Guidelines for Coding FORTRAN Programs

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Foreword

This guideline is designed to assist individuals in writing FORTRAN programs. Adherence to the conventions described herein should lead to readable and maintainable programs. In addition, it should significantly reduce the amount of time and effort required to transfer a program from one computer to another. Although this document was written to serve as a coding guideline, which the Acoustic Modeling Manager of the Surveillance Environmental Acoustic Support (SEAS) Project could provide to contractors and other Navy organizations supporting the SEAS effort, it could also be used, without modification, by any organization writing, or contracting for, FORTRAN programs.

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Guidelines for Coding Fortran Programs

Naval Ocean Research
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July 82
This document provides a set of conventions to be followed when writing FORTRAN programs. Enforcement of and adherence to these conventions should minimize problems in transferring programs to other computers, should lead to more readable programs, and should make programs more maintainable. For ease of reference, the guidelines have been arranged in the order the subjects they apply to would normally be covered in a FORTRAN reference manual. The final sections contain a FORTRAN program before and after the guidelines were applied.
applied, and describe techniques for implementing structured programming constructs.
Executive Summary

This document provides a set of conventions to be followed when writing FORTRAN programs. Enforcement of, and adherence to, these conventions should reduce problems in transferring programs to other computers, should lead to more readable programs, and should make programs more maintainable. For ease of reference, the guidelines have been arranged in the order that the subjects to which they apply would normally be covered in a FORTRAN reference manual. The final section shows the text of a FORTRAN program both before and after applying the guidelines. An appendix describes how to emulate with FORTRAN code the constructs of structured programming.
Acknowledgements

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1. Introduction

1.1 Scope

This document provides a set of conventions to be followed when writing FORTRAN programs. Adherence to these guidelines should make it easier for programmers to understand the programs they write, especially when they review them three weeks, three months, or three years after their inception. This increased understanding will also allow developers to concentrate on solving the problems that their programs were originally designed to address, rather than resolving the problems created by programming in an arbitrary, undisciplined style. Adherence to these guidelines should make program maintenance less time-consuming for the individual, and less expensive for the organization chartered with this responsibility. Adherence to these guidelines should also facilitate transferring a program from one computer to another.

Most of the conventions contained here are concrete and specific to facilitate enforcement.

This document assumes that the reader is conversant in FORTRAN, and thus does not attempt to explain the purpose or the meaning of FORTRAN statements and associated constructs. Readers interested in achieving a better understanding of the syntax and semantics of the FORTRAN statements mentioned herein are referred to the books by McCracken (1972a) and Control Data Corporation (1976) mentioned in the reference section of this report.

The American Standards Institute (ANSI) USA Standard FORTRAN X3.9-1966 was used as a starting point in writing this document. Photocopies of this standard may be purchased from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018 (Telephone: (212) 354-3300). At the time of writing, X3.9-1966 cost $24.95, and X3.9-1978 cost $16.50, with a $4.00 shipping charge. USA Standard Basic FORTRAN X3.10-1966 was not used because most programs for the underwater acoustics community do not run on the small systems for which this standard was designed. Although a more recent FORTRAN standard (ANSI Standard X3.9-1978, sometimes referred to as FORTRAN 77) exists, we have chosen not to use it because many FORTRAN compilers in the Navy do not support it, even though it was declared the approved standard on 3 Apr 78 and X3.9-1966 was withdrawn. The new FORTRAN Standard was designed, however, to minimize conflicts with X3.9-1966. We have modified this report to further reduce these conflicts. Unfortunately, adherence to these standards does not guarantee that programs will be written clearly or concisely, or will have a well-structured design. And X3.9-1966 does not permit many desirable FORTRAN constructs, such as specification of Hollerith characters without character counts. To achieve maximum transferability of software, developers must consider other factors not addressed by the standard, and even avoid the use of some statements permitted by the standard. Because many programmers may not be exactly sure what is, or what is not, permitted by the ANSI standard, this document comments on many commonly used constructs which are not permitted by the standard, and specifically states when they must be avoided.

This document was developed by considering coding conventions suggested in the works of Berkowitz (1976), Fleiss...
Their value has been well-established by the software engineering community. This document was designed to serve as a guideline to be followed by private contractors and other organizations when writing FORTRAN programs in support of the SEAS Project Office. The need for this document was clearly indicated by the lack of attention many software developers gave to the clarity, transportability, and maintainability of their programs. This neglect needlessly resulted in high program conversion costs, numerous maintenance headaches, and untold hours of wasted time trying to decipher the meaning of uncommented, spaghetti-like logic. Since other organizations have similar problems, it is hoped that this document will prove to be useful to them as well. It is believed that even a casual reading of this document will improve most programmers' style.

2. Coding Fortran Statements

2.1 General Remarks and Suggestions

M - All source code must (whenever possible) be written in a subset of American National Standards Institute (ANSI) FORTRAN, as described in X3.9-1966. The limits of this subset are defined below.

M - Extensions to the above standard must not be used, unless implementation of the program is impossible without their use. (Some manufacturers, e.g., Control Data Corporation, have compilers that will check for and flag noncompliance with the ANSI standard.)

M - If the conventions described herein are adopted as standards by an organization, any violation of those conventions designated by the letter M must be approved by the individual appointed to enforce them. Standards that are not enforced are useless.

M - Don't subvert the intended purpose of the language, i.e., avoid programming tricks.
M - Do not write programs that modify themselves as they execute.

S - For each installation and application, users should follow an adopted set of standard variable names. This procedure will make programs easier to understand and interface, if required, at a later time.

S - Build as many error checks into the program as possible, under the assumption that it will do something incorrectly. This will help reduce debugging time.

S - Avoid having one module (group of statements that perform a specific function) "fall" into another. It is better to have explicit transfers between modules than to rely upon the sequential execution of code.

S - Adopt the KISS (Keep It Simple, Stupid) philosophy. Always use the simplest language features that will solve the problem adequately.

S - Design the program listing so that it is pleasing to the eye.

S - Avoid including more significant digits in the output of a program than can be justified by its input.

2.2 FORTRAN Character Set

M - Do not use characters other than:

- equal sign
- plus sign
- asterisk
- slash
- left parenthesis
- blank
- alphabetic (A-Z)
- numeric (0 to 9)
- apostrophe

S - FORTRAN statements should be numbered in columns 73-80. This facilitates communication of updates and reconstruction of dropped decks.

S - All elements related to a specific level of the control structure should be aligned to the same column.

S - All dependent processes associated with a structure should be indented by a fixed amount, usually two to five spaces. The optimum amount is three spaces. The dependent process could also be a control structure, in which case processes subordinate to the dependent control structure should again be indented to indicate their relative position in the structure.

2.3 FORTRAN Statements

M - FORTRAN keywords must be clearly set off by a blank character or other separator to improve program clarity.

M - The executable statements in the range of a DO loop must be indented at least three spaces from the DO statement and terminating CONTINUE statement.

S - FORTRAN statements should be numbered in columns 73-80. This facilitates communication of updates and reconstruction of dropped decks.

2.4 Continuation lines

M - Do not use more than nine (9) consecutive continuation lines. Nineteen is the maximum permitted by the ANSI standards 3.9-1966 and X3.9-1978. But the subset language of X3.9-1978 permits only nine.

M - Continuation lines must be designated by nonzero alphanumeric characters in column 6. They must be numbered sequentially, starting with 1 through 9, then, if needed, go A through K. Column 7 of a continuation line must always be left blank, except when this prevents outputting a Hollerith string begun on the previous line. This step is especially important in
FORMAT statements, since the integers in column 6 could be adjacent to integers in format fields, thereby reducing readability. For example, 25X where the 2 is in column 6 might be incorrectly interpreted as "skip 25 blanks."

**M -** Columns 1-5 of a continuation line must contain blanks. This step is included to increase agreement with X3.9-1978.

### 2.5 Statement Separator

**M -** Do not put more than one statement on a line. Use of more than one statement per line can make programs extremely difficult to read. Also, it is not permitted by the ANSI standard.

### 2.6 Statement Labels

**M -** Statement labels (numbers) on statements (other than FORMAT statements) which are not transferred to from other points in the program must be eliminated from the source code. Extraneous labels make programs difficult to read and debug.

**M -** Assign statement numbers in ascending sequence of value, initially by 10's or 100's, so that additional statements can be inserted without renumbering.

**M -** Statement-label numbers must appear only on CONTINUE and FORMAT statements; e.g.,

```
100 CONTINUE
B = SQRT(A+C)
```

not

```
100 B = SQRT(A+C)
```

**M -** Do not put a statement number on an END statement. Its use on an END statement is not permitted by ANSI standard FORTRAN.

**M -** The statement labels used in a control statement must be associated with executable statements within the same program unit in which the control statement appears.

**S -** Keep statement numbers from one to four digits in length. Although ANSI X3.9-1966 FORTRAN permits up to five digits, four digits seems adequate and helps to prevent errors due to digits accidentally being typed in column 6.

**L -** Make all FORMAT statement numbers begin with the digit 9 and total four digits.

**L -** Statement-label numbers should be left justified in columns 2 through 5. This will help to prevent errors that can occur when one of the digits is accidentally punched in column 6. Also by starting in column 2, the first digit stands out more clearly than if the number started in column 1, since often there are comment cards, with Cs in column 1 before and after this card.

### 2.7 Comments (Also see Sect. 8.1)

**M -** All comment cards must begin with C in column 1. Other comment indicators, such as /, *, and $, are not permitted by the ANSI standard.

**M -** Programs must be divided into sections, each of which performs a given task. Before each section, comment cards must briefly describe the task being done by the section.

**M -** Include enough explanatory comments so that the reader can easily follow the code. Consider comments to be the equivalent of the text of a book. A well-documented FORTRAN program will often have more comment statements (C-statements) than executable statements. Contrary to some people's belief, comment statements do not slow down the execution of a program. Their absence, however, significantly impedes human comprehension.

**M -** Groups of comment statements must be set off by at least one blank
comment card before and after the group.

M - Write comment statements so that they will help the reader to understand the program. A program comment of the form "add 1 to N" before the statement N=N+1 is no help. The goal is to anticipate the questions the reader will have and to answer them in advance.

M - Display comments so that they will stand out clearly.

M - Do not refer to specific statement labels (numbers) in comment statements or in FORMAT statements (for debugging printout for example). Because the program may be resequenced later, such comments and printed messages could, as a consequence, become incorrect and grossly misleading.

M - Each major decision point in a subroutine or main program must have comment cards explaining the decision.

M - Do not extend the text of comments into columns 73 through 80, because these columns may be used to sequence the card deck at a later time.

S - Arrange code and comments into visual groups reflective of the program logic.

S - Break up long routines into subdivisions. Each subdivision might correspond to a chapter in a mathematical textbook, with numerical labels and subheadings. Display these subdivisions by using special columns and "ruling lines across the page," that is, comment statements containing complete rows of dashes, asterisks, etc. Actually, if routines are well written they should not be so long as to make this procedure necessary.

S - Whenever difficulty can be foreseen, insert a "warning" comment which is easily visible in the listing, e.g., by using asterisks or by punching WARNING in columns that are normally blank.

S - When using indentation, keep the spacing conventions as consistent as possible.

S - Programs should be "commented" as they are written, not afterward. This will help expose errors in logic and inadequacies in the code. Also it should be easier to annotate a piece of code while it is fresh in one's mind as opposed to several days (or weeks) after it is written.

S - Meaningful comments should be added to critical sections of code, but care should be taken not to detract the reader's eye from the code itself.

L - Use blank space liberally, both inter-line and intra-line.

2.8 Blank Lines

M - Do not use blank lines. Instead use a blank line with a C in column one. Some compilers do not accept completely blank lines.

M - Make heavy use of blank lines (with a C in column one) to improve program clarity. They are especially useful for separating modules of a program and highlighting critical sections.

