iterative loop. Other actions that must occur include readjusting forward jump lists and subroutine invocation lists if a division does occur. One interesting point worth noting is that when the length check is made additional steps must be allocated to the actual length to compensate for the possibility of prompting code being added for an invocation to a subroutine that does not currently reside in memory. This is the purpose of L_PCSSBRK in Figure 4.7.

The data structure operational procedures access the data structures through pointers which point to the structures. The pointer to the compiled code list is referred to as BUILT_CODE. The pointer to the sequential segment table structure is called SEGTBL. These are the only data which are passed among procedures. One point to remember is that SEGTBL points to the header node list containing the names of the subroutines. The actual sequential segment lists reside underneath the header nodes.

Since understanding the data structure and its construction is essential to understanding the remainder of the linker, an example will be examined to demonstrate the preceding sections.

In Figure 4.8 a sample topology of a TI-59 program is given. It includes four subroutines of various sizes and with various control flow indirections. In looking at the diagram it is important to note the absolute address locations given, for these will be critical to understanding the development of the sequential tables.

As was mentioned, the first operation is the restructuring of the generated TI-59 code. Figure 4.8 represents approximately this structuring. The actual code line is rebuilt internally in the machine and is pointed to by pointer BUILT_CODE.

Figure 4.9 is the completed sequential segment table, without the linked header node list. To understand the concept of sequential segment a comparative look at Figures 4.8 and 4.9 must be made. In Figure 4.9 the first sequential segment is defined as being between addresses 000 and 049. This is reflected in Figure 4.8. When looking at the sequential record one sees that the forward jump information is captured in the forward jump list node which, in this case, is only one node long. When looking at the second sequential segment one notes that there is a nested back jump. The sequential segment is defined to be that segment which is covered completely by back jumps. In this case it extends from 050 to 199. If for some reason the back jumps shown in Figure 4.8 did not fully contain each

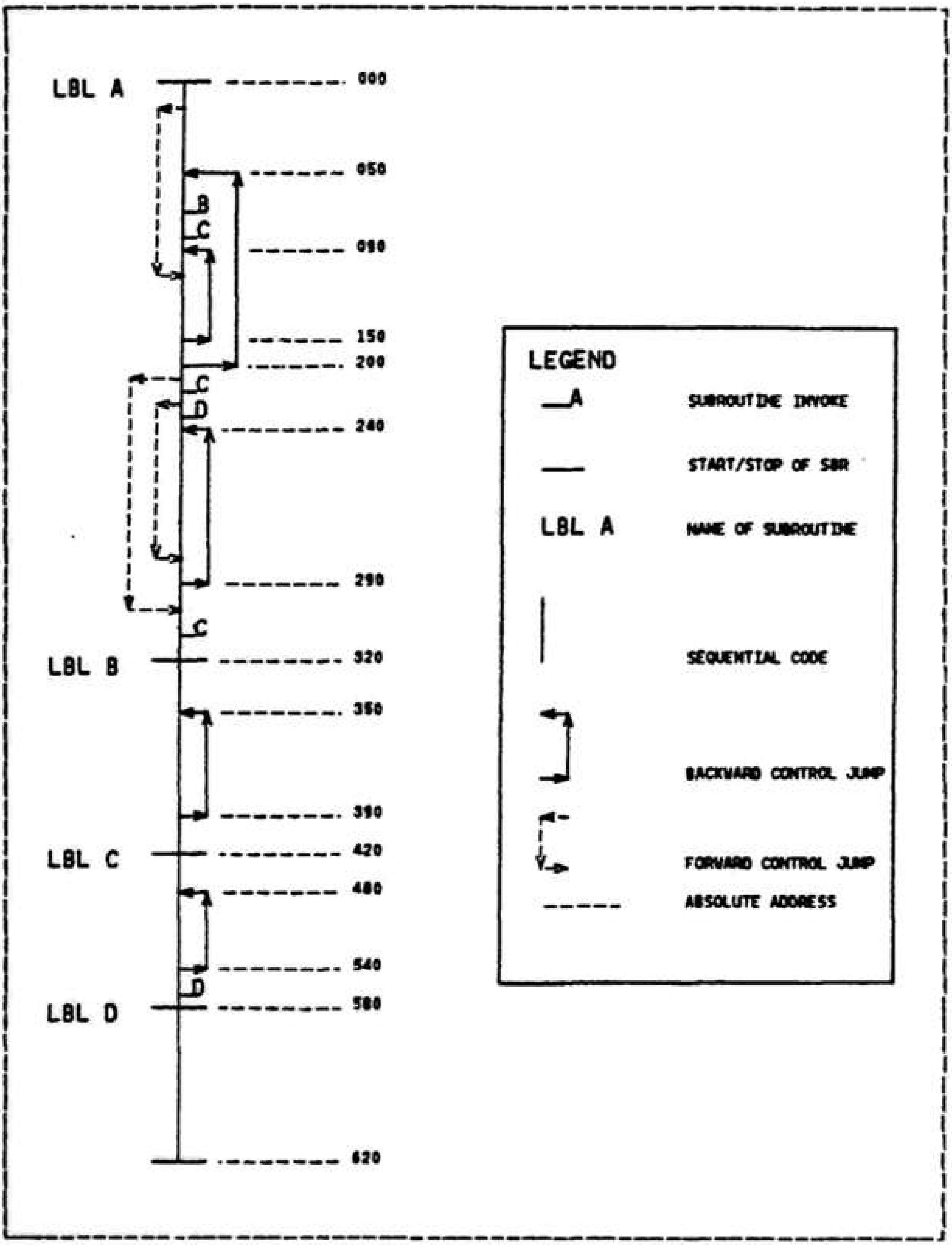

Figure 4.8 TI-59 Code.

other, that is to say, one jump started at 199 and stopped at 090 and the other started at 150 and stopped at 050, then the cover would still extend from 050 to 199. The reason is that this region of code is probably caught in an iterative loop and cannot under any circumstances sustain a break within this cover.

Another point to be made is the manner in which each subroutine's sequential segments are recorded together. In addition each invocation is recorded as is each forward jump. During the completion of the table, invocations to the same routines from different invocation locations are deleted, thus leaving only one link to the called routine for that sequential segment.

A final point concerns the recursive nature of the structure. By assuming that the first subroutine is the main routine and that all other lower level routines are below it (in the sense that they are pointed to from invocation nodes) one can see that any routine used to combine segments can be used on any subroutine's sequential segments. This opens the door for recursion to be used in a bottom up recombination scheme to be discussed later.

Many problems were encountered in the development of the preprocessor phase of the linker. Only the most difficult or annoying will be discussed.

One of the first problems concerned the multiple meaning of program steps in the generated TI-59 code. A separate TI-59 program step may be either a command, register number, flag number, or part of an address. The meaning is dependent on the last valid command. Commands can affect the interpretation of a program step as far as three step positions away (analogous to the concept of one-byte, two-byte, and three-byte instructions in assembly code). This had to be taken into account when doing any operation requiring an interpretation of the code. This

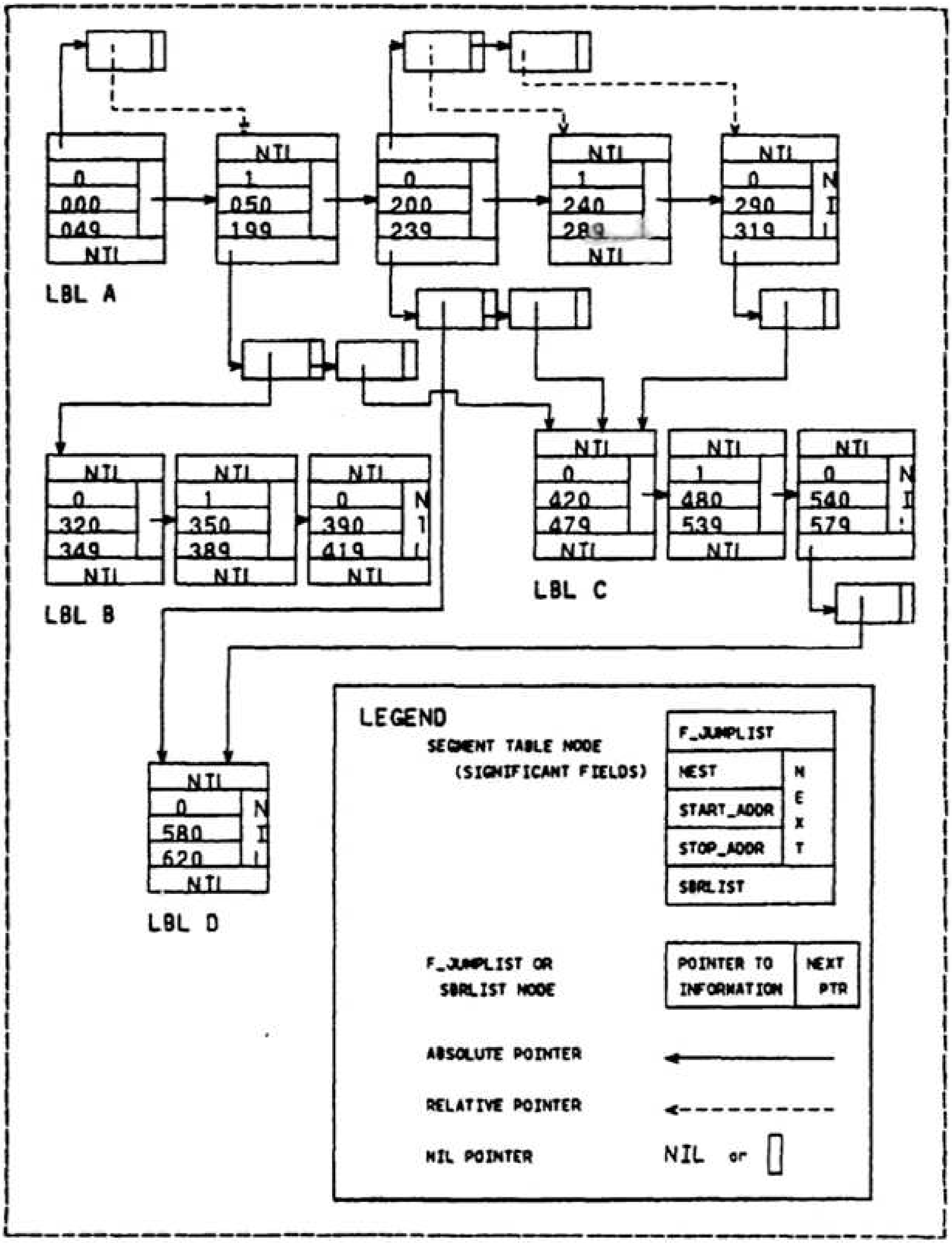

Figure 4.9 Sequential Segment Table.

resulted in special code sets being initialized and special routines being written to print out labels and move the compiled code list pointers. All of these are shown in Figure 4.6.

Improvements in this operative phase could be realized. In the early stages it was decided to separate the compiled code lists from the segment table lists. This was to avoid accidental tampering with the compiled code, since the integrity of the compiled code was the paramount consideration. It would be possible to make the compiled code lists a variant of the segment table. Then, instead of having relative pointer indexes to compiled code addresses, an absolute pointer could be used. This may reduce the size of the program significantly in that types would now be compatible and a reduction in the number of output routines due to the different types would be realized.

2. Segmentor

After the input file has been preprocessed then the linker passes into the segmenting phase of the operation. The routines that support this phase are built into the Pascal procedure called COALESCE depicted in Figure 4.10.

The informal strategy called for the sequential segments of a subroutine to be combined to form larger sequential segments. This recombination would be allowed as long as memory limits were not violated. This required that invoked subroutines be combined first before the caller so as to make room for the invoked routine's code. If the invoked routine could not reside then a break was placed in the dynamic link to the invoked routine and prompting code added to the caller's length for memory size checking purposes.

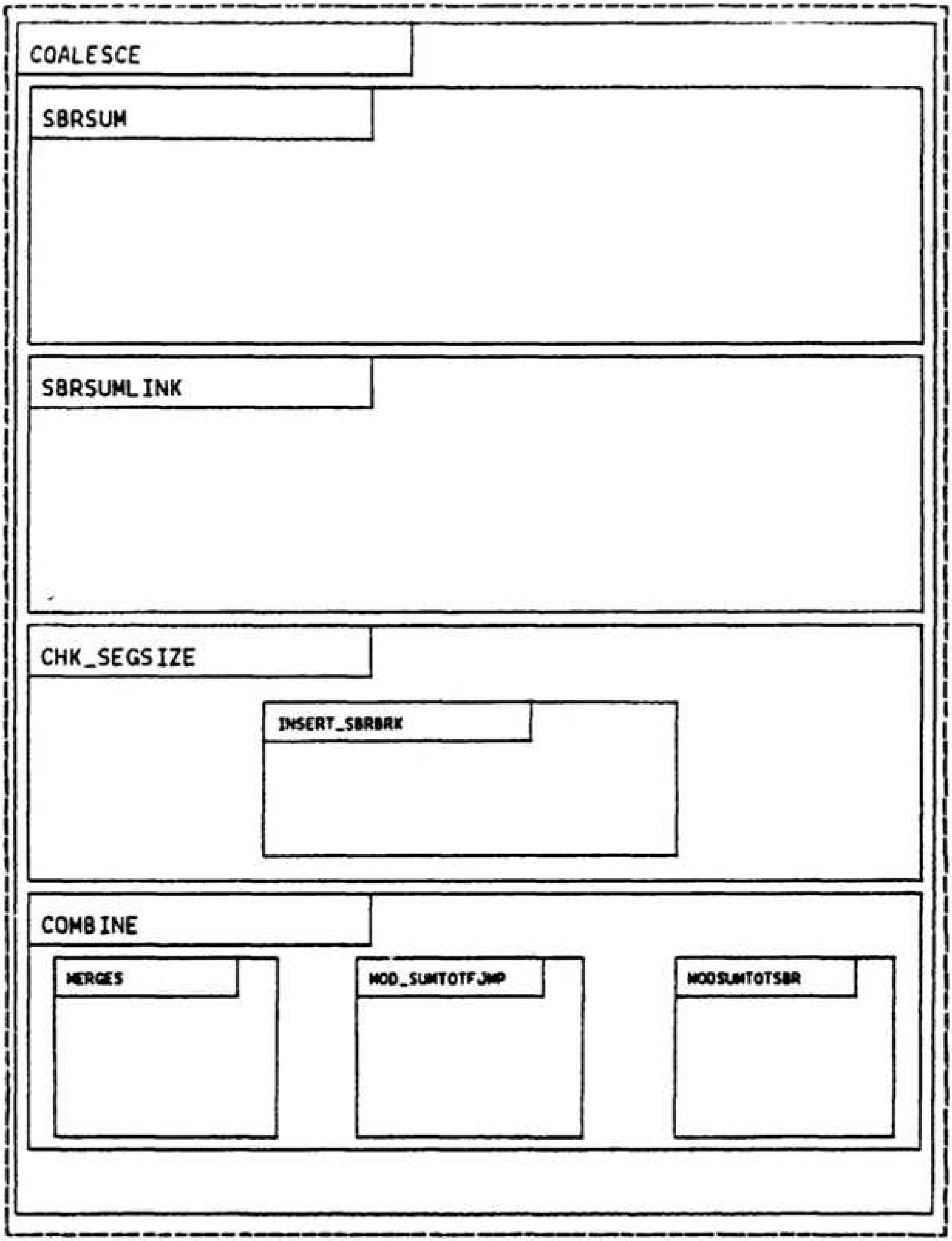

Figure 4.10 COALESCE Contour.

This strategy has one major requirement: the invoked routine must be recombined before the caller can be recombined. For this reason a recursive solution was adopted. In this solution, the main subroutine is recombined. The first part of the recombination process is to ensure that invoked subroutines will reside with the calling sequential segment. If a subroutine is encounterd that is not combined or coalesced, then the program will recurse on the new routine. Recursion will close out upon completion of coalescing of a particular routine. When all the sequential segments have been checked then adjacent segments are combined.

Another part of the strategy calls for the combination process to stop when a size limit is encounterd. When this happens then some sort of break notation must be used to mark where the limit was exceeded so as to prevent production of code segments that exceed the memory capabilities of the calculator. After the break has been set then the process of recombination begins on the other side of the break with the non-combined segments, starting again with a memory limit of zero.

This process of breaking and checking limits results in the sequential segment table containing break points. These break points delineate the exact locations where program segmentation will occur. These points will mark those portions of code which can fit in the calculator memory according to the rules of segmentation outlined in the preliminary design.

The data structure that supports this strategy is the sequential segment table. No other structure is used. The only addition to the structure is the node referred to as a subroutine invocation break node. This node is inserted between a subroutine invocation list node and the invoked subroutine sequential segment table. All other changes to the structure involve removing nodes and combining adjacent information into one node.

There are two major activities that support the above strategy. The first activity is the checking of a segment and the second activity is the combining of adjacent segments. Overseeing these activities is a single driver. This topology was suggested by the recursive nature of the solution. The procedures which support these activities are shown in Figure 4.10.

The driver is represented by the Pascal procedure COALESCE. This routine is called whenever a new subroutine is encountered that has not been combined or coalesced. The interior Pascal procedure CHK_SEGSIZE verifies that the specific segment it is looking at, together with all called subroutines on the subroutine invocation list for that segment, will reside in calculator memory. This routine uses SBRSUM and SBRSUMLINK to determine the lengths of invoked routines. It recurses mutually by calling COALESCE in the event that an invoked routine has not yet been coalesced. It determines this by looking at a boolean field in the segment table. This field is set true if the subroutine has been coalesced. The other procedure, COMBINE, accomplishes the actual combination of adjacent sequential segments. It uses the length predictor routines MOD_SUMTCTF_JMP and MOD_SUMTOTSBR to predict a combined length which takes into account any changes that might occur in the subroutine invocation or forward jump lists. If the combined length is within limits then a recombination occurs; if not, pointers are advanced. This means that any sequential segment records which follow the initial sequential segment records are part of a new memory calculation. In other words, any sequential segment links that are not nil represent a break between the linked sequential segments. Upon exiting COALESCE, the subroutine that has just been coalesced is marked as such in the sequential record's boolean field reserved for that information.

To visualize the result of the segmenting phase another look at the example is provided. Figure 4.11 represents a segmentation based on a memory limit of 550 steps. Note that each of the invoked subroutines has been coalesced into a single sequential segment. Also note that a break was made in the main subroutine. This is shown by the fact that the main routine is not a single segment record. By examining the table it can bee seen that the routine labelled "C" will be copied twice when the two memory sized segments are produced.

To interface between modules in this recursive environment several things were assumed or used. The first was that the data structure would serve as the repository of global data. In addition, a variable would be used to keep track of the current size of the combining memory program steps. This variable was passed as a parameter in order to preserve its value throughout the recursion. All pointers were passed as local parameters. This preserved locations in the data structure as the algorithm progressed through the different levels of recursion.

These operations did require some other work in order to obtain valid data that would correctly calculate code lengths to include multiple copies of subroutines. The problem occurred when there were multiple invocations to the same subroutine from different segments (or even different subroutines) that up to now were all included in the same memory limit calculation. To solve this another field was placed in the segment record to indicate whether or not the particular routine had been included or not in length calculations. Whenever a sum was calculated and a routine included then the field was set true. Whenever a new memory limit was reset back to zero following the implantation of a

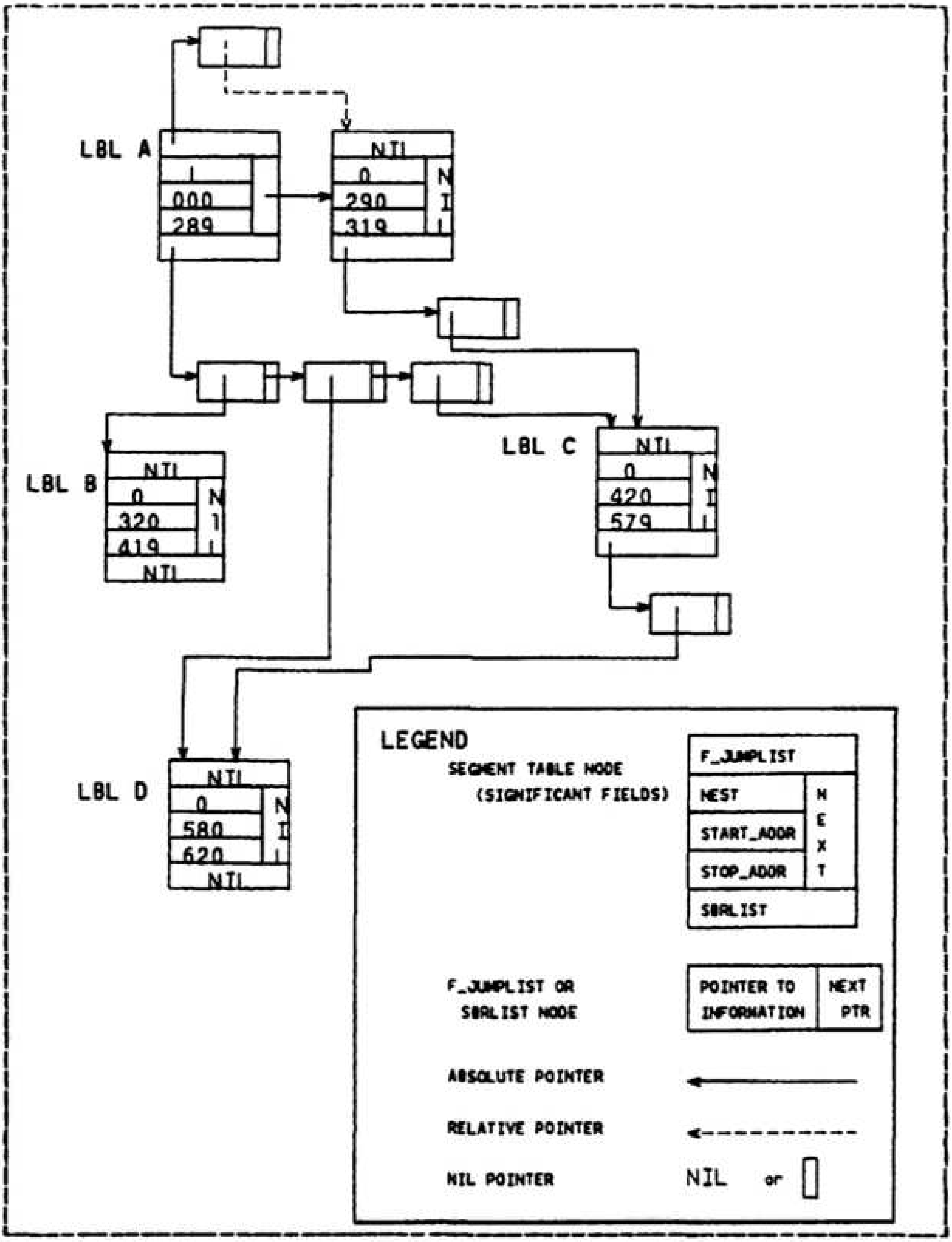

Figure 4.11 Coalesced Segment Table.

break point, a SYSTEM UTILITY procedure was used to reset all the included fields back to false. This means that only one copy of a subroutine would be considered for each calculator sized memory computation.

Future implementations should develop a better method for recording whether a segment is coalesced or included. The inclusion of this field in the segment table record was a "quick fix." This fix results in wasted storage as it is only used in the first record for each subroutine. An improvement would be to use another variant record to record all current data, with the exception of coalesced and included information, for all other sequential segment nodes other than the first sequential segment node. This would save memory.

3. Post Processor

After the segmentation phase, the linker passes into the postprocessor phase. It is this phase that provides the required output for the user.

The informal strategy divides this phase into three distinct operations. The first operation designates the start of each calculator sized segment of code. These segments, which meet the memory requirements of the calculator, are referred to as memory modules. The second operation copies the required code into each segment and inserts any segmentation prompting instructions that are needed for successful code execution. The last operation consists of ouputting the segmented code in a user friendly instruction sheet format. This completes all linker actions.

In order to support the informal strategy, several data structures are used, two of which were described earlier. They are the segment table and the compiled code list. At this point the segment table has been coalesced and contains the locations of the segmentation breaks that will minimize card reads. The compiled code will be copied by segment as delineated in the segment table. A third structure is built in this phase and a fourth structure is provided with the program.

The third structure is refered to as the memory module data structure. It is a Pascal variant of the segment table, which allows compatible pointer references between the two objects. The structure consists of a linked list of head nodes, which are named by respective memory module number. They represent one calculator's worth of available memory programming steps as determined by the calculator partition. Each node of this linked list points to two locations. One location is to the first sequential segment table record node following a segmentation break. The second link is to the copied code that will make up the programming steps of the memory module. In Figure 4.11, there would be two memory module header nodes. The first header node always points to the first sequential segment of the main subroutine. In the example this first memory module would be pointing to the node beginning with address 000. The second memory module node would point to a record that follows a break. This would be to the sequential segment node beginning with address 290. Just as there are no other breaks, there are no other memory module nodes. The other pointers would point to a linked list of code.

The copied compiled code list is a part of the memory module data structure. It is another Pascal variant of the same record type. This list is similar in structure to the compiled code list reproduced during the preprocessor phase. The only difference is in type. Another difference is that there are no jump pointers or dynamic pointers indicating a change in flow of control. The structure is just a linked list of sequential code. This structure is pointed to by the memory module header node. Another point to be made is that the linked code list, when completed, does contain other code that is needed for prompting. As such it is not a one for one copy of the compiled code list. Lastly, a look at Figure 4.11 will show exactly the segments of code that can be expected to form the two memory module structures. By looking at the sequential segment nodes and following their dynamic pointers of the subroutine lists all required code start and stop addresses are given. It is this "look down" facility of the sequential segment table that make it so useful.

The fourth data object is provided with the linker program. It is a textual file which contains text messages which are used by the linker. Each message is delineated by a $XXX where XXX is an integer. The linker, when provided the number portion of a message, can easily locate the message. Once located it can either extract values or copy the message verbatim to an output file. This is what occurs during the formatting of the instruction messages.

The operations that build and manipulate the data structures function in three phases. Figure 4.12 is the contour diagram of the subroutine that supports these operations.

The first operation is the construction of the header memory module nodes. This is accomplished by the Pascal procedure BLD_MEMODULENODES depicted in Figure 4.12. This procedure traverses the segment table and looks for break points. When it finds one, it checks to see if the break has already been detected. If it has not been detected then it builds the header node and assigns it a memory module number. The reason for the check is that the traversing mechanism is based on recursion. In this strategy, traversing is begun with the main subroutine. In Figure 4.11 this would correspond to subroutine LBL A, node

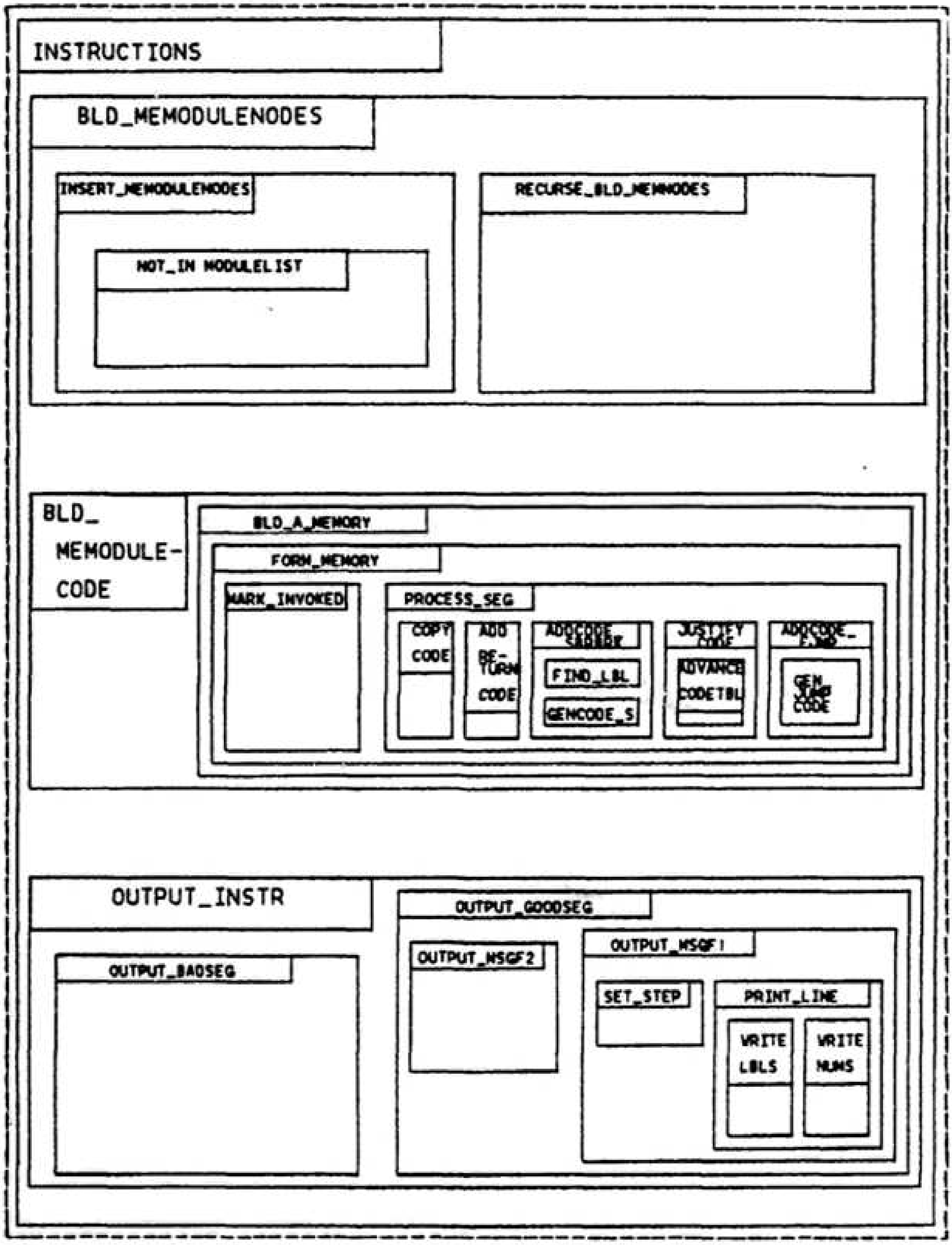

Figure 4.12 INSTRUCTIONS Contour.

start address 000. It then searches right along the same subroutine to detect all breaks of that subroutine. Then it resets back to the start of LBL A and begins to check the subroutine list of each node that comprises LBL A. Recursion is implemented at this point when the subroutine link is traversed and another subroutine is discovered. If a break is discovered in the subroutine list then another memory header node is built and the program bypasses the break and recurses on the next subroutine. This traversal mechanism leads to multiple discoveries of the same breaks. Consequently, the check is made to ensure multiple copies are not placed in the memory module header list.

The next operation consists of copying code from the compiled list, resetting address key codes for jumps and adding prompting code to each specific memory module code list. Figure 4.12 contains the Pascal procedure BLD_MEMODULECODE which accomplishes the above tasks. This is done by moving down the memory module header list in a sequential fashion. At each header, the link to the segment table is traversed to determine exactly what segments of the compiled code are to be copied. This is the duty of BLD_A_MEMORY in Figure 4.12. Once the start and stop points are determined and copied then recursion is utilized to traverse the subroutine links of the sequential segment table to obtain the required copies of resident subroutines to support the functioning of higher level segments. During this operation the segment table is used as a "check pad," that is, copies are marked included after being copied and are reset upon completion of copying. Another function accomplished during the processing of a memory module segment is the addition of prompting code. Lastly, addresses are reset and justified to include the resetting of jump address key codes to reflect new jumps to internal prompting messages and the absolute address of the originally compiled code list.

Once the memory module data structure is completed then the structure is presented to the user in an instruction type of format. This is the purpose of the Pascal procedure OUTPUT_INSTR. This procedure utilizes two data structures. It uses the provided message file structure and the memory module structure. The first action is to output the instruction introduction. This the procedure does through the use of the message file and the SYSTEM UTILITITY programs FIND_MSG, PRINTLN_MSG and PRINT_LINEMSG. These are depicted in Figure 4.6. These procedures allow the linker to copy verbatim messages in preformatted form. Once this is done the procedure copies the codelist from each of the memory module lists of code. Once a specific module is copied the driver routine, OUTPUT_MSGP1, prints out specific information to delineate each memory module. After this action is accomplished, the procedure traverses the segment table and prints out additional user information that will aid the user in the execution of his program.

Interfaces between modules are accomplished as usual with pointers. These pointers point to their respective data structures. Global information is recorded in the data structures or in special global variables which are passed as parameters during recursive operations.

One major problem that was encountered and solved in an interesting manner concerns the formatting of the output. The vast amount of instructional information that was required to be output made inclusion in the source code ridiculous. To solve this, the message file system was developed. This system consists of a text file containing preformatted messages and a several procedures located in the SYSTEM UTILITIES contour in Figure 4.6. Each message is delineated by a "$" and a number. Two types of messages can be processed. One kind of message results in a complete copy from the first line following the message code ($XXX) down to the line preceding the next "$" encoutered. The other messages are one-line messages which copied until the "$" at the end of the message. This gives the programmer the capability to write out blocks of text and to write out text and computer generated information on the same line.

Another capability provided by the package is the ability to search out messages from other files. The procedure FIND_MSG takes as parameters a file as well as a message number. This facility allowed the linker to be loosely coupled with the cross-compiler by interfacing with a message number coded file produced by the cross-compiler. All that the linker needed to know was under which number a required piece of information was coded and the interface file name to affect an interface.

An improvement might be realized in the output of the generated code list. Currently there are two separate sets of procedures used to output code lists. This was primarily due to typing differences. However, the second set of print procedures located in INSTRUCTIONS (see Figure 4.12) is probably more efficient. Furthermore, if the reconstructed code were changed to be a variant of the segment table structure then a reduction in Pascal code lines would be realized through the elimination of a code list group of printing procedures. A further increase in efficiency may be realized in any operations requiring use of the reconstructed compiled code list.

C. INTERFACE ENGINEERING

In any detailed design, careful consideration must be given to interfacing criteria. Interfacing criteria should be as explicit as possible, however this is not always possible. Sometimes, design decisions or engineering interpretations have implications that affect other modules or submodules. These are generally of an indirect nature in that the interface is implied in the system structure and is not explicitly passed from module to module.

These types of interfaces surface in the detailed design phase. Decisions regarding TI-59 address labelling and structure of the TI-59 subroutine greatly affected the design. In addition, assumptions about the use of structured programming and the prohibition of recursive WBASIC programs facilitated system design. Simple redefinition of the use of WBASIC commands READ/DATA provided any easy form of I/O, but again was an implied interface. These types of implied interfaces will be examined in the following sections since they are critical to understanding the system operations and to future maintenance.

1. Addressing TI-59 SBR

One implied interface resulted from a decision on the mechanism of subroutine invocation which would be used by the system. This decision arose from the fact that the TI-59 calculator may invoke subroutine code in several different ways.

To understand why a decision was required a look at the subroutine naming conventions and procedure for invocation are in order. A subroutine name is composed of two program steps. The first step is the keycode 76. This is the LBL code. It tells the calculator that the next key is a subroutine name. The next program step is the actual subroutine name. The keys which may serve as actual subroutine names may be one of two types. The first type comes from keys which are undefined. That is to say the keys are not used by the calculator to perform calculator functions; they are strictly reserved for naming subroutines. The other type of name comes from defined keys. By this we mean that the calculator uses the keys in some fashion in addition to naming subroutines. These keys are overloaded: they can have two meanings.

To define which meaning is to be interpreted the calculator requires that a subroutine definition be preceded with a special key called the label key. This alerts the calculator to the fact that the next program step is a subroutine name. To invoke a subroutine, the calculator requires double meaning labels to be preceded with a special key called the invocation key. This alerts the calculator to the double meaning much as the label key. For undefined keys, this alert key is not required though its use will not alter any transfers. There exists another method of invoking subroutines. This calls for the invocation alert key to be followed by an absolute address. It is the duality of meanings which presented problems.

To overcome these problems two decisions were made. The first decision required that all undefined keys be treated as if they were defined keys. This resulted in only one case to be developed to handle subroutine naming. The penalty for this decision is that an added step was generated whenever an undefined key was used as a label and a call to that label was made. The other decision disallowed the use of absolute addresses in the subroutine invocation. All invocations would use labels. This decision carried a penalty in terms of execution speed. The calculator must search program step memory to locate named subroutines whereas address references can be reached directly. On the other hand there are several benefits. One program step was saved since a label requires only one step whereas an absolute address requires three. The other benefit permitted the definition of the invocation alert key as a two step instruction and not a two or three step instruction. This was the primary reason for this implementation. All of the system was designed with this decision in mind.

2. Structured Subroutines

A problem arose with the defining of subroutines. The calculator permits subroutines to be defined within other subroutines. Though this in itself is not extraordinary, the fact that nested definitions may be closed out with the same subroutine return key is not usually permitted. This type of structure made subroutine detection for segmentation purposes very difficult.

To solve this problem it was decided to allow only structured subroutine definitions. That is to say, only one return was permitted for each label. In addition, it was decided to disallow nested definitions. In fact, the decision was made to require that the programmer position his main program first in WBASIC source code and to have all of his subroutines follow in the manner described above.

This interface design decision forced a specific program structure. This structure was easy to detect, easy to compile and easy to segment. These benefits were realized at a cost of not being able to generate efficient or "tricky" code and of reducing the programmer's leeway in developing his WBASIC source code program structure.

3. Recursion

Although TI-59 calculator instructions tend to be evasive on the subject, recursive programs can be executed in a few special situations. Some BASIC languages support recursion, others do not. Although the WBASIC language supports recursion, limitations imposed by the calculator forced us to disallow the translation of recursive source programs. Other reasons for this decision involved complexities which such programs would present to the linker.

4. Input/Output

The development of the input/output structure was designed around the three major limitations of the calculator: programming steps available, storage registers available, and the calculator numeric display. In order to develop an efficient system to allow for input and output, restrictions were placed on some WBASIC commands.

Since the calculator display allows only numeric input and output, then any information passed between a human operator and the calculator must be in numeric form. Prompts used to communicate with the human must be imbedded in the compiled code. In the case of input and output, these prompts have an overhead in that they use up valuable programming steps. For example, with each INPUT command in WBASIC, a total of seven steps are generated to produce a prompt and store a value in the calculator. The problem with this occurs when large numbers of variables need to be input. If 60 variables are required for input then the INPUT command will generate 420 steps. This is clearly unacceptable.

To solve this problem the semantics of the WBASIC commands READ and DATA were modified. Use of these commands within a source program does not increase the number of program steps in the translation. A table of WBASIC variable names assigned to TI-59 registers is produced and placed in the interface file. This allows the human to input all of his data prior to execution without having to pay the penalty of generating extra prompting code.

Another decision concerns the location of the DATA and READ statements: All DATA/READ pairs must occur together at the beginning of the program. The reason for this should be clear. It would be impossible to place the commands in the middle of the program because they would have no effect. With the exception of a single NOP (which is eliminated during peephole optimization), these commands generate no code. As a result, no run-time modification of variables can occur. Furthermore, DATA/READ statements placed within loops would invalidate the DATA to READ mapping, a static table.

The whole purpose of the redefinition of these commands was to give the user an optional form of I/O. This was expected to increase the efficiency of the generated code. These decisions influenced much of the design of the system.

V. TESTING

The test program and its generated output are provided in Appendices K through P of this report. The test program was chosen for several reasons. The first reason was to test the actual ability of the system to produce a usable TI-59 coded program. The second reason was to attempt to obtain an idea as to the efficiency of the system-generated code. The following sections present a description of the test program and comment on the efficiency of the generated code.

A. TEST PROGRAM DESCRIPTION

In developing a test program several considerations had to be taken into account. The first consideration required that the generated code be verifiable. To verify the generated code, it was decided to program a solution to a problem for which verifiable solutions existed. Verification would be achieved if the system-generated solutions matched those of the existing solutions for the same inputs. The second consideration was to attempt to arrive at some sort of efficiency comparison between the system generated TI-59 program and an optimized hand coded TI-59 program.

The test problem which was selected fit the above criteria. First of all, solutions to known input values existed. This ensured proper verification of the generated code. Secondly, a highly optimized hand coded solution to the problem existed for comparison. The problem selected is called the "Gunnery Problem."

The gunnery problem is to determine firing data for a howitzer cannon. It consists of inputting the following data: piece location, target location, piece corrections and howitzer ballistic coefficients. The output which is generated consists of time to target, elevation to achieve target hit and the lateral deflection (an angular measurement) to align with the target.

The solution involves calculating a range to target as well as an azimuth to the target. The azimuth is then converted to a lateral deflection, which is understood by the piece to be the correct azimuth on which to align. Next, three quadratic equations are solved to determine elevation, time of flight and shell drift. These are applied to the lateral deflection and to the piece elevation. A decision based on the calculated range to target is needed to ensure correct ballistic coefficients are used in the computation. These coefficients are based on the charge which is to be fired to achieve the range.

The hand coded version solution has been in use since 1976. The accuracy of this version was checked by artillery ballistic tables and by the Field Artillery Digital Computer (FADAC), the recognized source of all correct firing data. By using this solution, vast quantities of test input and output were available for program verification runs.

The hand developed version is highly optimized. For example, the hand version stores eight numbers in four storage registers. This is accomplised by storing the numbers on either side of the decimal point in a real number. This real number is then decomposed in a subroutine to obtain the correct number. In addition, this version makes use of calculator commands that were not implemented by the EAX59. For example, there is great use of the indirect store, decrement and skip on zero and polar to rectangular commands. All of these features made the hand coded version a highly optimized program.

B. TEST COMMENTS

The WBASIC solution was coded using basically the same program structure as the hand coded solution. This source code is presented in Appendix K. The interface file generated by the cross-compiler is presented in Appendix O. The final output generated by the linker is presented in Appendix P.

In verifying the accuracy of the generated code, many runs were made using input data for which known solutions existed. There were no deviations from the known solutions in any of the test runs. The conclusion is that the generated code was accurate.

In comparing efficiency a common unit of measurement was needed for comparison. This common unit was chosen to be the TI-59 program step. The reason for this is simple. Both registers and program steps reside in the same memory. Registers occupy eight programming steps. To measure how much memory a program uses it was only necessary to multiply the number of storage registers times eight and add it to the number of program steps to arrive at a figure which measured memory usage within the calculator.

This was done with the BAX59 generated code and the hand coded programs. The hand coded solution used 441 steps and 60 registers for a total step count of 921. The BAX59 generated code used 652 steps and 86 registers for a total step count of 1340. This represented an increase over the hand coded solution of 419 steps or a 45% increase.

A time to solution comparison was made next since the primary purpose of the BAX59 system is to allow an individual to quickly obtain a program capable of running on the TI-59 calculator. To begin with, the hand coded version was developed by three individuals over a period of several weeks. The BASIC program used as input for the BAX59 system took only one person one day to write and debug. The utility of a higher level language greatly simplified the programming process. It is this savings in programming development which makes the desirability of the BAX59 system readily apparant.

In looking at the system-generated program some more comments can be made about where the relative overhead occurs. Of the total 652 programming steps it was noted that 84 steps were due to prompting code. Six storage registers were used as manual return registers while one register was used as a temporary display storage register. Another register was used in the manual subroutine return prompting scheme. This totals for the Linker an overhead of 148 programming steps. This Linker overhead represents 11% of the total generated steps indicating that the compiler generated at least 34% more code than the hand optimized coded program.

One last comment concerning the actual running of the BAX59 generated program needs to be made. In running the BAX59 code it was determined that time of execution became totally dependent on the amount of cards required to be read in and out. If the head reader in the calculator functioned properly, then this required small amounts of time to accomplish. If however, the head reader malfunctioned, then the reading of cards became an ordeal. In addition, the user had to pay close attention to the program prompting scheme or he would become lost between card reads.

VI. CONCLUSION

In the following discussions, the test program is evaluated together with the actual design. Based on this evaluation several conclusions are drawn and recommendations presented.

A. EVALUATION OF TEST RESULTS

In examining the test data, it is important to realize that this is only a single test. As such, it does not represent the whole set of BASIC programs which may be executed by the BAX59 software system. However, the test does give an insight into the actual efficiencies which might be expected. While actual numerical data is given these data should not be viewed as a statistical analysis of the system. Rather, the data is meant to provide some frame of reference for the discussion of system efficiency.

In examining the test program, it is noted that excess code generated amounts to roughly 45%. Of this, approximately 11% can be attributed to the linker, while 34% can be attributed to the cross-compiler. Although the total overhead seems rather large, the reason for building the system must be recalled. The primary reason is to facilitate the rapid design and implementation of programs on the TI-59 calculator. In view of this, it becomes clear that the overhead is secondary to the problem. Our real yardstick for success is whether or not TI-59 programs can be developed more rapidly than hand coded programs. The test program provides an insight into this side of the problem. Development time was about one order of magnitude faster compared to the hand coded solution.

This rapid development time more than justifies the high overhead. This is true in most academic applications, as most program executions are limited in nature. If on the other hand, a program is to be executed many times, then an optimized hand coded program might be better than the machine generated version. The final decision lies with the user. His program execution requirements, and the amount of time he has available to design and build his solution, will drive his selection.

B. CONCLUSIONS

In view of the target machine limitations, it is probably safe to concluded that the system is a valid first-cut prototype. The prototype proved the desirability and feasibility of the concept, that quick calculator programming can be realized with the minimum of effort. The following paragraphs discuss the prototypes's limitations and suggest reasons why the current system is not yet useful as a good production system.

The calculator is severly limited in memory capacity. The TI-59 calculator has only 959 program steps for program usage. The overhead in code generation and segmentation prompts use up 45% of these steps. Together with the fact that only three memory partitions between program steps and storage registers are available, the 45% becomes a significant driving figure in calculator use.

The memory problem restricts the varieties of programs which may be written for translation. Programs may not be written which require a main routine having a long back jump that covers a vast portion of memory. This is because the linker segmentation rules will be violated underneath the covered iterative segment. The segmenter will fail to segment. Thus, only programs which are sequential in nature are suitable for the system.

Another related problem is that the smaller the memory, the more segmentation breaks will occur in the code. The more segmentation breaks, the more card reads will be required to achieve a successful program execution. Often, a problem will arise with the card reader of the calculator. Like any piece of equipment with a motor and magnetic tape head, it is fairly sensitive and prone to failure. If the card reader fails just once in the execution sequence, then there is a high probability that the program will fail to terminate successfully. The minimization of magnetic card reads is desirable for this reason as well as for reduction of user thrashing.

Another restriction occurs in the language subset. Arrays were not implemented in the first prototype design. This limitation impacts directly on the types of programs which can be developed for and translated by BAX59.

Arrays are used primarily for iterative work. Without arrays, iterative work, while still possible, is very limited. Much computer power lies in the ability to execute iteration rapidly. As noted in preceeding paragraphs, this limitation occurs as a result of the small memory capacity of the machine. Because of this, it is felt that the implementation of arrays should occur when the prototype is matched with a more capable calculator.

We have suggested major limitations of the system as it currently stands. For these reasons it is felt that the system should be viewed only as a first working prototype. However, we feel that this prototype successfully demonstrates the concept that the power and efficiency of calculator programming can be greatly extended through higher level language programming.

C. RECOMMENDATIONS

If the concept of BAX59 is useful, then the next logical step is to develop the second prototype. The second prototype should not be hindered by the current TI-59's limitations. Otherwise, the next machine should be a more practical one, allowing easy hand held calculator programming. Many firms now market machines which have built-in BASIC language interpreters.

1. Hardware Related Suggestions

In order to avoid the major restriction, namely memory, the BAX59 system must target a larger capacity calculator. This calculator should have about 10,000 program steps and approximatly 400 to 500 storage registers. A memory partitioning capability should be available to maximize memory usage.

As a follow on to increased memory capacity, the next prototype should have a hardware device available which will enable the host computer to download the generated calculator program into the target machine. This would eliminate hand punching program steps, which would be be prohibitive on a calculator program of 10,000 or more steps.

The linker algorithm examines the dynamic structure of the program to facilitate segmenting the program. This alogorithm segments sequential code that is not covered by a back loop. It may be possible to use this algorithm in the development of a single page swapping mechanism/system for a small microcomputer. The purpose of the algorithm in such a system would be to segment a program too large for the microcomputer, in such a manner so as to minimize the number of single page swaps with the system's disk storage unit. Such a system might be desirable for a small microcomputer in which memory is a problem.

2. Array Implementation

A very useful extension of the language subset would be the inclusion of arrays. Coupled with memory expansion, the capability to process arrays would make it possible to do more iterative programming.

A simple but costly implementation of single dimensional arrays is, perhaps, the most feasible approach. For each array declared, three registers will be required to store indexing and access information. Call the WBASIC record fields which will store the assigned register numbers BASE, HOLD, and CALL. BASE stores the number of the array base register (array index 0). During assignment statement translation, HOLD stores the index for an array identifier on the left hand side of the assignment statement equal sign. CALL stores the index of any array identifier currently being evaluated in simple expression. Of course, registers will be necessary for storage of the array itself. The simplest technique is to require that all array index ranges start at zero. Additionally, there will be no run-time checking of range limits. With the foregoing restrictions, estimated TI-59 program step requirements for translation of even simple assignments involving single dimensional arrays are very high. Evaluation of one array reference such as "A(X)" translates to 13 program steps. The assignment statement "A(X)=A(Y)" translates to 26 steps. A more complex reference such as "A(A(X))" requires about 24 steps. Together with the number of registers needed to store values and access data, usage of calculator memory may rapidly approach capacity levels with array manipulation.

Particular array values are accessed with the IND (indirect) instruction. Our basic strategy is to add the evaluated array subscript to the register number in BASE, and store it in HOLD (for left side of assignment statements) or CALL (for all others). When a value is to be assigned to an array element on the left of an assignment statement, then the right side is evaluated and "STO IND" HOLD stores the value at the correct location. If it is only necessary to evaluate an array item within an expression, then "RCL IND" CALL recalls the value of the appropriate item. More efficient translation schemes might be possible; however, our technique has been tested on the TI-59 calculator, and works well.

The most difficult aspect of implementation is the the task of installing the translation scheme and a parsing scheme. Fortunately, the BASIC language requires explicit array declarations using the DIM statement. Procedure PDIM must be written to parse these declarations, create symbol table entries, and make register assignments. The SLCTRCD record would need an additional variant tag type for array types, call it ARRID. A slot with this tag would carry fields BASE, HOLD, and CALL in its variant part. Finally, we would have to adjust the simple expression parsing and code generating procedures PEXPR and PPRIMARY so that they could recognize array references and act accordingly. Of course, there are other source code adjustments that would be necessary to fine tune the system. However, this discussion has suggested our outline of major steps involved in array implementation.

APPENDIX A

WBASIC SUBSET RECOGNIZED BY BAX59

Command Reserved Words:

DATA	ENDIF	GOTO	NEXT	REM
DEF	ENDLOOP	IF	PAUSE	RESTORE
ELSE	FNEND	INPUT	PRINT	RETURN
ELSEIF	FOR	LET	QUIT	STOP
END	GOSUB	LOOP	READ	UNTIL
				WHILE

OPTION (special--does not follow WBASIC syntax)

Supplemental Reserved Words:

NOT	<>	<	+	(
STEP	<=	>	-	)
THEN	>=	=	*	,
TO	**	!	/	.

& (special--recognized by scanner directly)
_ (special--recognized by scanner directly)

Unimplemented Reserved Words:

CHAIN	LINPUT	RANDOMIZE	SLEEP
CLOSE	LOCK	REMOVE	SORT
DIM	MAT	RENAME	TAGSORT
ENDGUESS	ON	RESUME	UNLOCK
GUESS	OPEN	SCRATCH	USE

OPTION (special--syntax of WBASIC not implemented)

AND	OR	
#	$	'

Description of Command Reserved Words:

DATA: Create an internal data list (see READ, RESTORE)

```
DATA <integer|real> {, <integer|real>}
```

DEF: Define a single or multi-line function (see FNEND).

```
single line: DEF <fn_name> [ (<parameter-list>) ] = <expr>
multi-line : DEF <fn_name> [ (<parameter-list>) ]
                 ...body of definition
             FNEND
```

ELSE: Indicate instructions to execute if no IF/ELSEIF conditions were satisfied (see IF, ELSEIF, ENDIF).

```
ELSE
```

ELSEIF: Cause execution of a number of statements depending on the given condition (see IF, ELSE, ENDIF).

```
ELSEIF <boolean-expr>
```

END: Mark the end-of-source in the program (last line).

```
END
```

ENDIF: Indicate the end of an IF-ELSEIF-ELSE structure (see IF, ELSEIF, ELSE).

```
ENDIF
```

ENDLOOP: Mark the end of a loop (see UNTIL, WHILE, LOOP).

```
ENDLOOP
```

FNEND: Mark the end of a function definition (see DEF).

```
FNEND
```

FOR: Mark the start of a loop (see NEXT).

```
FOR <for-var> = <expr> TO <expr> [STEP <expr>]
    ...statements to execute in loop
NEXT <for-var>
```

GOSUB: Transfer control to the line specified, until a RETURN is reached (see RETURN).

```
GOSUB <line#>            (Note:  GO SUB is not recognized)
```

GOTO: Transfer control to the line specified (see ON).

```
GOTO <line#>             (Note:  GO TO  is not recognized)
```

IF: (1) Cause transfer of control to either of two statements or QUIT a loop depending on a condition.

```
IF <boolean-expr> THEN <line#>|QUIT [ELSE <line#>|QUIT]
   NOTE:  This is an exception to WBASIC which
          allows any single statement after THEN
          and/or ELSE.
```

(2) Cause execution of either of a group of statements depending on a condition (see ELSE, ELSEIF, ENDIF).

```
IF <boolean-expr>
   ...statements to execute if expression TRUE
[ELSEIF <boolean-expr>
   ...statements to execute if 2nd expression TRUE]
[ELSE
   ...statements to execute if none are TRUE]
ENDIF
```

INPUT: Transmit data from the terminal to a number of variables (see PRINT). No variables stops execution.

```
INPUT [<expr> {, <expr>}]
```

LET: Assign the value of an expression to a variable.

```
[LET] <var> = <expr>
```

LOOP: Mark the beginning of a loop (see WHILE, ENDLOOP, UNTIL).

```
LOOP
   ...statements to execute in loop
ENDLOOP
```

NEXT: Mark the end of a FOR loop (see FOR).

```
FOR <for-var> = ...
   ...statements to execute in loop
NEXT <for-var>
```

PAUSE: Suspend execution of the program.

```
PAUSE
```

PRINT: Transfer a series of values to printer or display. If no expression is found, a line space will result. (see OPTION)

```
PRINT [<expr> {, <expr>}]
```

QUIT: Leave the current block (WHILE, UNTIL, LOOP).

```
QUIT
```

READ: Transfer data from the list of items specified in DATA statements (see DATA, RESTORE).

```
READ <variable> {, <variable>}
```

REM: Indicate that the line is a comment. The exclamation character (!) may also be used to indicate a comment.

```
REM [<comment>]
```

RESTORE: Cause the next READ statement to get data values starting at the first item in the DATA list (see READ, DATA).

```
RESTORE
```

RETURN: Transfer control to the statement following the last GOSUB executed (see GOSUB).

```
RETURN
```

STOP: Terminate program execution.

```
STOP
```

UNTIL: Mark the end of a loop to be executed until the given condition is true (see WHILE, LOOP, ENDLOOP).

```
LOOP
   ...statements to execute in loop
UNTIL <boolean-expr>
```

WHILE: Mark the beginning of a loop to be executed until the given condition is no longer true (see LOOP, ENDLOOP, UNTIL).

```
WHILE <boolean-expr>
   ...statements to execute in loop
ENDLOOP
```

OPTION: Set/reset boolean toggles within BAX59 to control generation of output files.
CAUTION: This is not the WBASIC OPTION! This OPTION should be used only after a correct WBASIC program has been constructed and is ready for translation.

```
OPTION <opt-parm> {<opt-parm>}

      where <opt-parm> (option parameter) is
            an integer range -8..+8;
            sign indicates the direction of toggle:
            positive = true/on, negative = false/off;
            sign is assumed positive if omitted.

                                                     Default
 0 = generate linker interface file...............false
 1 = generate code for PC-100 printer.............true
 2 = optimize out unnecessary parentheses.........true
 3 = optimize out unnecessary NOP's...............true
 4 = translated TI-59 code to list file...........true
 5 = contents of symbol table to list file........false
 6 = contents of code structure to list file......false
 7 = each lexical token to terminal................false
 8 = each lexical token to list file...............false
```

Description of Supplemental Reserved Words:

NOT: Negate a boolean expression (see IF, WHILE, UNTIL).

```
NOT <boolean-expr>
```

STEP: Designate the increment (decrement) value of a FOR variable (see FOR). (default = +1)

```
FOR <for-var> = <expr> TO <expr> STEP <expr>
```

THEN: Mark the beginning of the true branch of a line-oriented IF statement (see IF).

```
IF <boolean-expr> THEN <line#>|QUIT [ELSE <line#>|QUIT]
```

TO: Mark the expression which represents the limiting value of a for-variable (see FOR)

```
FOR <for-var> = <expr> TO <expr> [STEP <expr>]
```

Symbols and Operators:

<>	not equal	+	addition
<=	less than or equal	-	subtraction
>=	greater than or equal	*	multiplication
**	raise to the power	/	division
<	less than	(	open expression
>	greater than	)	close expression
=	equal	,	list item separator
!	end of line cmt	.	decimal point

Special Characters:

(not reserved words--recognized directly within the scanner without reference to the RW table)

& Signifies that the current line is continued on the next line or is a continuation of the last line.

```
00120 REM This comment is to long for one line, so it &
00130 & must be continued on the next line.
```

_ Underscore; used within variable identifier names to assist in readability; also used to designate a user defined function identifier.

```
LET FINAL_SUM_VALUE = FIRST_VALUE + SECOND_VALUE
DEF FN_FACTORIAL...
```

Built-in Functions:

```
    ABS      ATN      CSC      IP       PI       SIN
    ACOS     COS      EXP      LOG      RND      SQR
    ASIN     COT      FP       LOG10    SEC      TAN
```

ABS: Returns the absolute value (magnitude) of parameter
ABS(x)

ACOS: Returns the arccosine (in radians) of parameter
ACOS(x)

ASIN: Returns the arcsine (in radians) of parameter
ASIN(x)

ATN: Returns the arctangent (in radians) of parameter
ATN(x)

COT: Returns the cotangent of parameter angle in radians
COT(x)

CSC: Returns the cosecant of parameter angle in radians
CSC(x)

EXP: Returns the value of e raised to the power x
EXP(x)

FP: Returns the fractional part and sign of parameter
FP(x)

IP: Returns the integer part and sign of real parameter
IP(x)

LOG: Returns the natural logarithm (base e) of parameter
LOG(x)

LOG10: Returns the logarithm (base 10) of parameter
LOG10(x)

PI: Returns the value of the constant pi
(pi = 3.141593 WBASIC ==> pi = 3.14159265359 TI-59)
PI

RND: Returns a pseudo-random number in the range (0,1)
RND(x)

SEC: Returns the secant of parameter angle in radians
SEC(x)

SIN: Returns the sine of parameter angle in radians
SIN(x)

SQR: Returns the square root of parameter
SQR(x)

TAN: Returns the tangent of parameter angle in radians
TAN(x)

APPENDIX B

CONDENSED BAX59 USER'S GUIDE

This guide is intended to be a useful compendium of important points the user should consider when preparing, cross-compiling, and linking a WBASIC source program with the BAX59 system. Included are suggested programming techniques which will optimize and improve resulting TI-59 code. Some of the information contained in the design document is repeated here for the sake of consistency. There are a few previously unmentioned items, many of which are essential to successful use of the system.

1. Whether you are translating a prewritten WBASIC program or one which you are writing yourself, review it for constructs and functions which are not implemented in BAX59. Use Appendix A as a quick reference for this purpose. Finding and eliminating unimplemented functions is more important than constructs. BAX59 will detect and report construct subset errors, however, unimplemented functions are assumed to be variable identifiers and will be entered in the symbol table as such. An error may or may not be reported as a result of faulty syntax; this depends upon the context of the unimplemented function.
2. Every line of the source program must have a line number, including blank lines. Every line number must be in chronological order between 00000 and 99999 exclusive.
3. The end of the source file does not require the END statement; however, whenever an END statement is encountered, the end of the source program is assumed

and translation halts. The END statement will not generate a TI-59 program stop. If you desire that a TI-59 program halt gracefully, you must use the STOP statement(s) in the WBASIC source code.

