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RFC 194
NIC 7139
Category: D.4
Updates: None
Obsoletes: None

THE DATA RECONFIGURATION SERVICE --

COMPILER/INTERPRETER IMPLEMENTATION NOTES

I. NEW FEATURES OF THE LANGUAGE

1. The meaning of S(#,E,,l) is only find an arbitrary number (<=256) of EBCDIC characters and store them in identifier S. This descriptor is terminated only by an invalid EBCDIC or by exceeding maximum permissible character count (256).
2. The assignment (S .<=. T) causes all attributes of identifier T to be given to S, i.e., length, type, and contents.
3. (S .<=. T || X) concatenates X onto the right-hand side of T and stores the result in S. If T and X are binary the resulting value has a length equal to the sum L(T) + L(X).
4. T(X) joins L(X) and V(X) as a built-in identifier function.
   T(X) = type of identifier X.
   L(X) = length of contents of X.
   V(X) = contents of X converted to binary
   (decimal - binary is presently the only transformation).
5. New types ED and AD are EBCDIC and ASCII encoded decimal, respectively. These have been added to complement the V(X) function.
6. New type SB has been added as signed binary. Type B is a logical binary string.
7. The syntactic notation for return-from-a-form has been changed. See new syntax.

II. NEW SYNTAX

```
form              :: = rule | form
rule              :: = label  inputstream outputstream;
label             :: = INTEGER | NULL
inputstream       :: = terms | NULL
terms             :: = term | terms, term
outputstream      :: = :terms | NULL
term              :: = identifier | identifier descriptor |
                       descriptor | comparator
identifier        :: = <alpha followed by 0-3 alphanumerics>
descriptor        :: = (replicationexpr, datatype, valueexpr,
                       lengthexpr control)
comparator        :: = (concatexpr connective concatexpr control) |
                       (identifier .<=. concatexpr control)
replicationexpr   :: = # | arithmetricexpr | NULL
datatype          :: = B | O | X | E | A | ED | AD | SB | T (identifier)
valueexpr         :: = concatexpr | NULL
lengthexpr        :: = arithmeticexpr | NULL
connective        :: = .LE. | .LT. | .GT. | .GE. | .EQ. | .NE.
concatexpr        :: = value | concatexpr    value
value             :: = literal | arithmeticexpr
arithmeticexpr    :: = primary | arithmeticexpr operator primary
primary           :: = identifier | L(identifier) | V(identifier) |
                         INTEGER
operator          :: = + | - | * | /
literal           :: = literaltype "string"

literaltype       :: = B | 0 | X | E | A | ED | AD | SB
string            :: = <from 0 to 256 chars>
control           :: = :options | NULL
options           :: = SFUR (arithmeticexpr) | SFUR (arithmeticexpr),
                       SFUR (arithmeticexpr)
SFUR              :: = S | F | U | SR | FR | UR
```

III. THE FORM INTERPRETER

Interpreter Overview

The interpreter is a simple minded machine having the virtue of helping the compiler writer by providing a rather powerful instruction set for hard-to-compile operations. Figure 1 shows the machine configuration:

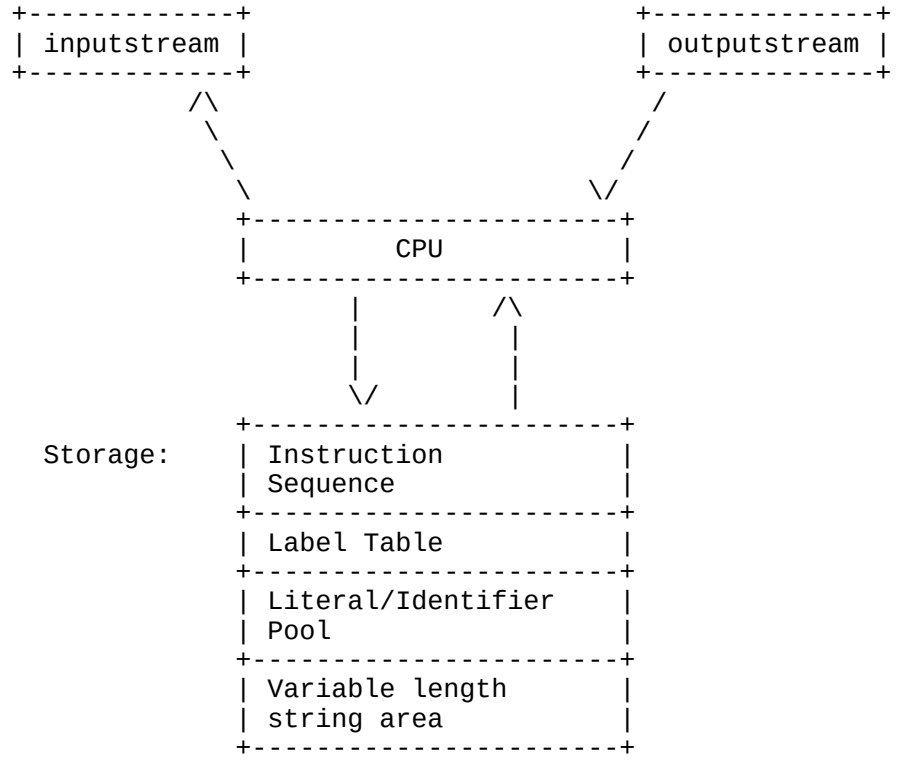


Fig. 1. Form Interpreter

The CPU is a box full of miscellaneous parts, the most important being the Arithmetic Logic Unit and the instruction decoding unit. The CPU also maintains a collection of state registers to keep track of what it is doing. Figure 2 shows the rough layout.

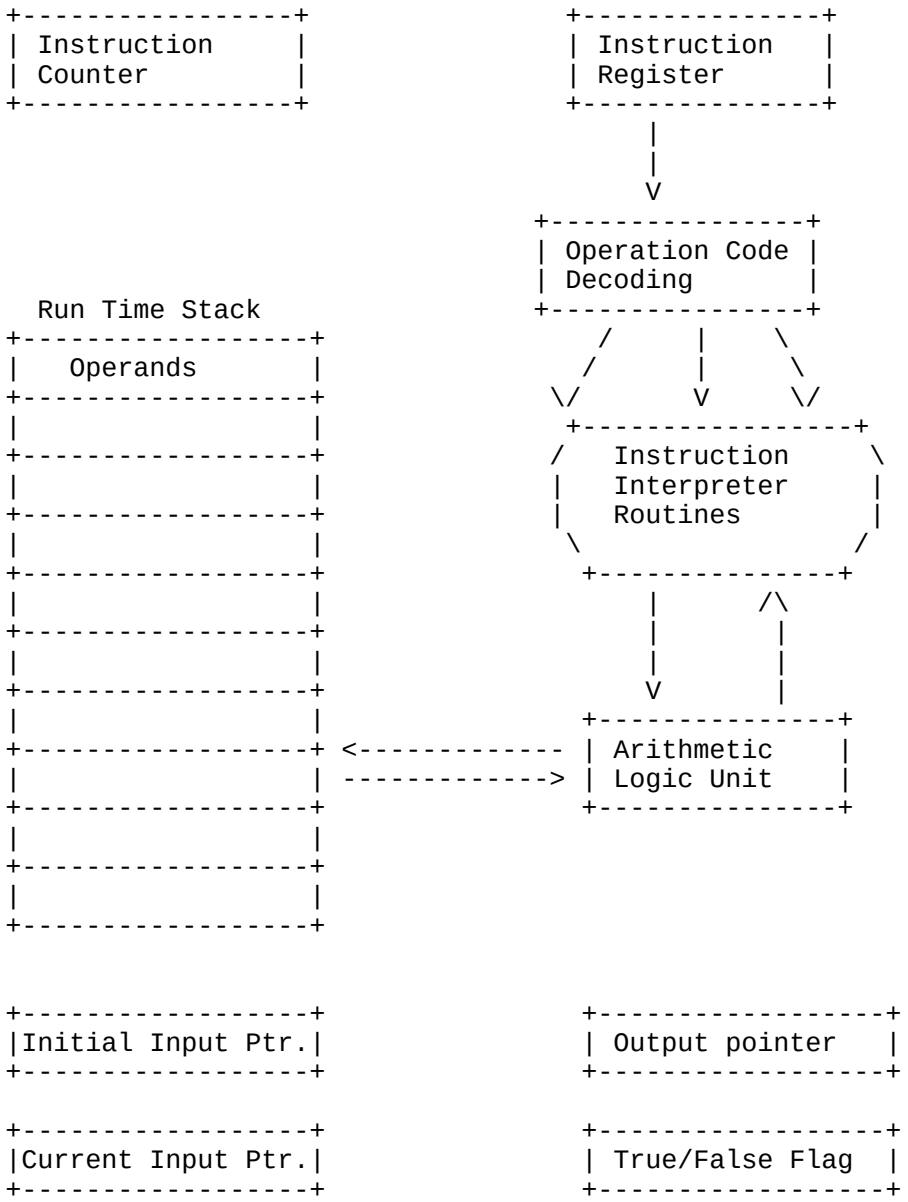


Fig. 2. The Central Processor

The CPU is a stack machine driven by a Polish postfix instruction sequence. Operands placed on the Run Time Stack are used for arithmetic expression evaluation and for parameter passing between the interpreter and the built-in functions.