3. Language Elements

3.1 Constants

M - Use only integer, real, double precision, complex, logical, and Hollerith constants. Only these constants are permitted by ANSI standard X3.9-1966.

S - Whenever possible, constant data items should be isolated in DATA statements. This separation leads to greater readability and easier program modification.
3.1.1 Integer Constants

No recommended guidelines.

3.1.2 Real Constants

M - Do not divide by 0.0, as it is not permitted by the ANSI standards. Division by zero may result in values such as 0., 10^-41, etc., depending on the system.

3.1.3 Double Precision Constants

No recommended guidelines.

3.1.4 Complex Constants

No recommended guidelines.

3.1.5 Octal Constants

M - Do not use octal or hexadecimal constants, such as 525B, in FORTRAN programs. These, unfortunately, are not permitted by the ANSI standard. This constraint is indeed regrettable because an octal constant can often be more easily understood than a real constant when doing operations such as masking and shifting. Their use, however, could reduce the transferability of the program.

3.1.6 Hollerith Constants

M - Hollerith constants used in expressions and data statements must not have more than four, nor less than one, characters, e.g., 4HABCD is permissible but 6HABCDEF is not. This restriction is due to the limited word length of some machines.

M - Do not use right-justified with binary zero fill (NRf) or left-justified with binary zero fill (NLf) Hollerith constants, e.g., do not use

\[ A = 4LABCD \text{ or } A = 4RABCD. \]

Although these constructs are very valuable, they are not allowed by ANSI standard X3.9-1966.

M - Do not use Hollerith constants in statements other than in the argument of a CALL statement or in a data statement. Their use in other statements is not permitted by the ANSI standard X3.9-1966.

S - Avoid use of the apostrophe or other characters, such as * or $ to establish limits of size of Hollerith constants, e.g., A = 'ABCD'. Although this construct is extremely valuable and time-saving, it, regrettably, is not permitted by ANSI Standard X3.9-1966. Apostrophes are permitted by ANSI X3.9-1978 (see section 9.4).

3.1.7 Logical Constants

M - Do not use .T. or .F. to designate logical constants, use only .TRUE. or .FALSE. The abbreviated forms are not permitted by ANSI Standard X3.9-1966.

M - Put a blank character on either side of a logical constant to improve readability. For example,

\[ \text{LOGICAL X1, X2} \]
\[ \ldots \]
\[ X1 = .TRUE. \]
\[ X2 = .FALSE. \]

3.2 Variables

M - Variable names must have no more than six alphanumeric characters and no special characters. This restriction is unfortunate, but necessary, due to the inadequacies of some FORTRAN compilers and the definition of ANSI standard FORTRAN X3.9-1966.

M - The characters of a name must not be separated by blanks.

M - The first character of a variable name must be alphabetic.

M - The standard naming conventions, namely, using the letters A through H and 0 through Z as the first characters of real variables, and I
through N as the first characters of integer variables, must be used and not overridden.

M - Variables that are never used in a program or a routine must be eliminated. Their presence reduces program readability and wastes storage space.

M - Variable names must not correspond to FORTRAN keywords. A table of FORTRAN keywords is provided in Appendix A.

M - Variable names must be as descriptive as possible to improve readability, e.g., the variable name for the number of ships should be NSHIPS, not simply N, or NS.

M - All variables must be clearly defined before being used in statements. Programmers must not assume that variables are initialized to zero (or any other value) at the beginning of a job.

M - Do not put part of a variable name on one line and the rest of it on a continuation line below. Keep variable names on the same line.

S - Variables ending with the letter 0 should be avoided. This letter has a tendency to be confused with the number zero.

S - One should not use the same variable name in different contexts to save memory space. Doing so is confusing to the reader and leads to massive confusion if someone later changes any of the meanings. Modern computers typically are never so storage-space-limited that this practice is justified, except possibly for very large arrays.

S - Use symbolic variables, rather than integer constants, for array dimensions in the text, e.g., in DO-loops, IF statements, I/O lists, etc. Put them all together in COMMON, and initialize them all in one routine. Then only this routine and the COMMON/DIMENSION statements need be altered if the dimensions need to be changed, e.g., to put the program on a smaller machine.

S - Avoid changing variable names across subroutine boundaries. For example, when passing a parameter from one routine to another, do not change its name unless it is unavoidable. Changing names across boundaries makes the program less readable.

3.2.1 Integer Variables

M - All integer variables must begin with the letter I, J, K, L, M, or N.

S - In general, counters (variables which are incremented and tested) should be integer. The incrementing and testing of integers is faster than the incrementing and testing of floating point (real) numbers.

3.2.2 Real Variables

M - All real variables must begin with one of the letters A through H, or Q through Z.

3.2.3 Double Precision Variables

M - Do not use the implicit declaration of double-precision variables.

3.2.4 Complex Variables

M - Do not use integer complex variables. They are not permitted by the ANSI standard.

3.2.5 Logical Variables

No recommended guidelines.

3.3 Arrays

S - The total storage for any one array should not exceed 32767 (decimal) words.

S - The number of subscripts of an array in a calling program should
be the same as the number of subscripts of the corresponding array in the called subroutine. For example, passing a two-dimensional array to a one-dimensional array via a subroutine call is a confusing and error prone practice and should be avoided. That is, avoid constructs such as

```
PROGRAM A
DIMENSION B(10,10)

CALL SUB1 (B)

END
SUBROUTINE SUB1 (C)
DIMENSION C(100)

RETURN
END
```

This is not a "must" because there are instances, where this procedure is very valuable, such as when one wishes to operate on columns of a multidimensional array with a column-oriented subroutine. Also the indexing problem is minimal, since virtually every machine stores arrays in the same column-wise manner in accordance with the following table from ANSI Standard X3.9-1966:

<table>
<thead>
<tr>
<th>Dimensionality</th>
<th>Subscript Declaration</th>
<th>Subscript Value</th>
<th>Maximum Subscript Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(a)</td>
<td>0</td>
<td>( V )</td>
</tr>
<tr>
<td>2</td>
<td>(a, b)</td>
<td>(a, b)</td>
<td>( V )</td>
</tr>
<tr>
<td>3</td>
<td>(a, b, c)</td>
<td>( a ), ( b ), ( c )</td>
<td>( V )</td>
</tr>
</tbody>
</table>

3.3.1 Subscripts

M - The number of subscripts in an array appearing in an executable statement must always equal the number of declared dimensions of the array, except in an EQUIVALENCE statement.

M - Do not use expressions other than the following for subscripts:

\[ C \times V + K \]
\[ C \times V - K \]
\[ C \times V \]
\[ V + K \]
\[ V - K \]
\[ V \]
\[ K \]

where \( V \) is an integer variable, and \( C \) and \( K \) are integer constants. These are the only subscript expressions permitted by ANSI standard X3.9-1966.

M - Subscript bounds must never be exceeded. A subscript must never be given a value less than one or larger than the maximum length specified by the upper bound declared for that subscript. This rule is included to increase agreement with X3.9-1978.

M - Never use more than three subscripts. This number is the maximum permitted by the ANSI standard X3.9-1966.

M - Do not use implicit indices for the first element of an array. For example, for a singly dimensioned array \( A \), declared by

```
DIMENSION A(5), use
```

```
TEMP = A(1)
```

not

```
TEMP = A
```

The lack of parentheses makes the program significantly less readable.

S - If the installation's compiler has an array subscript checking feature use it, at least during the initial testing phases of the program development. Since the automatic array subscript error checking feature tends to slow down a program considerably, it may be desirable to turn it off during production runs.
3.3.2 Array Structure

S - Avoid making assumptions regarding the sequential order in which array elements are stored in memory. For example, avoid using data statements of the form:

```
DIMENSION A(2,3)
DATA A/1.,2.,3.,6.,8.,9./
```

4. Expressions

4.1 Arithmetic Expressions

4.1.1 Evaluation of Expressions

M - Never assume that some finite value, e.g., 0.0, will be substituted for a division by 0.

M - Always check, if possible, for the case when the denominator of an expression is zero.

M - Do not use ambiguous statements such as N+FUNC(N)*N where FUNC(N) alters N. The results of such a statement depends upon the compiler scanning algorithm. If the original value of N is not stored in a temporary location, FUNC(N) may destroy it.

M - Make heavy usage of parentheses to improve program clarity. There is no penalty in modern compilers for use of unnecessary parentheses. Do not rely upon the left to right evaluation of arithmetic expressions. For example, write the expression \( A/B*C \) as \( (A/B)*C \), even though it is defined this way according to the ANSI standard. Some individuals might think it means \( A/(B*C) \). Leave no possible doubt as to what the compiler will do.

S - Break long arithmetic expressions into several simpler expressions. That is, by using intermediate variables, break an assignment statement having a long arithmetic expression into a series of assignments each of which has a simpler expression. This will improve program readability. For example, instead of writing

\[ A = (B*C) + (((3**D)/(−3))*X)+(Y*4) \]

write

\[
P1 = B*C \\
P2 = X*((3**D)/(−3)) \\
P3 = Y*6 \\
A = P1 + P2 + P3
\]

L - Polynomials such as \( A*X**4+B*X**3+C*X**2+D*X+E \) should be programmed as \( E+X*(D+X*(C+X*(B+X*A))) \) when efficiency is important. The expanded form is preferable when efficiency is not important because it is more readable.

4.1.2 Type of Arithmetic Expressions

M - Mixed mode expressions must be avoided, e.g., do not use \( A+B/C+D/7+E/4+F \) instead of \( A+B/C+D/7.0+E/4.0+F \), or \( RCUT + NORDER*PERD \) instead of \( RCUT + FLOATF(NORDER)*PERD \). The ANSI standard does not permit mixed mode expressions.

4.1.3 Exponentiation

M - Integer expressions must be raised to only integer powers, never real powers.

M - Do not use double exponentiation without parentheses, e.g., \( A**B**C \). This form is not defined in the standard, so it may be implemented as \( A**(B**C) \), or \( (A**B)**C \). If it is necessary to use double exponentiations, use parentheses to explicitly define the meaning intended.

4.2 Relational Expressions

The relational operators are: \( .GT. \) (greater than), \( .LE. \) (less than or equal to), \( .LT. \) (less than), \( .GE. \) (greater than or equal to), \( .EQ. \) (equal to), and \( .NE. \) (not equal to). Relational expressions have the form \( A1 \ OP \ A2 \), where \( A1 \) and \( A2 \) are arithmetic or masking expressions, and \( OP \) is a relational operator.
M - Relational operators must compare only integer expressions or integer expressions or real expressions with either real expressions or double precision expressions. Only these comparisons are permitted by the ANSI Standard X3.9-1966.

M - Do not use masking expressions with relational operators to form relational expressions. For example, do not use expressions such as (A .AND. B) .GT. (M .AND. .NOT. 77B). Masking expressions are not permitted by the ANSI X3.9-1966 standard.

M - Do not use relational operators for expressions of a COMPLEX data type. For example, do not use expressions such as AMT .LT. (1., 6.55). Use of expressions of the COMPLEX data type in this context is not defined by the ANSI X3.9-1966 standard.

M - Put at least one blank space on each side of a relational operator to improve program readability, e.g., A .GT. B.

4.3 Logical Expressions

Logical expressions have the form L1 OP L2 OP L3...OP LN, where L1, ..., LN are logical operands or relational expressions and OP is a logical operator. The logical operators are .AND., .OR., and .NOT..

M - Do not use .N. for .NOT., .A. for .AND., or .O. for .OR. These abbreviations are not permitted by ANSI Standard 3.9-1966, and they make programs difficult to read.

M - Put a blank character on each side of a logical operator to improve program readability.

M - When an IF statement contains compound conditions, parenthesize the separate simple conditions to make the range and strength of the logical operators (.AND., .OR., and .NOT.) crystal clear. If there are more than two simple conditions, use continuation cards to put each continuation on a separate line and align conditions vertically.

