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TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

CCITT HIGH LEVEL LANGUAGE (CHILL)

ITU-T Recommendation Z.200 (10/96)

Superseded by a more recent version

(Previously "CCITT Recommendation")

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INTERNATIONAL TELECOMMUNICATION UNION

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Z.200

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SERIES Z: PROGRAMMING LANGUAGES

ITU-T High Level Language (CHILL)

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FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation Z.200 was revised by ITU-T Study Group 10 (1993-1996) and was approved by the WTSC (Geneva, 9-18 October 1996).

NOTE

In this Recommendation, the expression “Administration” is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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INTERNATIONAL STANDARD

ITU-T RECOMMENDATION

CCITT HIGH LEVEL LANGUAGE (CHILL)

(revised in 1996)

1 Introduction

This Recommendation defines the CCITT high level programming language CHILL. CHILL stands for CCITT High Level Language.

The following subclauses introduce some of the motivations behind the language design and provide an overview of the language features.

For information concerning the variety of introductory and training material on this subject, the reader is referred to the CCITT manuals, "Introduction to CHILL" and "CHILL user's manual".

An alternative definition of CHILL, in a strict mathematical form (based on the VDM notation), is available in the CCITT manual entitled "Formal definition of CHILL".

1.1 General

CHILL is a strongly typed, block structured language designed primarily for the implementation of large and complex embedded systems.

CHILL was designed to:

- enhance reliability and run time efficiency by means of extensive compile-time checking;
- be sufficiently flexible and powerful to encompass the required range of applications and to exploit a variety of hardware;
- provide facilities that encourage piecewise and modular development of large systems;
- cater for real-time applications by providing built-in concurrency and time supervision primitives;
- permit the generation of highly efficient object code;
- be easy to learn and use.

The expressive power inherent in the language design allow engineers to select the appropriate constructs from a rich set of facilities such that the resulting implementation can match the original specification more precisely.

Because CHILL is careful to distinguish between static and dynamic objects, nearly all the semantic checking can be achieved at compile time. This has obvious run time benefits. Violation of CHILL dynamic rules results in run-time exceptions which can be intercepted by an appropriate exception handler (however, generation of such implicit checks is optional, unless a user defined handler is explicitly specified).

CHILL permits programs to be written in a machine independent manner. The language itself is machine independent; however, particular compilation systems may require the provision of specific implementation defined objects. It should be noted that programs containing such objects will not, in general, be portable.

1.2 Language survey

A CHILL program consists essentially of three parts:

- a description of objects;
- a description of actions which are to be performed upon the objects;
- a description of the program structure.

Objects are described by data statements (declaration and definition statements), actions are described by action statements and the program structure is described by program structuring statements.

The manipulatable objects of CHILL are values and locations where values can be stored. The actions define the operations to be performed upon the objects and the order in which values are stored into and retrieved from locations. The program structure determines the lifetime and visibility of objects.

CHILL provides for extensive static checking of the use of objects in a given context.

In the following subclauses, a summary of the various CHILL concepts is given. Each subclause is an introduction to a main clause with the same title, describing the concept in detail.

1.3 Modes and classes

A location has a mode attached to it. The mode of a location defines the set of values which may reside in that location and other properties associated with it (note that not all properties of a location are determinable by its mode alone). Properties of locations are: size, internal structure, read-onlines, referability, etc. Properties of values are: internal representation, ordering, applicable operations, etc.

A value has a class attached to it. The class of a value determines the modes of the locations that may contain the value.

CHILL provides the following categories of modes:

- Discrete modes: Integer, character, boolean, set (enumerations) modes and ranges thereof.
- Real modes: Floating point modes and ranges thereof.
- Powerset modes: Sets of elements of some discrete mode.
- Reference modes: Bound references, free references and rows used as references to locations.
- Composite modes: String, array and structure modes.
- Procedure modes: Procedures considered as manipulatable data objects.
- Instance modes: Identifications for processes.
- Synchronisation modes: Event and buffer modes for process synchronisation and communication.
- Input-output modes: Association, access and text modes for input-output operations.
- Timing modes: Duration and absolute time modes for time supervision.
- Moreta modes: Module, region and task modes for object orientation with single inheritance.

CHILL provides denotations for a set of standard modes. Program defined modes can be introduced by means of mode definitions. Some language constructs have a so-called dynamic mode attached. A dynamic mode is a mode of which some properties can be determined only dynamically. Dynamic modes are always parameterised modes with run-time parameters. A mode that is not dynamic is called a static mode.

With moreta modes, CHILL supports object oriented programming in a very versatile manner. There are three kinds of modes for objects:

- Module modes: The values of these modes behave very much like modules and resemble therefore mostly the objects in classical object oriented programming (e.g. Smalltalk, C++, Eiffel).
- Region modes: The values of these modes behave very much like regions. Such objects are usually not found in classical object oriented programming.
- Task modes: The values of these modes have essentially the same structure as regions but have their own thread of control, and communication between them and other objects is done asynchronously.

Classes have no denotation in CHILL. They are introduced in the metalanguage only to describe static and dynamic context conditions.

1.4 Locations and their accesses

Locations are places where values can be stored or from which values can be obtained. In order to store or obtain a value, a location has to be accessed.

Declaration statements define names to be used for accessing a location. There are:

1) location declarations;

2) loc-identity declarations.

The first one creates locations and establishes access names to the newly created locations. The latter one establishes new access names for locations created elsewhere.

Apart from location declarations, new locations can be created by means of a *GETSTACK* or *ALLOCATE* built-in routine call yielding reference values (see below) to the newly created location.

A location may be **referable**. This means that a corresponding reference value exists for the location. This reference value is obtained as the result of the referencing operation, applied to the **referable** location. By dereferencing a reference value, the referred location is obtained. CHILL requires certain locations to be **referable** and others to be not **referable**, but for other locations it is left to the implementation to decide whether or not they are **referable**. Referability must be a statically determinable property of locations.

A location may have a **read-only** mode, which means that it can only be accessed to obtain a value and not to store a new value into it (except when initialising).

A location may be composite, which means that it has sublocations which can be accessed separately. A sublocation is not necessarily **referable**. A location containing at least one **read-only** sublocation is said to have the **read-only property**. The accessing methods delivering sublocations (or subvalues) are indexing and slicing for strings and for arrays, and selection for structures.

A location has a mode attached. If this mode is dynamic, the location is called a dynamic mode location.

The following properties of a location, although statically determinable, are not part of the mode:

referability: whether or not a reference value exists for the location.

storage class: whether or not it is statically allocated.

regionality: whether or not the location is declared within a region.

1.5 Values and their operations

Values are basic objects on which specific operations are defined. A value is either a (CHILL) defined value or an **undefined** value (in the CHILL sense). The usage of an undefined value in specified contexts results in an undefined situation (in the CHILL sense) and the program is considered to be incorrect.

CHILL allows locations to be used in contexts where values are required. In this case, the location is accessed to obtain the value contained in it.

A value has a class attached. **Strong** values are values that besides their class also have a mode attached. In that case the value is always one of the values defined by the mode. The class is used for compatibility checking and the mode for describing properties of the value. Some contexts require those properties to be known and a **strong** value will then be required.

A value may be **literal**, in which case it denotes an implementation independent discrete value, known at compile time. A value may be **constant**, in which case it always delivers the same value, i.e. it need only be evaluated once. When the context requires a **literal** or **constant** value, the value is assumed to be evaluated before run time and therefore cannot generate a run-time exception. A value may be **intraregional**, in which case it can refer somehow to locations declared within a region. A value may be composite, i.e. contain subvalues.

Synonym definition statements establish new names to denote **constant** values.

1.6 Actions

Actions constitute the algorithmic part of a CHILL program.

The assignment action stores a (computed) value into one or more locations. The procedure call invokes a procedure, a built-in routine call invokes a built-in routine (a built-in routine is a procedure whose definition need not be written in CHILL and whose parameter and result mechanism may be more general). To return from and/or establish the result of a procedure call, the return and result actions are used.

To control the sequential action flow, CHILL provides the following flow of control actions:

- If action: For a two-way branch.
- Case action: For a multiple branch. The selection of the branch may be based upon several values, similarly to a decision table.
- Do action: For iteration or bracketing.
- Exit action: For leaving a bracketed action or a module in a structured manner.
- Cause action: To cause a specific exception.
- Goto action: For unconditional transfer to a labelled program point.

Action and data statements can be grouped together to form a module or begin-end block, which form a (compound) action.

To control the concurrent action flow, CHILL provides the start, stop, delay, continue, send, delay case, and receive case actions, and receive and start expressions.

1.7 Input and output

The input and output facilities of CHILL provide the means to communicate with a variety of devices in the outside world.

The input-output reference model knows three states. In the free state there is no interaction with the outside world.

Through an *ASSOCIATE* operation, the file handling state is entered. In the file handling state there are locations of association mode, which denote outside world objects. It is possible via built-in routines to read and modify the language defined attributes of associations, i.e. **existing**, **readable**, **writeable**, **indexable**, **sequencible** and **variable**. File creation and deletion are also done in the file handling state.

Through the *CONNECT* operation, a location of access mode is connected to a location of an association mode, and the data transfer state is entered. The *CONNECT* operation allows positioning of a **base** index in a file. In the data transfer state various attributes of locations of access mode can be inspected and the data transfer operations *READRECORD* and *WRITERECORD* can be applied.

Through the text transfer operations, CHILL values can be represented in a human-readable form which can be transferred to or from a file or a CHILL location.

1.8 Exception handling

The dynamic semantic conditions of CHILL are those (non context-free) conditions that, in general, cannot be statically determined. (It is left to the implementation to decide whether or not to generate code to test the dynamic conditions at run time, unless an appropriate handler is explicitly specified.) The violation of a dynamic semantic rule causes a run-time exception; however, if an implementation can determine statically that a dynamic condition will be violated, it may reject the program.

Exceptions can also be caused by the execution of a cause action or, conditionally, by the execution of an assert action. When, at a given program point, an exception occurs, control is transferred to the associated handler for that exception, if one is specified. Whether or not a handler is specified for an exception at a given point can be statically determined. If no explicit handler is specified, control may be transferred to an implementation defined exception handler.

Exceptions have a name, which is either a CHILL defined exception name, an implementation defined exception name, or a program defined exception name. Note that when a handler is specified for an exception name, the associated dynamic condition must be checked.

1.9 Time supervision

Time supervision facilities of CHILL provide the means to react to the elapsing of time in the external world. A process becomes **timeoutable** when it reaches a well-defined point in the execution of certain actions. At this point it may be interrupted. When this happens, control is transferred to an appropriate handler.

Programs may detect the elapsing of a period of time or may synchronize to an absolute point of time or at precise intervals without cumulated drifts. Built-in routines for time are provided to convert absolute time values and duration values into integer values, to suspend a process until a time supervision expires.

1.10 Program structure

The program structuring statements are the begin-end block, module, procedure, process, region and moreta mode. The program structuring statements provide the means of controlling the lifetime of locations and the visibility of names.

The lifetime of a location is the time during which a location exists within the program. Locations can be explicitly declared (in a location declaration) or generated (*GETSTACK* or *ALLOCATE* built-in routine call), or they can be implicitly declared or generated as the result of the use of language constructs.

A name is said to be **visible** at a certain point in the program if it may be used at that point. The scope of a name encompasses all the points where it is **visible**, i.e. where the denoted object is identified by that name.

Begin-end blocks determine both visibility of names and lifetime of locations.

Modules are provided to restrict the visibility of names to protect against unauthorised usage. By means of visibility statements, it is possible to exercise control over the visibility of names in various program parts.

A procedure is a (possibly parameterised) subprogram that may be invoked (called) at different places within a program. It may return a value (value procedure) or a location (location procedure), or deliver no result. In the latter case the procedure can only be called in a procedure call action.

Processes, task locations, regions and region locations provide the means by which a structure of concurrent executions can be achieved.

Generic templates provide the means by which generic modules, regions, procedures, processes and moreta modes can be constructed. These templates can be parameterised by SYN constants, modes and procedures. Generic instantiation statements are used to obtain (non-generic) modules, regions, procedures, processes and moreta modes which are called generic instances. A generic instance is obtained from a generic template T by replacing in T the formal generic parameters with the corresponding actual generic parameters.

A complete CHILL program is a list of program units that is considered to be surrounded by an (imaginary) process definition. This outermost process is started by the system under whose control the program is executed. A program unit can be a module, a region, a moreta synmode definition statement, a moreta newmode definition statement or a generic template.

Constructs are provided to facilitate various ways of piecewise development of programs. A spec module and spec region are used to define the static properties of a program piece, a context is used to define the static properties of seised names. In addition it is possible to specify that the text of a program piece is to be found somewhere else through the remote facility.

1.11 Concurrent execution

CHILL allows for the concurrent execution of program units. A thread (process or task) is the unit of concurrent execution. The evaluation of a start expression causes the creation of a new process of the indicated process definition. The process is then considered to be executed concurrently with the starting thread. CHILL allows for one or more processes with the same or different definition to be active at one time. The stop action, executed by a process or a task, causes its termination.

A thread is always in one of two states; it can be active or delayed. The transition from active to delayed is called the delaying of the thread; the transition from delayed to active is called the reactivation of the thread. The execution of delaying actions on events, or receiving actions on buffers or signals, or sending actions on buffers, or call action to a component procedure of a region location, or call action to a component procedure of a task location in case there is not enough storage to perform can cause the executing thread to become delayed. The execution of a continue action on events, or sending actions on buffers or signals, or receiving actions on buffers, or release of a region location, or at the beginning of the execution of an externally called component procedure of a task location can cause a delayed thread to become active again.

Buffers and events are locations with restricted use. The operations send, receive and receive case are defined on buffers; the operations delay, delay case and continue are defined on events. Buffers are a means of synchronizing and transmitting information between processes. Events are used only for synchronisation. Signals are defined in signal definition statements. They denote functions for composing and decomposing lists of values transmitted between processes. Send actions and receive case actions provide for communication of a list of values and for synchronisation.

A region or region location is a special kind of module. Its use is to provide for mutually exclusive access to data structures that are shared by several threads.

1.12 General semantic properties

The semantic (non context-free) conditions of CHILL are the mode and class compatibility conditions (mode checking) and the visibility conditions (scope checking). The mode rules determine how names may be used; the scope rules determine where names may be used.

The mode rules are formulated in terms of compatibility requirements between modes, between classes and between modes and classes. The compatibility requirements between modes and classes and between classes themselves are defined in terms of equivalence relations between modes. If dynamic modes are involved, mode checking is partly dynamic.

The scope rules determine the visibility of names through the program structure and explicit visibility statements. The explicit visibility statements influence the scope of the mentioned names. Names introduced in a program have a place where they are defined or declared. This place is called the defining occurrence of the name. The places where the name is used are called applied occurrences of the name. The name binding rules associate a unique defining occurrence with each applied occurrence of the name.

1.13 Implementation options

CHILL allows for implementation defined integer modes, implementation defined built-in routines, implementation defined **process** names, implementation defined exception handlers and implementation defined exception names.

An implementation defined integer mode must be denoted by an implementation defined **mode** name. This name is considered to be defined in a newmode definition statement that is not specified in CHILL. Extending the existing CHILL-defined arithmetic operations to the implementation defined integer modes is allowed within the framework of the CHILL syntactic and semantic rules. Examples of implementation defined integer modes are long integers and short integers.

A built-in routine is a procedure whose definition need not be written in CHILL and that may have a more general parameter passing and result transmission scheme than CHILL procedures.

A built-in **process** name is a process name whose definition need not be written in CHILL and that may have a more general parameter passing scheme than CHILL processes. A CHILL process may cooperate with built-in processes or start such processes.

An implementation defined exception handler is a handler appended to a process definition. If this handler receives control after the occurrence of an exception, the implementation decides which actions are to be taken. An implementation defined exception is caused if an implementation defined dynamic condition is violated.

2 Preliminaries

2.1 The metalanguage

The CHILL description consists of two parts:

- the description of the context-free syntax;
- the description of the semantic conditions.

2.1.1 The context-free syntax description

The context-free syntax is described using an extension of the Backus-Naur Form. Syntactic categories are indicated by one or more English words, written in slanted characters, enclosed between angular brackets (< and >). This indicator is called a non-terminal symbol. For each non-terminal symbol, a production rule is given in an appropriate syntax section. A production rule for a non-terminal symbol consists of the non-terminal symbol at the left-hand side of the symbol *::=*, and one or more constructs, consisting of non-terminal and/or terminal symbols at the right-hand side. These constructs are separated by a vertical bar (|) to denote alternative productions for the non-terminal symbol.

Sometimes the non-terminal symbol includes an underlined part. This underlined part does not form part of the context-free description but defines a semantic category (see 2.1.2).

Syntactic elements may be grouped together by using curly brackets ({ and }). Repetition of curly bracketed groups is indicated by an asterisk (*) or plus ($^+$). An asterisk indicates that the group is optional and can be further repeated any number of times; a plus indicates that the group must be present and can be further repeated any number of times. For example, { *A* }* stands for any sequence of *A*'s, including zero, while { *A* }$^+$ stands for any sequence of at least one *A*. If syntactic elements are grouped using square brackets ([and]), then the group is optional. A curly or square bracketed group may contain one or more vertical bars, indicating alternative syntactic elements.

A distinction is made between strict syntax, for which the semantic conditions are given directly, and derived syntax. The derived syntax is considered to be an extension of the strict syntax and the semantics for the derived syntax is indirectly explained in terms of the associated strict syntax.

It is to be noted that the context-free syntax description is chosen to suit the semantic description in this document and is not made to suit any particular parsing algorithm (e.g. there are some context-free ambiguities introduced in the interest of clarity). The ambiguities are resolved using the semantic category of the syntactic elements.