4. There is no overhead involved in using blank lines or comments. Although a NOP is generated for each, it is subsequently optimized out during resolution. This also allows unconditional jumps to such constructs without cause for concern. However, such practice is not reccommended and will hamper debugging.

5. You are strongly urged to practice structured programming. While an unstructured program will be translated, its physical correspondence to the original WBASIC source code is likely to be less reccognizable. Also, such a translation will very probably confuse the linker. Ensure that your subroutines have only one entry point and one RETURN, otherwise you will definitely confuse the linker! In order to improve the physical correspondence between source and translation, you are encouraged to use blank lines and comments. This will usually assist in debugging, if required.

6. The structured order of WBASIC program parts should be as follows:

   A. OPTION statement (for BAX59 only)
   B. DATA/READ statements
   C. Main Body (including a at least one STOP)
   D. Function DEF's and Subroutines
   E. END statement

   Note: The linker expects to find the label representing the main body (LBL A) as the first two TI-59 keycodes.

7. There is only one type of numeric data: real. Integers and reals are both considered reals in the TI-59 run-time environment. Numeric entries without

exponent will always be truncated to ten significant digits. If the entry contains an exponent or if the entry must be converted to exponent notation in order to maintain equivalence, then only eight significant digits will be saved (plus two in the exponent). These rules can have a profound effect upon precision errors in numerical computations.

8. Avoid proliferation of variable names. Variable names use registers, your most precious resource! Whenever possible reuse variable names to prevent new register assignments.

9. Do not forget to reserve registers for your own requirements. The "long" function facility always requires one in the range 10-99. The linker always requires two in the range 00-09. An additional two per segment in the range 10-99 will be taken dynamically by the linker after the cross-compiler has made all its assignments. The interface information is passed through the SCRATCH file. Never reserve the last available register, otherwise a memory overflow will never be reported in a warning message.

10. Optimize expressions using the standard rules of operator precedence. Failure to do so may result in unnecessary generation of parentheses.

11. Avoid use of the STEP option in FOR loops. Rely on the default increment (+1) whenever possible.

12. If a user-defined function is to be applied for its side effects only, then use one variable name to invoke all such function calls. For example:

```
00120 INVOKE = FN_ALPHA
00130 INVOKE = FN_BETA(X,Y)
00140 INVOKE = FN_GAMMA
```

13. Although contrary to principles of good structured programming, do not pass any parameters unless

absolutely necessary. Parameter passing uses a great deal of program steps. Furthermore, since actual parameters may be simple expressions, nesting of parentheses can become arbitrarily deep very quickly in a function call. The TI-59 places a limit of nine on the depth of parentheses nests.

14. Remember that the TI-59 allows subroutine (SBR) nesting to a maximum of six levels. This restricts the depth of recursion. However, if the recursive call always returns to the same address, The recursion will probably work. This is because the subroutine return stack will always maintain the correct return address, even if it overflows.

15. BAX59 distinguishes between upper and lower case characters in variable identifiers. Exceptions are the "E" in an exponent, the "FN_" preface of a function, and reserved words. Built-in functions must be written as they appear in the BIFNQF or BIFNLF files (currently, all upper case).

16. WBASIC trignometric functions compute in radians. By default, TI-59 trignometric functions compute in degrees. If trignometric functions are translated, then prior to execution the TI-59 must be reset to the radian mode by entering "2ND RAD."

17. If you plan to modify TI-59 code that has been generated by BAX59, remember that only subroutines have relative addresses. All other addresses are absolute justified. Code insertions or deletions do not rejustify absolute addresses! Unless you are familiar enough with the calculator to know what you are doing, you will create more problems than you fix.

18. The special construct, PAUSE, is provided for assistance in debugging. This is somewhat like a message to the compiler. It translates to the TI-59

keycodes 82 and 31, which are a void key and the "LRN" key. These keycodes cannot be entered directly into the calculator. Instead, enter "STO 31" followed by the editing sequence "BST BST NOP SST." The original "STO 31" will have been changed to "NOP 31." When encountered during run-time, these keys will interrupt execution and cause the calculator to enter its Learn Mode. Other than stopping execution, no other harmful effects result. To resume processing, simply hit "LRN" to show the contents of the current display register, and "R/S" to continue execution. This facility provides a convenient method of process suspension which corresponds physically and logically to the WBASIC source code.

19. The BAX59 OPTION statement may provide other useful facilities for debugging. However, most of these were designed for debugging during installation of enhancements to the BAX59 Cross-Compiler Beware of OPTION parameters 6, 7, and 8. These tend to produce a great deal of output!
20. The BAX59 system will not execute properly unless all associated data files are available to the host operating system on which BAX59 will run. You may modify the information contained in them, however, you should not change the formats. (These files are Appendices D, E, F, G, H, and J.)
21. Do not design excessively long iterative loops or back jumps: the linker cannot handle them. If iteration is required, design loops which translate to back jumps that are well within the TI-59 memory constaints.
22. The key to successful use of the linker is to break very large programs into smaller parts which can be processed sequentially without much repetition.