S - Avoid unnecessarily complicated logical expressions, e.g.

IF (A .AND. B .OR. .NOT. C) GO TO 6

S - Avoid negative logical expressions whenever possible. Their positive equivalents are generally easier to understand. For example, instead of writing

IF (.NOT. FLAG) GO TO 10
X = Y
GO TO 20
10 CONTINUE
A = B
20 CONTINUE

write

IF (FLAG) GO TO 10
A = B
GO TO 20
10 CONTINUE
X = Y
20 CONTINUE

L - Use only logical variables or logical constants with logical operations. This approach is recommended only to achieve maximum portability of programs through compliance with X3.9-1966.

4.4 Masking Expressions

Masking expressions are similar to logical expressions, but the elements of the masking expression are of any data type (variable, constant, or expression) other than logical.

S - Avoid use of masking expressions (e.g., do not use: KAY .OR. 63, or .NOT. 55). This guideline is suggested because such expressions are not permitted by the ANSI X3.9-1966 standard, and also because they often depend upon the word-length of the computer. Both of these factors reduce program portability. This constraint is indeed unfortunate, since masking operations are extremely useful for
bit-oriented operations, which are awkward to perform in FORTRAN in any other manner.

5. Assignment Statements

5.1 Arithmetic Assignment Statements

M - Do not use assignments of the form A = B, where (1) A is of the integer data type and B is of a complex data type, (2) A is real and B is complex, (3) A is double precision and B is complex, or (4) A is complex and B is anything but complex.

S - Avoid "run-on" equations. When possible, divide large equations into meaningful parts. This approach will help improve program clarity.

S - Do not use assignment statements requiring implicit conversion to REAL or INTEGER values. This should help avoid problems arising from rounding upon assignment to variables. For example, avoid expressions such as XI = I + 1 or I = J + 1.5

S - Put at least one blank character on either side of each equal (=) sign, to help improve program readability.

5.2 Logical Assignment

No recommended guidelines.

5.3 Masking Assignment

S - Avoid the use of assignments of the form V = masking expression. This type of assignment is not permitted by the ANSI standard, and the portability of programs is reduced by its use.

5.4 Multiple Assignment

M - Do not use assignments of the form V = V1 = V2 = V3... = expression. For example, do not use X = Y = Z = 4. This type of expression is not permitted by the ANSI standard. Also, its meaning can be ambiguous and depend upon the order in which it is evaluated.

6. Control Statements

6.1 GO TO Statement

M - Do not use small gains in efficiency and thereby sacrifice program clarity.

M - Always put a blank character between the keywords GO and TO when using a GO TO statement. Also, put a blank to the right of TO and GO. For example, use GO TO 5, not GOTO 5.

6.1.1 Unconditional GO TO Statement

S - GO TO statements should be avoided wherever possible. Programs containing excessive GO TO's are inherently difficult to document and understand, since they tend to have spaghetti-like logic. If the GO TO statement is used, it should be used in a highly-controlled manner.

S - Where possible, use a DO loop, an IF statement, or a built-in function in lieu of a GO TO statement.

Example 1 (due to Ledgard and Chmura, see references)

Instead of:

```
10 CONTINUE
IF (N .GT. M) GO TO 20
   . . . . .
   N = N + 1
   GO TO 10
20 CONTINUE
```

Use:

```
DO 10 N = 1, M
   . . . . .
10 CONTINUE
```

Example 2

Instead of:
IF (A .GT. B) GO TO 10
C = B - A
GO TO 20
10 CONTINUE
C = A - B
20 CONTINUE

Use:
C = A - B
IF (C .LT. 0.) C = -C

Or, better still, use:
C = ABS(A - B)

6.1.2 Computed GO TO Statement

M - Do not use an arithmetic or masking expression in a computed GO TO statement. Use only an integer variable. For example, do not use GO TO (10, 110, 11, 12, 13), X/Y. Use of the latter is not permitted by ANSI standard X3.9-1966.

M - The right parenthesis of a computed GO TO statement must always be followed by a comma to comply with X3.9-1966. For example, use

GO TO (10, 20, 30), L

not

GO TO (10, 20, 30) L

M - Do not assume that an incorrectly computed GO TO variable will result in a default condition such as "falling through." For example, do not use statements such as GO TO (100, 200, 300), M where M is 4.

M - If a flag has more than three values and is used for transfer of control to one of N locations, a computed GO TO statement is clearer than testing with multiple IF statements. For example, use

GO TO (10, 20, 30, 40, 50, 60), L

not

IF (L-2) 10, 20, 25
25 CONTINUE
IF (L-4) 30, 40, 45

45 CONTINUE
IF (L-6) 50, 60, 65
65 CONTINUE

S - Check each computed GO TO statement for an out-of-bounds value of its index variable.

S - Avoid using the computed GO TO statement, except to simulate the CASE statement of structured programming as described in Appendix D.

6.1.3 ASSIGN Statement

M - Do not use the ASSIGN statement.

6.1.4 Assigned GO TO Statement

M - Do not use the assigned GO TO statement. It is a form of a program modifying itself, and it makes programs difficult to comprehend and debug. For example, when one sees an assigned GO TO statement in a listing, one has to make extra effort to determine to where that statement transfers control. These disadvantages outweigh any small advantages that may be gained in CPU time and memory savings. Also it is always possible to do the same thing another way, e.g., using a computed GO TO statement or an IF statement.

6.2 Arithmetic IF Statement

6.2.1 Three-Branch Arithmetic IF Statement

M - Use a three-way branch IF statement only when the three branches are distinct, e.g., IF (A-80.) 500, 600, 700 is acceptable, but IF (A-80.) 500, 500, 700 is not. Instead use

IF (A .GT. 80.) GO TO 700
GO TO 500

M - The expression of an arithmetic IF statement must be either integer, real, or double precision.

S - The expression in an IF statement should explicitly include all levels of parentheses for clarity.
L - When testing a variable that can assume N possible values, include an (N+1)st check for the possibility that the variable has assumed an illegal value.

6.2.2 Two-Branch Arithmetic IF Statement

M - Do not use the two-branch IF statements, e.g., do not use IF (X*Y) 10, 20. It is not permitted by X3.9-1966.

6.3 Logical IF Statement

6.3.1 Standard Logical IF Statement

This statement has the form IF (eir) stat, where eir is a logical expression and stat is an unlabelled executable statement other than DO, END, or another standard-form logical IF statement.

S - Avoid testing floating-point variables for equality, since the results can be misleading and machine dependent. Due to the inherent inaccuracies of floating-point representations, it may happen that a test for a specific number will fail when the user would think it should pass. For example, A = 1.0-3.0/3.0 may result in A being set to 0.0000001 and a subsequent test for (A .EQ. 0.) would fail. Instead of the test

IF (A .EQ. B) GO TO 2

use a statement like

IF (ABS(A-B) .LE. 1.E-08) GO TO 2.

Tests for greater-than-or-equal-to or less-than-or-equal-to are preferred to tests for equality. This guideline is not a "must" because in some circumstances the value of the variable may have been previously set to an "exact" value.

S - In IF statements of the form IF (A .AND. B) (statement) do not assume that both A and B will be evaluated because, according to the ANSI Standard 3.9-1966, they don't have to be. For example, on the Univac 1108 system, if A is false, B is not checked for its status and the test fails. On the CDC 6600 system, both A and B are checked. As an example, if C is an array of size N and if core is preset to negative infinity, the statement

IF ((I .LT. N) .AND. (C(I) .LE. C(I+1))) GO TO 100

would abort on the CDC machine if I = N when C(N+1) was evaluated, but it would not abort on the Univac system. This problem could be avoided on the CDC system by replacing it with

IF(I .GE. N) GO TO 20
IF(C(I) .LE. C(I+1)) GO TO 100
20 CONTINUE

L - If a few statements are to be executed only if some condition is met, it is a simple matter to set a logical value TRUE if the condition is true, and then use a series of logical IF's containing just that logical variable as the logical expression. The loss in computer time involved in repeating the test of the logical variable is very small in most cases, and will be more than compensated by increased clarity. This step helps avoid use of the GO TO statement.

Example

OK = .TRUE.
IF((I .GT. N) .OR. (I .LT. 1)) OK = .FALSE.
IF (.NOT. OK) A(I,J) = TEMP
IF (.NOT. OK) WRITE (6,9110) I
IF (.NOT. OK) NERROR = NERROR+1

6.3.2 Two-Branch Logical IF Statement

M - Do not use the two-branch logical IF statement. For example, do not use statements such as

IF (K .EQ. 100) 60, 70.

This statement is not permitted by the ANSI X3.9-1966 standard.
6.4 DO Statement

6.4.1 DO Loops

M - DO loop variables must not be assigned a new value within the range of the DO-loop. Specifically, \( m_1, m_2, \) and \( m_3 \) should never be changed while executing a DO-loop of the form

\[
\text{DO } n \ I = m_1, m_2, m_3
\]
or

\[
\text{DO } n \ I = m_1, m_2.
\]

Altering a DO parameter within a loop may produce varying results, depending upon how the DO-loop feature was implemented in the compiler (pre-test, post-test, index in core, index in register, etc.). Changing of the DO-loop variables is not permitted by the ANSI standard. For example, do not write code such as

\[
\begin{align*}
\text{DO } 15 \ K &= 1,10 \\
K &= K + 1 \\
\text{WRITE}(5,2)K \\
15 \text{ CONTINUE} \\
2 \text{ FORMAT (15)}
\end{align*}
\]

M - Do not use nonpositive indices \( (I, m_1, m_2, m_3) \) in DO-loops. Loops in the form \( \text{DO } 10 \ I = K, J \) where \( J \) is less than \( K \) may or may not be executed once, depending upon where the test for completion is made. Non-zero values of these indices are not permitted by ANSI standard X3.9-1966. Although statements such as \( \text{DO } 10 \ I = 0, I \) are permitted in Univac FORTRAN, they are not legal in CDC FORTRAN. Instead, replace such constructs with

\[
\begin{align*}
\text{DO } 10 \ II &= 1,2 \\
I &= II - 1
\end{align*}
\]

The effects of negative incrementing such as \( \text{DO } 10 \ I = NP,1,-1 \) can be achieved with the statements such as

\[
\begin{align*}
\text{DO } 10 \ ID &= 1,NP \\
I &= NP+1-ID
\end{align*}
\]

M - Do not use real variables as DO-loop indices. Although some machines, such as the Burroughs B5500, permit this feature, it is not allowed by the ANSI standard.

M - To improve program clarity, the executable statements in the range of a DO loop must be indented at least three spaces from the DO statement and terminating CONTINUE statement. Three spaces allow the "DO" to stand out, and nested loops will not deprive the programmer of too many card columns. For example, a DO-loop must appear as follows:

\[
\begin{align*}
\text{DO } 10 \ I &= 1, \text{NSHIPS} \\
\text{Statement} &= 1 \\
\text{Statement} &= 2 \\
\text{...} \\
\text{Statement} &= n \\
10 \text{ CONTINUE}
\end{align*}
\]

M - Do not assume that a DO-loop is always executed once.

M - Test for the case of zero iterations of a DO-loop, if this occurrence is a possibility. For example:

\[
\begin{align*}
\text{IF((K-J) .LE. 0)} \text{ GO TO } 1 \\
\text{DO } 6 \ N &= J,K \\
\text{...} \\
6 \text{ CONTINUE} \\
1 \text{ CONTINUE}
\end{align*}
\]

M - Do not assume that if \( m_1 \) is greater than \( m_2 \), the loop will be executed once. For example, the scope of \( \text{DO } 10 \ I = 4, \text{N} \) where \( \text{N}=3 \) may not be executed once.