2.1.2 The semantic description

Each syntactic category (non-terminal symbol) is described in subclauses **semantics**, **static properties**, **dynamic properties**, **static conditions** and **dynamic conditions**.

The subclause **semantics** describes the concepts denoted by the syntactic categories (i.e. their meaning and behaviour).

The subclause **static properties** defines statically determinable semantic properties of the syntactic category. These properties are used in the formulation of static and/or dynamic conditions in the sections where the syntactic category is used.

The subclause **dynamic properties** defines the properties of the syntactic category, which are known only dynamically.

The subclause **static conditions** describes the context-dependent, statically checkable conditions which must be fulfilled when the syntactic category is used. Some static conditions are expressed in the syntax by means of an underlined part in the non-terminal symbol (see 2.1.1). This use requires the non-terminal to be of a specific semantic category. E.g. <u>*boolean*</u> *expression* is identical to <*expression*> in the context-free sense, but semantically it requires the *expression* to be of a boolean class.

The subclause **dynamic conditions** describes the context-dependent conditions that must be fulfilled during execution. In some cases, conditions are static if no dynamic modes are involved. In those cases, the condition is mentioned under **static conditions** and referred to under **dynamic conditions**. In other cases, dynamic conditions can be checked statically; an implementation may treat this as a violation of a static condition.

In the semantic description, different fonts are used in the following ways: slanted font (without < and >) is used to indicate syntactic objects; corresponding terms in roman font indicate corresponding semantic objects (e.g. a *location* denotes a location). Bolding is used to name semantic properties; sometimes a property can be expressed syntactically as well as semantically (e.g. the sentence "the *expression* is **constant**" means the same as "the *expression* is a *constant expression*").

Unless otherwise specified, the semantics, properties and conditions described in the subclause of a syntactic category hold regardless of the context in which in other subclauses that syntactic category may appear.

The properties of a syntactic category *A* that has a production rule of the form *A ::= B*, where *B* is a syntactic category, are the same as *B* unless otherwise specified.

In this Recommendation | International Standard, virtual names are introduced to describe modes, locations and values which do not occur explicitly in the program text. In such cases the name is preceded by an ampersand (&) symbol. These names are introduced for descriptive purposes only.

2.1.3 The examples

For most syntax subclauses, there is a subclause **examples** giving one or more examples of the defined syntactic categories. These examples are extracted from a set of program examples contained in Appendix IV. References indicate via which syntax rule each example is produced and from which example it is taken.

E.g. *6.20 (d+5)/5 (1.2)* indicates an example of the terminal string *(d+5)/5*, produced via rule *(1.2)* of the appropriate syntax subclause, taken from program example No. *6* line *20*.

2.1.4 The binding rules in the metalanguage

Sometimes the semantic description mentions CHILL **special** simple name strings (see Appendix III). These **special** simple name strings are always used with their CHILL meaning and are therefore not influenced by the binding rules of an actual CHILL program.

2.2 Vocabulary

Programs are represented using the CHILL character set (see Appendix I). The alphabet is represented by the syntactic category *<character>*, from which any character that is in the CHILL character set can be derived as terminal production.

The lexical elements of CHILL are:

- special symbols;
- simple name strings;
- literals.

The special symbols are listed in Appendix III. They can be formed by a single character or by character combinations.

Simple name strings are formed according to the following syntax:

syntax:

```
<simple name string> ::=                                        (1)
        <letter> { <letter> | <digit> | _ }*                    (1.1)

<letter> ::=                                                    (2)
        A | B | C | D | E | F | G | H | I | J | K | L | M       (2.1)
      | N | O | P | Q | R | S | T | U | V | W | X | Y | Z       (2.2)
      | a | b | c | d | e | f | g | h | i | j | k | l | m       (2.3)
      | n | o | p | q | r | s | t | u | v | w | x | y | z       (2.4)

<digit> ::=                                                     (3)
        0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9                   (3.1)
```

semantics: The underline character (_) forms part of the simple name string, e.g. the simple name string *life_time* is different from the simple name string *lifetime*. Lower case and upper case letters are different, e.g. *Status* and *status* are two different simple name strings.

The language has a number of **special** simple name strings with predetermined meanings (see Appendix III). Some of them are **reserved**, i.e. they cannot be used for other purposes.

The **special** simple name strings in a piece must either all be in upper case representation or all be in lower case representation. The **reserved** simple name strings are only reserved in the chosen representation (e.g. if the lower case fashion is chosen, **row** is reserved, **ROW** is not).

static conditions: A *simple name string* may not be one of the **reserved** simple name strings (see III.1).

2.3 The use of spaces

A sequence of one or more spaces is allowed before and after each lexical element. Such a sequence is called a delimiter. Lexical elements are also terminated by the first character that cannot be part of the lexical element. For instance, *IFBTHEN* will be considered a *simple name string* and not as the beginning of an action **IF** B **THEN**, //* will be considered as the concatenation symbol (//) followed by an asterisk (*) and not as a divide symbol (/) followed by a comment opening bracket (/*).

2.4 Comments

syntax:

<comment> ::= *(1)*
<bracketed comment> *(1.1)*
| *<line-end comment>* *(1.2)*

<bracketed comment> ::= *(2)*
/* *<character string>* */ *(2.1)*

<line-end comment> ::= *(3)*
– – *<character string> <end-of-line>* *(3.1)*

<character string> ::= *(4)*
{ *<character>* }* *(4.1)*

NOTE – *end-of-line* denotes the end of the line in which the comment occurs.

semantics: A *comment* conveys information to the reader of a program. It has no influence on the program semantics.

A *comment* may be inserted at all places where spaces are allowed as delimiters.

A *bracketed comment* is terminated by the first occurrence of the special sequence: */. A *line-end comment* is terminated by the first occurrence of the end of the line.

examples:

4.1 */* from collected algorithms from CACM No. 93 */* *(2.1)*

2.5 Format effectors

The format effectors BS (Backspace), CR (Carriage return), FF (Form feed), HT (Horizontal tabulation), LF (Line feed), VT (Vertical tabulation) of the CHILL character set (see Appendix I, positions FE_0 to FE_5) and the *end-of-line* are not mentioned in the CHILL context-free syntax description. When used, they have the same delimiting effect as a space. Spaces and format effectors may not occur within lexical elements (except character string literals).

2.6 Compiler directives

syntax:

<directive clause> ::= *(1)*
<> *<directive>* { , *<directive>* }* <> *(1.1)*

<directive> ::= *(2)*
<implementation directive> *(2.1)*

semantics: A directive clause conveys information to the compiler. This information is specified in an implementation defined format.

An implementation directive must not influence the program semantics, i.e. a program with implementation directives is correct, in the CHILL sense if, and only if, it is correct without these directives.

A *directive clause* is terminated by the first occurrence of the directive ending symbol (<>). A *directive* may contain any character of the character set (see Appendix I).

static properties: A *directive clause* may be inserted at any place where spaces are allowed as delimiters. It has the same delimiting effect as a space. The names used in a *directive clause* follow an implementation defined name binding scheme which does not influence the CHILL name binding rules (see 12.2).

2.7 Names and their defining occurrences

syntax:

<name> ::= *(1)*
<name string> *(1.1)*
| *<qualified name>* *(1.2)*
| *<moreta component name>* *(1.3)*

<name string> ::= *(2)*
<simple name string> *(2.1)*
| *<prefixed name string>* *(2.2)*

<prefixed name string> ::= *(3)*
<prefix> ! *<simple name string>* *(3.1)*

<prefix> ::= *(4)*
<simple prefix> { ! *<simple prefix>* }* *(4.1)*

<simple prefix> ::= *(5)*
<simple name string> *(5.1)*

<defining occurrence> ::= *(6)*
<simple name string> *(6.1)*

<defining occurrence list> ::= *(7)*
<defining occurrence> { , *<defining occurrence>* }* *(7.1)*

<set element name> ::= *(8)*
<simple name string> *(8.1)*

<set element name defining occurrence> ::= *(9)*
<simple name string> *(9.1)*

<field name> ::= *(10)*
<simple name string> *(10.1)*

<field name defining occurrence> ::= *(11)*
<simple name string> *(11.1)*

<field name defining occurrence list> ::= *(12)*
<field name defining occurrence> { , *<field name defining occurrence>* }* *(12.1)*

<exception name> ::= *(13)*
<simple name string> *(13.1)*
| *<prefixed name string>* *(13.2)*

<text reference name> ::= *(14)*
<simple name string> *(14.1)*
| *<prefixed name string>* *(14.2)*

<component name> ::= *(15)*
<simple name string> *(15.1)*

<component name defining occurrence> ::= *(16)*
<simple name string> *(16.1)*

<qualified name> ::= *(17)*
<simple name string> ! *<component name>* *(17.1)*

<moreta component name> ::= *(18)*
<moreta location>. { *<simple name string>* | *<qualified name>* } *(18.1)*

semantics: Names in a program denote objects. Given an occurrence of a *name* (formally: an occurrence of a terminal production of *name*) in a program, the binding rules of 12.2 provide *defining occurrences* (formally: occurrences of terminal productions of *defining occurrence*) to which that (occurrence of) *name* is **bound**. The *name* then denotes the object defined or declared by the *defining occurrences*. (There can be more than one *defining occurrence* for a *name* in the case of *names* with **quasi** *defining occurrences* and in the case of *names* of components of moreta modes.)

Defining occurrences are said to define the *name*. A *name* is said to be an applied occurrence of the name created by the *defining occurrence* to which it is **bound**. The *name* has its rightmost *simple name string* equal to that of the name.

Similarly, field names are **bound** to field name defining occurrences and denote the fields (of a structure mode) defined by those field name defining occurrences. *Moreta component names* are bound to *component defining occurrences* and denote the components (of a moreta mode) defined by those *component name defining occurrences*.

Exception names are used to identify exception handlers according to the rules stated in clause 8.

Text reference names are used to identify descriptions of pieces of source text in an implementation defined way, subject to the rules in 10.10.1.

When a name is **bound** to more than one defining occurrence, each of the defining occurrences to which the name is **bound** defines or declares the same object (see 10.10 and 12.2.2 for precise rules).

Qualified names are used to identify components of *moreta modes*.

definition of notation: Given a *name string* NS, and a string of characters P, which is either a *prefix* or is empty, the result of prefixing NS with P, written P ! NS, is defined as follows:

- if P is empty, then P ! NS is NS;
- otherwise P ! NS is the name string obtained by concatenating all the characters in P, a prefixing operator and all the characters in NS.

For example, if P is “*q ! r*” and NS is “*s ! n*” then P ! NS is “*q ! r ! s ! n*”.

static properties: Each *simple name string* has a **canonical** name string attached which is the *simple name string* itself. A *name string* has a **canonical** name string attached which is:

- if the *name string* is a *simple name string*, then the **canonical** name string of that *simple name string*;
- if the *name string* is a *prefixed name string*, then the concatenation in left to right order of all *simple name strings* in the *name string*, separated by prefixing operators, i.e. interspersed spaces, comments and format effectors (if any) are left out.

In the rest of this Recommendation | International Standard:

- the name string of a *name*, *exception name* or *text reference name* is used to denote the **canonical** name string of the *name string* in that *name*, *exception name* or *text reference name*, respectively;
- the name string of a *defining occurrence*, *field name*, *field name defining occurrence*, *moreta component name* or *moreta component defining occurrence* is used to denote the **canonical** name string of the *simple name string* in that *defining occurrence*, *field name*, *field name defining occurrence*, *moreta component name* or *moreta component defining occurrence*, respectively.

The binding rules are such that:

- names with a simple name string are **bound** to defining occurrences with the same name string;
- names with a prefixed name string are **bound** to defining occurrences with the same name string as the rightmost simple name string in the prefixed name string of the name;
- field names are **bound** to field name defining occurrences with the same name string as the field names;
- *moreta component names* are bound to *moreta component name defining occurrences* with the same *name string* as the *moreta component names*.

A *name* inherits all the static properties attached to the name defined by the *defining occurrence* to which it is **bound**. A *field name* inherits all static properties attached to the field name defined by the *field name defining occurrence* to which it is **bound**. A *moreta component name* inherits all static properties attached to the *moreta component name* defined by the *moreta component name defining occurrence* to which it is bound.

static conditions: The *simple name string* denoted in a *qualified name* and followed by **!** must be a *moreta mode name*.

If a qualified name of the form “M ! component name” occurs outside the definition of the moreta mode M, then the component name must be the name of a SYN, a SYNMODE, or a NEWMODE component of M.

3 Modes and classes

3.1 General

A location has a mode attached to it; a value has a class attached to it. The mode attached to a location defines the set of values that may be contained in the location, the access methods of the location and the allowed operations on the values. The class attached to a value is a means of determining the modes of the locations that may contain the value. Some values are **strong**. A **strong** value has a class and a mode attached. **Strong** values are required in those value contexts where mode information is needed.

3.1.1 Modes

CHILL has static modes (i.e. modes for which all properties are statically determinable) and dynamic modes (i.e. modes for which some properties are only known at run time). Dynamic modes are always parameterised modes with run-time parameters.

Static modes are terminal productions of the syntactic category *mode*.

Modes are also parameterised by values not explicitly denoted in the program text.

3.1.2 Classes

Classes have no denotation in CHILL.

The following kinds of classes exist and any value in a CHILL program has a class of one of these kinds:

For a mode M there exists the M-value class. All values with such a class and only those values are **strong** and the mode attached to the value is M.

- For a mode M there exists the M-derived class.
- For any mode M there exists the M-reference class.
- The **null** class.
- The **all** class.

The last two classes are constant classes, i.e. they do not depend on a mode M. A class is said to be dynamic if, and only if, it is an M-value class, an M-derived class, or an M-reference class, where M is a dynamic mode.

3.1.3 Properties of, and relations between, modes and classes

Modes in CHILL have properties. These may be hereditary or non-hereditary properties. A hereditary property is inherited from a defining mode to a **mode** name defined by it. Below a summary is given of the properties that apply to all modes (except for the first, they are all defined in 12.1):

- A mode has a **novelty** (defined in 3.2.2, 3.2.3 and 3.3).
- A mode can have the **read-only property**.
- A mode can be **parameterisable**.
- A mode can have the **referencing property**.
- A mode can have the **tagged parameterised property**.
- A mode can have the **non-value property**.

Classes in CHILL may have the following properties (defined in 12.1):

- A class can have a **root** mode.
- One or more classes may have a **resulting class**.

Operations in CHILL are determined by the modes and classes of locations and values. This is expressed by the mode checking rules which are defined in 12.1 as a number of relations between modes and classes. There exist the following relations:

- Two modes can be **similar**.

- Two modes can be **v-equivalent**.
- Two modes can be **equivalent**.
- Two modes can be **l-equivalent**.
- Two modes can be **alike**.
- Two modes can be **novelty bound**.
- Two modes can be **read-compatible**.
- Two modes can be **dynamic read-compatible**.
- Two modes can be **dynamic equivalent**.
- A mode can be **restrictable** to a mode.
- A mode can be **compatible** with a class.
- A class can be **compatible** with a class.

3.2 Mode definitions

3.2.1 General

syntax:

<mode definition> ::=	*(1)*
<defining occurrence list> = <defining mode>	*(1.1)*
<defining mode> ::=	*(2)*
<mode>	*(2.1)*

derived syntax: A *mode definition* where the *defining occurrence list* consists of more than one *defining occurrence* is derived from several mode definitions, one for each *defining occurrence*, separated by commas, with the same *defining mode*. For example:

NEWMODE *dollar, pound = INT*;

is derived from:

NEWMODE *dollar = INT, pound = INT*;

semantics: A mode definition defines a name that denotes the specified mode. Mode definitions occur in synmode and newmode definition statements. A synmode is **synonymous** with its defining mode. A newmode is not **synonymous** with its defining mode. The difference is defined in terms of the property **novelty**, that is used in the mode checking (see 12.1).

static properties: A *defining occurrence* in a *mode definition* defines a **mode** name.

Predefined **mode** names, implementation defined integer **mode** names and implementation defined floating point **mode** names (if any, see 3.4.2 and 3.5.1) are also **mode** names.

A **mode** name has a **defining** mode which is the *defining mode* in the *mode definition* which defines it. (For predefined and implementation defined **mode** names this **defining** mode is a virtual mode). The hereditary properties of a **mode** name are those of its **defining** mode.

A set of recursive definitions is a set of mode definitions or synonym definitions (see 5.1) such that the *defining mode* in each *mode definition* or <u>*constant*</u> *value* or *mode* in each *synonym definition* is, or directly contains, a **mode** name or a **synonym** name defined by a definition in the set.

A set of recursive mode definitions is a set of recursive definitions having only mode definitions.

Any mode being or containing a **mode** name defined in a set of recursive mode definitions is said to denote a recursive mode. A path in a set of recursive mode definitions is a list of **mode** names, each name indexed with a marker such that:

- all names in the path have a different definition;

- for each name, its successor is or directly occurs in its defining mode (the successor of the last name is the first name);
- the marker indicates uniquely the position of the name in the defining mode of its predecessor (the predecessor of the first name is the last name).

(Example: **NEWMODE** *M* = **STRUCT** *(i M, n* **REF** *M)*; contains two paths: $\{M_i\}$ and $\{M_n\}$.)