APPENDIX C

CROSS-COMPILER SOURCE CODE

```
{****************************************************************}
{*                                                              *}
{*                   BAX59 CROSS-COMPILER                       *}
{*                                                              *}
{* IMPLEMENTS A RECURSIVE DESCENT PARSER AND GENERATES          *}
{* A LINKED RECORD DATA STRUCTURE OF TI-59 CODE                 *}
{* TRANSLATED FROM WBASIC LANGUAGE SOURCE CODE.                 *}
{* THE DATA STRUCTURE IS USED TO RESOLVE RELATIVE TI-59         *}
{* ADDRESSES.  A LISTING OF THE ORIGINAL WBASIC PROGRAM         *}
{* INCLUDING DETECTED ERRORS IS GENERATED DURING                *}
{* TRANSLATION.  VARIOUS FORMS OF OUTPUT BESIDES THE            *}
{* LISTING FILE CAN BE TOGGLED ON/OFF FROM WITHIN THE           *}
{* INPUT FILE USING THE "OPTION" STATEMENT.  THIS VERSION       *}
{* OF THE PROGRAM IS DESIGNED TO SUPPLEMENT A WATERLOO          *}
{* BASIC (WBASIC) LANGUAGE INTERPRETER OR COMPILER.  AS         *}
{* SUCH, IT DOES NOT DETECT ALL WBASIC SYNTAX OR SEMANTIC       *}
{* ERRORS.  WBASIC PROGRAMS SHOULD BE SUCCESSFULLY RUN          *}
{* IN THE WBASIC SYSTEM ENVIRONMENT PRIOR TO TRANSLATION        *}
{* WITH THIS CROSS-COMPILER.  THE BAX59 SYSTEM INCLUDES         *}
{* AN INDEPENDENT LINKER (TSDRIVER) WHICH WILL PROPERLY         *}
{* SEGMENT AND ISSUE INSTRUCTIONS FOR MANUALLY LINKING          *}
{* AND EXECUTING A TI-59 PROGRAM GENERATED BY THE CROSS-        *}
{* COMPILER BUT WHICH IS TOO LARGE FOR THE CALCULATOR           *}
{* MEMORY CAPACITY.                                             *}
{*                                                              *}
{****************************************************************}

PROGRAM BAX59    (INPUT,    OUTPUT, BASICF, MSGF,
                  RWTBLF,   LABELF, CTEXTF, BIFNOF, BIFNLF,
                  OUTFILE,  LISTF,  NAMEF,  READF,  SCRATCH);

{****************************************************************}
{*                                                              *}
{*                   SYSTEM PARAMETERS                          *}
{*                                                              *}
{****************************************************************}

{*--------------------------------------------------------------*}
{*                                                              *}
{*                CONST DECLARATIONS (MAIN)                     *}
{*                                                              *}
{*--------------------------------------------------------------*}

CONST RWCHARCT    =    270;  {* TOTAL # OF CHARS IN RW ARRAY     *}
      RWWCRDCT    =     72;  {* TOTAL # OF WORDS IN RW ARRAY     *}
      RWLENGCT    =      9;  {* # OF CHARS IN LONGEST RW         *}
      MAXTOKLEN   =     20;  {* MAX ACCUM LENGTH => MAX TOKEN    *}
      MAXLINLEN   =     66;  {* MAX LENGTH OF BASIC TEXT LINE    *}
      MAXBASLIN   =  99999;  {* MAX BASIC PROGRAM LINE NUMBER    *}
      HASHBASE    =     99;  {* INDEX OF LAST BUCKET (0-99)      *}
      STARTREG    =     00;  {* 1ST REGISTER (LOWEST NUMBER)     *}
      REGBASE     =     90;  {* MAX # AVAILABLE REGISTERS        *}
      LBLBASE     =     72;  {* MAX # OF AVAILABLE LABELS        *}
      FNQLEN      =      4;  {* MAX # STEPS IN QUICK FUNCTION    *}
      FNLLEN      =     15;  {* MAX # STEPS IN  LONG FUNCTION    *}
      FNLREG      =     10;  {* REG USED FOR PARM OF LONG FNS    *}
      FNSTACKLIM  =      6;  {* MAX SBR/FN NESTING LEVEL         *}
      TEXTLEN     =     20;  {* MAX # CHARS IN A CODE TEXT IN    *}
```

```
(*****************************************************************)
(*                                                               *)
(*                    GLOBAL DECLARATIONS                        *)
(*                                                               *)
(*****************************************************************)

(*---------------------------------------------------------------*)
(*    TI-59 KEY CODES:                          OTHER SYMBOLS:  *)
(*---------------------------------------------------------------*)

    K_ZERO =  0;      K_EE     = 52;      BLANK  = ' ';
    K_1    =  1;      K_OPAREN = 53;      ENDLIN = '@';
    K_2    =  2;      K_CPAREN = 54;      ENDFIL = '%';
    K_3    =  3;      K_DIVOP  = 55;      PERIOD = '.';
    K_4    =  4;      K_ENG    = 57;      COMMA  = ',';
    K_5    =  5;      K_FIX    = 58;      USCORE = '_';
    K_6    =  6;      K_INT    = 59;      EXCLAM = '!';
    K_7    =  7;      K_DEG    = 60;      QUOTE  = '''';
    K_8    =  8;      K_GTO    = 61;
    K_9    =  9;      K_PGMIND = 62;
    K_EPR  = 10;      K_EXCIND = 63;
    K_A    = 11;      K_PRDIND = 64;
    K_B    = 12;      K_MULTOP = 65;
    K_C    = 13;      K_PAUSE  = 66;
    K_D    = 14;      K_IFXEQT = 67;
    K_E    = 15;      K_NOP    = 68;
    K_APR  = 16;      K_OP     = 69;
    K_BPR  = 17;      K_RAD    = 70;
    K_CPR  = 18;      K_SBR    = 71;
    K_DPR  = 19;      K_STOIND = 72;
    K_2CLR = 20;      K_RCLIND = 73;
    K_INV  = 22;      K_SUMIND = 74;
    K_LNX  = 23;      K_SUBOP  = 75;
    K_CE   = 24;      K_LBL    = 76;
    K_CLR  = 25;      K_IFXGET = 77;
    K_2INV = 27;      K_SIGMA  = 78;
    K_LOG  = 28;      K_XBAR   = 79;
    K_CP   = 29;      K_GRAD   = 80;
    K_TAN  = 30;      K_RST    = 81;
    K_X_T  = 32;      K_GTOIND = 83;
    K_XSQR = 33;      K_OPIND  = 84;
    K_SRTX = 34;      K_ADDOP  = 85;
    K_XINV = 35;      K_STFLG  = 86;
    K_PGM  = 36;      K_IFFLG  = 87;
    K_P_R  = 37;      K_DMS    = 88;
    K_SIN  = 38;      K_PI     = 89;
    K_COS  = 39;      K_LIST   = 90;
    K_IND  = 40;      K_RS     = 91;
    K_STO  = 42;      K_INVSBR = 92;
    K_RCL  = 43;      K_DECPT  = 93;
    K_SUM  = 44;      K_NEG    = 94;
    K_POWR = 45;      K_EQUALS = 95;
    K_CMS  = 47;      K_WRITE  = 96;
    K_EXC  = 48;      K_DSZ    = 97;
    K_PRD  = 49;      K_ADV    = 98;
    K_ABSX = 50;      K_PRT    = 99;
```

```
(*-----------------------------------------------------------------*)
(* TOKEN NUMBERS USED MOST OFTEN OUTSIDE OF MAIN DRIVER.          *)
(*-----------------------------------------------------------------*)

    ERRORTOK   =  0;          IDENTOK    = RWWORDCT + 1;
    CMTOKEXC   =  1;          NUMBERTOK  = RWWORDCT + 2;
    EQUALTOK   =  2;          ENDLINTOK  = RWWORDCT + 3;
    PLUSTOK    =  3;          ENDFILTOK  = RWWORDCT + 4;
    MINUSTOK   =  4;
    MULTOK     =  5;
    DIVTOK     =  6;          TOTOK      = 20;
    OPARENTOK  =  7;          ORTOK      = 21;
    CPARENTOK  =  8;          CMTOKREM   = 24;
    GTTOK      =  9;          NOTTOK     = 28;
    LTTOK      = 10;          ANDTOK     = 30;
    COMMATOK   = 11;          THENTOK    = 33;
    EXPTOK     = 15;          ELSETOK    = 34;
    NOTEQTOK   = 16;          QUITTOK    = 38;
    GTEQTOK    = 17;          STEPTOK    = 42;
    LTEQTOK    = 18;          ENDLOOPTOK= 67;
```

```
(*---------------------------------------------------------------*)
(*                                                               *)
(*               TYPE DECLARATIONS (MAIN)                        *)
(*                                                               *)
(*---------------------------------------------------------------*)

TYPE  BASLINRNG  = 0..MAXBASLIN;                  (* SUBRANGES *)
      TOKENRNG   = 0..RWWORDCT + 4;
      HASHRNG    = 0..HASHBASE;
      ACCRNG     = 0..MAXTOKLEN;
      LBLRNG     = 0..LBLBASE + 1;
      REGRNG     = 0..99;
      KEYRNG     = 0..99;
      CTEXTRNG   = -2..99;

      LNSTRING   = PACKED ARRAY (.0..MAXLINLEN + 1.) OF CHAR;
      TKSTRING   = PACKED ARRAY (.1..MAXTOKLEN.) OF CHAR;

      LEVEL1     = ARRAY (.1..RWCHARCT + 1.) OF CHAR;
      LEVEL2     = ARRAY (.1..RWWORDCT + 1.) OF INTEGER;
      LEVEL3     = ARRAY (.1..RWLENGCT + 1.) OF INTEGER;

      LBLSTACK   = ARRAY (.LBLRNG.) OF INTEGER;

(*---------------------------------------------------------------*)
(* DATA STRUCTURE USED FOR WBASIC READ/DATA STATEMENTS;          *)
(* ONE DATA ENTRY CONSISTS OF AN OPTIONAL SIGN (DEFAULT          *)
(* IS POSITIVE) AND AN INTEGER OR REAL NUMBER.                   *)
(*---------------------------------------------------------------*)

      DATAITEM = RECORD
                   NUMB : TKSTRING;
                   SIGN : CHAR
                 END;                             (* DATAITEM *)
      DATASTORE = ARRAY (.1..REGBASE.) OF DATAITEM;

(*---------------------------------------------------------------*)
(* DATA STRUCTURE WHICH HOLDS THE TEXT TRANSLATION OF            *)
(* ALL TI-59 KEY CODES READ FROM THE CTEXTF FILE;                *)
(* UNIT FIELD INDICATES INSTRUCTION TYPE:                        *)
(*      0 = SINGLE STEP INSTR (INDEPENDENT)                      *)
(*      1 = 2-STEP INSTR (FOLLOWED BY REG NUMBER)                *)
(*      2 = 3-STEP INSTR (FOLLOWED BY ABSOLUTE ADDR)             *)
(*      3 = 4-STEP INSTR (FOLLOWED BY REG OR FLAG NUMBER         *)
(*                        AND AN ABSOLUTE ADDR)                  *)
(*---------------------------------------------------------------*)

      CODETEXT = RECORD
                   UNIT     : 0..3;
                   CODECHAR : PACKED ARRAY
                                (.1..TEXTLEN.) OF CHAR
                 END;                             (* CODETEXT *)
      CTEXTSTORE = ARRAY (.CTEXTRNG.) OF CODETEXT;
```

```
(*-----------------------------------------------------------*)
(* CODERCD IS A SINGLE NODE IN THE TI-59 CODE DATA          *)
(* STRUCTURE; LINERCD IS A SINGLE NODE IN THE CHAIN OF      *)
(* WBASIC LINE NUMBERS TO WHICH THE TI-59 CODE STRUCTURE    *)
(* IS ATTACHED; THIS PART OF THE CODE DATA STRUCTURE IS     *)
(* USED TO LOCATE PORTIONS OF TI-59 CODE WHICH DIRECTLY     *)
(* CORRESPOND TO WBASIC LINE NUMBERS.                       *)
(*-----------------------------------------------------------*)

     CODEPTR = @CODERCD;
     CODERCD = RECORD
                 ADDR : INTEGER;
                 KEY  : INTEGER;
                 JMPP : CODEPTR;
                 SEQP : CODEPTR;
                 BAKP : CODEPTR
               END;                                 (* CODERCD *)

     LINEPTR = @LINERCD;
     LINERCD = RECORD
                 LINO : BASLINRNG;
                 LPTR : LINEPTR;
                 CPTR : CODEPTR
               END;                                 (* LINERCD *)

(*-----------------------------------------------------------*)
(* SLOTRCDS ARE SYMBOL TABLE SLOTS; SLOTS ARE ATTACHED TO   *)
(* HASH; HASH IS THE SYMBOL TABLE REPRESENTED AS A STATIC   *)
(* ARRAY OF SLOT POINTERS; EACH SLOT POINTER IN HASH        *)
(* REPRESENTS A SINGLE HASH BUCKET; EACH BUCKET MAY HAVE    *)
(* ANY NUMBER OF SLOTS ATTACHED AT THE HEAD POINTER OF      *)
(* EACH BUCKET (LIMITED ONLY BY MACHINE CAPACITY).          *)
(* SLOTS MAY BE OF 4 DIFFERENT TYPES:  VARIABLE IDS,        *)
(* LONG FUNCTION IDS, QUICK FUNCTION IDS, AND PARAMETER     *)
(* (OR PARAMETERLESS) FUNCTION IDS.                         *)
(*-----------------------------------------------------------*)

     IDTYP   = (VARID, FNQID, FNLID, FNPID);
     SLOTPTR = @SLOTRCD;
     HASH    = ARRAY (.HASHRNG.) OF SLOTPTR;
     QKEYSEQ = ARRAY (.1..FNQLEN.) OF KEYRNG;
     LKEYSEQ = ARRAY (.1..FNLLEN.) OF KEYRNG;
     SLOTRCD = RECORD
                 IDENT : TKSTRING;
                 SLOT  : SLOTPTR;
                 CASE TYP : IDTYP OF
                   VARID : (REGNO    : INTEGER;
                            AUXREG1  : INTEGER;
                            AUXREG2  : INTEGER);
                   FNQID : (FNQ      : QKEYSEQ);
                   FNLID : (FNL      : LKEYSEQ;
                            FNLLINK  : SLOTPTR);
                   FNPID : (FNREGNO  : INTEGER;
                            FNP      : SLOTPTR;
                            LBL      : LBLRNG;
                            FNPLINK  : SLOTPTR)
               END;                                 (* SLOTRCD *)
```

```
(*----------------------------------------------------------------*)
(*                                                                *)
(*                  VAR DECLARATIONS (MAIN)                       *)
(*                                                                *)
(*----------------------------------------------------------------*)

(*----------------------------------------------------------------*)
(* OPTION TOGGLES ARE BOOLEANS WHICH CAN BE SWITCHED FROM        *)
(* WITHIN THE WBASIC SOURCE PROGRAM USING THE "OPTION"           *)
(* STATEMENT; EXCEPT FOR ZERO (LINKER INTERFACE TOGGLE),         *)
(* THE RULE IS THAT A '+' SETS/RESETS TOGGLE TRUE, WHILE         *)
(* A '-' SETS/RESETS TOGGLE FALSE; DEFAULT VALUES ARE            *)
(* INDICATED IN THE COMMENT FOLLOWING EACH DECLARATION.          *)
(*----------------------------------------------------------------*)

VAR     LINK59 : BOOLEAN;                (* OPTION 0 = FALSE *)
        PC100  : BOOLEAN;                (* OPTION 1 = TRUE  *)
        OPTPAR : BOOLEAN;                (* OPTION 2 = TRUE  *)
        OPTNOP : BOOLEAN;                (* OPTION 3 = TRUE  *)
        CODUMP : BOOLEAN;                (* OPTION 4 = TRUE  *)
        SYDUMP : BOOLEAN;                (* OPTION 5 = FALSE *)
        DSDUMP : BOOLEAN;                (* OPTION 6 = FALSE *)
        TOKOUT : BOOLEAN;                (* OPTION 7 = FALSE *)
        TOKLIS : BOOLEAN;                (* OPTION 8 = FALSE *)

(*----------------------------------------------------------------*)
(* SETS USED IN VARIOUS TESTS FOR CHARS, TOKEN NUMBERS,          *)
(* TI-59 KEY CODES, AND REGISTERS.                               *)
(*----------------------------------------------------------------*)

        LETTERS, DIGITS, ALFANUM : SET OF CHAR;
        DOUBLE1, DOUBLE2         : SET OF CHAR;
        SPECIALS, SIGNS          : SET OF CHAR;
        SUBERROR, CRITICAL       : SET OF CHAR;
        BINOPTOKS, RELOPTOKS     : SET OF TOKENRNG;
        TRAILTOKS, SIGNTOKS      : SET OF TOKENRNG;
        BEGIN_EXPRTOKS           : SET OF TOKENRNG;
        NUMERICKEY               : SET OF KEYRNG;
        RESERVE_REG              : SET OF REGRNG;

(*----------------------------------------------------------------*)
(* RESERVED WORD TABLE CHARACTER AND INDEX ARRAYS.               *)
(*----------------------------------------------------------------*)

        RWCHAR : LEVEL1;
        RWWORD : LEVEL2;
        RWLENG : LEVEL3;

(*----------------------------------------------------------------*)
(* SCANNER ASSOCIATED GLOBAL VARIABLES.                          *)
(*----------------------------------------------------------------*)

        ACCUM                    : TKSTRING;
        ACCINX                   : ACCRNG;
        LINEBUF                  : LNSTRING;
        LNBINX                   : 0..MAXLINLEN + 1;
        LINUM, LLINUM, CLINUM    : BASLINRNG;
        TOKNUM, LTOKNUM          : TOKENRNG;
        LCOUNT, RCOUNT, ECOUNT   : INTEGER;
        FLAGCMT                  : BOOLEAN;
```

```
(*-------------------------------------------------------------*)
(* PARSE ASSOCIATED GLOBAL VARIABLES.                          *)
(*-------------------------------------------------------------*)

     ERRORCT, WARNCT : INTEGER;
     NEXTREG         : INTEGER;
     LBLCT           : LBLRNG;
     RESERVECT       : REGRNG;

     CTEXT           : CTEXTSTORE;
     DATALIST        : DATASTORE;
     DATAIX, READIX  : 1..REGBASE;
     INDEXERROR      : BOOLEAN;
     FIRSTREAD       : BOOLEAN;

     CLABEL                       : LBLSTACK;

     BUCKET                       : HASH;
     IDSLOT                       : SLOTPTR;
     LP, LPCUR                    : LINEPTR;
     LPLEAD, LPTRAIL              : LINEPTR;
     CP, CPCUR                    : CODEPTR;
     FIRSTLP, LASTLP              : LINEPTR;          (* MARKERS *)
     BEGINCP, ENDCP               : CODEPTR;          (* MARKERS *)

     FNSTACK, FNLLIST             : SLOTPTR;
     FNSTACKCT                    : INTEGER;

     IFSTACK, ENDIFSTACK          : CODEPTR;
     LOOPSTACK, ENDLOOPSTACK      : CODEPTR;
     FORSTACK, NEXTSTACK          : CODEPTR;

(*-------------------------------------------------------------*)
(* FILES                                                       *)
(*-------------------------------------------------------------*)

     RWTBLF, LABELF, CTEXTF       : TEXT;  (* INITIAL FILES     *)
     BIFNCF, BIFNLF               : TEXT;  (* BUILT-IN FNS      *)
     BASICF, MSGF                 : TEXT;  (* INPUT FILES       *)
     LISTF,  NAMEF, READF         : TEXT;  (* OUTPUT FILES      *)
     OUTFILE                      : TEXT;  (* TERMINAL FILE     *)
     SCRATCH                      : TEXT;  (* LINKER INTERFACE  *)
```

```
(*****************************************************************)
(*                                                               *)
(*                  PRIMITIVE CHAR ROUTINES                      *)
(*                                                               *)
(*****************************************************************)

(*-01-----------------------------------------------------------*)
(* UPCASE CONVERTS ANY LOWER CASE EBCDIC (OR ASCII) CHAR       *)
(* TO UPPER CASE EQUIVALENT.                                   *)
(*-------------------------------------------------------------*)

FUNCTION UPCASE (VAR CH : CHAR) : CHAR;

BEGIN
  IF CH IN (.'a'..'i'.) THEN
    UPCASE := CHR(ORD(CH) - ORD('a') + ORD('A'))
  ELSE IF CH IN (.'j'..'r'.) THEN
    UPCASE := CHR(ORD(CH) - ORD('j') + ORD('J'))
  ELSE IF CH IN (.'s'..'z'.) THEN
    UPCASE := CHR(ORD(CH) - ORD('s') + ORD('S'))
  ELSE
    UPCASE := CH
END;                                         (* UPPERCASE *)

(*****************************************************************)

(*-02-----------------------------------------------------------*)
(* TRANSDIGIT RETURNS THE INTEGER VALUE FOR NUMERIC CHARS      *)
(*-------------------------------------------------------------*)

FUNCTION TRANSDIGIT (CH : CHAR) : INTEGER;

BEGIN
  TRANSDIGIT := ORD (CH) - ORD ('0')
END;                                        (* TRANSDIGIT *)

(*****************************************************************)

(*-03-----------------------------------------------------------*)
(* XNUMBER RETURNS INTEGER VALUE OF A NUMERIC CHAR STRING      *)
(*-------------------------------------------------------------*)

FUNCTION XNUMBER (ACCUM:TKSTRING; ACCINX:ACCRNG) : INTEGER;

VAR   I, TEMPNR : INTEGER;

BEGIN
  TEMPNR := 0;
  FOR I := 1 TO ACCINX DO
    TEMPNR := TEMPNR * 10 + TRANSDIGIT (ACCUM(.I.));
  XNUMBER := TEMPNR
END;                                           (* XNUMBER *)

(*****************************************************************)
```

```
(*-04-----------------------------------------------------------*)
(* ZEROPAD WRITES INTEGERS TO AN OUTFILE WITH LEADING 0'S *)
(*--------------------------------------------------------------*)

PROCEDURE ZEROPAD (VAR WFILE : TEXT; N, ZCT : INTEGER);

VAR  I, TN : INTEGER;

BEGIN
  TN := N;
  REPEAT
    TN := TN DIV 10;
    ZCT := ZCT - 1
  UNTIL TN = 0;
  FOR I := 1 TO ZCT DO
    WRITE (WFILE, '0');
  IF N >= 0 THEN
    WRITE (WFILE, N:1)
  ELSE
    WRITE (WFILE, -N:1, '-')
END;                                                  (* ZEROPAD *)
```

```
(*********************************************************************)
(*                                                                   *)
(*                            SCANNER                                *)
(*                                                                   *)
(*********************************************************************)

(*-05---------------------------------------------------------------*)
(* SCAN USES THE RESERVED WORD ARRAYS TO ISOLATE AND                 *)
(* RETURN SINGLE TOKENS FROM THE WBASIC SOURCE FILE;                 *)
(* IT ALSO REWRITES THE SOURCE CODE TO THE LISTF FILE                *)
(* ALONG WITH ANY SCANNER DETECTED ERRORS; SCAN INSERTS              *)
(* ITS OWN END-OF-LINE AND END-OF-FILE CONTROL CHARACTERS            *)
(* INTO ITS LINE BUFFER (LINBUF) AS THESE CHARS ARE                  *)
(* DETECTED IN THE SOURCE FILE.                                      *)
(*-----------------------------------------------------------------*)

PROCEDURE SCAN (VAR TOKNUM : TOKENRNG);

VAR    TCHAR : CHAR;
       I     : INTEGER;

(*=================================================================*)

(*-05-01-----------------------------------------------------------*)
(* LINENR RETURNS NUMBER OF THE CURRENTLY SCANNED WBASIC           *)
(* LINE; WRITES THE LINE NUMBER TO THE LISTF FILE                  *)
(* PADDED WITH ZEROS.                                              *)
(*-----------------------------------------------------------------*)

FUNCTION LINENR : BASLINRNG;

VAR I : BASLINRNG;

BEGIN
  READ (BASICF, I);
  ZEROPAD (LISTF, I, 5);
  LINENR := I
END;                                                  (* LINENR *)

(*-----------------------------------------------------------------*)

(*-05-02-----------------------------------------------------------*)
(* RDLINE READS TEXT IMMEDIATELY FOLLOWING LINE NUMBER;            *)
(* RETURNS THE TEXT IN A MAXLINLEN CHAR BUFFER; UNUSED             *)
(* PORTION OF BUFFER IS FILLED WITH BLANKS; WRITES EACH            *)
(* CHAR OF TEXT TO THE LISTF FILE AS IT IS READ; REPORTS           *)
(* AN ERROR IF NUMBER OF CHARS EXCEEDS MAXLINLEN.                  *)
(*-----------------------------------------------------------------*)

FUNCTION RDLINE : LNSTRING;

VAR I, J, LINLENGTH : INTEGER;
    CH : CHAR;

BEGIN
  I := 0;
  WHILE (NOT(EOLN(BASICF))) AND (I < MAXLINLEN) DO
    BEGIN
      I := I + 1;
      READ (BASICF, CH);
      RDLINE(.I.) := CH;
      WRITE (LISTF, CH)
    END;
  WRITELN (LISTF);
  LINLENGTH := I;
  LNBINX := 0;
  IF LINLENGTH < MAXLINLEN THEN   (* FILL UNUSED W/ BLANKS *)
    FOR J := LINLENGTH + 1 TO MAXLINLEN DO
      RDLINE(.J.) := BLANK;
```

```
  IF (LINLENGTH = MAXLINLEN) AND (NOT EOLN(BASICF)) THEN
    BEGIN
      WRITE   (LISTF,'**F** SCAN ERROR...LENGTH OF TEXT ');
      WRITELN (LISTF,'AFTER LINUM > ',MAXLINLEN:2,' CHARS');
      ERRORCT := ERRORCT + 1;
      REPEAT              (* LOCATE THE EOLN CHAR TO RECOVER *)
        GET (BASICF)
      UNTIL EOLN(BASICF)
    END;
  RDLINE(.LINLENGTH + 1.) := ENDLIN;   (* INSERT EOLN CHAR *)
  GET (BASICF);      (* MOVE FILE PTR PAST PASCAL EOLN CHAR *)
  IF EOF(BASICF) THEN         (* OVERWRITE EOLN CHAR IF EOF *)
    RDLINE(.LINLENGTH + 1.) := ENDFIL
END;                                              (* RDLINE *)

(*-------------------------------------------------------------*)

(*-05-03-------------------------------------------------------*)
(* GETNOBLANK RETURNS FIRST NON-BLANK CHAR STARTING WITH      *)
(* THE CURRENT CHAR REFERENCED BY THE LINBUF INDEX.           *)
(*-------------------------------------------------------------*)

FUNCTION GETNOBLANK : CHAR;

BEGIN
  WHILE LINBUF(.LNBINX.) = BLANK DO
    LNBINX := LNBINX + 1;
  GETNOBLANK := LINBUF(.LNBINX.)
END;                                          (* GETNOBLANK *)

(*-------------------------------------------------------------*)

(*-05-04-------------------------------------------------------*)
(* GETCHAR RETURNS THE CHAR FOLLOWING LINE BUFFER INDEX       *)
(* AND INCREMENTS THE LINE BUFFER INDEX.                       *)
(*-------------------------------------------------------------*)

FUNCTION GETCHAR : CHAR;

BEGIN
  LNBINX := LNBINX + 1;
  GETCHAR := LINBUF(.LNBINX.)
END;                                             (* GETCHAR *)

(*-------------------------------------------------------------*)

(*-05-05-------------------------------------------------------*)
(* PUTCHAR INCREMENTS THE ACCUM INDEX AND PLACES A CHAR       *)
(* INTO THAT POSITION IN THE ACCUM ARRAY.                      *)
(*-------------------------------------------------------------*)

PROCEDURE PUTCHAR (CH : CHAR);

BEGIN
  IF NOT (ACCINX >= MAXTOKLEN) THEN
    BEGIN
      ACCINX := ACCINX + 1;
      ACCUM(.ACCINX.) := CH
    END
END;                                             (* PUTCHAR *)

(*-------------------------------------------------------------*)
```

```
(*-05-06-----------------------------------------------------*)
(* PUTANDGET PUTS A CURRENT CHAR INTO ACCUM AND GETS THE     *)
(* NEXT CHAR FROM THE LINE BUFFER.                           *)
(*-----------------------------------------------------------*)

FUNCTION PUTANDGET (CH : CHAR) : CHAR;

BEGIN
  PUTCHAR (CH);
  PUTANDGET := GETCHAR
END;                                         (* PUTANDGET *)

(*-----------------------------------------------------------*)

(*-05-07-----------------------------------------------------*)
(* NUMSPOOL READS ALL DIGITS WHICH COMPRISE ONE UNSIGNED     *)
(* INTEGER AND PUTS THEM INTO THE ACCUM IN SEQUENCE;         *)
(* THE NUMBER OF DIGITS SPOOLED IS RETURNED.                 *)
(*-----------------------------------------------------------*)

FUNCTION NUMSPOOL : INTEGER;

VAR I : INTEGER;
BEGIN
  IF TCHAR IN DIGITS THEN
    BEGIN
      I := 0;
      WHILE TCHAR IN DIGITS DO
        BEGIN
          TCHAR := PUTANDGET(TCHAR);
          I := I + 1
        END;
      NUMSPOOL := I
    END
  ELSE
    NUMSPOOL := 0
END;                                         (* NUMSPOOL *)

(*-----------------------------------------------------------*)

(*-05-08-----------------------------------------------------*)
(* EXPONENT READS THE CHARS WHICH COMPRISE AN EXPONENT       *)
(* PART, COUNTS THEM, AND PUTS THEM INTO THE ACCUM.          *)
(*-----------------------------------------------------------*)

PROCEDURE EXPONENT;

BEGIN
  IF (UPCASE(TCHAR) = 'E') THEN
    BEGIN
      TCHAR := PUTANDGET(TCHAR);
      IF TCHAR IN SIGNS THEN
        TCHAR := PUTANDGET(TCHAR)
      ELSE
        PUTCHAR('+');
      ECOUNT := NUMSPOOL
    END
END;                                         (* EXPONENT *)

(*-----------------------------------------------------------*)
```

```
(*-05-09------------------------------------------------------*)
(* DECIMALPT READS AND COUNTS THE DIGITS IN THE               *)
(* FRACTIONAL PART OF A NUMBER AND PUTS THEM INTO ACCUM.      *)
(*------------------------------------------------------------*)

PROCEDURE DECIMALPT;

BEGIN
  IF TCHAR = PERIOD THEN
    BEGIN
      TCHAR := PUTANDGET(TCHAR);
      RCCUNT := NUMSECOL
    END
END;                                          (* DECIMALPT *)

(*------------------------------------------------------------*)

(*-05-10------------------------------------------------------*)
(* ADJUST IS HIGHLY CALCULATOR-DEPENDENT; ADJUSTS ALL         *)
(* LITERAL NUMERICS TO TI-59 FORMAT; SETS VALUES FOR          *)
(* LCCUNT, RCOUNT, AND ECOUNT (LEFT, RIGHT, EXPONENT).        *)
(* TI-59 WILL ACCEPT FROM ITS KEYBOARD A MAX OF 10 DIGITS     *)
(* (PLUS DECIMAL POINT AND SIGN) FOR INTEGERS OR REALS        *)
(* WITHOUT EXPONENT, OR 8 DIGITS (PLUS DECIMAL POINT AND      *)
(* SIGN) AND 2 DIGIT SIGNED EXPONENT.  SINCE NUMBERS ARE      *)
(* SCANNED AND PUT INTO THE ACCUM AS THEY ARE READ IN         *)
(* WBASIC SOURCE CODE, THOSE WHICH EXCEED THE ABOVE           *)
(* MAXIMUMS MUST BE CONVERTED WHILE IN THE ACCUM.             *)
(* THIS ROUTINE IS DIFFICULT TO UNDERSTAND, MUCH LESS         *)
(* VISUALIZE, WITHOUT USING A SPECIFIC EXAMPLE TO WALK-       *)
(* THROUGH ON PAPER.                                          *)
(*------------------------------------------------------------*)

PROCEDURE ADJUST;

(*-05-10-01---------------------------------------------------*)
(* MOVEXP SHIFTS THE POSITION OF THE EXPONENT PART SO         *)
(* THAT THE NUMBER HAS MAX OF 8 SIGNIFICANT DIGITS, SIGN,     *)
(* AND DECIMAL POINT (NOTE:  SIGNIFICANCE IS LOST).           *)
(*------------------------------------------------------------*)

PROCEDURE MOVEXP;

VAR I : INTEGER;

BEGIN
  FOR I := 1 TO (2 + ECOUNT) DO
    ACCUM(.9 + I.) := ACCUM(.LCOUNT + RCOUNT + 1 + I.);
  ACCINX := 11 + ECOUNT
END;                                             (* MOVEXP *)

(*------------------------------------------------------------*)
```

```
(*-05-10-02-----------------------------------------------------*)
(* ADJEXP CONVERTS NUMBERS TO EQUIVALENT TI-59 COMPATIBLE      *)
(* FORM BY COORDINATING EXPONENT VALUE ADJUSTMENT WITH         *)
(* DECIMAL POINT MOVEMENT AND DIGIT TRUNCATION.                *)
(*--------------------------------------------------------------*)

PROCEDURE ADJEXP (DIFF : INTEGER);

VAR E1, E2, EXP, NEWEXP : INTEGER;

BEGIN
  E1  := ORD(ACCUM(.12.)) - ORD('0');
  E2  := ORD(ACCUM(.13.)) - ORD('0');
  EXP := 10 * E1 + E2;
  IF ACCUM(.11.) = '-' THEN
    NEWEXP := EXP - DIFF
  ELSE
    NEWEXP := EXP + DIFF;
  E1 := TRUNC(NEWEXP/10);
  E2 := NEWEXP - (E1 * 10);
  ACCUM(.12.) := CHR(E1 + ORD('0'));
  ACCUM(.13.) := CHR(E2 + ORD('0'))
END;                                                 (* ADJEXP *)

(*--------------------------------------------------------------*)

BEGIN    (* ADJUST MAIN *)
  IF (LCOUNT > 10) OR ((LCOUNT > 8) AND (ECOUNT <> 0)) THEN
    BEGIN
      ACCUM(.9.) := PERIOD;
      IF ECOUNT = 0 THEN
        BEGIN
          ACCUM(.10.) := 'E';
          ACCUM(.11.) := '+';
          ACCUM(.12.) := '0';
          ACCUM(.13.) := '0';
          ACCINX := 13
        END
      ELSE
        BEGIN
          MOVEXP;
          IF ECOUNT = 1 THEN
            BEGIN
              ACCUM(.13.) := ACCUM(.12.);
              ACCUM(.12.) := '0';
              ACCINX := 13
            END
        END;
      ADJEXP(LCOUNT - 8);
      LCOUNT := 8;  RCOUNT := 0;  ECOUNT := 2
    END
  ELSE IF (LCOUNT + RCOUNT > 10) OR
          ((LCOUNT + RCOUNT > 8) AND (ECOUNT <> 0)) THEN
    BEGIN
      IF ECOUNT = 0 THEN
        BEGIN
          ACCINX := 11;
          RCOUNT := 10 - LCOUNT
        END
      ELSE
        BEGIN
          MOVEXP;
          RCOUNT := 8 - LCOUNT
        END
    END
END;                                                 (* ADJUST *)

(*--------------------------------------------------------------*)
```

```
(*-05-11--------------------------------------------------------*)
(* RWLOOKUP LOOKS UP TOKEN IN RESERVE WORD TBL BASED UPON       *)
(* TOKEN LENGTH; RETURNS TOKEN NUMBER; IF NOT FOUND,            *)
(* TCKNUM = IDENTOK (IE. TOKEN IS ASSUMED IDENTIFIER).          *)
(*--------------------------------------------------------------*)

FUNCTION RWLOOKUP : INTEGER;

VAR MATCH : BOOLEAN;
    CHINDX, WDINDX, LGINDX, ACINDX : INTEGER;

BEGIN
  LGINDX := ACCINX;
  WDINDX := RWLENG(.LGINDX.);
  REPEAT
    MATCH := TRUE;
    ACINDX := 1;
    CHINDX := RWWORD(.WDINDX.);
    WHILE (MATCH) AND (ACINDX <= LGINDX) DO
      BEGIN
        IF UPCASE(ACCUM(.ACINDX.)) <> RWCHAR(.CHINDX.) THEN
          MATCH := FALSE
        ELSE
          BEGIN
            ACINDX := ACINDX + 1;
            CHINDX := CHINDX + 1
          END
      END;
    WDINDX := WDINDX + 1
  UNTIL (MATCH) OR (CHINDX = RWWORD(.RWLENG(.LGINDX+1.).));
  IF MATCH THEN
    RWLOOKUP := WDINDX - 1         (* BACK-UP THE WORD INDEX *)
  ELSE
    RWLOOKUP := IDENTOK
END;                                             (* RWLOOKUP *)

(*--------------------------------------------------------------*)

(*-05-12--------------------------------------------------------*)
(* CMTSPOOL READS AND DISREGARDS THE TEXT OF COMMENTS.          *)
(* FLAGCMT IS USED FOR COMMENTS CONTINUED ON NEW LINE.          *)
(*--------------------------------------------------------------*)

PROCEDURE CMTSPOOL;

BEGIN
  FLAGCMT := FALSE;       (* RESET COMMENT CONTINUATION FLAG *)
  WHILE NOT (TCHAR IN CRITICAL) DO
    TCHAR := GETCHAR;
  IF TCHAR = '&' THEN
    FLAGCMT := TRUE
END;                                             (* CMTSPOOL *)

(*--------------------------------------------------------------*)

(*-05-13--------------------------------------------------------*)
(* RECOVER SCANS AND DISREGARDS THE REMAINDER OF THE            *)
(* CURRENT TOKEN AND STOPS AT START OF NEXT TOKEN.              *)
(*--------------------------------------------------------------*)

PROCEDURE RECOVER;

BEGIN
  WHILE NOT (TCHAR IN (CRITICAL + (.BLANK.))) DO
    TCHAR := GETCHAR      (* SKIP TO NEXT TOKEN AND RETURN *)
END;                                              (* RECOVER *)

(*==============================================================*)
```

```
BEGIN   (* SCAN MAIN *)

  LTOKNUM := TOKNUM;     (* SAVE LAST TOKNUM IN LTOKNUM          *)
  TOKNUM := ERRORTOK;    (* INITIALIZE NEW TOKEN NUMBER          *)
  ACCINX := 0;           (* INDICATES TOKEN LENGTH IN ACCUM      *)
  LCOUNT := 0;           (* NO. OF DIGITS LEFT  OF DECIMAL       *)
  RCOUNT := 0;           (* NO. OF DIGITS RIGHT OF DECIMAL       *)
  ECOUNT := 0;           (* NO. OF DIGITS IN EXPONENT            *)
  TCHAR := GETNOBLANK;   (* GET NEXT NON-BLANK CHAR              *)

  IF (TCHAR = ENDFIL) THEN
    TOKNUM := ENDFILTOK

  ELSE IF (TCHAR = '&') THEN
    BEGIN
      CLINUM := LINENR;       (* READ LINE NO. OF CONT LINE      *)
      LINBUF := RDLINE;       (* READ TEXT OF CONT LINE          *)
      TCHAR := GETCHAR;       (* MOVE LNBINX PAST TRAIL "&"      *)
      TCHAR := GETNOBLANK;    (* FIND LEADING "&" ON NEW LINE    *)
      TCHAR := GETCHAR;       (* MOVE LNBINX PAST CONT "&"       *)
      IF FLAGCMT THEN
        CMTSPOOL              (* COMMENT CONTINUATION            *)
      ELSE
        SCAN (TOKNUM)         (* SCAN NEXT TOKEN AFTER "&"       *)
    END

  ELSE IF (TCHAR = ENDLIN) THEN
    BEGIN
      LLINUM := LINUM;        (* PASS LINUM TO LAST LINUM         *)
      LINUM := LINENR;        (* READ LINE NO. OF NEW LINE        *)
      LINBUF := RDLINE;       (* READ TEXT OF NEW LINE            *)
      TCHAR := GETCHAR;       (* MOVE LNBINX PAST ENDLIN CHAR     *)
      TOKNUM := ENDLINTOK     (* ASSIGN TOKEN NO. FOR ENDLIN      *)
    END

  ELSE IF (TCHAR IN LETTERS) THEN
    BEGIN
      WHILE (TCHAR IN ALFANUM) DO
        BEGIN
          TCHAR := PUTANDGET(TCHAR);
          IF TCHAR = USCORE THEN      (* ASSUMES USCORE WILL *)
            TCHAR := PUTANDGET(TCHAR) (* NOT OCCUR AT END    *)
        END;
      IF ACCINX <= RWLENGCT THEN
        BEGIN
          TOKNUM := RWLOOKUP;
          IF TOKNUM = CMTOKREM THEN   (* LOOK FOR REM CMT *)
            CMTSPOOL
        END
      ELSE
        TOKNUM := IDENTOK
    END

  ELSE IF (TCHAR IN DIGITS) THEN
    BEGIN
      LCOUNT := NUMSPCOL;
      IF TCHAR = PERIOD THEN
        DECIMALPT
      ELSE IF (UPCASE(TCHAR) = 'E') THEN
        PUTCHAR(PERIOD);
      EXPONENT;
      ADJUST;
      TOKNUM := NUMBERTOK
    END
```

```
ELSE IF (TCHAR = PERIOD) THEN
   BEGIN
      DECIMALPT;
      EXECNENT;
      ADJUST;
      TOKNUM := NUMBERTOK
   END

ELSE IF (TCHAR IN DOUBLE1) THEN
   BEGIN
      TCHAR := PUTANDGET(TCHAR);
      IF (TCHAR IN DOUBLE2) THEN
         TCHAR := PUTANDGET(TCHAR);
      TOKNUM := RWLOCKUP
   END

ELSE IF (TCHAR IN SPECIALS) THEN
   BEGIN
      TCHAR := PUTANDGET(TCHAR);
      TOKNUM := RWLOCKUP;
      IF TOKNUM = CMTCKEXC THEN      (* LOOK FOR EXCLAM CMT *)
         CMTSPOOL
   END

ELSE IF (TCHAR IN SUBERROR) THEN
   BEGIN
      WRITE   (LISTF, '**F** SCAN ERROR FOUND AT "', TCHAR);
      WRITELN (LISTF, '"...CHAR NOT IN THIS SUBSET');
      ERRCRCT := ERRCRCT + 1;
      RECOVER
   END

ELSE
   BEGIN
      WRITE   (LISTF, '**F** SCAN ERROR FOUND AT "', TCHAR);
      WRITELN (LISTF, '"...UNRECOGNIZABLE CHAR');
      ERRCRCT := ERRORCT + 1;
      RECOVER
   END;

FOR I := (ACCINX + 1) TO MAXTOKLEN DO
   ACCUM(.I.) := BLANK;   (* BLANK OUT REMAINDER OF ACCUM *)

(*-------------------------------------------------------------*)
(* DEBUGGING TOOL:  LISTS TOKNUM AND TOKEN AS IT IS READ.     *)
 IF TOKCUT THEN                                (* OPTION 7 *)
   WRITELN (OUTFILE, ' ':6, TOKNUM:2, '   |', ACCUM, '|');
 IF TOKLIS THEN                                (* OPTION 8 *)
   WRITELN (LISTF, ' ':6, TOKNUM:2, '   |', ACCUM, '|')
(*-------------------------------------------------------------*)

END;                                             (* SCAN *)
```

```
(*****************************************************************)
(*                                                               *)
(*            ERROR/LINE END HANDLING ROUTINES                   *)
(*                                                               *)
(*****************************************************************)

(*-06-----------------------------------------------------------*)
(* PRECOVER SCANS A LINE AND DISREGARDS TOKENS UNTIL IT        *)
(* FINDS A COMMENT, AN END OF LINE, OR AN END OF FILE.         *)
(*-------------------------------------------------------------*)

PROCEDURE PRECOVER;

BEGIN
  WHILE NOT (TOKNUM IN TRAILTOKS) DO
    SCAN (TOKNUM)
END;                                          (* PRECOVER *)

(*****************************************************************)

(*-20-*)
PROCEDURE GENKEY (OPCODE : INTEGER);                  FORWARD;

(*****************************************************************)

(*-07-----------------------------------------------------------*)
(* PERROR IS THE GENERAL PURPOSE ERROR HANDLER WHICH:          *)
(* GENERATES SPACE FOR REGISTER OR ADDRESS INSERTION IN        *)
(* ORDER TO PREVENT THE CODEDUMP ROUTINE FROM CAUSING A        *)
(* SYSTEM ERROR DUE TO INVALID TI-59 CODE GENERATION;          *)
(* ANNOTATES THE LISTING FILE WITH THE ERROR LOCATION;         *)
(* INCREMENTS THE ERROR COUNT; RECOVERS TO END OF LINE.        *)
(*-------------------------------------------------------------*)

PROCEDURE PERROR;

BEGIN
  GENKEY (-1);  (* GENERATE REG/ADDR SPACE TO PROTECT CODE *)
  GENKEY (-1);  (* DUMP ROUTINE FROM OPERATING SYS ERROR.  *)
  WRITELN (LISTF,'**F** FATAL ERROR FOUND AT "',ACCUM,'"');
  ERRORCT := ERRORCT + 1;
  PRECOVER
END;                                            (* PERROR *)

(*****************************************************************)

(*-08-----------------------------------------------------------*)
(* PSUBERROR DISTINGUISHES AN ERROR WHICH IS A RESULT OF       *)
(* USING A WBASIC COMMAND NOT IN THIS IMPLEMENTATION.          *)
(*-------------------------------------------------------------*)

PROCEDURE PSUBERROR;

BEGIN
  WRITELN (LISTF,'**F** SUBSET ERROR FOUND AT "',ACCUM,'"');
  ERRORCT := ERRORCT + 1;
  PRECOVER
END;                                         (* PSUBERROR *)

(*****************************************************************)
```

```
(*-09-----------------------------------------------------------*)
(* PWARN IS USED TO LOCATE THE CAUSE OF A WARNING FOR THE     *)
(* USER AND TO INCREMENT THE WARNING MSG COUNT; NOTE THAT     *)
(* NORMAL COMPILATION CONTINUES.                              *)
(*-------------------------------------------------------------*)

PROCEDURE PWARN;

BEGIN
  WRITELN (LISTF, '**W** WARNING TRIGGERED AT "',ACCUM,'"');
  WARNCT := WARNCT + 1
END;                                               (* PWARN *)

(***************************************************************)

(*-10-----------------------------------------------------------*)
(* CLOSELINE IS A GENERAL PURPOSE PROCEDURE USED WHEN THE     *)
(* END OF A LINE IS EXPECTED BUT IT IS NOT KNOWN WHETHER      *)
(* OR NOT THE LINE BUFFER INDEX IS IN FRONT OF OR AT THE      *)
(* END OF LINE/FILE CHAR; MAY ALSO BE A COMMENT PRIOR TO.     *)
(*-------------------------------------------------------------*)

PROCEDURE CLOSELINE;

BEGIN
  IF NOT (TCKNUM IN TRAILTOKS) THEN
    SCAN (TCKNUM);
  IF NOT (TCKNUM IN TRAILTOKS) THEN
    PERROR
END;                                           (* CLOSELINE *)
```

```
(****************************************************************)
(*                                                              *)
(*             SYMBOL TABLE MANAGEMENT ROUTINES                 *)
(*                                                              *)
(****************************************************************)

(*-11----------------------------------------------------------*)
(* HASHVAL RETURNS THE HASH VALUE OF THE STRING CONTAINED     *)
(* IN THE ACCUM (SUM OF ORD VALUES OF CHARS MOD HASHBASE)     *)
(*-------------------------------------------------------------*)

FUNCTION HASHVAL (ACCUM:TKSTRING; ACCINX:INTEGER) : HASHRNG;

VAR   HASHSUM, I : INTEGER;

BEGIN
  HASHSUM := 0;
  FOR I := 1 TO ACCINX DO
    HASHSUM := HASHSUM + ORD (ACCUM(.I.));
  HASHVAL := HASHSUM MOD (HASHBASE + 1)
END;                                                (* HASHVAL *)

(****************************************************************)

(*-12----------------------------------------------------------*)
(* GETSLCT HASHES ID STRING IN ACCUM INTO SYMBOL TABLE;       *)
(* INSERTS NEW SLOT INTO CORRECT HASH BUCKET AND ENTERS       *)
(* IDENTIFIER NAME INTO IDENT FIELD; RETURNS SLOT POINTER     *)
(* TO THE NEW SLOT BUT VARIANT TAG TYP IS UNDECLARED.         *)
(*-------------------------------------------------------------*)

FUNCTION GETSLOT (ACCUM:TKSTRING; ACCINX:ACCRNG) : SLOTPTR;

VAR CURHASH : HASHRNG;
    IDSLCT  : SLOTPTR;

BEGIN
  CURHASH := HASHVAL (ACCUM, ACCINX);
  NEW (IDSLCT);
  IDSLOT@.IDENT := ACCUM;
  IDSLCT@.SLOT := BUCKET(.CURHASH.);
  BUCKET(.CURHASH.) := IDSLCT;
  GETSLOT := IDSLOT
END;                                                (* GETSLCT *)

(****************************************************************)

(*-13----------------------------------------------------------*)
(* FN_CHK RETURNS TRUE/FALSE AS TO WHETHER OR NOT AN          *)
(* ACCUM STRING DESIGNATES A USER DEFINED FUNCTION OR NOT     *)
(*-------------------------------------------------------------*)

FUNCTION FN_CHK (ACCUM : TKSTRING) : BOOLEAN;

BEGIN
  FN_CHK := FALSE;
  IF (UPCASE (ACCUM(.1.)) = 'F') AND
     (UPCASE (ACCUM(.2.)) = 'N') AND
             (ACCUM(.3.)  = USCORE)
  THEN
    FN_CHK := TRUE
END;                                                (* FN_CHK *)

(****************************************************************)
```

```
(*-14-----------------------------------------------------------*)
(* NEWREG RETURNS THE VALUE OF THE NEXT REGISTER WHICH         *)
(* AVAILABLE FOR USE AS VARIABLE STORAGE; RESERVED REGS        *)
(* ARE SKIPPED AND A COUNT IS MAINTAINED TO IDENTIFY THE       *)
(* POINT AT WHICH TOO MANY REGISTERS HAVE BEEN USED.           *)
(* NOTE THAT IF THE LAST REG IS RESERVED AN OVERFLOW WILL      *)
(* NOT BE DETECTED AND PROCESSING WILL CONTINUE.  NOTE         *)
(* ALSO THAT A MEMORY OVERFLOW DOES NOT STOP THE PARSER        *)
(* FROM ANALYSIS AND CODE GENERATION, HOWEVER THE REG          *)
(* SUMMARY MAY NOT REFLECT ACCURATE REGISTER INFO.             *)
(*-------------------------------------------------------------*)

FUNCTION NEWREG : INTEGER;

BEGIN
  WHILE NEXTREG IN RESERVE_REG DO
     NEXTREG := NEXTREG + 1;
  NEWREG := NEXTREG;
  IF NEXTREG = (REGBASE + STARTREG) THEN
     BEGIN      (* NOTE THAT IF LAST REG IS RESERVED, THEN *)
       PWARN;   (*        THIS WARNING WILL NOT BE TRIGGERED *)
       WRITE    (LISTF, '***** MEMORY OVERFLOW...> ');
       WRITE    (LISTF, REGBASE:1);
       WRITELN  (LISTF, ' VARIABLE NAMES IN USE...REUSING.');
       NEXTREG := STARTREG        (* RESET THE REGISTER STACK *)
     END
  ELSE
     NEXTREG := NEXTREG + 1
END;                                                (* NEWREG *)

(***************************************************************)

(*-15-----------------------------------------------------------*)
(* NEWLBL RETURNS THE KEY CODE FOR THE NEXT LABEL ON THE       *)
(* LABEL STACK; IF A LABEL STACK OVERFLOW OCCURS, THE          *)
(* SUMMARY ITEM WHICH INDICATES NUMBER OF LABELS USED MAY      *)
(* NOT REFLECT ACCURATE INFORMATION.                           *)
(*-------------------------------------------------------------*)

FUNCTION NEWLBL : LBLRNG;

BEGIN
  NEWLBL := CLABEL(.LBLCT.);
  LBLCT := LBLCT + 1;
  IF LBLCT = LBLBASE + 1 THEN
     BEGIN
       PWARN;
       WRITE    (LISTF, '***** LABEL OVERFLOW...> ');
       WRITE    (LISTF, LBLBASE:1);
       WRITELN  (LISTF, ' IN USE...RESET TO 0.');
       LBLCT := 1
     END;
END;                                                (* NEWLBL *)

(***************************************************************)
```

```
(*-16------------------------------------------------------------*)
(* FNSTACKLOOK SEARCHES THE FNP ACTIVATION STACK FOR THE        *)
(* IDENTIFIER IN ACCUM AND RETURNS A POINTER TO ITS SLOT        *)
(* IF IT IS A FORMAL PARAMETER IN AN ACTIVE FNP, OTHER-         *)
(* WISE THE POINTER RETURNED IS NIL.                            *)
(*---------------------------------------------------------------*)

FUNCTION FNSTACKLOOK (ACCUM : TKSTRING) : SLOTPTR;

VAR  FLOOK, PARMPTR, TPARMPTR : SLOTPTR;
     FOUND : BOOLEAN;

BEGIN
  FLOOK := FNSTACK;
  FOUND := FALSE;
  PARMPTR := NIL;
  TPARMPTR := NIL;
  WHILE (FLOOK <> NIL) AND (NOT FOUND) DO
    BEGIN
      PARMPTR := FLOOK@.FNP;
      IF PARMPTR <> NIL THEN
        REPEAT
          TPARMPTR := PARMPTR;
          FOUND := (PARMPTR@.IDENT = ACCUM);
          PARMPTR := PARMPTR@.SLOT
        UNTIL (FOUND) OR (PARMPTR = NIL);
      FLOOK := FLOOK@.FNPLINK
    END;
  FNSTACKLOOK := PARMPTR;
  IF FOUND THEN
    FNSTACKLOOK := TPARMPTR
END;                                              (* FNSTACKLOOK *)

(*****************************************************************)
```

```
(*- 17-------------------------------------------------------*)
(* IDLOOKUP FIRST SEARCHES ACTIVE FNP STACK (FORMAL         *)
(* PARAMETERS), THEN THE SYM TBL UNTIL IT FINDS THE          *)
(* IDENTIFIER NAME CURRENTLY IN ACCUM; RETURNS POINTER TO    *)
(* THE SLOT FOR THAT IDENTIFIER; CREATES AND ENTERS A        *)
(* SLOT FOR THE IDENTIFIER IF IT DOES NOT YET EXIST.         *)
(*-----------------------------------------------------------*)

FUNCTION IDLOOKUP (ACCUM:TKSTRING; ACCINX:ACCRNG) : SLOTPTR;

VAR   HLOOK, TLOOK : SLOTPTR;

(*-----------------------------------------------------------*)

(*- 17-01----------------------------------------------------*)
(* ENTERID INSERTS AN APPROPRIATE SLOT INTO THE SYM TBL      *)
(* FOR THE IDENTIFIER IN ACCUM AND RETURNS A POINTER TO      *)
(* THAT SLOT.                                                *)
(*-----------------------------------------------------------*)

FUNCTION ENTERID (ACCUM:TKSTRING; ACCINX:ACCRNG) : SLOTPTR;

VAR  IDSLOT : SLOTPTR;

BEGIN
  IDSLOT := GETSLOT (ACCUM, ACCINX);
  IF NOT FN_CHK(ACCUM) THEN
    WITH IDSLOT@ DO
      BEGIN
        TYP   := VARID;
        REGNO := NEWREG;
        AUXREG1  := -1;              (* USED FOR INDEX VARS TO *)
        AUXREG2  := -1;              (*   FOR-NEXT LOOPS ONLY.  *)
        WRITE (NAMEF, ' ':8);
        ZEROPAD  (NAMEF, REGNO, 2);
        WRITELN  (NAMEF, ' ':3, IDENT)
      END
  ELSE
    WITH IDSLOT@ DO
      BEGIN
        TYP := FNPID;
        FNP := NIL;
        FNPLINK := NIL;
        FNREGNO := NEWREG;
        LBL := NEWLBL;
        WRITELN  (NAMEF, ' ':5, FNREGNO:5, ' ':3, IDENT)
      END;
  ENTERID := IDSLOT
END;                                        (* ENTERID *)

(*-----------------------------------------------------------*)
```

```
BEGIN    (* IDLOOKUP MAIN *)
  TLOOK := FNSTACKLOOK (ACCUM);
  IF TLOOK = NIL THEN
    BEGIN
      HLOOK := BUCKET (.HASHVAL (ACCUM, ACCINX).);
      IF HLOOK <> NIL THEN
        BEGIN
          TLOOK := HLOOK;
          HLOOK := HLOOK@.SLOT;
          WHILE (HLOOK<>NIL) AND (TLOOK@.IDENT<>ACCUM) DO
            BEGIN
              HLOOK := HLOOK@.SLOT;
              TLOOK := TLOOK@.SLOT
            END;
          IF TLOOK@.IDENT = ACCUM THEN
            IDLOOKUP := TLOOK
          ELSE
            IDLOOKUP := ENTERID (ACCUM, ACCINX)
        END
      ELSE
        IDLOOKUP := ENTERID (ACCUM, ACCINX)
    END
  ELSE
    IDLOOKUP := TLOOK
END;                                                    (* IDLOOKUP *)
```

```
(*************************************************************)
(*                                                           *)
(*        CODE DATA STRUCTURE MANAGEMENT ROUTINES            *)
(*                                                           *)
(*************************************************************)

(*-18-------------------------------------------------------*)
(* NEWCODE RETURNS A POINTER TO A NEW CODE DATA NODE;        *)
(* FIELDS ARE INITIALIZED TO A DEFAULT VALUE (EXCEPT KEY)    *)
(*----------------------------------------------------------*)

FUNCTION NEWCODE (OPCODE : INTEGER) : CODEPTR;

VAR  CP : CODEPTR;

BEGIN
  NEW (CP);
  CP@.SEQP := NIL;
  CP@.JMPP := NIL;
  CP@.BAKP := NIL;
  CP@.ADDR := -1;
  CP@.KEY  := OPCODE;
  NEWCODE  := CP;
END;                                          (* NEWCODE *)

(*************************************************************)

(*-19-------------------------------------------------------*)
(* PUTKEY INSERTS A CODE DATA NODE INTO THE CODE DATA        *)
(* STRUCTURE IN FRONT OF CPCUR BUT AFTER ENDCP WHICH IS      *)
(* TO SAY THAT THE NODE IS THE NEW END CODE DATA NODE.       *)
(*----------------------------------------------------------*)

PROCEDURE PUTKEY (VAR HOLDP : CODEPTR);

BEGIN
  IF HOLDP = NIL THEN
    HOLDP := NEWCODE (-1);
  ENDCP@.SEQP := HOLDP;
  HOLDP@.SEQP := CPCUR;
  ENDCP := ENDCP@.SEQP
END;                                          (* PUTKEY *)

(*************************************************************)

(*-20-------------------------------------------------------*)
(* GENKEY FILLS THE CPCUR REFERENCED NODE WITH THE OPCODE    *)
(* PASSED TO IT, AND ATTACHES ANOTHER EMPTY NODE TO THE      *)
(* CODE DATA STRUCTURE AFTER THE ONE JUST FILLED.            *)
(*----------------------------------------------------------*)

PROCEDURE GENKEY;                  (* FORWARD DECLARATION WITH *)
                                   (*  ERROR HANDLING ROUTINES *)
VAR  CP : CODEPTR;

BEGIN
  CPCUR@.KEY := CPCODE;
  CPCUR@.SEQP := NEWCODE (-1);
  CPCUR := CPCUR@.SEQP;
  ENDCP := ENDCP@.SEQP
END;                                          (* GENKEY *)

(*************************************************************)
```

```
(*-21--------------------------------------------------------*)
(* INSERTKEY IS USED AFTER ALL CODE HAS BEEN GENERATED TO   *)
(* INSERT LABELS TO GOSUB REFERENCES; NOTE THAT ENDCP       *)
(* MUST NOT BE MOVED OR USED BY THIS PROCEDURE SINCE IT     *)
(* NOW RESIDES AT THE END OF THE CODE STRUCTURE AND WILL    *)
(* BE USED TO FLAG THE END OF THE STRUCTURE TO TRAVERSING   *)
(* POINTER PROCEDURES.                                       *)
(*-----------------------------------------------------------*)

PROCEDURE INSERTKEY (OPCODE : INTEGER; VAR LOCUS : CODEPTR);

VAR  CP : CODEPTR;

BEGIN
  CP := NEWCODE (OPCODE);
  CP@.SECP := LOCUS;
  LOCUS := CP
END;                                          (* INSERTKEY *)

(*************************************************************)

(*-22--------------------------------------------------------*)
(* GETNEWHDR CONSTRUCTS AND RETURNS A POINTER TO A LINE     *)
(* AND CODE DATA NODE PAIR; ALL FIELDS OF BOTH NODES ARE    *)
(* INITIALIZED; THIS PAIR OF NODES IS USED TO HEAD THE      *)
(* CHAIN OF CODE GENERATED FOR A PARTICULAR WBASIC SOURCE   *)
(* LINE.  (NOTE THAT NEWCODE INITIALIZES CODE NODE)         *)
(*-----------------------------------------------------------*)

FUNCTION GETNEWHDR (LINUM : BASLINRNG) : LINEPTR;

VAR   LP : LINEPTR;
      CP : CODEPTR;
BEGIN
  NEW (LP);
  LP@.CPTR := NEWCODE (-1);
  LP@.LINO := LINUM;
  LP@.LPTR := NIL;
  GETNEWHDR := LP
END;                                          (* GETNEWHDR *)

(*************************************************************)

(*-23--------------------------------------------------------*)
(* PUTNEWHDR INSERTS A HEADER (LINE/CODE DATA NODE PAIR)    *)
(* INTO THE CODE DATA STRUCTURE AT THE POSITION OF THE      *)
(* CURRENT LINE MARKING POINTER, LPCUR.  NOTE THAT THE      *)
(* BAKP IS USED HERE TO MARK THE LOCATION OF THE START OF   *)
(* CODE CORRESPONDING TO A NEW SOURCE LINE.                 *)
(*-----------------------------------------------------------*)

PROCEDURE PUTNEWHDR (VAR LPCUR, LP : LINEPTR);

BEGIN
  LP@.LPTR := LPCUR@.LPTR;
  LPCUR@.LPTR := LP;
  LPCUR := LP;
  ENDCP@.SECP := LP@.CPTR;
  CPCUR := LP@.CPTR;
  CPCUR@.BAKP := ENDCP
END;                                          (* PUTNEWHDR *)

(*************************************************************)
```

```
(*-24-----------------------------------------------------------*)
(* SETLINE COORDINATES THE SET UP OF THE CODE DATA              *)
(* STRUCTURE FOR THE BEGINNING OF CODE GENERATED FOR A          *)
(* NEW WBASIC SOURCE LINE; IF LINE NUMBER HEADER NODES          *)
(* ALREADY EXIST BECAUSE FORWARD JUMP REFERENCES REQUIRED       *)
(* THEIR EXISTENCE, THEN THESE NODES ARE CHECKED FIRST          *)
(* FOR THE CURRENT LINE NUMBER.                                 *)
(*--------------------------------------------------------------*)

PROCEDURE SETLINE (VAR LPCUR, LP : LINEPTR);

VAR  LNUMBER : BASLINRNG;

BEGIN
  LNUMBER := LINUM;
  IF TOKNUM = ENDLINTOK THEN
     LNUMBER := LLINUM;
  IF LPCUR@.LPTR <> NIL THEN      (* IF LINE DATA NODES        *)
     BEGIN                        (*  EXIST FROM JUMP REFS.    *)
       IF (LPCUR@.LPTR@.LINO) = LNUMBER THEN
          BEGIN                   (* CURRENT LINE NUMBER IS    *)
            LPCUR := LPCUR@.LPTR; (*  THE NEXT ONE IN CHAIN    *)
            ENDCP@.SEQP := LPCUR@.CPTR;
            CPCUR := LPCUR@.CPTR;
            CPCUR@.BAKP := ENDCP
          END
       ELSE
          BEGIN
            LP := GETNEWHDR (LNUMBER);
            PUTNEWHDR (LPCUR, LP)
          END
     END
  ELSE
     BEGIN
       LP := GETNEWHDR (LNUMBER);
       PUTNEWHDR (LPCUR, LP)
     END
END;                                              (* SETLINE *)

(***************************************************************)
```

```
(*-25--------------------------------------------------------------*)
(* SETJMPEXT SETS THE EXTERNAL JMP PTR FROM CPCUR@.JMPP            *)
(* TO THE WBASIC LINUM INDICATED BY THE GOTO OR GOSUB              *)
(*-----------------------------------------------------------------*)

PROCEDURE SETJMPEXT (LINUM : BASLINRNG);

BEGIN
  IF LINUM > LPCUR@.LINO THEN
    BEGIN                                    (* FORWARD JUMP  *)
      LPLEAD  := LPCUR@.LPTR;
      LPTRAIL := LPCUR;
      WHILE (LPTRAIL@.LINO < LINUM) AND (LPLEAD <> NIL) DO
        BEGIN
          LPLEAD  := LPLEAD@.LPTR;
          LPTRAIL := LPTRAIL@.LPTR
        END;
      IF LPTRAIL@.LINO = LINUM THEN
        BEGIN
          CPCUR@.JMPP := LPTRAIL@.CPTR;     (* SET JMPP PTR *)
          LPTRAIL@.CPTR@.ADDR := 0   (* MARK JMPP TERMINAL *)
        END
      ELSE
        BEGIN
          LPTRAIL@.LPTR := GETNEWHDR (LINUM);
          LASTLP := LPTRAIL@.LPTR;
          CPCUR@.JMPP := LASTLP@.CPTR;      (* SET JMPP PTR *)
          LASTLP@.CPTR@.ADDR := 0    (* MARK JMPP TERMINAL *)
        END
    END

  ELSE
    BEGIN                                    (* BACKWARD JUMP *)
      LPLEAD := FIRSTLP;
      WHILE (LPLEAD@.LINO <> LINUM) AND (LPLEAD <> NIL) DO
        LPLEAD := LPLEAD@.LPTR;
      IF LPLEAD@.LINO = LINUM THEN
        BEGIN
          CPCUR@.JMPP := LPLEAD@.CPTR;      (* SET JMPP PTR *)
          LPLEAD@.CPTR@.ADDR := 0    (* MARK JMPP TERMINAL *)
        END
    END     (* ASSUMES THAT A LINO = LINUM ALWAYS EXISTS ! *)

END;                                          (* SETJMPEXT *)
```

```
(**************************************************************)
(*                                                            *)
(*                  FUNCTION CALL ROUTINES                    *)
(*                                                            *)
(**************************************************************)

(*-40-*)
PROCEDURE PEXPR;                                       FORWARD;

(*-41-*)
PROCEDURE PPRIMARY;                                    FORWARD;

(**************************************************************)

(*-26--------------------------------------------------------*)
(* GENFNQ GENERATES THE CODE FOR SHORT, SIMPLE CALCULATOR  *)
(* ARITHMETIC FUNCTIONS ("QUICK" FUNCTIONS).                *)
(*----------------------------------------------------------*)

PROCEDURE GENFNQ (OPND : SLOTPTR);

VAR    I : 1..FNQLEN;

BEGIN
  SCAN (TOKNUM);
  IF TOKNUM <> OPARENTOK THEN                          (* '(' *)
    PERROR
  ELSE
    BEGIN
      SCAN (TOKNUM);
      PEXPR;
      I := 1;
      WITH OPND@ DO
        REPEAT
          GENKEY (FNQ(.I.));
          I := I + 1
        UNTIL (I >= FNQLEN) OR (FNQ(.I.) = K_NOP)
    END
END;                                                (* GENFNQ *)

(**************************************************************)

(*-27--------------------------------------------------------*)
(* CHKFNLLIST SEARCHES THE FNL USE LIST TO DETERMINE IF    *)
(* THE FNL HAS EVER BEEN CALLED BEFORE; IF NOT, THEN IT    *)
(* MUST BE ADDED TO THE USE LIST.                           *)
(*----------------------------------------------------------*)

PROCEDURE CHKFNLLIST (VAR IDSLOT : SLOTPTR);

VAR    LISTPTR, HOLDPTR : SLOTPTR;
       USED : BOOLEAN;

BEGIN
  LISTPTR := FNLLIST;                  (* GET THE LONG FN LIST *)
  IF LISTPTR <> NIL THEN               (* TRAVERSE THE FNLLIST *)
    REPEAT
      USED := (IDSLOT@.IDENT = LISTPTR@.IDENT);
      LISTPTR := LISTPTR@.FNLLINK;
    UNTIL (USED) OR (LISTPTR = NIL);
  IF LISTPTR = NIL THEN       (* IF NOT FOUND ON LIST, THEN *)
    BEGIN           (* ADD THIS LONG FUNCTION TO THE FNLLIST *)
      HOLDPTR := FNLLIST;
      FNLLIST := IDSLOT;
      IDSLOT@.FNLLINK := HOLDPTR
    END
END;                                            (* CHKFNLLIST *)

(**************************************************************)
```

```
(*-28-----------------------------------------------------------*)
(* GENFNL GENERATES THE SBR CALL TO A FNL BODY AND THEN        *)
(* CALLS ON PROCEDURE CHKFNLLIST TO SEE IF THE FNL HAS          *)
(* BEEN USED BEFORE.                                            *)
(*--------------------------------------------------------------*)

PROCEDURE GENFNL (VAR IDSLOT : SLOTPTR);

BEGIN
  SCAN (TOKNUM);
  IF TOKNUM <> OPARENTOK THEN                              (* '(' *)
    PERROR
  ELSE
    BEGIN
      SCAN (TOKNUM);
      PEXPR;
      GENKEY (K_STO);
      GENKEY (FNLREG);
      GENKEY (K_SBR);
      GENKEY (IDSLOT@.LBL);
      CHKFNLLIST (IDSLOT)
    END
END;                                                    (* GENFNL *)

(*****************************************************************)

(*-29-----------------------------------------------------------*)
(* NEWPARM IS CALLED WHEN A FIRST CALL TO A PARAMETER FN        *)
(* IS ENCOUNTERED IN THE WBASIC SOURCE FILE; AT THIS TIME      *)
(* NO REGISTERS HAVE BEEN DESIGNATED FOR THE FORMAL FN          *)
(* PARMS; THIS PROCEDURE CREATES THE SYM TBL ENTRY AND          *)
(* DESIGNATES THE RESPECTIVE REGISTER FOR THE NEW PARM          *)
(* ENCOUNTERED IN THE FN CALL; NOTE THAT THE FORMAL PARM        *)
(* IDENT NAME IS NOT YET KNOWN AND WILL BE ENTERED ONLY          *)
(* AFTER THE FN DEFINITION STATEMENT IS ENCOUNTERED LATER       *)
(*--------------------------------------------------------------*)

FUNCTION NEWPARM : SLOTPTR;

VAR  PARMSLOT : SLOTPTR;

BEGIN
  NEW (PARMSLOT);
  WITH PARMSLOT@ DO
    BEGIN
      TYP := VARID;
      REGNO := NEWREG;
      WRITELN (NAMEP, ' ':5,REGNO:5,' ':5,'(FN PARAMETER)');
      SLOT := NIL
    END;
  NEWPARM := PARMSLOT
END;                                                   (* NEWPARM *)

(*****************************************************************)
```

```
(*-30----------------------------------------------------------*)
(* GENPARM GENERATES THE FORMAL PARAMETER LIST FOR            *)
(* PARAMETER FUNCTIONS; IT ALSO GENERATES THE CODE WHICH      *)
(* WILL EVALUATE AN ACTUAL PARAMETER AND STORE IT IN THE      *)
(* FORMAL PARAMETER STORAGE LOCATION PRIOR TO FN EXECUTE.     *)
(*-------------------------------------------------------------*)

PROCEDURE GENPARM (VAR IDSLOT : SLOTPTR);

VAR  PARMPTR : SLOTPTR;

BEGIN
  SCAN (TOKNUM);
  IF TOKNUM = OPARENTOK THEN
    BEGIN
      PARMPTR := IDSLOT@.FNP;
      IF PARMPTR = NIL THEN
        BEGIN
          PARMPTR := NEWPARM;
          IDSLOT@.FNP := PARMPTR
        END;
      REPEAT
        SCAN (TOKNUM);
        PEXPR;              (* STOP AT EACH ',' AND LAST ')' *)
        GENKEY (K_STC);
        GENKEY (PARMPTR@.REGNO);
        IF TOKNUM = COMMATOK THEN
          BEGIN
            IF PARMPTR@.SLOT = NIL THEN
              PARMPTR@.SLOT := NEWPARM;
            PARMPTR := PARMPTR@.SLOT      (* NEXT PARAMETER *)
          END
      UNTIL (TOKNUM = CPARENTOK)     (* PEXPR WILL FIND ')' *)
            OR (TOKNUM IN TRAILTOKS)  (* OR WILL FIND END *)
    END
END;                                          (* GENPARM *)

(**************************************************************)

(*-31----------------------------------------------------------*)
(* GENFNP GENERATES CODE SEQUENCE WHICH CALLS A PARM FNP.     *)
(*-------------------------------------------------------------*)

PROCEDURE GENFNP (VAR IDSLOT : SLOTPTR);

BEGIN
  GENPARM (IDSLOT);
  GENKEY (K_CPAREN);
  GENKEY (K_SBR);
  GENKEY (IDSLOT@.LBL);
  GENKEY (K_CPAREN)
END;                                           (* GENFNP *)
```

```
(**************************************************************)
(*                                                            *)
(*              FUNCTION DEFINITION ROUTINES                  *)
(*                                                            *)
(**************************************************************)

(*-32---------------------------------------------------------*)
(* PUSHFN PUSHES A FNP SLOT ONTO THE FNP ACTIVATION STACK    *)
(*------------------------------------------------------------*)

PROCEDURE PUSHFN (VAR FNSLOT : SLOTPTR);

BEGIN
  FNSLOT@.FNPLINK := FNSTACK;
  FNSTACK := FNSLOT;
  FNSTACKCT := FNSTACKCT + 1;
  IF FNSTACKCT > FNSTACKLIM THEN
    BEGIN
      FWARN;
      WRITE   (LISTF, '***** SBR STACK OVERFLOW...> ');
      WRITELN (LISTF, FNSTACKLIM:1, ' RETURN ADDRESSES.')
    END
END;                                              (* PUSHFN *)

(**************************************************************)

(*-33---------------------------------------------------------*)
(* POPFN POPS A FNP SLOT OFF TOP OF FNP ACTIVATION STACK.    *)
(*------------------------------------------------------------*)

PROCEDURE POPFN;

VAR  HOLDPTR : SLOTPTR;

BEGIN
  HOLDPTR := FNSTACK;
  FNSTACK := FNSTACK@.FNPLINK;
  HOLDPTR@.FNPLINK := NIL;
  FNSTACKCT := FNSTACKCT - 1;
  IF FNSTACKCT < 0 THEN
    BEGIN
      FWARN;
      WRITE   (LISTF, '***** ATTEMPT TO POP RETURN ADDR ');
      WRITELN (LISTF, 'FROM EMPTY STACK...RESET CT = 0');
      FNSTACKCT := 0
    END
END;                                               (* POPFN *)

(**************************************************************)
```

```
(*-34-----------------------------------------------------------*)
(* FILLPARMIDS READS THE FORMAL PARAMETER IDENTIFIER           *)
(* NAMES IN THE FNP DEF STATEMENT AND FILLS THE IDENT          *)
(* FIELD OF THE RESPECTIVE PARAMETER SLOT (ATTACHED TO         *)
(* RESPECTIVE FNP SLOT IN SYM TBL).                             *)
(*-------------------------------------------------------------*)

PROCEDURE FILLPARMIDS (VAR FNSLOT : SLOTPTR);

VAR   FNPARM : SLOTPTR;

BEGIN
  IF FNSLOT@.FNP = NIL THEN                 (* IN CASE FNP HAS NOT *)
    FNSLOT@.FNP := NEWPARM;                 (*  BEEN CALLED AT ALL *)
  FNPARM := FNSLOT@.FNP;
  SCAN (TOKNUM);
  IF TOKNUM <> IDENTOK THEN
    PERROR
  ELSE
    BEGIN
      WHILE TOKNUM <> CPARENTOK DO
        BEGIN
          FNPARM@.IDENT := ACCUM;
          SCAN (TOKNUM);
          IF TOKNUM = COMMATOK THEN
            BEGIN
              SCAN (TOKNUM);
              IF FNPARM@.SLOT = NIL THEN        (* FNP HAS NOT  *)
                FNSLOT@.SLOT := NEWPARM;        (*  BEEN CALLED *)
              FNPARM := FNPARM@.SLOT
            END
        END;
      SCAN (TOKNUM)                        (* SCAN TOKEN AFTER ')' *)
    END
END;                                               (* FILLPARMIDS *)

(**************************************************************)

(*-35-----------------------------------------------------------*)
(* PFNEND GENERATES CODE FOR THE END OF A FUNCTION BODY        *)
(* DEFINITION; IT INCLUDES THE HOUSE-KEEPING REQUIRED TO       *)
(* RESET THE SCOPE AND VISIBILITY OF VARIABLE NAMES IN         *)
(* THE SYMBOL TABLE THROUGH THE FN ACTIVATION STACK.           *)
(*-------------------------------------------------------------*)

PROCEDURE PFNEND;

BEGIN
  GENKEY (K_RCL);
  GENKEY (FNSTACK@.FNREGNO);
  GENKEY (K_INVSBR);
  POPFN;
  IF NOT (TOKNUM IN TRAILTOKS) THEN (* GUARD AGAINST OVER *)
    SCAN (TOKNUM) (* SCANNING END LINE IF CALLED BY PDEF. *)
END;                                                (* PFNEND *)

(**************************************************************)
```

```
(*-36-----------------------------------------------------------*)
(* PDEF GENERATES THE CODE WHICH DEFINES THE SCOPE AND         *)
(* VISIBILITY FOR VARIABLE NAMES; RESETS THE VALUE OF THE      *)
(* REGISTER IN WHICH THE FUNCTION VALUE IS RETURNED.           *)
(*--------------------------------------------------------------*)

PROCEDURE PDEF;

VAR  FNSLOT : SLOTPTR;

BEGIN
  SCAN (TOKNUM);
  IF NOT FN_CHK (ACCUM) THEN
    PERROR
  ELSE
    BEGIN
      FNSLOT := IDLOOKUP (ACCUM, ACCINX);
      GENKEY (K_LBL);
      GENKEY (FNSLOT@.LBL);
      GENKEY (K_ZERO);          (* MUST ZERO THE VALUE OF THE *)
      GENKEY (K_STO);           (*  REGISTER IN WHICH THE FN  *)
      GENKEY (FNSLOT@.FNREGNO);       (* VALUE IS RETURNED. *)
      PUSHFN (FNSLOT);
      SCAN (TOKNUM);
      IF TOKNUM = OPARENTOK THEN        (* LOOKING FOR PARMS *)
        FILLPARMIDS (FNSLOT);
      IF TOKNUM = EQUALTOK THEN      (* LOOK FOR ONE LINE FN *)
        BEGIN
          SCAN (TOKNUM);
          PEXPR;
          PFNEND   (* GENERATE THE RETURN FROM ONE LINE FN *)
        END;
      CLOSELINE
    END
END;                                                (* PDEF *)

(**************************************************************)

(*-37-----------------------------------------------------------*)
(* GETFNLS IS CALLED AFTER ALL OTHER CODE HAS BEEN             *)
(* GENERATED; IT GENERATES THE CODE FOR THE BODIES OF ALL      *)
(* BUILT-IN LONG FUNCTIONS WHICH HAVE BEEN CALLED AT           *)
(* LEAST ONCE AND ARE, THUS, ON THE FNLLIST.                   *)
(*--------------------------------------------------------------*)

PROCEDURE GETFNLS;

VAR  LISTPTR : SLOTPTR;
     I : 1..FNLLEN + 1;

BEGIN
  LISTPTR := FNLLIST;                      (* GET LONG FN LIST *)
  WHILE LISTPTR <> NIL DO
    BEGIN        (* INSERT CODE FOR NEXT LONG FN ON FNLLIST *)
      GENKEY (K_LBL);
      GENKEY (LISTPTR@.LBL);
      I := 1;
      WHILE (I <= FNLLEN) AND
            (LISTPTR@.FNL(.I.) <> K_NOP) DO
        BEGIN
          GENKEY (LISTPTR@.FNL(.I.));
          I := I + 1
        END;
      GENKEY (K_INVSER);
      LISTPTR := LISTPTR@.FNLLINK (* NEXT LONG FN ON LIST *)
    END
END;                                               (* GETFNLS *)
```

```
(*****************************************************************)
(*                                                               *)
(*                EXPRESSION GENERATOR ROUTINES                  *)
(*                                                               *)
(*****************************************************************)

(*-38-----------------------------------------------------------*)
(* GENID GENERATES CODE FOR A VARIABLE OR FUNCTION IDENT.       *)
(*--------------------------------------------------------------*)

PROCEDURE GENID;

VAR   OPND : SLOTPTR;

BEGIN
   OPND := IDLOOKUP (ACCUM, ACCINX);
   CASE OPND@.TYP OF
      VARID : BEGIN
                 IF OPND@.REGNO = -314 THEN (* REGNO FOR PI  *)
                    GENKEY (K_PI)
                 ELSE
                    BEGIN
                       GENKEY (K_RCL);
                       GENKEY (OPND@.REGNO)
                    END
              END;
      FNOID : GENFNO  (OPND);
      FNLID : GENFNL  (OPND);
      FNPID : GENFNP  (OPND)
   END   (* CASE *)
END;                                                  (* GENID *)

(*****************************************************************)

(*-39-----------------------------------------------------------*)
(* GENNUM GENERATES TI-59 EQUIVALENT CODE FOR A LITERAL         *)
(* NUMERIC (BOTH INTEGER AND REAL).                             *)
(*--------------------------------------------------------------*)

PROCEDURE GENNUM;

VAR   I, DECPTLOC, ESIGNLOC : INTEGER;

BEGIN
   DECPTLOC := LCOUNT + 1;
   FOR I := 1 TO LCOUNT DO
      GENKEY (TRANSDIGIT (ACCUM(.I.)));
   IF RCOUNT > 0 THEN
      BEGIN
         GENKEY (K_DECPT);
         FOR I := (DECPTLOC + 1) TO (DECPTLOC + RCOUNT) DO
            GENKEY (TRANSDIGIT (ACCUM(.I.)))
      END;
   IF ECOUNT > 0 THEN
      BEGIN
         ESIGNLOC := LCOUNT + 1 + RCOUNT + 2;
         IF ACCUM(.DECPTLOC.) <> PERIOD THEN
            ESIGNLOC := ESIGNLOC - 1;
         GENKEY (K_EE);
         IF ACCUM(.ESIGNLOC.) = '-' THEN
            GENKEY (K_NEG);
         FOR I := (ESIGNLOC + 1) TO (ESIGNLOC + ECOUNT) DO
            GENKEY (TRANSDIGIT (ACCUM(.I.)))
      END
END;                                                 (* GENNUM *)

(*****************************************************************)
```

```
(*-40-------------------------------------------------------------*)
(* PEXPR PARSES AND GENERATES CODE FOR EXPRESSIONS.               *)
(*----------------------------------------------------------------*)

PROCEDURE PEXPR;                     (* FORWARD DECLARATION WITH *)
                                     (*  FUNCTION CALL ROUTINES  *)
BEGIN
  GENKEY (K_OPAREN);
  PPRIMARY;
  WHILE TOKNUM IN BINOPTOKS DO
    BEGIN
      CASE TOKNUM OF
        PLUSTOK  : GENKEY (K_ADDOP);                          (* '+'  *)
        MINUSTOK : GENKEY (K_SUBOP);                          (* '-'  *)
        MULTOK   : GENKEY (K_MULTOP);                         (* '*'  *)
        DIVTOK   : GENKEY (K_DIVOP);                          (* '/'  *)
        EXPTOK   : GENKEY (K_POWR)                            (* '**' *)
      END;   (* CASE *)
  IF NOT (TOKNUM IN TRAILTOKS) THEN BEGIN
      SCAN (TOKNUM);
      PPRIMARY                              END
    END;
  GENKEY (K_CPAREN)
END;                                                      (* PEXPR *)

(*****************************************************************)

(*-41-------------------------------------------------------------*)
(* PPRIMARY PARSES AND GENERATES CODE FOR A PRIMARY ITEM          *)
(* EXPECTED AS PART OF EXPRESSIONS.                               *)
(*----------------------------------------------------------------*)

PROCEDURE PPRIMARY;                  (* FORWARD DECLARATION WITH *)
                                     (*  FUNCTION CALL ROUTINES  *)
BEGIN
  CASE TOKNUM OF
    PLUSTOK   : BEGIN                                        (* '+' *)
                  SCAN (TOKNUM);
                  PPRIMARY
                END;
    MINUSTOK  : BEGIN                                        (* '-' *)
                  SCAN (TOKNUM);
                  PPRIMARY;
                  GENKEY (K_NEG)
                END;
    OPARENTOK : BEGIN                                        (* '(' *)
                  SCAN (TOKNUM);
                  PEXPR;
                  SCAN (TOKNUM)
                END;
    IDENTOK   : BEGIN
                  GENID;
                  IF (TOKNUM=IDENTOK) OR (TOKNUM=CPARENTOK)
                    THEN SCAN (TOKNUM)
                END;
    NUMBERTOK : BEGIN
                  GENNUM;
                  SCAN (TOKNUM)
                END
  END   (* CASE *)
END;                                                   (* PPRIMARY *)

(*****************************************************************)
```

```
(*-42-----------------------------------------------------------*)
(* PCONDITION PARSES AND GENERATES CODE FOR BOOLEAN EXPRS     *)
(*--------------------------------------------------------------*)

PROCEDURE PCONDITION;

VAR  RELOP  : TOKENRNG;
     INVERT : BOOLEAN;

BEGIN
  INVERT := FALSE;
  SCAN (TOKNUM);                                  (* SCAN FOR "NOT" *)
  IF TOKNUM = NOTTOK THEN
    BEGIN
      INVERT := TRUE;
      SCAN (TOKNUM)
    END;
  PEXPR;
  GENKEY (K_X_T);
  IF INVERT THEN
    CASE TOKNUM OF
      EQUALTOK : TOKNUM := NOTEQTOK;
      NOTEQTOK : TOKNUM := EQUALTOK;
      GTTOK    : TOKNUM := LTEQTOK;
      GTEQTOK  : TOKNUM := LTTOK;
      LTTOK    : TOKNUM := GTEQTOK;
      LTEQTOK  : TOKNUM := GTTOK;
    END;   (* CASE *)
  RELOP := TOKNUM;
  SCAN (TOKNUM);                                  (* BEGIN NEXT EXPR *)
  PEXPR;
  CASE RELOP OF
    EQUALTOK : BEGIN
                 GENKEY (K_INV);
                 GENKEY (K_IFXEQT)
               END;
    NOTEQTOK : GENKEY (K_IFXEQT);
    GTTOK    : GENKEY (K_IFXGET);
    GTEQTOK  : BEGIN
                 GENKEY (K_X_T);
                 GENKEY (K_INV);
                 GENKEY (K_IFXGET)
               END;
    LTEQTOK  : BEGIN
                 GENKEY (K_INV);
                 GENKEY (K_IFXGET)
               END;
    LTTOK    : BEGIN
                 GENKEY (K_X_T);
                 GENKEY (K_IFXGET)
               END
  END   (* CASE *)
END;                                              (* PCONDITION *)
```

```
(**************************************************************)
(*                                                            *)
(*                     LOOPING ROUTINES                       *)
(*                                                            *)
(**************************************************************)

(*-43---------------------------------------------------------*)
(* PUSHCODE PUSHES THE RCODE DATA NODE ONTO THE LOOP/IF      *)
(* STACK DESIGNATED BY STACK.                                 *)
(*------------------------------------------------------------*)

PROCEDURE PUSHCODE (RCODE : CODEPTR; VAR STACK : CODEPTR);

BEGIN
  RCODE@.SEQP := STACK;
  STACK := RCODE
END;                                          (* PUSHCODE *)

(**************************************************************)

(*-44---------------------------------------------------------*)
(* POPCODE POPS AND RETURNS THE CODE DATA NODE ON THE TOP    *)
(* OF THE LOOP/IF STACK DESIGNATED.                           *)