M - Always put a blank character between the keyword DO and the statement number following it, and between the statement number and the looping variable following it to improve clarity. For example, write \( \text{DO } 10 \ I = 1,30, \) not \( \text{DO}10\I=1,30. \)
M - Do not use large numbers as DO indices. Example: DO 10 I=1, N where N=2**17. The maximum size for a looping index must not exceed 2**15-1, i.e., 32767. Although the ANSI standard does not specify a value, this size is the maximum for some CDC FORTRAN compilers.

M - Every DO statement must refer to its own unique CONTINUE at the end of its range. Some compilers put special restrictions on nested DO-loops that terminate on one statement. The XDS Sigma 5/7, for instance, only allows the innermost DO to transfer directly to its termination point.

M - Do not assume a value of a DO index outside a DO loop if the loop terminated because the control variable is greater than its associated terminal parameter. In this case the ANSI Standard X3.9-1966 says its value is undefined. If the loop was exited by a GO TO statement or an arithmetic IF statement, i.e., by not satisfying the loop, the control variable is defined and is equal to the most recent value.

M - Do not transfer into a DO range. Although such a transfer was permitted by X3.9-1966, it is not permitted by X3.9-1978. The range of a DO loop may be entered only by the execution of a DO statement. Also, most compilers do not guarantee the results of such illegal transfers.

S - Invariant expressions should be factored out of DO loops to improve efficiency and program readability. For example, instead of

\[
\begin{align*}
\text{DO 25 K = 1,30} \\
C & = 3.0 \\
A(K) & = C \\
25 \text{ CONTINUE}
\end{align*}
\]

write

\[
\begin{align*}
C & = 3.0 \\
\text{DO 25 K = 1,30} \\
A(K) & = C \\
25 \text{ CONTINUE}
\end{align*}
\]

S - Parameterize DO loop indices rather than using literals whenever possible. For example, use

\[
\begin{align*}
\text{DO 10 I = NL, NH} \\
\text{DO 10 I = 100, 325.}
\end{align*}
\]

6.4.2 Nested DO loops

M - Do not use the same single CONTINUE statement to terminate nested DO loops. Always end each DO Loop with its own unique CONTINUE statement. This convention should help isolate bodies of DO loops and thereby lead to a clearer code. For example, instead of

\[
\begin{align*}
\text{DO 10 I=H,L} \\
\text{DO 10 K=KL,KH} \\
\text{...} \\
\text{10 CONTINUE}
\end{align*}
\]

use

\[
\begin{align*}
\text{DO 10 I = H, L} \\
\text{DO 20 K = KL, KH} \\
\text{...} \\
\text{20 CONTINUE} \\
\text{10 CONTINUE}
\end{align*}
\]

M - DO loops must not be nested more than 25 deep. Although the ANSI standard does not have a limit, certain IBM FORTRAN compilers have 25 as an upper limit. As a practical matter and to preserve readability, DO loops should not be more than four deep.

M - The range of a contained DO must be a subset of the range of the containing DO.

6.5 CONTINUE Statement

M - Always end each DO loop with its own unique CONTINUE statement.

S - Use CONTINUE statements liberally to improve program clarity and to facilitate debugging.

S - Put blank comment statements before and after each CONTINUE statement that is a major decision point in
program. Add additional comment statements to explain the decision being made.

6.6 PAUSE Statement

M - Do not use the PAUSE statement. Some computer facilities do not permit its use, even though it is permitted by ANSI Standard X3.9-1966.

6.7 STOP Statement

M - Do not use the form of the STOP statement, STOP #C...#C, where C...C is a string of characters. Use only the simple four-character STOP, or STOP n, where n is an actual digit string of length one to five. The character form is not permitted by ANSI Standard X3.9-1966.

6.8 END Statement

M - Do not put a statement label (number) on an END statement. Such a label is not permitted by the ANSI standard.

M - Every program must physically terminate with an END statement.

6.9 RETURN Statement

M - Do not use return statements of the form RETURN i. This form is not permitted by the ANSI standard. Use only the six-character form, RETURN.

M - Do not use a RETURN statement in the main program. A RETURN statement may appear only in a procedure subprogram, according to ANSI Standard 3.9-1966.

M - Use at most one RETURN statement per subroutine. Although the use of more than one RETURN is permitted by the ANSI standard, it can lead to poorly structured programs, since it defeats the one-in one-out principle of structured programming.

M - A RETURN statement must be used only as the last executable statement of a subroutine or function. This convention will help produce one-in/one-out control structures. Some machines permit the END statement to act also as a normal RETURN statement, but other machines require at least one RETURN statement before the END. Always include the RETURN statement.

7. Specification Statements

M - Keep all specification statements at the beginning of routines (programs, subroutines, or functions).

M - When used, specification statements must appear in the following order:

TYPE
DIMENSION
COMMON
EQUIVALENCE (to be avoided, if possible; see Section 7.4)

M - Do not scatter specification statements. Group all DIMENSION statements together. Similarly, group COMMON blocks and DATA statements together. Incremental compilers cannot handle scattered type, DIMENSION, and DATA statements; yet this form of compiler is desirable from a speed/user interface standpoint.

7.1 Type Statements

7.1.1 EXPLICIT Type Statements

M - The only data types permitted are INTEGER, REAL, DOUBLE PRECISION, COMPLEX and LOGICAL

M - The standard naming conventions, namely, using the letters A through H and O through Z as the first characters of real variables, and I through N as the first characters of integer variables, must be used and not overridden. For example, do not use INTEGER SUM, A, B, or REAL ZERO.
M - Always include the word PRECISION in DOUBLE PRECISION type statements. For example, instead of using DOUBLE ALIST, J, B, use DOUBLE PRECISION ALIST, J, B. This statement is required by ANSI standard X3.9-1966, and also improves program clarity.

M - Do not specify the type of a name more than once in a program unit, as per X3.9-1978.

7.1.2 IMPLICIT Type Statements

M - IMPLICIT type statements must not be used. For example, do not use IMPLICIT INTEGER (A-F,H). These statements are not permitted by the ANSI standard 3.9-1966. They also reduce program readability.

7.2 DIMENSION Statement

M - Do not use more than three dimensions in an array. For example, do not use DIMENSION A(10,20,30,5). The use of more than three dimensions is not permitted by ANSI standard 3.9-1966.

M - If an array appears in a COMMON area, it must be dimensioned within the COMMON block and not in a DIMENSION declaration, e.g., use COMMON/INK/A(100), B not

DIMENSION A(100)
COMMON/INK/A,B

This guideline improves clarity and conciseness.

M - Do not use adjustable dimensions in the main program. They may appear only in procedure subprograms, according to ANSI X3.9-1966. For example, DIMENSION A(L,K,M) is permitted in the main program of Univac 1108 FORTRAN programs, with values set by parameter cards. It is not permitted, however, in CDC FORTRAN.

M - Adjustable dimensions must only be integer variables.

M - In a subprogram, a symbolic name that appears in a COMMON statement must not identify an adjustable array.

L - Group dimensioned variables in alphabetical order under one dimension declaration. This grouping can improve program clarity by making it easier to find the variables.

7.3 COMMON Statement

M - Numbered COMMON must not be used. It is not permitted by the ANSI standard X3.9-1966.

M - COMMON block names must not exceed six characters.

M - A given COMMON block must have the same number of variables, and each variable must have the same number of elements, independent of the routine in which the common block appears.

M - Do not declare a COMMON block name more than once in a COMMON statement or program unit.

M - Corresponding variables in COMMON blocks must use the same names in all routines.

M - Include a COMMON area in a subroutine only if it is used in that subroutine. Following this guideline will improve program readability.

M - Do not use more than 60 COMMON blocks.

M - Do not use blank COMMON unless absolutely necessary. If necessary, lay out blank COMMON in one central routine and treat variables there as if they were global. This procedure assists in avoiding duplication and is a form of documentation
S - Avoid excessive use of labelled COMMON. (Insufficient blank COMMON may result in inability to load in OS/360 due to the loader sharing that space.)

S - In specifying COMMON block names, leave space for six characters, e.g., COMMON/LINK1 /I,J, A(100). This guideline will simplify program modifications should it be necessary to change a block name.

S - When using COMMON be careful to avoid the hazards of context effects.

L - Although INTEGER and REAL variables should never needlessly be equivalenced to each other, there are some instances when this is very valuable, such as when creating data structures. In general, however, avoid declarations such as EQUIVALENCE (A,1), since they severely reduce program readability.

7.5 LEVEL Statement

M - Do not use LEVEL statements. They are not permitted by ANSI standard X3.9-1966.

7.6 EXTERNAL Statement

M - If an external procedure name is used as an argument to another external procedure, it must appear in an EXTERNAL statement in the program unit in which it is so used, in accordance with ANSI X3.9-1966.

S - Avoid EXTERNAL statements whenever possible. Although permitted by ANSI 3.9-1966, they are confusing to many programmers.

7.7 DATA Statement

M - Do not use parentheses in DATA statements. For example, do not assume

```
DIMENSION ZEBRA(10)
EQUIVALENCE (ZEBRA, TIGER)
```

means the same as

```
DIMENSION ZEBRA(10)
EQUIVALENCE (ZEBRA(1), TIGER(1))
```

This is an unfortunate rule since the first form is inherently clearer than the second. The reason for it is that the parenthesized form is not permitted by the ANSI standard. To comply with the ANSI standard, DATA statements must have only the form DATA Vlist1/Dlist1/,...Vlistn/Dlistn/ where,

Vlist = a list of array elements or variable names, separated by commas. Array elements must have integer constant subscripts.
Dlist = a list of one or more of the following forms, separated by commas: a constant or rf*constant, where rf is an integer constant. The constant is repeated rf times.

M - The number of elements in the Vlist must equal the number in the corresponding Dlist.

M - The type of the constant in the Dlist must agree with the type associated with the corresponding name in the Vlist.

M - Do not use an implied DO in a DATA statement. For example, do not use DATA (A(I), I=1,10)/1.,2.,3.,7*2.5/. Unfortunately, the implied loop is not permitted by the ANSI standard. It is, however, far superior to just using the array name (especially for two or three dimensional arrays). For example, the implied loop is easier to read and write, and is less error prone than the following:

DATA A /1.,2.,3.,2.5,2.5,2.5,2.5,2.5,2.5,2.5/

Unfortunately, the ANSI recommendations are:

DATA A(1), A(2), A(3), A(4), A(5),
A(6), A(7), A(8), A(9),
A(10)/1.,2.,3.,2.5,2.5,2.5,2.5,2.5/

or

DATA A(1)/1./,A(2)/2./,A(3)/3./,
A(4)/2.5./,A(5)/2.5./,A(6)/2.5./,
A(7)/2.5./,A(8)/2.5./,A(9)/2.5./,
A(10)/2.5/

M - An initially defined variable or array element may not be in a block common, according to X3.9-1966.

M - A variable or array element in a labeled COMMON block may be initially defined in only a block data subprogram, in accordance with X3.9-1966.

S - Avoid defining the value of the same variable in several places throughout a program. For example, avoid setting the variable PI = 3.14159 in several subroutines. It would be better to initialize this variable once, and pass it to other routines via a COMMON block.

8. Programs, Subprograms, and Procedures

A program unit consists of a set of FORTRAN statements, with comments, followed by an END card. A main program is a program unit that does not begin with a SUBROUTINE, FUNCTION, or BLOCK DATA statement. It can be used as a self-contained computing procedure. A subprogram is a program unit that begins with SUBROUTINE, FUNCTION, or a BLOCK DATA statement.

8.1 Main Programs

M - The beginning of the text of the main program must describe, in comment cards, the following:

(1) - The purpose of the program.

(2) - The author(s) name, address, organization, and phone number.

(3) - The version number of the program.

(4) - The date of the first program compilation.

(5) - The date the program was last updated.

(6) - The organization for which the program was written.

(7) - The processing performed by the program.