A path is **safe** if, and only if, at least one of its names is contained in a *reference mode*, a *row mode*, or a *procedure mode* at the marked place.

static conditions: For any set of recursive mode definitions, all its paths must be **safe**. (The first path of the example above is not **safe**).

examples:

1.15	*operand_mode = INT*	*(1.1)*
3.3	*complex* = **STRUCT** *(re,im FLOAT)*	*(1.1)*

3.2.2 Synmode definitions

syntax:

<synmode definition statement> ::=	*(1)*
SYNMODE *<mode definition>* { , *<mode definition>* }* ;	*(1.1)*
| *<remote program unit>*	*(1.2)*

semantics: A synmode definition statement defines **mode** names which are **synonymous** with their defining mode.

static properties: A *defining occurrence* in a *mode definition* in a *synmode definition statement* defines a **synmode** name (which is also a **mode** name). A **synmode** name is said to be **synonymous** with a mode M (conversely, M is said to be **synonymous** with the **synmode** name) if, and only if:

- either M is the **defining** mode of the **synmode** name; or
- the **defining** mode of the **synmode** name is itself a **synmode** name **synonymous** with M.

The **novelty** of a **synmode** name is that of its **defining** mode.

If the **defining** mode is a discrete range mode or a floating point range mode, then the **parent** mode of the **synmode** name is that of its **defining** mode. If the **defining** mode is a **varying** string mode, then the **component** mode of the **synmode** name is that of its **defining** mode.

examples:

6.3	**SYNMODE** *month* = **SET** *(jan, feb, mar, apr, may, jun,* *jul, aug, sep, oct, nov, dec);*	*(1.1)*

3.2.3 Newmode definitions

syntax:

<newmode definition statement> ::=	*(1)*
NEWMODE *<mode definition>* { , *<mode definition>*}* ;	*(1.1)*
| *<remote program unit>*	*(1.2)*

semantics: A newmode definition statement defines **mode** names which are not **synonymous** with their defining mode.

static properties: A *defining occurrence* in a *mode definition* in a *newmode definition statement* defines a **newmode** name (which is also a **mode** name).

The **novelty** of the **newmode** name is the *defining occurrence* which defines it. If the **defining** mode of the **newmode** name is a discrete range mode or a floating point range mode, then the virtual mode &*name* is introduced as the **parent** mode of the **newmode** name. The **defining** mode of &*name* is the **parent** mode of the discrete range mode or the one of the floating point range mode, and the **novelty** of &*name* is that of the **newmode** name.

If the **defining** mode is a **varying** string mode, then the virtual mode &*name* is introduced as the **component** mode of the **newmode** name. The defining mode of &*name* is the **component** mode of the **varying** string mode, and the **novelty** of &*name* is that of the **newmode** name.

If the *defining occurrence* of the mode definition is a **quasi** *defining occurrence*, then the **novelty** is a **quasi novelty**, otherwise it is a **real novelty**.

static conditions: If the **novelty** is a **quasi novelty**, then at most one **real novelty** must be **novelty bound** to it.

examples:

11.6	**NEWMODE** *line* = *INT* (1:8);	*(1.1)*
11.12	**NEWMODE** *board* = **ARRAY** *(line)* **ARRAY** *(column) square*;	*(1.1)*

3.3 Mode classification

syntax:

<*mode*> *::=*	*(1)*
[**READ**] <*non-composite mode*>	*(1.1)*
| [**READ**] <*composite mode*>	*(1.2)*
| <*formal generic mode indication*>	*(1.3)*

<*non-composite mode*> *::=*	*(2)*
<*discrete mode*>	*(2.1)*
| <*real mode*>	*(2.2)*
| <*powerset mode*>	*(2.3)*
| <*reference mode*>	*(2.4)*
| <*procedure mode*>	*(2.5)*
| <*instance mode*>	*(2.6)*
| <*synchronisation mode*>	*(2.7)*
| <*input-output mode*>	*(2.8)*
| <*timing mode*>	*(2.9)*

semantics: A mode defines a set of values and the operations which are allowed on the values. A mode may be a **read-only** mode, indicating that a location of that mode may not be accessed to store a value. A mode has a **novelty**, indicating whether it was introduced via a newmode definition statement or not.

static properties: A mode has the following hereditary properties:

- It is a **read-only** mode if it is an explicit or an implicit **read-only** mode.
- It is an explicit **read-only** mode if **READ** is specified or it is a **parameterised** array mode, a **parameterised** string mode or a **parameterised** structure mode, where the **origin** array mode name, **origin** string mode name or **origin variant** structure mode name, respectively, in it is a **read-only** mode.
- It is an implicit **read-only** mode if it is not an explicit **read-only** mode and if:
  - it is the element mode of a read-only string mode or a read-only array mode (see 3.13.2 and 3.13.3);
  - it is a field mode of a read-only structure mode or it is the mode of a tag field of a parameterised structure mode (see 3.13.4).

A *mode* has the same properties as the *non-composite mode* or *composite mode* in it. In the following subclauses, the properties are defined for predefined **mode** names and for *modes* that are not <u>*mode*</u> *names*; the properties of <u>*mode*</u> *names* are defined in 3.2. **Read-only** modes have the same properties as their corresponding non-**read-only** modes except for the **read-only property** (see 12.1.1.1).

A mode has the following non-hereditary properties:

- A **novelty** that is either **nil** or the *defining occurrence* in a *mode definition* in a *newmode definition statement*. The **novelty** of a mode which is not a <u>*mode*</u> *name* (nor **READ** <u>*mode*</u> *name*) is defined as follows:
  - if it is a **parameterised** string mode, a **parameterised** array mode or a **parameterised** structure mode, its **novelty** is that of its **origin** string mode, **origin** array mode or **origin variant** structure mode, respectively;
  - if it is a discrete range mode or a floating point range mode, its **novelty** is that of its **parent** mode;

– otherwise its **novelty** is **nil**.

The **novelty** of a mode that is a <u>*mode*</u> *name* (**READ** <u>*mode*</u> *name*) is defined in 3.2.2 and 3.2.3.

- A **size** that is the value delivered by *SIZE (&M)*, where *&M* is a virtual **synmode** name **synonymous** with the *mode*.

3.4 Discrete modes

3.4.1 General

syntax:

<discrete mode> ::=	*(1)*
<integer mode>	*(1.1)*
| *<boolean mode>*	*(1.2)*
| *<character mode>*	*(1.3)*
| *<set mode>*	*(1.4)*
| *<discrete range mode>*	*(1.5)*

semantics: A discrete mode defines sets and subsets of totally-ordered values.

3.4.2 Integer modes

syntax:

<integer mode> ::=	*(1)*
<<u>integer mode</u> name>	*(1.1)*

predefined names: The name *INT* is predefined as an **integer mode** name.

semantics: An integer mode defines a set of signed integer values between implementation defined bounds over which the usual ordering and arithmetic operations are defined (see 5.3). An implementation may define other integer modes with different bounds (e.g. *LONG_INT*, *SHORT_INT*, *UNSIGNED_INT*) that may also be used as **parent** modes for ranges (see 13.2). The *&INT* mode is introduced as the virtual mode that contains all the values of all **predefined** integer modes defined by the implementation. The internal representation of an integer value is the integer value itself. Note that *&INT* is not a **predefined** mode (although it may have the same bounds as those of a **predefined** integer mode).

static properties: An integer mode has the following hereditary properties:

- An **upper bound** and a **lower bound** which are the literals denoting respectively the highest and lowest value defined by the integer mode. They are implementation defined.
- A **number of values** which is **upper bound – lower bound** + 1.

examples:

1.5	*INT*	*(1.1)*

3.4.3 Boolean modes

syntax:

<boolean mode> ::=	*(1)*
<<u>boolean mode</u> name>	*(1.1)*

predefined names: The name *BOOL* is predefined as a **boolean mode** name.

semantics: A boolean mode defines the logical truth values (*TRUE* and *FALSE*), with the usual boolean operations (see 5.3). The internal representations of *FALSE* and *TRUE* are the integer values 0 and 1, respectively. This representation defines the ordering of the values.

static properties: A boolean mode has the following hereditary properties:

- An **upper bound** which is *TRUE*, and a **lower bound** which is *FALSE*.

- A **number of values** which is 2.

examples:

5.4 *BOOL* *(1.1)*

3.4.4 Character modes

syntax:

<character mode> ::= *(1)*
<character mode name> *(1.1)*

predefined names: The name *CHAR* is predefined as a **character mode** name.

semantics: A character mode defines the character values as described by the CHILL character set (see Appendix I). This alphabet defines the ordering of the characters and the integer values which are their internal representations.

static properties: A character mode has the following hereditary properties:

- An **upper bound** and a **lower bound** which are the character literals denoting respectively the highest and lowest value defined by *CHAR*.
- A **number of values** which is 256.

examples:

8.4 *CHAR* *(1.1)*

3.4.5 Set modes

syntax:

<set mode> ::= *(1)*
SET (*<set list>*) *(1.1)*
| *<set mode name>* *(1.2)*

<set list> ::= *(2)*
<numbered set list> *(2.1)*
| *<unnumbered set list>* *(2.2)*

<numbered set list> ::= *(3)*
<numbered set element> { , *<numbered set element>*}* *(3.1)*

<numbered set element> ::= *(4)*
<set element name defining occurrence> = *<integer literal expression>* *(4.1)*

<unnumbered set list> ::= *(5)*
<set element> { , *<set element>*}* *(5.1)*

<set element> ::= *(6)*
<set element name defining occurrence> *(6.1)*

semantics: A set mode defines a set of named and unnamed values. The named values are denoted by the names defined by *defining occurrences* in the *set list*; the unnamed values are the other values. The internal representation of the named values is the integer value associated with them. This representation defines the ordering of the values.

The maximum **number of values** of a set mode is implementation defined.

static properties: A *defining occurrence* in a *set list* defines a **set element** name. A **set element** name has a **set** mode attached, which is the set mode.

A set mode has the following hereditary properties:

- A set of **set element** names which is the set of names defined by *defining occurrences* in its *set list*.
- Each **set element** name of a set mode has an internal representation value attached which is, in the case of a *numbered set element*, the value delivered by the *integer literal expression* in it; otherwise one of the values 0, 1, 2, etc., according to its position in the *unnumbered set list*. For example in: **SET** *(a,b)*, *a* has representation value 0, and *b* has representation value 1 attached.

- An **upper bound** and a **lower bound** which are its **set element** names with the highest and lowest representation values, respectively.
- A **number of values** which is the highest of the values attached to the **set element** names plus 1.
- It is a **numbered** set mode if the *set list* in it is a *numbered set list*; otherwise it is an **unnumbered** set mode.

static conditions: For each pair of *integer literal expressions* e_1, e_2 in the *set list NUM* (e_1) and *NUM* (e_2) must deliver different non-negative results.

examples:

11.7	**SET** *(occupied, free)*	*(1.1)*
6.3	*month*	*(1.2)*

3.4.6 Discrete range modes

syntax:

<discrete range mode> ::= *(1)*
    <discrete mode name> (*<literal range>*) *(1.1)*
  | **RANGE** (*<literal range>*) *(1.2)*
  | **BIN** (*<integer literal expression>*) *(1.3)*
  | *<discrete range mode name>* *(1.4)*

<literal range> ::= *(2)*
    <lower bound> : *<upper bound>* *(2.1)*

<lower bound> ::= *(3)*
    <discrete literal expression> *(3.1)*

<upper bound> ::= *(4)*
    <discrete literal expression> *(4.1)*

derived syntax: The notation **BIN** *(n)* is derived from **RANGE** $(0 : 2^n - 1)$, e.g. **BIN** *(2 + 1)* stands for **RANGE** *(0 : 7)*.

semantics: A discrete range mode defines the set of values ranging between the bounds specified (bounds included) by the *literal range*. The range is taken from a specific **parent** mode that determines the operations on and ordering of the range values.

static properties: A discrete range mode has the following non-hereditary property: it has a **parent** mode, defined as follows:

- If the discrete range mode is of the form:

  <discrete mode name> (*<literal range>*)

  then if the *discrete mode name* is not a discrete range mode, the **parent** mode is the *discrete mode name*; otherwise it is the **parent** mode of the *discrete mode name*.

- If the discrete range mode is of the form:

  RANGE (*<literal range>*)

  then the **parent** mode depends on the **resulting class** of the classes of the *upper bound* and *lower bound* in the *literal range*:

  – if it is an M-derived class, where M is an integer mode, then the **parent** mode is a **predefined** integer mode chosen by the implementation such that it contains the range of values delivered by *literal range;*

  – otherwise it is the **root** mode of the **resulting class**.

- If the discrete range mode is a *discrete range mode name* which is a **synmode** name, then its **parent** mode is that of the **defining** mode of the **synmode** name; otherwise it is a **newmode** name and then its **parent** mode is the virtually introduced **parent** mode (see 3.2.3).

A discrete range mode has the following hereditary properties:

- An **upper bound** and a **lower bound** which are the literals denoting the values delivered by *lower bound* and *upper bound*, respectively, in the *literal range*.
- A **number of values** which is the value delivered by *NUM* (*U*) – *NUM* (*L*) + 1, where *U* and *L* denote respectively the **upper bound** and **lower bound** of the discrete range mode.
- It is a **numbered** range mode if its **parent** mode is a **numbered** set mode.

static conditions: The classes of *upper bound* and *lower bound* must be **compatible** and both must be **compatible** with the <u>*discrete mode*</u> *name*, if specified.

Lower bound must deliver a value that is less than or equal to the value delivered by *upper bound*, and both values must belong to the set of values defined by <u>*discrete mode*</u> *name*, if specified.

The <u>*integer literal*</u> *expression* in case of **BIN** must deliver a non-negative value.

If the **parent** mode is an integer mode, there must exist a **predefined** integer mode that contains the set of values included between the **lower bound** and the **upper bound**.

If the discrete range mode is of the form:

RANGE (<*literal range*>) or <<u>*discrete mode*</u> *name*> (<*literal range*>)

then the evaluation of the 1.*lower bound*, 2.*upper bound*, must not depend directly or indirectly on the value of the 1.**lower bound**, 2.**upper bound** of the discrete range mode. If the discrete range mode is of the form:

BIN (<<u>*integer literal*</u> *expression*>)

then the evaluation of the <u>*integer literal*</u> *expression* must not depend directly or indirectly on the value of the **upper bound** of the discrete range mode.

examples:

9.5	*INT (2:max)*	*(1.1)*
11.12	*line*	*(1.4)*

3.5 Real modes

syntax:

```
<real mode> ::=                                   (1)
        <floating point mode>                     (1.1)
      | <floating point range mode>               (1.2)
```

semantics: A real mode specifies a set of numerical values which approximate a continuous range of real numbers.

3.5.1 Floating point modes

syntax:

```
<floating point mode> ::=                         (1)
        <floating point mode name>                (1.1)
```

predefined names: The name *FLOAT* is predefined as a **floating point mode** name.

semantics: A floating point mode defines a set of numeric approximations to a range of real values, together with their minimum relative accuracy, between implementation defined bounds, over which the usual ordering and arithmetic operations are defined (see 5.3). This set contains only the values which can be represented by the implementation. An implementation may define other floating point modes with different bounds and/or **precision** (e.g. *LONG_FLOAT*, *SHORT_FLOAT*) that may also be used as **parent** modes for ranges (see 13.3). The *&FLOAT* mode is introduced as the virtual mode that contains all the values of all **predefined** floating point modes defined by the implementation. The internal representation of a floating point value is the floating point value itself. Note that *&FLOAT* is not a **predefined** mode (although it may have the same bounds as those of a **predefined** floating point mode).

static properties: A floating point mode has the following hereditary properties:

- An **upper bound** and a **lower bound** which are the literals denoting respectively the highest and lowest value defined by the floating point mode. They are implementation defined.
- A **precision** which is the maximum number of significant decimal digits defined by the mode.
- A **positive lower limit** and a **negative upper limit** which are the literals denoting respectively the smallest positive value and the largest negative value exactly representable in the floating point mode, zero excluded.

examples:

FLOAT *(1.1)*

3.5.2 Floating point range modes

syntax:

<*floating point range mode*> *::=* *(1)*
<*floating point mode name*> (<*float value range*>) *(1.1)*
| **RANGE** (<*float value range*> [, <*significant digits*>]) *(1.2)*
| <*floating point range mode name*> *(1.3)*

<*float value range*> *::=* *(2)*
<*lower float bound*> : <*upper float bound*> *(2.1)*

<*lower float bound*> :: = *(3)*
<*floating point literal expression*> *(3.1)*

<*upper float bound*> :: = *(4)*
<*floating point literal expression*> *(4.1)*

<*significant digits*> *::=* *(5)*
<*integer literal expression*> *(5.1)*

semantics: A floating point range mode defines the set of values ranging between the bounds specified (bounds included) by *float value range* with the number of significant digits specified by *significant digits*. The range is taken from a specific **parent** mode that determines the operations on and ordering of the range values. E.g. **RANGE** (–10.0*E*1 : 10.0*E*1, 2) denotes the values: –10.0, –9.9, …, –0.11, –0.1, 0, 0.1, …, 10.0.

static properties: A floating point range mode has the following non-hereditary property: it has a **parent** mode, defined as follows:

- If the floating point range mode is of the form:

  <*floating point mode name*> (<*float value range*>)

  then if the *floating point mode name* is not a floating point range mode, the **parent** mode is the *floating point mode name*; otherwise it is the **parent** mode of the *floating point mode name*.

- If the floating point range mode is of the form:

  RANGE (<*float value range*> [, <*significant digits*>])

  then the **parent** mode depends on the **resulting class** of the classes of the *upper float bound* and *lower float bound* in the *literal range*:

  – if it is an M-derived class, where M is a floating point mode, then the **parent** mode is a **predefined** floating point mode chosen by the implementation such that it contains the range of values delivered by *float value range*, with the **precision** defined below;

  – otherwise it is the **root** mode of the **resulting class**.

- If the floating point range mode is a *floating point range mode name* which is a **synmode** name, then its **parent** mode is that of the **defining** mode of the **synmode** name; otherwise it is a **newmode** name and then its **parent** mode is the virtually introduced **parent** mode (see 3.2.3).