(*------------------------------------------------------------*)

FUNCTION POPCODE (VAR STACK : CODEPTR) : CODEPTR;

BEGIN
  IF STACK = NIL THEN
    BEGIN
      WRITE   (LISTF, '***** INCORRECT NESTING OF CONTROL');
      WRITELN (LISTF, ' STATEMENTS (IF, FOR, OR LOOP).');
      PERROR;
      POPCODE := NIL
    END
  ELSE
    BEGIN
      POPCODE := STACK;
      STACK := STACK@.SEQP
    END
END;                                          (* POPCODE *)

(**************************************************************)

(*-45---------------------------------------------------------*)
(* SETFWDJMP IS USED TO SET THE JUMP POINTER (JMPP) OF       *)
(* THE CURRENT CODE DATA NODE POINTING TO THE MOST RECENT    *)
(* CODE DATA NODE ON THE DESIGNATED LOOP/IF STACK; THE       *)
(* POTENTIAL ABSOLUTE ADDRESS SPACE IS GENERATED WITH THE    *)
(* ASSUMPTION THAT THE CODE DATA NODE IN THE STACK TO        *)
(* WHICH THE FIRST ADDRESS SPACE NODE IS POINTING WILL       *)
(* LATER BE POPPED AND INSERTED INTO THE CODE AT THE         *)
(* APPROPRIATE POSITION.                                      *)
(*------------------------------------------------------------*)

PROCEDURE SETFWDJMP (STACK : CODEPTR);

BEGIN
  CPCUR@.JMPP := STACK;  (* SET JMPP TO NODE JUST PUSHED    *)
  STACK@.ADDR := 0;      (* MARK THE TERMINAL NODE OF JUMP  *)
  GENKEY (-2);           (* GEN SPACE FOR ABSOLUTE ADDRESS  *)
  GENKEY (-2)
END;                                          (* SETFWDJMP *)

(**************************************************************)
```

```
(*-46-----------------------------------------------------------*)
(* SETBAKJUMP IS SIMILAR TO SETFWDJMP EXCEPT IN THIS CASE      *)
(* THE FIRST NODE OF A POTENTIAL ADDRESS SPACE PAIR IS          *)
(* PUSHED ONTO THE DESIGNATED LOOP/IF STACK AFTER ITS           *)
(* JMPP HAS BEEN SET TO A CODE DATA NODE INSERTED AS AN         *)
(* ANCHOR FOR THIS BACK JUMP; THE POTENTIAL ADDRESS SPACE        *)
(* NODE WILL LATER BE POPPED AND INSERTED (ALONG WITH ITS       *)
(* THE INSERTION OF ANOTHER NODE TO COMPOSE AN ADDR PAIR)       *)
(*--------------------------------------------------------------*)

PROCEDURE SETBAKJMP (VAR STACK : CODEPTR);

VAR  JCODE : CODEPTR;

BEGIN
  JCODE := NEWCODE (-2);
  JCODE@.JMPP := CPCUR;
  CPCUR@.ADDR := 0;
  GENKEY (K_NOP);
  PUSHCODE (JCODE, STACK)
END;                                           (* SETBAKJMP *)

(***************************************************************)

(*-47-----------------------------------------------------------*)
(* PLOOP GENERATES CODE FOR THE LOOP COMMAND;                   *)
(* IT SETS UP THE START OF A LOOP CONSTRUCT BY GENERATING       *)
(* AN ANCHOR NODE FOR THE BACK JUMP IN THE LOOP.                *)
(*--------------------------------------------------------------*)

PROCEDURE PLOOP;

BEGIN
  SETBAKJMP (LOOPSTACK);
  PUSHCODE (NEWCODE (K_NOP), ENDLOOPSTACK);
  SCAN (TCKNUM);
  CLOSELINE
END;                                               (* PLOOP *)

(***************************************************************)

(*-48-----------------------------------------------------------*)
(* PWHILE GENERATES CODE FOR THE WHILE COMMAND;                 *)
(* IT IS SIMILAR TO PLOOP EXCEPT IT INSERTS CODE TO             *)
(* EVALUATE A BOOLEAN EXPRESSION (CONDITION).                   *)
(*--------------------------------------------------------------*)

PROCEDURE PWHILE;

BEGIN
  SETBAKJMP (LOOPSTACK);
  PCONDITION;
  PUSHCODE (NEWCODE (K_NOP), ENDLOOPSTACK);
  SETFWDJMP (ENDLOOPSTACK)
END;                                              (* PWHILE *)

(***************************************************************)
```

```
(*-49--------------------------------------------------------------*)
(* PENDLOOP POPS AND INSERTS CODE WHICH HAD BEEN STACKED          *)
(* EARLIER AS A RESULT OF THE START OF A LOOP CONSTRUCT.          *)
(*-----------------------------------------------------------------*)

PROCEDURE PENDLOOP;

VAR   JCODE : CODEPTR;

BEGIN
  IF TOKNUM = ENDLOOPTOK THEN
    GENKEY (K_GTO);
  JCODE := POPCODE (LOOPSTACK);
  PUTKEY (JCODE);
  GENKEY (-2);
  JCODE := POPCODE (ENDLOOPSTACK);
  PUTKEY (JCODE);
  CLOSELINE
END;                                                 (* PENDLOOP *)

(*****************************************************************)

(*-50--------------------------------------------------------------*)
(* PUNTIL GENERATES CODE TO EVALUATE A BOOLEAN EXPRESSION *)
(* AND CALLS PENDLOOP TO CLOSE OUT THE LOOP.                       *)
(*-----------------------------------------------------------------*)

PROCEDURE PUNTIL;

BEGIN
  PCONDITION;
  PENDLOOP
END;                                                   (* PUNTIL *)

(*****************************************************************)

(*-51--------------------------------------------------------------*)
(* PNEXT GENERATES CODE FOR THE NEXT COMMAND.                     *)
(* THIS ROUTINE IS WEAK IN SYNTAX ERROR CHECKING.                 *)
(*-----------------------------------------------------------------*)

PROCEDURE PNEXT;

VAR   ISLOT : SLOTPTR;
      JCODE : CODEPTR;

BEGIN
  SCAN (TOKNUM);
  ISLOT := IDLOOKUP (ACCUM, ACCINX);
  IF ISLOT@.AUXREG2 = -1 THEN
    GENKEY (K_1)
  ELSE
    BEGIN
      GENKEY (K_RCL);
      GENKEY (ISLOT@.AUXREG2)
    END;
  GENKEY (K_SUM);
  GENKEY (ISLOT@.REGNO);
  GENKEY (K_GTO);
  JCODE := POPCODE (FORSTACK);
  PUTKEY (JCODE);
  GENKEY (-2);
  JCODE := POPCODE (NEXTSTACK);
  PUTKEY (JCODE);
  CLOSELINE
END;                                                    (* PNEXT *)

(*****************************************************************)
```

```
(*-52-----------------------------------------------------------*)
(* PFOR GENERATES CODE FOR THE FOR COMMAND.  THIS ROUTINE *)
(* (AND THE PNEXT ROUTINE) IS WEAK IN SYNTAX ERROR CHECK- *)
(* ING.  THERE ARE MANY PLACES WHERE SIMPLE CHECKS FOR     *)
(* CORRECT SYNTAX COULD HAVE BEEN PERFORMED BUT WERE NOT   *)
(* BECAUSE OF COMPLEXITY SUCH CHECKS WOULD HAVE INDUCED.   *)
(*-------------------------------------------------------------*)

PROCEDURE PFOR;

VAR  ISLOT : SLOTPTR;

BEGIN
  SCAN (TOKNUM);
  ISLOT := IDLOOKUP (ACCUM, ACCINX);
  ISLOT@.AUXREG1 := NEWREG;
  SCAN (TOKNUM);
  SCAN (TOKNUM);
  PEXPR;
  GENKEY (K_STO);
  GENKEY (ISLOT@.REGNO);
  SCAN (TOKNUM);
  PEXPR;
  GENKEY (K_STO);
  GENKEY (ISLOT@.AUXREG1);
  IF TOKNUM = STEPTOK THEN
    BEGIN
      SCAN (TOKNUM);
      PEXPR;
      GENKEY (K_STO);
      ISLOT@.AUXREG2 := NEWREG;
      GENKEY (ISLOT@.AUXREG2)
    END;
  PUSHCODE (NEWCODE (-2), FORSTACK);
  FORSTACK@.JMPP := CPCUR;
  GENKEY (K_RCL);
  GENKEY (ISLOT@.REGNO);
  GENKEY (K_X_T);
  GENKEY (K_RCL);
  GENKEY (ISLOT@.AUXREG1);
  GENKEY (K_INV);
  GENKEY (K_IFXGET);
  PUSHCODE (NEWCODE (K_NOP), NEXTSTACK);
  CPCUR@.JMPP := NEXTSTACK;
  GENKEY (-2);
  GENKEY (-2);
  CLOSELINE
END;                                                (* PFOR *)
```

```
(*****************************************************************)
(*                                                               *)
(*                    IF-BRANCHING ROUTINES                      *)
(*                                                               *)
(*****************************************************************)

(*-53-----------------------------------------------------------*)
(* QUITERROR IS CALLED WHENEVER A QUIT STATEMENT IS             *)
(* ENCOUNTERED WHILE NOT WITHIN THE SCOPE OF A LOOP.            *)
(*-------------------------------------------------------------*)

PROCEDURE QUITERROR;

BEGIN
  WRITE   (LISTF, '***** ATTEMPT TO "QUIT" WHILE NOT ');
  WRITELN (LISTF, 'INSIDE A LOOP.');
  PERROR
END;                                          (* QUITERROR *)

(*****************************************************************)

(*-54-----------------------------------------------------------*)
(* PQUIT GENERATES POTENTIAL ADDRESS SPACE WHOSE JMPP           *)
(* POINTS TO THE MOST CURRENT CODE NODE ON THE ENDLOOP          *)
(* STACK; THUS, CONTROL WILL LEAVE THE MOST CURRENTLY           *)
(* EXECUTING LOOP DURING TI-59 EXECUTION.  NOTE THAT THIS       *)
(* IMPLEMENTATION WILL NOT ALLOW LINE# TO FOLLOW 'QUIT'         *)
(*-------------------------------------------------------------*)

PROCEDURE PQUIT;

BEGIN
  IF ENDLOOPSTACK = NIL THEN
    QUITERROR
  ELSE
    BEGIN
      GENKEY (K_GTO);
      SETFWDJMP (ENDLOOPSTACK);
      SCAN (TOKNUM);
      IF TOKNUM = NUMBERTOK THEN
        BEGIN
          PSUBERROR;
          WRITE   (LISTF, '***** "QUIT" DOES NOT ACCEPT ');
          WRITELN (LISTF, 'LINE NUMBERS THIS IMPLEMENT.');
        END
      ELSE
        CLOSELINE
    END
END;                                              (* PQUIT *)

(*****************************************************************)

(*-56-*)
PROCEDURE PTHENLINE;                                   FORWARD;

(*****************************************************************)
```

```
(*-55--------------------------------------------------------*)
(* PTHENELSE DETERMINES WHETHER THE ELSE BRANCH OF AN        *)
(* IF-THEN-ELSE IS LINE-ORIENTED (LINE#) OR LOOP-ORIENTED    *)
(* ('QUIT'); APPROPRIATE ROUTINE IS CALLED TO SET JUMP.      *)
(*-----------------------------------------------------------*)

PROCEDURE PTHENELSE;

BEGIN
  SCAN (TOKNUM);
  IF TOKNUM = NUMBERTOK THEN
    BEGIN
      GENKEY (K_GTO);
      PTHENLINE
    END
  ELSE IF TOKNUM = QUITTOK THEN
    PQUIT
  ELSE
    BEGIN
      WRITE   (LISTF, '***** "IF-THEN-ELSE" LIMITED TO ');
      WRITELN (LISTF, '"QUIT" OR LINE NUMBERS.');
      PERROR
    END
END;                                          (* PTHENELSE *)

(************************************************************)

(*-56--------------------------------------------------------*)
(* PTHENLINE SETS THE LINE-ORIENTED JUMPS FOR THE IF-THEN   *)
(* OR IF-THEN-ELSE STATEMENTS.                               *)
(*-----------------------------------------------------------*)

PROCEDURE PTHENLINE;

BEGIN
  SETJMPEXT (XNUMBER (ACCUM, ACCINX));
  GENKEY (-2);
  GENKEY (-2);
  SCAN (TOKNUM);
  IF TOKNUM = ELSETOK THEN
    PTHENELSE
  ELSE
    CLOSELINE
END;                                          (* PTHENLINE *)

(************************************************************)

(*-57--------------------------------------------------------*)
(* PTHENQUIT SETS THE LOOP-ORIENTED JUMPS FOR IF-THEN OR    *)
(* IF-THEN-ELSE STATEMENTS.                                  *)
(*-----------------------------------------------------------*)

PROCEDURE PTHENQUIT;

BEGIN
  IF ENDLOOPSTACK = NIL THEN
    QUITERROR
  ELSE
    BEGIN
      SETFWDJMP (ENDLOOPSTACK);
      SCAN (TOKNUM);
      IF TOKNUM = ELSETOK THEN
        PTHENELSE
      ELSE
        CLOSELINE
    END
END;                                          (* PTHENQUIT *)

(************************************************************)
```

```
(*-58---------------------------------------------------------*)
(* PIF DETERMINES THE TYPE OF 'IF' STATEMENT; IT WILL          *)
(* CALL THE REQUIRED SET ROUTINES FOR UNSTRUCTURED JUMPS       *)
(* (LINE OR LOOP ORIENTED) OR PERFORM THE SET UP ITSELF        *)
(* FOR STRUCTURED JUMPS.                                       *)
(*------------------------------------------------------------*)

PROCEDURE PIF;

BEGIN
  PCONDITION;
  IF TOKNUM = THENTOK THEN
    BEGIN
      SCAN (TOKNUM);
      IF TOKNUM = NUMBERTOK THEN
        PTHENLINE
      ELSE IF TOKNUM = QUITTOK THEN
        PTHENQUIT
      ELSE
        PERROR
    END
  ELSE
    BEGIN
      PUSHCODE (NEWCODE (K_NOP), ENDIFSTACK);
      CPCUR@.BAKP := ENDIFSTACK;
      ENDIFSTACK@.BAKP := CPCUR;
      PUSHCODE (NEWCODE (K_NOP), IFSTACK);
      SETFWDJMP (IFSTACK);
      CLOSELINE
    END
END;                                                  (* PIF *)

(*************************************************************)

(*-59---------------------------------------------------------*)
(* ELSE_ADJUST PERFORMS HOUSE-KEEPING ON THE VARIOUS 'IF'     *)
(* STACKS DEPENDENT UPON THE FORM OF THE STRUCTURED 'IF'      *)
(* STATEMENT ENCOUNTERED; IF-ENDIF REQUIRES A DIFFERENT       *)
(* SEQUENCE OF PUSH/POP STACK THAN DOES IF-ELSE-ENDIF OR      *)
(* IF-ELSEIF-ELSE-ENDIF.                                      *)
(*------------------------------------------------------------*)

PROCEDURE ELSE_ADJUST;

BEGIN
  WITH ENDIFSTACK@ DO
    BEGIN
      IF BAKP <> NIL THEN
        BEGIN
          BAKP@.BAKP := NIL;
          BAKP@.JMPP@.BAKP := NIL;
          BAKP := NIL
        END
    END
END;                                          (* ELSE_ADJUST *)

(*************************************************************)
```

```
(*-60-----------------------------------------------------------*)
(* PELSEIF PERFORMS A SEQUENCE OF STACK MANIPULATIONS IN        *)
(* ORDER TO GENERATE THE ADDRESS SPACES AND JUMPS WHICH         *)
(* IMPLEMENT THE ELSEIF CONSTRUCT.                              *)
(*--------------------------------------------------------------*)

PROCEDURE PELSEIF;

VAR  JCODE : CODEPTR;

BEGIN
  ELSE_ADJUST;
  GENKEY (K_GTO);
  SETFWDJMP (ENDIFSTACK);
  JCODE := POPCODE (IFSTACK);
  PUTKEY (JCODE);
  PCONDITION;
  PUSHCODE (NEWCODE (K_NOP), IFSTACK);
  SETFWDJMP (IFSTACK);
  CLOSELINE
END;                                              (* PELSEIF *)

(**************************************************************)

(*-61-----------------------------------------------------------*)
(* PELSE IS SIMILAR TO ELSEIF EXCEPT IT DOES NOT PARSE/         *)
(* GENERATE CODE TO EVALUATE A BOOLEAN EXPRESSION.              *)
(*--------------------------------------------------------------*)

PROCEDURE PELSE;

VAR  JCODE : CODEPTR;

BEGIN
  ELSE_ADJUST;
  GENKEY (K_GTO);
  SETFWDJMP (ENDIFSTACK);
  JCODE := POPCODE (IFSTACK);
  PUTKEY (JCODE);
  SCAN (TOKNUM);
  CLOSELINE
END;                                              (* PELSE *)

(**************************************************************)
```

```
(*-62-------------------------------------------------------------*)
(* PENDIF CLOSES UP THE SCOPE OF A STRUCTURED 'IF'               *)
(* CONSTRUCT BY POPPING THE APPROPRIATE STACKS AND               *)
(* INSERTING AND DISCARDING CODE WHICH HAD BEEN STACKED:         *)
(* DISCARDING/INSERTING IS DEPENDENT UPON THE PARTICULAR         *)
(* TYPE OF 'IF' CONSTRUCT (IF-ENDIF OR IF-ELSE-ENDIF).           *)
(*----------------------------------------------------------------*)

PROCEDURE PENDIF;

VAR  DUMPC, JCODE : CODEPTR;

BEGIN
  WITH ENDIFSTACK@ DO
    BEGIN
      IF BAKP <> NIL THEN
        BEGIN                    (* NO ELSE/ELSEIF HAS BEEN SEEN *)
          BAKP@.BAKP := NIL;              (* NULLIFY POINTERS *)
          BAKP := NIL;
          DUMPC := PCPCODE (ENDIFSTACK);     (* CLEAR STACK *)
          DUMPC@.ADDR := -1;
          JCODE := PCPCODE (IFSTACK);       (* INSERT ENDIF *)
          PUTKEY (JCODE)
        END
      ELSE                       (* ELSE/ELSEIF HAS BEEN SEEN *)
        BEGIN
          JCODE := PCPCODE (ENDIFSTACK);  (* INSERT ENDIF *)
          JCODE@.ADDR := 0;  (* MARK TERMINAL NODE OF JUMP *)
          PUTKEY (JCODE)          (* ELSE ADJUST HAS ALREADY *)
        END                       (*  CLEARED ENDIFSTACK.    *)
    END;
  SCAN (TOKNUM);
  CLOSELINE
END;                                            (* PENDIF *)
```

```
(*****************************************************************)
(*                                                               *)
(*                     I/O COMMAND ROUTINES                      *)
(*                                                               *)
(*****************************************************************)

(*-84-*)
PROCEDURE WRITLN (VAR WFILE, MSGFILE : TEXT;
                      MSG_NO : INTEGER);                 FORWARD;

(*****************************************************************)

(*-63-----------------------------------------------------------*)
(* PDATA GENERATES SINGLE NOP TO PROTECT FROM LINE-            *)
(* ORIENTED JUMP REFERENCES; THIS COMMAND IS INTENDED FOR      *)
(* USE AT THE START OF A PROGRAM SINCE ITS USE WITHIN          *)
(* LOOPS, SBR'S, OR FUNCTIONS WOULD RENDER THE DATA TO         *)
(* READ MAPPING MEANINGLESS.  THIS ROUTINE READS THE DATA      *)
(* VALUES FOUND AS ITS PARAMETERS, COUNTS THEM, AND            *)
(* STORES THEM IN AN ARRAY OF RECORDS WHICH IS ACCESSED        *)
(* BY SUBSEQUENT READ COMMANDS.                                *)
(*-------------------------------------------------------------*)

PROCEDURE PDATA;

VAR  DATASIGN : CHAR;

BEGIN
  GENKEY (K_NOP);
  SCAN (TOKNUM);
  WHILE (TOKNUM IN SIGNTOKS) OR (TOKNUM = NUMBERTOK) DO
    BEGIN
      DATASIGN := BLANK;
      IF TOKNUM IN SIGNTOKS THEN
        BEGIN
          IF TOKNUM = MINUSTOK THEN
            DATASIGN := '-';
          SCAN (TOKNUM)
        END;
      IF DATAIX = REGBASE + 1 THEN
        BEGIN
          PWARN;
          WRITE   (LISTF,'***** EXCEEDED DATASTORE ');
          WRITE   (LISTF,'CAP = ', REGBASE : 1);
          WRITELN (LISTF, '...RESET DATA INDEX TO 1.');
          DATAIX := 1
        END;
      DATALIST(.DATAIX.).NUMB := ACCUM;
      DATALIST(.DATAIX.).SIGN := DATASIGN;
      DATAIX := DATAIX + 1;
      SCAN (TOKNUM);
      IF TOKNUM = COMMATOK THEN
        SCAN (TOKNUM)
    END;
  CLOSELINE
END;                                                     (* PDATA *)

(*****************************************************************)
```

```
(*-64-----------------------------------------------------------*)
(* PREAD ONLY GENERATES A NOP INSTRUCTION TO ALLOW FOR          *)
(* LINE-ORIENTED JUMP REFERENCES; OTHERWISE, THIS COMMAND       *)
(* WRITES THE READF FILE WHICH INDICATES DATA VALUES FOR        *)
(* RESPECTIVE REGISTERS AND THEIR WBASIC VARIABLE NAMES;        *)
(* THE READF FILE IS USED TO INPUT DATA PRIOR TO PROGRAM        *)
(* EXECUTION ON THE TI-59, THUS, SAVING PROGRAM STEPS.          *)
(* THE CONSTRUCT IS INTENDED FOR USE AT THE START OF A          *)
(* PROGRAM.  IF NESTED WITHIN THE PROGRAM, LOOPS, SBR'S,        *)
(* AND FN'S WOULD RENDER THE DATA/READ MAP MEANINGLESS.         *)
(*--------------------------------------------------------------*)

PROCEDURE PREAD;

VAR  IDSLOT : SLOTPTR;

BEGIN
  GENKEY (K_NOP);
  IF FIRSTREAD THEN
    BEGIN
      REWRITE (READF, 'NAME=READF.WBASIC.A');
      WRITLN (READF, MSGF, 9);
      FIRSTREAD := FALSE
    END;
  IF NOT INDEXERROR THEN
    BEGIN
      SCAN (TOKNUM);
      WRITELN (READF);
      WHILE TOKNUM = IDENTOK DO
        BEGIN
          IDSLOT := IDLOOKUP (ACCUM, ACCINX);
          WITH IDSLOT@ DO
            BEGIN
              IF READIX >= DATAIX THEN
                BEGIN
                  PWARN;
                  WRITE     (LISTF, '***** READ PAST DATA ');
                  WRITE     (LISTF, 'INDEX...IGNORING ');
                  WRITELN   (LISTF, 'SUBSEQUENT READ/DATA.');
                  WRITELN   (READF);
                  WRITE     (READF, '***** READ PAST DATA ');
                  WRITE     (READF, 'INDEX...SUBSEQUENT ');
                  WRITELN   (READF, 'READ/DATA IGNORED.');
                  INDEXERROR := TRUE;
                  PRECOVER
                END
              ELSE
                BEGIN
                  WRITE     (READF, ' ':5);
                  WRITE     (READF, DATALIST(.READIX.).SIGN);
                  WRITE     (READF, DATALIST(.READIX.).NUMB);
                  WRITE     (READF, ' ':2);
                  ZEROPAD   (READF, REGNO, 2);
                  WRITELN   (READF, ' ':3, IDENT);
                  READIX := READIX + 1;
                  SCAN (TOKNUM);
                  IF TOKNUM = COMMATOK THEN
                    SCAN (TOKNUM)
                END
            END
        END
    END
  ELSE
    PRECOVER;
  CLOSELINE
END;                                                   (* PREAD *)

(****************************************************************)
```

```
(*-65-----------------------------------------------------------*)
(* PRESTORE GENERATES A SINGLE NOP TO PROTECT FROM LINE-      *)
(* ORIENTED JUMP REFERENCES.  IN THIS IMPLEMENTATION,         *)
(* THIS CONSTRUCT IS NOT OF GREAT VALUE SINCE DATA/READ        *)
(* STATEMENTS ARE SUGGESTED FOR USE AT THE START OF A          *)
(* PROGRAM ONLY; THIS ROUTINE RESETS THE READ INDEX TO         *)
(* ITS INITIAL VALUE (=1).                                     *)
(*-------------------------------------------------------------*)

PROCEDURE PRESTORE;

BEGIN
  GENKEY (K_NOP);
  READIX := 1;
  SCAN (TOKNUM);
  CLOSELINE
END;                                            (* PRESTORE *)

(*************************************************************)

(*-66----------------------------------------------------------*)
(* PINPUT PARSES A LIMITED FORM OF THE WBASIC "INPUT"         *)
(* STATEMENT; THE LIST OF INPUT PARAMETERS MAY CONSIST OF     *)
(* VARIABLE NAMES ONLY.                                        *)
(*-------------------------------------------------------------*)

PROCEDURE PINPUT;

VAR  TENDIG : -1..9;
     INPVAR : SLCTPTR;

BEGIN
  SCAN (TOKNUM);
  GENKEY (K_CE);
  TENDIG := -1;      (* FLAG CHECKS IF INPUT VARS ARE LISTED *)
  WHILE TOKNUM = IDENTOK DO
    BEGIN
      INPVAR := IDLOOKUP (ACCUM, ACCINX);
      TENDIG := INPVAR@.REGNO DIV 10;
      GENKEY (TENDIG); (* REG IN WHICH INPUT TO BE STORED *)
      GENKEY (INPVAR@.REGNO - (TENDIG * 10));
      GENKEY (K_INT);                  (* CLOSES DISPLAY REG *)
      GENKEY (K_RS);
      GENKEY (K_STO);
      GENKEY (INPVAR@.REGNO);
      SCAN (TOKNUM);
      IF TOKNUM = COMMATOK THEN      (* PARAMETERS SEPARATED *)
        SCAN (TOKNUM)                (* BY COMMAS OR BLANKS. *)
    END;
  IF TENDIG = -1 THEN            (* GENERATES A R/S IF "INPUT" *)
    GENKEY (K_RS);               (* IS USED WITHOUT A VAR LIST *)
  CLOSELINE
END;                                              (* PINPUT *)

(*************************************************************)
```

```
(*-67-------------------------------------------------------*)
(* PPRINT PARSES A LIMITED FORM OF THE WBASIC "PRINT"      *)
(* STATEMENT; IT ALLOWS EXPRESSIONS, VARIABLE NAMES, AND   *)
(* LITERAL NUMERICS IN THE LIST OF PARAMETERS.             *)
(*---------------------------------------------------------*)

PROCEDURE PPRINT;

BEGIN
  SCAN (TOKNUM);
  WHILE TOKNUM IN BEGIN_EXPRTOKS DO
    BEGIN
      PEXPR;
      IF PC100 THEN                                 (* WITH PC100 *)
        GENKEY (K_PRT)
      ELSE                                       (* WITHOUT PC100 *)
        BEGIN
          GENKEY (K_PAUSE);
          GENKEY (K_RS)
        END;
      IF TOKNUM = COMMATOK THEN    (* CAN SEPARATE ITEMS BY *)
        SCAN (TOKNUM)              (* COMMAS OR BLANKS.     *)
    END;
  IF PC100 THEN                                     (* WITH PC100 *)
    GENKEY (K_ADV);
  CLOSELINE
END;                                                   (* PPRINT *)
```

```
(*****************************************************************)
(*                                                               *)
(*       OTHER COMMAND WORD PARSE/GENERATE ROUTINES              *)
(*                                                               *)
(*****************************************************************)

(*-68-----------------------------------------------------------*)
(* POPTION SETS/RESETS THE OPTION TOGGLES WHICH ALLOW THE      *)
(* USER OUTSIDE CONTROL OF COMPILER OUTPUTS; NOTE THAT         *)
(* THIS CONSTRUCT IS NOT THE SAME AS THE OPTION STATEMENT      *)
(* OF WBASIC; IT IS INTENDED FOR USE AT THE BEGINNING OF       *)
(* THE SOURCE PROGRAM; USE ANYWHERE ELSE MAY PRODUCE           *)
(* UNEXPECTED RESULTS AND/OR OPERATING SYSTEM ERRORS.          *)
(*-------------------------------------------------------------*)

PROCEDURE POPTION;

VAR  SWITCH : BOOLEAN;
     TOGGLE : INTEGER;

BEGIN
  GENKEY (K_NOP);
  SCAN (TOKNUM);
  WHILE NOT (TOKNUM IN TRAILTOKS) DO
    BEGIN
      SWITCH := TRUE;
      IF TOKNUM IN SIGNTOKS THEN
        BEGIN
          IF TOKNUM = MINUSTOK THEN
            SWITCH := FALSE;
          SCAN (TOKNUM)
        END;
      IF TOKNUM = NUMBERTOK THEN
        BEGIN
          TOGGLE := XNUMBER (ACCUM, ACCINX);
          IF TOGGLE IN (.0..8.) THEN
            CASE TOGGLE OF
              0 : LINK59 := TRUE;
              1 : PC100  := SWITCH;
              2 : OPTPAR := SWITCH;
              3 : OPTNOP := SWITCH;
              4 : CODUMP := SWITCH;
              5 : SYDUMP := SWITCH;
              6 : DSDUMP := SWITCH;
              7 : TOKOUT := SWITCH;
              8 : TOKLIS := SWITCH
            END   (* CASE *)
          ELSE
            BEGIN
              PWARN;
              WRITE   (LISTF, '***** NO SUCH OPTION...');
              WRITELN (LISTF, ACCUM)
            END
        END
      ELSE
        BEGIN
          PWARN;
          WRITE   (LISTF, '***** OPTION PARAMETERS ARE ');
          WRITELN (LISTF, '-8..0..+8 ONLY.');
        END;
      SCAN (TOKNUM)
    END;
  CLOSELINE
END;                                          (* POPTION *)

(*****************************************************************)
```

```
(*-69-----------------------------------------------------------*)
(* PNOLET PARSES AND GENERATES CODE FOR AN ASSIGNMENT           *)
(* STATEMENT WHICH DOES NOT BEGIN WITH THE 'LET' COMMAND.       *)
(*--------------------------------------------------------------*)

PROCEDURE PNOLET;

VAR   RESULT : SLOTPTR;

BEGIN
  RESULT := IDLOOKUP (ACCUM, ACCINX);
  SCAN (TOKNUM);
  IF TOKNUM <> EQUALTOK THEN                              (* '=' *)
    PERROR
  ELSE
    BEGIN
      SCAN (TOKNUM);
      PEXPR;
      GENKEY (K_STO);
      IF RESULT@.TYP = VARID THEN
        GENKEY (RESULT@.REGNO)
      ELSE IF RESULT@.TYP = FNPID THEN
        GENKEY (RESULT@.FNREGNO)
      ELSE
        PERROR
    END
END;                                                    (* PNOLET *)

(****************************************************************)

(*-70-----------------------------------------------------------*)
(* PLET PARSES AND GENERATES CODE FOR A 'LET' STATEMENT.        *)
(*--------------------------------------------------------------*)

PROCEDURE PLET;

BEGIN
  SCAN (TOKNUM);
  PNOLET
END;                                                      (* PLET *)

(****************************************************************)

(*-71-----------------------------------------------------------*)
(* PREM GUARDS AGAINST USE OF A GOTO DIRECTED TO A REM BY       *)
(* CAUSING GENERATION OF A NODE (LOADED W/ A NOP INSTRUC)       *)
(* WHICH CAN BE REFERENCED BY A JMPP POINTER; THE SCANNER       *)
(* HAS RESPONSIBILITY FOR SKIPPING OVER THE CMT TEXT.           *)
(*--------------------------------------------------------------*)

PROCEDURE PREM;

BEGIN
  GENKEY (K_NOP);
  SCAN (TOKNUM)
END;                                                      (* PREM *)

(****************************************************************)
```

```
(*-72-----------------------------------------------------------*)
(* PGOTO GENERATES THE TI-59 GTO STATEMENT AND ITS             *)
(* POTENTIAL ADDRESS SPACE; THE JUMP POINTER FROM THE 1ST      *)
(* NODE OF THIS ADDRESS SPACE IS POINTED TO THAT NODE IN       *)
(* THE CODE DATA STRUCTURE WHICH IS THE START (OR, IN THE      *)
(* CASE OF FORWARD JUMPS, THE POTENTIAL START) OF CODE         *)
(* GENERATED FOR THE WBASIC LINE NUMBER REFERENCED IN THE      *)
(* GOTO COMMAND.                                               *)
(*-------------------------------------------------------------*)

PROCEDURE PGOTO;

BEGIN
  GENKEY (K_GTO);
  SCAN (TOKNUM);
  IF TOKNUM <> NUMBERTOK THEN
    PERROR
  ELSE
    BEGIN
      SETJMPEXT (XNUMBER (ACCUM, ACCINX));
      GENKEY (-2);
      GENKEY (-2)
    END;
  CLOSELINE
END;                                                  (* PGOTO *)

(***************************************************************)

(*-73-----------------------------------------------------------*)
(* PGOSUB GENERATES A CALL TO A SUBROUTINE REFERENCED BY       *)
(* WBASIC LINE NUMBER; NOTE THAT ALTHOUGH WBASIC CALLS         *)
(* SUBROUTINES BY LINE NUMBER, THE TI-59 CODE GENERATED        *)
(* CALLS A SUBROUTINE BY A LABEL NAME; AN EXTERNAL JUMP        *)
(* IS SET (AS IN THE GOTO), HOWEVER, RESOLUTION OF THE         *)
(* JUMP WILL BE MADE BY INSERTING THE LABEL USED IN THE        *)
(* CALL IN FRONT OF THE NODE REFERENCED BY THE JMPP; THIS      *)
(* INSERTION IS DONE AFTER ALL CODE HAS BEEN GENERATED.        *)
(* NOTE THAT THIS ROUTINE NEITHER CHECKS FOR NOR DOES IT       *)
(* KNOW OF THE EXISTENCE OF A RETURN STATEMENT IN THE          *)
(* SEQUENCE OF SOURCE CODE ASSUMED TO BE THE GOSUB BODY;       *)
(* IF THE USER DOES NOT PROVIDE A RETURN STATEMENT, THEN       *)
(* NO CORRESPONDING TI-59 INVSBR (SBR RETURN) WILL BE          *)
(* GENERATED, AND THE SBR RETURN REGISTER IN THE               *)
(* CALCULATOR WILL NEVER BE CLEARED OF THAT SBR CALL.          *)
(*-------------------------------------------------------------*)

PROCEDURE PGOSUB;

BEGIN
  GENKEY (K_SBR);
  SCAN (TOKNUM);
  IF TOKNUM <> NUMBERTOK THEN
    PERROR
  ELSE
    BEGIN
      SETJMPEXT (XNUMBER (ACCUM, ACCINX));
      GENKEY (NEWLBL)
    END;
  CLOSELINE
END;                                                 (* PGOSUB *)

(***************************************************************)
```

```
(*-74-------------------------------------------------------*)
(* PRETURN GENERATES THE RETURN FROM A SUBROUTINE.          *)
(* STRUCTURED PROGRAMMING DISCIPLINE DEMANDS A RETURN FOR   *)
(* EACH SUBROUTINE CALL; NOTE THAT THE TI-59 HAS A LIMIT    *)
(* OF SBR RETURN ADDRESSES WHICH CAN BE STACKED; THE USER   *)
(* SHOULD REMEMBER THAT THE WBASIC RETURN STATEMENT IS      *)
(* THE ONLY ONE WHICH WILL GENERATE THE TI-59 INVSBR        *)
(* FOR A GOSUB GENERATED SBR CALL (FUNCTIONS GENERATE SBR   *)
(* AND INVSBR ALSO, BUT THEY DO THIS AS A RESULT OF THE     *)
(* FNEND STATEMENT OR A ONE-LINE FUNCTION).                 *)
(*----------------------------------------------------------*)

PROCEDURE PRETURN;

BEGIN
  GENKEY (K_INVSBR);
  CLOSELINE
END;                                          (* PRETURN *)

(***********************************************************)

(*-75-------------------------------------------------------*)
(* PPAUSE GENERATES (82) (31) WHICH ARE ACTUALLY A VOID     *)
(* CODE AND THE 'LRN' KEY; WHEN ENTERING HIS PROGRAM INTO   *)
(* THE CALCULATOR THE USER MUST ENTER 'STO 31' INSTEAD OF   *)
(* (82) (31) WHICH CANNOT BE ENTERED DIRECTLY ANYWAY; THEN  *)
(* THE USER MUST BACKSTEP AND CHANGE THE ORIGINAL 'STO 31'*)
(* BY ISSUING THE FOLLOWING EDITING KEY STROKE SEQUENCE     *)
(* TO THE CALCULATOR IMMEDIATELY AFTER ENTERING THE         *)
(* 'STO 31':  BST,BST,NOP,SST.  THIS WILL REVISE THE        *)
(* ORIGINAL 'STO 31' TO 'NOP 31'; WHEN ENCOUNTERED BY THE   *)
(* CALCULATOR THESE 2 INSTRUCTIONS WILL STOP EXECUTION BY   *)
(* SHIFTING THE CALCULATOR INTO THE LEARN (LRN) MODE;       *)
(* IN ORDER TO RESUME EXECUTION, THE USER MUST ENTER        *)
(* 'LRN' (PLACING THE DISPLAY REG BACK INTO VIEW)           *)
(* FOLLOWED BY 'R/S' (WHICH RESUMES THE PROCESSING MODE);  *)
(* THIS INTERRUPTION OF EXECUTION DOES NOT CAUSE ANY SIDE   *)
(* EFFECTS AND PROVIDES AN ACCURATE INDICATION OF THE       *)
(* LOCATION OF ANY 'PAUSE' STATEMENTS PLACED IN THE         *)
(* WBASIC SOURCE CODE; THIS IMPLEMENTATION OF THE 'PAUSE'   *)
(* INSTRUCTION PROVIDES A CONVENIENT AND RECOGNIZABLE       *)
(* DEBUGGING/TRANSLATION TOOL WHICH CARRIES A LOW           *)
(* OVERHEAD IN TERMS OF REGISTER/PROGRAM STEP USE.          *)
(*----------------------------------------------------------*)

PROCEDURE PPAUSE;

BEGIN
  GENKEY (82);                (* VOID  *)
  GENKEY (31);                (* LEARN *)
  CLOSELINE
END;                                           (* PPAUSE *)

(***********************************************************)
```

```
(*-76-----------------------------------------------------------*)
(* PSTOP GENERATES CODE WHICH CAUSES THE TI-59 TO HALT         *)
(* EXECUTION AND DISPLAY '888' THUS SIGNALING THAT A           *)
(* PROGRAM STOP HAS BEEN ENCOUNTERED INSTEAD OF A DATA         *)
(* INPUT OR MAGNETIC CARD LINKING INSTRUCTION.                 *)
(*-------------------------------------------------------------*)

PROCEDURE PSTOP;

VAR   I : 1..4;

BEGIN
  GENKEY (K_CE);
  FOR I := 1 TO 3 DO
    GENKEY (8);
  GENKEY (K_RS);
  CLOSELINE
END;                                                (* PSTOP *)

(***************************************************************)

(*-77----------------------------------------------------------*)
(* PEND ASSUMES THAT THE END OF THE WBASIC SOURCE FILE        *)
(* HAS BEEN ENCOUNTERED AND WILL INSERT THE END OF FILE       *)
(* CHAR INTO THE TOKEN STREAM, CAUSING IMMEDIATE              *)
(* TERMINATION OF THE COMPILATION PROCESS.                    *)
(*------------------------------------------------------------*)

PROCEDURE PEND;

BEGIN
  GENKEY (K_NOP);
  TOKNUM := ENDFILTOK
END;                                                 (* PEND *)
```

```
(****************************************************************)
(*                                                              *)
(*                  CODE RESOLUTION ROUTINES                    *)
(*                                                              *)
(****************************************************************)

(*-78-----------------------------------------------------------*)
(* PUTGOSUBLBL USES PROCEDURE INSERTKEY TO ENTER THE LBL       *)
(* REFERENCED BY THE GOSUB CALL INTO THE CODE SEQUENCE AT      *)
(* LOCATION POINTED TO BY TO BY THE JMPP (LBLP).               *)
(*--------------------------------------------------------------*)

PROCEDURE PUTGOSUBLBL (LBL : LBLRNG; VAR LBLP : CODEPTR);

BEGIN
  WITH LBLP@.BAKP@ DO
    BEGIN
      INSERTKEY (LBL, SEQP);
      INSERTKEY (K_LBL, SEQP)
    END
END;                                         (* PUTGOSUBLBL *)

(****************************************************************)

(*-79-----------------------------------------------------------*)
(* FINDGOSUBLBL SEARCHES THE CODE DATA STRUCTURE TO FIND       *)
(* SBR CALLS FOR WHICH THE JMPP HAS BEEN SET; THESE WILL       *)
(* CORRESPOND TO WBASIC GOSUB STATEMENTS; THE JMPP IS          *)
(* FOLLOWED AND THE CORRECT LABEL IS INSERTED INTO THE         *)
(* CODE SEQUENCE USING THE BAKP AND PROCEDURE PUTGOSUBLBL      *)
(*--------------------------------------------------------------*)

PROCEDURE FINDGOSUBLBL (VAR START : CODEPTR);

VAR  TRAVELP, TAILP : CODEPTR;

BEGIN
  TRAVELP := START@.SEQP;
  TAILP := START;
  WHILE TRAVELP <> ENDCP@.SEQP DO
    BEGIN
      WITH TRAVELP@ DO
        IF (JMPP <> NIL) AND (TAILP@.KEY = K_SBR) THEN
          BEGIN     (* FIRST CHECK FOR REDUNDANT GOSUB CALL *)
            IF JMPP@.BAKP@.SEQP@.KEY = K_LBL THEN
              KEY := JMPP@.BAKP@.SEQP@.SEQP@.KEY
            ELSE
              PUTGOSUBLBL (KEY, JMPP);  (* INSERT A LABEL *)
            JMPP@.ADDR := -1;           (* UNMARK JMPP ADDR  *)
            JMPP := NIL                 (* RESET JMPP TO NIL *)
          END;
      TAILP := TRAVELP;
      TRAVELP := TRAVELP@.SEQP
    END
END;                                         (* FINDGOSUBLBL *)

(****************************************************************)
```

```
(*-80-------------------------------------------------------*)
(* OSQPAREN (OPTIMIZE SQUEEZE PARENTHESES) REMOVES          *)
(* UNNECESSARY PARENTHESES (IN PAIRS) FROM THE CODE DATA    *)
(* STRUCTURE FOR THE MOST COMMON CASES, NAMELY '(RCL NN)'   *)
(* AND '(<LITERAL NUMERIC>)'.                               *)
(*----------------------------------------------------------*)

PROCEDURE OSQPAREN (START : CODEPTR);

VAR   OPEN, CLOSE, TAILP, MOVEP : CODEPTR;
      OPENCT, CLOSECT           : INTEGER;

(*----------------------------------------------------------*)

(*-80-01----------------------------------------------------*)
(* COUNTREP COUNTS THE NUMBER OF SEQUENTIAL OCCURENCES OF   *)
(* KEYC AT A PARTICULAR LOCATION IN THE CODE DATA STRUCTR   *)
(* STRUCTURE; NOTE THAT IT ALSO CHECKS FOR JMPP POINTERS    *)
(* TO THESE KEYS.                                           *)
(*----------------------------------------------------------*)

FUNCTION COUNTREP (VAR MOVEP:CODEPTR; KEYC:INTEGER):INTEGER;

VAR   COUNT : INTEGER;

BEGIN
  COUNT := 0;
  WHILE (MOVEP@.KEY = KEYC) AND (MOVEP@.ADDR = -1) DO
    BEGIN
      MOVEP := MOVEP@.SEQP;
      COUNT := COUNT + 1
    END;
  COUNTREP := COUNT
END;                                          (* COUNTREP *)

(*----------------------------------------------------------*)

(*-80-02----------------------------------------------------*)
(* NUMBERUN MOVES ITS POINTER PARAMETER PASSED ANY NODE     *)
(* WHICH CONTAINS A NUMERIC LITERAL KEY CODE AND HAS NO     *)
(* POINTER REFERENCE; IT IS ASSUMED HERE THAT NO JUMP       *)
(* POINTER IS EVER SET IN THE MIDDLE OF A NUMERIC LITERAL   *)
(* KEY SEQUENCE, ELSE PART OF THE NUMBER MAY BE REMOVED.    *)
(*----------------------------------------------------------*)

PROCEDURE NUMBERUN (VAR MOVEP : CODEPTR);

BEGIN
  WHILE (MOVEP@.KEY IN NUMERICKEY) AND (MOVEP@.ADDR = -1) DO
    MOVEP := MOVEP@.SEQP
END;                                          (* NUMBERUN *)

(*----------------------------------------------------------*)
```

```
(*-30-03-------------------------------------------------------*)
(* REMOVEPAREN TAKES PAIRS OF NODES OUT OF THE CODE DATA      *)
(* STRUCTURE; NOTE THAT THIS PROCEDURE DOES NOT KNOW WHAT     *)
(* CODE IT IS REMOVING; THAT IS DEFINED BY OSQPAREN.          *)
(*-------------------------------------------------------------*)

PROCEDURE REMOVEPAREN (VAR OPEN, CLOSE : CODEPTR;
                           OPENCT, CLOSECT : INTEGER);
BEGIN
  REPEAT
    OPEN@.SEQP := OPEN@.SEQP@.SEQP;
    OPENCT := OPENCT - 1;
    CLOSE@.SEQP := CLOSE@.SEQP@.SEQP;
    CLOSECT := CLOSECT - 1
  UNTIL (OPENCT = 0) OR (CLOSECT = 0)
END;                                         (* REMOVEPAREN *)

(*-------------------------------------------------------------*)

BEGIN    (* OSQPAREN MAIN *)
  MOVEP := START;
  WHILE MOVEP@.SEQP <> NIL DO
    BEGIN
      IF (MOVEP@.KEY = K_OPAREN) AND (MOVEP@.ADDR = -1) THEN
        BEGIN
          OPEN := TAILP;                     (* SET OPEN PTR  *)
          OPENCT := COUNTREP (MOVEP, K_OPAREN);
          IF (MOVEP@.KEY=K_RCL) AND (MOVEP@.ADDR=-1) THEN
            BEGIN
              CLOSE := MOVEP@.SEQP;          (* SET CLOSE PTR *)
              MOVEP := MOVEP@.SEQP@.SEQP;      (* MOVE AHEAD *)
              CLOSECT := COUNTREP (MOVEP, K_CPAREN);
              IF CLOSECT > 0 THEN       (* IF EXTRAS, DELETE *)
                REMOVEPAREN (OPEN, CLOSE, OPENCT, CLOSECT)
            END
          ELSE IF (MOVEP@.KEY IN NUMERICKEY) AND
                  (MCVEP@.ADDR = -1)                 THEN
            BEGIN
              WHILE MOVEP@.SEQP@.KEY IN NUMERICKEY DO
                MOVEP := MOVEP@.SEQP; (* PASS OVER NUMBER *)
              CLOSE := MOVEP;                (* SET CLOSE PTR *)
              MOVEP := MOVEP@.SEQP;            (* MOVE AHEAD *)
              CLOSECT := COUNTREP (MOVEP, K_CPAREN);
              IF CLOSECT > 0 THEN       (* IF EXTRAS, DELETE *)
                REMOVEPAREN (OPEN, CLOSE, OPENCT, CLOSECT)
            END
        END;
        TAILP := MOVEP;
        MOVEP := MOVEP@.SEQP
    END
END;                                            (* OSQPAREN *)

(***************************************************************)
```

```
(*-81------------------------------------------------------------*)
(* OSQNOP (OPTIMIZE SQUEEZE NOP) LOCATES ALL 'NOP' KEY          *)
(* CODES, RESETS POINTER REFERENCES TO THEM IF THEY EXIST,      *)
(* AND THEN PINCHES THEM OUT OF THE CODE DATA STRUCTURE.        *)
(*---------------------------------------------------------------*)

PROCEDURE OSQNOP (VAR START : CODEPTR);

VAR  CUR   : CODEPTR;
     I     : 0..3;
     INDEX : CTEXTRNG;

BEGIN
  CUR := START;                         (* RESET JMPPS PAST NOPS *)
  WHILE CUR <> NIL DO                   (*  ASSUMES THAT NO JMPP *)
    BEGIN                               (*  IS SET ON POTENTIAL  *)
      IF CUR@.JMPP <> NIL THEN          (*  ADDR SPACE NOPS.     *)
        WHILE (CUR@.JMPP@.KEY = K_NOP)
              AND (CUR@.JMPP <> ENDCP) DO
          BEGIN
            CUR@.JMPP@.ADDR := -1;
            CUR@.JMPP := CUR@.JMPP@.SEQP;
            CUR@.JMPP@.ADDR := 0
          END;
      CUR := CUR@.SEQP
    END;
  CUR := START;                         (* SQUEEZE OUT NOPS *)
  WHILE CUR@.SEQP <> NIL DO
    BEGIN
      INDEX := CUR@.KEY;           (* FIX THE INDEX TO CTEXT *)
      FOR I := 1 TO (CTEXT(.INDEX.).UNIT) DO
        CUR := CUR@.SEQP;          (* BYPASS REG/ADDR SPACES *)
      IF (CUR@.SEQP@.KEY = K_NOP) AND (CUR@.SEQP@.ADDR = -1)
        THEN CUR@.SEQP := CUR@.SEQP@.SEQP    (* REMOVE NOP *)
      ELSE
        CUR := CUR@.SEQP                     (* NEXT NODE  *)
    END
END;                                          (* OSQNOP *)

(*****************************************************************)
```

```
(*-82--------------------------------------------------------*)
(* RESOLVE_ADDR FILLS THE ADDR FIELDS OF ALL TI-59 CODE      *)
(* NODES LINKED IN THE CODE DATA STRUCTURE, AND THEN         *)
(* FILLS THE KEY FIELDS OF NODES WHICH HAVE NON-NIL          *)
(* JMPP'S WITH THE ABSOLUTE ADDR POINTED TO BY THOSE         *)
(* JMPP'S; JMPP'S ARE THEN SET BACK TO NIL.                  *)
(*-----------------------------------------------------------*)

PROCEDURE RESOLVE_ADDR (START : CODEPTR);

VAR   TRAVEL : CODEPTR;
      I : INTEGER;

(*-----------------------------------------------------------*)

(*-82-01-----------------------------------------------------*)
(* INSERT_JMPADDR CONVERTS THE ADDR FOUND AT THE NODE        *)
(* REFERENCED BY JMPP PTR INTO A TI-59 MACHINE CODE ADDR     *)
(* (2 INTEGERS IN RANGE 0..99), AND INSERTS IT INTO THE      *)
(* THE KEY FIELDS (OCCUPIED BY -2'S) OF THE NODES FROM       *)
(* WHICH THE JMPP ORIGINATES.                                *)
(*-----------------------------------------------------------*)

PROCEDURE INSERT_JMPADDR (JADDR : INTEGER);

VAR   HIPART, LOPART : INTEGER;

BEGIN
  HIPART := JADDR DIV 100;                    (* SPLIT ADDR INTO *)
  LOPART := JADDR - HIPART * 100;             (* HI/LO PARTS;    *)
  TRAVEL@.KEY := HIPART;                      (* OVERWRITE NOP'S *)
  TRAVEL@.SEQP@.KEY := LOPART                 (* W/ ABS ADDR'S.  *)
END;                                           (* INSERT_JMPADDR *)

(*-----------------------------------------------------------*)

BEGIN   (* RESOLVE_ADDR MAIN *)
  TRAVEL := START;
  I := 0;
  WHILE TRAVEL <> ENDCP@.SEQP DO   (* INSERT ABSOLUTE ADDR *)
    BEGIN
      TRAVEL@.ADDR := I;
      TRAVEL := TRAVEL@.SEQP;
      I := I + 1
    END;
  TRAVEL := START;
  WHILE TRAVEL <> ENDCP@.SEQP DO (* FIND/JUSTIFY JMP ADDR *)
    BEGIN
      WITH TRAVEL@ DO
        IF JMPP <> NIL THEN   (* FIND JMPP'S WHICH ARE SET *)
          BEGIN
            INSERT_JMPADDR (JMPP@.ADDR);
            JMPP := NIL              (* SET JMPP BACK TO NIL *)
          END;
      TRAVEL := TRAVEL@.SEQP
    END
END;                                         (* RESOLVE_ADDR *)
```

```
(*****************************************************************)
(*                                                               *)
(*                    OUTPUT DUMP ROUTINES                       *)
(*                                                               *)
(*****************************************************************)

(*-83-----------------------------------------------------------*)
(* FINDMSG LOCATES THE START OF THE CORRECT MESSAGE IN         *)
(* THE MSGFILE.                                                *)
(*-------------------------------------------------------------*)

PROCEDURE FINDMSG (VAR MSGFILE : TEXT; VAR ESCHAR : CHAR;
                                       MSG_NO : INTEGER);
VAR  CH : CHAR;
     I  : INTEGER;

BEGIN
  RESET  (MSGFILE, 'NAME=MSGF.PASCAL.A');
  READLN (MSGFILE, ESCHAR);
  REPEAT
    READ (MSGFILE, CH);
    IF CH = ESCHAR THEN (* CHECK FOR ESCAPE CHAR & MSG NO *)
      READLN (MSGFILE, I)
    ELSE
      READLN (MSGFILE)
  UNTIL (EOF (MSGFILE)) OR
        ((CH = ESCHAR) AND (I = MSG_NO))
END;                                          (* FINDMSG *)

(*****************************************************************)

(*-84-----------------------------------------------------------*)
(* WRITLN WRITES A FULL MESSAGE FROM '$N' TO $N' AS FOUND *)
(* IN THE MSGFILE.                                             *)
(*-------------------------------------------------------------*)

PROCEDURE WRITLN;    (* FWD DECL WITH I/O COMMAND ROUTINES *)

VAR  CH, ESCHAR : CHAR;
     I : INTEGER;

BEGIN
  FINDMSG (MSGFILE, ESCHAR, MSG_NO);
  REPEAT
    READ (MSGFILE, CH);
    IF CH=ESCHAR THEN   (* CHECK FOR EMBEDDED ESCAPE CHARS *)
      READLN (MSGFILE, I)          (* AND DISCARD IF FOUND. *)
    ELSE
      WRITE (WFILE, CH);
    IF EOLN (MSGFILE) THEN                    (* NEXT LINE *)
      BEGIN
        READLN (MSGFILE);
        WRITELN (WFILE)
      END
  UNTIL (EOF (MSGFILE)) OR
        ((CH = ESCHAR) AND (I = MSG_NO))
END;                                          (* WRITLN *)

(*****************************************************************)
```

```
(*-85-------------------------------------------------------*)
(* WRIT WRITES A ONE-LINE MESSAGE OR THE FIRST LINE OF A   *)
(* MESSAGE FROM THE MSGFILE.                                *)
(*----------------------------------------------------------*)

PROCEDURE WRIT (VAR WFILE, MSGFILE : TEXT;
                          MSG_NO : INTEGER);
VAR   CH, ESCHAR : CHAR;
      I : INTEGER;

BEGIN
  FINDMSG (MSGFILE, ESCHAR, MSG_NO);
  REPEAT
    READ (MSGFILE, CH);
    WRITE (WFILE, CH)
  UNTIL EOLN (MSGFILE)
END;                                          (* WRIT *)

(***********************************************************)

(*-86-------------------------------------------------------*)
(* REPORT COMPUTES AND WRITES THE REGISTER/LABEL SUMMARY.  *)
(*----------------------------------------------------------*)

PROCEDURE REPORT (VAR WFILE : TEXT);

VAR    LTOTAL : LBLRNG;
       RTOTAL : INTEGER;

BEGIN
  WRITLN (WFILE, MSGF, 3);
  WRITELN (WFILE, ERRCRCT:7, ' FATAL ERRORS.');
  WRITELN (WFILE, WARNCT:7, ' WARNING MSGS.');
  IF ERRCRCT > 0 THEN            (* CALCULATIONS INCOMPLETE *)
    WRITLN (WFILE, MSGF, 14);
  RTOTAL := NEXTREG - STARTREG;
  LTOTAL := LBLCT - 1;
  WRITELN (WFILE);
  WRITELN (WFILE, NEXTREG:1, ' IS NEXT AVAILABLE REGISTER');
  WRITELN (WFILE,'TOTAL REGISTERS RESERVED = ',RESERVECT: 1);
  WRITELN (WFILE,'TOTAL REGISTERS USED     = ', RTOTAL:1);
  WRITELN (WFILE,'TOTAL  LABELS   USED     = ', LTOTAL:1);
  WRITLN (WFILE, MSGF, 4)
END;                                          (* REPORT *)

(***********************************************************)
```

```
(*-87-----------------------------------------------------------*)
(* CODEDUMP WRITES THE TI-59 CODE STORED IN THE CODE DATA      *)
(* STRUCTURE AND APPLIES THE CTEXTF FILE TO EACH STEP TO       *)
(* PRODUCE THE LITERAL TEXT OF FOR THE KEY STROKES.            *)
(*--------------------------------------------------------------*)

PROCEDURE CODEDUMP (VAR WFILE : TEXT; VAR TICODE : CODEPTR);

VAR   CUR, HOLD : CODEPTR;
      I : 0..3;

(*--------------------------------------------------------------*)

(*-87-01--------------------------------------------------------*)
(* WRCODE WRITES THE NUMERICAL FORM OF TI-59 ADDR AND KEY      *)
(*--------------------------------------------------------------*)

PROCEDURE WRCODE (VAR CUR : CODEPTR);

BEGIN
  WRITE (WFILE, ' ':5);
  ZEROPAD (WFILE, CUR@.ADDR, 3);
  WRITE (WFILE, ' ':3);
  ZEROPAD (WFILE, CUR@.KEY, 2);
  WRITE (WFILE, ' ':3)
END;                                              (* WRCODE *)

(*--------------------------------------------------------------*)

BEGIN    (* CODEDUMP MAIN *)
  CUR := TICODE;
  WRITLN  (WFILE, MSGF, 5);                       (* HEADER MSG *)
  WRITE   (WFILE, '$'); (* '$' MUST BE WRITTEN HERE,          *)
                        (*  ELSE WILL INTERFERE W/ WRITLN     *)
  WRITLN  (WFILE, MSGF, 6);                   (* BEGIN CODE MSG *)
  WHILE CUR@.SEQP <> NIL DO
    BEGIN
      WRCODE (CUR);
      WRITELN (WFILE, CTEXT(.CUR@.KEY.).CODECHAR);
      IF CUR@.KEY IN (.K_SBR, K_LBL.) THEN
        BEGIN    (* MUST NOT TAKE SBR'S OR LBL'S LITERALLY *)
          CUR := CUR@.SEQP;
          WRCODE (CUR);
          WRITELN (WFILE, CTEXT(.CUR@.KEY.).CODECHAR)
        END
      ELSE
        BEGIN
          HOLD := CUR;
          FOR I := 1 TO (CTEXT(.HOLD@.KEY.).UNIT) DO
            BEGIN  (* UNIT FIELD DEFINES TYPE INSTRUCTION *)
              CUR := CUR@.SEQP;
              WRCODE (CUR);
              ZEROPAD (WFILE, CUR@.KEY, 2);
              WRITELN (WFILE)
            END
        END;
      CUR := CUR@.SEQP
    END
END;                                            (* CODEDUMP *)

(***************************************************************)
```

```
(*-88-----------------------------------------------------------*)
(* LINK_INTERFACE CREATES THE SCRATCH FILE WHICH PROVIDES *)
(* THE LINKER WITH ALL THE INFORMATION IT MUST HAVE TO    *)
(* SEGMENT THE TI-59 CODE; ENTRIES IN SCRATCH ARE IN THE  *)
(* FORM OF SUB-FILES (MESSAGES) DELIMITED BY "$N".        *)
(*---------------------------------------------------------------*)

PROCEDURE LINK_INTERFACE;

(*-88-01--------------------------------------------------------*)
(* LOGTO IS USED BY LINK_INTERFACE TO READ AND WRITE      *)
(* FILES TO THE SCRATCH FILE (COPY).                      *)
(*---------------------------------------------------------------*)

PROCEDURE LOGTO (VAR WFILE, RFILE : TEXT; MSGNO : INTEGER);

VAR  CH : CHAR;

BEGIN
  WRITE (WFILE, '$', MSGNO: 1);       (* WRITE MSG DELIMITER *)
  WHILE NOT EOF (RFILE) DO
    BEGIN
      WHILE NOT EOLN (RFILE) DO
        BEGIN                         (* COPY THE FILE TO SCRATCH *)
          READ (RFILE, CH);
          WRITE (WFILE, CH)
        END;
      WRITELN (WFILE);
      IF NOT EOF (RFILE) THEN
        READLN (RFILE)
    END;
  WRITELN (WFILE, '$', MSGNO:1);     (* WRITE MSG DELIMITER *)
  WRITELN (WFILE)
END;                                                (* LOGTO *)

(*---------------------------------------------------------------*)

BEGIN   (* LINK_INTERFACE MAIN *)

  REWRITE (SCRATCH, 'NAME=SCRATCH.PASCAL.A');

  WRITELN (SCRATCH, '$1');           (* NEXT REGISTER = MSG $1 *)
  WRITELN (SCRATCH, NEXTREG:1, ' IS NEXT AVAILABLE REG.');
  WRITELN (SCRATCH, '$1');  WRITELN (SCRATCH);

  WRITELN (SCRATCH, '$2');           (* TI-59 CODE     = MSG $2 *)
  CODEDUMP (SCRATCH, BEGINCF);
  WRITLN  (SCRATCH, MSGF, 7);                 (* END CODE MSG *)
  WRITELN (SCRATCH, '$2');  WRITELN (SCRATCH);

  RESET (NAMEF, 'NAME=NAMEF.WBASIC.A');  (* REG/NAME MAP     *)
  LOGTO (SCRATCH, NAMEF, 3);             (*          = MSG $3 *)

  IF NOT FIRSTREAD THEN              (* DATA/READ MAP = MSG $4 *)
    BEGIN
      RESET (READF, 'NAME=READF.WBASIC.A');
      LOGTO (SCRATCH, READF, 4)
    END

END;                                       (* LINK_INTERFACE *)

(***************************************************************)
```

```
(*-89-------------------------------------------------------------*)
(* SYMTBLDUMP IS A SPECIAL PURPOSE ROUTINE USED FOR              *)
(* DEBUGGING; IT WILL DUMP THE ENTIRE CONTENTS OF THE            *)
(* COMPILER SYMBOL TABLE BUCKET BY BUCKET; THIS ROUTINE          *)
(* IS TOGGLED USING OPTION NUMBER 5.                             *)
(*---------------------------------------------------------------*)

PROCEDURE SYMTBLDUMP (VAR WFILE : TEXT; BUCKET : HASH);

VAR    I    : INTEGER;
       LOOK : SLOTPTR;

BEGIN
  WRITLN (WFILE, MSGP, 10);                         (* HEADER MSG *)
  FOR I := 0 TO HASHBASE DO
    IF BUCKET(.I.) <> NIL THEN           (* SKIP EMPTY BUCKETS *)
      BEGIN
        ZEROPAD (WFILE, I, 2);
        WRITLN (WFILE, MSGP, 11);   (* BUCKET BOUNDARY MSG *)
        LOOK := BUCKET(.I.);
        REPEAT                          (* UNTIL LOOK = NIL *)
          WRITE (WFILE, ' ':11, LOOK@.IDENT, ' ':1);
          WITH LOOK@ DO
          CASE TYP OF
            VARID : BEGIN
                      IF REGNO < 0 THEN           (* PI = -314 *)
                        WRITELN (WFILE, '..   CONSTANT')
                      ELSE
                        BEGIN
                          ZEROPAD (WFILE, REGNO, 2);
                          WRITELN (WFILE, '   GLOBAL VAR');
                          IF AUXREG1<>-1 THEN   (* IF USED *)
                            BEGIN
                              WRITE    (WFILE, ' ':32);
                              ZEROPAD  (WFILE, AUXREG1, 2);
                              WRITELN  (WFILE, '    AUXREG 1')
                            END;
                          IF AUXREG2<>-1 THEN   (* IF USED *)
                            BEGIN
                              WRITE    (WFILE, ' ':32);
                              ZEROPAD  (WFILE, AUXREG2, 2);
                              WRITELN  (WFILE, '    AUXREG 2')
                            END
                        END
                    END;
            FNQID : WRITELN (WFILE, '..   QUICK FN');
            FNLID : BEGIN
                      ZEROPAD (WFILE, FNLREG, 2);
                      WRITELN (WFILE, '    LONG FN')
                    END;
            FNPID : BEGIN
                      ZEROPAD (WFILE, FNREGNO, 2);
                      WRITELN (WFILE, '    PARAMETER FN')
                    END
          END;   (* CASE *)
          LOOK := LOOK@.SLOT
        UNTIL LOOK = NIL
      END;
  WRITLN (WFILE, MSGP, 12)                      (* END SYMTBL MSG *)
END;                                            (* SYMTBLDUMP *)

(*****************************************************************)
```

```
(*-90-------------------------------------------------------*)
(* SEARCH IS A SPECIAL PURPOSE DEBUGGING TOOL;              *)
(* THIS PROCEDURE FOLLOWS AND PRINTS THE CONTENTS OF ALL    *)
(* POINTERS IN THE CODE DATA STRUCTURE (LINE AND CODEPTR)   *)
(* THIS ROUTINE CAN BE TOGGLED USING OPTION NUMBER 6.       *)
(*----------------------------------------------------------*)

PROCEDURE SEARCH (VAR WFILE : TEXT; LSTART : LINEPTR);

VAR LPSEARCH : LINEPTR; CODP : CODEPTR;

BEGIN
  WRITLN (WFILE, MSGF, 13);                         (* HEADER MSG *)
  LPSEARCH := LSTART;
  REPEAT
    WRITE   (WFILE, 'LINUM = ');
    ZEROPAD (WFILE, LPSEARCH@.LINO, 5); (* WBASIC LINE NO *)
    WRITELN (WFILE);
    CODP := LPSEARCH@.CPTR;
    REPEAT          (* TI-59 CODE ATTACHED TO WBASIC LINE NO *)
      WRITE    (WFILE, ' ':2);
      ZEROPAD  (WFILE, CODP@.ADDR, 3);
      WRITE    (WFILE, ' ':2);
      ZEROPAD  (WFILE, CODP@.KEY, 2);
      WRITELN  (WFILE);
      CODP := CODP@.SEQP
    UNTIL (CODP = LPSEARCH@.LPTR@.CPTR) OR (CODP = NIL);
    LPSEARCH := LPSEARCH@.LPTR
  UNTIL LPSEARCH@.LINO = MAXBASLIN     (* MAXBASLIN IS END *)
END;                                               (* SEARCH *)
```

```
(*****************************************************************)
(*                                                               *)
(*                    INITIALIZATION ROUTINE                     *)
(*                                                               *)
(*****************************************************************)

(*-91-----------------------------------------------------------*)
(* INITIALIZE SETS UP ALL FILES, DATA STRUCTURES, SETS,         *)
(* AND INITIAL VARIABLE VALUES REQUIRED TO BEGIN THE            *)
(* READING AND COMPILATION OF THE WBASIC SOURCE CODE, AND       *)
(* THE OUTPUT OF THE TRANSLATED TI-59 CODE AND LISTINGS.        *)
(*--------------------------------------------------------------*)

PROCEDURE INITIALIZE;

VAR I : INTEGER;

(*--------------------------------------------------------------*)

(*-91-01--------------------------------------------------------*)
(* LOADRW READS THE RWTBLF FILE (RESERVED WORD TABLE) AND       *)
(* LOADS THE RESERVED WORD CHAR/INDEX ARRAYS; NOTE THAT         *)
(* THE ARRAYS ARE STATIC FIXED AND ARE DEFINED BY THE           *)
(* SYSTEM PARAMETERS RWCHARCT, RWWORDCT, RWLENGCT IN THE        *)
(* CONSTANT DECLARATION BLOCK AT THE FRONT OF THE PROGRAM       *)
(*--------------------------------------------------------------*)

PROCEDURE LOADRW (VAR RWTBLF : TEXT);

VAR   CHINX, STARTCHINX : 0..RWCHARCT + 1;
      WINX              : 0..RWWORDCT + 1;
      LINX, LENG        : 0..RWLENGCT + 1;
      CH                : CHAR;

BEGIN
  LINX := 0;                                 (* INIT LENGTH INDEX *)
  CHINX := 1;                                (* INIT  CHAR  INDEX *)
  WHILE NOT EOF(RWTBLF) DO
    BEGIN
      STARTCHINX := CHINX;
      READ (RWTBLF, WINX);       (* READ WORD INDEX (INTEGER)  *)
      READ (RWTBLF, CH, CH);     (* READ OFF 2 BLANK SPACES    *)
      RWWCRD(.WINX.) := CHINX;
      REPEAT      (* READ CHARS OF ONE WORD INTO CHAR ARRAY *)
        READ (RWTBLF, RWCHAR(.CHINX.));
        CHINX := CHINX + 1
      UNTIL EOLN(RWTBLF);
      READLN (RWTBLF);                             (* NEXT WORD *)
      LENG := CHINX - STARTCHINX;
      IF LENG > LINX THEN            (* IF LENGTH CHANGE, THEN *)
        BEGIN                        (*  INDEX ITS LOCATION IN *)
          LINX := LENG;              (*  THE LENGTH ARRAY.     *)
          RWLENG(.LINX.) := WINX
        END
    END;
  RWCHAR(.RWCHARCT + 1.) := BLANK;   (* SET DELIMITERS FOR *)
  RWWCRD(.RWWORDCT + 1.) := RWCHARCT + 1;   (* ARRAYS AND *)
  RWLENG(.RWLENGCT + 1.) := RWWORDCT + 1    (*    INDICES *)
END;                                              (* LOADRW *)

(*--------------------------------------------------------------*)
```

```
(*-91-02----------------------------------------------------------*)
(* LOADLIB READS PREDEFINED FUNCTION LIBRARIES IN BIFNLF         *)
(* AND BIFNQF FILES; MAKES APPROPRIATE SYM TBL ENTRIES.          *)
(*----------------------------------------------------------------*)

PROCEDURE LOADLIB (VAR LIBFILE : TEXT; FNTYPE : IDTYP;
                                      SEQLEN : INTEGER);
VAR  IDSLOT : SLOTPTR;
     I : INTEGER;

BEGIN
  READLN (LIBFILE); READLN (LIBFILE);     (* SKIP HEAD LINES *)
  WHILE NOT EOF(LIBFILE) DO
    BEGIN
      ACCINX := 0;                        (* INIT ACCUM INDX *)
      REPEAT                              (* READ NAME OF FN *)
        ACCINX := ACCINX + 1;
        READ (LIBFILE, ACCUM(.ACCINX.));
      UNTIL ACCUM(.ACCINX.) = BLANK;      (* TO 1ST BLANK    *)
      FOR I := ACCINX TO MAXTOKLEN DO     (* FILL REST BLANK *)
        ACCUM(.I.) := BLANK;
      ACCINX := ACCINX - 1;  (* SET INDEX BACK TO NAME LEN *)
      IDSLOT := GETSLOT(ACCUM,ACCINX);    (* ENTER IN SYMTBL *)
      IDSLOT@.TYP := FNTYPE;              (* SET IDENT TYPE  *)
      FOR I := 1 TO SEQLEN DO             (* READ KEY CODES  *)
        CASE FNTYPE OF
          FNQID : READ (LIBFILE, IDSLOT@.FNQ(.I.));
          FNLID : BEGIN
                    IDSLOT@.FNLLINK := NIL;
                    READ (LIBFILE, IDSLOT@.FNL(.I.))
                  END
        END;   (* CASE *)
      READLN (LIBFILE)                    (* SKIP TO NEXT LN *)
    END
END;                                            (* LOADLIB *)

(*----------------------------------------------------------------*)

(*-91-03----------------------------------------------------------*)
(* LOADCTEXT READS THE CTEXTF FILE AND LOADS THE DATA            *)
(* STRUCTURE WHICH WILL PROVIDE THE TRANSLATIONS OF TI-59        *)
(* KEY CODES DURING THE FINAL CODE DUMP.                         *)
(*----------------------------------------------------------------*)

PROCEDURE LOADCTEXT;

VAR   I    : INTEGER;
      J, K : 1..TEXTLEN + 1;
      CH   : CHAR;

BEGIN
  READLN (CTEXTF); READLN (CTEXTF);
  WHILE NOT EOF(CTEXTF) DO
    BEGIN
      READ (CTEXTF, I, CTEXT(.I.).UNIT);
      READ (CTEXTF, CH, CH);              (* SKIP TWO BLANKS *)
      J := 1;
      WHILE NOT EOLN(CTEXTF) DO
        BEGIN
          READ (CTEXTF, CTEXT(.I.).CODECHAR(.J.));
          J := J + 1
        END;
      FOR K := J TO TEXTLEN DO
        CTEXT(.I.).CODECHAR(.K.) := BLANK;
      READLN (CTEXTF);
    END
END;                                          (* LOADCTEXT *)

(*----------------------------------------------------------------*)
```

```
BEGIN   (* INITIALIZE MAIN *)

(*-------------------------------------------------------------*)
(* OPEN ALL FILES AND WRITE OUTPUT FILE HEADERS.               *)
(*-------------------------------------------------------------*)

  TERMOUT (OUTFILE);
  RESET  (BASICF, 'NAME=BASICF.WBASIC.A');
  RESET  (MSGF,   'NAME=MSGF.PASCAL.A');
  RESET  (RWTBLF, 'NAME=RWTBLF.PASCAL.A');
  RESET  (LABELF, 'NAME=LABELF.PASCAL.A');
  RESET  (CTEXTF, 'NAME=CTEXTF.PASCAL.A');
  RESET  (BIFNQF, 'NAME=BIFNQF.PASCAL.A');
  RESET  (BIFNLF, 'NAME=BIFNLF.PASCAL.A');
  REWRITE (LISTF, 'NAME=LISTF.WBASIC.A');
  REWRITE (NAMEF, 'NAME=NAMEF.WBASIC.A');
  WRITLN  (LISTF, MSGF, 2);            (* HEADER MSG TO LISTF *)
  WRITLN  (OUTFILE, MSGF, 1);          (* TERMINAL INVOKE MSG *)
  WRITLN  (NAMEF, MSGF, 8);            (* HEADER MSG TO NAMEF *)

(*-------------------------------------------------------------*)
(* INITIALIZE OPTION TOGGLES                                   *)
(*-------------------------------------------------------------*)

  LINK59 := FALSE;                                   (* OPTION 0 *)
  PC100  := TRUE;                                    (* OPTION 1 *)
  OPTPAR := TRUE;                                    (* OPTION 2 *)
  OPTNOF := TRUE;                                    (* OPTION 3 *)
  CODUMP := TRUE;                                    (* OPTION 4 *)
  SYDUMP := FALSE;                                   (* OPTION 5 *)
  DSDUMP := FALSE;                                   (* OPTION 6 *)
  TOKOUT := FALSE;                                   (* OPTION 7 *)
  TOKLIS := FALSE;                                   (* OPTION 8 *)

(*-------------------------------------------------------------*)
(* INITIALIZE RESERVED WORD ARRAY INDEXES.                     *)
(*-------------------------------------------------------------*)

  LOADRW (RWTBLF);

(*-------------------------------------------------------------*)
(* INITIALIZE CHARACTER SETS.                                  *)
(*-------------------------------------------------------------*)

  LETTERS    := (.'A'..'I'.) + (.'J'..'R'.) + (.'S'..'Z'.)
                (.'a'..'i'.) + (.'j'..'r'.) + (.'s'..'z'.);
  DIGITS     := (.'0'..'9'.);
  ALFANUM    := LETTERS + DIGITS;
  SIGNS      := (.'+'.) + (.'-'.);
  DOUBLE1    := (.'<'.) + (.'>'.) + (.'*'.);
  DOUBLE2    := (.'>'.) + (.'='.) + (.'*'.);
  SPECIALS   := (.'+'.) + (.'-'.) + (.'/'.) + (.'*'.)
                (.'='.) + (.'('.) + (.')'.) + (.COMMA.)
                (.'<'.) + (.'>'.) + (.EXCLAM.);
  SUBERROR   := (.''''.) + (.'$'.) + (.'#'.);
  CRITICAL   := (.ENDLIN.) + (.ENDFIL.) + (.'&'.);
  TRAILTOKS  := (.CMTOKEXC.) + (.ENDLINTOK.) + (.ENDFILTOK.);
  BINOPTOKS  := (.PLUSTOK.) + (.MINUSTOK.) + (.MULTOK.)
                (.DIVTOK .) + (. EXPTOK .);
  RELOPTOKS  := (.EQUALTOK.) + (.NOTEQTOK.) + (.GTEQTOK.)
                (.LTEQTOK.)  + (.LTTOK.)    + (.GTTOK.);
  NUMERICKEY:= (.K_DECPT.) + (.K_EE.) + (.K_NEG.)
                (.K_ZERO..K_9.);
  SIGNTOKS   := (.PLUSTOK.) + (.MINUSTOK.);
  BEGIN_EXPRTOKS := SIGNTOKS + (.IDENTOK.) + (.OPARENTOK.);
```

```
(*---------------------------------------------------------------*)
(* INITIALIZE HASH TABLE AND REGISTER COUNT.                     *)
(*---------------------------------------------------------------*)

  FOR I := 0 TO HASHBASE DO
    BUCKET(.I.) := NIL;
  NEXTREG := STARTREG;

(*---------------------------------------------------------------*)
(* INITIALIZE ARRAY HOLDING OUTPUT TEXT OF TI-59 CODE.           *)
(*---------------------------------------------------------------*)

  LOADCTEXT;

(*---------------------------------------------------------------*)
(* INITIALIZE BUILT-IN FUNCTION LIBRARY.                         *)
(*---------------------------------------------------------------*)

  LOADLIB (BIFNOF, FNCID, FNOLEN);
  LOADLIB (BIFNLF, FNLID, FNLLEN);

(*---------------------------------------------------------------*)
(* ENTER 'PI' = 3.14159265359 IN SYMBOL TABLE.                   *)
(*---------------------------------------------------------------*)

  ACCUM(.1.) := 'P';  ACCUM(.2.) := 'I';
  ACCINX := 2;
  FOR I := 3 TO MAXTOKLEN DO
    ACCUM(.I.) := BLANK;
  IDSLOT := GETSLOT (ACCUM, ACCINX);
  IDSLOT@.TYP   := VARID;
  IDSLOT@.REGNO := -314;          (* SPECIAL REGNO FOR 'PI' *)

(*---------------------------------------------------------------*)
(* INITIALIZE LABEL STACK (ARRAY OF INTEGER KEY CODES).          *)
(*---------------------------------------------------------------*)

  READLN (LABELF);                       (* SKIP HEAD LINE *)
  FOR I := 1 TO LBLBASE DO
    READ (LABELF, CLABEL(.I.));
  LBLCT := 1;

(*---------------------------------------------------------------*)
(* INITIALIZE RESERVED REGISTER SET.                             *)
(*---------------------------------------------------------------*)

  READLN (LABELF); READLN(LABELF); READLN (LABELF);
  RESERVECT := 0;
  RESERVE_REG := (..);           (* INITIALIZE TO EMPTY SET *)
  WHILE NOT EOF (LABELF) DO
    BEGIN
      WHILE NOT EOLN (LABELF) DO
        BEGIN
          READ (LABELF, I);
          RESERVE_REG := RESERVE_REG + (.I.);  (* MAKE SET *)
          RESERVECT := RESERVECT + 1          (* COUNT MEMBERS *)
        END;
      READLN (LABELF)
    END;

(*---------------------------------------------------------------*)
(* INITIALIZE FNP ACTIVATION STACK AND FNL USE LIST.             *)
(*---------------------------------------------------------------*)

  FNSTACKCT := 0;
  FNSTACK := NIL;
  FNLLIST := NIL;
```

```
(*-------------------------------------------------------------------*)
(* INITIALIZE FIRST CALL TO SCAN.                                    *)
(*-------------------------------------------------------------------*)

  LINEUF(.0.) := BLANK;
  LINEUF(.1.) := ENDLIN;
  TOKNUM   := ENDLINTCK;
  LNBINX   := 0;
  ERRORCT  := 0;
  WARNCT   := 0;
  FLAGCMT  := FALSE;
  LINUM    := 0;
  LLINUM   := 0;
  CLINUM   := 0;

(*-------------------------------------------------------------------*)
(* INITIALIZE LINKED DATA STRUCTURE FOR TI-59 CODE.                  *)
(*-------------------------------------------------------------------*)

  FIRSTLP := GETNEWHDR (LINUM);   (* SET A COMMON REF NODE *)
  LPCUR   := FIRSTLP;        (* ANCHOR ALL MARKER PTRS TO IT *)
  LASTLP  := FIRSTLP;
  ENDCP   := FIRSTLP@.CPTR;
  BEGINCP := ENDCP;
  CPCUR   := ENDCP;
  SETLINE (LPCUR, LP); (* SET UP FOR MAIN PROCEDURE LABEL *)
  GENKEY  (K_LBL);
  GENKEY  (NEWLBL);                 (* MAIN PROCEDURE = LBL A *)
  BEGINCP := BEGINCP@.SEQP;         (* BYPASS THE HEADER NODE *)

(*-------------------------------------------------------------------*)
(* INITIALIZE LOOP/BRANCH STACKS.                                    *)
(*-------------------------------------------------------------------*)

  IFSTACK        := NIL;
  ENDIFSTACK     := NIL;
  LOOPSTACK      := NIL;
  ENDLOOPSTACK   := NIL;
  FORSTACK       := NIL;
  NEXTSTACK      := NIL;

(*-------------------------------------------------------------------*)
(* INITIALIZE READ/DATA STATEMENT INDEXES/FLAGS.                     *)
(*-------------------------------------------------------------------*)

  READIX := 1;
  DATAIX := 1;
  INDEXERROR := FALSE;
  FIRSTREAD  := TRUE

END;                                               (* INITIALIZE *)
```

```
(*****************************************************************)
(*                                                               *)
(*                   EAX59:  MAIN DRIVER                         *)
(*                                                               *)
(*****************************************************************)

BEGIN   (* EAX59 MAIN *)

  INITIALIZE;

  REPEAT   (* UNTIL TOKNUM = ENDFILTOK *)

    SCAN (TOKNUM);           (* SCAN FIRST WORD OF NEW LINE      *)
    IF ERRORCT = 0 THEN      (* PARSING IS DICONTINUED AFTER     *)
      BEGIN                  (* FIRST FATAL ERROR ENCOUNTERED    *)
        SETLINE (LPCUR, LP); (* NEW WBASIC LINE NO & LINE        *)
        CASE TOKNUM OF       (* RECURSIVE DESCENT PARSE PROC     *)

(*---------------------------------------------------------------*)
(* KEYWORDS MARKED IN RIGHT CMT COLUMN BY ASTERISKS MUST         *)
(* ALWAYS RESULT IN A PARSE ERROR IF USED AS A COMMAND           *)
(* (IE. 1ST WORD ON A LINE) REGARDLESS OF IMPLEMENTATION:        *)
(*        ** IMPLEMENTED IN THIS SUBSET                          *)
(*       *** NOT IMPEMENTED IN THIS SUBSET                       *)
(*---------------------------------------------------------------*)

          ERRORTOK      : BEGIN END;          (* SCAN ERROR      *)
          CMTOKEXC      : PREM;               (* EXCLAM          *)
          2,3,4,5,6     : PERROR;             (* 1-CHAR SYMBOLS  *)
          7,8,9,10,11   : PERROR;             (* 1-CHAR SYMBOLS  *)
          12,13,14      : BEGIN END;          (* SCAN ERROR      *)
          15,16,17,18   : PERROR;             (* 2-CHAR SYMBOLS  *)

          19            : PIF;                          (* IF          *)
          20            : PERROR;                       (* TO  **      *)
          21            : PERROR;                       (* OR  ***     *)
          22                     : PSUBERROR;           (* ON          *)
          23            : PLET;                         (* LET         *)
          CMTOKREM      : PREM;                         (* REM         *)
          25            : PFOR;                         (* FOR         *)
          26            : PEND;                         (* END         *)
          27            : PDEF;                         (* DEF         *)
          28            : PERROR;                       (* NOT  **     *)
          29                     : PSUBERROR;           (* DIM         *)
          30            : PERROR;                       (* AND  ***    *)
          31,32                  : PSUBERROR;           (*             *)
          33            : PERROR;                       (* THEN  **    *)
          34            : PELSE;                        (* ELSE        *)
          35            : PGOTO;                        (* GOTO        *)
          36            : PLOOP;                        (* LOOP        *)
          37            : PNEXT;                        (* NEXT        *)
          38            : PQUIT;                        (* QUIT        *)
          39            : PSTOP;                        (* STOP        *)
          40            : PDATA;                        (* DATA        *)
          41            : PREAD;                        (* READ        *)
          42            : PERROR;                       (* STEP  **    *)
          43,44,45               : PSUBERROR;           (*             *)
          46            : PENDIF;                       (* ENDIF       *)
          47            : PFNEND;                       (* FNEND       *)
          48            : PGOSUB;                       (* GOSUB       *)
          49            : PINPUT;                       (* INPUT       *)
          50            : PUNTIL;                       (* UNTIL       *)
          51            : PWHILE;                       (* WHILE       *)
          52            : PPAUSE;                       (* PAUSE       *)
          53            : PPRINT;                       (* PRINT       *)
          54,55,56,57,58         : PSUBERROR;           (*             *)
```

```
          59          : PELSEIF;                         (* ELSEIF       *)
          60          : PRETURN;                         (* RETURN       *)
          61          : POPTION;                         (* OPTION       *)
          62,63,64,65,66      : PSUBERROR;               (*              *)
          67          : PENDLOOP;                        (* ENDLOOP      *)
          68          : PRESTORE;                        (* RESTORE      *)
          69,70,71,72         : PSUBERROR;               (*              *)

          IDENTOK   : PNOLET;                            (* NO LET       *)
          NUMBERTOK : PERROR;                            (* NUMERIC      *)
          ENDLINTOK: GENKEY  (K_NOP);                    (* BLANK LN     *)
          ENDFILTOK: GENKEY  (K_NOP)                     (* END FILE     *)

        END   (* CASE *)
      END

  UNTIL TCKNUM = ENDFILTOK;

  GETFNLS;                                 (* INSERT LONG FN BODIES *)
  ENDCP@.SECP := NEWCCDE (-1);             (* CLOSE CODE SEQUENCE  *)
  LPCUR@.IPTR := GETNEWHDR (MAXBASLIN); (* CLOSE LINE SEQ         *)

  FINDGOSUBLBL (BEGINCP);                  (* INSERT LABELS FOR SER *)
  IF OPTPAR THEN                           (* OPTION 2              *)
    OSQPAREN (BEGINCP);                    (* OPTIMIZE PARENTHESES  *)
  IF OPTNCP THEN                           (* OPTION 3              *)
    CSCNCP    (BEGINCP);                   (* OPTIMIZE (OUT) NOP'S  *)
  RESOLVE_ADDR  (BEGINCP);                 (* OVERLAY ABSOLUTE ADDR *)

  REPORT (LISTF);                          (* ERROR/REG/LBL SUMMARY *)
  REPORT (OUTFILE);
  IF CODUMP THEN                           (* OPTION 4              *)
    CODEDUMP (LISTF, BEGINCP);             (* WRITE TRANSLATED CODE *)
  IF LINK59 THEN                           (* CREATE SCRATCH FILE   *)
    LINK_INTERFACE;                        (*   FOR LINKER INTERFACE *)

(*----------------------------------------------------------------*)
(* DEBUGGING TOOL:    DUMPS EACH SLOT OF EACH BUCKET IN THE        *)
(*                    SYMBOL TABLE TO NAME FILE.                   *)
  IF SYDUMP THEN                           (* OPTION 5              *)
    SYMTBLDUMP (LISTF, BUCKET);
(*----------------------------------------------------------------*)

(*----------------------------------------------------------------*)
(* DEBUGGING TOOL:    DUMPS ENTIRE CODE DATA STRUCTURE             *)
(*                    INCLUDING LINE AND CODE NODES.               *)
  IF DSDUMP THEN                           (* OPTION 6              *)
    SEARCH (LISTF, FIRSTLP)
(*----------------------------------------------------------------*)

END;                                                   (* EAX59 *)

(*****************************************************************)
(*****************************************************************)
```