(8) - A listing of external reports, books, or other documents describing the algorithms used, or other information about the program.

(9) - A list of COMMON block variables modified by the main program.
(10) - A description of the card input required by the program (optional).

(11) - The names and contents (briefly described) of all files (tape or disk) written and/or read by the program.

(12) - The names of subroutines in which the above files are read or written (optional).

(13) - A description of the output produced by the program (optional).

(14) - A list of "options" available in the program (optional).

(15) - A list of changes made to the program and dates of those changes (optional).

M - The main program must have no more than 50 executable statements. Longer programs are generally difficult to understand and maintain.

M - If an entity of a given common block is given an initial value in a BLOCK DATA subprogram, a complete set of specification statements for the entire block must be included. This is required by X3.9-1966.

S - Use a top-down approach when designing programs.

8.2 Block Data Subprogram

M - Do not use BLOCK DATA subroutines that have names. They are not permitted by ANSI Standard X3.9-1966. Use only unnamed BLOCK DATA statements.

M - A program must contain no more than one BLOCK DATA subprogram. (In compliance with X3.9-1978).

8.3 Procedures

M - Make frequent use of functions and subprograms to clarify and modularize the source code.

M - Main programs, subroutines, and functions should be kept to a minimum number of lines. They must have no more than 50 executable statements. This constraint helps to make programs more understandable by reducing the need for the programmer to keep in mind the actions of large blocks of code.

M - At the beginning of each procedure, a blank comment statement must be followed by a set of comment statements which describe what the procedure does and the meaning of each of the formal parameters. Parameters must be identified as to whether they are input, output, or input-output variables.

M - At the beginning of each procedure, there must be a set of comments indicating which common block variables are modified by this subroutine. These comments are needed to facilitate maintenance of the program and to avoid wasting time searching through cross reference lists.

M - Procedures must be arranged in the source code in alphabetic order following the main program. This arrangement makes programs significantly easier to debug and understand, since it cuts down on time searching for subroutines in large printouts.

M - Procedures which are never called must be eliminated from the source deck. Extraneous routines waste others' time trying to determine their purpose and relevance. They also waste memory space.

M - Always put at least one blank character after the keyword CALL.

M - Do not use recursive procedures. Most compilers do not allow them.

S - Procedures should describe, in comment statements at the beginning of each routine, the meaning of
internal variables used in the routine.

S - Sections of code likely to change in the future should be isolated into procedures and clearly identified whenever possible.

S - Make procedures general purpose whenever possible.

L - The comment-statement list of descriptions of the formal parameters of a procedure should appear in alphabetic order, thereby making it easier to find the description of a given variable.

8.3.1 SUBROUTINE Subprograms (also see Section 6.9, RETURN statement.)

M - Do not use subroutine calls that include a return list; for example, CALL PGMI(A,B,C), RETURNS (5,10). Instead use the simple RETURN statement. The return list is not permitted by ANSI standard 3.9-1966.

M - Do not use the RETURN i form of returning from a subroutine. Use the simple RETURN statement. The RETURN i form is not permitted by the ANSI standard X3.9-1966.

M - The symbolic name of the formal parameters of a subroutine subprogram must not appear in an EQUIVALENCE, COMMON, or DATA statement in the subprogram.

M - The symbolic name of a subroutine must not appear in any statement in the subprogram except in the symbolic name of the subroutine itself. This is required by ANSI X3.9-1966.

M - Do not use a subroutine when a function is needed. Use the right tool for the job.

M - Do not use the ENTRY statement. Although its use is permitted by the ANSI standards, it defeats the one-in/one-out principle of structured programming, since it allows more than one entrance into a program unit. Also it is annoying to search code looking for it, i.e., it makes a program less readable.

M - Do not use any language feature which permits subprograms defined within other programs to have access to all parent program variables. Some compilers, such as the XDS Sigma 7, allow this to occur. The use of this feature is not permitted by the ANSI standards.

8.3.2 FUNCTION Subprograms

M - Do not declare double-precision type functions with just the identifier DOUBLE; always use DOUBLE PRECISION. The use of DOUBLE alone is not permitted by the ANSI standard.

M - Always include a RETURN statement in a function, do not assume just an END statement will suffice.

M - The formal parameters of a function must not be assigned new values within the body of the function. That is, there must not be any input-output or output formal parameters; only input parameters are permitted. If formal parameters must be changed, a subroutine must be used.

M - Do not use a function when you need a subroutine.

M - Do not alter COMMON block variables in a function.

8.3.3 Basic External Functions

M - Appendix B lists the functions required by X3.9-1966. Avoid using any other external function, other than TAN. It is unfortunate TAN, the tangent function, was not included in X3.9-1966.

S - Avoid using the external functions SINH, DSINH, COSH, DCOSH, ACOS, ASIN, DTANH, DTAN, CDABS. Some systems may not recognize these routines.
8.3.4 Intrinsic Functions

M - Appendix C lists the intrinsic functions allowed by X3.9-1966. Do not use other intrinsic functions.

S - Avoid using the following intrinsic functions since some systems may not support them:

- logical product AND(X,Y,Z)
- logical sum OR(X,Y,Z)
- exclusive or XOR(X,Y,Z)
- complement COMPL(A)
- shifting SHIFT(A,I)
- masking MASK(I)
- random number RANF(A)
- location of variable LOCF(Q)

Shifting algorithms are usually word-size and hardware dependent. If it is necessary to use such routines, include comment statements describing their purpose.

8.3.5 Additional Utility Subprograms

S - Avoid all operating system interface routines, such as calls to DATE, TIME, SENSE SWITCH settings, overlays, and recovery routines. These routines tend to significantly reduce the portability of programs among different computers. If they are used, clearly describe their function in comment cards.

S - Avoid embedding system-dependent debugging aids in programs.

S - Avoid using system-dependent calls to random number generators.

S - Avoid calls to system-dependent mass storage I/O routines.

S - Avoid calls to system-dependent routines that check for end-of-file, or parity errors.

S - Avoid calls to other system-dependent I/O routines, such as those that give information on size of last buffer read in, or that define tape labels.

S - Avoid calls to routines that manipulate the transfer of data to and from extended (ECS) or large (LCS) core storage.

S - Avoid calls to routines that handle terminal I/O.

8.3.6 Statement Functions

M - Do not use statement functions that include masking expressions.

M - Aside from dummy arguments, the expression of a statement function may only contain non-Hollerith constants, variable references, intrinsic function references, references to previously defined statement functions, and external function references.

8.3.7 Procedure Communication

M - Do not use more than 60 formal parameters in each procedure call. The ANSI standard does not specify any limit. Some CDC compilers, however, have a limit of 60 parameters.

M - With the exception of a Hollerith constant, the actual arguments in a subroutine call must agree in type and number with the corresponding formal parameters in the subroutine, e.g., a call to a subroutine using CALL SUBI(A,1.0) must be avoided when the subroutine begins as subroutine SUBI(A,1). The Hollerith constant is an exception to the rule regarding agreement of type.

M - Literals must never be used as arguments in subroutine calls when their corresponding formal parameters can be changed in the called routine.

M - Do not use multiple entry points into a routine. Each subroutine and function must have only one entry point. Use of more than one entry point defeats the one-in/one-out structured-programming concept.
M - Do not use variable-length argument strings in procedure calls. Some compilers will not deal successfully with missing arguments (variable length) in a subroutine CALL.

M - The formal parameters of a function must not be assigned new values within the body of the function.

M - Do not assume subroutines will be called with correct arguments.

S - The actual parameters of a subroutine should be listed so that input parameters are given first, input-output parameters are given second, and output parameters are specified last. This listing order should help improve the readability of the programs.

S - Calling sequences should be used as little as possible. COMMON is a much more efficient method of communication between program units.

S - Calls to machine-dependent subroutines should be avoided.

S - Parameters should always be checked for validity when read from cards, files, or upon entering subroutines. The intent here is to detect input errors as early during program execution as possible.

9. Input/Output

9.1 FORTRAN Record Length

M - Logical record lengths must not exceed 80 characters.

S - The record length for print files should not exceed 120 characters. There are some circumstances, however, such as when making line printer plots, where the additional length is necessary.

9.2 Carriage Control

M - Use separate field specification for printer control, e.g., use FORMAT (1H1,7HBUFFER=) instead of FORMAT (8H1BUFFER=).

9.3 READ and WRITE Statements

M - Do not use PRINT statements. These are not permitted by the ANSI standard X3.9-1966.

M - Do not use PUNCH statements. These are not permitted by ANSI standard X3.9-1966.

M - A simple I/O list enclosed in parentheses is prohibited from appearing in an I/O list (in compliance with X3.9-1978).

M - Do not use expressions for unit numbers, e.g., READ(2*K+1,10). They are not permitted by the ANSI standard X3.9-1966. The unit number must be either an integer variable or an integer constant.

M - Assume the users of a program will provide it with bad input data. Always check these data for validity.

M - All printed output must be annotated so that it is understandable to a user who does not understand the inner workings of the program.

S - All input parameters should be checked very closely for proper values. Parameters should be printed out with an identifying label as soon after input as possible, to facilitate debugging.

S - Avoid operator interaction (typewriter I/O). Some installations may not support this feature.

S - Avoid using alternative action flags; for example, READ (N,ERR=101,END=122). These are not permitted by the ANSI standard. This is not a mandatory requirement because with some FORTRAN compilers (e.g., Univac 1108) they are needed to check for an end-of-file, and to perform other file operations.

S - Check input parameters for reasonableness and validity as soon as possible after they have been read
in. Avoid beginning calculations without first checking the inputs.

S - Incorporate a debug switch in the program which will print out useful trace information. This switch should be designed so that it can be turned on and off after the program is compiled (i.e., at execution time).

S - Make use of as many operating system checks on tape labels as possible. By checking tape labels in the software, one can often avoid disastrous mistakes.

9.3.1 Formatted

M - For formatted I/O, use only write statements of the form WRITE (un,fn) iolist and READ statements of the form READ(un,fn) iolist. Here un and fn identify the input/output unit and format specification, respectively.

M - I/O device numbers must not be negative. Negative numbers were permitted by X3.9-1966, but not X3.9-1978.

S - I/O device numbers (un) often depend upon the system. They should, therefore, be referred to symbolically, e.g., NREAD, NWRITE, rather than by literals, such as 5 and 6. This practice facilitates moving the programs to another machine and also enables the user to easily modify his program to output to a private file, instead of the system output file, if he so wishes. Only unsubscripted integer variables should be used for I/O device numbers.

9.3.2 Unformatted

M - For unformatted I/O, use only the form READ(u) iolist or WRITE(u) iolist to comply with ANSI standard X3.9-1966.

S - Design magnetic tape outputs for general compatibility with other machines. Avoid complicated blocking or binary (non-formatted) file outputs.

9.4 FORMAT Statements

M - REAL constants must never be read from cards with INTEGER formats and vice versa.

M - Do not use octal or hexadecimal specifications in FORMAT statements, since they are not permitted by ANSI standard X3.9-1966.

M - In each program module, all FORMAT statements must be listed after all executable statements. This makes programs easier to debug and read.

M - Do not use list-directed (free-field input) I/O statements. For example, do not use statements such as READ(U,*) iolist or READ *,iolist. These are not permitted by ANSI standard X3.9-1966.

M - Do not perform alphanumeric conversion of the form rRw.

M - Put a comma after each field (except groups of more than one slash (/)) in a FORMAT statement, even though the compiler may accept the statement without the commas. These commas make FORMAT statements more readable, and some compilers require their presence. For example, do not write

9510 FORMAT (F10.0,9XL1).

Instead, write

9510 FORMAT (F10.0, 9X, L1)

M - Put at least one blank space after the comma following each field in a FORMAT statement. This will make it easier to read and modify formats in the future.