The Current Input Pointer and the Output Pointer keep track of the two data streams. Two input pointers are needed because of the backup requirement in the event of rule failure. All of these pointers are bit pointers into the two streams.

Various implementations of the Run Time Stack are independent of the interpretation of the DRS machine's instruction set. It is suggested that the stack will contain instruction operands from the instruction stream.

The format of a compiled instruction sequence for a form is shown in Fig. 3.

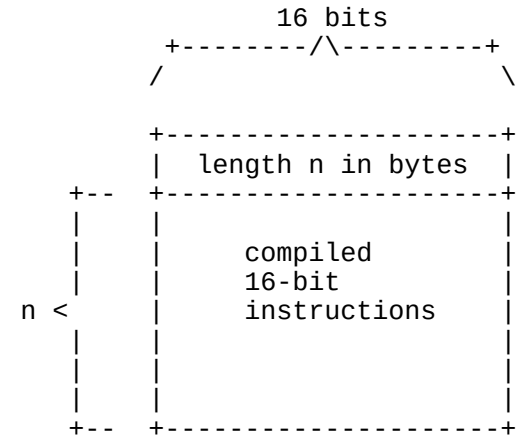


Fig. 3. Compiled Instruction Sequence Format

The format of the compiled Label Table is shown in Fig. 4.

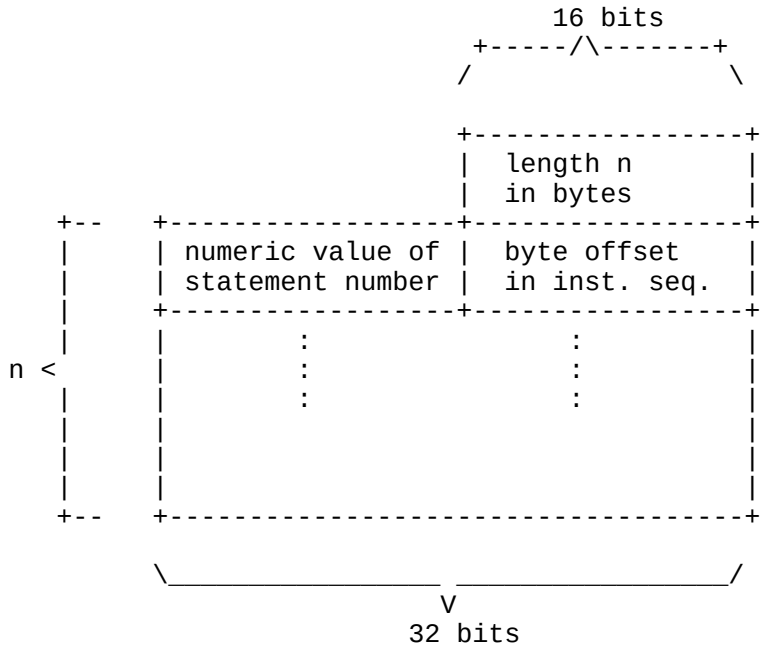
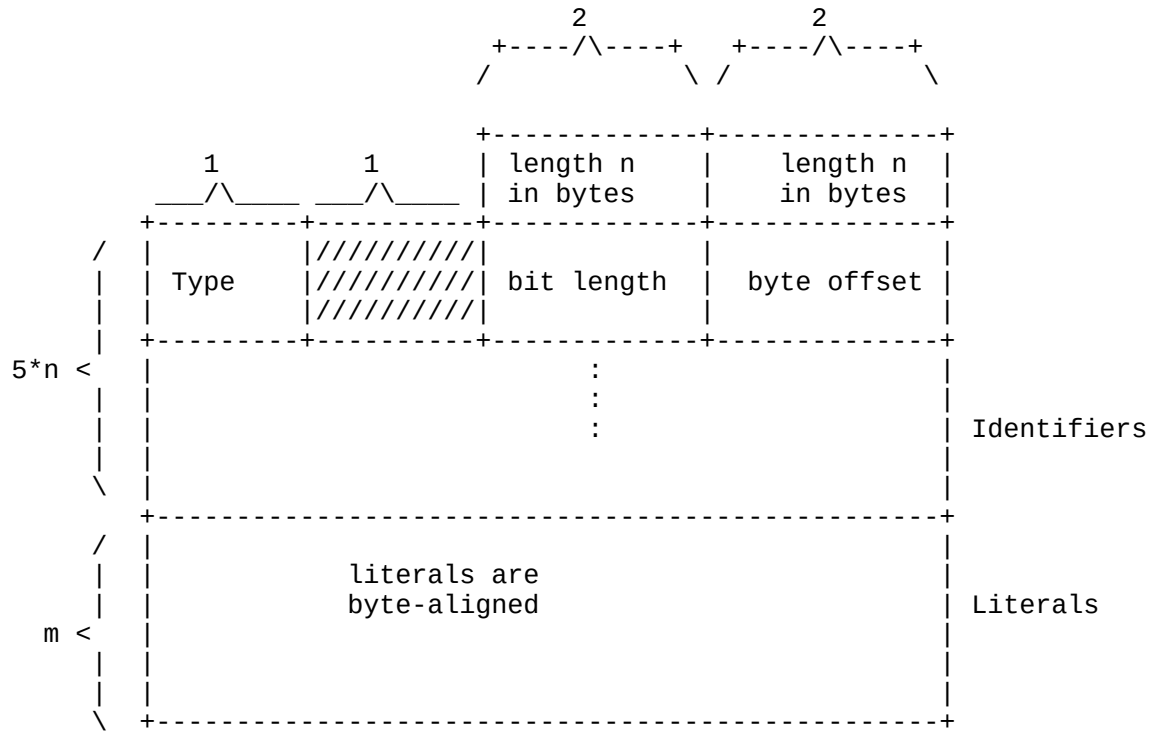