APPENDIX D

RWTBLF FILE--ORDERED RESERVED WORDS

```
 1  !
 2  =
 3  +
 4  -
 5  *
 6  /
 7  (
 8  )
 9  >
10  <
11
12  ,
13  #
14  $
15  **
16  <>
17  >=
18  <=
19  IF
20  TO
21  OR
22  ON
23  LET
24  REM
25  FOR
26  END
27  DEF
28  NOT
29  DIM
30  AND
31  MAT
32  USE
33  THEN
34  ELSE
35  GOTO
36  LOOP
37  NEXT
38  QUIT
39  STOP
40  DATA
41  READ
42  STEP
43  LOCK
44  OPEN
45  SORT
46  ENDIF
47  FNEND
48  GOSUB
49  INPUT
50  UNTIL
51  WHILE
52  PAUSE
53  PRINT
54  CHAIN
55  ADMIT
56  CLOSE
57  GUESS
58  SLEEP
59  ELSEIF
```

```
60   RETURN
61   OPTION
62   LINPUT
63   REMOVE
64   RENAME
65   RESUME
66   UNLOCK
67   ENDLOOP
68   RESTORE
69   SCRATCH
70   TAGSORT
71   ENDGUESS
72   RANDOMIZE
```

APPENDIX E

LABELF FILE--TI-59 LABELS/RESERVED REGISTERS

KEY CODES FOR TI-59 LABELS:

```
11 12 13 14 15 16 17 18 19 10
20 22 23 24 25 27 28 29 30 32
33 34 35 36 37 38 39 42 43 44
45 47 48 49 50 52 53 54 55 57
58 59 60 61 65 66 67 68 69 70
71 75 76 77 78 79 80 81 85 86
87 88 89 90 91 93 94 95 96 97
98 99
```

REGISTERS RESERVED BY USER:

00 01 02 03 04 05 06 07 08 09 10

APPENDIX F

BIFNQF/BIFNLF FILES--BUILT-IN FUNCTIONS

BUILT-IN "QUICK" FUNCTION NAMES AND TI-59 KEY CODES:

ABS	50	68	68	68
ACOS	27	39	68	68
ASIN	27	38	68	68
ATN	27	30	68	68
COS	39	68	68	68
COT	30	35	68	68
CSC	38	35	68	68
EXP	22	23	68	68
FP	27	59	68	68
IP	59	68	68	68
LOG	23	68	68	68
LOG10	28	68	68	68
SEC	39	35	68	68
SIN	38	68	68	68
SQR	34	68	68	68
TAN	30	68	68	68

BUILT-IN "LONG" FUNCTION NAMES AND TI-59 KEY CODE SEQUENCES:

RND 36 15 10 43 10 36 15 15 36 15 71 88 68 68 68

APPENDIX G

CTEXTF FILE--TI-59 KEYCODE TRANSLATIONS

TI-59 KEY	CODE	TEXT........
-2	0	UNRESOLVED ADDR $$$$
-1	0	UNFILLED CODE $$$$$$
00	0	0
01	0	1
02	0	2
03	0	3
04	0	4
05	0	5
06	0	6
07	0	7
08	0	8
09	0	9
10	0	2ND E'
11	0	A
12	0	B
13	0	C
14	0	D
15	0	E
16	0	2ND A'
17	0	2ND B'
18	0	2ND C'
19	0	2ND D'
20	0	2ND CLR
21	0	2ND $$$$ ERROR $$$$$
22	0	INV
23	0	LNX
24	0	CE
25	0	CLR
26	0	2ND $$$$ ERROR $$$$$
27	0	2ND INV
28	0	2ND LOG
29	0	2ND CP
30	0	2ND TAN
31	0	LRN (DEBUGGING TOOL)
32	0	X<=>T
33	0	X**2
34	0	SQRT(X)
35	0	1/X
36	1	2ND PGM
37	0	2ND P=>R
38	0	2ND SIN
39	0	2ND COS
40	0	2ND IND
41	0	SST $$$$ ERROR $$$$$
42	1	STO
43	1	RCL
44	1	SUM
45	0	Y**X
46	0	INS $$$$ ERROR $$$$$
47	0	2ND CMS
48	1	2ND EXC
49	1	2ND PRD
50	0	|X|
51	0	BST $$$$ ERROR $$$$$
52	0	EE
53	0	(
54	0	)

```
55   0   /
56   0   DEL  $$$$ ERROR $$$$$
57   0   2ND  ENG
58   0   2ND  FIX
59   0   2ND  INT
60   0   2ND  DEG
61   2   GTC
62   1   2ND  PGM  2ND  IND
63   1   2ND  EXC  2ND  IND
64   1   2ND  PRD  2ND  IND
65   0   *
66   0   2ND  PAUSE
67   2   2ND  X=T
68   0   2ND  NOP
69   1   2ND  OP
70   0   2ND  RAD
71   2   SBR
72   1   STO  2ND  IND
73   1   RCL  2ND  IND
74   1   SUM  2ND  IND
75   0   -
76   0   2ND  LBL
77   2   2ND  X>=T
78   0   2ND  SUMMATION
79   0   X-BAR
80   0   2ND  GRAD
81   0   RST
82   0   $$$$ VOID CODE $$$$$
83   1   GTO  2ND  IND
84   1   2ND  OP 2ND IND
85   0   +
86   1   2ND  STFLG
87   3   2ND  IFFLG
88   0   2ND  D.MS
89   0   2ND  PI
90   0   2ND  LIST
91   0   R/S
92   0   INV  SBR
93   0   .
94   0   +/-
95   0   =
96   0   2ND  WRITE
97   3   2ND  DSZ
98   0   2ND  ADV
99   0   2ND  PRT
```

APPENDIX H

MSGF FILE--CROSS-COMPILER OUTPUT MESSAGES

```
$ IS THE ESCAPE CHAR (MSG DELIMITER) FOR THIS MESSAGE FILE.
$1 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
        INVOKING WBASIC CROSS-COMPILER FOR TI-59 PC
                     EAX59 VERSION 1.0

$1 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$2 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=============================================================
                    WBASIC PROGRAM LISTING
=============================================================

$2 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$3 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=============================================================
                     COMPILATION SUMMARY
=============================================================

$3 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$4 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

----------------- COMPILATION TERMINATES -----------------

$4 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$5 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=============================================================
              TI-59 CODE TRANSLATED FROM WBASIC
                        (UNSEGMENTED)
=============================================================

    ADDR    CODE
$5 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$6 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
0 ------------------------------------- BEGIN TI-59 CODE.
$6 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$7 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
-1 -------------------------------------- END TI-59 CODE.

$7 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$8 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=============================================================
              TI-59 REGISTER TO NAME MAPPING
=============================================================

      REG#   BASIC NAME

$8 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$9 $$$$$$$$$$$$$$ $$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=============================================================
                 INPUT DATA TO READ MAPPING
=============================================================

      DATA                      REG   NAME
```

```
$9  $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$10 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=================================================================
                  BAX59 SYMBOL TABLE DUMP
=================================================================

BUCKET     CONTENTS                  REG    TYP

$10 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$11 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 ---------------------------------------------------------------
$11 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$12 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
-----------------------------------------------------------------

$12 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$13 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

=================================================================
                  TI-59 CODE DATA STRUCTURE
=================================================================

$13 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$14 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

BEFORE THE FIRST FATAL ERROR, THESE STATS WERE COMPUTED:

$14 $$$$$$$$$$$$$$$$$$$$$$$$$ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

APPENDIX I

LINKER SOURCE CODE

```
(****************************************************************)
(* PURPOSE: THIS PROGRAM TAKES AS INPUT A TI-59 PROGRAM.       *)
(*          IT SEGMENTS THE PROGRAM SO THAT IT WILL FIT         *)
(*          INTO THE TI-59 CALCULATOR.  INSTRUCTIONS AND        *)
(*          CODE LISTINGS ARE PROVIDED AS OUTPUT.               *)
(*          COMMENT: PROGRAM MAY LOOP INFINITELY IF SMALL;*)
(*                   LIMIT IS USED BECAUSE OF DIVIDE            *)
(*                   ALGORITHM.                                 *)
(*          COMMENT: FILEDEFS WERE USED FOR THIS PROGRAM        *)
(*                   CONSEQUENTLY THEY WERE NOT DEFINED         *)
(*                   IN THE PROGRAM.  SPECIFIC FILEDEFS         *)
(*                   FOLLOW: SCRATCH--"SCRATCH PASCAL"          *)
(*                                PASSED FROM COMPILER          *)
(*                           OUTFILE--"ANY DESIRED NAME"        *)
(*                                YOUR OUTPUT FILE              *)
(*                           TEMPFILE--"ANY DESIRED NAME"       *)
(*                                A TEMPORARY SCRATCH PAD       *)
(*                           MESSAGEFILE--MESSAGEFILE FILE*)
(*                                LINKER'S MESSAGES             *)
(****************************************************************)

PROGRAM TSDRIVER(INPUT,OUTPUT);

(****************************************************************)
(* DECLARATIONS:                                                *)
(****************************************************************)

  (*-----------------------------------------------------------*)
  CONST
    FJUMPCONST   = 10;        (* NUM STEPS FOR F JUMP CODE *)
    SBRCONST     = 15;        (* NUM STEPS FOR SBR BRK CODE*)
    SBRCNTCONST  = 7;         (* NUM STEPS FOR SBR BRK RTN *)

    STO = 42;                               (* TI59 KEYCODES *)
    LBL = 76;
    RCLIND = 73;
    STOIND = 72;
    OP = 69;
    DECIMAL = 93;
    RS = 91;
    CE = 24;                                (* END  KEYCODES *)

    DISPLAYREGSTORE = 00;      (* TEMP STORE OF THE DISPLAY *)
    RTNREGNUM =  6;   (* NUMBER OF MANUAL RETURN REGISTERS *)
    MANRTNREG = 08;          (* MANUAL SBR RETURN REGISTER *)

    NONE  = 101;                            (* MESSAGE NUMS*)
    ASTER = 102;          (* SEE MESSAGEFILE FOR TRANSLATION *)
    YES   = 103;
    MCDPRCMPTS  = 100;
    RTNRGTOP    = 104;
    CODENUM     = 0;
    STOINRG     = 105;
    PGMPARTIS   = 106;
    PARTNUMIS   = 107;
    MCDN  = 108;
    CARD1 = 109;
    CARD2 = 110;
```

```
  SIDE1 = 111;
  SIDE2 = 112;
  EAXINSTR  = 81;
  SPECIFICS = 82;
  ENDLEL    = 83;
  FAILINSTR = 84;
  UNSEGCODLBL = 5;
  PSEQ      = 6;
  PMANRTN   = 7;
  PFWDJ     = 8;
  PSBRINV   = 9;
  REGMAP    = 3;
  DATAREAD  = 4;
  RGCT      = 1;
  ALPHALBL  = 99;                          (* END MESSAGE NUMS *)
(*-------------------------------------------------------------*)

TYPE
(*-------------------------------------------------------------*)

  LABELS = PACKED ARRAY (.1 .. 15.) OF CHAR;
  TYPELABELS = ARRAY (.0..99.) OF LABELS;   (* TI59 KEYS *)
(*-------------------------------------------------------------*)

  CODEPTR = @CODERCD;         (* THIS RECORD IS BUILT_CODE *)
  CODERCD = RECORD
            AADDR:INTEGER;
            MEMNUM:INTEGER;
            RADDR:INTEGER;
            KEY:INTEGER;
            JMP:CODEPTR;
            SEQ:CODEPTR;
          END;                  (* SHOULD HAVE MADE A VARI *)
(*-------------------------------------------------------------*)

  INSTR_SET = SET OF 0 .. 99 ; (* RANGE  INSTRUCTION SET*)
(*-------------------------------------------------------------*)

  NODE = (TABLE,SBRPTR,SBRBREAK,FWD_JUMP,MEMODULE,CODE);
  TBLPTR = @NODES;
  NODES = RECORD
          CASE TAG: NODE OF
            TABLE:(NEST:INTEGER;
                   START_ADDR:INTEGER;
                   STOP_ADDR:INTEGER;
                   LENGTH:INTEGER;
                   INCLUDED:BOOLEAN;
                   COALESCED:BOOLEAN;
                   SBRLIST:TBLPTR;
                   NUM_F:INTEGER;
                   F_JUMPLIST:TBLPTR;
                   TABLELIST:TBLPTR);    (* NEXT TABLE *)

             SBRPTR: (SBR:TBLPTR;
                      FROM:INTEGER;
                      NEXT_SBR:TBLPTR);     (* NEXT PTR *)

             MEMODULE: (MEMNUM:INTEGER;
                        OFFSET:INTEGER;
                        HIGHOFFSET:INTEGER;
                        LOWOFFSET:INTEGER;
                        RETURNCODE_NEEDED:BOOLEAN;
                        SEGTBLS:TBLPTR;         (* TABLE *)
                        CODELIST:TBLPTR;
                        NEXT:TBLPTR);
```

```
          CODE:(ADDRESS:INTEGER;
                ABS_ADDR:INTEGER;
                KEYCODE:INTEGER;
                SEQUENTIAL:TBLPTR);

          SBRBREAK:(SBRZ:TBLPTR);

          FWD_JUMP:(JUMP_ADDRFR:INTEGER;
                    JUMP_ADDRTO:INTEGER;
                    JUMP_ADDRTO1:INTEGER; (*HUNDREDS*)
                    JUMP_ADDRTO2:INTEGER; (*TEN/UNIT*)
                    MEM_ADDR:INTEGER;        (*MEMNUM*)
                    JUMP_INTADDRTO1:INTEGER; (*LOCAL*)
                    JUMP_INTADDRTO2:INTEGER;
                    NEXT_PJUMP:TBLPTR);
        END;
                                     (* SEGMENT TABLE STRUCTURE *)
(*----------------------------------------------------------*)
VAR

  OUTFILE:TEXT;                                (* OUTPUT FILE *)
  TEMPFILE:TEXT;                      (* NEST DIAGS TEMP FILE *)
  SCRATCH:TEXT;           (* INFORMATION FROM COMPILER FILE*)
  MESSAGEFILE:TEXT;                   (* MESSAGE INPUT FILE *)
(*----------------------------------------------------------*)

  PARTITION:REAL;             (* CALCULATOR PARTITION INFO *)
  REGCOUNT:INTEGER;
  GOOD_SEGMENT:BOOLEAN;
  SBRINVNEST:INTEGER;             (* SBR NEST LEVEL CHECK *)
  NUMBANKS,PART_NUM:INTEGER;
  LIMIT:INTEGER;                    (* MEMORY SIZE LIMIT *)
(*----------------------------------------------------------*)

  BUILT_CODE,CURCP:CODEPTR;                 (* CODE TBL VARS*)
  BUILT_CODE_COUNT:INTEGER;
  HDRPTR,SEGTBL:TBLPTR;                        (* TABLE VARS *)
(*----------------------------------------------------------*)

  STEP_0,STEP_1,STEP_2,STEP_3:INSTR_SET;  (* INS SET VAR *)
(*----------------------------------------------------------*)

  TILBL:TYPELABELS;                      (* PROGRAM LABELS *)
(*----------------------------------------------------------*)
```

```
(*************************************************************)
(* PROCEDURES AND FUNCTIONS:                                 *)
(*************************************************************)

(*===========================================================*)
(* FOLLOWING ROUTINES ARE USED AS UTILITIES SUCH AS PRINT   *)
(*    AND SCRATCHFILE AND MESSAGE FILE MANIPULATORS         *)
(*===========================================================*)

 (*--------------------------------------------------------*)
 (* DUMP_SEGTBL: DUMPS THE SEGMENT TABLE. USED FOR DEBUG   *)
 (*    AND IS NOT CALLED IN THIS PROGRAM.                  *)
 (*--------------------------------------------------------*)
 PROCEDURE DUMP_SEGTBL(VAR OUTFILE:TEXT; HDRPTR:TBLPTR);
  VAR F_JMPLINK,SBRLINK,SBR,CURTP,SBRTP:TBLPTR;
  BEGIN
    SBRTP:=HDRPTR;
    WHILE SBRTP <> NIL DO
      BEGIN
        WRITELN(OUTFILE);
        WRITELN(OUTFILE);
        WRITELN(OUTFILE,'=================================');
        WRITE(OUTFILE,' SBR CODE NUMBER ');
        WRITELN(OUTFILE,SBRTP@.STOP_ADDR:2);
        WRITELN(OUTFILE,'=================================');
        CURTP:=SBRTP@.TABLELIST;
        WHILE CURTP <> NIL DO
          BEGIN
            WITH CURTP@ DO
              BEGIN
                WRITELN(OUTFILE);
                WRITELN(OUTFILE,'NEST',NEST:3);
                WRITELN(OUTFILE,'START',START_ADDR:4);
                WRITELN(OUTFILE,'STOP',STOP_ADDR:4);
                WRITELN(OUTFILE,'LENGTH',LENGTH:5)
              END;
            SBRLINK:=CURTP@.SBRLIST;
            F_JMPLINK:=CURTP@.F_JUMPLIST;
            WHILE (SBRLINK <> NIL) OR (F_JMPLINK <> NIL) DO
              BEGIN
                IF SBRLINK <> NIL THEN
                  BEGIN
                    SBR:=SBRLINK@.SBR;
                    CASE SBR@.TAG OF
                      TABLE: SBR:=SBR;
                      SBRBREAK:
                        BEGIN
                          SBR:=SBR@.SBRZ;
                          WRITELN(OUTFILE,'*** BREAK ***');
                        END;
                    END;
                    WRITE(OUTFILE,'SBR INVOKE FROM',
                          SBRLINK@.FROM:5,' TO ',
                          SBR@.START_ADDR:5,' *** ');
                    SBRLINK:=SBRLINK@.NEXT_SBR;
                  END
                ELSE
                  WRITE(OUTFILE,'                              ');
                  WRITE(OUTFILE,'              *** ');
                IF F_JMPLINK <> NIL THEN
                  BEGIN
                    WRITE(OUTFILE,'JUMP FROM ',
                          F_JMPLINK@.JUMP_ADDRFR:5,' TO ',
                          F_JMPLINK@.JUMP_ADDRTO:5);
                    F_JMPLINK:=F_JMPLINK@.NEXT_FJUMP;
                  END;
                WRITELN(OUTFILE);
              END;
```

```
          CURTP:=CURTP@.TABLELIST;
        END;
      SBRTP:=SBRTP@.SBRLIST;
    END;
 END;                          (* DUMP_SEGTBL TEST ROUTINE *)
(*-----------------------------------------------------------*)


(*-----------------------------------------------------------*)
(* DUMP_MEMODULENODES: PRINTS OUT THE CONTENTS OF THE        *)
(*    MEMODULENODE LIST FORMED.  THIS IS A DEBUGGING         *)
(*    ROUTINE AND IS NOT INVOKED IN THE PROGRAM.             *)
(*-----------------------------------------------------------*)
PROCEDURE DUMP_MEMODULENODES(HEAD_MEMODULE:TBLPTR);
  VAR S:TBLPTR;
  BEGIN
    S:=HEAD_MEMODULE;
    WHILE S<>NIL DO
      BEGIN
        WITH S@ DO
          BEGIN
            WRITELN(OUTFILE);
            WRITE(OUTFILE,'MEMNUM  OFFSET  HIGH  LOW');
            WRITELN(OUTFILE,'  SEGTBLSTART');
            WRITELN(OUTFILE,MEMNUM:6,OFFSET:8,HIGHOFFSET:6
                   ,LOWOFFSET:5,SEGTBLS@.START_ADDR:10);
            WRITELN(OUTFILE);
          END;
        S:=S@.NEXT;
      END;
  END;                             (* DUMP_MEMODULNODES *)
(*-----------------------------------------------------------*)


(*-----------------------------------------------------------*)
(* WRITE_LEADZERO: PADS INTEGER FIELD WITH LEADING           *)
(*    ZEROS                                                  *)
(*-----------------------------------------------------------*)
PROCEDURE WRITE_LEADZERO(VAR OUTFILE:TEXT;NUM,FLD:INTEGER);
 VAR I,TN:INTEGER;
 BEGIN
   TN:=NUM;
   REPEAT
     TN:=TN DIV 10;
     FLD:=FLD-1;
   UNTIL (TN=0);
   FOR I:=1 TO FLD DO
     WRITE(OUTFILE,'0');
   WRITE(OUTFILE,NUM:1);
 END;                                 (* WRITE_LEADZERO *)
(*-----------------------------------------------------------*)
```

```
(*----------------------------------------------------------*)
(* WRITELBL: WRITES OUT THE TI-59 CODED LABELS              *)
(*----------------------------------------------------------*)
PROCEDURE WRITELBL(VAR OUTFILE:TEXT; CODESS:INTEGER);
   BEGIN
     WRITELN(OUTFILE,TILBL(.CODESS.));
   END;                                      (* WRITELBL *)
(*----------------------------------------------------------*)


(*----------------------------------------------------------*)
(* WRITECODES: WRITES THE ADDRESS AND KEYCODE TO LINE       *)
(*----------------------------------------------------------*)
PROCEDURE WRITECODES(VAR OUTFILE:TEXT; CUR:CODEPTR);
      BEGIN
        WRITE_LEADZERO(OUTFILE,CUR@.AADDR,3);
        WRITE(OUTFILE,'     ');
        WRITE_LEADZERO(OUTFILE,CUR@.KEY,2);
        WRITE(OUTFILE,'         ');
      END;                                   (* WRITECODES *)
(*----------------------------------------------------------*)


(*----------------------------------------------------------*)
(* WRITENUM: WRITES KEYCODE AS A NUMBER NOT A LABEL         *)
(*----------------------------------------------------------*)
PROCEDURE WRITENUM(VAR OUTFILE:TEXT; CUR:CODEPTR);
     BEGIN
       WRITE_LEADZERO(OUTFILE,CUR@.KEY,2);
     END;                                    (* WRITENUM *)
(*----------------------------------------------------------*)


(*----------------------------------------------------------*)
(* HANDLE_#STEPS: PRINTS OUT DIFFERENT CASES OF CODES,      *)
(*    EG. WHETHER ONE OR TWO STEP INSTRUCTION.              *)
(*    USED FOR CODEPTR TYPE OF NODES.                       *)
(*----------------------------------------------------------*)
  PROCEDURE HANDLE_0STEP(VAR OUTFILE:TEXT;
                             VAR CUR:CODEPTR);
    BEGIN
      WRITE(OUTFILE,'                         ');
      WRITECODES(OUTFILE,CUR);
      WRITE(OUTFILE,'      ');
      WRITELBL(OUTFILE,CUR@.KEY);
    END;

  PROCEDURE HANDLE_1STEP(VAR OUTFILE:TEXT;
                            VAR CUR:CODEPTR);
    BEGIN
      CUR:=CUR@.SEQ;
      WRITE(OUTFILE,'                         ');
      WRITECODES(OUTFILE,CUR);
      WRITE(OUTFILE,'        ');
      WRITENUM(OUTFILE,CUR);
      WRITELN(OUTFILE)
    END;    (* HANDLE_1STEP *)
```

```
  PROCEDURE HANDLE_2STEP(VAR OUTFILE:TEXT;
                         VAR CUR:CODEPTR);
    VAR I:INTEGER;
    BEGIN
      FOR I:=1 TO 2 DO
        BEGIN
          CUR:=CUR@.SEQ;
          WRITE(OUTFILE,'                          ');
          WRITECODES(OUTFILE,CUR);
          WRITE(OUTFILE,'      ');
          WRITENUM(OUTFILE,CUR);
          WRITELN(OUTFILE);
        END;
    END;    (* HANDLE_2STEP *)

  PROCEDURE HANDLE_3STEP(VAR OUTFILE:TEXT;
                         VAR CUR:CODEPTR);
     VAR I:INTEGER;
     BEGIN
       FOR I:=1 TO 3 DO
         BEGIN
           CUR:=CUR@.SEQ;
           WRITE(OUTFILE,'                          ');
           WRITECODES(OUTFILE,CUR);
           WRITE(OUTFILE,'      ');
           WRITENUM(OUTFILE,CUR);
           WRITELN(OUTFILE);
         END;
     END;                                      (* HANDLE_#STEP *)
(*-----------------------------------------------------------------*)


(*-----------------------------------------------------------------*)
(* PRINT_CODELIST: PRINTS OUT THE TI-59 CODE FOR                   *)
(*   CODEPTR NODES ONLY.                                           *)
(*-----------------------------------------------------------------*)
PROCEDURE PRINT_CODELIST(VAR OUTFILE:TEXT;
                         VAR BUILTCODE:CODEPTR);
  VAR CUR:CODEPTR;
  BEGIN
    CUR:=BUILTCODE;
    WHILE CUR <> NIL DO
      BEGIN
        HANDLE_0STEP(OUTFILE,CUR);
        IF CUR@.KEY IN (.71,76.) THEN
          BEGIN
            CUR:=CUR@.SEQ;
            HANDLE_0STEP(OUTFILE,CUR);
          END
        ELSE
          BEGIN
            IF CUR@.KEY IN STEP_1 THEN
              HANDLE_1STEP(OUTFILE,CUR);
            IF CUR@.KEY IN STEP_2 THEN
              HANDLE_2STEP(OUTFILE,CUR);
            IF CUR@.KEY IN STEP_3 THEN
              HANDLE_3STEP(OUTFILE,CUR);
          END;
        IF CUR <> NIL THEN
          CUR:=CUR@.SEQ;
      END;
  END;                                    (* PRINT CODELIST *)
(*-----------------------------------------------------------------*)
```

```
{*----------------------------------------------------------*}
{* FIND_MSG:   SEARCHES INPUT FILE TO FIND MSG NUMBER.      *}
{*----------------------------------------------------------*}
PROCEDURE FIND_MSG(VAR MESSAGEFILE:TEXT; MSG:INTEGER);
  VAR C1:CHAR; DIGIT:INTEGER;
  BEGIN
    RESET (MESSAGEFILE);
    C1:=' ';
    DIGIT:=-1;
    REPEAT
      READ(MESSAGEFILE,C1);
      IF C1 = '$' THEN
        READLN(MESSAGEFILE,DIGIT)
      ELSE
        READLN(MESSAGEFILE);
    UNTIL ((C1='$') AND (DIGIT=MSG));
  END;                                        (* FIND_MSG *)
(*----------------------------------------------------------*)


{*----------------------------------------------------------*}
{* INIT_SETS: INITIALIZES IMPORTANT DATA SUCH AS KEY-       *}
{*    CODE LABEL ARRAY, STEP SETS, KEY VARIABLES AND        *}
{*    INTIALIZES THE SCRATCH FILE                           *}
{*----------------------------------------------------------*}
PROCEDURE INIT_SETS(VAR TEMPFILE:TEXT; VAR STEP_0,STEP_1,
                                   STEP_2,STEP_3:INSTR_SET;
          VAR GOOD_SEGMENT:BOOLEAN;  VAR MESSAGEFILE:TEXT;
          VAR TILBI:TYPELABELS;   VAR SBRINVNEST:INTEGER);
  VAR C:CHAR;
      DIGIT,J,L,K,I:INTEGER;

   {*--------------------------------------------------------*}
   {* GET_REGCOUNT: GOES TO SCRATCH FILE AND FINDS THE       *}
   {*    MESSAGE NUMBER CONTAINING THE REGISTER COUNT        *}
   {*--------------------------------------------------------*}
   PROCEDURE GET_REGCOUNT(VAR REGCOUNT:INTEGER);
    BEGIN
      FIND_MSG(SCRATCH,RGCT);
      READLN(SCRATCH,REGCOUNT);
    END;                                  (* GET_REGCOUNT *)
   {*--------------------------------------------------------*}
   BEGIN
    SBRINVNEST:=0; (* INITIALIZES THE INVOKE NEST CHECK *)

    RESET(MESSAGEFILE);               (* INITIALIZE TILABELS *)
    DIGIT:=-1;                       (* LABELS IN MESSAGEFILE *)
    L:=1;
    REPEAT
      READ(MESSAGEFILE,C);
      IF C = '$' THEN
        READLN(MESSAGEFILE,DIGIT)
      ELSE
        READLN(MESSAGEFILE);
    UNTIL (C = '$') AND (DIGIT = ALPHALBL);
    L:=0;
    FOR I:=0 TO ALPHALBL DO
      BEGIN
        IF NOT(I IN(.21,26,31,41,46,51,56,82.)) THEN
          BEGIN
            READ(MESSAGEFILE,TILBL(.I.));
            L:=L+1;
            IF L = 4 THEN
              BEGIN
                READLN(MESSAGEFILE);
                L:=0;
              END;
          END
```

```
        ELSE
          TILBL(.I.):= 'BLANK              ';
      END;

    GET_REGCOUNT(REGCOUNT);

    REWRITE(TEMPFILE);                    (* OPENNING AND MARKING *)
    WRITELN(TEMPFILE,'$9');  (* THE TEMPFILE  WITH MSG 9 *)

    REWRITE(OUTFILE);                     (* INIT OUTPUTFILE *)

    GOOD_SEGMENT:=TRUE;

    STEP_3:=(.87,97.);        (* STEP TYPES OF INSTRUCTIONS *)
    STEP_2:=(.61,67,77.);
    STEP_1:=(.36,40,42,43,44,48,49,58,62,63,64,69,72,73,74
            ,83,84,86.);
    STEP_0:=(.0..99.)-(STEP_3+STEP_2+STEP_1);
  END;                                          (* INIT_SETS *)
(*-----------------------------------------------------------*)


(*-----------------------------------------------------------*)
(* ADVANCE_CODEPTR: MOVES ALONG CODE SKIPPING 1, 2, OR 3*)
(*   STEP INSTRUCTIONS AND STOPS ON NEXT COMMAND INSTR. *)
(*   TREATS 71 AND 76 AS SINGLE STEPS.                  *)
(*-----------------------------------------------------------*)
PROCEDURE ADVANCE_CODEPTR(VAR CUR:CODEPTR);
  VAR L:INTEGER;
  BEGIN
    IF CUR@.KEY IN STEP_3 THEN
      BEGIN
        FOR L:= 1 TO 4 DO
          IF CUR@.SEQ <> NIL THEN
             CUR:=CUR@.SEQ
      END
    ELSE
      IF CUR@.KEY IN STEP_2 THEN
        BEGIN
          FOR L:= 1 TO 3 DO
            IF CUR@.SEQ <> NIL THEN
              CUR:=CUR@.SEQ
        END
      ELSE
        IF CUR@.KEY IN STEP_1 THEN
          BEGIN
            FOR L:= 1 TO 2 DO
              IF CUR@.SEQ <> NIL THEN
                CUR:=CUR@.SEQ
          END
        ELSE
          IF CUR@.SEQ <> NIL THEN
            CUR:=CUR@.SEQ;
  END;                                (* END ADVANCE_CODEPTR *)
(*-----------------------------------------------------------*)
```

```
{*----------------------------------------------------------*}
{* PRINTLN_MSG: PRINTS A SPECIFIC MSG FROM ONE FILE         *}
{*    TO ANOTHER FILE.  THIS ROUTINE WILL TAKE THE          *}
{*    WHOLE MESSAGE AND PRINT IT.  IT EXECUTES A WRITELN    *}
{*    AT THE END OF THE PRINT                               *}
{*----------------------------------------------------------*}
PROCEDURE PRINTLN_MSG(VAR OUTFILE,MESSAGEFILE:TEXT;
                                          MSG:INTEGER);
  VAR C1:CHAR;
  BEGIN
    FIND_MSG(MESSAGEFILE,MSG);
    READ(MESSAGEFILE,C1);
    WHILE C1<>'$' DO
      BEGIN
        WRITE(OUTFILE,C1);
        WHILE NOT EOLN(MESSAGEFILE) DO
          BEGIN
            READ(MESSAGEFILE,C1);
            WRITE(OUTFILE,C1);
          END;
        READLN(MESSAGEFILE);
        WRITELN(OUTFILE);
        READ(MESSAGEFILE,C1);
      END;
  END;                                    (* PRINTLN_MSG *)
(*----------------------------------------------------------*)


{*----------------------------------------------------------*}
{* PRINT_LINEMSG: PRINTS A SPECIFIC ONE-LINE MESSAGE        *}
{*    TO ANOTHER FILE. DOES NOT WRITELN TO FILE.            *}
{*    USED FOR LINE LABELS OF GENERATED DATA.               *}
{*----------------------------------------------------------*}
PROCEDURE PRINT_MSGLINE1(VAR OUTFILE,MESSAGEFILE:TEXT;
                                      MSG:INTEGER);
  VAR C1:CHAR;
  BEGIN
    FIND_MSG(MESSAGEFILE,MSG);
    READ(MESSAGEFILE,C1);
    WHILE C1<>'$' DO
      BEGIN
        WRITE(OUTFILE,C1);
        READ(MESSAGEFILE,C1);
      END;
  END;                                  (* PRINT_MSGLINE1*)
(*----------------------------------------------------------*)


{*----------------------------------------------------------*}
{* DET_LIMIT: DETERMINES MEMORY LIMITS BASED ON REG_CNT.*}
{*    ONLY THREE PARTITIONS WERE CONSIDERED. THIS WAS       *}
{*    BECAUSE ANY OTHER PARTITION SPLITS THE SIDE           *}
{*    OF A MAG CARD BETWEEN REGISTERS AND PROGRAM.          *}
{*    THIS WOULD CHANGE REGISTERS DURING REPROGRAMMING      *}
{*    AND IS THEREFORE UNACCEPTABLE.                        *}
{*----------------------------------------------------------*}
PROCEDURE DET_LIMIT(VAR REGCOUNT,LIMIT,NUMBANKS,
                                   PART_NUM:INTEGER;
                                VAR PARTITION:REAL);
  BEGIN
    IF REGCOUNT+RTNREGNUM IN (.0..29.) THEN
      BEGIN
        NUMBANKS:=3;
        PARTITION:=719.29;
        PART_NUM:=3;
        LIMIT:=719;
      END
```

```
    ELSE
      IF REGCOUNT+RTNREGNUM IN (.30..59.) THEN
        BEGIN
          NUMBANKS:=2;
          PARTITION:=479.59;
          PART_NUM:=6;
          LIMIT:=479;
        END
      ELSE
        BEGIN
          NUMBANKS:=1;
          PARTITION:=239.89;
          PART_NUM:=9;
          LIMIT:=239;
        END;
  END;                                             (* DET_LIMIT *)
(*--------------------------------------------------------------*)


(*--------------------------------------------------------------*)
(* CLEAN: REMOVES SAME F_JUMPS AND SAME SBRS IN A SEG          *)
(*    TBL NODE.  ALSO GIVES DELETE COUNT FOR F_JUMPS           *)
(*    INCLUDED IN THE CONFINES OF THE SEGMENT. DOUBLE          *)
(*    DUTY ROUTINE. USED BY COMBINE AND BY SET_LENGTH          *)
(*--------------------------------------------------------------*)
PROCEDURE CLEAN(VAR CURTP:TBLPTR; VAR DELETE:INTEGER);
  VAR F,S:TBLPTR;

  (*-----------------------------------------------------------*)
  (* PRUNE_SAMEF: REMOVES SAME FJUMP ADDRESSTO FROM TEL *)
  (*-----------------------------------------------------------*)
  PROCEDURE PRUNE_SAMEF(VAR F:TBLPTR);
    VAR T,S:TBLPTR;
    BEGIN
      WHILE F@.NEXT_FJUMP<>NIL DO
        BEGIN
          S:=F@.NEXT_FJUMP;
          T:=F;
          WHILE (S<>NIL) DO
            IF S@.JUMP_ADDRTO = F@.JUMP_ADDRTO THEN
              BEGIN
                T@.NEXT_FJUMP:=S@.NEXT_FJUMP;
                DISPOSE(S,FWD_JUMP);
                S:=T@.NEXT_FJUMP
              END
            ELSE
              BEGIN
                T:=T@.NEXT_FJUMP;
                S:=S@.NEXT_FJUMP;
              END;
          IF F@.NEXT_FJUMP<>NIL THEN
            F:=F@.NEXT_FJUMP;
        END;
    END;                                           (* PRUNE_SAMEF *)
  (*-----------------------------------------------------------*)
```

```
(*-----------------------------------------------------------*)
(* PRUNE_GREATOR: REMOVES FJUMPS CONTAINED IN SEGTBL         *)
(*-----------------------------------------------------------*)
PROCEDURE PRUNE_GREATOR(VAR F,S:TBLPTR;
                        VAR DELETE:INTEGER);
  BEGIN
    WHILE F<>NIL DO
      BEGIN
        IF F@.JUMP_ADDRTO<=CURTP@.STOP_ADDR THEN
          BEGIN
            S@.NEXT_FJUMP:=F@.NEXT_FJUMP;
            DISPOSE(F,FWD_JUMP);
            F:=S@.NEXT_FJUMP;
            DELETE:=DELETE+1;
          END
        ELSE
          BEGIN
            S:=S@.NEXT_FJUMP;
            F:=F@.NEXT_FJUMP
          END;
      END;
    IF CURTP@.F_JUMPLIST@.JUMP_ADDRTO<=CURTP@.STOP_ADDR
                                                THEN
      BEGIN
        F:=CURTP@.F_JUMPLIST;
        CURTP@.F_JUMPLIST:=F@.NEXT_FJUMP;
        DISPOSE(F,FWD_JUMP);
        DELETE:=DELETE+1;
      END;
  END;                                    (* PRUNE GREATOR *)
(*-----------------------------------------------------------*)


(*-----------------------------------------------------------*)
(* PRUNE_SAMES: REMOVES SAME SBR INVOKES FROM SEGTBL         *)
(*-----------------------------------------------------------*)
PROCEDURE PRUNE_SAMES(VAR F:TBLPTR);
  VAR S,T,SS,FF:TBLPTR;

  (*---------------------------------------------------------*)
  (* PASS_BRK: PASSES OVER THE SBR BREAK NODE                *)
  (*---------------------------------------------------------*)
  FUNCTION PASS_BRK(F:TBLPTR):TBLPTR;
    BEGIN
      CASE F@.TAG OF
        SBRBREAK: PASS_BRK:=F@.SBRZ;
        TABLE: PASS_BRK:=F;
      END;
    END;                                     (* PASS_BRK *)
  (*---------------------------------------------------------*)
  BEGIN
    WHILE F<>NIL DO
      BEGIN
        S:=F@.NEXT_SBR;
        IF S<>NIL THEN
          BEGIN
            FF:=PASS_BRK(F@.SBR);
            SS:=PASS_BRK(S@.SBR);
          END;
        T:=F;
        WHILE (S<>NIL) DO
          IF SS = FF THEN
            BEGIN
              T@.NEXT_SBR:=S@.NEXT_SBR;
              DISPOSE(S,SBRPTR);
              S:=T@.NEXT_SBR;
              IF S<>NIL THEN
                SS:=PASS_BRK(S@.SBR);
            END
```

```
            ELSE
              BEGIN
                T:=T@.NEXT_SBR;
                S:=S@.NEXT_SBR;
                IF S<>NIL THEN
                  SS:=PASS_BRK(S@.SBR);
              END;
          F:=F@.NEXT_SBR;
        END;
    END;                                             (* PRUNE_SAMESBR *)
  (*----------------------------------------------------------------*)
  BEGIN
    DELETE:=0;
    IF CURTP@.F_JUMPLIST<>NIL THEN
      BEGIN
        F:=CURTP@.F_JUMPLIST;
        PRUNE_SAMEF(F);
      END;
    IF CURTP@.F_JUMPLIST<>NIL THEN
      BEGIN
        S:=CURTP@.F_JUMPLIST;
        F:=S@.NEXT_FJUMP;
        PRUNE_GREATOR(F,S,DELETE);
      END;
    IF CURTP@.SBRLIST<>NIL THEN
      BEGIN
        F:=CURTP@.SBRLIST;
        PRUNE_SAMES(F);
      END;
  END;                                                   (* CLEAN *)
(*------------------------------------------------------------------*)


(*------------------------------------------------------------------*)
(* DIAGS_NEST1SBRBRK: DIAGNOSTIC PRINTOUT IF THERE IS A            *)
(*    A SBR BREAK WITHIN AN ITERATIVE LOOP. NEEDS TO SET           *)
(*    GOOD_SEGMENT VARIABLE FALSE                                  *)
(*------------------------------------------------------------------*)
PROCEDURE DIAGS_NEST1SBRBRK(VAR TEMPFILE:TEXT; SEG:TBLPTR;
                                  VAR GOOD_SEGMENT:BOOLEAN);
  VAR IS_BRK_BELOW:BOOLEAN;

  (*----------------------------------------------------------------*)
  (* BELOW_BREAK: SEARCHES OUT BELOW TO SEE IF A BREAK             *)
  (*    IS PRESENT SO DIAGS_NEST1 CAN CHECK FOR A BREAK            *)
  (*    WITHIN A LOOP                                              *)
  (*----------------------------------------------------------------*)
  PROCEDURE BELOW_BREAK(SEG:TBLPTR; VAR IS_BRK_BELOW:
                                                      BOOLEAN);
    VAR SBR,SBRL:TBLPTR;
    BEGIN
      IF NOT IS_BRK_BELOW THEN
        BEGIN
          IF SEG@.SBRLIST<>NIL THEN
            BEGIN
              SBRL:=SEG@.SBRLIST;
              WHILE SBRL<>NIL DO
                BEGIN
                  SBR:=SBRL@.SBR;
                  IF SBR@.TAG=SBRBREAK THEN
                    IS_BRK_BELOW:=TRUE
                  ELSE
                    BELOW_BREAK(SBR,IS_BRK_BELOW);
                  SBRL:=SBRL@.NEXT_SBR;
                END;
            END;
        END;
    END;                                           (* BELOW_BREAK *)
```

```
  (*-----------------------------------------------------------------*)
  BEGIN
    IS_BRK_BELOW:=FALSE;
    BELOW_BREAK(SEG,IS_BRK_BELOW);
    IF (IS_BRK_BELOW)AND(SEG@.NEST=1) THEN
      BEGIN
        GOOD_SEGMENT:=FALSE;
        WRITELN(TEMPFILE);
        WRITE(TEMPFILE,'          ');
        WRITELN(TEMPFILE,'* SBR BREAK WITHIN A LOOP');
        WRITE(TEMPFILE,'          ');
        WRITELN(TEMPFILE,'LOOP BOUNDS',SEG@.START_ADDR:4
          ,' TO ',SEG@.STOP_ADDR:4);
      END;
  END;                              (* DIAGS_NEST1SBRBRK *)
(*-----------------------------------------------------------------*)


(*-----------------------------------------------------------------*)
(* DIAGS_NEST1LENGTHCHK: PRINTS OUT DIAGNOSTIC IF THERE *)
(*    EXISTS AN ITERATIVE LOOP OF TOO GREAT A LENGTH.     *)
(*    TAKES INTO ACCOUNT OUT OF LOOP JUMPS.  NEEDS TO     *)
(*    SET GOOD_SEGMENT FALSE IF ENCOUNTERED               *)
(*-----------------------------------------------------------------*)
PROCEDURE DIAGS_NEST1LENGTHCHK(VAR TEMPFILE:TEXT;
                 CUR:TBLPTR;  VAR GOOD_SEGMENT:BOOLEAN);
  BEGIN
    IF (CUR@.LENGTH > LIMIT) AND (CUR@.NEST=1) THEN
      BEGIN
        GOOD_SEGMENT:=FALSE;
        WRITELN(TEMPFILE);
        WRITE(TEMPFILE,'          ');
        WRITELN(TEMPFILE,'* BACK JUMP NEST TOO LONG');
        WRITE(TEMPFILE,'          ');
        WRITELN(TEMPFILE,'  LOOP BOUNDS',
             CUR@.START_ADDR:4,' TO ',CUR@.STOP_ADDR:4);
      END;
  END;                              (* DIAGS_NEST1SBRBRK *)
(*-----------------------------------------------------------------*)
```

```
(*-------------------------------------------------------------*)
(* DIAGS_NEST6SBRINVCHK: CHECKS THAT THE SBR NEST LEVEL  *)
(*    DOES NOT EXCEED 6                                        *)
(*-------------------------------------------------------------*)
PROCEDURE DIAGS_NEST6SBRINVCHK(VAR TEMPFILE:TEXT;
                   CUR:TBLPTR;  VAR GOOD_SEGMENT:BOOLEAN;
                                 SBRINVNEST:INTEGER);
  BEGIN
    IF SBRINVNEST > 7 THEN
      BEGIN
        GOOD_SEGMENT:=FALSE;
        WRITE(TEMPFILE,'          ');
        WRITELN(TEMPFILE,'* SBR INVOKE NEST LEVEL > 6');
        WRITE(TEMPFILE,'          ');
        WRITE(TEMPFILE,'     CALLES ROUTINE STARTS ');
        WRITELN(TEMPFILE,'AT ABS ADDR ',CUR@.START_ADDR:3)
      END;
  END;                          (* DIAGS_NEST6SBRINVCHK *)
(*-------------------------------------------------------------*)


(*-------------------------------------------------------------*)
(* RESET_INCLUDED: SETS ALL INCLUDES TO FALSE. DOES SO    *)
(*    FOR ALL ROUTINES ON THE SBRLIST AND BELOW SBRS       *)
(*-------------------------------------------------------------*)
PROCEDURE RESET_INCLUDED(VAR SBRL:TBLPTR);
  VAR SBRLST,SBR:TBLPTR;
  BEGIN
    SBRLST:=SBRL;
    WHILE SBRLST<>NIL DO
      BEGIN
        SBR:=SBRLST@.SBR;
        CASE SBR@.TAG OF
          TABLE:
            SBR:=SBR;
          SBRBREAK:
            SBR:=SBR@.SBRZ
        END;
        IF (SBR@.SBRLIST<>NIL)AND(SBR@.COALESCED=
                                              TRUE) THEN
          RESET_INCLUDED(SBR@.SBRLIST);
        IF (SBR@.COALESCED=TRUE) THEN
          SBR@.INCLUDED:=FALSE;
        SBRLST:=SBRLST@.NEXT_SBR;
      END;
  END;                               (* RSET_INCLUDED *)
(*-------------------------------------------------------------*)


(*-------------------------------------------------------------*)
(* INPUT:                                                      *)
(*    PURPOSE: TO READ AN INPUT FILE AND FORM SEQ LINKS.  *)
(*    THIS FORMS THE INTERNAL CODE STRUCTURE WHICH WILL    *)
(*    BE MANIPULATED                                           *)
(*-------------------------------------------------------------*)
PROCEDURE INPUT(VAR SCRATCH:TEXT; VAR BUILT_CODE:CODEPTR;
                          VAR BUILT_CODE_COUNT:INTEGER);
  VAR   ADDRESS:INTEGER;
        TEMP,COUNT:INTEGER;
        CUR,TRAIL:CODEPTR;
   BEGIN
     FIND_MSG(SCRATCH,CODENUM);
     READ(SCRATCH,TEMP);
     IF TEMP > -1 THEN
       BEGIN
         NEW(CUR);
         BUILT_CODE:=CUR;
```

```
        COUNT:=0;
        CUR@.AADDR:=TEMP;
        CUR@.RADDR:=COUNT;
        READLN(SCRATCH,CUR@.KEY);
        TRAIL:=CUR
      END; (*IF*)

    REPEAT
      NEW(CUR);
      COUNT:=COUNT+1;
      READ(SCRATCH,CUR@.AADDR);
      IF CUR@.AADDR<>-1 THEN
        BEGIN
          CUR@.RADDR:=COUNT;
          READLN(SCRATCH,CUR@.KEY);
          TRAIL@.SEQ:=CUR;
          TRAIL@.JMP:=NIL;
          TRAIL:=CUR;
        END;
    UNTIL (CUR@.AADDR = -1);
    BUILT_CODE_COUNT:=COUNT-1;
    TRAIL@.JMP:=NIL;
    TRAIL@.SEQ:=NIL

  END;                                              (* INPUT *)
(*-----------------------------------------------------------*)


(*-----------------------------------------------------------*)
(*  SETJMP:                                                  *)
(*    PURPOSE: TO SET THE JUMP POINTER OF THE BUILTCODE      *)
(*-----------------------------------------------------------*)
PROCEDURE SETJMPS(VAR BUILT_CODE:CODEPTR);
  VAR  CUR:CODEPTR;

  (*---------------------------------------------------------*)
  (* SETJMP_PTR: SETS THE JUMPTR OF THE CURRENT NODE         *)
  (*---------------------------------------------------------*)
  PROCEDURE SETJMP_PTR(VAR BUILT_CODE:CODEPTR;
                                           CUR:CODEPTR);
    VAR MARKER,SEARCH:CODEPTR;
        ADDRESS:INTEGER;
    BEGIN
      MARKER:=CUR@.SEQ;
      IF CUR@.KEY IN STEP_3 THEN
        MARKER:=MARKER@.SEQ;
      ADDRESS:=100*MARKER@.KEY;
      ADDRESS:=ADDRESS+MARKER@.SEQ@.KEY;
      SEARCH:=BUILT_CODE;
      WHILE (SEARCH@.AADDR<>ADDRESS) DO
        SEARCH:=SEARCH@.SEQ;
      MARKER@.SEQ@.JMP:=SEARCH;
    END;                                      (* SETJMPS_PTR *)
  (*---------------------------------------------------------*)
  BEGIN
    CUR:=BUILT_CODE;
    WHILE CUR@.SEQ <> NIL DO
      BEGIN
        IF CUR@.KEY IN (STEP_2+STEP_3) THEN
          SETJMP_PTR(BUILT_CODE,CUR);
        IF CUR@.KEY IN (.77,76.) THEN
          CUR:=CUR@.SEQ@.SEQ
        ELSE
          ADVANCE_CODEPTR(CUR);
      END;
  END;                                        (* TEST_SETJMP *)
(*-----------------------------------------------------------*)
```

```
(*==========================================================*)
(* BUILD SEGMENT TABLE ROUTINES:  ON THIS TABLE ALL        *)
(*   OF THE COALESCING IS DONE, AND NOT THE CODE.          *)
(*==========================================================*)
PROCEDURE BUILD_SEGTBL(BUILT_CODE:CODEPTR;
                     VAR SEGTBL:TBLPTR; LIMIT:INTEGER;
                              BUILT_CODE_COUNT:INTEGER);
  VAR HDRPTR:TBLPTR;

  (*------------------------------------------------------*)
  (* BLD_PRIMSEGTBL: RESULTS IN A TABLE WITH CRITICAL     *)
  (*   POINTS IDENTIFIED.  THESE ARE BACK JUMP POINTS     *)
  (*   TO AND FROM LOCATIONS.  STOP IS STORED IN STOP     *)
  (*   ADDRESS OF THE FIRST NODE.                         *)
  (*------------------------------------------------------*)
  PROCEDURE BLD_PRIMSEGTBL(BUILT_CODE:CODEPTR;
                           VAR HDRPTR:TBLPTR);
    VAR CURCP:CODEPTR;
        CURTP:TBLPTR;

    (*----------------------------------------------------*)
    (* PROCESS_SBRLBL: STORES THE SBRLBL IN THE HEADER    *)
    (*    SBRLIST AND PRODUCES THE FIRST SEGMENT OF THE   *)
    (*    SEGMENT TABLE FOR EACH SBR.                     *)
    (*    THIS IS CONFUSING IN THAT THE SAME TYPE OF NODE*)
    (*    IS USED TO STORE THE LABEL NAME AS IS USED FOR *)
    (*    THE SEGTABLE.  KEY FIELD REDEFINITIONS FOR THIS*)
    (*    FUNCTION SO THAT THE NAME GOES INTO THE FIELD   *)
    (*    STOP_ADDR. THESE LABEL NODES ARE NEEDED TO BE   *)
    (*    ABLE TO SET THE SBR INVOKE POINTERS LATER ON.   *)
    (*----------------------------------------------------*)
    PROCEDURE PROCESS_SBRLBL(VAR CURCP:CODEPTR;
                             VAR CURTP:TBLPTR);
      VAR TRAILTP:TBLPTR;
      BEGIN
        TRAILTP:=CURTP;
        NEW(CURTP,TABLE);
        CURTP@.TAG:=TABLE;
        CURTP@.TABLELIST:=NIL;
        CURTP@.COALESCED:=FALSE;
        CURTP@.INCLUDED:=FALSE;
        CURTP@.SBRLIST:=NIL;
        CURTP@.START_ADDR:=CURCP@.AADDR;
        CURTP@.STOP_ADDR:=-1;
        IF CURCP@.KEY = 76 THEN
          BEGIN
            CURTP@.STOP_ADDR:=CURCP@.SEQ@.KEY;
            CURCP:=CURCP@.SEQ@.SEQ
          END
        ELSE
          CURTP@.STOP_ADDR:=-1;
        IF TRAILTP <> NIL THEN
          TRAILTP@.SBRLIST:=CURTP;
      END;                             (* PROCESS_SBRLBL *)
    (*----------------------------------------------------*)
```

```
(*-----------------------------------------------------*)
(* PROCESS_SBRCODE: PROCESS THE TI-59 SBR CODE FOR     *)
(*   CRITICAL INFO AND BUILDS THE PRIMITIVE SEGS       *)
(*-----------------------------------------------------*)
PROCEDURE PROCESS_SBRCODE(VAR CURCP:CODEPTR;
                          VAR SBRHDRTP:TBLPTR);
  VAR TOPTP,CURTP:TBLPTR;

  (*---------------------------------------------------*)
  (* IS_BCK_JMP: DETERMINES IF THE JUMP IS BACKWARDS*)
  (*---------------------------------------------------*)
  FUNCTION IS_BACK_JMP(CURCP:CODEPTR):BOOLEAN;
   VAR ADDRESS:INTEGER;
   BEGIN
     IF (CURCP@.KEY IN STEP_2) THEN
       BEGIN
         ADDRESS:=CURCP@.SEQ@.SEQ@.JMP@.AADDR;
         IF ADDRESS > CURCP@.AADDR THEN
           IS_BACK_JMP:=FALSE
         ELSE
           IS_BACK_JMP:=TRUE;
       END
     ELSE
       IF (CURCP@.KEY IN STEP_3) THEN
         BEGIN
           ADDRESS:=CURCP@.SEQ@.SEQ@.SEQ@.JMP@.AADDR;
           IF ADDRESS > CURCP@.AADDR THEN
             IS_BACK_JMP:=FALSE
           ELSE
             IS_BACK_JMP:=TRUE;
         END
       ELSE
         IS_BACK_JMP:=FALSE;
   END;                                (* IS_BACK_JMP *)
  (*---------------------------------------------------*)


(*-----------------------------------------------------*)
(* APND_JMP_TBL: DETERMINES ALL OUT OF CODE JUMPS      *)
(*   FROM A "FROM" ADDRESS TO A "TO" ADDRESS.          *)
(*-----------------------------------------------------*)
PROCEDURE APND_JMP_TBL(CURCP:CODEPTR;
                       VAR TOPTP:TBLPTR);
  VAR ADDRESSFR,ADDRESSTO:INTEGER;

  (*---------------------------------------------------*)
  (* INSERT_CRITS: PLACES CRITICALS IN SEGTBL.         *)
  (*   CRITICAL IS ADDRESS WHERE A BACK JUMP NEST      *)
  (*   LEVEL CHANGE TAKES PLACE, IE START OR STOP.     *)
  (*---------------------------------------------------*)
  PROCEDURE INSERT_CRITS(ADDRESS:INTEGER;
                         VAR TOPTP:TBLPTR);
    VAR  CURTP,TRAILTP,INSERTTP:TBLPTR;
    BEGIN
      TRAILTP:=TOPTP;
      CURTP:=TOPTP@.TABLELIST;
      WHILE (CURTP@.START_ADDR < ADDRESS) AND
            (CURTP@.TABLELIST <> NIL)      DO
        BEGIN
          TRAILTP:=CURTP;
          CURTP:=CURTP@.TABLELIST;
        END;
      NEW(INSERTTP,TABLE);
      INSERTTP@.TAG:=TABLE;
      INSERTTP@.START_ADDR:=ADDRESS;
      INSERTTP@.STOP_ADDR:=-2;
      IF (CURTP@.TABLELIST=NIL) AND
         (CURTP@.START_ADDR < ADDRESS) THEN
```

```
          BEGIN
            CURTP@.TABLELIST:=INSERTTP;
            INSERTTP@.TABLELIST:=NIL
          END
        ELSE
          IF (CURTP@.TABLELIST=NIL) AND
                   (CURTP@.START_ADDR > ADDRESS)  THEN
            BEGIN
              TRAILTP@.TABLELIST:=INSERTTP;
              INSERTTP@.TABLELIST:=CURTP
            END
          ELSE
            IF CURTP@.START_ADDR > ADDRESS THEN
              BEGIN
                INSERTTP@.TABLELIST:=CURTP;
                TRAILTP@.TABLELIST:=INSERTTP
              END
            ELSE
              DISPOSE(INSERTTP,TABLE);
    END;                                    (* INSERT_CRITS *)
  (*------------------------------------------------------*)


  (*------------------------------------------------------*)
  (* SET_NESTS: SEARCHES THE PRIM SEGTBL AND MARKS      *)
  (*   AS 1 ALL OVERLAPPING BACK JUMPS TO DESIGNATE     *)
  (*   THAT THEY ARE IN A NO BREAK AREA                 *)
  (*------------------------------------------------------*)
  PROCEDURE SET_NESTS (ADDRESSFR,ADDRESSTO:INTEGER;
                           VAR TOPTP:TBLPTR);
    VAR CURTP:TBLPTR;
    BEGIN
      CURTP:=TOPTP;
      WHILE CURTP@.START_ADDR <> ADDRESSTO DO
        CURTP:=CURTP@.TABLELIST;
      WHILE CURTP@.START_ADDR <> ADDRESSFR DO
        BEGIN
          CURTP@.NEST:= 1;
          CURTP:=CURTP@.TABLELIST
        END;
      CURTP@.NEST:=0;
      IF ((CURTP@.TABLELIST <> NIL) AND (CURTP@.NEST =
           1)) THEN
        CURTP@.NEST:=1
    END;                                    (* SET_NESTS *)
  (*------------------------------------------------------*)
  BEGIN
    IF CURCP@.KEY IN STEP_2 THEN
      BEGIN
        ADDRESSTO:=CURCP@.SEQ@.SEQ@.JMP@.AADDR;
        ADDRESSFR:=CURCP@.SEQ@.SEQ@.AADDR
      END
    ELSE
      BEGIN
        ADDRESSTO:=CURCP@.SEQ@.SEQ@.SEQ@.JMP@.AADDR;
        ADDRESSFR:=CURCP@.SEQ@.SEQ@.SEQ@.AADDR
      END;
    INSERT_CRITS(ADDRESSFR,TOPTP);
    INSERT_CRITS(ADDRESSTO,TOPTP);
    SET_NESTS(ADDRESSFR,ADDRESSTO,TOPTP)
  END;                                      (* APND_JMP_TBL *)
(*--------------------------------------------------------*)
BEGIN
  NEW(CURTP,TABLE);
  CURTP@.TAG:=TABLE;
  CURTP@.START_ADDR:=SBRHDRTP@.START_ADDR;
  CURTP@.NEST:=0;
  CURTP@.COALESCED:=FALSE;
```