M - When formatted records are prepared for printing, the first character of the record is not printed. The
first character determines vertical spacing as follows: blank—one line, 0-two lines, 1 to the first line of the next page, + no advance. These are the only control characters allowed by ANSI X3.9-1966, and only these can be used.

M - Do not use format-controlled records of more than 120 characters.

S - When performing alphanumeric conversions in the form raw, r should be no greater than 4. This is because we can only assume that machines will have at a minimum the ability to pack four characters per computer word.

S - Format statement fields after slashes (/) should begin on a new line. That is, the record terminator "/" that appears in a format statement should mark the end of the FORTRAN text as it appears on a line of the source listing (except for a succeeding comma). Thus the end of a line on the printer output will correspond to the end of a line on the FORTRAN source listing, e.g., use

\[
\text{FORMAT (16H NO. OF FREQS = , 13, 17H NO. OF DEPTHS = , 13)}
\]

not

\[
\text{FORMAT(16H NO. OF FREQS = ,13,/ ,17H NO. OF DEPTHS = ,13).}
\]

S - In FORMAT statements use the specification form NH----- instead of '--------'. For example, use 4HABC, not 'ABCD' (or 'ABCD*'). Although the apostrophe notation is a tremendous timesaver for the programmer since it alleviates the need to count characters (which is highly error prone), it is not permitted by ANSI standard X3.9-1966. It is permitted by X3.9-1978 and is generally supported in one form or another on most compilers. For maximum portability, it should be avoided.

S - Repeated specifications in FORMAT statements should not be more than two deep. For example, avoid statements like 9110 FORMAT (1X, 3(I5, 2(I,13,3(I4, 2X))).

S - Separate multiple card format statements by blank comment statements.

L - Following the E or D in an E or D output field, a + or - should be used prior to the exponent. This increases compliance with ANSI X3.9-1978. ANSI X3.9-1966 permitted a blank as a replacement for a +.

L - All format statement numbers should begin with 4 and have four digits.

L - Group all input format statements together and precede with a comment statement with the word "INPUT". Put a comment card, with all asterisks before and after this card, to make it stand out.

L - Group all input format statements together and precede with the word "OUTPUT". Add asterisk comment cards as described above.

L - Group all error message format statements together and precede with the words "ERROR MESSAGES". Add asterisk comment cards as described above.

9.5 File Manipulation Statements

M - A record must not be written after an end of file record in a sequential file. X3.9-1966 does not prohibit this, but X3.9-1978 does.

M - A sequential file must not contain both formatted and unformatted records.
Mixing of the two is permitted by X3.9-1966, but not X3.9-1978.

S - The use of overlays should be avoided (whenever possible). They are not permitted by X3.9-1966.

S - The use of segmentation should be avoided (whenever possible). It is not permitted by X3.9-1966.

S - Avoid special disc or drum-oriented instructions. They are not standard forms. If necessary, be sure they are well-isolated and clearly identified with comments.

S - Avoid making assumptions regarding number and kind of peripherals available.

S - Isolate and clearly mark code that checks for end-of-files. This practice should help reduce coding changes necessary to transfer the program to another computer. Such statements should be avoided whenever possible, because of their machine dependence.

9.6 BUFFER Statements

M - Do not use BUFFER statements. They are not permitted by the ANSI standard X3.9-1966.

9.7 NAMELIST

M - Do not use the NAMELIST capability. This is not permitted by ANSI standard X3.9-1966.

9.8 ENCODE and DECODE

M - Do not use the ENCODE and DECODE facilities. Their use is not permitted by ANSI standard X3.9-1966.

10. Miscellaneous Machine/System Dependencies

M - Do not assume that memory will be zeroed before the program runs.

M - Whenever a variable has a chance of being used without initialization, on another system, always explicitly initialize memory to zero, even if the system presently being used does it for you. For example,

C ** CLEAR ARRAYS
DO 20 I = 1, 10
  X(I) = 0.0
DO 10 J = 1, 8,
  A(I,J) = 0.0
10 CONTINUE
20 CONTINUE

M - Machine-dependent code that cannot be eliminated must be isolated and clearly identified with comment cards.

M - Programs must be modularized into machine/system-dependent and independent sections.

M - Do not use any code, such as sorting, that depends upon the internal representation of characters.

M - Do not use hexadecimal and octal literals (an example of internal representations).

M - Do not write code that depends upon BCD, or EBCDIC card code differences.

M - Do not use word, byte, character, or system implementation-dependent coding.

M - Always assume the character set will be different for different machines. Do not make programs dependent upon the internal character representation of a particular machine.

M - Do not use programming tricks dependent upon machine idiosyncrasies.

M - Write your programs so the machine operator can use his time and talents efficiently. For example, don't require him to set sense switches or needlessly mount and dismount tapes.

M - Make your programs as operator-proof as possible. Don't have a
program ask the operator for information if this same information can be obtained from the operating system another way. For example, don't require him to type in the date.

S - Avoid assembly language interfaces. Their use is not permitted by the ANSI standard.

S - When writing programs, estimate the range of values variables can take and document the same. The precision of integer and floating-point arithmetic is machine and software dependent. If future systems have fewer bits assigned to the characteristic in floating-point representations, for example, the current data may generate over/underflows (which may go undetected).

S - Never assume the computer operator has done everything correctly.

S - Avoid whenever possible multitasking statements, e.g., statements such as ATTACH and DELETE in System/360, the FORK statement in the XDS-940, and the ZIP statement in the Burroughs B5500. The structure of most multitasking programs is very complex and difficult to debug.

11. Summary of Fortran Statements and Recommendations

The following is a list of FORTRAN statements and recommendations regarding their use. This list contains statements which must not be used under any circumstance (--), which can be used only when necessary (-), which can be used at will (+), and which are highly recommended (++).

The notation used here is as follows:

V = variable
Sn = statement number
iv = integer variable
m1, m2, m3 = integer constants
n = integer
Section No. | Rating
---|---
See 5.1 | Assignment Statements
See 5.2 | $V = \text{arithmetic expression}$ +
See 5.3 | $V = \text{masking expression}$ --
See 5.4 | **Multiple Assignment** --

$$V = V_1 = V_2 = \ldots = V_n = \text{expression}$$

Control Statements

See 6.1.1 | GO TO Sn --
See 6.1.2 | GO TO (Sn$_1$, Sn$_2$---Sn$_m$), iv --
See 6.1.2 | GO TO (Sn$_1$, Sn$_2$---Sn$_m$), expression --
See 6.1.4 | GO TO iv (Sn$_1$, Sn$_2$---Sn$_m$) --
See 6.1.4 | GO TO iv (Sn$_1$,Sn$_2$---Sn$_m$) --
See 6.1.3 | ASSIGN Sn to iv --
See 6.2.1 | IF (arithmetic exp) Sn$_1$, Sn$_2$, Sn$_3$ +
See 6.2.1 | IF (masking exp) Sn$_1$, Sn$_2$, Sn$_3$ --
See 6.2.2 | IF (arithmetic or masking exp) Sn$_1$, Sn$_2$ --
See 6.3.1 | IF (logical expression or relational exp) stat +
See 6.3.2 | IF (logical express or relational exp) Sn$_1$, Sn$_2$ --
See 6.4 | DO Sn iv=m$_1$, m$_2$, m$_3$ +
See 6.4 | DO Sn iv=m$_1$, m$_2$ +
See 6.5 | CONTINUE ++
See 6.6 | PAUSE --
See 6.6 | PAUSE n --
See 6.6 | PAUSE #c...c# --
See 6.7 | STOP --
See 6.7 | STOP n --
See 6.7 | STOP #c...c# --
See 6.8 | END +

See 7.1 | **Type Declaration**

```
INTEGER name$_1$,..,name$_n$
TYPE INTEGER name$_1$,..,name$_n$
REAL name$_1$,..,name$_n$
TYPE REAL name$_1$,..,name$_n$
COMPLEX name$_1$,..,name$_n$
TYPE COMPLEX name$_1$,..,name$_n$
DOUBLE PRECISION name$_1$,..,name$_n$
DOUBLE name$_1$,..,name$_n$
TYPE DOUBLE PRECISION name$_1$,..,name$_n$
TYPE DOUBLE name$_1$,..,name$_n$
LOGICAL name$_1$,..,name$_n$
TYPE LOGICAL name$_1$,..,name$_n$
IMPLICIT type (ac),..,typen(ac)
```

See 7.6 | Declaration

```
EXTERNAL name$_1$,..,name$_n$
```
**Storage Allocation**

| See 7.1.1 | type name, (di) | -- |
| See 7.1.1 | TYPE type name (di) | -- |
| See 7.2 | DIMENSION name1 (di)...name, (dn) | + |
| | array declarator, one to three integer constants; or if name is a dummy argument in a subprogram, one to three integer variables or constants | |
| See 7.3 | COMMON V1,...,Vn | - |
| See 7.3 | COMMON /blk name/V1,...,Vn | + |
| See 7.3 | COMMON // V1, V2,...,Vn | - |
| | where blk name symbolic name or 1-7 digits | + |
| See 7.3 | // blank common | - |
| See 7.4 | EQUIVALENCE (glist1),...(glistn) | -- |
| See 7.5 | LEVEL n,a1,...an | -- |
| See 7.7 | Data Vlistl/dlistl// Vlistn/dlistn/ | + |
| See 7.7 | Data (Vlistl + dlistl),...(Vlistn + dlistn) | -- |
| | Vlistl List of array elements, variable names, separated by commas | + |
| | List of array names, implied DO list | - |
| | dlist One or more of the following forms separated by commas: | - |
| | constant | + |
| | rf* constant | + |
| | (constant list) | -- |
| | rf* (constant list) | -- |
| | constant list: list of constants separated by commas | - |
| | rf: integer constant, the constant or constant list is repeated the number of times indicated by rf | - |

**Main Programs**

| See 8.1 | PROGRAM Name | + |
| | PROGRAM name (par1,...,park) | - |

**Subprograms**

| See 8.3.2 | Function name (p1,...,pn) | ++ |
| See 8.3.2 | type FUNCTION name (p1,...,pn) where type is COMPLEX, DOUBLE PRECISION, LOGICAL | + |
| | where type is DOUBLE, INTEGER, REAL | -- |
| See 8.3.1 | SUBROUTINE name (p1,...,pn) | ++ |
| See 8.3.1 | SUBROUTINE name | ++ |
| See 8.3.1 | SUBROUTINE name (p1,...,pn) returns (b1,...,bm) | -- |
| See 8.3.1 | SUBROUTINE name, RETURNS (b1,...,bm) | -- |
| See 8.3.1 | ENTRY name | -- |

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Statement Functions

See 8.3.6 \[ \text{name (p_1, \ldots, p_n) = expression} \]

Subprogram Control Statements

See 8.3.7 \[ \text{CALL name} \]

See 8.3.7 \[ \text{CALL name (p_1, \ldots, p_n)} \]

See 8.3.7 \[ \text{CALL name (p_1, \ldots, p_n) RETURNS (b_1, \ldots, b_m)} \]

See 8.3.7 \[ \text{CALL name, RETURNS (b_1, \ldots, b_m)} \]

See 8.9 \[ \text{RETURN} \]

See 8.9 \[ \text{RETURN i} \]

See 8.2 \[ \text{BLOCK DATA} \]

See 8.2 \[ \text{BLOCK DATA name} \]

Input/Output

See 9.3 \[ \text{PRINT anything} \]

See 9.3 \[ \text{PUNCH anything} \]

See 9.3.1 \[ \text{WRITE (u,fn) Vlist} \]

See 9.3.1 \[ \text{WRITE (u,fn)} \]

See 9.3.1 \[ \text{WRITE fn, Vlist} \]

See 9.3.1 \[ \text{WRITE fn} \]

See 9.3.2 \[ \text{WRITE (u) iolist} \]

See 9.3.2 \[ \text{WRITE (u)} \]

See 9.3.2 \[ \text{WRITE (w,*) iolist} \]