Fig. 4. Compiled Label Table

Literals and Identifiers are compiled as shown in fig. 5.

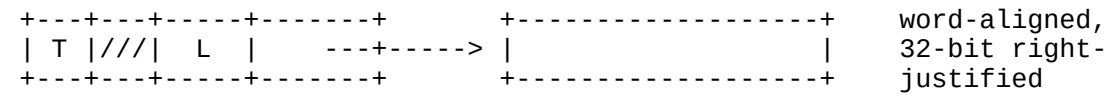


Legend:

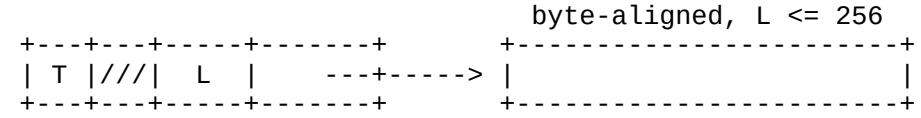
Type 0 = undefined
1 = B (binary)
2 = 0 (octal)
3 = X (hexadecimal)
4 = E (EBCDIC)
5 = A (ASCII)
6 = ED (EBCDIC encoded decimal)
7 = AD (ASCII encoded decimal)
8 = SB (signed binary, two’s complement)

Fig. 5. Compiled Literals and Identifiers

Types B, 0, X, AD, ED, and SB point to 32-bit word- aligned data shown below.

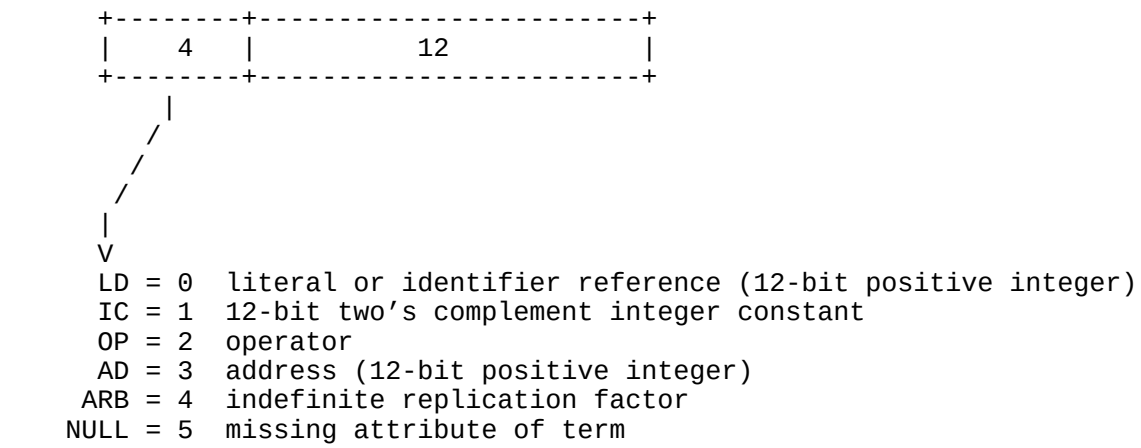


Types E and A point to byte-aligned symbol streams as shown below.