A floating point range mode has the following hereditary properties:

- An **upper bound** and a **lower bound** which are the literals denoting the values delivered by *lower float bound* and *upper float bound*, respectively, in the *float value range*.

- A **precision** which is, if the floating point range mode is of the form:

  RANGE (<*float value range*> [, <*significant digits*>])

  – the value delivered by *significant digits* if specified;

  – otherwise the greatest **precision** of the **precisions** of *lower float bound* and *upper float bound*.

  Otherwise it is that of the floating point mode name or the floating point range mode name.

static conditions: *Lower float bound* must deliver a value that is less than or equal to the value delivered by *upper float bound*, and both values must belong to the set of values defined by *floating point mode name*, if specified.

There must exist a **predefined** floating point mode that contains both **upper bound** and **lower bound** with the specified **precision**.

The value delivered by *significant digit* must be greater than zero.

The evaluation of the: 1.*lower float bound*, 2.*upper float bound*, must not depend directly or indirectly on the value of the: 1.**lower bound**, 2.**upper bound** of the floating point range mode.

3.6 Powerset modes

syntax:

<powerset mode> ::= *(1)*
  POWERSET *<member mode>* *(1.1)*
  | *<powerset mode name>* *(1.2)*

<member mode> ::= *(2)*
  <discrete mode> *(2.1)*

semantics: A powerset mode defines values that are sets of values of its member mode. Powerset values range over all subsets of the member mode. The usual set-theoretic operators are defined on powerset values (see 5.3).

The maximum **number of values** of the member mode is implementation defined.

static properties: A powerset mode has the following hereditary property:

- A **member** mode which is the *member mode*.

examples:

8.4	**POWERSET** *CHAR*	*(1.1)*
9.5	**POWERSET** *INT (2:max)*	*(1.1)*
9.6	*number_list*	*(1.2)*

3.7 Reference modes

3.7.1 General

syntax:

<reference mode> ::= *(1)*
  <bound reference mode> *(1.1)*
  | *<free reference mode>* *(1.2)*
  | *<row mode>* *(1.3)*

semantics: A reference mode defines references (addresses or descriptors) to **referable** locations. By definition, bound references refer to locations of a given static mode or a set of related moreta modes; free references may refer to locations of any static mode; rows refer to locations of a dynamic mode.

The dereferencing operation is defined on reference values (see 4.2.3, 4.2.4 and 4.2.5), delivering the location that is referenced.

Two reference values are equal if, and only if, they both refer to the same location, or both do not refer to a location (i.e. they are the value *NULL*).

3.7.2 Bound reference modes

syntax:

<bound reference mode> ::=		*(1)*
	REF *<referenced mode>*	*(1.1)*
	| *<<u>bound reference mode</u> name>*	*(1.2)*
<referenced mode> ::=		*(2)*
	<mode>	*(2.1)*

semantics: A bound reference mode defines reference values to locations of the specified referenced mode.

If the referenced mode is a non-moreta mode M, then the bound reference mode defines reference values to locations of M.

If the referenced mode is a moreta mode MM, then the bound reference mode defines reference values to locations of MM or any successor of MM.

static properties: A bound reference mode has the following hereditary property:

- A **referenced** mode which is the *referenced mode*.

examples:

10.42	**REF** *cell*	*(1.1)*

3.7.3 Free reference modes

syntax:

<free reference mode> ::=		*(1)*
	<<u>free reference mode</u> name>	*(1.1)*

predefined names: The name *PTR* is predefined as a **free reference mode** name.

semantics: A free reference mode defines reference values to locations of any static mode.

examples:

19.8	*PTR*	*(1.1)*

3.7.4 Row modes

syntax:

<row mode> ::=		*(1)*
	ROW *<<u>string</u> mode>*	*(1.1)*
	| **ROW** *<<u>array</u> mode>*	*(1.2)*
	| **ROW** *<<u>variant structure</u> mode>*	*(1.3)*
	| *<<u>row mode</u> name>*	*(1.4)*

semantics: A row mode defines reference values to locations of dynamic mode (which are locations of some parameterised mode with non **constant** parameters).

A row value may refer to:

- string locations with non **constant string length**;
- array locations with non **constant upper bound**;
- parameterised structure locations with non **constant** parameters.

static properties: A row mode has the following hereditary property:

- A **referenced origin** mode which is the *<u>string</u> mode*, the *<u>array</u> mode*, or the *<u>variant structure</u> mode*, respectively.

static condition: The *<u>variant structure</u> mode* must be **parameterisable**.

examples:

8.6 **ROW CHARS** *(max)* *(1.1)*

3.8 Procedure modes

syntax:

<procedure mode> ::= *(1)*
PROC ([*<parameter list>*]) [*<result spec>*]
[**EXCEPTIONS** (*<exception list>*)] *(1.1)*
| *<procedure mode name>* *(1.2)*

<parameter list> ::= *(2)*
<parameter spec> { , *<parameter spec>*}* *(2.1)*

<parameter spec> ::= *(3)*
<mode> [*<parameter attribute>*] *(3.1)*

<parameter attribute> ::= *(4)*
IN | OUT | INOUT | LOC [**DYNAMIC**] *(4.1)*

<result spec> ::= *(5)*
RETURNS (*<mode>* [*<result attribute>*]) *(5.1)*

<result attribute>::= *(6)*
[**NONREF**] **LOC** [**DYNAMIC**] *(6.1)*

<exception list> ::= *(7)*
<exception name> { , *<exception name>*}* *(7.1)*

semantics: A procedure mode defines (**general**) procedure values, i.e. the objects denoted by **general procedure** names that are names defined in procedure definition statements. Procedure values indicate pieces of code in a dynamic context. Procedure modes allow for manipulating a procedure dynamically, e.g. passing it as a parameter to other procedures, sending it as message value to a buffer, storing it into a location, etc.

Procedure values can be called (see 6.7).

Two procedure values are equal if, and only if, they denote the same procedure in the same dynamic context, or if they both denote no procedure (i.e. they are the value *NULL*).

static properties: A procedure mode has the following hereditary properties:

- A list of **parameter specs**, each consisting of a mode and possibly a parameter attribute. The **parameter specs** are defined by the *parameter list*.
- An optional **result spec**, consisting of a mode and an optional result attribute. The **result spec** is defined by the *result spec*.
- A possibly empty list of **exception** names which are those mentioned in the *exception list*.

static conditions: All names mentioned in *exception list* must be different.

If **LOC** is specified in the *parameter spec* or in the *result spec*, the *mode* in it may have the **non-value property**.

If **DYNAMIC** is specified in the *parameter spec* or in the *result spec*, the *mode* in it must be **parameterisable**.

3.9 Instance modes

syntax:

<instance mode> ::= *(1)*
<instance mode name> *(1.1)*

predefined names: The name *INSTANCE* is predefined as an **instance mode** name.

semantics: An instance mode defines values which identify processes. The creation of a new process (see 5.2.15, 6.13 and 11.1) yields a unique instance value as identification for the created process.

Two instance values are equal if, and only if, they identify the same process, or they both identify no process (i.e. they are the value *NULL*).

examples:

15.39 *INSTANCE* *(1.1)*

3.10 Synchronisation modes

3.10.1 General

syntax:

<synchronisation mode> ::= *(1)*
<event mode> *(1.1)*
| *<buffer mode>* *(1.2)*

semantics: A synchronisation mode provides a means for synchronisation and communication between processes (see clause 11). There exists no expression in CHILL denoting a value defined by a synchronisation mode. As a consequence, there are no operations defined on the values.

3.10.2 Event modes

syntax:

<event mode> ::= *(1)*
EVENT [(*<event length>*)] *(1.1)*
| *<event mode name>* *(1.2)*

<event length> ::= *(2)*
<integer literal expression> *(2.1)*

semantics: An event mode location provides a means for synchronisation between processes. The operations defined on event mode locations are the continue action, the delay action and the delay case action, which are described in 6.15, 6.16 and 6.17, respectively.

The *event length* specifies the maximum number of processes that may become delayed on an event location; that number is unlimited if no *event length* is specified.

An event mode location which contains the **undefined** value is an “empty” event, i.e. no delayed processes are attached to it.

static properties: An event mode has the following hereditary property:

- An optional **event length** which is the value delivered by *event length*.

static conditions: The *event length* must deliver a positive value.

The evaluation of the *event length* must not depend directly or indirectly on the value of the **event length** of the event mode.

examples:

14.10 **EVENT** *(1.1)*

3.10.3 Buffer modes

syntax:

<buffer mode> ::= *(1)*
BUFFER [(*<buffer length>*)] *<buffer element mode>* *(1.1)*
| *<buffer mode name>* *(1.2)*

<buffer length> ::= *(2)*
<integer literal expression> *(2.1)*

<buffer element mode> ::= *(3)*
<mode> *(3.1)*

semantics: A buffer mode location provides a means for synchronisation and communication between processes. The operations defined on buffer locations are the send action and the receive case action, described in 6.18 and 6.19, respectively.

The *buffer length* specifies the maximum number of values that can be stored in a buffer location; that number is unlimited if no *buffer length* is specified.

A buffer mode location which contains the **undefined** value is an "empty" buffer, i.e. no delayed processes are attached to it nor are there messages in the buffer.

static properties: A buffer mode has the following hereditary properties:

- An optional **buffer length** which is the value delivered by *buffer length*.
- A **buffer element** mode which is the *buffer element mode*.

static conditions: The *buffer length* must deliver a non-negative value.

The *buffer element mode* must not have the **non-value property**.

The evaluation of the *buffer length* must not depend directly or indirectly on the value of the **buffer length** of the buffer mode.

examples:

16.30 **BUFFER** *(1) user_messages* *(1.1)*
16.34 *user_buffers* *(1.2)*

3.11 Input-output modes

3.11.1 General

syntax:

<input-output mode> ::= *(1)*
<association mode> *(1.1)*
| *<access mode>* *(1.2)*
| *<text mode>* *(1.3)*

semantics: An input-output mode provides a means for input-output operations as defined in clause 7. There exists no expression in CHILL denoting a value defined by an input-output mode. As a consequence, there are no operations defined on the values.

examples:

20.17 *ASSOCIATION* *(1.1)*

3.11.2 Association modes

syntax:

<association mode> ::= *(1)*
<association mode name> *(1.1)*

predefined names: The name *ASSOCIATION* is predefined as an **association mode** name.

semantics: An association mode location provides a means for representing a relation to an outside world object. Such a relation is called an association in CHILL; associations can be created by the built-in routine *ASSOCIATE* and be ended by *DISSOCIATE*.

An association mode location which contains the **undefined** value is "empty", i.e. it does not contain an association.

3.11.3 Access modes

syntax:

<access mode> ::= *(1)*

ACCESS [(<*index mode*>)] [<*record mode*> [**DYNAMIC**]] *(1.1)*
| <*access mode name*> *(1.2)*

<*record mode*> *::=* *(2)*
<*mode*> *(2.1)*

<*index mode*> *::=* *(3)*
<*discrete mode*> *(3.1)*
| <*literal range*> *(3.2)*

derived syntax: The index mode notation *literal range* is derived from the discrete mode **RANGE** (*literal range*).

semantics: An access mode location provides a means for positioning a file and for transferring values from a CHILL program to a file in the outside world, and vice versa.

An access mode may define a *record mode*; this record mode defines the **root** mode of the class of the values that can be transferred via a location of that access mode to or from a file. The mode of the transferred value may be dynamic, i.e. the **size** of the record may vary, when the attribute **DYNAMIC** is specified in the access mode denotation or when *record mode* is a **varying** string mode. In the latter case **DYNAMIC** need not be specified.

An access mode may also define an *index mode*; such an index mode defines the size of a “window” to (a part of) the file, from which it is possible to read (or write) records randomly. Such a window can be positioned in an (**indexable**) file by the connect operation. If no *index mode* is specified, then it is possible to transfer records only sequentially.

An access mode location which contains the **undefined** value is “empty”, i.e. it is not connected to an association.

static properties: An access mode has the following hereditary properties:

- An optional **record** mode which is the *record mode* if present. It is a **dynamic record** mode if **DYNAMIC** is specified or if *record mode* is a **varying** string mode, otherwise it is a **static record** mode.
- An optional **index** mode which is the *index mode*.
- Optional **upper bound** and **lower bound** which are the **upper bound** and **lower bound** of the *index mode*, if present.

static conditions: The optional *record mode* must not have the **non-value property**.

If **DYNAMIC** is specified, the **record** mode must be **parameterisable** and must not be a **tagless** structure mode.

The *index mode* must neither be a **numbered** set mode nor a **numbered** range mode.

If the *index mode* is a *literal range* of the form:

<*lower bound*> : <*upper bound*>

then, the evaluation of the 1.*lower bound*, 2.*upper bound*, must not depend, directly or indirectly, on the value of the 1.**lower bound**, 2.**upper bound** of the access mode.

examples:

20.18	**ACCESS** *(index_set) record_type*	*(1.1)*
22.20	**ACCESS** *string* **DYNAMIC**	*(1.1)*
20.18	*record_type*	*(2.1)*
20.18	*index_set*	*(3.1)*

3.11.4 Text modes

syntax:

<*text mode*> *::=* *(1)*
TEXT (<*text length*>) [<*index mode*>] [**DYNAMIC**] *(1.1)*

<*text length*> *::=* *(2)*
<*integer literal expression*> *(2.1)*

semantics: A text mode location provides a means for transferring values represented in human-readable form from a CHILL program to a file in the outside world, and vice versa. A text mode location has a **text record** sub-location and an **access** sub-location. The **text record** sub-location is initialised with an empty string.

A text mode has a **text length**, which defines the maximum length of the records that can be transferred, and possibly an **index** mode that has the same meaning as for access modes. The **actual length** attribute of a text mode location is the **actual length** of its **text record**.

A text mode location which contains the **undefined** value has a **text record** sub-location that contains the empty string and an **access** sub-location that contains the **undefined** value.

static properties: A text mode has the following hereditary properties:

- A **text length** which is the value delivered by *text length*.
- A **text record** mode which is **CHARS** (<*text length*>) **VARYING**.
- It has an **access** mode which is **ACCESS** [(<*index mode*>)] **CHARS** (<*text length*>) [**DYNAMIC**] (<*index mode*> and **DYNAMIC** are part of the mode only if they are specified).
- Optional **upper bound** and **lower bound** which are the **upper bound** and **lower bound** of the *index mode*, if present.

static conditions: If the *index mode* is a *literal range* of the form:

<*lower bound*> : <*upper bound*>

then, the evaluation of the 1.*lower bound*, 2.*upper bound*, must not depend directly or indirectly on the value of the 1.**lower bound**, 2.**upper bound** of the text mode.

examples:

26.8 **TEXT** *(80)* **DYNAMIC** *(1.1)*

3.12 Timing modes

3.12.1 General

syntax:

<*timing mode*> *::=* *(1)*
<*duration mode*> *(1.1)*
| <*absolute time mode*> *(1.2)*

semantics: A timing mode provides a means for time supervision of processes as described in clause 9. Timing values are created by a set of built-in routines. The relational operators are defined on timing values.

3.12.2 Duration modes

syntax:

<*duration mode*> *::=* *(1)*
<*duration mode name*> *(1.1)*

predefined names: The name *DURATION* is predefined as a **duration mode** name.

semantics: A duration mode defines values which represent periods of time. The set of values defined by the duration mode is implementation defined. An implementation may choose to represent duration values as pairs of precision and value. Duration values are ordered in the intuitive way.

3.12.3 Absolute time modes

syntax:

<*absolute time mode*> *::=* *(1)*
<*absolute time mode name*> *(1.1)*

predefined names: The name *TIME* is predefined as an **absolute time mode** name.

semantics: An absolute time mode defines values which represent points in time. The set of values defined by the absolute time mode is implementation defined. Absolute time values are ordered in the intuitive way.

3.13 Composite modes

3.13.1 General

syntax:

<composite mode> ::= *(1)*
  <string mode> *(1.1)*
| *<array mode>* *(1.2)*
| *<structure mode>* *(1.3)*
| *<moreta mode>* *(1.4)*

semantics: A composite mode defines composite values, i.e. values consisting of sub-components which can be accessed or obtained (see 4.2.6-4.2.10 and 5.2.6-5.2.10).

3.13.2 String modes

syntax:

<string mode> ::= *(1)*
  <string type> (*<string length>*) [**VARYING**] *(1.1)*
| *<parameterised string mode>* *(1.2)*
| *<string mode name>* *(1.3)*

<parameterised string mode> ::= *(2)*
  <origin string mode name> (*<string length>*) *(2.1)*
| *<parameterised string mode name>* *(2.2)*

<origin string mode name> ::= *(3)*
  <string mode name> *(3.1)*

<string type> ::= *(4)*
  BOOLS *(4.1)*
| **CHARS** *(4.2)*

<string length> ::= *(5)*
  <integer literal expression> *(5.1)*

semantics: A **fixed** string mode defines bit or character string values of a length indicated or implied by the string mode. A **varying** string mode defines bit or character string values whose **actual length** ranges from 0 to the **string length**. The length is known only at runtime from the value of the attribute **actual length**. For a **fixed** string mode, the **actual length** is always equal to the **string length**. Character strings are sequences of character values; bit strings are sequences of boolean values.

String values are either empty or have string elements which are numbered from 0 upward.

The string values of a given string mode are totally-ordered in accordance with the ordering of the component values and the following definition.

Two strings s and t are equal if, and only if, they are empty or have the same length l and $s(i) = t(i)$ for all $0 \le i < l$. A string s precedes t when either:

- there exists an index j such that $s(j) < t(j)$ and $s(0 : j – 1) = t(0 : j – 1)$; or
- *LENGTH* (s) < *LENGTH* (t) and $s = t$(0 **UP** *LENGTH* (s)).