```
    CURTP@.INCLUDED:=FALSE;
    CURTP@.TABLELIST:=NIL;
    CURTP@.SERLIST:=NIL;
    SBRHDRTP@.TABLELIST:=CURTP;
    TOPTP:=SBRHDRTP;
    WHILE ((CURCP@.KEY <> 76) AND (CURCP@.SEQ <> NIL ))
      DO
      IF IS_BACK_JMP(CURCP) THEN
        BEGIN
          APND_JMP_TBL(CURCP,TOPTP);
          ADVANCE_CODEPTR(CURCP)
        END
      ELSE
        ADVANCE_CODEPTR(CURCP);
    IF CURCP@.SEQ = NIL THEN
      TOPTP@.TABLELIST@.STOP_ADDR:=CURCP@.AADDR
    ELSE
      TOPTP@.TABLELIST@.STOP_ADDR:=CURCP@.AADDR-1;
  END;                                     (* PROCESS_SBRCODE *)
(*-----------------------------------------------------------*)
  BEGIN
    CURCP:=BUILT_CODE;
    CURTP:=NIL;
    PROCESS_SBRLBL(CURCP,CURTP);
    HDRPTR:=CURTP;
    WHILE (CURCP@.SEQ <> NIL) DO
      BEGIN
        PROCESS_SBRCODE(CURCP,CURTP);
        IF CURCP@.KEY = 76 THEN
          PROCESS_SBRLBL(CURCP,CURTP);
      END;
  END;                                     (* BLD_PRIMSEGTBL *)
(*-----------------------------------------------------------*)


(*-----------------------------------------------------------*)
(* BLD_ADVSEGTBL: FILLS IN THE STOPS AND MERGES SAME         *)
(*    NESTED LEVELS INTO ONE SEGMENT.                        *)
(*    STOPS ARE STOP_ADDR FIELD                              *)
(*-----------------------------------------------------------*)
PROCEDURE BLD_ADVSEGTBL(VAR HDRPTR:TBLPTR);
  VAR  SBRTP:TBLPTR; STOP:INTEGER;

  (*-------------------------------------------------------*)
  (* MERGE_ONES: COMBINES SAME NESTED ADJACENT 1 SEGS      *)
  (*-------------------------------------------------------*)
  PROCEDURE MERGE_ONES(VAR SBRTP:TBLPTR);
    VAR MARK,ZERO,ONE:TBLPTR;

    (*---------------------------------------------------*)
    (* MERGE: DOES ACTUAL MERGING OF ADJACENT SEGMENTS*)
    (*---------------------------------------------------*)
    PROCEDURE MERGE(VAR ONE,ZERO,MARK:TBLPTR);
      VAR DIS:TBLPTR;
      BEGIN
        ONE@.STOP_ADDR:=ZERO@.START_ADDR;
        DIS:=ONE@.TABLELIST;
        WHILE ONE@.TABLELIST <> ZERO DO
          BEGIN
            ONE@.TABLELIST:=DIS@.TABLELIST;
            DISPOSE(DIS,TABLE);
            DIS:=ONE@.TABLELIST
          END;
        IF ZERO@.TABLELIST <> NIL THEN
          ONE@.TABLELIST:=ZERO@.TABLELIST
        ELSE
          ONE@.TABLELIST:=NIL;
        MARK:=ONE;
```

```
      DISPOSE(DIS,TABLE);
    END;                                              (* MERGE *)
  (*------------------------------------------------------------*)
  BEGIN
    MARK:=SBRTP@.TABLELIST;
    WHILE MARK@.TABLELIST <> NIL  DO
      BEGIN
        IF (MARK@.NEST = 0) AND (MARK@.TABLELIST<>NIL)
          THEN  MARK:=MARK@.TABLELIST;
        ONE:=MARK;
        WHILE  (MARK@.NEST=1) AND (MARK@.TABLELIST<>NIL)
          DO     MARK:=MARK@.TABLELIST;
        ZERO:=MARK;
        IF ONE <> ZERO THEN
          BEGIN
            MERGE(ONE,ZERO,MARK);
            MARK:=ONE;
          END;
        IF MARK@.TABLELIST <> NIL THEN
          MARK:=MARK@.TABLELIST;
      END;
  END;                                           (* MERGE_ONES *)
(*--------------------------------------------------------------*)


(*--------------------------------------------------------------*)
(* ADD_ZEROS: FILLS IN GAPS IN TABLE WITH  0 SEG                *)
(*--------------------------------------------------------------*)
PROCEDURE ADD_ZEROS(VAR SBRTP:TBLPTR);
  VAR CUR,TRAIL,INSERT:TBLPTR;  STOP:INTEGER;
  BEGIN
    TRAIL:=SBRTP;
    CUR:=SBRTP@.TABLELIST;
    STOP:=CUR@.STOP_ADDR;
    WHILE CUR@.TABLELIST <> NIL DO
      BEGIN
        CUR:=CUR@.TABLELIST;
        WHILE TRAIL@.TABLELIST <> CUR DO
          TRAIL:=TRAIL@.TABLELIST;
        IF TRAIL@.NEST<> CUR@.NEST THEN
          TRAIL@.STOP_ADDR:=CUR@.START_ADDR-1
        ELSE
          BEGIN
            NEW(INSERT,TABLE);
            INSERT@.NEST:=0;
            INSERT@.START_ADDR:=TRAIL@.STOP_ADDR+1;
            INSERT@.STOP_ADDR:=CUR@.START_ADDR-1;
            INSERT@.TABLELIST:=CUR;
            TRAIL@.TABLELIST:=INSERT
          END;
      END;
      IF CUR@.STOP_ADDR <> STOP THEN
        BEGIN
          NEW(INSERT,TABLE);
          INSERT@.NEST:=0;
          INSERT@.START_ADDR:=CUR@.STOP_ADDR+1;
          INSERT@.STOP_ADDR:=STOP;
          INSERT@.TABLELIST:=NIL;
          CUR@.TABLELIST:=INSERT
        END;
  END;                                            (* ADD_ZEROS *)
(*--------------------------------------------------------------*)
BEGIN
  SBRTP:=HDRPTR;
  WHILE SBRTP <> NIL DO
    BEGIN
      MERGE_ONES(SBRTP);
      ADD_ZEROS(SBRTP);
```

```
        SBRTP:=SBRTP@.SBRLIST;
      END;
  END;                                          (* BLD_ADVSEGTBL *)
(*-----------------------------------------------------------*)

(*-----------------------------------------------------------*)
(* BLD_FINSEGTBL: PROCESS CODE FOR SBR INVOKES AND           *)
(*    FJUMPS.  WHEN ENCOUNTERED IT PLACES INTO SEGTBL.       *)
(*    THESE WILL INCLUDE ONLY ONE INVOKE PER SEGMENT         *)
(*    AND ONLY ONE FJUMP TO SAME LOCATIONS.  REPEATS         *)
(*    WILL BE IGNORED.  LENGTHS OF SEGMENTS WILL ALSO        *)
(*    BE CALCULATED.  LENGTHS DO NOT INCLUDE CODE FOR        *)
(*    SBR INVOKES/PROMPT CODE.  ONLY SEQUENTIAL CONTIN-*)
(*    UATION CODE IS INCLUDED IN LENGTH CALCULATION TO-*)
(*    GETHER WITH FJUMP PROMPT CODE.                         *)
(*-----------------------------------------------------------*)
PROCEDURE BLD_FINSEGTBL(BUILTCODE:CODEPTR;
                        VAR HDRPTR:TBLPTR;  LIMIT:INTEGER);
  VAR CURCP:CODEPTR;
      SBRTP:TBLPTR;

  (*--------------------------------------------------------*)
  (* PROCESS SBRSEGTBL: PLACES SBRS & FJMP INTO SEGTBL*)
  (*--------------------------------------------------------*)
  PROCEDURE PROCESS_SBRSEGTBL(VAR CURCP:CODEPTR;
                              VAR HDRPTR,SBRTP:TBLPTR);
    VAR CURTP,SBRINVOKE,FJMP:TBLPTR;

    (*-----------------------------------------------------*)
    (* HANDLE_FWDJMP: INSERTS FWD JUMPS INTO TABLE.      *)
    (*-----------------------------------------------------*)
    PROCEDURE HANDLE_FWDJMP(CURCP:CODEPTR;
                            VAR HDRPTR,CURTP,FJMP:TBLPTR);
      VAR ADDRESSTO,ADDRESSFR:INTEGER;
          INSERT:TBLPTR;
      BEGIN
        IF CURCP@.KEY IN STEP_3 THEN
          BEGIN
            ADDRESSFR:=CURCP@.SEQ@.SEQ@.SEQ@.AADDR;
            ADDRESSTO:=CURCP@.SEQ@.SEQ@.SEQ@.JMP@.AADDR;
          END
        ELSE
          BEGIN
            ADDRESSFR:=CURCP@.SEQ@.SEQ@.AADDR;
            ADDRESSTO:=CURCP@.SEQ@.SEQ@.JMP@.AADDR;
          END;
        NEW(INSERT,FWD_JUMP);
        INSERT@.TAG:=FWD_JUMP;
        INSERT@.JUMP_ADDRFR:=ADDRESSFR;
        INSERT@.JUMP_ADDRTO:=ADDRESSTO;
        INSERT@.JUMP_ADDRTO1:=-1;
        INSERT@.JUMP_ADDRTO2:=-2;
        INSERT@.MEM_ADDR:=-1;
        INSERT@.JUMP_INTADDRTO1:=-1;
        INSERT@.JUMP_INTADDRTO2:=-2;
        INSERT@.NEXT_FJUMP:=NIL;
        IF CURTP@.F_JUMPLIST = NIL THEN
          BEGIN
            CURTP@.F_JUMPLIST:=INSERT;
            FJMP:=INSERT;
          END
        ELSE
          BEGIN
            FJMP@.NEXT_FJUMP:=INSERT;
            FJMP:=INSERT
          END;
      END;                                  (* HANDLE_FWDJMP *)
    (*-----------------------------------------------------*)
```

```
(*---------------------------------------------------------*)
(* IS_FWD_JMP: BOOLEAN TRUE IF KEYCODE IS FWD JMP          *)
(*---------------------------------------------------------*)
FUNCTION IS_FWD_JMP(CURCP:CODEPTR):BOOLEAN;
 VAR ADDRESS:INTEGER;
 BEGIN
   IF (CURCP@.KEY IN STEP_2) THEN
     BEGIN
       ADDRESS:=CURCP@.SEQ@.SEQ@.JMP@.AADDR;
       IF ADDRESS > CURCP@.AADDR THEN
         IS_FWD_JMP:=TRUE
       ELSE
         IS_FWD_JMP:=FALSE;
     END
   ELSE
     IF (CURCP@.KEY IN STEP_3) THEN
       BEGIN
         ADDRESS:=CURCP@.SEQ@.SEQ@.SEQ@.JMP@.AADDR;
         IF ADDRESS > CURCP@.AADDR THEN
           IS_FWD_JMP:=TRUE
         ELSE
           IS_FWD_JMP:=FALSE;
       END
     ELSE
       IS_FWD_JMP:=FALSE;
  END;                                     (* IS_FWD_JMP *)
(*---------------------------------------------------------*)


(*---------------------------------------------------------*)
(* HANDLE SBRINVOKE: PLACES SBR CALL INTO TABLE           *)
(*---------------------------------------------------------*)
PROCEDURE HANDLE_SBRINVOKE(VAR CURCP:CODEPTR;
                 VAR HDRPTR,CURTP,SBRINVOKE:TBLPTR);
  VAR TOSBR,INSERT:TBLPTR;
      KEYY:INTEGER;
  BEGIN
    TOSBR:=HDRPTR;
    KEYY:=CURCP@.SEQ@.KEY;
    WHILE TOSBR@.STOP_ADDR<> KEYY DO
      TOSBR:=TOSBR@.SBRLIST;
    NEW(INSERT,SBRPTR);
    INSERT@.TAG:=SBRPTR;
    INSERT@.FROM:=CURCP@.AADDR+1;
    INSERT@.SBR:=TOSBR@.TABLELIST;
    INSERT@.NEXT_SBR:=NIL;
    IF CURTP@.SBRLIST = NIL THEN
      BEGIN
        CURTP@.SBRLIST:=INSERT;
        SBRINVOKE:=INSERT
      END
    ELSE
      BEGIN
        SBRINVOKE@.NEXT_SBR:=INSERT;
        SBRINVOKE:=INSERT;
      END;
  END;                              (* HANDLE_SBRINVOKE *)
(*---------------------------------------------------------*)
BEGIN
  CURTP:=SBRTP@.TABLELIST;
  REPEAT
    CURTP@.SBRLIST:=NIL;
    CURTP@.F_JUMPLIST:=NIL;
    SBRINVOKE:=NIL;
    FJMP:=NIL;
    WHILE CURCP@.AADDR < CURTP@.STOP_ADDR DO
      BEGIN
        IF CURCP@.KEY = 71 THEN
```

```
          HANDLE_SBRINVOKE(CURCP,HDRPTR,CURTP,
                           SBRINVOKE);
        IF IS_FWD_JMP(CURCP) THEN
          HANDLE_FWDJMP(CURCP,HDRPTR,CURTP,FJMP);
        IF (CURCP@.KEY=76) OR (CURCP@.KEY=71) THEN
          CURCP:=CURCP@.SEQ@.SEQ
        ELSE
          ADVANCE_CODEPTR(CURCP);
      END;
    CURTP:=CURTP@.TABLELIST
  UNTIL (CURTP = NIL);
 END;                                (* PROCESS_SBRSEGTBL *)
(*-------------------------------------------------------*)


(*-------------------------------------------------------*)
(* SET_LENGTH: ENSURES LENGTH IS WITHIN MEMORY LIMIT*)
(*    IF NOT WILL DIVIDE THE SEGMENT IN HALF AND       *)
(*    RESET ALL SBRLISTS AND FJUMPLISTS THEN CONTINUE*)
(*    NOTE:  MAY LEAD TO PROBLEMS IS LIMIT IS          *)
(*    ARBITRARILY SMALL.                               *)
(*-------------------------------------------------------*)
PROCEDURE SET_LENGTH(BUILT_CODE:CODEPTR;
                     VAR SBRTP:TBLPTR; LIMIT:INTEGER);
  VAR CURTP:TBLPTR;
      LENGTH,DELETE,L_POSSBR:INTEGER;

  (*-----------------------------------------------------*)
  (* CALCULATE: DETERMINES LENGTH OF A SEGMENT. WILL*)
  (*    NOT ADD ADDITIONAL STEPS FOR DUPLICATE FJMP  *)
  (*    ADDRTOS                                        *)
  (*-----------------------------------------------------*)
  PROCEDURE CALCULATE(CURTP:TBLPTR;
                      VAR LENGTH:INTEGER);
    VAR S,F:TBLPTR;
        ADDITIONS:INTEGER;
    BEGIN
      LENGTH:=CURTP@.STOP_ADDR-CURTP@.START_ADDR
                               +FJUMPCONST+1;
      IF CURTP@.F_JUMPLIST<>NIL THEN
        BEGIN
          ADDITIONS:=0;
          F:=CURTP@.F_JUMPLIST;
          IF F@.JUMP_ADDRTO > CURTP@.STOP_ADDR THEN
            ADDITIONS:=1;
          S:=F;
          F:=F@.NEXT_FJUMP;
          WHILE F<> NIL DO
            BEGIN
              IF F@.JUMP_ADDRTO>CURTP@.STOP_ADDR THEN
                BEGIN
                  ADDITIONS:=ADDITIONS+1;
                  S:=CURTP@.F_JUMPLIST;
                  WHILE ((S<>F) AND (S@.JUMP_ADDRTO<>
                                     F@.JUMP_ADDRTO)) DO
                    S:=S@.NEXT_FJUMP;
                  IF S<> F THEN
                    ADDITIONS:=ADDITIONS-1;
                END;
              F:=F@.NEXT_FJUMP;
            END;
          LENGTH:=LENGTH+(ADDITIONS)*(FJUMPCONST);
        END;
    END;                                (* CALCULATE *)
  (*-----------------------------------------------------*)
```

```
(*----------------------------------------------------*)
(* L_POSSBRRK: CALCULATES ANY SBR INVOKES AS A        *)
(*   POSSIBLE BREAK FOR DIVISION PURPOSES. DOES       *)
(*   NOT INCLUDE MULTIPLE INVOKES OF SAME SBR         *)
(*----------------------------------------------------*)
PROCEDURE LENGTH_SBRBRKS(CURTP:TBLPTR;
                          VAR L_POSSBR:INTEGER);
  VAR F,T:TBLPTR;    COUNT:INTEGER;
  BEGIN
    COUNT:=0;
    IF CURTP@.SBRLIST<>NIL THEN
      BEGIN
        F:=CURTP@.SBRLIST;
        WHILE F<>NIL DO
          BEGIN
            IF NOT(F@.SBR@.INCLUDED) THEN
              BEGIN
                COUNT:=COUNT+1;
                F@.SBR@.INCLUDED:=TRUE;
              END;
            F:=F@.NEXT_SBR;
          END;
        F:=CURTP@.SBRLIST;
        WHILE F<>NIL DO
          BEGIN
            F@.SBR@.INCLUDED:=FALSE;
            F:=F@.NEXT_SBR;
          END;
      END;
    L_POSSBR:=COUNT*SBRCONST;
  END;                                  (* L_SBRBRKS *)
(*----------------------------------------------------*)
```

```
(*-----------------------------------------------------*)
(* DIVIDE: DIVIDES A SEG IN HALF AND RESETS PJMP      *)
(*   AND SBR POINTERS.                                  *)
(*-----------------------------------------------------*)
PROCEDURE DIVIDE(BUILT_CODE:CODEPTR;
                 VAR CURTP:TBLPTR);
  VAR INSERT:TBLPTR;
      S,F:TBLPTR;
      NEW_STOP:INTEGER;

  (*---------------------------------------------------*)
  (* SETT: ENSURES THAT DIVIDE CALCULATED STOP IS     *)
  (*    NOT SPLITTING A 1,2,3 PART INSTRUCTION.        *)
  (*---------------------------------------------------*)
  PROCEDURE SETT(BUILT_CODE:CODEPTR;
                 VAR NEW_STOP:INTEGER);
   VAR P,T:CODEPTR;
   BEGIN
     P:=BUILT_CODE;
     WHILE (P@.AADDR <= NEW_STOP) DO
       BEGIN
         T:=P;
         IF (P@.KEY = 76) OR (P@.KEY = 71) THEN
           P:=P@.SEQ@.SEQ
         ELSE
           ADVANCE_CODEPTR(P);
       END;
     IF (T@.KEY = 76) OR (T@.KEY = 71) THEN
       T:=T@.SEQ@.SEQ;
     NEW_STOP:=T@.AADDR-1;
   END;                                        (* SETT *)
  (*---------------------------------------------------*)


  (*---------------------------------------------------*)
  (* FIND_INSSBRLIST: DIVIDES UP THE SBRLIST          *)
  (*    BETWEEN THE OLD AND NEW SEGMENTS               *)
  (*---------------------------------------------------*)
  PROCEDURE FIND_INSSBRLIST(VAR CURTP,S:TBLPTR;
                            NEW_STOP:INTEGER);
   VAR LIMIT:INTEGER;
       T:TBLPTR;
   BEGIN
     LIMIT:=NEW_STOP+1;
     IF CURTP@.SBRLIST<> NIL THEN
       BEGIN
         S:=CURTP@.SBRLIST;
         IF (S@.NEXT_SBR<>NIL) AND(S@.FROM
                                < LIMIT) THEN
           BEGIN
             S:=S@.NEXT_SBR;
             T:=CURTP@.SBRLIST;
             WHILE(S@.FROM<LIMIT) AND
                  (S@.NEXT_SBR<>NIL) DO
               BEGIN
                 S:=S@.NEXT_SBR;
                 T:=T@.NEXT_SBR;
               END;
             IF S@.FROM >=LIMIT THEN
               T@.NEXT_SBR:=NIL
             ELSE
               S:=NIL
           END
         ELSE
           BEGIN
             IF S@.FROM >= LIMIT THEN
               CURTP@.SBRLIST:=NIL
             ELSE
               S:=NIL
```

```
            END;
         END
      ELSE
         S:=NIL;
    END;                                  (* FIND_INSSBRLIST *)
   (*-----------------------------------------------------------*)

   (*-----------------------------------------------------------*)
   (* FIND_INSFJMPLIST: DIVIDES FJUMPLIST BETWEEN               *)
   (*    OLD AND NEW SEGMENTS.                                   *)
   (*-----------------------------------------------------------*)
   PROCEDURE FIND_INSFJMPLIST(VAR CURTP,F:TBLPTR;
                              NEW_STOP:INTEGER);
    VAR LIMIT:INTEGER;
        T:TBLPTR;
    BEGIN
      LIMIT:=NEW_STOP+1;
      IF CURTP@.F_JUMPLIST<> NIL THEN
         BEGIN
           F:=CURTP@.F_JUMPLIST;
           IF (F@.NEXT_FJUMP<>NIL) AND (F@.JUMP_ADDRFR
                                  < LIMIT) THEN
              BEGIN
                F:=F@.NEXT_FJUMP;
                T:=CURTP@.F_JUMPLIST;
                WHILE (F@.JUMP_ADDRFR<LIMIT) AND
                      (F@.NEXT_FJUMP<>NIL) DO
                   BEGIN
                     F:=F@.NEXT_FJUMP;
                     T:=T@.NEXT_FJUMP;
                   END;
                IF F@.JUMP_ADDRFR >=LIMIT THEN
                   T@.NEXT_FJUMP:=NIL
                ELSE
                   F:=NIL
              END
           ELSE
              BEGIN
                IF F@.JUMP_ADDRFR >= LIMIT THEN
                   CURTP@.F_JUMPLIST:=NIL
                ELSE
                   F:=NIL
              END;
         END
      ELSE
         F:=NIL;
    END;                                  (* FIND_INSFJUMPLIST *)
   (*-----------------------------------------------------------*)
   BEGIN
    NEW_STOP:=(((CURTP@.STOP_ADDR-CURTP@.START_ADDR
                +1)DIV 2))+CURTP@.START_ADDR;
    SETT(BUILT_CODE,NEW_STOP);
    NEW(INSERT_TABLE);
    INSERT@.NEST:=CURTP@.NEST;
    INSERT@.START_ADDR:=NEW_STOP+1;
    INSERT@.STOP_ADDR:=CURTP@.STOP_ADDR;
    FIND_INSSBRLIST(CURTP,S,NEW_STOP);
    FIND_INSFJMPLIST (CURTP,F,NEW_STOP);
    INSERT@.SBPLIST:=S;
    INSERT@.F_JUMPLIST:=F;
    INSERT@.TABLELIST:=CURTP@.TABLELIST;
    CURTP@.TABLELIST:=INSERT;
    CURTP@.STOP_ADDR:=NEW_STOP;
  END;                                              (* DIVIDE *)
  (*------------------------------------------------------------*)
 BEGIN
  CURTP:=SBRTP@.TABLELIST;
  REPEAT
```

```
          CALCULATE(CURTP,LENGTH);
          IF (CURTP@.NEST = 0)THEN
            BEGIN
              LENGTH_SBRBRKS(CURTP,L_POSSBR);
              IF LENGTH+L_POSSBR > LIMIT THEN
                DIVIDE(BUILT_CODE,CURTP)
              ELSE
                BEGIN
                  CLEAN(CURTP,DELETE);
                  DELETE:=0;  (*CALCULATE HAS THIS COVERED*)
                  CURTP@.LENGTH:=LENGTH-DELETE*FJUMPCONST;
                  IF CURTP@.TABLELIST=NIL THEN
                   CURTP@.LENGTH:=CURTP@.LENGTH-FJUMPCONST
                                              +SBRCONTCONST;
                  CURTP:=CURTP@.TABLELIST;
                END
            END
          ELSE
            BEGIN
              CLEAN(CURTP,DELETE);
              DELETE:=0;     (* CALCULATE HAS THIS COVERED *)
              CURTP@.LENGTH:=LENGTH-DELETE*FJUMPCONST;
              CURTP:=CURTP@.TABLELIST
            END;
        UNTIL (CURTP = NIL);
      END;                                 (* SET_LENGTH *)
     (*-------------------------------------------------------*)
     BEGIN
       CURCP:=BUILTCODE;
       SBRTP:=HDRPTR;
       WHILE SBRTP <> NIL DO
         BEGIN
           PROCESS_SERSEGTBL(CURCP,HDRPTR,SBRTP);
           SET_LENGTH(BUILT_CODE,SBRTP,LIMIT);
           SBRTP:=SBRTP@.SBRLIST
         END;
     END;                                (* BLD_FINSEGTBL *)
   (*---------------------------------------------------------*)
   BEGIN
     IF BUILT_CODE_COUNT<=LIMIT THEN
       BEGIN
         NEW(SEGTBL,TABLE);
         SEGTBL@.TAG:=TABLE;
         SEGTBL@.TABLELIST:=NIL;
         SEGTBL@.SBRLIST:=NIL;
         SEGTBL@.COALESCED:=TRUE;
         SEGTBL@.INCLUDED:=FALSE;
         SEGTBL@.START_ADDR:=0;
         SEGTBL@.STOP_ADDR:=BUILT_CODE@.SEQ@.KEY;
         NEW(HDRPTR,TABLE);
         HDRPTR@.START_ADDR:=0;
         HDRPTR@.STOP_ADDR:=BUILT_CODE_COUNT;
         HDRPTR@.NEST:=0;
         HDRPTR@.TABLELIST:=NIL;
         HDRPTR@.SBRLIST:=NIL;
         HDRPTR@.F_JUMPLIST:=NIL;
         HDRPTR@.COALESCED:=TRUE;
         HDRPTR@.INCLUDED:=FALSE;
         HDRPTR@.LENGTH:=BUILT_CODE_COUNT+1;
         SEGTBL@.TABLELIST:=HDRPTR;
       END
     ELSE
       BEGIN
         BLD_PRIMSEGTBL(BUILT_CODE,HDRPTR);
         BLD_ADVSEGTBL(HDRPTR);
         BLD_FINSEGTBL(BUILT_CODE,HDRPTR,LIMIT);
         SEGTBL:=HDRPTR;
       END;
   END;                                    (* BLD_SEGTBL *)
```

```
(*==============================================================*)
(* COALESCE: COALESCES THE SEG TABLE MAKING GOOD BRK.           *)
(*    ONLY LOSS OF EFFICIENCY IS WITH CROSS SEGMENT             *)
(*    FORWARD JUMPS.  THESE MAY PRECLUDE THE COMBINING          *)
(*    OF A SEGMENT BECAUSE OF ADDED CODE FOR THE JUMP           *)
(*==============================================================*)
PROCEDURE COALESCE(VAR SBR:TBLPTR; LIMIT:INTEGER;
        VAR GOOD_SEGMENT:BOOLEAN; VAR SBRINVNEST:INTEGER);
  VAR CURSEG:TBLPTR;

  (*-----------------------------------------------------------*)
  (* SBRSUM: SUMS ALL SBRS ON A SBRLIST. SETS INCLUDES          *)
  (*    TRUE.  ADDS SBRCONST IF SBRBREAK IS ENCOUNTERED.        *)
  (*-----------------------------------------------------------*)
  PROCEDURE SBRSUM(VAR SBRLST:TBLPTR; VAR SUMSBR:INTEGER);
    VAR SBRL,SBR:TBLPTR;
    BEGIN
      SBRL:=SBRLST;
      WHILE SBRL<>NIL DO
        BEGIN
          SBR:=SBRL@.SBR;
          CASE SBR@.TAG OF
            TABLE:
              BEGIN
                IF(SBR@.COALESCED) THEN
                  IF NOT(SBR@.INCLUDED)THEN
                    BEGIN
                      SBR@.INCLUDED:=TRUE;
                      SUMSBR:=SUMSBR+SBR@.LENGTH
                                    -SBRCONTCONST;
                      IF SBR@.SBRLIST<>NIL THEN
                        SBRSUM(SBR@.SBRLIST,SUMSBR);
                    END;
              END;
            SBRBREAK:
              SUMSBR:=SUMSBR+SBRCONST;
          END;
          SBRL:=SBRL@.NEXT_SBR;
        END;
    END;                                              (* SBRSUM *)
  (*-----------------------------------------------------------*)

  (*-----------------------------------------------------------*)
  (* SBRSUMLINK: ADDS ALL SBRS BELOW AN INVOKE NODE.            *)
  (*    IT DOES NOT DO THE WHOLE SBRLIST. THAT IS SUMSBR        *)
  (*-----------------------------------------------------------*)
  PROCEDURE SBRSUMLINK(VAR SBRPTR:TBLPTR;VAR SUMT:INTEGER);
    VAR PTR:TBLPTR;
    BEGIN
      PTR:=SBRPTR@.SBR;
      CASE PTR@.TAG OF
        TABLE:
          IF (PTR@.COALESCED)AND(PTR@.TABLELIST=NIL) THEN
            IF (NOT(PTR@.INCLUDED)) THEN
              BEGIN
                PTR@.INCLUDED:=TRUE;
                SBRSUM(PTR@.SBRLIST,SUMT);
                SUMT:=SUMT+PTR@.LENGTH-SBRCONTCONST;
              END
            ELSE
              IF (PTR@.COALESCED)AND(NOT (PTR@.INCLUDED))
                                                            THEN
                SUMT:=SUMT+PTR@.LENGTH-SBRCONTCONST;
        SBRBREAK:
          SUMT:=SUMT;
      END;
    END;                                          (* SBRSUMLINK *)
  (*-----------------------------------------------------------*)
```

```
(*---------------------------------------------------------------*)
(* CHK_SEGSIZE: VERIFIES THAT THE SEGMENT OF NEST 0              *)
(*    TOGETHER WITH ITS REQUIRED SBR INVOKES IS WITHIN           *)
(*    MEMORY CONSTRAINTS.  IF IT DOES NOT FIT THEN A             *)
(*    SBRBREAK IS INSERTED.  THIS ROUTINE ASSUMES THAT           *)
(*    THE SEGMENT LENGTH IS OK. SET_LENGTH ENSURES THIS*)
(*    IF A SBR IS NOT COALESCED THIS ROUTINE MUTUALLY            *)
(*    RECURSES WITH COALESCE.  DURING ITS CHECK, IT              *)
(*    WILL INCLUDE AND RESET_INCLUDES.                           *)
(*---------------------------------------------------------------*)
PROCEDURE CHK_SEGSIZE(VAR CURSEG:TBLPTR; LIMIT:INTEGER);
  VAR SEG,SBR,SBRL:TBLPTR;
      CHKLENGTH,SUMSBR:INTEGER;

   (*-------------------------------------------------------*)
   (* INSERT_SBRBRK: INSERTS THE SBRBREAK NODE              *)
   (*-------------------------------------------------------*)
   PROCEDURE INSERT_SBRBRK(SBRNODE:TBLPTR);
     VAR INSERT,CUR,FWD:TBLPTR;
     BEGIN
       CUR:=SBRNODE;
       IF CUR@.SBR@.TAG <> SBRBREAK THEN
         BEGIN
           FWD:=CUR@.SBR;
           NEW(INSERT,SBRBREAK);
           INSERT@.TAG:=SBRBREAK;
           INSERT@.SBRZ:=CUR@.SBR;
           CUR@.SBR:=INSERT;
         END;
     END;                                  (* INSERT_SBRBRK *)
   (*-------------------------------------------------------*)
   BEGIN
     SEG:=CURSEG;
     WHILE SEG<>NIL DO
       BEGIN
         CHKLENGTH:=SEG@.LENGTH;
         IF SEG@.TABLELIST=NIL THEN
           CHKLENGTH:=CHKLENGTH-SBRCONTCONST;
         IF SEG@.SBRLIST<>NIL THEN
           BEGIN
             SBRL:=SEG@.SBRLIST;
             WHILE SBRL<>NIL DO
               BEGIN
                 SBR:=SBRL@.SBR;
                 CASE SBR@.TAG OF
                   TABLE:
                     BEGIN
                       IF(SBR@.COALESCED=FALSE)THEN
                            COALESCE(SBR,LIMIT,
                                 GOOD_SEGMENT,SBRINVNEST);
                       IF SBR@.TABLELIST<>NIL THEN
                         BEGIN
                           INSERT_SBRBRK(SBRL);
                         END;
                       SUMSBR:=0;
                       SBRSUMLINK(SBRL,SUMSBR);
                       CHKLENGTH:=CHKLENGTH+SUMSBR;
                       IF (CHKLENGTH>LIMIT) THEN
                         BEGIN
                           INSERT_SBRBRK(SBRL);
                           CHKLENGTH:=CHKLENGTH-SUMSBR;
                           RESET_INCLUDED(SEG@.SBRLIST);
                         END;
                     END;
                   SBRBREAK:
                 END;
                 SBRL:=SBRL@.NEXT_SBR;
               END;
           END;
```

```
        IF SEG@.SBRLIST<>NIL THEN
           RESET_INCLUDED(SEG@.SBRLIST);
        DIAGS_NESTISBRBRK(TEMPFILE,SEG,GOOD_SEGMENT);
        SEG:=SEG@.TABLELIST;
      END;
  END;                                              (* CHK_SEGSIZE *)
(*-----------------------------------------------------------------*)


(*-----------------------------------------------------------------*)
(* COMBINE:  TAKES THE CHECKED SEGTABLE AND COMBINES             *)
(*    IT INTO A MAXIMIZED COMBINATION OF SEGMENTS AND             *)
(*    SBR.  BASICALLY, IT MERGES THE ADJACENT SEGMENTS            *)
(*    IF THEY CAN BE MERGED.                                      *)
(*-----------------------------------------------------------------*)
PROCEDURE COMBINE(VAR CURSEG:TBLPTR; LIMIT:INTEGER);
  VAR SUMSBRF,SUMSBRC,SUMFWD,SUMCUR,SUMTOT:INTEGER;
      CUR,FWD:TBLPTR;
      DELSUMSBRZ,DELSUMFJMP:INTEGER;

  (*---------------------------------------------------------------*)
  (* MERGES: MERGES ADJACENT SEGMENTS TO INCLUDE THEIR*)
  (*    RESPECTIVE FJUMPLISTS AND SBRLISTS.  IT THEN    *)
  (*    USES CLEAN TO REMOVE ANY DUPLICATE JUMPS/SBRS   *)
  (*    USES CLEAN'S DELETE FACILITY TO READJUST LENGTH*)
  (*    THE LENGTH FOR THE SBRBREAK CODE IS NOT         *)
  (*    INCLUDED IN SEGMENT LENGTH, ROOM IS LEFT.       *)
  (*---------------------------------------------------------------*)
  PROCEDURE MERGES(VAR CUR,FWD:TBLPTR);
    VAR SBRTAIL,JMPTAIL:TBLPTR; DELETE:INTEGER;
    BEGIN
      IF FWD@.F_JUMPLIST<>NIL THEN
        IF CUR@.F_JUMPLIST<>NIL THEN
          BEGIN
            JMPTAIL:=CUR@.F_JUMPLIST;
            WHILE JMPTAIL@.NEXT_FJUMP<>NIL DO
              JMPTAIL:=JMPTAIL@.NEXT_FJUMP;
            JMPTAIL@.NEXT_FJUMP:=FWD@.F_JUMPLIST;
          END
        ELSE
          CUR@.F_JUMPLIST:=FWD@.F_JUMPLIST;
      IF FWD@.SBRLIST<>NIL THEN
        IF CUR@.SBRLIST<>NIL THEN
          BEGIN
            SBRTAIL:=CUR@.SBRLIST;
            WHILE SBRTAIL@.NEXT_SBR<>NIL DO
              SBRTAIL:=SBRTAIL@.NEXT_SBR;
            SBRTAIL@.NEXT_SBR:=FWD@.SBRLIST;
          END
        ELSE
          CUR@.SBRLIST:=FWD@.SBRLIST;
      CUR@.STOP_ADDR:=FWD@.STOP_ADDR;
      CUR@.TABLELIST:=FWD@.TABLELIST;
      CUR@.NEST:=0;
      DELETE:=0;
      CLEAN(CUR,DELETE);
      CUR@.LENGTH:=CUR@.LENGTH+FWD@.LENGTH-((DELETE+1)*
                                                  FJUMPCONST);
      DISPOSE(FWD,TABLE);
    END;                                            (* MERGES *)
  (*---------------------------------------------------------------*)
```

```
(*-----------------------------------------------------------------*)
(*  MOD_SUMTOTFJMP: SIMULATES THE COMBINE OF THE FJMP*)
(*    THIS IS A PREDICTION IF ADJACENT SEGMENTS WERE *)
(*    MERGED.                                         *)
(*-----------------------------------------------------------------*)
PROCEDURE MOD_SUMTOTFJMP(CUR,FWD:TBLPTR;
                              VAR DELSUMFJMP:INTEGER);
  VAR P,T:TBLPTR;   FCOUNT:INTEGER;
  BEGIN
    FCOUNT:=0;
    P:=CUR@.F_JUMPLIST;
    WHILE P<>NIL DO
      BEGIN
        IF P@.JUMP_ADDRTO<=FWD@.STOP_ADDR THEN
          FCOUNT:=FCOUNT+1;
        T:=FWD@.F_JUMPLIST;
        WHILE T<>NIL DO
          BEGIN
            IF P@.JUMP_ADDRTO = T@.JUMP_ADDRTO THEN
              FCOUNT:=FCOUNT+1;
            T:=T@.NEXT_FJUMP;
          END;
        P:=P@.NEXT_FJUMP;
      END;
    DELSUMFJMP:=(FCOUNT+1)*FJUMPCONST;
  END;                                  (* MOD_SUMTOTFJMP *)
(*-----------------------------------------------------------------*)


(*-----------------------------------------------------------------*)
(*  MOD_SUMTOTSBR: SIMULATES THE CHANGE TO TOTAL LEN *)
(*    BECAUSE OF THE MERGING OF ADJACENT SEGMENTS.   *)
(*-----------------------------------------------------------------*)
PROCEDURE MOD_SUMTOTSBR(CUR,FWD:TBLPTR;
                              VAR DELSUMSBRZ:INTEGER);
  VAR P,T,PP,TT:TBLPTR; SCOUNT:INTEGER;
  BEGIN
    SCOUNT:=0;
    P:=CUR@.SBRLIST;
    WHILE P<>NIL DO
      BEGIN
        T:=FWD@.SBRLIST;
        WHILE T<>NIL DO
          BEGIN
            PP:=P@.SBR;
            IF PP@.TAG = SBRBREAK THEN
              BEGIN
                TT:=T@.SBR;
                IF TT@.TAG = SBRBREAK THEN
                  IF PP@.SBRZ = TT@.SBRZ THEN
                    SCOUNT:=SCOUNT+1;
              END;
            T:=T@.NEXT_SBR;
          END;
        P:=P@.NEXT_SBR;
      END;
    DELSUMSBRZ:=SCOUNT*SBRCONST;
  END;                                  (* MOD_SUMTOTSBR *)
(*-----------------------------------------------------------------*)
BEGIN
  CUR:=CURSEG;
  DIAGS_NEST1LENGTHCHK(TEMPFILE,CUR,GOOD_SEGMENT);
  SUMTOT:=0;
  SUMSBRC:=0;
  IF CUR@.SBRLIST<>NIL THEN
    SBRSUM(CUR@.SBRLIST,SUMSBRC);
  SUMCUR:=CUR@.LENGTH+SUMSBRC;
  WHILE (CUR@.TABLELIST<>NIL) DO
```

```
        BEGIN
          FWD:=CUR@.TABLELIST;
          SUMSBRF:=0;
          IF FWD@.SBRLIST<>NIL THEN
            SBRSUM(FWD@.SBRLIST,SUMSBRF);
          SUMFWD:=FWD@.LENGTH+SUMSBRF;
          SUMTOT:=SUMCUR+SUMFWD;
          MOD_SUMTOTFJMP(CUR,FWD,DELSUMFJMP);
          MOD_SUMTOTSBR(CUR,FWD,DELSUMSBRZ);
          SUMTOT:=SUMTOT-DELSUMFJMP-DELSUMSBRZ;
          IF SUMTOT<=LIMIT THEN
            BEGIN
              MERGES(CUR,FWD);
              CUR@.LENGTH:=CUR@.LENGTH-DELSUMSBRZ;
              SUMCUR:=SUMTOT;
            END
          ELSE
            BEGIN
              RESET_INCLUDED(FWD@.SBRLIST);
              RESET_INCLUDED(CUR@.SBRLIST);
              CUR:=FWD;
              DIAGS_NEST1LENGTHCHK(TEMPFILE,CUR,
                                               GOOD_SEGMENT);
              SUMCUR:=CUR@.LENGTH;
              SUMSBRC:=0;
              SBRSUM(CUR@.SBRLIST,SUMSBRC);
              SUMCUR:=SUMCUR+SUMSBRC;
            END;
          SUMTOT:=0;
        END;
      IF CUR@.SBRLIST<>NIL THEN
        RESET_INCLUDED(CUR@.SBRLIST);  (*ALL INCLUDES RST*)
      CURSEG@.COALESCED:=TRUE;
    END;                                          (* COMBINE *)
  (*---------------------------------------------------------*)
  BEGIN
    CURSEG:=SBR;
    SBRINVNEST:=SBRINVNEST+1;
    DIAGS_NEST6SBRINVCHK(TEMPFILE,CURSEG,GOOD_SEGMENT,
                                         SBRINVNEST);
    CHK_SEGSIZE(CURSEG,LIMIT);
    COMBINE(CURSEG,LIMIT);
    SBRINVNEST:=SBRINVNEST-1;
  END;                                            (* COALESCE *)
(*===========================================================*)
```

```
(*===============================================================*)
(* INSTRUCTIONS: PRINTS OUT THE SEGMENTED CODE TOGETHER         *)
(*    WITH OTHER INFORMATION TO USE THE SEGMENTED CODE.          *)
(*    DOES THIS BY FIRST CHECKING THE SEGMENT TABLE AND          *)
(*    ASSIGNING A MEMORY MODULE NUMBER TO SPECIFIC LOCA-         *)
(*    TIONS IN THE TABLE WHERE SBR BREAKS OCCUR.  AN             *)
(*    IMPLIED ASSIGNMENT IS MADE TO THE FIRST SBR AS A           *)
(*    START POINT.  OTHERS ARE INCLUDED IF THERE IS A BRK*)
(*    LEADING TO IT.  ONCE MODULES ARE ASSIGNED THEN CODE*)
(*    WITH PROMPTS ADDED ARE COPIED FROM THE ORIGINALS.          *)
(*    THESE COPIES ARE THEN PRINTED OUT.                         *)
(*===============================================================*)
PROCEDURE INSTRUCTIONS(VAR OUTFILE,MESSAGEFILE,
                       TEMPFILE:TEXT; BUILT_CODE:CODEPTR;
                            SEGTBL:TBLPTR; PART_NUM:INTEGER;
                  PARTITION:REAL; GOOD_SEGMENT:BOOLEAN);
  VAR HEAD_MEMODULE:TBLPTR;

  (*-----------------------------------------------------------*)
  (* BLD_MEMODULNODES: BUILDS THE MEMODULES BASED ON THE*)
  (*    BREAKS ENCOUNTERED IN THE SEGTBL                         *)
  (*-----------------------------------------------------------*)
  PROCEDURE BLD_MEMODULENODES(SEGTBL:TBLPTR;
                  VAR HEAD_MEMODULE:TBLPTR);
    VAR TAIL_MEMODULE,SEG:TBLPTR;
        MEMCOUNT:INTEGER;

    (*-------------------------------------------------------*)
    (* INSERT_MEMODULENODES: INSERTS A MEMODULENODE INTO*)
    (*    THE MEMODULELIST.  IT MUST FIRST CHECK TO SEE      *)
    (*    THAT IT IS NOT ALREADY ACCOUNTED FOR AS THERE      *)
    (*    MAY BE MULTIPLE INVOKES OF THE SAME BREAK.         *)
    (*-------------------------------------------------------*)
    PROCEDURE INSERT_MEMODULENODES(SEGTBL:TBLPTR;
                  VAR HEAD_MEMODULE,TAIL_MEMODULE:TBLPTR;
                  VAR MEMCOUNT:INTEGER);
      VAR INSERT:TBLPTR;

      (*---------------------------------------------------*)
      (* NOT_IN_MODULELIST: CHECKS TO SEE IF IN LIST     *)
      (*---------------------------------------------------*)
      FUNCTION NOT_IN_MODULELIST(SEGTBL,HEAD_MEMODULE
                                                 :TBLPTR):
                                                 BOOLEAN;
        VAR S:TBLPTR;
        BEGIN
          S:=HEAD_MEMODULE;
          NOT_IN_MODULELIST:=TRUE;
          IF S<>NIL THEN
            BEGIN
              WHILE S<>NIL DO
                BEGIN
                  IF S@.SEGTBLS = SEGTBL THEN
                    NOT_IN_MODULELIST:=FALSE;
                  S:=S@.NEXT;
                END;
            END;
        END;                          (* NOT_IN_MODULELIST *)
      (*---------------------------------------------------*)
      BEGIN
        IF NOT_IN_MODULELIST(SEGTBL,HEAD_MEMODULE) THEN
          BEGIN
            NEW(INSERT,MEMODULE);
            INSERT@.TAG:=MEMODULE;
            INSERT@.MEMNUM:=MEMCOUNT;
            MEMCOUNT:=MEMCOUNT+1;
            INSERT@.OFFSET:=-SEGTBL@.START_ADDR;
            INSERT@.HIGHOFFSET:=-(SEGTBL@.START_ADDR DIV
                                                    100);
```

```
        INSERT@.LOWOFFSET:=-(SEGTBL@.START_ADDR
                                    100*INSERT@.HIGHOFFSET);
        INSERT@.RETURNCODE_NEEDED:=FALSE;
        INSERT@.CODELIST:=NIL;
        INSERT@.SEGTBLS:=SEGTBL;
        INSERT@.NEXT:=NIL;
        IF HEAD_MEMODULE = NIL THEN
          HEAD_MEMODULE:=INSERT;
        IF TAIL_MEMODULE <> NIL THEN
          TAIL_MEMODULE@.NEXT:=INSERT;
        TAIL_MEMODULE:=INSERT;
      END;
  END;                          (* INSERT_MEMODULENODES *)
(*----------------------------------------------------------*)


(*----------------------------------------------------------*)
(* RECURSE_BLD_MEMODULENODES: IS THE RECURSIVE PART        *)
(*    OF THE BLD MEMNODE ROUTINE.  GOES WITHIN THE         *)
(*    THE SBRFIRST THEN DOWN THE SBRLIST.                  *)
(*    RECURSION IS USED TO TRAVERSE THE SEGTBL.            *)
(*----------------------------------------------------------*)
PROCEDURE RECURSE_BLD_MEMNODES(SEG:TBLPTR;
             VAR HEAD_MEMODULE,TAIL_MEMODULE:TBLPTR;
                            VAR MEMCOUNT:INTEGER);
  VAR SEG_SBR,SBR,SBRL:TBLPTR;
  BEGIN
    SEG_SBR:=SEG@.TABLELIST;
    WHILE SEG_SBR<>NIL DO
      BEGIN
        INSERT_MEMODULENODES(SEG_SBR,HEAD_MEMODULE,
                             TAIL_MEMODULE,MEMCOUNT);
        SEG_SBR:=SEG_SBR@.TABLELIST;
      END;
    SEG_SBR:=SEG;
    WHILE SEG_SBR<>NIL DO
      BEGIN
        IF SEG_SBR@.SBRLIST<>NIL THEN
          BEGIN
            SBRL:=SEG_SBR@.SBRLIST;
            WHILE SBRL<>NIL DO
              BEGIN
                SBR:=SBRL@.SBR;
                IF SBR@.TAG = SBRBREAK THEN
                  INSERT_MEMODULENODES(SBR@.SBRZ,
                HEAD_MEMODULE,TAIL_MEMODULE,MEMCOUNT);
                IF SBR@.TAG = SBRBREAK THEN
                  SBR:=SBR@.SBRZ;
                RECURSE_BLD_MEMNODES(SBR,
                  HEAD_MEMODULE,TAIL_MEMODULE,
                                          MEMCOUNT);
                SBRL:=SBRL@.NEXT_SBR;
              END;
          END;
        SEG_SBR:=SEG_SBR@.TABLELIST;
      END;
  END;                     (* RECURSE_BLD_MEMODULENODES *)
(*----------------------------------------------------------*)
BEGIN
  HEAD_MEMODULE:=NIL;
  TAIL_MEMODULE:=NIL;
  MEMCOUNT:=1;
  SEG:=SEGTBL;
  INSERT_MEMODULENODES(SEG,HEAD_MEMODULE,
                             TAIL_MEMODULE,MEMCOUNT);
  RECURSE_BLD_MEMNODES(SEG,HEAD_MEMODULE,
                             TAIL_MEMODULE,MEMCOUNT);
END;                               (* BLD_MEMODULENODES *)
(*----------------------------------------------------------*)
```

```
{*---------------------------------------------------------*}
{* BLD_MEMODULECODE: THIS ROUTINE BUILDS THE CODE FOR      *}
{*   THE MEMORY MODULE CODELISTS. IT WILL JUSTIFY ALL      *}
{*   THE ADDRESSES AND ADD BREAK CODE.                     *}
{*---------------------------------------------------------*}
PROCEDURE BLD_MEMODULECODE(BUILT_CODE:CODEPTR;
                           VAR HEAD_MEMODULE:TBLPTR);
  VAR CURMEM:TBLPTR;

  {*------------------------------------------------------*}
  {* BLD_A_MEMORY: THIS ROUTINE INITIALIZES THE           *}
  {*   RECURSIVE PROCESS THAT WILL BE DONE IN THE         *}
  {*   FORM_MEMORY ROUTINE.                               *}
  {*------------------------------------------------------*}
  PROCEDURE BLD_A_MEMORY(BUILT_CODE:CODEPTR;
                         VAR HEAD_MEMODULE:TBLPTR;
                                    CURMEM:TBLPTR);
    VAR ADDRESSS:INTEGER;
        CODE_H,CODE_T:TBLPTR;
        SEG:TBLPTR;

    {*---------------------------------------------------*}
    {* FORM_MEMORY: BUILDS A COMPLETE MEMORY MODULE      *}
    {*   CODE COMPLETE WITH BREAK CODE AND JUSTIFY.      *}
    {*   ROUTINE RECURSES ON EACH SBR ON THE SBRLISTS    *}
    {*---------------------------------------------------*}
    PROCEDURE FORM_MEMORY(BUILT_CODE:CODEPTR;
             VAR HEAD_MEMODULE,CURMEM,SEG,CODE_H,
                                     CODE_T:TBLPTR;
                           VAR ADDRESSS:INTEGER);
      VAR CODE_HH,CODE_TT,SBR,SBRL:TBLPTR;
      {*-------------------------------------------------*}
      {* PROCESS_SEG: TAKES CARE OF ONE SEGMENT IN THE*}
      {*    SEGMENT TABLE'S WORTH OF CODE.              *}
      {*-------------------------------------------------*}
      PROCEDURE PROCESS_SEG(BUILT_CODE:CODEPTR;
                                VAR HEAD_MEMODULE,
                          CURMEM:TBLPTR; SEG:TBLPTR;
                         VAR CODE_HH,CODE_TT:TBLPTR;
                              VAR ADDRESSS:INTEGER);
        VAR START,STOP:INTEGER;

        {*---------------------------------------------*}
        {* COPY_CODE: COPIES CODE FROM A START TO A    *}
        {*    STOP POINT OF THE BUILT_CODE             *}
        {*---------------------------------------------*}
        PROCEDURE COPYCODE(BUILT_CODE:CODEPTR;
                       VAR CODE_HH,CODE_TT:TBLPTR;
                              VAR ADDRESSS:INTEGER;
                                START,STOP:INTEGER);
          VAR INSERT,CURTP:TBLPTR;
              CURCP:CODEPTR;
          BEGIN
            CURCP:=BUILT_CODE;
            WHILE CURCP@.AADDR<>START DO
              CURCP:=CURCP@.SEQ;
            NEW(INSERT,CODE);
            INSERT@.TAG:=CODE;
            INSERT@.ABS_ADDR:=CURCP@.AADDR;
            INSERT@.ADDRESS:=ADDRESSS;
            ADDRESSS:=ADDRESSS+1;
            INSERT@.KEYCODE:=CURCP@.KEY;
            INSERT@.SEQUENTIAL:=NIL;
            CODE_HH:=INSERT;
            CODE_TT:=INSERT;
            REPEAT
              NEW(INSERT,CODE);
              CURCP:=CURCP@.SEQ;
              INSERT@.TAG:=CODE;
```

```
      INSERT@.ABS_ADDR:=CURCP@.AADDR;
      INSERT@.ADDRESS:=ADDRESSS;
      ADDRESSS:=ADDRESSS+1;
      INSERT@.KEYCODE:=CURCP@.KEY;
      CODE_TT@.SEQUENTIAL:=INSERT;
      CODE_TT:=INSERT;
    UNTIL (CURCP@.AADDR = STOP);
    CODE_TT@.SEQUENTIAL:=NIL;
  END;                                   (* COPYCODE *)
(*----------------------------------------------------*)


(*----------------------------------------------------*)
(* ADD_RETURNCODE: ADDS SBR RETURN CODE TO THE*)
(*   TAIL SEGMENT OF THE INVOKED SBR              *)
(*----------------------------------------------------*)
PROCEDURE ADD_RETURNCODE(VAR CODE_TT:TBLPTR;
                         VAR ADDRESSS:INTEGER);
  VAR INSERT:TBLPTR;
  BEGIN
    CODE_TT@.KEYCODE:=STO;   (*INVSBR CHG 2 STO*)
    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=DISPLAYREGSTORE; (*DISPLAY*)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=RCLIND;          (* RCL IND *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=MANRTNREG; (* MAN RTN REG *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=OP;                    (* OP *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=30+MANRTNREG;(*+MANRTNREG*)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=RS;              (* RUN/STOP *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;
```

```
    CODE_TT@.SEQUENTIAL:=NIL;
  END;                              (* ADD_RETURNCODE *)
(*-----------------------------------------------*)


(*-----------------------------------------------*)
(* ADDCODE_SBRBRK_MARKINVOKED: ADDS CODE FOR A*)
(*   SBRBRK AND WILL MARK THE INVOKED RTN FOR *)
(*   MANUAL RETURN CODE                         *)
(*-----------------------------------------------*)
PROCEDURE ADDCODE_SBRBRK_MARKINVOKED
                (VAR HEAD_MEMODULE,CURMEM:TBLPTR;
                  SEG:TBLPTR; VAR CODE_TT:TBLPTR;
                              VAR ADDRESSS:INTEGER);
  VAR INSERT,SBR,SBRL:TBLPTR;
      LBLADDR:INTEGER;

  (*-------------------------------------------*)
  (* FIND_LBL: FINDS THE LABEL FROM A GIVEN    *)
  (*   ADDRESS USING THE BUILT_CODE LIST       *)
  (*-------------------------------------------*)
  FUNCTION FIND_LBL(BUILT_CODE:CODEPTR;
                    ADDRESS:INTEGER):INTEGER;
    VAR C:CODEPTR;
    BEGIN
      C:=BUILT_CODE;
      WHILE C@.AADDR<>ADDRESS DO
        C:=C@.SEQ;
      FIND_LBL:=C@.SEQ@.KEY;
    END;                              (* FIND_LBL *)
  (*-------------------------------------------*)


  (*-------------------------------------------*)
  (* GENCODESBR: ADDS CODE FOR A BRK SBR INVOK*)
  (*-------------------------------------------*)
  PROCEDURE GENCODESBR(VAR CODE_TT:TBLPTR;
              HEAD_MEMODULE,CURMEM,SBR:TBLPTR;
                          VAR ADDRESSS:INTEGER);
    VAR RELADDR,HUNDREDS,TENS,UNITS:INTEGER;
        MEMPTR:TBLPTR;
    BEGIN
      MEMPTR:=HEAD_MEMODULE;
      WHILE(MEMPTR@.SEGTBLS<>SBR@.SBRZ) DO
        MEMPTR:=MEMPTR@.NEXT;
      RELADDR:=SBR@.SBRZ@.START_ADDR+MEMPTR@.
                                         OFFSET;
      HUNDREDS:=RELADDR DIV 100;
      TENS:=(RELADDR-(HUNDREDS*100)) DIV 10;
      UNITS:=RELADDR-(HUNDREDS*100+TENS*10);
      NEW(INSERT,CODE);
      INSERT@.TAG:=CODE;
      INSERT@.ADDRESS:=ADDRESSS;
      ADDRESSS:=ADDRESSS+1;
      INSERT@.KEYCODE:=LBL;              (* LBL *)
      IF CODE_TT <> NIL THEN
        CODE_TT@.SEQUENTIAL:=INSERT;
      CODE_TT:=INSERT;

      NEW(INSERT,CODE);
      INSERT@.TAG:=CODE;
      INSERT@.ADDRESS:=ADDRESSS;
      ADDRESSS:=ADDRESSS+1;
      INSERT@.KEYCODE:=FIND_LBL      (* KEY LBL *)
              (BUILT_CODE,SBR@.SBRZ@.START_ADDR);
      CODE_TT@.SEQUENTIAL:=INSERT;
      CODE_TT:=INSERT;
```

```
NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=STO;                (* STORE *)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=DISPLAYREGSTORE;  (*DISP*)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=OP;                  (* OP *)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=20+MANRTNREG;    (* INCR *)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=CURMEM@.MEMNUM; (* MEM# *)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=STOIND;        (* IND STO *)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=MANRTNREG;     (* MAN RTN *)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
INSERT@.KEYCODE:=MEMPTR@.MEMNUM; (* MEM #*)
CODE_TT@.SEQUENTIAL:=INSERT;
CODE_TT:=INSERT;

NEW(INSERT,CODE);
INSERT@.TAG:=CODE;
INSERT@.ADDRESS:=ADDRESSS;
ADDRESSS:=ADDRESSS+1;
```

```
        INSERT@.KEYCODE:=DECIMAL;                     (* . *)
        CODE_TT@.SEQUENTIAL:=INSERT;
        CODE_TT:=INSERT;

        NEW(INSERT,CODE);
        INSERT@.TAG:=CODE;
        INSERT@.ADDRESS:=ADDRESSS;
        ADDRESSS:=ADDRESSS+1;
        INSERT@.KEYCODE:=HUNDREDS;   (* HUNDREDS *)
        CODE_TT@.SEQUENTIAL:=INSERT;
        CODE_TT:=INSERT;

        NEW(INSERT,CODE);
        INSERT@.TAG:=CODE;
        INSERT@.ADDRESS:=ADDRESSS;
        ADDRESSS:=ADDRESSS+1;
        INSERT@.KEYCODE:=TENS;                     (* TENS *)
        CODE_TT@.SEQUENTIAL:=INSERT;
        CODE_TT:=INSERT;

        NEW(INSERT,CODE);
        INSERT@.TAG:=CODE;
        INSERT@.ADDRESS:=ADDRESSS;
        ADDRESSS:=ADDRESSS+1;
        INSERT@.KEYCODE:=UNITS;                   (* UNITS *)
        CODE_TT@.SEQUENTIAL:=INSERT;
        CODE_TT:=INSERT;

        NEW(INSERT,CODE);
        INSERT@.TAG:=CODE;
        INSERT@.ADDRESS:=ADDRESSS;
        ADDRESSS:=ADDRESSS+1;
        INSERT@.KEYCODE:=RS;                        (* R/S *)
        INSERT@.SEQUENTIAL:=NIL;
        CODE_TT@.SEQUENTIAL:=INSERT;
        CODE_TT:=INSERT;
    END;                                  (* GENCODE_SBR *)
  (*-----------------------------------------------------*)
  BEGIN
    IF SEG@.SBRLIST<>NIL THEN
      BEGIN
        SBRL:=SEG@.SBRLIST;
        WHILE SBRL<>NIL DO
          BEGIN
            SBR:=SBRL@.SBR;
            IF SBR@.TAG=SBRBREAK THEN
              GENCODESBR(CODE_TT,HEAD_MEMODULE,
                               CURMEM,SBR,ADDRESSS);
            SBRL:=SBRL@.NEXT_SBR;
          END;
      END;
  END;                (* ADDCODE_SBRBRK_MARKINVOKED *)
(*-------------------------------------------------------*)
```