See 9.3.2 \[ \text{WRITE *, iolist} \]

See 9.3.1 \[ \text{READ (u,fn) iolist} \]

See 9.3.1 \[ \text{READ (u,fn)} \]

See 9.3.1 \[ \text{READ fn, iolist} \]

See 9.3.2 \[ \text{READ (u) iolist} \]

See 9.3.2 \[ \text{READ (u)} \]

See 9.3 \[ \text{READ (u,*) iolist} \]

See 9.3 \[ \text{READ *, iolist} \]

See 9.6 \[ \text{BUFFER IN (n, p) (a, b)} \]

See 9.6 \[ \text{BUFFER OUT (u, p) (a, b)} \]

See 9.7 \[ \text{NAMELIST /group name/a_1, \ldots, a_n/group name_a_1, \ldots, a_n/} \]

See 9.8 \[ \text{READ(u, group name)} \]

See 9.8 \[ \text{WRITE(u, group name)} \]

See 9.8 \[ \text{Internal Transfer of Data} \]

\[ \text{ENCODE (c, fn, v) iolist} \]

\[ \text{DECODE (c, fn, v) iolist} \]

File Manipulation

\[ \text{REWIND u} \]

\[ \text{BACKSPACE u} \]

\[ \text{ENDFILE u} \]

\[ \text{EOF(U)} \]

Format Specification

\[ S_n \text{ FORMAT (f_{s_1}, \ldots, f_{s_n})} \]

\[ f_{s_1} \text{ one or more field specifications separated by commas and/or grouped by parentheses} \]
Data Conversion

srEw.d  Single precision floating-point with exponent
srEw.dDe Floating point with specified exponent length
srEw.dDe Floating point with specified exponent length
srFw.d  Single-precision floating-point without exponent
srGw.d  Single-precision floating-point with or without exponent
srDw.d  Double-precision floating-point with exponent
rw     Decimal integer conversion
riw.z  Integer with specified minimum digits
rlw    Logical conversion
raw    Alphanumeric conversion
rsw    Alphanumeric conversion
row    Octal integer conversion
row.z  Octal with conversion with minimum number
rzw    Hexadecimal conversion
srVw.d Variable type conversion
s      Optional scale factor of from: nP
r      Optional repetition factor, non-zero unsigned integer
w      Integer constant indicating field width
d      Integer constant indicating digits to right of decimal point
e      Integer indicating digits in exponent field
z      Integer specifying minimum number of digits

See 9.4
nX     Intraline spacing
nH     Hollerith
*....* Hollerith
#..... Hollerith
"...." Hollerith
/      Format separator; indicates end of FORTRAN record
Tn     Column tabulation
V      Display code substitution
=      Numeric substitution
,      Comma (field separator)

Overlays

See 9.5
Call OVERLAY (fname, i, j, recall, k)
12. Example Program

12.1 CNOISE Model Before Application of Guidelines
C
C SLO CO
C C
C C It
C C C 00
C go
C C
C C SIlo.
C
C C 00
C go
C C
C C IsAD.
C
C C 00
C go
C C
C C SIlo.
C
C C 00
C go
C C
C C IsAD.
C
C C 00
C go
C C
C C SIlo.
C
C C 00
C go
C C
C C IsAD.
C
C C 00
C go
C C
C C SIlo.
C
C C 00
C go
C C
C C IsAD.
C
C C 00
C go
C C
C C SIlo.
C
C C 00
C go
13. Conclusion

This document has addressed the issue of programming style. Its application will certainly require more work for the programmer in the short term, but in the long term, the rewards to the programmer, his organization, and other organizations and individuals using the programs could be substantial. The programmer should gain in the long term, because his programs will be easier for him to understand, and will be more likely to be used by others. The organization will gain because the costs it incurs for maintenance and software conversion will be lower. Other individuals and organizations will profit because less effort will be required to understand, use, extend, and adapt the programs.

14. References


McCracken, D. D., C. M. Weinberg (1972b). How to Write a Readable FORTRAN Program, Datamation, October p. 73-76.


Appendix A. Fortran Keywords

The following is a list of FORTRAN keywords and other character strings that should be avoided when naming quantities such as variables, programs, subroutines and arrays:

- ACCESS
- FALSE
- PARAMETER
- AND
- FILE
- PAUSE
- ARRAYS
- FMT
- PDUMP
- ASSIGN
- FORM
- PLOT
- BACKSPACE
- FORMAT
- PRECISION
- BLANK
- FUNCTION
- PROGRAM
- BLOCK
- GE
- PUNCH
- BUFFER
- GET
- PUT
- CALL
- GOTO
- READ
- CHARACTER
- GT
- READMS
- CLOSE
- IF
- REAL
- CLOSEM
- IMPLICIT
- REC
- COMMON
- INQUIRE
- RECL
- COMPLEX
- INTEGER
- RECOVR
- CONTINUE
- INTRINSICS
- REMARK
- DATA
- LABEL
- RETURNS
- DATE
- LOGICAL
- Rewind
- DECODE
- LT
- DIMENSION
- SAVE
- DO
- STATUS
- DOUBLE
- MAXREC
- STOP
- DUMP
- NAME
- SUBROUTINE
- ELSE
- NAMED
- SYMBOL
- ENCODE
- NAMELIST
- TAPE
- END
- NE
- THEN
- ENDFILE
- NEXTREC
- TIME
- ENTRY
- NOT
- TRACE
- EOF
- NUMBER
- TRUE
- EQ
- TYPE
- EQUIVALENCE
- OPEN
- UNFORMATTED
- ERR
- OPENED
- UNIT
- ERRSET
- OPENM
- EXIST
- OPENMS
- EXIT
- OR
- WEOR
- EXTERNAL
- OVERLAY
- WRITE
- WRTEC
- WRITMS
Appendix B. Basic External Functions

(From ANSI Standard X3.9-1986)

<table>
<thead>
<tr>
<th>Basic External Function</th>
<th>Definition</th>
<th>Number of Arguments</th>
<th>Symbolic Name</th>
<th>Argument Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exponential</td>
<td>( e^a )</td>
<td>1</td>
<td>EXP</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DEXP</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CEXP</td>
<td>Complex</td>
</tr>
<tr>
<td>Natural Logarithm</td>
<td>( \log_e(a) )</td>
<td>1</td>
<td>ALOG</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DLOG</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ALOG10</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DLOG10</td>
<td>Double</td>
</tr>
<tr>
<td>Common Logarithm</td>
<td>( \log_{10}(a) )</td>
<td>1</td>
<td>ALOG10</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DLOG10</td>
<td>Double</td>
</tr>
<tr>
<td>Trigonometric Sine</td>
<td>( \sin(a) )</td>
<td>1</td>
<td>SIN</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DSIN</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CSIN</td>
<td>Complex</td>
</tr>
<tr>
<td>Trigonometric Cosine</td>
<td>( \cos(a) )</td>
<td>1</td>
<td>COS</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DCOS</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CCOS</td>
<td>Complex</td>
</tr>
<tr>
<td>Hyperbolic Tangent</td>
<td>( \tanh(a) )</td>
<td>1</td>
<td>TANH</td>
<td>Real</td>
</tr>
<tr>
<td>Square Root</td>
<td>( a^{1/2} )</td>
<td>1</td>
<td>SQRT</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DSQRT</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CSQRT</td>
<td>Complex</td>
</tr>
<tr>
<td>Arctangent</td>
<td>( \arctan(a) )</td>
<td>1</td>
<td>ATAN</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td>( \arctan(a_1/a_2) )</td>
<td>2</td>
<td>DATAN</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ATAN2</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DATAN2</td>
<td>Double</td>
</tr>
<tr>
<td>Remaindering</td>
<td>( a_1 \mod a_2 )</td>
<td>2</td>
<td>DMOD</td>
<td>Double</td>
</tr>
<tr>
<td>Modulus</td>
<td></td>
<td>1</td>
<td>CABS</td>
<td>Complex</td>
</tr>
</tbody>
</table>

*The function DMOD \( (a_1, a_2) \) is defined as \( a_1 - \lfloor a_1/a_2 \rfloor a_2 \), where \( \lfloor x \rfloor \) is the integer whose magnitude does not exceed the magnitude of \( x \) and whose sign is the same as the sign of \( x \).*
## Appendix C. Basic Intrinsic Functions

(From ANSI Standard X3.9-1966)

<table>
<thead>
<tr>
<th>Intrinsic Function</th>
<th>Definition</th>
<th>Number of Arguments</th>
<th>Symbolic Name</th>
<th>Type of Argument</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Value</td>
<td>(</td>
<td>a</td>
<td>)</td>
<td>1</td>
<td>ABS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IABS</td>
<td>Integer</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DABS</td>
<td>Double</td>
<td>Double</td>
</tr>
<tr>
<td>Truncation</td>
<td>Sign of (a) times largest integer &lt; (</td>
<td>a</td>
<td>)</td>
<td>1</td>
<td>AINT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>INT</td>
<td>Integer</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IDINT</td>
<td>Double</td>
<td>Integer</td>
</tr>
<tr>
<td>Remaindering</td>
<td>(a_1 \mod a_2)</td>
<td>2</td>
<td>AMOD</td>
<td>Real</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MOD</td>
<td>Integer</td>
<td>Integer</td>
</tr>
<tr>
<td>Choosing Largest Value</td>
<td>(\text{Min}(a_1, a_2, \ldots))</td>
<td>&gt;2</td>
<td>AMAXO</td>
<td>Integer</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AMAXI</td>
<td>Real</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MAXO</td>
<td>Integer</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MAXI</td>
<td>Double</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DMAXO</td>
<td>Double</td>
<td>Double</td>
</tr>
<tr>
<td>Choosing Smallest Value</td>
<td>(\text{Min}(a_1, a_2, \ldots))</td>
<td>&gt;2</td>
<td>AMINO</td>
<td>Integer</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AMINI</td>
<td>Real</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MINO</td>
<td>Integer</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MINI</td>
<td>Double</td>
<td>Double</td>
</tr>
<tr>
<td>Float</td>
<td>Conversion from integer to real</td>
<td>1</td>
<td>FLOAT</td>
<td>Integer</td>
<td>Real</td>
</tr>
<tr>
<td>Fix</td>
<td>Conversion from real to integer</td>
<td>1</td>
<td>IFIX</td>
<td>Real</td>
<td>Integer</td>
</tr>
<tr>
<td>Transfer of Sign</td>
<td>Sign of (a_2) times (</td>
<td>a_1</td>
<td>)</td>
<td>2</td>
<td>SIGN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ISIGN</td>
<td>Integer</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DSIGN</td>
<td>Double</td>
<td>Integer</td>
</tr>
<tr>
<td>Positive Difference</td>
<td>(a_1 - \text{Min}(a_1, a_2))</td>
<td>2</td>
<td>DIM</td>
<td>Real</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IDIM</td>
<td>Integer</td>
<td>Integer</td>
</tr>
<tr>
<td>Obtain Most Significant Part of Double Precision Argument</td>
<td></td>
<td>1</td>
<td>SNGL</td>
<td>Double</td>
<td>Real</td>
</tr>
<tr>
<td>Obtain Real Part of Complex Argument</td>
<td></td>
<td>1</td>
<td>REAL</td>
<td>Complex</td>
<td>Real</td>
</tr>
<tr>
<td>Obtain Imaginary Part of Complex Argument</td>
<td></td>
<td>1</td>
<td>AIMAG</td>
<td>Complex</td>
<td>Real</td>
</tr>
<tr>
<td>Express Single Precision Argument in Double Precision Form</td>
<td></td>
<td>1</td>
<td>DBLE</td>
<td>Real</td>
<td>Double</td>
</tr>
<tr>
<td>Express Two Real Arguments in Complex Form</td>
<td>(a_1 + a_2)</td>
<td>2</td>
<td>CMPLX</td>
<td>Real</td>
<td>Complex</td>
</tr>
<tr>
<td>Obtain Conjugate of a Complex Argument</td>
<td></td>
<td>1</td>
<td>CONJG</td>
<td>Complex</td>
<td>Complex</td>
</tr>
</tbody>
</table>

*The function \(\text{MOD}(a_1, a_2)\) is defined as \(a_1 - \lfloor a_1/a_2 \rfloor a_2\) where \(|x|\) is the integer whose magnitude does not exceed the magnitude of \(x\) and whose sign is the same as \(x\).*
Appendix D. Fortran Structures for Emulating Structured Programming Constructs

It is generally recognized that FORTRAN (X3.9-1966) is not a good language for structured programming (Yourdon, 1975; Jensen, 1979). Its major deficiencies are: (1) lack of block structures, as are available in languages such as Pascal and Algol; (2) lack of a nested IF-THEN-ELSE statement; and (3) lack of DO-WHILE and PERFORM-UNTIL statements.