The concatenation operator is defined on string values. The usual logical operators are defined on bit string values and operate between their corresponding elements (see 5.3).

The maximum length of string modes is implementation defined.

static properties: A string mode has the following hereditary properties:

- A **string length** which is the value delivered by *string length*.

- An **upper bound** and a **lower bound** which are the values delivered by **string length** – 1 and 0, respectively.
- An **element** mode which is either *M* or **READ** *M*, where *M* is *BOOL* or *CHAR* depending on whether *string type* specifies **BOOLS** or **CHARS**, or the **element** mode of the *origin string mode name*, respectively. The **element** mode will be **READ** *M* if and only if the *string mode* is a **read-only** mode; in such case it is an implicit **read-only** mode.
- It is a **varying** string mode if **VARYING** is specified or if the *origin string mode name* denotes a **varying** string mode; otherwise it is a **fixed** string mode.

A string mode is **parameterised** if, and only if, it is a *parameterised string mode*.

A **parameterised** string mode has an **origin** string mode which is the mode denoted by *origin string mode name*.

A **varying** string mode has the following non-hereditary property: it has a **component** mode, defined as follows:

- If the **varying** string mode is of the form:

  <*string type*> (<*string length*>) **VARYING**

  then it is <string type> (<string length>).
- If the **varying** string mode is of the form:

  <*origin string mode name*> (<*string length*>)

  then the **component** mode is *&name* (*string length*), where *&name* is a virtually introduced **synmode** name **synonymous** with the **component** mode of the *origin string mode name*.
- If the **varying** string mode is a <u>*string mode*</u> *name* which is a **synmode** name, then its **component** mode is that of the **defining** mode of the **synmode** name; otherwise it is a **newmode** name and then its **component** mode is the virtually introduced **component** mode (see 3.2.3).

static conditions: The *string length* must deliver a non-negative value.

The value delivered by the *string length* directly contained in a *parameterised string mode* must be less than or equal to the **string length** of the *origin string mode name*. This condition applies only to the **parameterised** string modes that are not introduced virtually.

The evaluation of the *string length* must not depend directly or indirectly on the value of the **string length** of the string mode.

examples:

7.51	**CHARS** *(20)* *(1.1)*	
22.22	**CHARS** *(20)* **VARYING**	*(1.1)*

3.13.3 Array modes

syntax:

<*array mode*> *::=*		*(1)*
	ARRAY (<*index mode*> { , <*index mode*> }*)	
	<*element mode*> { <*element layout*> }*	*(1.1)*
	| <*parameterised array mode*>	*(1.2)*
	| <<u>*array mode*</u> *name*>	*(1.3)*
<*parameterised array mode*> *::=*		*(2)*
	<*origin array mode name*> (<*upper index*>)	*(2.1)*
	| <<u>*parameterised array mode*</u> *name*>	*(2.2)*
<*origin array mode name*> *::=*		*(3)*
	<<u>*array mode*</u> *name*>	*(3.1)*
<*upper index*> *::=*		*(4)*
	<<u>*discrete literal*</u> *expression*>	*(4.1)*
<*element mode*> *::=*		*(5)*
	<*mode*>	*(5.1)*

derived syntax: An *array mode* with more than one index mode (denoting a multi-dimensional array), is derived syntax for an *array mode* with an *element mode* that is an *array mode*. For example:

ARRAY (*1:20,1:10*) *INT*

is derived from:

ARRAY (**RANGE** (*1:20*)) **ARRAY** (**RANGE** (*1:10*)) *INT*

Only if this derived syntax is used, is more than one *element layout* occurrence allowed. The number of *element layout* occurrences must be less than or equal to the number of *index mode* occurrences. In that case, the leftmost *element layout* is associated with the innermost *element mode*, etc.

semantics: An array mode defines composite values, which are lists of values defined by its element mode. The physical layout of an array location or value can be controlled by *element layout* specification (see 3.13.5). Two array values are equal if and only if they have the same **number of elements** and the corresponding element values are equal.

The maximum **number of elements** of array modes is implementation defined.

static properties: An array mode has the following hereditary properties:

- An **index** mode which is the *index mode* if it is not a *parameterised array mode*, otherwise the **index** mode is the discrete range mode constructed as:

  &name (*lower bound* : *upper bound*)

  where *&name* is a virtual **synmode** name **synonymous** with the **index** mode of *origin array mode name*, *lower bound* is the lower bound of the **index** mode of the *origin array mode name* and *upper bound* is the *upper index*.

- An **upper bound** and a **lower bound** which are the **upper bound** and the **lower bound** of its **index** mode, respectively.

- An **element** mode which is either *M* or **READ** *M*, where *M* is the *element mode*, or the **element** mode of the *origin array mode name*, respectively. The **element** mode will be **READ** *M* if, and only if, *M* is not a **read-only** mode and the *array mode* is a **read-only** mode. The **element** mode is an implicit **read-only** mode if it is **READ** *M*.

- An **element layout** which, if it is a *parameterised array mode*, is the **element layout** of its *origin array mode name*; otherwise it is either the specified *element layout*, or the implementation default, which is either **PACK** or **NOPACK**.

- A **number of elements** which is the value delivered by:

  NUM (*upper bound*) – *NUM* (*lower bound*) + 1

  where *upper bound* and *lower bound* are respectively the **upper bound** and the **lower bound** of its **index** mode.

- It is a **mapped** mode if *element layout* is specified and is a *step*.

An array mode is **parameterised** if, and only if, it is a *parameterised array mode*.

A **parameterised** array mode has an **origin** array mode which is the mode denoted by *origin array mode name*.

static conditions: The class of *upper index* must be **compatible** with the **index** mode of the *origin array mode name* and the value delivered by it must lie in the range defined by that **index** mode.

If the array mode is a *parameterised array mode*, the evaluation of the *upper index* must not depend directly or indirectly on the value of the **upper bound** of the array mode. If the array mode is neither a *parameterised array mode* nor an <u>*array mode*</u> *name*, and if the *index mode* is a *literal range* of the form:

<*lower bound*> : <*upper bound*>

then, the evaluation of the 1.*lower bound*, 2.*upper bound*, must not depend directly or indirectly on the value of the 1.**lower bound**, 2.**upper bound** of the array mode.

examples:

5.27 **ARRAY** *(1:16)* **STRUCT** *(c4, c2, c1 BOOL)* *(1.1)*

11.12 **ARRAY** *(line)* **ARRAY** *(column) square* *(1.1)*
11.17 *board* *(1.3)*

3.13.4 Structure modes

syntax:

<structure mode> ::= *(1)*
STRUCT (*<field>* { , *<field>*}*) *(1.1)*
| *<parameterised structure mode>* *(1.2)*
| *<structure mode name>* *(1.3)*

<field> ::= *(2)*
<fixed field> *(2.1)*
| *<alternative field>* *(2.2)*

<fixed field> ::= *(3)*
<field name defining occurrence list> *<mode>* [*<field layout>*] *(3.1)*

<alternative field> ::= *(4)*
CASE [*<tag list>*] **OF**
<variant alternative> { , *<variant alternative>*}*
[**ELSE** [*<variant field>* { , *<variant field>* }*]] **ESAC** *(4.1)*

<variant alternative> ::= *(5)*
[*<case label specification>*] : [*<variant field>* { , *<variant field>* }*] *(5.1)*

<tag list> ::= *(6)*
<tag field name> { , *<tag field name>*}* *(6.1)*

<variant field> ::= *(7)*
<field name defining occurrence list> *<mode>* [*<field layout>*] *(7.1)*

<parameterised structure mode> ::= *(8)*
<origin variant structure mode name> (*<literal expression list>*) *(8.1)*
| *<parameterised structure mode name>* *(8.2)*

<origin variant structure mode name> ::= *(9)*
<variant structure mode name> *(9.1)*

<literal expression list> ::= *(10)*
<discrete literal expression> { , *<discrete literal expression>* }* *(10.1)*

derived syntax: A *fixed field* occurrence or *variant field* occurrence, where *field name defining occurrence list* consists of more than one *field name defining occurrence*, is derived syntax for several *fixed field* occurrences or *variant field* occurrences with one *field name defining occurrence* respectively, each with the specified *mode* and optional *field layout*. In the case of *field layout*, this *field layout* must not be *pos*. For example:

STRUCT (*I,J BOOL* **PACK**)

is derived from:

STRUCT (*I BOOL* **PACK**, *J BOOL* **PACK**)

semantics: Structure modes define composite values consisting of a list of values, selectable by a component name. Each value is defined by a mode that is attached to the component name. Structure values may reside in (composite) structure locations, where the component name serves as an access to the sub-location. The components of a structure value or location are called fields and their names **field** names.

There are **fixed** structures, **variant** structures and **parameterised** structures.

Fixed structures consist only of fixed fields, i.e. fields that are always present and that can be accessed without any dynamic check.

Variant structures have variant fields, i.e. fields that are not always present. For **tagged variant** structures, the presence of these fields is known only at run time from the value(s) of certain associated fixed field(s) called **tag** fields. **Tag-less variant** structures do not have **tag** fields. Because the composition of a **variant** structure may change during run time, the **size** of a variant structure location is based upon the largest choice (worst case) of variant alternatives.

In an *alternative field* the *variant alternative* chosen is that for which values give in the case label specification match; if no value match, the *variant alternative* following **ELSE** (which will be present) is chosen.

A **parameterised** structure is determined from a **variant** structure mode for which the choice of variant alternatives is statically specified by means of **literal** expressions. The composition is fixed from the point of the creation of the parameterised structure and may not change during run time. The **tag** fields, if present, are **read-only** and automatically initialised with the specified values. For a parameterised structure location, a precise amount of storage can be allocated at the point of declaration or generation. Note that dynamic **parameterised** structure modes also exist; their semantics are defined in 3.14.4.

The layout of a structure location or value can be controlled by means of a field layout specification (see 3.13.5).

Two structure values are equal if, and only if, the corresponding component values are equal. However, if the structure values are **tag-less variant** structure values, the result of comparison is implementation defined.

For a mode with the **tagged parameterised property** the **undefined** value denotes a value in which **tag** field sub-values are equal to the corresponding parameter values and all the other ones are equal to the **undefined** value.

static properties:

general:

A structure mode has the following hereditary properties:

- It is a **fixed** structure mode if it is a *structure mode* that does not directly contain an *alternative field* occurrence.
- It is a **variant** structure mode if it is a *structure mode* and contains at least one *alternative field* occurrence.
- It is a **parameterised** structure mode if it is a *parameterised structure mode*.
- It has a set of **field** names. This set is defined below for the different cases. A name is said to be a **field** name if, and only if, it is defined in a *field name defining occurrence list* in *fixed fields* or *variant fields* in a *structure mode*.

  Each *fixed field*, *variant field* and therefore each **field** name of a structure mode has a **field** mode attached that is either *M* or **READ** *M*, where *M* is the *mode* in the *fixed field* or *variant field*. The **field** mode is **READ** *M* if *M* is not a **read-only** mode and either the structure mode is a **read-only** mode, or the field is a **tag** field of a **parameterised** structure mode. The **field** mode is an implicit **read-only** mode if it is **READ** *M*.

  A *fixed field*, *variant field* and therefore a **field** name of a given structure mode has a **field layout** attached to it that is the *field layout* in the *fixed field* or *variant field*, if present; otherwise it is the default field layout, which is either **PACK** or **NOPACK**.
- It is a **mapped** mode if its **field** names have a *field layout* that is *pos*.

fixed structures:

A **fixed** structure mode has the following hereditary property:

- A set of **field** names which is the set of names defined by any *field name defining occurrence list* in *fixed fields*. These **field** names are **fixed field** names.

variant structures:

A **variant** structure mode has the following hereditary properties:

- A set of **field** names which is the union of the set of names defined by any field name defining occurrence list in fixed fields and the set of names defined by any field name defining occurrence list in alternative fields. **Field** names defined by a field name defining occurrence list in fixed fields are the **fixed field** names of the **variant** structure mode; its other **field** names are the **variant field** names.

A **field** name of a **variant** structure mode is a **tag field** name if, and only if, it occurs in any tag list of an alternative field. Alternative fields in which no tag lists are specified are **tag-less** *alternative fields*.

- A **variant** structure mode is a **tag-less variant** structure mode if all its *alternative field* occurrences are **tag-less**. Otherwise it is a **tagged variant** structure mode.
- A **variant** structure mode is a **parameterisable variant** structure mode if it is either a **tagged variant** structure mode or a **tag-less variant** structure mode where for each of the *alternative field* occurrences a *case label specification* is given for all the *variant alternative* occurrences in it.
- A **parameterisable variant** structure mode has a list of classes attached, determined as follows:
  - if it is a **tagged variant** structure mode, the list of M_i -value classes, where M_i are the modes of the **tag field** names in the order that they are defined in *fixed fields*;
  - if it is a **tag-less variant** structure mode, the list is built up from the individual **resulting lists of classes** of each *alternative field* by concatenating them in the order as the *alternative fields* occur. The **resulting list of classes** of an *alternative field* occurrence is the **resulting list of classes** of the list of *case label specification* occurrences in it (see 12.3).

parameterised structures:

A **parameterised** structure mode has the following hereditary properties:

- An **origin variant** structure mode which is the mode denoted by *origin variant structure mode name*.
- A set of **field** names which is the union of the set of **fixed field** names of its **origin variant** structure mode and the set of those **variant field** names of its **origin variant** structure mode that are defined in *variant alternative* occurrences that are selected by the list of values defined by *literal expression list*.
- The set of **tag field** names of a *parameterised structure mode* is the set of **tag field** names of its **origin variant** structure mode.
- A list of values attached, defined by *literal expression list*.
- It is a **tagged parameterised** structure mode if its **origin variant** structure mode is a **tagged variant** structure mode; otherwise the **parameterised** structure mode is **tag-less**.

For dynamic **parameterised** structure modes, see 3.14.4.

static conditions:

general:

All **field** names of a structure mode must be different.

If any field has a field layout which is *pos*, all the fields must have a field layout which must be *pos*.

variant structures:

A **tag field** name must be a **fixed field** name and must be textually defined before all the *alternative field* occurrences in whose *tag list* it is mentioned. (As a consequence, a **tag** field precedes all the **variant** fields that depend upon it.) The mode of a **tag field** name must be a discrete mode.

The *mode* of *variant field* may have neither the **non-value property** nor the **tagged parameterised property**.

In a **variant** structure mode, the *alternative field* occurrences must be either all **tagged** or all **tag-less**. For **tagged** *alternative fields*, *case label specification* must be specified in each *variant alternative*. For **tag-less** *alternative fields*, *case label specification* may be omitted in all *variant alternative* occurrences together, or must be specified for each *variant alternative* occurrence.

If, for a **tag-less variant** structure mode, any of its *alternative fields* has *case label specification* given, all its *alternative fields* must have *case label specification*.

For *alternative fields*, the case selection conditions must be fulfilled (see 12.3), and the same completeness, consistency and compatibility requirements must hold as for the case action (see 6.4). Each of the **tag field** names of *tag list* (if present) serves as a case selector with the M-value class, where M is the mode of the **tag field** name. In the case of **tag-less** alternative fields, the checks involving the case selector are ignored.

For a **parameterisable variant** structure mode none of the classes of its attached list of classes may be the **all** class. (This condition is automatically fulfilled by a **tagged variant** structure mode.)

parameterised structures:

The *origin variant structure mode name* must be parameterisable.

There must be as many literal expressions in the *literal expression list* as there are classes in the list of classes of the *origin variant structure mode name*. The class of each literal expression must be compatible with the corresponding (by position) class of the list of classes. If the latter class is an M-value class, the value delivered by the literal expression must be one of the values defined by M.

examples:

3.3	**STRUCT** *(re, im INT)*	*(1.1)*

11.7	**STRUCT** *(status* **SET** *(occupied, free),*
	  CASE *status* **OF**
	    (occupied): p piece,
	    (free):
	  ESAC*)*
		(1.1)

2.6	*fraction*	*(1.3)*
11.7	*status* **SET** *(occupied, free)*	*(3.1)*
11.8	*status*	*(6.1)*
11.9	*p piece*	*(7.1)*

3.13.5 Layout description for array modes and structure modes

syntax:

<element layout> ::= *(1)*
  PACK | **NOPACK** | *<step>* *(1.1)*

<field layout> ::= *(2)*
  PACK | **NOPACK** | *<pos>* *(2.1)*

<step> ::= *(3)*
  STEP (*<pos>* [, *<step size>*]) *(3.1)*

<pos> ::= *(4)*
  POS (*<word>* , *<start bit>* , *<length>*) *(4.1)*
  | **POS** (*<word>* [, *<start bit>* [: *<end bit>*]]) *(4.2)*

<word> ::= *(5)*
  <<u>integer literal</u> expression> *(5.1)*

<step size> ::= *(6)*
  <<u>integer literal</u> expression> *(6.1)*

<start bit> ::= *(7)*
  <<u>integer literal</u> expression> *(7.1)*

<end bit> ::= *(8)*
  <<u>integer literal</u> expression> *(8.1)*

<length> ::= *(9)*
  <<u>integer literal</u> expression> *(9.1)*

semantics: It is possible to control the layout of an array or a structure by giving packing or mapping information in its mode. Packing information is either **PACK** or **NOPACK**, mapping information is either *step* in the case of array modes, or *pos* in the case of structure modes. The absence of *element layout* or *field layout* in an array or structure mode will always be interpreted as packing information, i.e. either as **PACK** or as **NOPACK**.

If **PACK** is specified for elements of an array or fields of a structure, it means that the use of memory space is optimised for the array elements or structure fields, whereas **NOPACK** implies that the access time for the array elements or the structure fields is optimised. **NOPACK** also implies **referable**.