```
(*-------------------------------------------*)
(* JUSTIFY_CODE: SETS ALL THE JUMPS AND ADDRS *)
(*-------------------------------------------*)
PROCEDURE JUSTIFY_CODE(SEG,CURMEM:TBLPTR;
                             VAR CODE_HH:TBLPTR);
  VAR T,F,JMPTR:TBLPTR;
      DELADDR,RELADDR,ABSADDR:INTEGER;

  (*----------------------------------------*)
  (* ADVANCE_CODETBL: ADVANCES THE CODEPTRS  *)
  (*    OF THE 1, 2, AND 3-STEP INSTRUCTIONS. *)
  (*----------------------------------------*)
  PROCEDURE ADVANCE_CODETBL(VAR F:TBLPTR);
    BEGIN
      IF F@.KEYCODE IN STEP_3 THEN
        F:=F@.SEQUENTIAL@.SEQUENTIAL@.SEQUENTIAL
                                   @.SEQUENTIAL
      ELSE
        IF F@.KEYCODE IN STEP_2 THEN
          F:=F@.SEQUENTIAL@.SEQUENTIAL@.
                                     SEQUENTIAL
        ELSE
          IF F@.KEYCODE IN (STEP_1+(.71,76.))
            THEN F:=F@.SEQUENTIAL@.SEQUENTIAL
          ELSE
            F:=F@.SEQUENTIAL;
    END;                   (* ADVANCE_CODETBL *)
  (*----------------------------------------*)
  BEGIN
    F:=CODE_HH;
    WHILE F<>NIL DO
      BEGIN
        IF F@.KEYCODE IN (STEP_3+STEP_2) THEN
          BEGIN
            IF F@.KEYCODE IN STEP_3 THEN
              T:=F@.SEQUENTIAL@.SEQUENTIAL
            ELSE
              T:=F@.SEQUENTIAL;
            ABSADDR:=T@.KEYCODE*100;
            ABSADDR:=ABSADDR
                    +T@.SEQUENTIAL@.KEYCODE;
            IF SEG@.STOP_ADDR >= ABSADDR THEN
              BEGIN
                DELADDR:=ABSADDR-T@.ABS_ADDR;
                RELADDR:=T@.ADDRESS+DELADDR;
                T@.KEYCODE:=RELADDR DIV 100;
                T@.SEQUENTIAL@.KEYCODE:=
                     RELADDR-(100*T@.KEYCODE);
              END
            ELSE
              BEGIN
                JMPTR:=SEG@.F_JUMPLIST;
                WHILE JMPTR@.JUMP_ADDRTO<>
                                   ABSADDR DO
                  JMPTR:=JMPTR@.NEXT_FJUMP;
                T@.KEYCODE:=JMPTR@.
                            JUMP_INTADDRTC1;
                T@.SEQUENTIAL@.KEYCODE:=JMPTR@.
                            JUMP_INTADDRTC2;
              END;
          END;
        ADVANCE_CODETBL(F);
    END;
  END;                           (* JUSTIFY *)
(*-------------------------------------------*)
```

```
(*-----------------------------------------------*)
(* ADDCODE_FJMP: ADDS CODE FOR JUMP BREAK        *)
(*-----------------------------------------------*)
PROCEDURE ADDCODE_FJMP(VAR HEAD_MEMODULE,CURMEM,
                           SEG,CODE_TT:TBLPTR;
                       VAR ADDRESSS:INTEGER);
 VAR CUR,INSERT,JUMPTR,MEMPTR:TBLPTR;
     ADDDRTO1,ADDDRTO2,MEM_ADDDRTO:INTEGER;
                       DELTA_ADDRESS:INTEGER;

  (*---------------------------------------------*)
  (* GEN_JUMPCODE_SETINTADDRS: GENERATES THE     *)
  (*    JUMP CODE AND SETS THE INTADDR FIELDS    *)
  (*    OF THE SEGMENT TABLE F JUMPLIST.         *)
  (*    INTADDR ARE THE ADDRESSES LOCAL TO THAT*)
  (*    SPECIFIC PIECE OF CODE (THE PROMPT).     *)
  (*---------------------------------------------*)
  PROCEDURE GEN_JUMPCODE_SETINTADDRS
   (VAR CODE_TT:TBLPTR; VAR ADDDRESS:INTEGER;
                        VAR JUMPTR:TBLPTR);
   VAR INSERT:TBLPTR;
       HUNDREDS,TENS,UNITS,RELADDRESS:INTEGER;
   BEGIN
     HUNDREDS:=JUMPTR@.JUMP_ADDRTO1;
     TENS:=JUMPTR@.JUMP_ADDRTO2 DIV 10;
     UNITS:=JUMPTR@.JUMP_ADDRTO2-(10*TENS);

     NEW(INSERT,CODE);
     INSERT@.TAG:=CODE;
     INSERT@.ADDRESS:=ADDRESSS;
     RELADDRESS:=ADDRESSS;
     ADDRESSS:=ADDRESSS+1;
     INSERT@.KEYCODE:=STO;                    (* STO *)
     IF CODE_TT<>NIL THEN
       CODE_TT@.SEQUENTIAL:=INSERT;
     CODE_TT:=INSERT;

     NEW(INSERT,CODE);
     INSERT@.TAG:=CODE;
     INSERT@.ADDRESS:=ADDRESSS;
     ADDRESSS:=ADDRESSS+1;
     INSERT@.KEYCODE:= DISPLAYREGSTORE; (*DISP*)
     CODE_TT@.SEQUENTIAL:=INSERT;
     CODE_TT:=INSERT;

     NEW(INSERT,CODE);
     INSERT@.TAG:=CODE;
     INSERT@.ADDRESS:=ADDRESSS;
     ADDRESSS:=ADDRESSS+1;
     INSERT@.KEYCODE:=CE;                      (* CE *)
     CODE_TT@.SEQUENTIAL:=INSERT;
     CODE_TT:=INSERT;

     NEW(INSERT,CODE);
     INSERT@.TAG:=CODE;
     INSERT@.ADDRESS:=ADDRESSS;
     ADDRESSS:=ADDRESSS+1;
     INSERT@.KEYCODE:= JUMPTR@.MEM_ADDR;
     CODE_TT@.SEQUENTIAL:=INSERT;
     CODE_TT:=INSERT;

     NEW(INSERT,CODE);
     INSERT@.TAG:=CODE;
     INSERT@.ADDRESS:=ADDRESSS;
     ADDRESSS:=ADDRESSS+1;
     INSERT@.KEYCODE:= DECIMAL;                  (*.*)
     CODE_TT@.SEQUENTIAL:=INSERT;
     CODE_TT:=INSERT;
```

```
    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=HUNDREDS;          (* 100S *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:= TENS;             (* 10S *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=UNITS;             (* 1S *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;

    NEW(INSERT,CODE);
    INSERT@.TAG:=CODE;
    INSERT@.ADDRESS:=ADDRESSS;
    ADDRESSS:=ADDRESSS+1;
    INSERT@.KEYCODE:=RS;                (* R/S *)
    CODE_TT@.SEQUENTIAL:=INSERT;
    CODE_TT:=INSERT;
    CODE_TT@.SEQUENTIAL:=NIL;
    JUMPTR@.JUMP_INTADDRTO1:=RELADDRESS
                                   DIV 100;
    JUMPTR@.JUMP_INTADDRTO2:=RELADDRESS- 100*
                       JUMPTR@.JUMP_INTADDRTO1;
  END;             (* GEN_JUMPCODE_SETINTADDR *)
(*-----------------------------------------*)
BEGIN
  IF SEG@.TABLELIST<>NIL THEN
    BEGIN
      MEMPTR:=HEAD_MEMODULE;
      WHILE NOT(SEG@.STOP_ADDR+1 = MEMPTR@.
                   SEGTBLS@.START_ADDR) DO
        MEMPTR:=MEMPTR@.NEXT;
      ADDDRTO1:=MEMPTR@.SEGTBLS@.START_ADDR
                                   DIV 100;
      ADDDRTO2:=MEMPTR@.SEGTBLS@.START_ADDR
                             - (100*ADDDRTO1);
      ADDDRTO1:=ADDDRTO1+MEMPTR@.HIGHOFFSET;
      ADDDRTO2:=ADDDRTO2+MEMPTR@.LOWOFFSET;
      MEM_ADDDRTO:=MEMPTR@.MEMNUM;
      NEW(JUMPTR,FWD_JUMP);
      WITH JUMPTR@ DO
        BEGIN
          JUMP_ADDRTO1:=ADDDRTO1;
          JUMP_ADDRTO2:=ADDDRTO2;
          MEM_ADDR:=MEM_ADDDRTO;
        END;
      GEN_JUMPCODE_SETINTADDR
                   (CODE_TT,ADDRESSS,JUMPTR);
      DISPOSE(JUMPTR,FWD_JUMP);
    END;
  IF SEG@.F_JUMPLIST<>NIL THEN
    BEGIN
      JUMPTR:=SEG@.F_JUMPLIST;
      WHILE JUMPTR<>NIL DO
        BEGIN
          MEMPTR:=HEAD_MEMODULE;
```

```
            WHILE NOT((JUMPTR@.JUMP_ADDRTO >=
                 MEMPTR@.SEGTBLS@.START_ADDR) AND
                        (JUMPTR@.JUMP_ADDRTO<=
                 MEMPTR@.SEGTBLS@.STOP_ADDR)) DO
               MEMPTR:=MEMPTR@.NEXT;

            DELTA_ADDRESS:=JUMPTR@.JUMP_ADDRTO-
                      MEMPTR@.SEGTBLS@.START_ADDR;
            ADDDRTO1:=DELTA_ADDRESS DIV 100;
            ADDDRTO2:=DELTA_ADDRESS-100*
                                        ADDDRTO1;
            MEM_ADDDRTO:=MEMPTR@.MEMNUM;
            JUMPTR@.JUMP_ADDRTO1:=ADDDRTO1;
            JUMPTR@.JUMP_ADDRTO2:=ADDDRTO2;
            JUMPTR@.MEM_ADDR:=MEM_ADDDRTO;
            GEN_JUMPCODE_SETINTADDRS
               (CODE_TT,ADDRESSS,JUMPTR);
            JUMPTR:=JUMPTR@.NEXT_FJUMP;
          END;
      END;
   END;                              (* ADDCODE_FJMP *)
(*--------------------------------------------------*)
BEGIN
   START:=SEG@.START_ADDR;
   STOP:=SEG@.STOP_ADDR;
   COPYCODE(BUILT_CODE,CODE_HH,CODE_TT,
                      ADDRESSS,START,STOP);
   IF (CURMEM@.RETURNCODE_NEEDED) AND
                    (SEG=CURMEM@.SEGTBLS) THEN
      ADD_RETURNCODE(CODE_TT,ADDRESSS);
   ADDCODE_FJMP(HEAD_MEMODULE,CURMEM,SEG,CODE_TT,
                                      ADDRESSS);
   ADDCODE_SBRBRK_MARKINVOKED(HEAD_MEMODULE,
                   CURMEM,SEG,CODE_TT,ADDRESSS);
   JUSTIFY_CODE(SEG,CURMEM,CODE_HH);
END;                               (* PROCESS_SEG *)
(*--------------------------------------------------*)
```

```
{*-----------------------------------------------------*}
{* MARKINVCKED: MARKS MEMODULE OF SBR WHICH WAS      *}
{*    INVOLVED IN A BREAK FOR A MANUAL RETURN.       *}
{*    ADD_RETRUNCODE USES THIS MARK TO ADD CODE.     *}
{*-----------------------------------------------------*}
PROCEDURE MARKINVOKED(VAR HEAD_MEMODULE:TBLPTR;
                                        SBR:TBLPTR);
  VAR MEMPTR, SBR_BRKINCLUDE:TBLPTR;
  BEGIN
    SBR_BRKINCLUDE:=SBR@.SBRZ;
    MEMPTR:=HEAD_MEMODULE;
    WHILE SBR_BRKINCLUDE@.TABLELIST<>NIL DO
       SBR_BRKINCLUDE:=SBR_BRKINCLUDE@.TABLELIST;
    WHILE MEMPTR@.SEGTBLS<>SBR_BRKINCLUDE DO
       MEMPTR:=MEMPTR@.NEXT;
    MEMPTR@.RETURNCODE_NEEDED:=TRUE;
  END;                                (* MARKINVOKED *)
{*-----------------------------------------------------*}
BEGIN
  IF (SEG@.INCLUDED = FALSE) THEN
    BEGIN
      PROCESS_SEG (BUILT_CODE,HEAD_MEMODULE,CURMEM,
                 SEG,CODE_HH,CODE_TT,ADDRESSS);
      IF CODE_H=NIL THEN
        CODE_H:=CODE_HH;
      IF CODE_T<>NIL THEN
          CODE_T@.SEQUENTIAL:=CODE_HH;
      SEG@.INCLUDED:=TRUE;
      CODE_T:=CODE_TT;
      IF (SEG@.SBRLIST<>NIL) THEN
        BEGIN
          SBRL:=SEG@.SBRLIST;
          WHILE SBRL<>NIL DO
            BEGIN
              SBR:=SBRL@.SBR;
              CASE SBR@.TAG OF
                SBRBREAK:
                  MARKINVOKED(HEAD_MEMODULE,SBR);
                TABLE:
                  FORM_MEMORY(BUILT_CODE,
                  HEAD_MEMODULE,CURMEM,SBR,CODE_H,
                                  CODE_T,ADDRESSS);
              END; (* CASE *)
              SBRL:=SBRL@.NEXT_SBR;
            END;
        END;
    END;
  END;                                (* FORM_MEMORY *)
{*-----------------------------------------------------*}
BEGIN
  SEG:=CURMEM@.SEGTBLS;
  ADDRESSS:=0;  CODE_H:=NIL;  CODE_T:=NIL;
  FORM_MEMORY(BUILT_CODE,HEAD_MEMODULE,CURMEM,SEG,
                         CODE_H,CODE_T,ADDRESSS);
  CURMEM@.CODELIST:=CODE_H;
END;                                  (* BLD_A_MEMORY *)
{*-----------------------------------------------------*}
BEGIN
  CURMEM:=HEAD_MEMODULE;
  WHILE CURMEM<>NIL DO
    BEGIN
      BLD_A_MEMORY(BUILT_CODE,HEAD_MEMODULE,CURMEM);
      CURMEM@.SEGTBLS@.INCLUDED:=FALSE;
      IF CURMEM@.SEGTBLS@.SBRLIST<>NIL THEN
        RESET_INCLUDED(CURMEM@.SEGTBLS@.SBRLIST);
      CURMEM:=CURMEM@.NEXT;
    END;
END;                                  (* BLD_MEMODULECODE *)
(*-----------------------------------------------------*)
```

```
(*----------------------------------------------------------*)
PROCEDURE OUTPUT_INSTR(VAR OUTFILE,MESSAGEFILE,
                  TEMPFILE:TEXT; BUILT_CODE:CODEPTR;
            HEAD_MEMODULE:TBLPTR; PART_NUM:INTEGER;
                                  PARTITION:REAL;
                        GOOD_SEGMENT:BOOLEAN);

  (*------------------------------------------------------*)
  (* OUTPUT_GOODSEGS: PRINTS OUT GOOD SEGMENT INSTRUC *)
  (*------------------------------------------------------*)
  PROCEDURE OUTPUT_GOODSEG(VAR OUTFILE,MESSAGEFILE:
          TEXT; HEAD_MEMODULE:TBLPTR; PART_NUM:INTEGER;
                                   PARTITION:REAL);

    (*--------------------------------------------------*)
    (* OUTPUT_MSGF1: PRINTS OUT GOOD SEGMENT GENERAL   *)
    (*   INSTRUCTIONS AND THE PROGRAM LISTING BY MEM   *)
    (*   MODULES.                                      *)
    (*--------------------------------------------------*)
    PROCEDURE OUTPUT_MSGF1(VAR OUTFILE,MESSAGEFILE:TEXT;
              HEAD_MEMODULE:TBLPTR; PARTNUM:INTEGER;
                                   PARTITION:REAL);
      VAR P,T:TBLPTR;
          STEP_TYPE:INTEGER;

      (*----------------------------------------------*)
      (* SET_STEP: SETS THE KEY CODE COUNTER FOR THE  *)
      (*   PRINTLINE PROCEDURE.  USED FOR CORRECT OUT-*)
      (*   PUT OF THE TI-59 CODE  (3,2,1,0 STEP INSTR) *)
      (*                                              *)
      (*   3 STEP       2 STEP      71&76    1     0  *)
      (*   AAA          AAA         AAA     AAA   AAA *)
      (*     X          XXX         AAA     XX   (.1.) *)
      (*   XXX          XXX      (.5,4.)/(.3,2.)   .  *)
      (*   XXX       (.8,7,6.)                     .  *)
      (*  (.12,11,10,9.)                       &(.0.)*)
      (*----------------------------------------------*)
      PROCEDURE SET_STEP(T:TBLPTR;
                          VAR STEP_TYPE:INTEGER);
        BEGIN
          IF STEP_TYPE IN (.0,1,3,5,8.) THEN
            IF T@.KEYCODE IN STEP_3 THEN
              STEP_TYPE:=12
            ELSE
              IF T@.KEYCODE IN STEP_2 THEN
                STEP_TYPE:=8
              ELSE
                IF T@.KEYCODE IN STEP_1 THEN
                  STEP_TYPE:=3
                ELSE
                  IF T@.KEYCODE IN (.71,76.) THEN
                    STEP_TYPE:=5
                  ELSE
                    STEP_TYPE:=1;
        END;                              (* SET_STEP *)
      (*----------------------------------------------*)
```

```
(*-----------------------------------------------*)
(* PRINT_LINE: PRINTS OUT ONE LINE OF CODE AT A *)
(*    TIME.                                      *)
(*-----------------------------------------------*)
PROCEDURE PRINT_LINE(VAR OUTFILE:TEXT; VAR T:
                    TBLPTR; VAR STEP_TYPE:INTEGER);

  (*---------------------------------------------*)
  (* WRITELBLS: WRITES TBLPTR LBLS IN WHOLE KEY  *)
  (*    CODE FORMAT IE.   NNN NN    AAA          *)
  (*---------------------------------------------*)
  PROCEDURE WRITELBLS(VAR OUTFILE:TEXT; T:TBLPTR);
    BEGIN
      WRITE(OUTFILE,'          ');
      WRITE_LEADZERO(OUTFILE,T@.ADDRESS,3);
      WRITE(OUTFILE,'   ');
      WRITE_LEADZERO(OUTFILE,T@.KEYCODE,2);
      WRITE(OUTFILE,'          ');
      WRITELBL(OUTFILE,T@.KEYCODE);
    END;                               (* WRITELBLS *)
  (*---------------------------------------------*)


  (*---------------------------------------------*)
  (* WRITENUMS: WRITES OUT A LINE OF DIGITS OF   *)
  (*   TI-59 CODE  (KEYCODES ARE DIGITS NOT LBLS) *)
  (*---------------------------------------------*)
  PROCEDURE WRITENUMS(VAR OUTFILE:TEXT; T:TBLPTR);
    BEGIN
      WRITE(OUTFILE,'          ');
      WRITE_LEADZERO(OUTFILE,T@.ADDRESS,3);
      WRITE(OUTFILE,'   ');
      WRITE_LEADZERO(OUTFILE,T@.KEYCODE,2);
      WRITE(OUTFILE,'          ');
      WRITE_LEADZERO(OUTFILE,T@.KEYCODE,2);
      WRITELN(OUTFILE);
    END;                               (* WRITENUMS *)
  (*---------------------------------------------*)
  BEGIN
    IF STEP_TYPE IN (.1,3,4,5,8,12.) THEN
      WRITELBLS(OUTFILE,T)
    ELSE
      WRITENUMS(OUTFILE,T);
    T:=T@.SEQUENTIAL;
    STEP_TYPE:=STEP_TYPE-1;
  END;                                (* PRINT_LINE *)
(*-----------------------------------------------*)
BEGIN
  PRINTLN_MSG(OUTFILE,MESSAGEFILE,BAXINSTR);
  PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,RTNRGTOP);
  WRITELN(OUTFILE,REGCOUNT:3);
  PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,STOINRG);
  WRITELN(OUTFILE,MANRTNREG:3);
  WRITELN(OUTFILE);
  PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,PGMPARTIS);
  WRITELN(OUTFILE,PARTITION:4:2);
  WRITELN(OUTFILE);
  PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,PARTNUMIS);
  WRITELN(OUTFILE,PARTNUM:1);
  WRITELN(OUTFILE);WRITELN(OUTFILE);
  P:=HEAD_MEMODULE;
  WHILE P<>NIL DO
    BEGIN
      T:=P@.CODELIST;
      STEP_TYPE:=0;
      WRITELN(OUTFILE); WRITELN(OUTFILE);
      WRITELN(OUTFILE);
      PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,MODN);
```

```
        WRITELN(OUTFILE,P@.MEMNUM:1);
        PRINTLN_MSG(OUTFILE,MESSAGEFILE,CARD1);
        PRINTLN_MSG(OUTFILE,MESSAGEFILE,SIDE1);
        WHILE T<>NIL DO
          BEGIN
            IF T@.ADDRESS=240 THEN
              BEGIN
                WRITELN(OUTFILE);WRITELN(OUTFILE);
                PRINTLN_MSG(OUTFILE,MESSAGEFILE,
                                                SIDE2);
              END;
            IF T@.ADDRESS = 480 THEN
              BEGIN
                WRITELN(OUTFILE);WRITELN(OUTFILE);
                PRINTLN_MSG(OUTFILE,MESSAGEFILE,
                                                CARD2);
                PRINTLN_MSG(OUTFILE,MESSAGEFILE,
                                                SIDE1);
              END;
            SET_STEP(T,STEP_TYPE);
            PRINT_LINE(OUTFILE,T,STEP_TYPE);
          END;
        P:=P@.NEXT;
      END;
  END;                                  (* OUTPUT_MSGF1 *)
(*-----------------------------------------------------*)


(*-----------------------------------------------------*)
(* OUTPUT_MSGF2: OUTPUTS SPECIFIC PROMPTS AND          *)
(*    SPECIAL PROGRAM INSTRUCTIONS                     *)
(*-----------------------------------------------------*)
PROCEDURE OUTPUT_MSGF2(VAR OUTFILE,MESSAGEFILE:TEXT;
                              HEAD_MEMODULE:TBLPTR);
  VAR SBRL,SEP,SM,P,F,SEG:TBLPTR;
      IS_SBRERR:BOOLEAN;
  BEGIN
    P:=HEAD_MEMODULE;
    PRINTLN_MSG(OUTFILE,MESSAGEFILE,SPECIFICS);
    WHILE P<>NIL DO
      BEGIN
        SEG:=P@.SEGTBLS;
        F:=SEG@.F_JUMPLIST;
        SBRL:=SEG@.SBRLIST;
        WRITELN(OUTFILE);
        PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,
                                    MODPROMPTS);
        WRITELN(OUTFILE,P@.MEMNUM:1);
        PRINTLN_MSG(OUTFILE,MESSAGEFILE,PFWDJ);
        IF F= NIL THEN
          PRINTLN_MSG(OUTFILE,MESSAGEFILE,NONE)
        ELSE
          BEGIN
            WHILE F<>NIL DO
              BEGIN
                PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,
                                                ASTER);
                WRITE(OUTFILE,F@.MEM_ADDR:1,'.');
                WRITE_LEADZERO(OUTFILE,(F@.
                                JUMP_ADDRTO1*100
                              F@.JUMP_ADDRTO2),3);
                WRITELN(OUTFILE);
                F:=F@.NEXT_FJUMP;
              END;
          END;
        PRINTLN_MSG(OUTFILE,MESSAGEFILE,PSBRINV);
        IF SBRL=NIL THEN
          PRINTLN_MSG(OUTFILE,MESSAGEFILE,NONE)
```

```
          ELSE
            BEGIN
              IS_SBRBRK:=FALSE;
              WHILE SBRL<>NIL DO
                BEGIN
                  SBR:=SBRL@.SBR;
                  IF SBR@.TAG = SBRBREAK THEN
                    BEGIN
                      SM:=HEAD_MEMODULE;
                      SBR:=SBR@.SBRZ;
                      WHILE SM@.SEGTBLS<>SBR DO
                        SM:=SM@.NEXT;
                      IS_SBRBRK:=TRUE;
                      PRINT_MSGLINE1(OUTFILE,
                                     MESSAGEFILE,ASTER);
                      WRITELN(OUTFILE,SM@.MEMNUM:1,
                                                '.000');
                    END;
                  SBRL:=SBRL@.NEXT_SBR;
                END;
              IF NOT IS_SBRBRK THEN
                PRINTLN_MSG(OUTFILE,MESSAGEFILE,NONE)
            END;
          PRINTLN_MSG(OUTFILE,MESSAGEFILE,PMANRTN);
          IF P@.RETURNCODE_NEEDED THEN
            PRINTLN_MSG(OUTFILE,MESSAGEFILE,YES)
          ELSE
            PRINTLN_MSG(OUTFILE,MESSAGEFILE,NONE);
          PRINTLN_MSG(OUTFILE,MESSAGEFILE,PSEQ);
          IF SEG@.TABLELIST <> NIL THEN
            BEGIN
              PRINT_MSGLINE1(OUTFILE,MESSAGEFILE,
                                              ASTER);
              WRITELN(OUTFILE,P@.NEXT@.
                                   MEMNUM:1,'.000')
            END
          ELSE
            PRINTLN_MSG(OUTFILE,MESSAGEFILE,NONE);
          P:=P@.NEXT;
        END;
      WRITELN(OUTFILE);WRITELN(OUTFILE);
      PRINTLN_MSG(OUTFILE,SCRATCH,DATAREAD);
      WRITELN(OUTFILE);WRITELN(OUTFILE);
      PRINTLN_MSG(OUTFILE,SCRATCH,REGMAP);
      WRITELN(OUTFILE);WRITELN(OUTFILE);
    END;                                (* OUTPUT_MSG2 *)
  (*-----------------------------------------------*)
  BEGIN
    OUTPUT_MSGF1(OUTFILE,MESSAGEFILE,HEAD_MEMODULE,
                           PART_NUM,PARTITION);
    OUTPUT_MSGF2(OUTFILE,MESSAGEFILE,HEAD_MEMODULE);
    WRITELN(OUTFILE);
    PRINTLN_MSG(OUTFILE,MESSAGEFILE,ENDLBL);
  END;                               (* OUTPUT_GOODSEG *)
(*-------------------------------------------------*)
```

```
{*-----------------------------------------------------------------*}
{* OUTPUT_BADSEG: HANDLES BAD SEG INSTRUCTIONS                     *}
{*-----------------------------------------------------------------*}
PROCEDURE OUTPUT_BADSEG(VAR OUTFILE,MESSAGEFILE,
                    TEMPFILE:TEXT; BUILT_CODE:CODEPTR);
  BEGIN
    WRITELN(OUTFILE);WRITELN(OUTFILE);
    PRINTLN_MSG(OUTFILE,MESSAGEFILE,FAILINSTR);
    RESET(TEMPFILE);
    PRINTLN_MSG(OUTFILE,TEMPFILE,9);
    WRITELN(OUTFILE); WRITELN(OUTFILE);
    PRINTLN_MSG(OUTFILE,MESSAGEFILE,UNSEGCODLBL);
    WRITELN(OUTFILE);WRITELN(OUTFILE);
    PRINT_CODELIST(OUTFILE,BUILT_CODE);
    WRITELN(OUTFILE);
    PRINTLN_MSG(OUTFILE,MESSAGEFILE,ENDLBL);
  END;                                    (* OUTPUT_BADSEG *)
 {*---------------------------------------------------------------*}
BEGIN
  IF NOT GOOD_SEGMENT THEN
    OUTPUT_BADSEG(OUTFILE,MESSAGEFILE,TEMPFILE,
                                            BUILT_CODE)
  ELSE
    OUTPUT_GOODSEG(OUTFILE,MESSAGEFILE,HEAD_MEMODULE
                            ,PART_NUM,PARTITION);
 END;                                     (* OUTPUT_INSTR *)
{*-----------------------------------------------------------------*}
BEGIN
  BLD_MEMODULENODES(SEGTBL,HEAD_MEMODULE);
  BLD_MEMODULECODE(BUILT_CODE,HEAD_MEMODULE);
  OUTPUT_INSTR(OUTFILE,MESSAGEFILE,TEMPFILE,BUILT_CODE,
                  HEAD_MEMODULE,PART_NUM,PARTITION,
                  GOOD_SEGMENT);
END;                                      (* INSTRUCTIONS *)
(*=================================================================*)
```

```
(*****************************************************************)
(*                        MAIN DRIVER                            *)
(*****************************************************************)

 BEGIN
   INIT_SETS(TEMPFILE,STEP_0,STEP_1,STEP_2,STEP_3,
     GOOD_SEGMENT,MESSAGEFILE,TILBL,SBRINVNEST);

   DET_LIMIT(REGCOUNT,LIMIT,NUMBANKS,PART_NUM,PARTITION);

   INPUT(SCRATCH,BUILT_CODE,BUILT_CODE_COUNT);

   SETJMPS(BUILT_CODE);

   BUILD_SEGTBL(BUILT_CODE,SEGTBL,LIMIT,BUILT_CODE_COUNT);

   COALESCE(SEGTBL@.TABLELIST,LIMIT,GOOD_SEGMENT
                                                ,SBRINVNEST);
   WRITELN(TEMPFILE,'$9');   (* CLOSES TEMPFILE DIAG FILE *)

   INSTRUCTIONS(OUTFILE,MESSAGEFILE,TEMPFILE,
          BUILT_CODE,SEGTBL@.TABLELIST,PART_NUM,PARTITION,
          GOOD_SEGMENT);

   REWRITE(TEMPFILE);        (* ERASES TEMPFILE DIAG FILE *)

 END.

(*****************************************************************)
(*                       END OF PROGRAM                          *)
(*****************************************************************)
```

APPENDIX J

MESSAGEFILE FILE--LINKER MESSAGES

```
$81
===================================================================
        EAX59 PROGRAM INSTRUCTIONS: VERSION 1.0
===================================================================

  * CONGRATULATIONS, YOU HAVE JUST COMPILED A BASIC PROGRAM
      INTO A TI-59 PROGRAM.  IN SO DOING IT IS VERY POSSIBLE
      THAT YOUR PROGRAM IS LARGER THAN THE MEMORY OF THE
      CALCULATOR.  IF THIS IS THE CASE THEN THE PROGRAM HAS
      BEEN SEGMENTED AND PROMPTING CODE INSERTED TO GUIDE
      YOUR CALCULATOR PROGRAM DURING ITS EXECUTION. THE RE-
      MAINDER OF THIS OUTPUT CONSISTS OF TI-59 CODE LISTINGS
      AND OTHER INFORMATION TO AID YOU IN YOUR PROGRAM
      EXECUTION.

  * THE FOLLOWING DEFINITIONS ARE PROVIDED AS AN AID TO
      READING THE PROGRAM LISTING FILE.

     * DEFINITIONS:

        * MODULE: A MODULE IS DEFINED TO BE ALL THE MEMORY
            DEDICATED TO PROGRAM STEPS.  THE SIZE IS VARI-
            ABLE AND IS DEPENDENT ON THE REGISTER REQUIRE-
            MENT.  VALUES RANGE FROM 0 TO 239, 479 OR 719
            DEPENDING ON THE AMOUNT OF REGISTERS USED BY
            THE PROGRAM.

        * CARD: A CARD IS DEFINED TO BE ONE MAGNETIC CARD.
            A CARD HOLDS 480 PROGRAM STEPS.  THESE STEPS
            ARE NOT CONTIGUOUS BUT ARE ARRANGED ON THE TWO
            SIDES OF THE CARD.

        * SIDE: A SIDE IS ONE HALF OF A CARD. IT CONTAINS
            UP TO 240 STEPS.  WHEN ONE SIDE OF A CARD IS
            READ BY THE CALCULATOR 240 PROGRAM STEPS ARE
            FILLED IN MEMORY.  THESE BLOCKS OF 240 STEPS
            ARE REFERED TO AS "BANKS" IN THE MANUFACTURER
            LITERATURE.  WHEN LOADING A CARD YOU WILL LOAD
            ONLY BANK NUMBER 1 AND/OR 2 FOR PROGRAM STEPS.

        * PARTITION: THIS IS DEFINED TO BE THE CURRENT
            SETTING OF CALCULATOR MEMORY AS APPLIED TO THE
            AMOUNT OF MEMORY DEDICATED TO STORAGE REGISTERS
            AND THE AMOUNT DEDICATED TO PROGRAM STEPS.
            WE WILL BE DEALING WITH 3 PARTITIONS. THESE
            ARE:
                              3         719.29
                              4         479.59
                              5         239.69

            FORMAT:           X         YYY.ZZ

            WHERE X STANDS FOR PARTITION NUMBER
                  YYY STANDS FOR PROGRAM STEPS (0-YYY)
                  ZZ STANDS FOR REGISTERS (0-ZZ).
```

```
===========================================================
        TI-59 PROGRAM LISTING BY MODULE/CARD/SIDE:
===========================================================

  * THE FOLLOWING IS YOUR PROGRAM LISTING. THE PROGRAM IS
      LISTED ACCORDING TO MODULE NUMBER AND ITS ASSOCIATED
      CARDS AND CARD SIDES.

  * REFER TO THE TI-59 PROGRAMMER'S GUIDE ON HOW TO INPUT A
      PROGRAM AND WRITE IT TO MAGNETIC CARDS.

  * CAUTION: ENSURE THAT THE CORRECT CALCULATOR PARTITION
      IS SET BEFORE INPUTTING A PROGRAM AND WRITING TO
      MAGNETIC CARDS.

  * CAUTION: ENSURE THAT YOU DO NOT CONFUSE BANK NUMBERS
      WITH CARD/MODULE OR SIDE NUMBERS.  THE NUMBERS WHICH
      REFER TO THE LISTING ARE AKIN TO A VIRTUAL ADDRESS
      AND DO NOT REPRESENT THE ACTUAL BANK NUMBER.
      IF IN DOUBT, REMEMBER TO USE THE TABLE BELOW TO
      TRANSLATE VIRTUAL TO ACTUAL BANK NUMBERS.

        VIRTUAL BANK                              ACTUAL BANK

        MODULE #
        CARD1
        SIDE1 ----------------------------------- BANK1

        MODULE #
        CARD1
        SIDE2 ----------------------------------- BANK2

        MODULE #
        CARD2
        SIDE1 ----------------------------------- BANK3
===========================================================
                       TI-59 LISTING
===========================================================

$81
```

==
TI-59 PROGRAM SPECIFIC INSTRUCTIONS:
==

* THE FOLLOWING INFORMATION WILL TELL YOU HOW TO RUN YOUR PROGRAM.

* YOU MUST ENTER YOUR PROGRAM MANUALLY INTO THE CALCULATOR AND WRITE THE PROGRAM TO MAGNETIC CARDS. THIS STEP ONLY NEEDS TO BE ACCOMPLISHED ONCE. AFTER THAT, THE PROGRAM IS ENTERED USING THE MAGNETIC CARD FACILITY OF THE CALCULATOR. SEE THE MANUFACTURER'S LITERATURE ON ENTERING A PROGRAM AND WRITTING IT TO MAGNETIC CARDS. YOU WILL NEED TO PARTITION MEMORY.

* HOW TO PARTITION THE MEMORY
  * KEY SEQUENCE:

```
X
2ND
OP
17
```

  * X IS THE PARTITION NUMBER GIVEN IN THE LISTING OF YOUR PROGRAM.

* WHEN TO PARTITION THE MEMORY
  * ONCE BEFORE READING IN CARDS.
  * ONCE BEFORE MANUALLY ENTERING PROGRAM IN ORDER TO WRITE TO CARDS.

* HOW TO START AND RUN YOUR PROGRAM
  * TURN ON CALCULATOR
  * PARTITION CALCULATOR
  * LOAD ALL MODULE 1 CARDS
  * OPTIONAL STEP: IF YOU SELECTED THE MANUAL DATA INPUT DENOTED IN YOUR BASIC PROGRAM BY USING THE "DATA" AND "READ" STATEMENTS THEN YOU MUST MANUALLY ENTER YOUR DATA INTO THE CALCULATOR MEMORY. THIS IS DONE BY REFERRING TO "INPUT DATA TO READ" TABLE PROVIDED AT THE END OF THIS LISTING. MANUALLY ENTER THE GIVEN DATA INTO THE REGISTERS USING THE FOLLOWING KEYSTROKES:

```
DATA
STO
XX
```

    WHERE XX IS THE DESIRED REGISTER NUMBER.
  * INITIALIZE THE MANUAL SBR RETURN CONTROL STACK WITH THE FOLLOWING KEYSTROKES:

```
XX
STO
08
```

    WHERE XX IS THE MANUAL RETURN REGISTER STACK TOP. (THIS IS GIVEN WITH THE PROGRAM LISTING NEAR THE PARTITION INFORMATION.)
  * PRESS "A" TO START.
  * FOLLOW DISPLAY PROMPTS.
    * DEFINITIONS:
      * RUN-TIME PROMPTS: ARE DEFINED TO BE CALCULATOR PROMPTS DISPLAYED IN THE CALCULATOR WINDOW IN THE FORM OF A 4 DIGIT DECIMAL, 2 DIGIT INTEGER OR A 1 DIGIT INTEGER. EACH PROMPT

```
               IS OUTLINED BELOW:
                 * 4 DIGIT DECIMAL
                       * FORMAT: X.YYY
                           * X STANDS FOR MODULE NUMBER (1-9)
                           * YYY STANDS FOR STARTING ADDRESS
                       * ACTIONS:
                           * LOAD ALL MODULE X CARDS.
                           * PRESS FOLLOWING KEY SEQUENCE TO
                             INTIALIZE:
                               RCL
                               00
                               GTO
                               Y
                               Y
                               Y
                           * PRESS R/S TO CONTINUE IN NEW MOD.
                 * 2 DIGIT INTEGER
                       * FORMAT: XX WHERE XX STANDS FOR A
                           REGISTER NUMBER.
                       * ACTIONS:
                           * LOOK UP IN REGISTER MAP PROVIDED
                               THE BASIC NAME THAT CORRESPONDS
                               TO THE XX NUMBER.
                           * ENTER THE BASIC VARIABLE VALUE.
                           * PRESS R/S TO CONTINUE WITH THE
                               ENTERED VALUE.
                 * 1 DIGIT INTEGER
                       * FORMAT: X WHERE IS A MODULE NUMBER.
                       * ACTIONS:
                           * LOAD ALL MODULE X CARDS.
                           * PRESS FOLLOWING SEQUENCE TO
                               INITIALIZE:
                               RCL
                               00
                               INV
                               SBR
                           * PRESS R/S TO CONTINUE IN NEW MCD.
                 * PAUSE IN DISPLAY
                       * AN UNFORMATTED DIGIT FLASHES IN THE
                         DISPLAY BEFORE BEING DISPLAYED.
                         THIS IS AN ANSWER THAT CORRESPONDS
                         TO A REQUESTED ANSWER IN THE BASIC
                         PROGRAM USING THE BASIC PRINT
                         STATEMENT.  THESE ANSWERS OCCUR IN
                         THE SAME ORDER AS THEY WERE
                         REQUESTED IN THE BASIC PRCGRAM.
                       * ACTIONS: NOTE ANSWER AND PRESS R/S.
                 * 888 IN DISPLAY
                       * SPECIFIC PROMPT THAT INDICATES THAT
                         THE PROGRAM HAS STOPPED EXECUTION.
                       * ACTIONS: IF DESIRED FIND ANSWERS IN
                         THE CALCULATOR MEMORY USING THE
                         "TI-59 REGISTER TO NAME MAPPING"
                         AT THE END OF THE INSTRUCTIONS.

          * EXPECTED CONTROL FLOW PROMPTS BY MODULE FOLLOW:
$82
$83
==========================================================
      END BAX59 SEGMENTATION/INSTRUCTION: VERSION 1.0
==========================================================
$83
$84
==========================================================
            BAX59 PROGRAM INSTRUCTIONS: VERSION 1.0
  **** SEGMENTER FAILURE ************ PROGRAM FAILURE****
                BAX59 DIAGNOSTICS FOLLOW:
==========================================================
* SEGMENTCR FAILURES:
```

```
  * THE SEGMENTOR COULD NOT SEGMENT THE COMPILED PROGRAM IN
      A SATISFACTORY MANNER.  POSSIBLE REASONS FOR THE
      FAILURE ARE GIVEN BELOW.
  * THERE ARE TWO TYPES OF SEGMENT BREAKS:
      * A JUMP BREAK OCCURS THROUGH AN ABSOLUTE JUMP TO SOME
          PORTION OF CODE IN ANOTHER MODULE.
      * A SBR BREAK OCCURS THROUGH A SBR INVOKE TO A SBR
          WHOSE DEFINITION RESIDES IN ANOTHER MODULE.
  * SEGMENT FAILURE OCCURS WHEN ONE OF THE ABOVE BREAKS
      OCCURS INSIDE A BACKWARD JUMPING LOOP THAT COVERS
      MORE PROGRAM STEPS THAN IS AVAILABLE IN THE CALCULATOR
      MEMORY.  SEGMENTATION IS NOT ALLOWED IN A LOOP AS IT
      IS IMPRACTICAL TO KEEP READING IN CARDS EVERY TIME THE
      THE PROGRAM LOOPS BACK OVER A BREAK (IMAGINE A 1 TO
      1000 LOOP OVER SUCH A BREAK).  TO AVOID SUCH A PROBLEM
      YOU MUST STRUCTURE YOUR BASIC PROGRAM TO AVOID LARGE
      BACKWARD-JUMPING LOOPS.
* PROGRAM FAILURES:  POSSIBLE PROGRAM FAILURE OCCURS WHEN
    SUBROUTINE CALLS ARE NESTED GREATER THAN SIX DEEP.
    THE CALCULATOR ONLY HAS SIX SUBROUTINE RETURN REGISTERS.
* BELOW ARE DIAGNOSTICS INDICATING THE SIZES OF THE LOOPS
    IN TI-59 PROGRAM STEPS AND THE TYPES OF BREAKS OCCURRING
    WITHIN THESE LOOPS.  DIAGNOSTICS ARE GIVEN IN ABSOLUTE
    CODE.  SBR NESTING LEVEL DIAGNOSTICS ARE GIVEN FOR
    INVOKED ROUTINE DEFINITION.

$84
$5
============================================================
                    EAX59 VERSION 1.0
      UNSEGMENTED ABSOLUTE COMPILED TI59 CODE FOLLOWS
============================================================
$5
$6
             * SEQUENTIAL CONTINUATION: 4 DIGIT REAL CODE.
$6
$7
             * MANUAL RETURN FROM A SUBROUTINE: 1 DIGIT CODE.
$7
$8
             * FORWARD JUMP CONTINUATION: 4 DIGIT REAL CODE.
$8
$9
             * SUBROUTINE INVOKE: 4 DIGIT REAL CODE.
$9
$99
0               1               2               3
4               5               6               7
8               9               2ND E'          A
B               C               D               E
2ND A'          2ND B'          2ND C'          2ND D'
2ND CLR         INV             LNX             CE
CLR             2ND INV         2ND LOG         2ND CP
2ND TAN         X<=>T           X**2            SQRT(X)
1/X             2ND PGM         2ND P=>R        2ND SIN
2ND COS         2ND INC         STO             RCL
SUM             Y**X            2ND CMS         2ND EXC
2ND PRD         |X|             EE              (
)               /               2ND ENG         2ND FIX
2ND INT         2ND DEG         GTO             2ND PGM 2ND IND
2ND EXC 2ND IND2ND PRC 2ND INDX                 2ND PAUSE
2ND X=T         2ND NOP         2ND OP          2ND RAD
SBR             STO 2ND IND     RCL 2ND IND     SUM 2ND IND
-               2ND LBL         2ND X>=T        2ND SUMMATION
X-BAR           2ND GRAD        RST             GTO 2ND IND
2ND OP 2ND IND  +               2ND STFLG       2ND IFFLG
2ND D.MS        2ND PI          2ND LIST        R/S
INV SBR         .               +/-             =
2ND WRITE       2ND DSZ         2ND ADV         2ND PRT
```

```
$99
$100
          * EXPECTED PROMPTS FOR MODULE # $
$100
$101
              * NONE
$101
$102
              * $
$102
$103
              * YES
$103
$104
  * MANUAL RETURN REGISTER TOP IS $
$104
$105
  STORE IN REGISTER: $
$105
$106
  * PROGRAM PARTITION IS $
$106
$107
  * PARTITION NUMBER IS $
$107
$108
  *MODULE # $
$108
$109
    CARD #1
$109
$110
    CARD #2
$110
$111
    SIDE #1
$111
$112
    SIDE #2
$112
```

APPENDIX K

ARTILLERY TEST PROGRAM SOURCE CODE

```
00005 OPTION 0 5
00010 REM ************************************************************
00011 REM
00012 REM          BAX59 TEST PROGRAM NUMBER1
00014 REM
00015 REM *THIS TEST PROGRAM IS AN ADAPTATION OF THE PROGRAM
00016 REM  USED BY THE FIELD ARTILLERY IN THE COMPUTATION
00017 REM  OF FIRING DATA FOR THEIR GUNS.  THE ORIGINAL
00018 REM  PROGRAM WAS WRITTEN FOR THE TI-59 CALCULATOR.
00019 REM  THIS TEST WAS CHOSEN NOT ONLY TO EVALUATE THE
00020 REM  THE COMPILER AND SEGMENTOR BUT TO COMPARE THE
00022 REM  THE RELATIVE EFFICIENCY OF THE TRANSLATED BASIC
00023 REM  PROGRAM WITH THAT OF A HUMAN CODED PROGRAM. BOTH
00024 REM  PROGRAMS ACCOMPLISH THE SAME TASK.
00025 REM
00026 REM ************************************************************
00027 REM
00050 REM *************** DATA SECTION M109 *****************
00055 REM
00100 REM      *CHARGE CONSTANTS  M109A1 SELF PROPELLED
00120 REM        *CHARGE 4
00130 DATA        -.0133670,21.2691,-105.7
00140 DATA        -.00001499,.06630,-.41
00150 DATA        .77,.01314,.00001720
00160 REM        *CHARGE 5
00170 DATA        -.0149331,24.3439,64.7
00180 DATA        -.00001420,.07069,.06
00190 DATA        1.26,.01508,.00001678
00200 REM        *CHARGE 7
00210 DATA        -.0173835,29.8741,2255.2
00220 DATA        -.00001668,.08487,3.29
00230 DATA        1.3,.02713,.00001306
00240 REM        *CHARGE 8
00250 DATA        -.0182137,32.3731,4107.4
00260 DATA        -.00001668,.09272,5.74
00270 DATA        1.36,.02891,.00001410
00280 REM
00290 REM      *M109 MAX RANGE OF CURVE FIT BY CHARGE
00300 DATA        5700,7000,10800,17600
00310 REM
00320 REM      *M109 HIGH ANGLE CROSS OVER POINT MILS
00330 DATA        715
00340 REM
00350 REM      *BATTERY DATA/ BTRYE,BTRYN,BTRYA,BTRYL
00360 DATA        0,0,0,800
00370 REM
00380 REM      *REGISTRATION DATA/RNGK,DFCOR
00390 DATA        1.0,0
00400 REM
00410 REM      *TARGET DATA/OBSERVOR LOCATION(DUAL MEANING)
00420 DATA        4000,4000,10
00430 REM
00440 REM      *OBSERVOR DATA
00450 DATA        4000,-400,10
00460 REM
00470 REM      *SPECIFIC CORRECTION FACTORS DATA
00471 DATA       1018.5924,1600,3200
00472 REM
00473 REM
```

```
00480 REM *************** VARIABLE READ INITIALIZATION *****
00490 REM
00495 REM      *M109 BALLISTIC CONSTANTS BY CHARGE
00500 REM        *CHARGE 4
00510 READ         A24,A14,A04
00520 READ         C24,C14,C04
00530 READ         B04,B14,B24
00540 REM        *CHARGE 5
00550 READ         A25,A15,A05
00560 READ         C25,C15,C05
00570 READ         B05,B15,B25
00580 REM        *CHARGE 7
00590 READ         A27,A17,A07
00600 READ         C27,C17,C07
00610 READ         B07,B17,B27
00620 REM        *CHARGE 8
00630 READ         A28,A18,A08
00640 READ         C28,C18,C08
00650 READ         B08,B18,B28
00660 REM
00670 REM      *M109 MAX RANGE OF CURVE FIT VARIABLES
00680 READ       CHG4MAX,CHG5MAX,CHG7MAX,CHG8MAX
00690 REM
00700 REM      *M109 HIGH ANGLE CROSS OVER VARIABLE
00710 READ       HACRCSS
00720 REM
00730 REM      *BATTERY VARIABLES
00740 READ       BTRYE,BTRYN,BTRYA,BTRYL
00750 REM
00760 REM      *REGISTRATION VARIABLES
00770 READ       RGK,DFCOR
00780 REM
00790 REM      *TARGET VARIABLES OR OBSERVOR INIT LOCATION
00800 READ       GRIDE,GRIDN,GRIDA
00810 REM
00820 REM      *OBSERVOR VARIABLES
00830 READ       OT,LATDEV,RGDEV
00840 REM
00845 REM      *SPECIFIC CORRECTION FACTORS VARIABLES
00860 READ       MILRAD,ROTCOR,REFDEF
00870 REM
00875 REM ************************************************
00880 REM ************** MAIN PROGRAM BEGINS ***************
00900 REM START
00910 REM    *COMPUTE TARGET GRID
00920           GOSUB 1050
00940 REM    *COMPUTE GUN RANGE,AZIMUTH
00950           GOSUB 1130
00970 REM    *COMPUTE FIRING DATA
00980           GOSUB 1240
00990 REM
01000       STOP
01010 REM ************** MAIN STOP ************************
01020 REM
01022 REM
01030 REM ************** SUBROUTINES **********************
01035 REM
01040 REM ************************************************
01050 REM *** COMPUTE NEW TARGET GRID FROM SHIFTS *********
01051 REM ************************************************
01055 REM     START
01060           GRIDN = GRIDN+(RGDEV*SIN((ROTCOR-OT)/        &
01070 &                MILRAD)-LATDEV*COS((ROTCOR-OT)/MILRAD))
01080           GRIDE = GRIDE+(RGDEV*COS((ROTCOR-OT)/        &
01090 &                MILRAD)+LATDEV*SIN((ROTCOR-OT)/MILRAD))
01100       RETURN
01110 REM ************************************************
01115 REM
01120 REM ************************************************
```

```
01130 REM **** COMPUTE GUN RANGE, AZIMUTH ******************
01131 REM ************************************************
01135 REM       START
01140            TGTRG = SQR((GRIDE-BTRYE)**2+                    &
01145 &                                      (GRIDN-BTRYN)**2)
01150            TGTAZ = ASIN((GRIDN-BTRYN)/TGTRG)*MILRAD
01160            IF GRIDE >= BTRYE
01170               TGTAZ = ROTCOR - TGTAZ
01180            ELSE
01190               TGTAZ = 3*ROTCOR + TGTAZ
01200            ENDIF
01210          RETURN
01220 REM ************************************************
01223 REM
01230 REM ************************************************
01240 REM **** FIRING DATA COMPUTATION ROUTINE *************
01245 REM ************************************************
01250 REM       START
01260           IF TGTRG <= CHG4MAX
01270             INVOKE= FN_FD(A24,A14,A04,C24,C14,C04,      &
01275 &                                          B24,B14,B04)
01280           ELSEIF TGTRG <= CHG5MAX
01290             INVOKE= FN_FD(A25,A15,A05,C25,C15,C05,      &
01295 &                                          B25,B15,B05)
01300           ELSEIF TGTRG <= CHG7MAX
01310             INVOKE= FN_FD(A27,A17,A07,C27,C17,C07,      &
01315 &                                          B27,B17,B07)
01320           ELSEIF TGTRG <= CHG8MAX
01330             INVOKE= FN_FD(A28,A18,A08,C28,C18,C08,      &
01335 &                                          B28,B18,BC8)
01340           ELSE
01350             PRINT TGTRG
01360           ENDIF
01370         RETURN
01380 REM ************************************************
01390 REM
01395 REM ************************************************
01400 REM *** FIRING DATA COMPUTATION FUNCTION *************
01405 REM ************************************************
01410 REM     START
01420           DEF FN_FD(A2,A1,A0,C2,C1,C0,B2,B1,B0)
01430              EL = (-A1+SQR(A1**2-(4*A2*(A0-TGTRG*RGK) &
01435 &                                         )))/(2*A2)
01440              IF EL > HACROSS
01450                PRINT TGTAZ,TGTRG
01460              ELSE
01470                PRINT C0+C1*EL+C2*EL**2
01480                PRINT REFDEF+DFCOR+(BTRYL-TGTAZ)+          &
01481 &                                 (B0+B1*EL+B2*EL**2)
01490                PRINT EL+((GRIDA-BTRYA+20)/TGTRG*1000)
01500              ENDIF
01510           FNEND
01515 REM ************************************************
01516 REM       END EAX59 TEST PROGRAM NUMBER ONE
01518 REM ************************************************
```

APPENDIX L

TEST PROGRAM LISTING FILE (LISTF)

```
=====================================================================
                       WBASIC PROGRAM LISTING
=====================================================================

00005 OPTION 0 5
00010 REM  *******************************************************
00011 REM
00012 REM              BAX59 TEST PROGRAM NUMBER1
00014 REM
00015 REM  *THIS TEST PROGRAM IS AN ADAPTATION OF THE PROGRAM
00016 REM    USED BY THE FIELD ARTILLERY IN THE COMPUTATION
00017 REM    OF FIRING DATA FOR THEIR GUNS.  THE ORIGINAL
00018 REM    PROGRAM WAS WRITTEN FOR THE TI-59 CALCULATOR.
00019 REM    THIS TEST WAS CHOSEN TO NOT ONLY EVALUATE THE
00020 REM    THE COMPILER AND SEGMENTOR BUT TO COMPARE THE
00022 REM    THE RELATIVE EFFICIENCY OF THE TRANSLATED WBASIC
00023 REM    PROGRAM WITH THAT OF A HUMAN CODED PROGRAM. BOTH
00024 REM    PROGRAMS ACCOMPLISH THE SAME TASK.
00025 REM
00026 REM  *******************************************************
00027 REM
00050 REM  *************** DATA SECTION M109 *****************
00055 REM
00100 REM        *CHARGE CONSTANTS  M109A1 SELF PROPELLED
00120 REM          *CHARGE 4
00130 DATA          -.0133670,21.2691,-105.7
00140 DATA          -.00001499,.06630,-.41
00150 DATA          .77,.01314,.00001720
00160 REM          *CHARGE 5
00170 DATA          -.0149331,24.3439,64.7
00180 DATA          -.00001420,.07069,.06
00190 DATA          1.26,.01508,.00001678
00200 REM          *CHARGE 7
00210 DATA          -.0173835,29.8741,2255.2
00220 DATA          -.00001668,.08487,3.29
00230 DATA          1.3,.02713,.00001306
00240 REM          *CHARGE 8
00250 DATA          -.0182137,32.3731,4107.4
00260 DATA          -.00001668,.09272,5.74
00270 DATA          1.36,.02891,.00001410
00280 REM
00290 REM        *M109 MAX RANGE OF CURVE FIT BY CHARGE
00300 DATA          5700,7000,10800,17600
00310 REM
00320 REM        *M109 HIGH ANGLE CROSS OVER POINT MILS
00330 DATA          715
00340 REM
00350 REM        *BATTERY DATA/ BTRYE,BTRYN,BTRYA,BTRYL
00360 DATA          0,0,0,800
00370 REM
00380 REM        *REGISTRATION DATA/RNGK,DFCOR
00390 DATA          1.0,0
00400 REM
00410 REM        *TARGET DATA/OBSERVOR LOCATION(DUAL MEANING)
00420 DATA          4000,4000,10
00430 REM
00440 REM        *OBSERVOR DATA
00450 DATA          4000,-400,10
00460 REM
```

```
00470 REM      *SPECIFIC CORRECTION FACTORS DATA
00471 DATA      1018.5924,1600,3200
00472 REM
00473 REM
00480 REM ************** VARIABLE READ INITIALIZATION *****
00490 REM
00495 REM      *M109 BALLISTIC CONSTANTS BY CHARGE
00500 REM        *CHARGE 4
00510 READ         A24,A14,A04
00520 READ         C24,C14,C04
00530 READ         B04,B14,B24
00540 REM        *CHARGE 5
00550 READ         A25,A15,A05
00560 READ         C25,C15,C05
00570 READ         B05,B15,B25
00580 REM        *CHARGE 7
00590 READ         A27,A17,A07
00600 READ         C27,C17,C07
00610 READ         B07,B17,B27
00620 REM        *CHARGE 8
00630 READ         A28,A18,A08
00640 READ         C28,C18,C08
00650 READ         B08,B18,B28
00660 REM
00670 REM      *M109 MAX RANGE OF CURVE FIT VARIABLES
00680 READ       CHG4MAX,CHG5MAX,CHG7MAX,CHG8MAX
00690 REM
00700 REM      *M109 HIGH ANGLE CROSS OVER VARIABLE
00710 READ       HACRCSS
00720 REM
00730 REM      *BATTERY VARIABLES
00740 READ       BTRYE,BTRYN,BTRYA,BTRYL
00750 REM
00760 REM      *REGISTRATION VARIABLES
00770 READ       RGK,DFCOR
00780 REM
00790 REM      *TARGET VARIABLES OR OBSERVOR INIT LOCATION
00800 READ       GRIDE,GRIDN,GRIDA
00810 REM
00820 REM      *OBSERVOR VARIABLES
00830 READ       OT,LATDEV,RGDEV
00840 REM
00845 REM      *SPECIFIC CORRECTION FACTORS VARIABLES
00860 READ       MILRAD,ROTCOR,REFDEF
00870 REM
00875 REM *********************************************
00880 REM ************* MAIN PROGRAM BEGINS ***************
00900 REM START
00910 REM    *COMPUTE TARGET GRID
00920            GOSUB 1050
00940 REM    *COMPUTE GUN RANGE,AZIMUTH
00950            GOSUB 1130
00970 REM    *COMPUTE FIRING DATA
00980            GOSUB 1240
00990 REM
01000        STOP
01010 REM ************* MAIN STOP *************************
01020 REM
01022 REM
01030 REM ************* SUBROUTINES **********************
01035 REM
01040 REM *********************************************
01050 REM *** COMPUTE NEW TARGET GRID FROM SHIFTS ********
01051 REM *********************************************
01055 REM      START
01060            GRIDN = GRIDN+(RGDEV*SIN((ROTCOR-OT)/       &
01070 &                MILRAD)-LATDEV*COS((ROTCOR-OT)/MILRAD))
01080            GRIDE = GRIDE+(RGDEV*COS((ROTCOR-OT)/       &
01090 &                MILRAD)+LATDEV*SIN((ROTCOR-OT)/MILRAD))
```