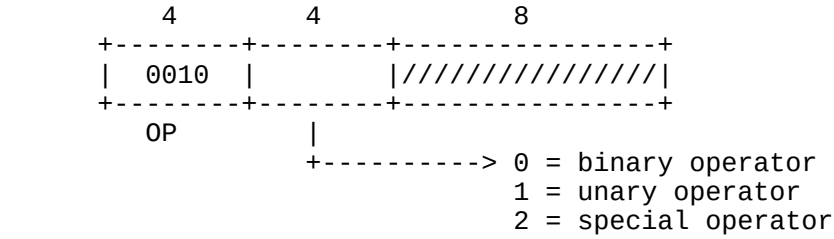
Instruction Format

Since literals and identifiers will be stored in the same data area, more than 256 literals plus identifiers might be encountered so more than 8 bits are needed to reference literal/id pool. Furthermore, such references must be distinguished from operators in the instruction stream, so a 16-bit instruction will be used, as shown below.



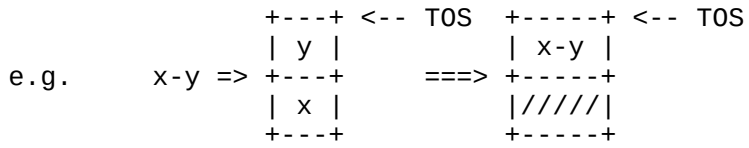
The operation code decoder picks up types 0, 1, 3, 4, and 5 and deposits them on top of the stack (TOS). LD is an index into the literal/identifier table, and AD is an index into the instruction sequence.

The decoder examines OP elements further:

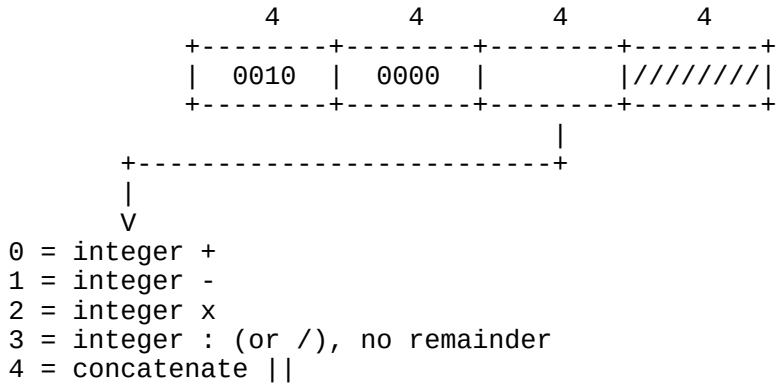


Binary Operators (*)

Let the TOS contain y and the next level, x. The binary operators compute x <bop> y, popping both x, y from stack, and put the result back on top of the stack.



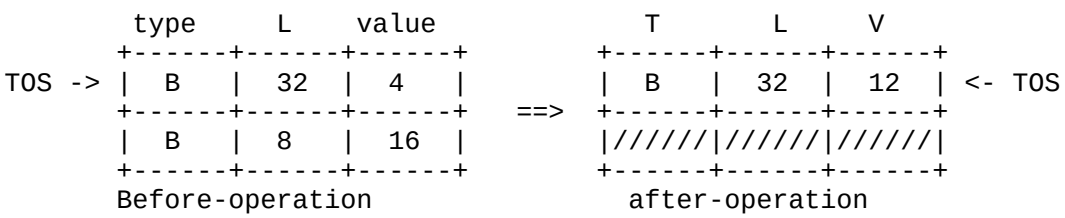
Binary Operator Encoding

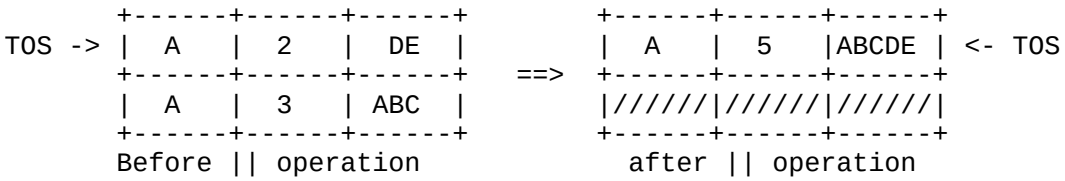


0 = integer +
1 = integer -
2 = integer x
3 = integer : (or /), no remainder
4 = concatenate ||