The **PACK**, **NOPACK** information is applied only for one level, i.e. it is applied to the elements of the array or fields of the structure, not for possible components of the array element or structure field. The layout information is always attached to the nearest mode to which it may apply and which does not already have layout attached. For example, if the default packing is **NOPACK**:

STRUCT (*f* **ARRAY** (*0:1*) *m* **PACK**)

is equivalent to:

STRUCT (*f* **ARRAY** (*0:1*) *m* **PACK NOPACK**)

It is also possible to control the precise layout of an array or a structure by specifying positioning information for its components in the mode. This positioning information is given in the following ways:

- For array modes, the positioning information is given for all elements together, in the form of a *step* following the array mode.
- For structure modes, the positioning information is given for each field individually, in the form of a *pos*, following the mode of the field.

Mapping information with *pos* is given in terms of word and bit-offsets. A *pos* of the form:

POS (<*word*> , <*start bit*> , <*length*>)

defines a bit-offset of

NUM (*word*) * WIDTH + *NUM* (*start bit*)

and a length of *NUM* (*length*) bits, where *WIDTH* is the (implementation defined) number of bits in a word, and *word* is an *<u>integer literal</u> expression*.

When *pos* is specified in *field layout* it defines that the corresponding field starts at the given bit-offset from the start of each location of the structure mode, and occupies the given length.

A *step* of the form:

STEP (<*pos*> , <*step size*>)

defines a series of bit-offsets b_i for *i* taking values 0 to *n* – 1 where *n* is the **number of elements** in the array and

$b_i = i$ * *NUM* (*step size*)

The *j*-th element of the array starts at a bit-offset of $p + b_j$ from the start of each location of the array mode, where *p* is the bit-offset specified in *pos*. Each element occupies the length given in *pos*.

Defaults

The notation:

POS (<*word*> , <*start bit*>: <*end bit*>)

is semantically equivalent to:

POS (<*word*> , <*start bit*> , *NUM (*<*end bit*>*) – NUM (*<*start bit*>) + 1)

The notation:

POS (<*word*> , <*start bit*>)

is semantically equivalent to:

POS (<*word*> , <*start bit*> , *BSIZE*)

where *BSIZE* is the minimum number of bits which is needed to be occupied by the component for which the *pos* is specified.

The notation:

POS (<*word*>)

is semantically equivalent to:

POS (<*word*> , *0* , *BSIZE*)

The notation:

STEP (<*pos*>)

is semantically equivalent to

STEP (<*pos*> , *SSIZE*)

where *SSIZE* is the <*length*> specified in *pos* or derivable from *pos* by the above rules.

static properties: For any location of an array mode the element layout of the mode determines the referability of its sub-locations (including sub-arrays, array slices) as follows:

- either all sub-locations are **referable**, or none of them are;
- if the element layout is **NOPACK**, all sub-locations are **referable**.

For any location of a structure mode, the referability of the structure field selected by a **field** name is determined by the field layout of the **field** name as follows:

- the **field** name is **referable** if the field layout is **NOPACK**.

static conditions: If the **element** mode of a given array mode or the **field** mode of a **field** name of a given structure mode, is itself an array or structure mode, then it must be a **mapped** mode if the given array or structure mode is **mapped**.

NUM (*word*), *NUM* (*start bit*), *NUM* (*end bit*), *NUM* (*length*) and *NUM* (*step size*) ≥ 0;
NUM (*start bit*) and *NUM* (*end bit*) ≤ *WIDTH*; *NUM* (*start bit*) ≤ *NUM* (*end bit*).

Each implementation defines for each mode a minimum number of bits its values need to occupy; call this the minimum bit occupancy. For discrete modes it is any number of bits not less than log to the base two of the **number of values** of the mode. For array modes it is the offset of the element of the highest index plus its occupied bits. For structure modes it is the offset of the highest bit occupied.

For each *pos* the *length* specified must not be less than the minimum bit occupancy of the mode of the associated field or array components.
For each **mapped** array mode the *step size* must not be less than the *length* given or implied in the *pos*.

Consistency and feasibility

Consistency:

No component of a structure may be specified such that it occupies any bits occupied by another component of the same object except in the case of two **variant field** names defined in the same *alternative field* occurrence; however, in the latter case the **variant field** names may not both be defined in the same *variant alternative* nor both following **ELSE**.

Feasibility:

There are no language defined feasibility requirements, except for the one that can be deduced from the rule that the referability of a sub-location of any (**referable** or non-**referable**) location is determined only by the (element or field) layout, which is a property of the mode of the location. This places some restrictions on the mapping of components that themselves have **referable** components.

examples:

17.5	**PACK**	*(1.1)*
19.14	**POS** *(1,0:15)*	*(4.2)*

3.14 Dynamic modes

3.14.1 General

A dynamic mode is a mode of which some properties are known only at run time. Dynamic modes are always parameterised modes with one or more run-time parameters. For description purposes, virtual denotations are introduced in this Recommendation | International Standard. These virtual denotations are preceded by the ampersand symbol (&) to distinguish them from actual notations which appear in a CHILL program text.

3.14.2 Dynamic string modes

virtual denotation: &<*origin string mode name*> (<*integer expression*>)

semantics: A dynamic string mode is a parameterised string mode with non **constant** length.

static properties: Dynamic string modes have the same properties as string modes, except for the properties described below.

dynamic properties:

- A dynamic string mode has a dynamic **string length** which is the value delivered by *integer expression*.
- A dynamic string mode has an **upper bound** and a **lower bound** which are the values delivered by **string length** –1 and 0, respectively.

3.14.3 Dynamic array modes

virtual denotation: &<*origin array mode name*> (<*discrete expression*>)

semantics: A dynamic array mode is a parameterised array mode with non **constant upper bound**.

static properties: Dynamic array modes have the same properties as array modes, except for the properties described below.

dynamic properties:

- A dynamic array mode has a dynamic **upper bound** which is the value delivered by *discrete expression*, and a dynamic **number of elements** which is the value delivered by:

  NUM (*discrete expression*) – *NUM* (*lower bound*) + 1

  where *lower bound* is the **lower bound** of the *origin array mode name*.

3.14.4 Dynamic parameterised structure modes

virtual denotation: &<*origin variant structure mode name*> (<*expression list*>)

semantics: A dynamic **parameterised** structure mode is a **parameterised** structure mode with non **constant** parameters.

static properties: The static properties of a dynamic **parameterised** structure mode are those of a static **parameterised** structure mode except for the following:

- The set of **field** names of a dynamic **parameterised** structure mode is the set of **field** names of its **origin variant** structure mode.

dynamic properties:

- A dynamic **parameterised** structure mode has a list of values attached that is the list of values delivered by the expressions in the *expression list.*

3.15 Moreta modes

3.15.1 General

syntax:

```
<moreta mode> ::=                                                   (1)
          <module mode>                                             (1.1)
        | <region mode>                                             (1.2)
        | <task mode>                                               (1.3)
        | <generic moreta mode instantiation>                       (1.4)
```

semantics:

- *module mode* – A location of *module mode* has the same properties as a *module* without an *action statement list*.
- *region mode* – A location of *region mode* has the same properties as a *region*.
- *task mode* – A location of *task mode* has essentially the same structure as a *module mode location without process definitions*. The direct access to the components of a location, whose mode is a *task mode*, is mutually exclusive. A location, whose mode is a *task mode*, may be executed concurrently with other threads (see 11.1).
- *generic moreta mode instantiation* – A generic moreta mode instantiation is obtained statically by an instantiation of a generic moreta mode template (see 10.11).

static conditions:

Moreta modes are not parameterisable.

Moreta modes and *generic moreta mode templates* cannot be nested.

3.15.2 Module modes

syntax:

<module mode> ::= *(1)*
<module mode specification> *(1.1)*
| *<module mode body>* *(1.2)*

<module mode specification> ::= *(2)*
MODULE SPEC [[**ASSIGNABLE** | **ABSTRACT**] |
[**NOT_ASSIGNABLE** [**ABSTRACT**]]]
[*<module inheritance>*] {*<module specification component>*}*
[*<invariant part>*] **END** [*<simple name string>*] *(2.1)*

<module mode body> ::= *(3)*
MODULE BODY [[**ASSIGNABLE** | **ABSTRACT**] |
[**NOT_ASSIGNABLE** [**ABSTRACT**]]]
[*<module inheritance>*] {*<module body component>*}* [*<invariant part>*]
END [*<handler>*] [*<simple name string>*] *(3.1)*

<module inheritance> ::= *(4)*
BASED_ON *<module mode name>* *(4.1)*

<module specification component> ::= *(5)*
<common module component> *(5.1)*
| *<declaration statement>* *(5.2)*
| *<simple guarded procedure specification statement>* *(5.3)*
| *<inline guarded procedure definition statement>* *(5.4)*
| *<process specification statement>* *(5.5)*
| *<signal definition statement>* *(5.6)*
| *<grant statement>* *(5.7)*

<module body component> ::= *(6)*
<common module component> *(6.1)*
| *<simple guarded procedure definition statement>* *(6.2)*
| *<process definition statement>* *(6.3)*

<common module component> ::= *(7)*
<synonym definition statement> *(7.1)*
| *<synmode definition statement>* *(7.2)*
| *<newmode definition statement>* *(7.3)*
| *<seize statement>* *(7.4)*

<invariant part> ::= *(8)*
INVARIANT *<boolean expression>* *(8.1)*

semantics: A module mode defines composite values consisting of a list of components selectable by component names.

Module values may reside in (composite) **module** locations.

A *module mode* is defined by giving two separate parts: a *module mode specification* and a *module mode body*.

The **specification** part defines the interface of the values of a *module mode*.

The **body** part defines the behaviour of the values of a *module mode*.

If a *module inheritance* clause is given, the mode being defined is immediately derived from the mode given in the *module inheritance* clause, and this mode is the immediate base mode of the mode being defined.

The effect of the *module inheritance* clause is that the derived mode behaves as if it contained all components of its immediate base mode except for the constructor and destructor component procedures of this base mode. If this base mode is itself a derived mode, this inheritance of components is to be understood in a transitive manner. For visibility, see 12.2.

The <u>*boolean*</u> *expression* of the *invariant part* must be true before and after any call of a **public** component procedure or a **public** component process.

static properties: If the attribute **ASSIGNABLE** is specified, the mode is an **assignable** module mode. An **assignable** module mode can be used in the same way as a mode for which **READ** is not specified (see 3.3).

If the attribute **NOT_ASSIGNABLE** is specified, the mode has the **not_assignable** property, indicating that the location of that mode may not be accessed to store the value and may not be accessed to copy its value.

If neither **ASSIGNABLE** nor **NOT_ASSIGNABLE** is specified, the mode is **not_assignable** by default.

If the attribute **ABSTRACT** is specified, the mode is an **abstract** mode.

A *module specification component* contained in a *module mode specification* M_S or SEIZEd into M_S, which is granted by M_S, is called a **public** component of the mode of M_S.

A *module specification component* contained in a *module mode specification* M_S or SEIZEd into M_S, which is not granted by M_S, is called an **internal** component of the mode of M_S.

A *module body component* C contained in a *module mode body* M_B or SEIZEd into M_B, is called a **private** component of the mode of M_B if C is neither a **public** nor an **internal** component of the mode of M_B.

An **abstract** module mode has the property **not_assignable**.

static conditions: A module mode cannot be used as the mode in a *synonym definition*.

For each *module mode specification*, there must be one *module mode body* with the same name string in the *defining occurrence*.

If specified, the *simple name string* after **END** must be equal to the name string of the defining occurrence of this mode definition. This holds for *module mode specification* and for *module mode body*.

If one of the attributes **ASSIGNABLE**, **NOT_ASSIGNABLE** or **ABSTRACT** is specified in a *module mode specification*, it must also be specified in the corresponding *module mode body*.

If a *module mode specification* contains a *module inheritance*, the corresponding *module mode body* must contain the same *module inheritance*.

If the attribute **INCOMPLETE** (see 10.4) is specified in a <u>*simple*</u> *guarded procedure specification*, then this procedure has the property **incomplete**.

If the attribute **INCOMPLETE** (see 10.4) is specified in a <u>*simple*</u> *guarded procedure specification statement*, this procedure must be **public**.

For each **simple**, **complete** *guarded procedure specification* of a *module mode specification*, the corresponding *module mode body* must contain a corresponding <u>*simple*</u> *guarded procedure definition* (see 12.1.3).

If P is a **simple**, **incomplete** *guarded procedure specification* of a *module mode specification*, the corresponding *module mode body* must not contain a *simple guarded procedure definition* matching P.

For each *process specification* of a *module mode specification*, the corresponding *module mode body* must contain a corresponding *process definition* (see 12.1.3).

If the attribute **REIMPLEMENT** (see 10.4) is specified in a *simple guarded procedure specification statement*, this procedure must be **public**.

If the attribute **REIMPLEMENT** (see 10.4) is specified in a *simple guarded procedure specification* PD contained in a *module mode specification* M, then the immediate base MB mode of M must contain or have inherited a **public** *simple guarded procedure specification* PB, where PB matches PD and PB is neither a constructor nor a destructor and PB is not SEIZEd.

A *module mode* is an **abstract** module mode if it contains at least one **incomplete** *component procedure* (see 10.4). In this case, the attribute **ABSTRACT** must be specified.

An **abstract** module mode name can only be used as the module mode *name* in a *module inheritance* or as a *referenced mode*.

If a module mode M has at least one (sub-)component with **non-value property**, then M also has the **non-value property** and the attribute **ASSIGNABLE** must not be specified (see 12.1.1.5).

3.15.3 Region modes

syntax:

<region mode> ::= *(1)*
  <region mode specification> *(1.1)*
  | *<region mode body>* *(1.2)*

<region mode specification> ::= *(2)*
  REGION SPEC [**ABSTRACT**] [*<region inheritance>*]
  {*<region specification component>*}* [*<invariant part>*]
  END [*<simple name string>*] *(2.1)*

<region mode body> ::= *(3)*
  REGION BODY [**ABSTRACT**] [*<region inheritance>*]
  {*<region body component>*}* [*<invariant part>*]
  END [*<handler>*] [*<simple name string>*] *(3.1)*

<region inheritance> ::= *(4)*
  BASED_ON {*<module mode name>* | *<region mode name>*} *(4.1)*

<region specification component> ::= *(5)*
  <common module component> *(5.1)*
  | *<declaration statement>* *(5.2)*
  | *<simple guarded procedure specification statement>* *(5.3)*
  | *<signal definition statement>* *(5.4)*
  | *<grant statement>* *(5.5)*

<region body component> ::= *(6)*
  <common module component> *(6.1)*
  | *<simple guarded procedure definition statement>* *(6.2)*

semantics: A *region mode* defines composite values consisting of a list of components selectable by component names.

Region values may reside in (composite) region locations.

A *region mode* is defined by giving two separate parts: a *region mode specification* and a *region mode body*.

The **specification** part defines the interface of the values of the *region mode*.

The **body** part defines the behaviour of the values of the *region mode*.

If a *region inheritance* clause is given, the mode being defined is immediately derived from the mode given in the *region inheritance* clause, and this mode is the immediate base mode of the mode being defined.

The effect of the *region inheritance* clause is that the derived mode behaves as if it contained all components of its immediate base mode except for the constructor and destructor component procedures of this base mode. If this base mode is itself a derived mode, this inheritance of components is to be understood in a transitive manner. For visibility, see 12.2.

The <u>*boolean*</u> *expression* of the *invariant part* must be true before and after any call of a **public** component procedure.

static properties: A *region mode* has always the **not_assignable** property.

If the attribute **ABSTRACT** is specified, the mode is an **abstract** mode.

A *region specification component* contained in a *region mode specification* M_S or SEIZEd into M_S, which is granted by M_S, is called a **public** component of the mode of M_S.

A *region specification component* contained in a *region mode specification* M_S or SEIZEd into M_S, which is not granted by M_S, is called an **internal** component of the mode of M_S.

A *region body component* C contained in a *region mode body* M_B or SEIZEd into M_B, is called a **private** component of the mode of M_B if C is neither a **public** nor an **internal** component of the mode of M_B.

static conditions: A region mode cannot be used as the mode in a *synonym definition*.

For each *region mode specification*, there must be one *region mode body* with the same name string in the *defining occurrence*.

If specified, the *simple name string* after **END** must be equal to the name string of the defining occurrence of this mode definition. This holds for *region mode specification* and for *region mode body*.

If the attribute **ABSTRACT** is specified in a *region mode specification*, it must also be specified in the corresponding *region mode body*.

If a *region mode specification* contains a *region inheritance*, the corresponding *region mode body* must contain the same *region inheritance*.

If the attribute **INCOMPLETE** (see 10.4) is specified in a <u>*simple*</u> *guarded procedure specification*, then this procedure has the property **incomplete**.

If the attribute **INCOMPLETE** (see 10.4) is specified in a <u>*simple*</u> *guarded procedure specification statement*, this procedure must be **public**.

For each **simple**, **complete** *guarded procedure specification* of a *region mode specification*, the corresponding *region mode body* must contain a corresponding <u>*simple*</u> *guarded procedure definition* (see 12.1.3).

If P is a **simple**, **incomplete** *guarded procedure specification* of a *region mode specification*, the corresponding *region mode body* must not contain a <u>*simple*</u> *guarded procedure definition* matching P.

If the attribute **REIMPLEMENT** (see 10.4) is specified in a <u>*simple*</u> *guarded procedure specification statement*, this procedure must be **public**.

If the attribute **REIMPLEMENT** (see 10.4) is specified in a <u>*simple*</u> *guarded procedure specification* PD contained in a *region mode specification* M, then the immediate base mode of M must contain or have inherited a **public** <u>*simple*</u> *guarded procedure specification* PB, where PB matches PD and PB is neither a constructor nor a destructor and PB is not SEIZEd.