```
01100          RETURN
01110 REM *********************************************************
01115 REM
01120 REM *********************************************************
01130 REM **** COMPUTE GUN RANGE, AZIMUTH ***********************
01131 REM *********************************************************
01135 REM      START
01140            TGTRG = SQR((GRIDE-BTRYE)**2+                    &
01145 &                                   (GRIDN-BTRYN)**2)
01150            TGTAZ = ASIN((GRIDN-BTRYN)/TGTRG)*MILRAD
01160            IF GRIDE >= BTRYE
01170              TGTAZ = ROTCOR - TGTAZ
01180            ELSE
01190              TGTAZ = 3*ROTCOR + TGTAZ
01200            ENDIF
01210          RETURN
01220 REM *********************************************************
01223 REM
01230 REM *********************************************************
01240 REM **** FIRING DATA COMPUTATION ROUTINE ******************
01245 REM *********************************************************
01250 REM      START
01260            IF TGTRG <= CHG4MAX
01270              INVCKE= FN_FD(A24,A14,A04,C24,C14,C04,         &
01275 &                                   B24,B14,B04)
01280            ELSEIF TGTRG <= CHG5MAX
01290              INVCKE= FN_FD(A25,A15,A05,C25,C15,C05,         &
01295 &                                   B25,B15,B05)
01300            ELSEIF TGTRG <= CHG7MAX
01310              INVCKE= FN_FD(A27,A17,A07,C27,C17,C07,         &
01315 &                                   B27,B17,B07)
01320            ELSEIF TGTRG <= CHG8MAX
01330              INVCKE= FN_FD(A28,A18,A08,C28,C18,C08,         &
01335 &                                   B28,B18,B08)
01340            ELSE
01350              PRINT TGTRG
01360            ENDIF
01370          RETURN
01380 REM *********************************************************
01390 REM
01395 REM *********************************************************
01400 REM *** FIRING DATA COMPUTATION FUNCTION *****************
01405 REM *********************************************************
01410 REM      START
01420            DEF FN_FD(A2,A1,A0,C2,C1,C0,B2,B1,B0)
01430              EL = (-A1+SQR(A1**2-(4*A2*(A0-TGTRG*RGK)&
01435 &                                   )))/(2*A2)
01440              IF EL > HACROSS
01450                PRINT TGTAZ,TGTRG
01460              ELSE
01470                PRINT C0+C1*EL+C2*EL**2
01480                PRINT REFDEF+DFCOR+(BTRYL-TGTAZ)+            &
01481 &                         (B0+B1*EL+B2*EL**2))
01490                PRINT EL+((GRIDA-BTRYA+20)/TGTRG*1000)
01500              ENDIF
01510            FNEND
01515 REM *********************************************************
01516 REM        END EAX59 TEST PROGRAM NUMBER ONE
01518 REM *********************************************************
```

```
=================================================================
                    COMPILATION SUMMARY
=================================================================

      0 FATAL ERRORS.
      0 WARNING MSGS.

81 IS NEXT AVAILABLE REGISTER
TOTAL REGISTERS RESERVED = 11
```

```
TOTAL REGISTERS USED      = 70
TOTAL  LABELS   USED      = 5

----------------- COMPILATION TERMINATES ------------------

============================================================
                TI-59 CODE TRANSLATED FROM WBASIC
                          (UNSEGMENTED)
============================================================

      ADDR   CODE
$0 ------------------------------------------ BEGIN TI-59 CODE.
      000    76     2ND  LBL
      001    11     A
      002    71     SBR
      003    12     B
      004    68     2ND  NOP
      005    71     SBR
      006    13     C
      007    68     2ND  NOP
      008    71     SBR
      009    14     D
      010    68     2ND  NOP
      011    24     CE
      012    08     8
      013    08     8
      014    08     8
      015    91     R/S
      016    76     2ND  LBL
      017    12     B
      018    53     (
      019    43     RCL
      020    59     59
      021    85     +
      022    53     (
      023    43     RCL
      024    63     63
      025    65     *
      026    53     (
      027    53     (
      028    43     RCL
      029    65     65
      030    75     -
      031    43     RCL
      032    61     61
      033    54     )
      034    55     /
      035    43     RCL
      036    64     64
      037    54     )
      038    38     2ND  SIN
      039    75     -
      040    43     RCL
      041    62     62
      042    65     *
      043    53     (
      044    53     (
      045    43     RCL
      046    65     65
      047    75     -
      048    43     RCL
      049    61     61
      050    54     )
      051    55     /
      052    43     RCL
      053    64     64
      054    54     )
      055    39     2ND  COS
```

```
056   54   )
057   54   )
058   42   STO
059   59   59
060   53   (
061   43   RCL
062   58   58
063   85   +
064   53   (
065   43   RCL
066   63   63
067   65   *
068   53   (
069   53   (
070   43   RCL
071   65   65
072   75   -
073   43   RCL
074   61   61
075   54   )
076   55   /
077   43   RCL
078   64   64
079   54   )
080   39   2ND  COS
081   85   +
082   43   RCL
083   62   62
084   65   *
085   53   (
086   53   (
087   43   RCL
088   65   65
089   75   -
090   43   RCL
091   61   61
092   54   )
093   55   /
094   43   RCL
095   64   64
096   54   )
097   38   2ND  SIN
098   54   )
099   54   )
100   42   STO
101   58   58
102   92   INV  SBR
103   76   2ND  LBL
104   13   C
105   53   (
106   53   (
107   53   (
108   43   RCL
109   58   58
110   75   -
111   43   RCL
112   52   52
113   54   )
114   45   Y**X
115   02   2
116   85   +
117   53   (
118   43   RCL
119   59   59
120   75   -
121   43   RCL
122   53   53
123   54   )
124   45   Y**X
```

125	02	2
126	54	)
127	34	SQRT (X)
128	54	)
129	42	STO
130	67	67
131	53	(
132	53	(
133	53	(
134	43	RCL
135	59	59
136	75	-
137	43	RCL
138	53	53
139	54	)
140	55	/
141	43	RCL
142	67	67
143	54	)
144	27	2ND INV
145	38	2ND SIN
146	65	*
147	43	RCL
148	64	64
149	54	)
150	42	STO
151	68	68
152	43	RCL
153	58	58
154	32	X<=>T
155	43	RCL
156	52	52
157	32	X<=>T
158	22	INV
159	77	2ND X>=T
160	01	01
161	74	74
162	53	(
163	43	RCL
164	65	65
165	75	-
166	43	RCL
167	68	68
168	54	)
169	42	STO
170	68	68
171	61	GTO
172	01	01
173	85	85
174	53	(
175	03	3
176	65	*
177	43	RCL
178	65	65
179	85	+
180	43	RCL
181	68	68
182	54	)
183	42	STO
184	68	68
185	92	INV SBR
186	76	2ND LBL
187	14	D
188	43	RCL
189	67	67
190	32	X<=>T
191	43	RCL
192	47	47
193	22	INV

```
194   77   2ND  X>=T
195   02   02
196   44   44
197   53   (
198   43   RCL
199   11   11
200   42   STO
201   71   71
202   43   RCL
203   12   12
204   42   STO
205   72   72
206   43   RCL
207   13   13
208   42   STO
209   73   73
210   43   RCL
211   14   14
212   42   STO
213   74   74
214   43   RCL
215   15   15
216   42   STO
217   75   75
218   43   RCL
219   16   16
220   42   STO
221   76   76
222   43   RCL
223   19   19
224   42   STO
225   77   77
226   43   RCL
227   18   18
228   42   STO
229   78   78
230   43   RCL
231   17   17
232   42   STO
233   79   79
234   53   (
235   71   SBR
236   15   E
237   54   )
238   54   )
239   42   STO
240   69   69
241   61   GTO
242   04   04
243   16   16
244   43   RCL
245   67   67
246   32   X<=>T
247   43   RCL
248   48   48
249   22   INV
250   77   2ND  X>=T
251   03   03
252   00   00
253   53   (
254   43   RCL
255   20   20
256   42   STO
257   71   71
258   43   RCL
259   21   21
260   42   STO
261   72   72
262   43   RCL
```

```
263   22   22
264   42   STO
265   73   73
266   43   RCL
267   23   23
268   42   STO
269   74   74
270   43   RCL
271   24   24
272   42   STO
273   75   75
274   43   RCL
275   25   25
276   42   STO
277   76   76
278   43   RCL
279   28   28
280   42   STO
281   77   77
282   43   RCL
283   27   27
284   42   STO
285   78   78
286   43   RCL
287   26   26
288   42   STO
289   79   79
290   53   (
291   71   SBR
292   15   E
293   54   )
294   54   )
295   42   STO
296   69   69
297   61   GTO
298   04   04
299   16   16
300   43   RCL
301   67   67
302   32   X<=>T
303   43   RCL
304   49   49
305   22   INV
306   77   2ND  X>=T
307   03   03
308   56   56
309   53   (
310   43   RCL
311   29   29
312   42   STO
313   71   71
314   43   RCL
315   30   30
316   42   STO
317   72   72
318   43   RCL
319   31   31
320   42   STO
321   73   73
322   43   RCL
323   32   32
324   42   STO
325   74   74
326   43   RCL
327   33   33
328   42   STO
329   75   75
330   43   RCL
331   34   34
```

```
332   42   STO
333   76   76
334   43   RCL
335   37   37
336   42   STO
337   77   77
338   43   RCL
339   36   36
340   42   STO
341   78   78
342   43   RCL
343   35   35
344   42   STO
345   79   79
346   53   (
347   71   SBR
348   15   E
349   54   )
350   54   )
351   42   STO
352   69   69
353   61   GTO
354   04   04
355   16   16
356   43   RCL
357   67   67
358   32   X<=>T
359   43   RCL
360   50   50
361   22   INV
362   77   2ND  X>=T
363   04   04
364   12   12
365   53   (
366   43   RCL
367   38   38
368   42   STO
369   71   71
370   43   RCL
371   39   39
372   42   STO
373   72   72
374   43   RCL
375   40   40
376   42   STO
377   73   73
378   43   RCL
379   41   41
380   42   STO
381   74   74
382   43   RCL
383   42   42
384   42   STO
385   75   75
386   43   RCL
387   43   43
388   42   STO
389   76   76
390   43   RCL
391   46   46
392   42   STO
393   77   77
394   43   RCL
395   45   45
396   42   STO
397   78   78
398   43   RCL
399   44   44
400   42   STO
```

401	79	79
402	53	(
403	71	SBR
404	15	E
405	54	)
406	54	)
407	42	STO
408	69	69
409	61	GTO
410	04	04
411	16	16
412	43	RCL
413	67	67
414	99	2ND PRT
415	98	2ND ADV
416	92	INV SBR
417	76	2ND LBL
418	15	E
419	00	0
420	42	STO
421	70	70
422	53	(
423	53	(
424	43	RCL
425	72	72
426	94	+/-
427	85	+
428	53	(
429	43	RCL
430	72	72
431	45	Y**X
432	02	2
433	75	-
434	53	(
435	04	4
436	65	*
437	43	RCL
438	71	71
439	65	*
440	53	(
441	43	RCL
442	73	73
443	75	-
444	43	RCL
445	67	67
446	65	*
447	43	RCL
448	56	56
449	54	)
450	54	)
451	54	)
452	34	SQRT(X)
453	54	)
454	55	/
455	53	(
456	02	2
457	65	*
458	43	RCL
459	71	71
460	54	)
461	54	)
462	42	STO
463	80	80
464	43	RCL
465	80	80
466	32	X<=>T
467	43	RCL
468	51	51
469	77	2ND X>=T

```
470    04    04
471    82    82
472    43    RCL
473    68    68
474    99    2ND  PRT
475    43    RCL
476    67    67
477    99    2ND  PRT
478    98    2ND  ADV
479    61    GTO
480    05    05
481    65    65
482    53    (
483    43    RCL
484    76    76
485    85    +
486    43    RCL
487    75    75
488    65    *
489    43    RCL
490    80    80
491    85    +
492    43    RCL
493    74    74
494    65    *
495    43    RCL
496    80    80
497    45    Y**X
498    02    2
499    54    )
500    99    2ND  PRT
501    98    2ND  ADV
502    53    (
503    43    RCL
504    66    66
505    85    +
506    43    RCL
507    57    57
508    85    +
509    53    (
510    43    RCL
511    55    55
512    75    -
513    43    RCL
514    68    68
515    54    )
516    85    +
517    53    (
518    43    RCL
519    79    79
520    85    +
521    43    RCL
522    78    78
523    65    *
524    43    RCL
525    80    80
526    85    +
527    43    RCL
528    77    77
529    65    *
530    43    RCL
531    80    80
532    45    Y**X
533    02    2
534    54    )
535    54    )
536    99    2ND  PRT
537    98    2ND  ADV
538    53    (
```

```
539   43   RCL
540   80   80
541   85   +
542   53   (
543   53   (
544   43   RCL
545   60   60
546   75   -
547   43   RCL
548   54   54
549   85   +
550   02   2
551   00   0
552   54   )
553   55   /
554   43   RCL
555   67   67
556   65   *
557   01   1
558   00   0
559   00   0
560   00   0
561   54   )
562   54   )
563   99   2ND  PRT
564   98   2ND  ADV
565   43   RCL
566   70   70
567   92   INV  SBR
```

BAX59 SYMBOL TABLE DUMP

BUCKET	CONTENTS	REG	TYP
03			
	REFDEF	66	GLOBAL VAR
05			
	LOG10	..	QUICK FN
06			
	GRIDA	60	GLOBAL VAR
08			
	EL	80	GLOBAL VAR
10			
	GRIDE	58	GLOBAL VAR
13			
	FP	..	QUICK FN
	ABS	..	QUICK FN
14			
	FN_FD	70	PARAMETER FN
16			
	PI	..	CONSTANT
	IP	..	QUICK FN
	CSC	..	QUICK FN
18			
	SEC	..	QUICK FN
20			
	DFCOR	57	GLOBAL VAR
24			
	LOG	..	QUICK FN
26			
	GRIDN	59	GLOBAL VAR
	RGK	56	GLOBAL VAR
	RND	10	LONG FN
28			
	ACOS	..	QUICK FN
30			
	MILRAD	64	GLOBAL VAR

33	TAN	..	QUICK FN
	ATN	..	QUICK FN
	ASIN	..	QUICK FN
35	COS	..	QUICK FN
36	COT	..	QUICK FN
38	RGDEV	63	GLOBAL VAR
40	SIN	..	QUICK FN
41	OT	61	GLOBAL VAR
43	EXP	..	QUICK FN
53	LATDEV	62	GLOBAL VAR
59	SQR	..	QUICK FN
63	BTRYA	54	GLOBAL VAR
64	INVOKE	69	GLOBAL VAR
67	BTRYE	52	GLOBAL VAR
69	TGTRG	67	GLOBAL VAR
71	HACROSS	51	GLOBAL VAR
74	CHG4MAX	47	GLOBAL VAR
75	CHG5MAX	48	GLOBAL VAR
77	CHG7MAX	49	GLOBAL VAR
	A04	13	GLOBAL VAR
78	CHG8MAX	50	GLOBAL VAR
	A05	22	GLOBAL VAR
	B04	17	GLOBAL VAR
	A14	12	GLOBAL VAR
79	TGTAZ	68	GLOBAL VAR
	B05	26	GLOBAL VAR
	A15	21	GLOBAL VAR
	B14	18	GLOBAL VAR
	C04	16	GLOBAL VAR
	A24	11	GLOBAL VAR
80	A07	31	GLOBAL VAR
	B15	27	GLOBAL VAR
	C05	25	GLOBAL VAR
	A25	20	GLOBAL VAR
	B24	19	GLOBAL VAR
	C14	15	GLOBAL VAR
81	BTRYL	55	GLOBAL VAR
	A08	40	GLOBAL VAR
	B07	35	GLOBAL VAR
	A17	30	GLOBAL VAR
	B25	28	GLOBAL VAR
	C15	24	GLOBAL VAR
	C24	14	GLOBAL VAR
82	B08	44	GLOBAL VAR
	A18	39	GLOBAL VAR
	B17	36	GLOBAL VAR
	C07	34	GLOBAL VAR

	A27	29	GLOBAL VAR
	C25	23	GLOBAL VAR
83	BTRYN	53	GLOBAL VAR
	B18	45	GLOBAL VAR
	C08	43	GLOBAL VAR
	A28	38	GLOBAL VAR
	B27	37	GLOBAL VAR
	C17	33	GLOBAL VAR
84	ROTCOR	65	GLOBAL VAR
	B28	46	GLOBAL VAR
	C18	42	GLOBAL VAR
	C27	32	GLOBAL VAR
85	C28	41	GLOBAL VAR

APPENDIX M

TEST PROGRAM NAME MAPPING FILE (NAMEF)

TI-59 REGISTER TO NAME MAPPING

REG#	BASIC NAME
11	A24
12	A14
13	A04
14	C24
15	C14
16	C04
17	B04
18	B14
19	B24
20	A25
21	A15
22	A05
23	C25
24	C15
25	C05
26	B05
27	B15
28	B25
29	A27
30	A17
31	A07
32	C27
33	C17
34	C07
35	B07
36	B17
37	B27
38	A28
39	A18
40	A08
41	C28
42	C18
43	C08
44	B08
45	B18
46	B28
47	CHG4MAX
48	CHG5MAX
49	CHG7MAX
50	CHG8MAX
51	HACROSS
52	BTRYE
53	BTRYN
54	BTRYA
55	BTRYL
56	RGK
57	DFCOR
58	GRIDE
59	GRIDN
60	GRIDA
61	OT
62	LATDEV
63	RGDEV

```
64    MILRAD
65    ROTCOR
66    REFDEF
67    TGTRG
68    TGTAZ
69    INVOKE
70    FN_FD
71        (FN   PARAMETER)
72        (FN   PARAMETER)
73        (FN   PARAMETER)
74        (FN   PARAMETER)
75        (FN   PARAMETER)
76        (FN   PARAMETER)
77        (FN   PARAMETER)
78        (FN   PARAMETER)
79        (FN   PARAMETER)
80    EL
```

APPENDIX N

TEST PROGRAM DATA/READ MAPPING FILE (READF)

INPUT DATA TO READ MAPPING

DATA	REG	NAME
-.0133670	11	A24
21.2691	12	A14
-105.7	13	A04
-.00001499	14	C24
.06630	15	C14
-.41	16	C04
.77	17	B04
.01314	18	B14
.00001720	19	B24
-.0149331	20	A25
24.3439	21	A15
64.7	22	A05
-.00001420	23	C25
.07069	24	C15
.06	25	C05
1.26	26	B05
.01508	27	B15
.00001678	28	B25
-.0173835	29	A27
29.8741	30	A17
2255.2	31	A07
-.00001668	32	C27
.08487	33	C17
3.29	34	C07
1.3	35	B07
.02713	36	B17
.00001306	37	B27
-.0182137	38	A28
32.3731	39	A18
4107.4	40	A08
-.00001668	41	C28
.09272	42	C18
5.74	43	C08
1.36	44	B08
.02891	45	B18
.00001410	46	B28
5700	47	CHG4MAX
7000	48	CHG5MAX
10800	49	CHG7MAX
17600	50	CHG8MAX

715	51	HACROSS
0	52	BTRYE
0	53	BTRYN
0	54	BTRYA
800	55	BTRYL
1.0	56	RGK
0	57	DFCOR
4000	58	GRIDE
4000	59	GRIDN
10	60	GRIDA
4000	61	OT
-400	62	LATDEV
10	63	RGDEV
1018.5924	64	MILRAD
1600	65	ROTCOR
3200	66	REFDEF

APPENDIX O

TEST PROGRAM LINK INTERFACE FILE (SCRATCH)

```
$1
81 IS NEXT AVAILABLE REG.
$1

$2

=================================================================
                TI-59 CODE TRANSLATED FROM WBASIC
                         (UNSEGMENTED)
=================================================================

     ADDR    CODE
$0 ------------------------------------------ BEGIN TI-59 CODE.
     000     76     2ND  LBL
     001     11     A
     002     71     SBR
     003     12     B
     004     68     2ND  NOP
     005     71     SBR
     006     13     C
     007     68     2ND  NOP
     008     71     SBR
     009     14     D
     010     68     2ND  NOP
     011     24     CE
     012     08     8
     013     08     8
     014     08     8
     015     91     R/S
     016     76     2ND  LBL
     017     12     B
     018     53     (
     019     43     RCL
     020     59     59
     021     85     +
     022     53     (
     023     43     RCL
     024     63     63
     025     65     *
     026     53     (
     027     53     (
     028     43     RCL
     029     65     65
     030     75     -
     031     43     RCL
     032     61     61
     033     54     )
     034     55     /
     035     43     RCL
     036     64     64
     037     54     )
     038     38     2ND  SIN
     039     75     -
     040     43     RCL
     041     62     62
     042     65     *
     043     53     (
     044     53     (
     045     43     RCL
```

```
046   65   65
047   75   -
048   43   RCL
049   61   61
050   54   )
051   55   /
052   43   RCL
053   64   64
054   54   )
055   39   2ND  COS
056   54   )
057   54   )
058   42   STO
059   59   59
060   53   (
061   43   RCL
062   58   58
063   85   +
064   53   (
065   43   RCL
066   63   63
067   65   *
068   53   (
069   53   (
070   43   RCL
071   65   65
072   75   -
073   43   RCL
074   61   61
075   54   )
076   55   /
077   43   RCL
078   64   64
079   54   )
080   39   2ND  COS
081   85   +
082   43   RCL
083   62   62
084   65   *
085   53   (
086   53   (
087   43   RCL
088   65   65
089   75   -
090   43   RCL
091   61   61
092   54   )
093   55   /
094   43   RCL
095   64   64
096   54   )
097   38   2ND  SIN
098   54   )
099   54   )
100   42   STO
101   58   58
102   92   INV  SBR
103   76   2ND  LBL
104   13   C
105   53   (
106   53   (
107   53   (
108   43   RCL
109   58   58
110   75   -
111   43   RCL
112   52   52
113   54   )
114   45   Y**X
```

```
115  02  2
116  85  +
117  53  (
118  43  RCL
119  59  59
120  75  -
121  43  RCL
122  53  53
123  54  )
124  45  Y**X
125  02  2
126  54  )
127  34  SQRT(X)
128  54  )
129  42  STO
130  67  67
131  53  (
132  53  (
133  53  (
134  43  RCL
135  59  59
136  75  -
137  43  RCL
138  53  53
139  54  )
140  55  /
141  43  RCL
142  67  67
143  54  )
144  27  2ND  INV
145  38  2ND  SIN
146  65  *
147  43  RCL
148  64  64
149  54  )
150  42  STO
151  68  68
152  43  RCL
153  58  58
154  32  X<=>T
155  43  RCL
156  52  52
157  32  X<=>T
158  22  INV
159  77  2ND  X>=T
160  01  01
161  74  74
162  53  (
163  43  RCL
164  65  65
165  75  -
166  43  RCL
167  68  68
168  54  )
169  42  STO
170  68  68
171  61  GTO
172  01  01
173  85  85
174  53  (
175  03  3
176  65  *
177  43  RCL
178  65  65
179  85  +
180  43  RCL
181  68  68
182  54  )
183  42  STO
```

184	68	68
185	92	INV SBR
186	76	2ND LBL
187	14	D
188	43	RCL
189	67	67
190	32	X<=>T
191	43	RCL
192	47	47
193	22	INV
194	77	2ND X>=T
195	02	02
196	44	44
197	53	(
198	43	RCL
199	11	11
200	42	STO
201	71	71
202	43	RCL
203	12	12
204	42	STO
205	72	72
206	43	RCL
207	13	13
208	42	STO
209	73	73
210	43	RCL
211	14	14
212	42	STO
213	74	74
214	43	RCL
215	15	15
216	42	STO
217	75	75
218	43	RCL
219	16	16
220	42	STO
221	76	76
222	43	RCL
223	19	19
224	42	STO
225	77	77
226	43	RCL
227	18	18
228	42	STO
229	78	78
230	43	RCL
231	17	17
232	42	STO
233	79	79
234	53	(
235	71	SBR
236	15	E
237	54	)
238	54	)
239	42	STO
240	69	69
241	61	GTO
242	04	04
243	16	16
244	43	RCL
245	67	67
246	32	X<=>T
247	43	RCL
248	48	48
249	22	INV
250	77	2ND X>=T
251	03	03
252	00	00

```
253  53  (
254  43  RCL
255  20  20
256  42  STO
257  71  71
258  43  RCL
259  21  21
260  42  STO
261  72  72
262  43  RCL
263  22  22
264  42  STO
265  73  73
266  43  RCL
267  23  23
268  42  STO
269  74  74
270  43  RCL
271  24  24
272  42  STO
273  75  75
274  43  RCL
275  25  25
276  42  STO
277  76  76
278  43  RCL
279  28  28
280  42  STO
281  77  77
282  43  RCL
283  27  27
284  42  STO
285  78  78
286  43  RCL
287  26  26
288  42  STO
289  79  79
290  53  (
291  71  SBR
292  15  E
293  54  )
294  54  )
295  42  STO
296  69  69
297  61  GTO
298  04  04
299  16  16
300  43  RCL
301  67  67
302  32  X<=>T
303  43  RCL
304  49  49
305  22  INV
306  77  2ND  X>=T
307  03  03
308  56  56
309  53  (
310  43  RCL
311  29  29
312  42  STO
313  71  71
314  43  RCL
315  30  30
316  42  STO
317  72  72
318  43  RCL
319  31  31
320  42  STO
321  73  73
```

```
322   43   RCL
323   32   32
324   42   STO
325   74   74
326   43   RCL
327   33   33
328   42   STO
329   75   75
330   43   RCL
331   34   34
332   42   STO
333   76   76
334   43   RCL
335   37   37
336   42   STO
337   77   77
338   43   RCL
339   36   36
340   42   STO
341   78   78
342   43   RCL
343   35   35
344   42   STO
345   79   79
346   53   (
347   71   SBR
348   15   E
349   54   )
350   54   )
351   42   STO
352   69   69
353   61   GTO
354   04   04
355   16   16
356   43   RCL
357   67   67
358   32   X<=>T
359   43   RCL
360   50   50
361   22   INV
362   77   2ND  X>=T
363   04   04
364   12   12
365   53   (
366   43   RCL
367   38   38
368   42   STO
369   71   71
370   43   RCL
371   39   39
372   42   STO
373   72   72
374   43   RCL
375   40   40
376   42   STO
377   73   73
378   43   RCL
379   41   41
380   42   STO
381   74   74
382   43   RCL
383   42   42
384   42   STO
385   75   75
386   43   RCL
387   43   43
388   42   STO
389   76   76
390   43   RCL
```

```
391   46   46
392   42   STO
393   77   77
394   43   RCL
395   45   45
396   42   STO
397   78   78
398   43   RCL
399   44   44
400   42   STO
401   79   79
402   53   (
403   71   SBR
404   15   E
405   54   )
406   54   )
407   42   STO
408   69   69
409   61   GTO
410   04   04
411   16   16
412   43   RCL
413   67   67
414   99   2ND  PRT
415   98   2ND  ADV
416   92   INV  SBR
417   76   2ND  LBL
418   15   E
419   00   0
420   42   STO
421   70   70
422   53   (
423   53   (
424   43   RCL
425   72   72
426   94   +/-
427   85   +
428   53   (
429   43   RCL
430   72   72
431   45   Y**X
432   02   2
433   75   -
434   53   (
435   04   4
436   65   *
437   43   RCL
438   71   71
439   65   *
440   53   (
441   43   RCL
442   73   73
443   75   -
444   43   RCL
445   67   67
446   65   *
447   43   RCL
448   56   56
449   54   )
450   54   )
451   54   )
452   34   SQRT(X)
453   54   )
454   55   /
455   53   (
456   02   2
457   65   *
458   43   RCL
459   71   71
```

```
460   54   )
461   54   )
462   42   STO
463   80   80
464   43   RCL
465   80   80
466   32   X<=>T
467   43   RCL
468   51   51
469   77   2ND  X>=T
470   04   04
471   82   82
472   43   RCL
473   68   68
474   99   2ND  PRT
475   43   RCL
476   67   67
477   99   2ND  PRT
478   98   2ND  ADV
479   61   GTO
480   05   05
481   65   65
482   53   (
483   43   RCL
484   76   76
485   85   +
486   43   RCL
487   75   75
488   65   *
489   43   RCL
490   80   80
491   85   +
492   43   RCL
493   74   74
494   65   *
495   43   RCL
496   80   80
497   45   Y**X
498   02   2
499   54   )
500   99   2ND  PRT
501   98   2ND  ADV
502   53   (
503   43   RCL
504   66   66
505   85   +
506   43   RCL
507   57   57
508   85   +
509   53   (
510   43   RCL
511   55   55
512   75   -
513   43   RCL
514   68   68
515   54   )
516   85   +
517   53   (
518   43   RCL
519   79   79
520   85   +
521   43   RCL
522   78   78
523   65   *
524   43   RCL
525   80   80
526   85   +
527   43   RCL
528   77   77
```

```
529    65    *
530    43    RCL
531    80    80
532    45    Y**X
533    02    2
534    54    )
535    54    )
536    99    2ND  PRT
537    98    2ND  ADV
538    53    (
539    43    RCL
540    80    80
541    85    +
542    53    (
543    53    (
544    43    RCL
545    60    60
546    75    -
547    43    RCL
548    54    54
549    85    +
550    02    2
551    00    0
552    54    )
553    55    /
554    43    RCL
555    67    67
556    65    *
557    01    1
558    00    0
559    00    0
560    00    0
561    54    )
562    54    )
563    99    2ND  PRT
564    98    2ND  ADV
565    43    RCL
566    70    70
567    92    INV  SBR
-1 ------------------------------------------------------------ END TI-59 CODE.
$2
```

TI-59 REGISTER TO NAME MAPPING

REG#	BASIC NAME
11	A24
12	A14
13	A04
14	C24
15	C14
16	C04
17	B04
18	B14
19	B24
20	A25
21	A15
22	A05
23	C25
24	C15
25	C05
26	B05
27	B15
28	B25
29	A27
30	A17
31	A07
32	C27
33	C17
34	C07
35	B07
36	B17
37	B27
38	A28
39	A18
40	A08
41	C28
42	C18
43	C08
44	B08
45	B18
46	B28
47	CHG4MAX
48	CHG5MAX
49	CHG7MAX
50	CHG8MAX
51	HACROSS
52	BTRYE
53	BTRYN
54	BTRYA
55	BTRYL
56	RGK
57	DFCOR
58	GRIDE
59	GRIDN
60	GRIDA
61	OT
62	LATDEV
63	RGDEV
64	MILRAD
65	ROTCOR
66	REFDEF
67	TGTRG
68	TGTAZ
69	INVOKE
70	FN_FD
71	(FN PARAMETER)
72	(FN PARAMETER)

```
        73    (FN  PARAMETER)
        74    (FN  PARAMETER)
        75    (FN  PARAMETER)
        76    (FN  PARAMETER)
        77    (FN  PARAMETER)
        78    (FN  PARAMETER)
        79    (FN  PARAMETER)
        80   EL
$3
```

INPUT DATA TO READ MAPPING

DATA	REG	NAME
-.0133670	11	A24
21.2691	12	A14
-105.7	13	A04
-.00001499	14	C24
.06630	15	C14
-.41	16	C04
.77	17	B04
.01314	18	B14
.00001720	19	B24
-.0149331	20	A25
24.3439	21	A15
64.7	22	A05
-.00001420	23	C25
.07069	24	C15
.06	25	C05
1.26	26	B05
.01508	27	B15
.00001678	28	B25
-.0173835	29	A27
29.8741	30	A17
2255.2	31	A07
-.00001668	32	C27
.08487	33	C17
3.29	34	C07
1.3	35	B07
.02713	36	B17
.00001306	37	B27
-.0182137	38	A28
32.3731	39	A18
4107.4	40	A08
-.00001668	41	C28
.09272	42	C18
5.74	43	C08
1.36	44	B08
.02891	45	B18
.00001410	46	B28
5700	47	CHG4MAX
7000	48	CHG5MAX
10800	49	CHG7MAX
17600	50	CHG8MAX
715	51	HACROSS
0	52	BTRYE
0	53	BTRYN
0	54	BTRYA
800	55	BTRYL
1.0	56	RGK
0	57	DFCOR

4000	58	GRIDE
4000	59	GRIDN
10	60	GRIDA
4000	61	OT
-400	62	LATDEV
10	63	RGDEV
1018.5924	64	MILRAD
1600	65	ROTCOR
3200	66	REFDEF

$4

APPENDIX P

TEST PROGRAM LINKER OUTPUT

```
================================================================
        BAX59 PROGRAM INSTRUCTIONS: VERSION 1.0
================================================================

  * CONGRATULATIONS, YOU HAVE JUST COMPILED A BASIC PROGRAM
      INTO A TI-59 PROGRAM.  IN SO DOING IT IS VERY POSSIBLE
      THAT YOUR PROGRAM IS LARGER THAN THE MEMORY OF THE
      CALCULATOR.  IF THIS IS THE CASE THEN THE PROGRAM HAS
      BEEN SEGMENTED AND PROMPTING CODE INSERTED TO GUIDE
      YOUR CALCULATOR PROGRAM DURING ITS EXECUTION. THE RE-
      MAINDER OF THIS OUTPUT CONSISTS OF TI-59 CODE LISTINGS
      AND OTHER INFORMATION TO AID YOU IN YOUR PROGRAM
      EXECUTION.

  * THE FOLLOWING DEFINITIONS ARE PROVIDED AS AN AID TO
      READING THE PROGRAM LISTING FILE.

    * DEFINITIONS:

      * MODULE: A MODULE IS DEFINED TO BE ALL THE MEMORY
          DEDICATED TO PROGRAM STEPS.  THE SIZE IS VARI-
          ABLE AND IS DEPENDENT ON THE REGISTER REQUIRE-
          MENT.  VALUES RANGE FROM 0 TO 239, 479 OR 719
          DEPENDING ON THE AMOUNT OF REGISTERS USED BY
          THE PROGRAM.

      * CARD: A CARD IS DEFINED TO BE ONE MAGNETIC CARD.
          A CARD HOLDS 480 PROGRAM STEPS.  THESE STEPS
          ARE NOT CONTIGUOUS BUT ARE ARRANGED ON THE TWO
          SIDES OF THE CARD.

      * SIDE: A SIDE IS ONE HALF OF A CARD. IT CONTAINS
          UP TO 240 STEPS.  WHEN ONE SIDE OF A CARD IS
          READ BY THE CALCULATOR 240 PROGRAM STEPS ARE
          FILLED IN MEMORY.  THESE BLOCKS OF 240 STEPS
          ARE REFERED TO AS "BANKS" IN THE MANUFACTURER
          LITERATURE.  WHEN LOADING A CARD YOU WILL LOAD
          ONLY BANK NUMBER 1 AND/OR 2 FOR PROGRAM STEPS.

      * PARTITION: THIS IS DEFINED TO BE THE CURRENT
          SETTING OF CALCULATOR MEMORY AS APPLIED TO THE
          AMOUNT OF MEMORY DEDICATED TO STORAGE REGISTERS
          AND THE AMOUNT DEDICATED TO PROGRAM STEPS.
          WE WILL BE DEALING WITH 3 PARTITIONS. THESE
          ARE:
                         3        719.29
                         4        479.59
                         5        239.69

          FORMAT:        X        YYY.ZZ

          WHERE X STANDS FOR PARTITION NUMBER
                YYY STANDS FOR PROGRAM STEPS (0-YYY)
                ZZ STANDS FOR REGISTERS (0-ZZ).
```

==
TI 59 PROGRAM LISTING BY MODULE/CARD/SIDE:
==

* THE FOLLOWING IS YOUR PROGRAM LISTING. THE PROGRAM IS LISTED ACCORDING TO MODULE NUMBER AND ITS ASSOCIATED CARDS AND CARD SIDES.

* REFER TO THE TI-59 PROGRAMMER'S GUIDE ON HOW TO INPUT A PROGRAM AND WRITE IT TO MAGNETIC CARDS.

* CAUTION: ENSURE THAT THE CORRECT CALCULATOR PARTITION IS SET BEFORE INPUTTING A PROGRAM AND WRITING TO MAGNETIC CARDS.

* CAUTION: ENSURE THAT YOU DO NOT CONFUSE BANK NUMBERS WITH CARD/MODULE OR SIDE NUMBERS. THE NUMBERS WHICH REFER TO THE LISTING ARE AKIN TO A VIRTUAL ADDRESS AND DO NOT REPRESENT THE ACTUAL BANK NUMBER. IF IN DOUBT, REMEMBER TO USE THE TABLE BELOW TO TRANSLATE VIRTUAL TO ACTUAL BANK NUMBERS.

```
VIRTUAL BANK                                ACTUAL BANK

MODULE #
CARD1
SIDE1 ---------------------------------- BANK1

MODULE #
CARD1
SIDE2 ---------------------------------- BANK2

MODULE #
CARD2
SIDE1 ---------------------------------- BANK3
```

==
TI-59 LISTING
==

* MANUAL RETURN REGISTER TOP IS 81
  STORE IN REGISTER: 8

* PROGRAM PARTITION IS 239.89

* PARTITION NUMBER IS 9

```
*MODULE # 1
   CARD #1
   SIDE #1
            000   76          2ND LBL
            001   11          A
            002   71          SBR
            003   12          B
            004   68          2ND NOP
            005   71          SBR
            006   13          C
            007   68          2ND NOP
            008   71          SBR
            009   14          D
            010   68          2ND NOP
            011   24          CE
            012   08          8
            013   08          8
```

014	08	8
015	91	R/S
016	76	2ND LBL
017	14	D
018	42	STO
019	00	00
020	69	2ND OP
021	28	28
022	01	1
023	72	STO 2ND IND
024	08	08
025	02	2
026	93	.
027	00	0
028	00	0
029	00	0
030	91	R/S
031	76	2ND LBL
032	12	B
033	53	(
034	43	RCL
035	59	59
036	85	+
037	53	(
038	43	RCL
039	63	63
040	65	X
041	53	(
042	53	(
043	43	RCL
044	65	65
045	75	-
046	43	RCL
047	61	61
048	54	)
049	55	/
050	43	RCL
051	64	64
052	54	)
053	38	2ND SIN
054	75	-
055	43	RCL
056	62	62
057	65	X
058	53	(
059	53	(
060	43	RCL
061	65	65
062	75	-
063	43	RCL
064	61	61
065	54	)
066	55	/
067	43	RCL
068	64	64
069	54	)
070	39	2ND COS
071	54	)
072	54	)
073	42	STO
074	59	59
075	53	(
076	43	RCL
077	58	58
078	85	+
079	53	(
080	43	RCL
081	63	63
082	65	X

```
083   53   (
084   53   (
085   43   RCL
086   65   65
087   75   -
088   43   RCL
089   61   61
090   54   )
091   55   /
092   43   RCL
093   64   64
094   54   )
095   39   2ND COS
096   85   +
097   43   RCL
098   62   62
099   65   X
100   53   (
101   53   (
102   43   RCL
103   65   65
104   75   -
105   43   RCL
106   61   61
107   54   )
108   55   /
109   43   RCL
110   64   64
111   54   )
112   38   2ND SIN
113   54   )
114   54   )
115   42   STO
116   58   58
117   92   INV SBR
118   76   2ND LBL
119   13   C
120   53   (
121   53   (
122   53   (
123   43   RCL
124   58   58
125   75   -
126   43   RCL
127   52   52
128   54   )
129   45   Y**X
130   02   2
131   85   +
132   53   (
133   43   RCL
134   59   59
135   75   -
136   43   RCL
137   53   53
138   54   )
139   45   Y**X
140   02   2
141   54   )
142   34   SQRT(X)
143   54   )
144   42   STO
145   67   67
146   53   (
147   53   (
148   53   (
149   43   RCL
150   59   59
151   75   -
```

152	43	RCL
153	53	53
154	54	)
155	55	/
156	43	RCL
157	67	67
158	54	)
159	27	2ND INV
160	38	2ND SIN
161	65	X
162	43	RCL
163	64	64
164	54	)
165	42	STO
166	68	68
167	43	RCL
168	58	58
169	32	X<=>T
170	43	RCL
171	52	52
172	32	X<=>T
173	22	INV
174	77	2ND X>=T
175	01	01
176	89	89
177	53	(
178	43	RCL
179	65	65
180	75	-
181	43	RCL
182	68	68
183	54	)
184	42	STO
185	68	68
186	61	GTO
187	02	02
188	00	00
189	53	(
190	03	3
191	65	X
192	43	RCL
193	65	65
194	85	+
195	43	RCL
196	68	68
197	54	)
198	42	STO
199	68	68
200	92	INV SBR

*MODULE # 2
CARD #1
SIDE #1

```
000   76   2ND LBL
001   14   D
002   43   RCL
003   67   67
004   32   X<=>T
005   43   RCL
006   47   47
007   22   INV
008   77   2ND X>=T
009   00   00
010   58   58
011   53   (
012   43   RCL
013   11   11
014   42   STO
015   71   71
016   43   RCL
017   12   12
018   42   STO
019   72   72
020   43   RCL
021   13   13
022   42   STO
023   73   73
024   43   RCL
025   14   14
026   42   STO
027   74   74
028   43   RCL
029   15   15
030   42   STO
031   75   75
032   43   RCL
033   16   16
034   42   STO
035   76   76
036   43   RCL
037   19   19
038   42   STO
039   77   77
040   43   RCL
041   18   18
042   42   STO
043   78   78
044   43   RCL
045   17   17
046   42   STO
047   79   79
048   53   (
049   71   SBR
050   15   E
051   54   )
052   54   )
053   42   STO
054   69   69
055   61   GTO
056   01   01
057   23   23
058   43   RCL
059   67   67
060   32   X<=>T
061   43   RCL
062   48   48
063   22   INV
064   77   2ND X>=T
```

065	01	01
066	32	32
067	53	(
068	43	RCL
069	20	20
070	42	STO
071	71	71
072	43	RCL
073	21	21
074	42	STO
075	72	72
076	43	RCL
077	22	22
078	42	STO
079	73	73
080	43	RCL
081	23	23
082	42	STO
083	74	74
084	43	RCL
085	24	24
086	42	STO
087	75	75
088	43	RCL
089	25	25
090	42	STO
091	76	76
092	43	RCL
093	28	28
094	42	STO
095	77	77
096	43	RCL
097	27	27
098	42	STO
099	78	78
100	43	RCL
101	26	26
102	42	STO
103	79	79
104	53	(
105	71	SBR
106	15	E
107	54	)
108	54	)
109	42	STO
110	69	69
111	61	GTO
112	01	01
113	23	23
114	42	STO
115	00	00
116	24	CE
117	03	3
118	93	.
119	00	0
120	00	0
121	00	0
122	91	R/S
123	42	STO
124	00	00
125	24	CE
126	03	3
127	93	.
128	01	1
129	01	1
130	06	6
131	91	R/S
132	42	STO
133	00	00

```
134    24          CE
135    03          3
136    93          .
137    00          0
138    00          0
139    00          0
140    91          R/S
141    76          2ND LBL
142    15          E
143    42          STO
144    00          00
145    69          2ND OP
146    28          28
147    02          2
148    72          STO 2ND IND
149    08          08
150    04          4
151    93          .
152    00          0
153    00          0
154    00          0
155    91          R/S
```

```
*MODULE # 3
     CARD #1
     SIDE #1
```

```
000    43          RCL
001    67          67
002    32          X<=>T
003    43          RCL
004    49          49
005    22          INV
006    77          2ND X>=T
007    00          00
008    56          56
009    53          (
010    43          RCL
011    29          29
012    42          STO
013    71          71
014    43          RCL
015    30          30
016    42          STO
017    72          72
018    43          RCL
019    31          31
020    42          STO
021    73          73
022    43          RCL
023    32          32
024    42          STO
025    74          74
026    43          RCL
027    33          33
028    42          STO
029    75          75
030    43          RCL
031    34          34
032    42          STO
033    76          76
034    43          RCL
035    37          37
036    42          STO
037    77          77
038    43          RCL
039    36          36
040    42          STO
```

```
041  78  78
042  43  RCL
043  35  35
044  42  STO
045  79  79
046  53  (
047  71  SBR
048  15  E
049  54  )
050  54  )
051  42  STO
052  69  69
053  61  GTO
054  01  01
055  16  16
056  43  RCL
057  67  67
058  32  X<=>T
059  43  RCL
060  50  50
061  22  INV
062  77  2ND  X>=T
063  01  01
064  12  12
065  53  (
066  43  RCL
067  38  38
068  42  STO
069  71  71
070  43  RCL
071  39  39
072  42  STO
073  72  72
074  43  RCL
075  40  40
076  42  STO
077  73  73
078  43  RCL
079  41  41
080  42  STO
081  74  74
082  43  RCL
083  42  42
084  42  STO
085  75  75
086  43  RCL
087  43  43
088  42  STO
089  76  76
090  43  RCL
091  46  46
092  42  STO
093  77  77
094  43  RCL
095  45  45
096  42  STO
097  78  78
098  43  RCL
099  44  44
100  42  STO
101  79  79
102  53  (
103  71  SBR
104  15  E
105  54  )
106  54  )
107  42  STO
108  69  69
109  61  GTO
```

```
110   01    01
111   16    16
112   43    RCL
113   67    67
114   99    2ND PRT
115   98    2ND ADV
116   42    STO
117   00    00
118   73    RCL 2ND IND
119   08    08
120   69    2ND OP
121   38    38
122   91    R/S
123   76    2ND LBL
124   15    E
125   42    STO
126   00    00
127   69    2ND OP
128   28    28
129   03    3
130   72    STO 2ND IND
131   08    08
132   04    4
133   93    .
134   00    0
135   00    0
136   00    0
137   91    R/S
```

*MODULE # 4
CARD #1
SIDE #1

```
000   76    2ND LBL
001   15    E
002   00    0
003   42    STO
004   70    70
005   53    (
006   53    (
007   43    RCL
008   72    72
009   94    +/-
010   85    +
011   53    (
012   43    RCL
013   72    72
014   45    Y**X
015   02    2
016   75    -
017   53    (
018   04    4
019   65    X
020   43    RCL
021   71    71
022   65    X
023   53    (
024   43    RCL
025   73    73
026   75    -
027   43    RCL
028   67    67
029   65    X
030   43    RCL
031   56    56
032   54    )
033   54    )
034   54    )
```

```
035   34   SQRT(X)
036   54   )
037   55   /
038   53   (
039   02   2
040   65   X
041   43   RCL
042   71   71
043   54   )
044   54   )
045   42   STO
046   80   80
047   43   RCL
048   80   80
049   32   X<=>T
050   43   RCL
051   51   51
052   77   2ND  X>=T
053   00   00
054   65   65
055   43   RCL
056   68   68
057   99   2ND  PRT
058   43   RCL
059   67   67
060   99   2ND  PRT
061   98   2ND  ADV
062   61   GTO
063   01   01
064   48   48
065   53   (
066   43   RCL
067   76   76
068   85   +
069   43   RCL
070   75   75
071   65   X
072   43   RCL
073   80   80
074   85   +
075   43   RCL
076   74   74
077   65   X
078   43   RCL
079   80   80
080   45   Y**X
081   02   2
082   54   )
083   99   2ND  PRT
084   98   2ND  ADV
085   53   (
086   43   RCL
087   66   66
088   85   +
089   43   RCL
090   57   57
091   85   +
092   53   (
093   43   RCL
094   55   55
095   75   -
096   43   RCL
097   68   68
098   54   )
099   85   +
100   53   (
101   43   RCL
102   79   79
103   85   +
```

```
104   43   RCL
105   78   78
106   65   X
107   43   RCL
108   80   80
109   85   +
110   43   RCL
111   77   77
112   65   X
113   43   RCL
114   80   80
115   45   Y**X
116   02   2
117   54   )
118   54   )
119   99   2ND PRT
120   98   2ND ADV
121   53   (
122   43   RCL
123   80   80
124   85   +
125   53   (
126   53   (
127   43   RCL
128   60   60
129   75   -
130   43   RCL
131   54   54
132   85   +
133   02   2
134   00   0
135   54   )
136   55   /
137   43   RCL
138   67   67
139   65   X
140   01   1
141   00   0
142   00   0
143   00   0
144   54   )
145   54   )
146   99   2ND PRT
147   98   2ND ADV
148   43   RCL
149   70   70
150   42   STO
151   00   00
152   73   RCL 2ND IND
153   08   08
154   69   2ND OP
155   38   38
156   91   R/S
```

==

TI-59 PROGRAM SPECIFIC INSTRUCTIONS:

==

* THE FOLLOWING INFORMATION WILL TELL YOU HOW TO RUN YOUR PROGRAM.

* YOU MUST ENTER YOUR PROGRAM MANUALLY INTO THE CALCULATOR AND WRITE THE PROGRAM TO MAGNETIC CARDS. THIS STEP ONLY NEEDS TO BE ACCOMPLISHED ONCE. AFTER THAT, THE PROGRAM IS ENTERED USING THE MAGNETIC CARD FACILITY OF THE CALCULATOR. SEE THE MANUFACTURER'S LITERATURE ON ENTERING A PROGRAM AND WRITING IT TO MAGNETIC CARDS. YOU WILL NEED TO PARTITION MEMORY.

* HOW TO PARTITION THE MEMORY
  * KEY SEQUENCE:

    X
    2ND
    OP
    17

  * X IS THE PARTITION NUMBER GIVEN IN THE LISTING OF YOUR PROGRAM.

* WHEN TO PARTITION THE MEMORY
  * ONCE BEFORE READING IN CARDS.
  * ONCE BEFORE MANUALLY ENTERING PROGRAM IN ORDER TO WRITE TO CARDS.

* HOW TO START AND RUN YOUR PROGRAM
  * TURN ON CALCULATOR
  * PARTITION CALCULATOR
  * LOAD ALL MODULE 1 CARDS
  * OPTIONAL STEP: IF YOU SELECTED THE MANUAL DATA INPUT DENOTED IN YOUR BASIC PROGRAM BY USING THE "DATA" AND "READ" STATEMENTS THEN YOU MUST MANUALLY ENTER YOUR DATA INTO THE CALCULATOR MEMORY. THIS IS DONE BY REFERRING TO "INPUT DATA TO READ" TABLE PROVIDED AT THE END OF THIS LISTING. MANUALLY ENTER THE GIVEN DATA INTO THE REGISTERS USING THE FOLLOWING KEYSTROKES:

    DATA
    STO
    XX

    WHERE XX IS THE DESIRED REGISTER NUMBER.
  * INITIALIZE THE MANUAL SBR RETURN CONTROL STACK WITH THE FOLLOWING KEYSTROKES:

    XX
    STO
    08

    WHERE XX IS THE MANUAL RETURN REGISTER STACK TOP. (THIS IS GIVEN WITH THE PROGRAM LISTING NEAR THE PARTITION INFORMATION.)

```
* PRESS "A" TO START.
* FOLLOW DISPLAY PROMPTS.
  * DEFINITIONS:
    * RUN-TIME PROMPTS:  ARE DEFINED TO BE CALCULATOR
      PROMPTS DISPLAYED IN THE CALCULATOR WINDOW
      IN THE FORM OF A 4 DIGIT DECIMAL, 2 DIGIT
      INTEGER OR A 1 DIGIT INTEGER. EACH PROMPT
      IS OUTLINED BELOW:
        * 4 DIGIT DECIMAL
              * FORMAT: X.YYY
                  * X STANDS FOR MODULE NUMBER (1-9)
                  * YYY STANDS FOR STARTING ADDRESS
              * ACTIONS:
                  * LOAD ALL MODULE X CARDS.
                  * PRESS FOLLOWING KEY SEQUENCE TO
                    INTIALIZE:
                      RCL
                      00
                      GTO
                      Y
                      Y
                      Y
                  * PRESS R/S TO CONTINUE IN NEW MOD.
        * 2 DIGIT INTEGER
              * FORMAT: XX WHERE XX STANDS FOR A
                  REGISTER NUMBER.
              * ACTIONS:
                  * LOOK UP IN REGISTER MAP PROVIDED
                      THE BASIC NAME THAT CORRESPONDS
                      TO THE XX NUMBER.
                  * ENTER THE BASIC VARIABLE VALUE.
                  * PRESS R/S TO CONTINUE WITH THE
                      ENTERED VALUE.
        * 1 DIGIT INTEGER
              * FORMAT: X WHERE IS A MODULE NUMBER.
              * ACTIONS:
                  * LOAD ALL MODULE X CARDS.
                  * PRESS FOLLOWING SEQUENCE TO
                      INITIALIZE:
                      RCL
                      00
                      INV
                      SBR
                  * PRESS R/S TO CONTINUE IN NEW MOD.
        * PAUSE IN DISPLAY
              * AN UNFORMATTED DIGIT FLASHES IN THE
                DISPLAY BEFORE BEING DISPLAYED.
                THIS IS AN ANSWER THAT CORRESPONDS
                TO A REQUESTED ANSWER IN THE BASIC
                PROGRAM USING THE BASIC PRINT
                STATEMENT.  THESE ANSWERS OCCUR IN
                THE SAME ORDER AS THEY WERE
                REQUESTED IN THE BASIC PROGRAM.
              * ACTIONS: NOTE ANSWER AND PRESS R/S.
        * 888 IN DISPLAY
              * SPECIFIC PROMPT THAT INDICATES THAT
                THE PROGRAM HAS STOPPED EXECUTION.
              * ACTIONS: IF DESIRED FIND ANSWERS IN
                THE CALCULATOR MEMORY USING THE
                "TI-59 REGISTER TO NAME MAPPING"
                AT THE END OF THE INSTRUCTIONS.

  * EXPECTED CONTROL FLOW PROMPTS BY MODULE FOLLOW:
```

```
* EXPECTED PROMPTS FOR MODULE # 1
  * FORWARD JUMP CONTINUATION: 4 DIGIT REAL CODE.
    * NONE
  * SUBROUTINE INVOKE: 4 DIGIT REAL CODE.
    * 2.000
  * MANUAL RETURN FROM A SUBROUTINE: 1 DIGIT CODE.
    * NONE
  * SEQUENTIAL CONTINUATION: 4 DIGIT REAL CODE.
    * NONE

* EXPECTED PROMPTS FOR MODULE # 2
  * FORWARD JUMP CONTINUATION: 4 DIGIT REAL CODE.
    * 3.116
    * 3.000
  * SUBROUTINE INVOKE: 4 DIGIT REAL CODE.
    * 4.000
  * MANUAL RETURN FROM A SUBROUTINE: 1 DIGIT CODE.
    * NONE
  * SEQUENTIAL CONTINUATION: 4 DIGIT REAL CODE.
    * 3.000

* EXPECTED PROMPTS FOR MODULE # 3
  * FORWARD JUMP CONTINUATION: 4 DIGIT REAL CODE.
    * NONE
  * SUBROUTINE INVOKE: 4 DIGIT REAL CODE.
    * 4.000
  * MANUAL RETURN FROM A SUBROUTINE: 1 DIGIT CODE.
    * YES
  * SEQUENTIAL CONTINUATION: 4 DIGIT REAL CODE.
    * NONE

* EXPECTED PROMPTS FOR MODULE # 4
  * FORWARD JUMP CONTINUATION: 4 DIGIT REAL CODE.
    * NONE
  * SUBROUTINE INVOKE: 4 DIGIT REAL CODE.
    * NONE
  * MANUAL RETURN FROM A SUBROUTINE: 1 DIGIT CODE.
    * YES
  * SEQUENTIAL CONTINUATION: 4 DIGIT REAL CODE.
    * NONE
```

INPUT DATA TO READ MAPPING

DATA	REG	NAME
-.0133670	11	A24
21.2691	12	A14
-105.7	13	A04
-.00001499	14	C24
.06630	15	C14
-.41	16	C04
.77	17	B04
.01314	18	B14
.00001720	19	B24
-.0149331	20	A25
24.3439	21	A15
64.7	22	A05
-.00001420	23	C25
.07069	24	C15
.06	25	C05
1.26	26	B05
.01508	27	B15
.00001678	28	B25
-.0173835	29	A27
29.8741	30	A17
2255.2	31	A07
-.00001668	32	C27
.08487	33	C17
3.29	34	C07
1.3	35	B07
.02713	36	B17
.00001306	37	B27
-.0182137	38	A28
32.3731	39	A18
4107.4	40	A08
-.00001668	41	C28
.09272	42	C18
5.74	43	C08
1.36	44	B08
.02891	45	B18
.00001410	46	B28
5700	47	CHG4MAX
7000	48	CHG5MAX
10800	49	CHG7MAX
17600	50	CHG8MAX
715	51	HACROSS
0	52	BTRYE
0	53	BTRYN
0	54	BTRYA
800	55	BTRYL
1.0	56	RGK
0	57	DFCOR

4000	58	GRIDE
4000	59	GRIDN
10	60	GRIDA
4000	61	OT
-400	62	LATDEV
10	63	RGDEV
1018.5924	64	MILRAD
1600	65	ROTCOR
3200	66	REFDEF

TI-59 REGISTER TO NAME MAPPING

REG#	BASIC NAME
11	A24
12	A14
13	A04
14	C24
15	C14
16	C04
17	B04
18	B14
19	B24
20	A25
21	A15
22	A05
23	C25
24	C15
25	C05
26	B05
27	B15
28	B25
29	A27
30	A17
31	A07
32	C27
33	C17
34	C07
35	B07
36	B17
37	B27
38	A28
39	A18
40	A08
41	C28
42	C18
43	C08
44	B08
45	B18
46	B28
47	CHG4MAX
48	CHG5MAX
49	CHG7MAX
50	CHG8MAX
51	HACROSS
52	BTRYE
53	BTRYN
54	BTRYA
55	BTRYL
56	RGK
57	DFCOR
58	GRIDE
59	GRIDN
60	GRIDA
61	OT
62	LATDEV
63	RGDEV
64	MILRAD
65	ROTCOR
66	REFDEF
67	TGTRG
68	TGTAZ
69	INVOKE
70	FN_FD
71	(FN PARAMETER)
72	(FN PARAMETER)
73	(FN PARAMETER)

```
74      (FN  PARAMETER)
75      (FN  PARAMETER)
76      (FN  PARAMETER)
77      (FN  PARAMETER)
78      (FN  PARAMETER)
79      (FN  PARAMETER)
80   EL
```

==

END BAX59 SEGMENTATION/INSTRUCTION: VERSION 1.0

==

LIST OF REFERENCES

1. Hamming, R.W., The Art of Programming the TI-59, Naval Postgraduate School, pp. 6-7, April 1980.

2. Graham, J.W., McPhee, K.I., and Welch, J.W., Waterloo Basic Primer and Reference Manual, WATPAC Publications Ltd., October 1980.

3. Jensen, K. and Wirth, N., Pascal User Manual and Report, 2d ed., Springer-Verlag, 1978.

4. Constantine, L. and Yourdon, E., Structured Design: Fundamentals of a Discipline of Computer Program and System Design, Prentice-Hall, Inc., 1979.

5. Basili, V. and Turner, A.J., "Iterative Enhancement: A Practical Technique for Software Development," IEEE Transactions on Software Engineering, v. 1, pp. 390-396, December 1975.

6. Aho, A.V. and Ullman, J.D., Principles of Compiler Design, Addison-Wesley, p. 340, 1977.

7. Master Library Manual, Texas Instruments Inc., p. 54, 1979.

BIBLIOGRAPHY

Augenstein, M.J., and Tenenbaum, A.M., Data Structures Using Pascal, Prentice-Hall, Inc., 1981.

Calingaert, P., Assemblers, Compilers, and Program Translation, Computer Science Press, Inc., 1979.

Computer Systems Group, University of Waterloo, Introduction to Waterloo Basic for VM/370 CMS, University of Waterloo, 31 October 1980.

Parish, R.F., O'Grady, C.D., and Oliva, R.A., Personal Programming, Texas Instruments Inc., 1979.

Gottfried, B.S., Programming with Basic, 2d ed., McGraw-Hill, Inc., 1982.

Kernighan, B.W. and Plauger, P.J., Software Tools, Addison-Wesley, 1976.

Lewis, P.M., Rosenkrantz, D.J., and Stearns, R.E., Compiler Design Theory, Addison-Wesley, 1976.

PASCAL/VS Language Reference Manual, 2d ed., International Business Machines Corporation, April 1981.

PASCAL/VS Programmer's Guide, International Business Machines Corporation, 31 December 1981.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Curricular Officer, Code 37 Computer Technology Naval Postgraduate School Monterey, California 93940	1
4.	Department Chairman, Code 52HQ Department of Computer Science Naval Postgraduate School Monterey, California 93940	1
5.	Dr. Bruce J. MacLennan, Code 52ML Department of Computer Science Naval Postgraduate School Monterey, California 93940	1
6.	Dr. Gordon E. Latta, Code 53LZ Department of Mathematics Naval Postgraduate School Monterey, California 93940	1
7.	Dr. Richard W. Hamming, Code 52HG Department of Computer Science Naval Postgraduate School Monterey, California 93940	1
8.	CPT Mark R. Kindl 413 E. Washington Street Villa Park, Illinois 60181	2
9.	CPT James H.W. Inskeep, Jr P.O. Box 444 Locust Grove, Virginia 22101	2
10.	CAPT T. F. Rogers, USN Box 327 Lumberport, West Virginia 26386	1
11.	CAPT J. C. White, USMC Computer Science Department U.S. Naval Academy Annapolis, Maryland 21401	1
12.	CPT Thomas A. Gandy SMC 1597 Naval Postgraduate School Monterey, California 93940	1