All binary operations except concatenate expect the top two elements on the stack to describe type B, 0, X, or SB. The result is always a 32-bit type B element. The concatenate operator fails unless both types are identical. For example:

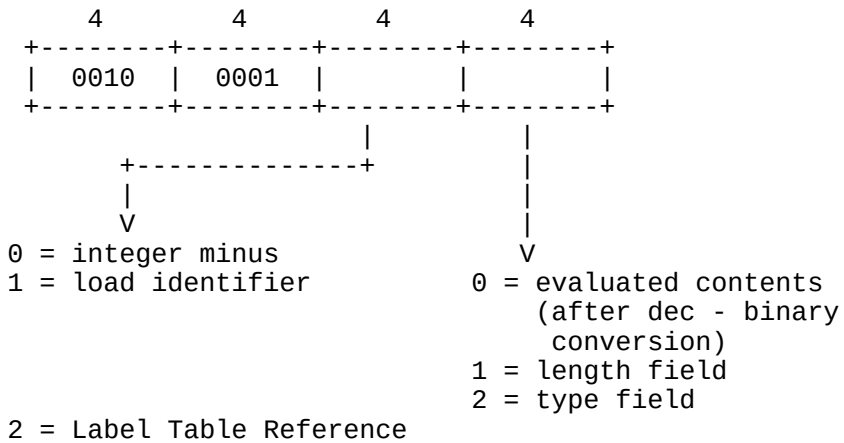
(*) As suggested above, the stack really contains instruction operands that describe data; for convenience in illustrations the data rather than their descriptors are shown on the stack.





No binary operator has any effect on the TRUE/FALSE flag.

Unary Operators

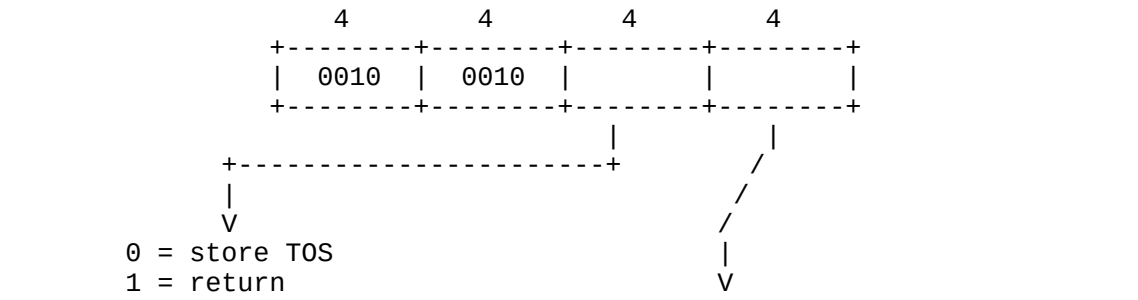


For the unary minus operator the data described by the top of the stack is replaced with its 2's complement. The form fails if the TOS type is not SB, B, 0, or X.

The Load identifier expects the TOS to describe an index into the literal/identifier pool (that is, an LD instruction) . The TOS described data is replaced by 32-bit type B values. The operation fails if the contents cannot be converted from encoded decimal to binary. B, 0, and X types are treated as unsigned integers, SB is treated as 2's complement.

The Label Table Reference operator expects a 32-bit type B value described by TOS and searches for this label in the label Table. If found, the TOS described data is replaced by the relative address in the instruction sequence of the label (in the form of an AD instruction). If not found, the form fails. No Unary operator has any effect on the TRUE/FALSE flag.

Special Operators



Store TOS

The TOS describes an index into the ID table and the next lower element in the stack describes a value to be stored. After execution, both elements are popped off the stack.

Return

The TOS describes a value to be returned to the routine which initiated the FORM MACHINE. The actual mechanism will be implementation dependent, but the FORM MACHINE will relin- quish control after this instruction completes execution.

Branch

The TOS describes an index into the instruction sequence to be used as the new instruction counter (IC) if the branch conditions are satisfied. The branch instruction checks the state of the TRUE/FALSE flag register and either increments the IC by 1 or replaces it with the TOS described element. In any case, the TOS is popped.

Compare

The compare operator takes the two elements described by the two top stack entries and compares them (.EQ.,.LT.,etc.). If n is at the top of the stack, and m is just below, then m.xx.n is performed, and the TRUE/False flag is set accordingly. For .xx. = .EQ. or .NE. we must have identical type, length, and content for equality to hold.