A *region mode* is an **abstract** region mode if it contains at least one **incomplete** *component procedure* (see 10.4). In this case, the attribute **ABSTRACT** must be specified.

An **abstract** region mode name can only be used as the region mode *name* in a *region inheritance* or as a *referenced mode*.

A *region mode* specification must not grant any location.

If the base mode of a *region mode* is a *module mode* M, then M must have the **not_assignable** property, must not grant any location and must not contain any <u>*inline*</u> *guarded component procedure* or any *component process*.

3.15.4 Task modes

syntax:

<task mode> ::= *(1)*
  <task mode specification> *(1.1)*
| *<task mode body>* *(1.2)*

<task mode specification> ::= *(2)*
  TASK SPEC [**ABSTRACT**] [*<task inheritance>*]
  {*<task specification component>*}* [*<invariant part>*]
  END [*<simple name string>*] *(2.1)*

<task mode body> ::= *(3)*
  TASK BODY [**ABSTRACT**] [*<task inheritance>*]
  {*<task body component>*}* [*<invariant part>*]
  END [*<handler>*] [*<simple name string>*] *(3.1)*

<task inheritance> ::= *(4)*
  BASED_ON {*<module mode name>* | *<task mode name>*} *(4.1)*

<task specification component> ::= *(5)*
  <region specification component> *(5.1)*

<task body component> ::= *(6)*
  <region body component> *(6.1)*

semantics: A *task mode* defines composite values consisting of a list of components selectable by component names.

Task values may reside in (composite) task locations.

A *task mode* is defined by giving two separate parts: a *task mode specification* and a *task mode body*.

The **specification** part defines the interface of the values of the *task mode*.

The **body** part defines the behaviour of the values of the *task mode*.

If a *task inheritance* clause is given, the mode being defined is immediately derived from the mode given in the *task inheritance* clause, and this mode is the immediate base mode of the mode being defined.

The effect of the *task inheritance* clause is that the derived mode behaves as if it contained all components of its immediate base mode except for the constructor and destructor component procedures of this base mode. If this base mode is itself a derived mode, this inheritance of components is to be understood in a transitive manner. For visibility, see 12.2.

The *boolean expression* of the *invariant part* must be true before and after any call of a **public** component procedure.

static properties: A *task mode* has the **not_assignable** property.

If the attribute **ABSTRACT** is specified, the mode is an **abstract** mode.

A *task specification component* contained in a *task mode specification* M_S or SEIZEd into M_S, which is granted by M_S, is called a **public** component of the mode of M_S.

A *task specification component* contained in a *task mode specification* M_S or SEIZEd into M_S, which is not granted by M_S, is called an **internal** component of the mode of M_S.

A *task body component* C contained in a *task mode body* M_B or SEIZEd into M_B, is called a **private** component of the mode of M_B if C is neither a **public** nor an **internal** component of the mode of M_B.

static conditions: A task mode cannot be used as the mode in a *synonym definition*.

For each *task mode specification*, there must be one *task mode body* with the same name string in the *defining occurrence*.

If specified, the *simple name string* after **END** must be equal to the name string of the defining occurrence of this mode definition. This holds for *task mode specification* and for *task mode body*.

If the attribute **ABSTRACT** is specified in a *task mode specification*, it must also be specified in the corresponding *task mode body*.

If a *task mode specification* contains a *task inheritance*, the corresponding *task mode body* must contain the same *task inheritance*.

All public component procedures of a task mode must only have IN parameters and must not have a *result spec*.

If the attribute **INCOMPLETE** (see 10.4) is specified in a *simple guarded procedure specification*, then this procedure has the property **incomplete**.

If the attribute **INCOMPLETE** (see 10.4) is specified in a *simple guarded procedure specification statement*, this procedure must be **public**.

For each **simple**, **complete** *guarded procedure specification* of a *task mode specification*, the corresponding *task mode body* must contain a corresponding *simple guarded procedure definition* (see 12.1.3).

If P is a **simple**, **incomplete** *guarded procedure specification* of a *task mode specification*, the corresponding *task mode body* must not contain a *simple guarded procedure definition* matching P.

If the attribute **REIMPLEMENT** (see 10.4) is specified in a *simple guarded procedure specification statement*, this procedure must be **public**.

If the attribute **REIMPLEMENT** (see 10.4) is specified in a *simple guarded procedure specification* PD contained in a *task mode specification* M, then the immediate base mode of M, must contain or have inherited a **public** *simple guarded procedure specification* PB, where PB matches PD and PB is neither a constructor nor a destructor and PB is not SEIZEd.

A *task mode* is an **abstract** task mode if it contains at least one **incomplete** *component procedure* (see 10.4). In this case, the attribute **ABSTRACT** must be specified.

An **abstract** task mode name can only be used as the task mode *name* in a *task inheritance* or as a *referenced mode*.

A *task mode* specification must not grant any location.

If the base mode of a *task mode* is a *module mode* M, then M must have the **not_assignable** property, must not grant any location, must not contain any *inline guarded component procedure* or any *component process*, and must contain only **public** procedures which fulfill the restrictions of **public** component procedures of task modes.

4 Locations and their accesses

4.1 Declarations

4.1.1 General

syntax:

<declaration statement> ::= *(1)*
DCL *<declaration>* { , *<declaration>* }* *;* *(1.1)*

<declaration> ::= *(2)*
<location declaration> *(2.1)*
| *<loc-identity declaration>* *(2.2)*

semantics: A declaration statement declares one or more names to be an access to a location.

examples:

6.9 **DCL** *j INT := julian_day_number,*
d, m, y INT; *(1.1)*
11.36 *starting_square* **LOC** *:= b(m.lin_1)(m.col_1)* *(2.2)*

4.1.2 Location declarations

syntax:

<location declaration> ::= *(1)*
<defining occurrence list> <mode> [**STATIC**] [*<initialisation>*] *(1.1)*

<initialisation> ::= *(2)*
<reach-bound initialisation> *(2.1)*
| *<lifetime-bound initialisation>* *(2.2)*
| *<moreta-bound initialisation>* *(2.3)*

<reach-bound initialisation> ::= *(3)*
<assignment symbol> <value> [*<handler>*] *(3.1)*

<lifetime-bound initialisation> ::= *(4)*
INIT *<assignment symbol> <<u>constant</u> value>* *(4.1)*

<moreta-bound initialisation> ::= *(5)*
([*<<u>constructor</u> actual parameter list>*] **)** [*<handler>*] *(5.1)*

semantics: A location declaration creates as many locations as there are *defining occurrences* specified in the *defining occurrence list*.

With *reach-bound initialisation*, the *value* is evaluated each time the reach in which the declaration is placed is entered (see 10.2) and the delivered value is assigned to the location(s). Before the *value* is evaluated, the location(s) contain(s) the **undefined** value.

With *lifetime-bound initialisation*, the value yielded by the *<u>constant</u> value* is assigned to the location(s) only once at the beginning of the lifetime of the location(s) (see 10.2 and 10.9).

If the *mode* is a *moreta mode*, first all initialisations in the components are performed in textual order. If a (possibly empty) parameter list is specified, the corresponding **constructor** of the *mode* is applied to the newly created location. If the *mode* is a *task mode*, the task belonging to the newly created location is started.

Specifying no *initialisation* is semantically equivalent to the specification of a *lifetime-bound initialisation* with the **undefined** value (see 5.3.1).

The meaning of the **undefined** value as initialisation for a location which has attached a mode with the **tagged parameterised property** or the **non-value property** is as follows:

- **tagged parameterised property**: The created **tag** field sub-location(s) are initialised with their corresponding parameter value.

- **non-value property**:
  - the created event and/or buffer (sub-)location(s) are initialised to "empty", i.e. no delayed processes are attached to the event or buffer nor are there messages in the buffer;
  - the created region and/or task (sub-)location(s) are initialised to "empty", i.e. no delayed threads are attached to them;
  - the created association (sub-)location(s) are initialised to "empty", i.e. they do not contain an association;
  - the created access (sub-)location(s) are initialised to "empty", i.e. they are not connected to an association;
  - the created text (sub-)location(s) have a **text record** sub-location which is initialised with an empty string and an **access** sub-location which is initialised with "empty", i.e. it is not connected to an association.
- The semantics of **STATIC** and *handler* can be found in 10.9 and clause 8, respectively.

If the lifetime of a **moreta** location L ends and the mode of the location contains a destructor, then this destructor is applied to L (see 10.2).

static properties: A *defining occurrence* in a *location declaration* defines a **location** name. The mode attached to the **location** name is the *mode* specified in the *location declaration*. A **location** name is **referable**.

static conditions: The class of the *value* or *constant value* must be **compatible** with the *mode* and the delivered value should be one of the values defined by the *mode*, or the **undefined** value.

If the *mode* has the **read-only property**, *initialisation* must be specified. If the *mode* has the **non-value property**, *reach-bound initialisation* must not be specified.

If *initialisation* is specified, the *value* must be **regionally safe** for the location (see 11.2.2).

dynamic conditions: In the case of *reach-bound initialisation*, the assignment conditions of *value* with respect to the *mode* apply (see 6.2).

examples:

5.7	*k2, x, w, t, s, r BOOL*	*(1.1)*
6.9	*:= julian_day_number*	*(3.1)*
8.4	**INIT** *:= ['A':'Z']*	*(4.1)*

4.1.3 Loc-identity declarations

syntax:

<loc-identity declaration> ::= *(1)*
    <defining occurrence list> <mode> **LOC** [**DYNAMIC**]
    <assignment symbol> <location> [*<handler>*] *(1.1)*

semantics: A loc-identity declaration creates as many access names to the specified location as there are *defining occurrences* specified in the *defining occurrence list*. The mode of the location may be dynamic only if **DYNAMIC** is specified.

If the *location* is evaluated dynamically, this evaluation is done each time the reach in which the loc-identity declaration is placed is entered. In this case, a declared name denotes an **undefined** location prior to the first evaluation during the lifetime of the access denoted by the declared name (see 10.2 and 10.9).

static properties: A *defining occurrence* in a *loc-identity declaration* defines a **loc-identity** name. The mode attached to a **loc-identity** name is, if **DYNAMIC** is not specified, the *mode* specified in the *loc-identity declaration*; otherwise, it is the dynamically parameterised version of it that has the same parameters as the mode of the *location*.

It is not allowed to create a location of a moreta mode with the **DYNAMIC** property.

A **loc-identity** name is **referable** if, and only if, the specified *location* is **referable**.

static conditions: If **DYNAMIC** is specified in the *loc-identity declaration*, the *mode* must be **parameterisable**. The specified *mode* must be **dynamic read-compatible** with the mode of the *location* if **DYNAMIC** is specified and **read-compatible** with the mode of the *location* otherwise.

The *location* must not be a *string element* or *string slice* in which the *mode* of the *string location* is a **varying** string mode.

dynamic conditions: The *RANGEFAIL* or *TAGFAIL* exception occurs if **DYNAMIC** is specified, and the above-mentioned **dynamic read-compatible** check fails.

example:

11.36 *starting square* **LOC** *:= b(m.lin_1)(m.col_1)* *(1.1)*

4.2 Locations

4.2.1 General

syntax:

<*location*> *::=* *(1)*
<*access name*> *(1.1)*
| <*dereferenced bound reference*> *(1.2)*
| <*dereferenced free reference*> *(1.3)*
| <*dereferenced row*> *(1.4)*
| <*string element*> *(1.5)*
| <*string slice*> *(1.6)*
| <*array element*> *(1.7)*
| <*array slice*> *(1.8)*
| <*structure field*> *(1.9)*
| <*location procedure call*> *(1.10)*
| <*location built-in routine call*> *(1.11)*
| <*location conversion*> *(1.12)*
| <*predefined moreta location*> *(1.13)*

semantics: A location is an object that can contain values. Locations have to be accessed to store or obtain a value.

static properties: A *location* has the following properties:

- A mode, as defined in the appropriate subclauses. This mode is either static or dynamic.
- It is **static** or not (see 10.9).
- It is **intra-regional** or **extra-regional** (see 11.2.2).
- It is **referable** or not. The language definition requires certain locations to be **referable** and others to be not **referable** as defined in the appropriate subclauses. An implementation may extend referability to other locations except when explicitly disallowed.

4.2.2 Access names

syntax:

<*access name*> *::=* *(1)*
<*location name*> *(1.1)*
| <*loc-identity name*> *(1.2)*
| <*location enumeration name*> *(1.3)*
| <*location do-with name*> *(1.4)*

semantics: An access name delivers a location. An access name is one of the following:

- a **location** name, i.e. a name explicitly declared in a *location declaration* or implicitly declared in a *formal parameter* without the **LOC** attribute;
- a **loc-identity** name, i.e. a name explicitly declared in a *loc-identity declaration* or implicitly declared in a *formal parameter* with the **LOC** attribute;
- a **location enumeration** name, i.e. a *loop counter* in a *location enumeration*;
- a **location do-with** name, i.e. a **field** name used as direct access in the *do action* with a *with part*.

If the location denoted by a *location do-with name* is a variant field of a tag-less variant structure location, the semantics are implementation defined.

static properties: The (possibly dynamic) mode attached to an *access name* is the mode of the *location name*, *loc-identity name*, *location enumeration name* or *location do-with name*, respectively.

An *access name* is **referable** if, and only if, it is a *location name*, a **referable** *loc-identity name*, a **referable** *location enumeration name*, or a **referable** *location do-with name*.

dynamic conditions: When accessing via a *loc-identity name*, it must not denote an **undefined** location.

When accessing via a *loc-identity name* a location which is a **variant** field, the variant field access conditions for the location must be satisfied (see 4.2.10). Accessing via a *location do-with name* causes a *TAGFAIL* exception if the denoted location is a **variant** field and the variant field access conditions for the location are not satisfied.

examples:

4.12	*a*	*(1.1)*
11.39	*starting*	*(1.2)*
15.35	*each*	*(1.3)*
5.10	*c1*	*(1.4)*

4.2.3 Dereferenced bound references

syntax:

<dereferenced bound reference> ::= *(1)*
<*bound reference primitive value*> –> [<*mode name*>] *(1.1)*

semantics: A dereferenced bound reference delivers the location that is referenced by the bound reference value.

static properties: The mode attached to a *dereferenced bound reference* is the *mode name* if specified, otherwise the **referenced** mode of the mode of the *bound reference primitive value*. A *dereferenced bound reference* is **referable**.

static conditions: The *bound reference primitive value* must be **strong**. If the optional *mode name* is specified, it must be **read-compatible** with the **referenced** mode of the mode of the *bound reference primitive value*.

dynamic conditions: The lifetime of the referenced location must not have ended.

The *EMPTY* exception occurs if the *bound reference primitive value* delivers the value *NULL*.

If the referenced location is a **variant** field, the variant field access conditions for the location must be satisfied (see 4.2.10).

example:

10.54	*p –>*	*(1.1)*

4.2.4 Dereferenced free references

syntax:

<dereferenced free reference> ::= *(1)*
<*free reference primitive value*> –> <*mode name*> *(1.1)*

semantics: A dereferenced free reference delivers the location that is referenced by the free reference value.

static properties: The mode attached to a *dereferenced free reference* is the *mode name*. A *dereferenced free reference* is **referable**.

static conditions: The *free reference primitive value* must be **strong**.

dynamic conditions: The lifetime of the referenced location must not have ended.

The *EMPTY* exception occurs if the *free reference primitive value* delivers the value *NULL*.

The *mode name* must be **read-compatible** with the mode of the referenced location.

If the referenced location is a **variant** field, the variant field access conditions for the location must be satisfied (see 4.2.10).

4.2.5 Dereferenced rows

syntax:

<dereferenced row> ::= *(1)*
<<u>row</u> primitive value> –> *(1.1)*

semantics: A dereferenced row delivers the location that is referenced by the row value.

static properties: The dynamic mode attached to a *dereferenced row* is constructed as follows:

&<*<u>origin mode</u> name*> (<*parameter*> { , <*parameter*> }*)

where &*<u>origin mode</u> name* is a virtual **synmode** name **synonymous** with the **referenced origin** mode of the mode of the *<u>row</u> primitive value* and where the parameters are, depending on the **referenced origin** mode:

- the dynamic **string length**, in the case of a string mode;
- the dynamic **upper bound**, in the case of an array mode;
- the list of values associated with the mode of the parameterised structure location, in the case of a **variant** structure mode.

A *dereferenced row* is **referable**.

static conditions: The *<u>row</u> primitive value* must be **strong**.

dynamic conditions: The lifetime of the referenced location must not have ended.

The *EMPTY* exception occurs if the *<u>row</u> primitive value* delivers *NULL*.

If the referenced location is a **variant** field, the variant field access conditions for the location must be satisfied (see 4.2.10).

example:

8.11 input -> *(1.1)*

4.2.6 String elements

syntax:

<string element> ::= *(1)*
<<u>string</u> location> (<start element>) *(1.1)*

<start element> ::= *(2)*
<<u>integer</u> expression> *(2.1)*

semantics: A string element delivers a (sub-)location which is the element of the specified string location indicated by *start element*.

static properties: The mode attached to the *string element* is the **element** mode of the mode of the *<u>string</u> location*.