Although the absence of these statements increases the difficulty of writing structured programs in FORTRAN, it should not be assumed that one cannot write structured programs in FORTRAN. One merely has to write control structures corresponding to those advocated by structured programming enthusiasts. Interestingly enough, however, to do so in FORTRAN requires the use of the GO TO statement, which at one time some structured programming enthusiasts were considering making illegal. Now it is generally agreed that the GO TO statement itself is not bad, but rather its uncontrolled use. One cannot be too upset with the original FORTRAN designers, because the language was around long before anyone even thought of structured programming. Some of the deficiencies of FORTRAN have been recognized and have been corrected in the more recent version of FORTRAN (X3.9-1978). For example, the revised language now includes the equivalent of an IF-THEN-ELSE statement. It still does not, however, include a DO-WHILE or PERFORM-UNTIL statement, nor does it include the block structure concepts of languages such as ALGOL and PASCAL. Inclusion of the latter would significantly change the whole design of FORTRAN and, in the author's opinion, block structure unlikely to be standardized in FORTRAN in the near future. This appendix describes the logical control structure diagrams, the equivalent structured programming pseudocode, and the FORTRAN code for implementing the following structured programming constructs: IF-THEN-ELSE, IF-ORIF-ELSE, CASE (two forms), POSIT (two forms), DO-WHILE, PERFORM-UNTIL, ESCAPE and CYCLE. The motivation for these constructs is described in considerable detail in Chapter 4 of Jensen and Tonies excellent book on software engineering (Jensen, 1979).

It should be pointed out that some of the above forms are not necessarily advocated by all software engineers. In particular, the IF-ORIF-ELSE, POSIT, ESCAPE and CYCLE constructs were not described in Yourdon's (1975) book. Nevertheless, Jensen and Tonies present good arguments for their inclusion and thus they are mentioned here. It should also be pointed out that we have taken the liberty of adding another construct, the PERFORM-UNTIL (Form 2). This construct is equivalent to the traditional FORTRAN DO loop, which is so useful for indexing arrays and performing other counting operations. It was included here because the author felt it was unreasonable to request that programmers implement their looping operations with the FORTRAN equivalent code PERFORM-UNTIL (form 1), which uses the GO TO and IF statements, when the standard FORTRAN DO loop could in many cases do the same task more concisely.
1. SEQUENCE

1.1 Logical Control Structure

- Code A
- Code B
- Code C

Figure D-1
Sequence Structure

1.2 Pseudocode

CODE A
CODE B
CODE C

1.3 FORTRAN Implementation

CODE A
CODE B
CODE C

2. IF-THEN-ELSE

2.1 Logical Control Structure

- Code B
- Code A
- Code C

2.2 Pseudocode

IF (condition) THEN
  CODE A
ELSE
  CODE B
ENDIF

2.3 FORTRAN Implementation

IF (condition) GO TO a
  CODE B
  GO TO c
a CONTINUE
  CODE A
c CONTINUE
3.0 IF-or-IF-ELSE

3.1 Logical Control Structure

Figure D-3
IF-OR-IF-ELSE Structure
3.2 Pseudocode

IF (condition 1)
  CODE A
ENDIF

ORIF (condition 2)
  CODE B
ORIF (condition 3)
  CODE C
ORIF (condition 4)
  CODE D
ELSE
  CODE E
ENDIF

3.3 FORTRAN Implementation

IF (.NOT. Condition 1) GO TO a
  CODE A
  GO TO e
a CONTINUE
  IF (.NOT. Condition 2) GO TO b
  CODE B
  GO TO e
b CONTINUE
  IF (.NOT. Condition 3) GO TO c
  CODE C
  GO TO e
d CONTINUE
  IF (.NOT. Condition 4) GO TO d
  CODE D
e CONTINUE
  CODE E

4. CASE Statement - (Form 1)

4.1 Logical Control Structure

Figure D-4
CASE Structure (Form 1)

4.2 Pseudocode

CASE OF (index)
  CASE (1)
    CODE A
  CASE (2)
    CODE B
  CASE (3)
    CODE C
  CASE (N)
    CODE N
  CASE ELSE
    CODE E
END CASE

4.3 FORTRAN Implementation

IF (index .LT. 1 .OR. index .GT. n) GO TO e
  GO TO (a, b, c, ...n), index
a CONTINUE
  CODE A
  GO TO g
b CONTINUE
  CODE B
  GO TO g
c CONTINUE
  CODE C
  GO TO g
d CONTINUE
  CODE D
  GO TO g
e CONTINUE
  CODE E
  GO TO g
n CONTINUE
  CODE N
  GO TO g
  ...
  ...
  ...
  ...
n CONTINUE
  CODE N
  GO TO g
e CONTINUE
  CODE E
g CONTINUE
5. CASE Statement (Form 2)

5.1 Logical Control Structure

![Diagram of CASE Structure (Form 2)](image)

5.2 Pseudocode

```plaintext
CASE OF (index)
CASE (1,n)
    CODE A
CASE (2)
    CODE B
CASE (3)
    CODE C
CASE ELSE
    CODE E
END CASE
```

5.3 FORTRAN Implementation

```fortran
IF (index .NE. 1 .AND. index 
    .NE. n) GO TO b
    CODE A
    GO TO f
b CONTINUE
    IF (index .NE. 2) GO TO c
    CODE B
    GO TO f
c CONTINUE
    IF (index .NE. 3) GO TO d
    CODE C
    GO TO f
d CONTINUE
    CODE E
f CONTINUE
```

6. POSIT - (Form 1)

6.1 Logical Control Structure

![Diagram of POSIT Structure (Form 1)](image)
6.2 Pseudocode

```pseudocode
POSIT
  CODE A
  QUIT POSIT IF (Condition 1)
  CODE B
  QUIT POSIT IF (Condition 2)
  CODE C
  ...
  POSIT ELSE
  CODE Z
END POSIT
```

6.3 FORTRAN Implementation

```fortran
CODE A
  IF (Condition 1) GO TO a
  CODE B
  IF (Condition 2) GO TO a
  CODE C
  IF (Condition 3) GO TO a
  CODE D
  GO TO b
  a CONTINUE
  CODE Z
  b CONTINUE
```
7. POSIT - (Form 2)

7.1 Logical Control Structure

![Diagram of logical control structure with conditions and codes]

Figure D-7
POSIT Structure (Form 2)
7.2 Pseudocode

POSIT
CODE A
IF (Condition 1)
CODE X1
QUIT POSIT
ENDIF
CODE B
IF (Condition 2)
CODE X2
QUIT POSIT
ENDIF
CODE C
IF (Condition 3)
CODE X3
QUIT POSIT
ENDIF
CODE D
POSIT ELSE
CODE Z
END POSIT

7.3 FORTRAN Implementation

CODE A
IF (.NOT. Condition 1) GO TO a
CODE XI
GO TO z
a CONTINUE
CODE B
IF (.NOT. Condition 2) GO TO b
CODE X2
GO TO z
b CONTINUE
CODE C
IF (.NOT. Condition 3)) GO TO c
CODE X3
GO TO z
c CONTINUE
CODE D
GO TO d
z CONTINUE
Code Z
d CONTINUE

8. DO-WHILE

8.1 Logical Control Structure

8.2 Pseudocode

WHILE (condition)
CODE A
END WHILE

8.3 FORTRAN Implementation

a CONTINUE
IF (.NOT. condition) GO TO b
CODE A
GO TO a
b CONTINUE

An alternative, but less popular, implementation which has the advantage of a positive test on the predicate is:

GO TO a
c CONTINUE
CODE A
a CONTINUE
IF (condition) GO TO c
9. PERFORM-UNTIL (Form 1)

9.1 Logical Control Structure

9.2 Pseudocode

UNTIL (condition)
CODE A
END UNTIL

9.3 FORTRAN Implementation

a CONTINUE
CODE A
IF (.NOT. condition) GO TO a

An alternative implementation which has the advantage of a positive test on the predicate is:

GO TO b
a CONTINUE
IF (condition) GO TO d
b CONTINUE
CODE A
GO TO a
d CONTINUE

10. PERFORM-UNTIL (Form 2 - DO LOOP Equivalent)

10.1 Logical Control Structure

10.2 Pseudocode

i=m₁
UNTIL (i .GT. m₂)
CODE A
i=i+m₃
END-UNTIL

10.3 FORTRAN Implementation

DO i=m₁, m₂, m₃
CODE A
a CONTINUE

11. ESCAPE

The ESCAPE structure is an unconditional branch to the "outside" of its associated structure. If the exit is from an iterative loop, the branch would be to the outside of the loop.

This provides a mechanism for an easy exit from the interior of a set of nested iterative loops.
11.1 Logical Control Structure

Example of an escape in a DO-WHILE structure. The code B's branch to the condition controlling the next iteration, i.e. to the "inside" of the iteration loop. This provides a mechanism for easily by-passing code in the loop to advance to the next iteration.

12. CYCLE

The CYCLE structure is an unconditional branch to the condition controlling the next iteration, i.e. to the "inside" of the iteration loop. This provides a mechanism for easily by-passing code in the loop to advance to the next iteration.

12.1 Logical Control Structure

Example of a cycle in a DO-WHILE

11.2 Pseudocode (Example)

S: WHILE (condition)
    CODE A
    IF (escape-condition)
        CODE B
        ESCAPE WHILE S
    ENDIF
    CODE D
    END WHILE

11.3 FORTRAN Implementation

a CONTINUE
    IF (.NOT. condition) GO TO b
    CODE A
    IF (.NOT. escape-condition) GO TO d
    CODE B
    GO TO b

d CONTINUE
    CODE D
    GO TO a

b CONTINUE

12.2 Pseudocode

C: WHILE (condition)
    CODE A
    IF (cycle-condition) CYCLE C
    CODE B
    END WHILE

12.3 FORTRAN Implementation

a CONTINUE
    IF (.NOT. condition) GO TO b
    CODE A
    IF (cycle-condition) GO TO a
    CODE B
    GO TO a

b CONTINUE
13. Example of a DO-WHILE Construct
Incorporating ESCAPE and CYCLE

13.1 Logical Control Structure

Figure D-13
DO-WHILE Construction
Incorporating ESCAPE and CYCLE
12 Pseudocode

S: WHILE (while condition)
   CODE A
   IF (condition 2)
      CODE B
      ESCAPE WHILE S
   ENDIF
   IF (.NOT. condition 3)
      CODE C
      CYCLE S
   ENDIF
   CODE D
   END WHILE S

3.3 FORTRAN Implementation

c CONTINUE
   IF (.NOT. while condition) GO TO d
   CODE A
   IF (.NOT. condition 2) GO TO e
   CODE B
   GO TO d
c CONTINUE
   IF (.NOT. condition 3) GO TO f
   CODE C
   GO TO a
f CONTINUE
   CODE D
   GO TO a
d CONTINUE
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