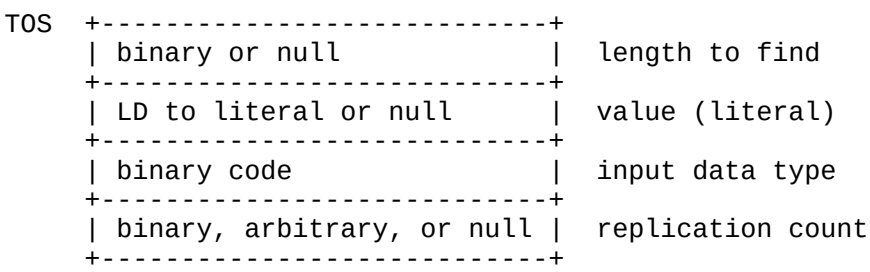
The other boolean comparators will not be attempted if types are different (i.e., form fails), but for same types, B, 0, X cause binary-justified compares, and A, E, AD, ED cause left-justified string compares with the shorter string padded with blanks.

Move Input Pointer

This operator (no operands) replaces the Current Input Pointer with the Initial Input Pointer (back-up), or the Initial Input Pointer with the current one (entry to rule).

Input Call

This is the most complex operator thus far encountered. It requires four operands from the run-time stack:



The input call operator can be invoked with the "no compare" flag set, in which case the value expression parameter is ignored and only the input type and length expressions are used. In this case, the input routine tries to find in the input stream as many characters of the required type (bits, digits, etc.) as needed to fill the length expression requirement. If successful, the TRUE/FALSE flag is set TRUE, the stack is popped to remove the input parameters, and the string obtained is described by the TOS. If the input stream cannot be matched then the parameters are popped off the stack, and the TRUE/FALSE flag is set FALSE.

If the "compare" flag is set, the input stream must be searched for the value expression. However, we must take some care here to be sure we know what to look for. There are several cases:

a) The length expression parameter is greater than the length of the value expression but the type of input desired is the same as the value expression type. For B, 0 and X types, right-justify value expression in length-expression field, sign bit is extended left if type BS. If type A, E, AD, or ED pad on the right with blanks. b) Same as a) but length is too small. B, 0, and X type strings are truncated on the left. A, E, AD and ED are truncated on the right. c) The type of the value expression and the type parameter differ. This case is deferred for discussion and presently is considered an error causing form failure.

If the input string matches, then the TRUE/FALSE flag is set true, the parameters are popped from the stack, and the resulting string is described by the TOS. Otherwise, the FALSE flag is set and the parameters are popped.

When a successful match is found the input subroutine always advances the Current Input Pointer by the appropriate amount. Since we are dealing at the bit level this pointer must be maintained as a bit pointer!

Output Call

This routine utilizes the same parameters as the input call, but operates on the output stream. The TRUE/FALSE flag is not distributed by this operator. As for input, there are four parameters on top of the stack, the length expression value, the value expression value, the desired output type, and the replication expression value. When there is a mis- match between the output type and the value expression type, a conversion must take place. The value expression is trans- formed into the desired output type and fitted into the field length specified by the length expression.

Truncation and Padding Rules

a) Character -> character (A,E,AD,ED -> A,E,AD,ED) conversion is left-justified and truncated or padded with blanks on the right. b) Character -> numeric and numeric -> character conversion is right-justified and truncated or padded on the left with zeros. Beware! Two's complement numbers may be bollixed by this. c) Numeric -> character conversion is right-justified and left padded with blanks or left-truncated. As for the unary operators, a numeric bit-string is treated as unsigned, except SB which is treated as two's complement. Thus we have:

```
              (1,ED,X"FF",3) = E'255'
             (1,ED,X"100",3) = E'256'
     but (1,ED,SB"10000000",4) = E'-256'
```

If the output routine is able to perform the desired action, it advances the Output Stream Pointer, and pops all parameters from the run-time stack.

V. INSTRUCTION SET

it/id ref	LD <num>	Literal or identifier reference -> TOS	
int const	IC <num>	small 2's comp. integer constant -> TOS	
address	AD <num>	Address -> TOS	
null parameter	NULL	missing term attribute	
add	ADD	TOS = x,y	x + y -> TOS
subtract	SUB	TOS = x,y	x - y -> TOS
multiply	MUL	TOS = x,y	x * y -> TOS
divide	DIV	TOS = x,y	x/y -> TOS
concatenate	CON	TOS = x,y	x||y -> TOS
unary minus	UNIN	TOS = x	-x -> TOS
load id value	LIV	TOS = LD x	V(LD x) -> TOS
load id length	LIL	TOS = LD x	V(LD x) -> TOS
load id type	LIT	TOS = LD x	V(LD x) -> TOS
look up label	LVL	TOS = x	AD x -> TOS
sto	STO	TOS = x,y	y -> x
return	RET	TOS = x	return to caller with x
branch true	BT	TOS = AD x	AD x -> Instr. counter
branch false	BF	TOS = AD x	AD x -> Instr. counter
branch	BU	TOS = AD x	AD x -> Instr. counter
compare equal	CEQ	TOS = x,y	(y.EQ.x) -> TRUE/FALSE flag
compare not equal	CNE	TOS = x,y	(y.NE.x) -> T/FF
compare <=	CLE	TOS = x,y	(y.LE.x) -> T/FF
call output	OUT	TOS = r,t,v,l	(r,t,v,l) -> output
call input	IN (INC = compare INN = no compare)	TOS = r,t,v,l	(r,t,v,l) -> TOS
current -> initial	SCIP	CIP -> IIP	(store current input ptr - initial IP)
initial -> current	SICP	IIP -> CIP	(store initial input ptr - CIP)

VI. EXAMPLE COMPILATION

```
FORM SOURCE              GENERATED POLISH INSTRUCTION SEQUENCE

                      ADDR. INSTR.     COMMENTS
(NUMB.<=.1);          0     SICP       RULE PRELUDE
                      1     IC   1
                      2     LD   0     REFERENCE TO NUMB
                      3     STO        STORE IN NUMB
                      4     SCIP       RULE POSTLUDE
1 CC(,E,,1:FR(99)),   5     SICP       RULE PRELUDE
                      6     NULL       NO REPLICATION EXPRESSION
                      7     IC   4     TYPE EBCDIC
                      8     NULL       NO VALUE EXPRESSION
                      9     IC   1     LENGTH
                      10    INN        INPUT CALL WITH NO COMPARE
                      11    AD   15
                      12    BT         SKIP RETURN IF INN SUCCEEDS
                      13    IC   99    RETURN CODE
                      14    RET        RETURN TO CALLER IF FAILED
                      15    LD   1     REFERENCE TO CC
                      16    STO        STORE INPUT DATA IN CC
LINE(,E,,121:         17    NULL       NO REPLICATION EXPRESSION
         FR(99)),     18    IC   4     TYPE IS EBCDIC
                      19    NULL       NO VALUE EXPRESSION
                      20    IC   121   LENGTH
                      21    INN        INPUT WITH NO COMPARE
                      22    AD   26
                      23    BT         SKIP RETURN IF OK
                      24    IC   98    RETURN CODE
                      25    RET        RETURN TO CALLER IF FAILED
                      26    LD   2     REFERENCE TO LINE
                      27    STO        STORE INPUT IN LINE
:CC,                  28    SCIP       SUCCESSFUL INPUT
                      29    NULL       NO REPLICATION FACTOR
                      30    LD   1     REFERENCE TO CC
                      31    LIT        TYPE OF CC
                      32    LD   1     REFERENCE TO VALUE OF CC
                      33    LD   1     CC AGAIN
                      34    LIL        LENGTH OF CC
                      35    OUT        OUTPUT CC
(,ED,NUMB,2),         36    NULL       NO REPLICATION
                      37    IC   6     TYPE IS ED
                      38    LD   0     REFERENCE TO VALUE OF NUMB
                      39    IC   2     LENGTH OF OUTPUT FIELD
                      40    OUT        OUTPUT NUMB AS EBCDIC DEC.
(,E,E".",1),          41    NULL       NO REPLICATION
                      42    IC   4     TYPE IS EBCDIC
```

```
                    43    LD   3   REFERENCE TO E"."
                    44    IC   1   LENGTH TO OUTPUT
                    45    OUT       OUTPUT THE PERIOD
(,E,LINE,117),      46    NULL      NO REPLICATION
                    47    IC   4   TYPE IS EBCDIC
                    48    LD   2   REFERENCE TO LINE
                    49    IC   117 LENGTH TO OUTPUT
                    50    OUT       PUT OUT CONTENTS OF LINE
(NUMB.<=.NUMB+1:    51    LD   0   REFERENCE TO NUMB
         U(1));     52    IC   1   AMOUNT TO ADD
                    53    ADD       ADD TO NUMB
                    54    LD   0   REFERENCE TO NUMB
                    55    STO       STORE BACK INTO NUMB
                    56    AD   5   PLACE TO GO
                    57    B         UNCONDITIONAL BRANCH BACK


              LITERAL/IDENTIFIER TABLE

                    0     NUMB
                    1     CC
                    2     LINE
                    3     E"."


                    LABEL TABLE

                LABEL     OFFSET
                  1         5
```

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