If the mode of the *<u>string</u> location* is a **varying** string mode, then the *string element* is not **referable**.

dynamic conditions: The *RANGEFAIL* exception occurs if the following relation does not hold:

$0 \leq NUM\ (start\ element) \leq L - 1$

where *L* is the **actual length** of the *<u>string</u> location*.

example:

18.16 string ->(i) *(1.1)*

4.2.7 String slices

syntax:

<string slice> ::= *(1)*
<<u>string</u> location> (<left element> : <right element>) *(1.1)*
| *<<u>string</u> location> (<start element>* **UP** *<slice size>)* *(1.2)*

<left element> ::= *(2)*
<<u>integer</u> expression> *(2.1)*

<*right element*> ::= *(3)*
<*integer expression*> *(3.1)*

<*slice size*> ::= *(4)*
<*integer expression*> *(4.1)*

semantics: A string slice delivers a (possibly dynamic) string location that is the part of the specified string location indicated by *left element* and *right element* or *start element* and *slice size*. The (possibly dynamic) length of the string slice is determined from the specified expressions.

A *string slice* in which the *right element* delivers a value which is less than that delivered by the *left element* or in which *slice size* delivers a non-positive value denotes an empty string.

static properties: The (possibly dynamic) mode attached to a *string slice* is a **parameterised** string mode constructed as:

&*name (string size)*

where &*name* is a virtual **synmode** name **synonymous** with the (possibly dynamic) mode of the *string location* if it is a **fixed** string mode, otherwise with the **component** mode, and where *string size* is either:

NUM (*right element*) – *NUM* (*left element*) + 1

or:

NUM (*slice size*).

However, if an empty string is denoted, *string size* is 0. The mode attached to a *string slice* is static if *string size* is **literal**, i.e. *left element* and *right element* are **literal** or *slice size* is **literal**; otherwise the mode is dynamic.

If the mode of the *string location* is a **varying** string mode, then the *string slice* is not **referable**.

static conditions: The following relations must hold:

$0 \leq NUM\ (left\ element) \leq L - 1$

$0 \leq NUM\ (right\ element) \leq L - 1$

$0 \leq NUM\ (start\ element) \leq L - 1$

$NUM\ (start\ element) + NUM\ (slice\ size) \leq L$

where *L* is the **actual length** of the *string location*. If *L* and the value all *integer expressions* are known statically, the relations can be checked statically.

dynamic conditions: The *RANGEFAIL* exception occurs if a dynamic part of the check of the relations above fails.

examples:

18.26 *blanks (count : 9)* *(1.1)*
18.23 *string ->(scanstart* **UP** *10)* *(1.2)*

4.2.8 Array elements

syntax:

<*array element*> ::= *(1)*
<*array location*> (<*expression list*>) *(1.1)*

<*expression list*> ::= *(2)*
<*expression*> { , <*expression*> }* *(2.1)*

derived syntax: The notation: (<*expression list*>) is derived syntax for:

(<*expression*>) { (<*expression*>) }*

where there are as many parenthesised expressions as there are expressions in the *expression list*. Thus an *array element* in the strict syntax has only one (index) expression.

semantics: An array element delivers a (sub-)location which is the element of the specified array location indicated by *expression*.

static properties: The mode attached to the *array element* is the **element** mode of the mode of the *array location*.

An *array element* is **referable** if the **element layout** of the mode of the *array location* is **NOPACK**.

static conditions: The class of the *expression* must be **compatible** with the **index** mode of the mode of the *array location*.

dynamic conditions: The *RANGEFAIL* exception occurs if the following relation does not hold:

$L \leq expression \leq U$

where *L* and *U* are the **lower bound** and the (possibly dynamic) **upper bound** of the mode of the *array location*, respectively.

examples:

11.36 *b(m.lin_1)(m.col_1)* *(1.1)*

4.2.9 Array slices

syntax:

<array slice> ::= *(1)*
<array location> (*<lower element>* : *<upper element>*) *(1.1)*
| *<array location>* (*<first element>* **UP** *<slice size>*) *(1.2)*

<lower element> ::= *(2)*
<expression> *(2.1)*

<upper element> ::= *(3)*
<expression> *(3.1)*

<first element> ::= *(4)*
<expression> *(4.1)*

semantics: An array slice delivers a (possibly dynamic) array location which is the part of the specified array location indicated by *lower element* and *upper element* or *first element* and *slice size*. The **lower bound** of the array slice is equal to the lower bound of the specified array; the (possibly dynamic) **upper bound** is determined from the specified expressions.

static properties: The (possibly dynamic) mode attached to an *array slice* is a **parameterised** array mode constructed as:

&*name (upper index)*

where &*name* is a virtual **synmode** name **synonymous** with the (possibly dynamic) mode of the *array location* and *upper index* is either an expression whose class is **compatible** with the classes of *lower element* and *upper element* and delivers a value such that:

$NUM\ (upper\ index) = NUM\ (L) + NUM\ (upper\ element) - NUM\ (lower\ element)$

or is an expression whose class is **compatible** with the class of *first element* and delivers a value such that:

$NUM\ (upper\ index) = NUM\ (L) + NUM\ (slice\ size) - 1$

where *L* is the **lower bound** of the mode of the *array location*.

The mode attached to an *array slice* is static if *upper index* is **literal**, i.e. *lower element* and *upper element* are both **literal** or *slice size* is **literal**; otherwise, the mode is dynamic.

An *array slice* is **referable** if the **element layout** of the mode of the *array location* is **NOPACK**.

static conditions: The classes of *lower element* and *upper element* or the class of *first element* must be **compatible** with the **index** mode of the *array location*.

The following relations must hold:

$L \leq NUM\ (lower\ element) \leq NUM\ (upper\ element) \leq U$

$1 \leq NUM\ (slice\ size) \leq NUM\ (U) - NUM\ (L) + 1$

$NUM\ (L) \leq NUM\ (first\ element) \leq NUM\ (first\ element) + NUM\ (slice\ size) - 1 \leq NUM\ (U)$

where *L* and *U* are respectively the **lower bound** and **upper bound** of the mode of the *array location*. If *U* and the value of all *expressions* are known statically, the relations can be checked statically.

dynamic conditions: The *RANGEFAIL* exception occurs if a dynamic part of the check of the relations above fails.

example:

17.27 res (0 : count – 1) (1.1)

4.2.10 Structure fields

syntax:

<structure field> ::= (1)
<structure location> . <field name> (1.1)

semantics: A structure field delivers a (sub-)location which is the field of the specified structure location indicated by *field name*. If the *structure location* has a **tag-less variant** structure mode and the *field name* is a **variant field** name, the semantics are implementation defined.

static properties: The mode of the *structure field* is the mode of the *field name*.

A *structure field* is **referable** if the **field layout** of the *field name* is **NOPACK**.

static conditions: The *field name* must be a name from the set of **field** names of the mode of the *structure location*.

dynamic conditions: A *location* must not denote:

- a **tagged variant** structure mode location in which the associated **tag** field value(s) indicate(s) that the field does not exist;
- a dynamic **parameterised** structure mode location in which the associated list of values indicates that the field does not exist.

The above-mentioned conditions are called the variant field access conditions for the location. The *TAGFAIL* exception occurs if they are not satisfied for the *structure location*.

example:

10.57 last ->.info (1.1)

4.2.11 Location procedure calls

syntax:

<location procedure call> ::= (1)
<location procedure call> (1.1)

semantics: A location procedure call delivers the location returned from the procedure.

static properties: The mode attached to a *location procedure call* is the mode of the **result spec** of the *location procedure call* if **DYNAMIC** is not specified in it; otherwise, it is the dynamically parameterised version of it that has the same parameters as the mode of the delivered location.

The *location procedure call* is **referable** if **NONREF** is not specified in the **result spec** of the *location procedure call*.

dynamic conditions: The *location procedure call* must not deliver an **undefined** location and the lifetime of the delivered location must not have ended.

4.2.12 Location built-in routine calls

syntax:

<location built-in routine call> ::= (1)
<location built-in routine call> (1.1)

semantics: A location built-in routine call delivers the location returned from the built-in routine call.

static properties: The mode attached to the *location built-in routine call* is the mode of the **result spec** of the *location built-in routine call*.

dynamic conditions: The *location built-in routine call* must not deliver an **undefined** location and the lifetime of the delivered location must not have ended.

4.2.13 Location conversions

syntax:

<location conversion> ::= *(1)*
<*mode name*> # (<*static mode location*>) *(1.1)*

semantics: A location conversion delivers the location denoted by *static mode location*. However, it overrides the CHILL mode checking and compatibility rules and explicitly attaches a mode to the location without any change in the internal representation.

The precise dynamic semantics of a location conversion are implementation defined.

static properties: The mode of a *location conversion* is the *mode name*.

A location conversion is **referable**.

static conditions: The *static mode location* must be **referable**.

The following relation must hold:

SIZE (mode name) = SIZE (static mode location)

4.2.14 Predefined moreta location

syntax:

<predefined moreta location> ::= *(1)*
SELF *(1.1)*

semantics: In a component procedure and/or process **P** of a *moreta mode*, **SELF** denotes that moreta location ML to which **P** is currently being applied. The mode of **SELF** is the mode of ML.

static conditions: The use of **SELF** is allowed only inside the definition of a moreta mode.

5 Values and their operations

5.1 Synonym definitions

syntax:

<synonym definition statement> ::= *(1)*
SYN *<synonym definition>* { , *<synonym definition>*}* *;* *(1.1)*

<synonym definition> ::= *(2)*
<defining occurrence list> [*<mode>*] = *<constant value>* *(2.1)*

derived syntax: A *synonym definition*, where *defining occurrence list* consists of more than one *defining occurrence*, is derived from several *synonym definition* occurrences, one for each *defining occurrence* with the same *constant value* and *mode*, if present. E.g. **SYN** *i , j = 3;* is derived from **SYN** *i = 3, j = 3;*.

semantics: A synonym definition defines a name that denotes the specified **constant** value.

static properties: A *defining occurrence* in a *synonym definition* defines a **synonym** name.

The class of the **synonym** name is, if a *mode* is specified, the M-value class, where M is the *mode*, otherwise the class of the *constant value*.

A **synonym** name is **undefined** if, and only if, the *constant value* is an **undefined** value (see 5.3.1).

A **synonym** name is **literal** if, and only if, the *constant value* is **literal**.

static conditions: If a *mode* is specified, it must be **compatible** with the class of the *constant value* and the value delivered by the *constant value* must be one of the values defined by the *mode*.

The evaluation of the *constant value* must not depend, directly or indirectly, on the **constant** value of the **synonym** name.

examples:

1.17	**SYN** *neutral_for_add = 0,*	
	neutral_for_mult = 1;	*(1.1)*
2.18	*neutral_for_add fraction = [0,1]*	*(2.1)*

5.2 Primitive value

5.2.1 General

syntax:

<primitive value> ::= *(1)*
<location contents> *(1.1)*
| *<value name>* *(1.2)*
| *<literal>* *(1.3)*
| *<tuple>* *(1.4)*
| *<value string element>* *(1.5)*
| *<value string slice>* *(1.6)*
| *<value array element>* *(1.7)*
| *<value array slice>* *(1.8)*
| *<value structure field>* *(1.9)*
| *<expression conversion>* *(1.10)*
| *<representation conversion>* *(1.11)*
| *<value procedure call>* *(1.12)*
| *<value built-in routine call>* *(1.13)*
| *<start expression>* *(1.14)*
| *<zero-adic operator>* *(1.15)*
| *<parenthesised expression>* *(1.16)*

semantics: A primitive value is the basic constituent of an expression. Some primitive values have a dynamic class, i.e. a class based on a dynamic mode. For these primitive values, the compatibility checks can only be completed at run time. Check failure will then result in the *TAGFAIL* or *RANGEFAIL* exception.

static properties: The class of the *primitive value* is the class of the *location contents, value name,* etc., respectively.

A *primitive value* is **constant** if, and only if, it is a **constant** *value name*, a *literal*, a **constant** *tuple*, a **constant** *expression conversion*, a **constant** *representation conversion*, a **constant** *value built-in routine call* or a **constant** *parenthesised expression*.

A *primitive value* is **literal** if, and only if, it is a *value name* that is **literal**, a **discrete** *literal*, or a *value built-in routine call* that is **literal**.

5.2.2 Location contents

syntax:

<location contents> ::=	*(1)*
<location>	*(1.1)*

semantics: A location contents delivers the value contained in the specified location. The location is accessed to obtain the stored value.

static properties: The class of the *location contents* is the M-value class, where M is the (possibly dynamic) mode of the *location*.

static conditions: The mode of the *location* must not have the **non-value property**.

dynamic conditions: The delivered value must not be **undefined**.

example:

3.7	*c2.im*	*(1.1)*

5.2.3 Value names

syntax:

<value name> ::=	*(1)*
<<u>synonym</u> name>	*(1.1)*
| *<<u>value enumeration</u> name>*	*(1.2)*
| *<<u>value do-with</u> name>*	*(1.3)*
| *<<u>value receive</u> name>*	*(1.4)*
| *<<u>general procedure</u> name>*	*(1.5)*

semantics: A value name delivers a value. A value name is one of the following:

- a **synonym** name, i.e. a name defined in a *synonym definition statement*;
- a **value enumeration** name, i.e. a name defined by a *loop counter* in a *value enumeration*;
- a **value do-with** name, i.e. a **field** name introduced as value name in the *do action* with a *with part*;
- a **value receive** name, i.e. a name introduced in a *receive case action*;
- a **general procedure** name (see 10.4).

If the value denoted by a *<u>value do-with</u> name* is a variant field of a tag-less variant structure value, the semantics are implementation defined.

static properties: The class of a *value name* is the class of the *<u>synonym</u> name*, *<u>value enumeration</u> name*, *<u>value do-with</u> name*, *<u>value receive</u> name* or the M-derived class, where M is the mode of the *<u>general procedure</u> name*, respectively.

A *value name* is **literal** if, and only if, it is a *<u>synonym</u> name* that is **literal**.

A *value name* is **constant** if it is a *<u>synonym</u> name* or a *<u>general procedure</u> name* denoting a **procedure** name which has attached a *procedure definition* which is not surrounded by a block.

static conditions: The *<u>synonym</u> name* must not be **undefined**.

dynamic conditions: Evaluating a <u>*value do-with*</u> *name* causes a *TAGFAIL* exception if the denoted value is a **variant** field and the variant field access conditions for the value are not satisfied.

examples:

10.12	*max*	*(1.1)*
8.8	*i*	*(1.2)*
15.54	*this_counter*	*(1.4)*

5.2.4 Literals

5.2.4.1 General

syntax:

<literal> ::= *(1)*
  <integer literal> *(1.1)*
| *<floating point literal>* *(1.2)*
| *<boolean literal>* *(1.3)*
| *<character literal>* *(1.4)*
| *<set literal>* *(1.5)*
| *<emptiness literal>* *(1.6)*
| *<character string literal>* *(1.7)*
| *<bit string literal>* *(1.8)*

semantics: A literal delivers a **constant** value.

static properties: The class of the *literal* is the class of the *integer literal*, *boolean literal*, etc., respectively. A *literal* is **discrete** if it is either an *integer literal*, a *boolean literal*, a *character literal* or a *set literal*.

The letter together with the following apostrophe which starts an *integer literal*, *boolean literal*, and *bit string literal* (i.e. *B’*, *D’*, *H’*, *O’*, *b’*, *d’*, *h’*, *o’*) is a literal qualification.

5.2.4.2 Integer literals

syntax:

<integer literal> ::= *(1)*
  <unsigned integer literal> *(1.1)*
| *<signed integer literal>* *(1.2)*

<unsigned integer literal> ::= *(2)*
  <decimal integer literal> *(2.1)*
| *<binary integer literal>* *(2.2)*
| *<octal integer literal>* *(2.3)*
| *<hexadecimal integer literal>* *(2.4)*

<signed integer literal> ::= *(3)*
  - *<unsigned integer literal>* *(3.1)*

<decimal integer literal> ::= *(4)*
  [{ D | d } ’] *<digit sequence>* *(4.1)*

<binary integer literal> ::= *(5)*
  { B | b } ’ { 0 | 1 | _ }$^+$ *(5.1)*

<octal integer literal> ::= *(6)*
  { O | o } ’ { *<octal digit>* | _ }$^+$ *(6.1)*

<hexadecimal integer literal> ::= *(7)*
  { H | h >} ’ { *<hexadecimal digit>* | _ }$^+$ *(7.1)*

<hexadecimal digit> ::= *(8)*
  <digit> | A | B | C | D | E | F | a | b | c | d | e | f *(8.1)*

<octal digit> ::= *(9)*
  0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 *(9.1)*

<digit sequence> ::= *(10)*
{ *<digit>* | _ }$^{+}$ *(10.1)*

semantics: An integer literal delivers an integer value. The usual decimal (base 10) notation is provided as well as binary (base 2), octal (base 8) and hexadecimal (base 16). The underline character (_) is not significant, i.e. it serves only for readability and it does not influence the denoted value.

A signed integer literal delivers a value which is the additive inverse of that delivered by the *unsigned integer literal* in it.

static properties: The class of an *integer literal* is the *&INT*-derived class. An *integer literal* is **constant** and **literal**.

static conditions: The string following the apostrophe (') and the *digit sequence* must not consist solely of underline characters.

The value delivered by *integer literal* must be one of the values defined by the *&INT* mode.

examples:

6.11 *1_721_119* *(2.1)*
D'1_721_119 *(2.1)*
B'101011_110100 *(2.2)*
O'53_64 *(2.3)*
H'AF4 *(2.4)*

5.2.4.3 Floating point literals

syntax:

<floating point literal> ::= *(1)*
<unsigned floating point literal> *(1.1)*
| *<signed floating point literal>* *(1.2)*

<unsigned floating point literal> ::= *(2)*
<digit sequence> . [*<digit sequence>*] [*<exponent>*] *(2.1)*
[*<digit sequence>*] . *<digit sequence>* [*<exponent>*] *(2.2)*

<signed floating point literal> ::= *(3)*
- *<unsigned floating point literal>* *(3.1)*

<exponent> ::= *(4)*
E *<digit sequence>* *(4.1)*
E - *<digit sequence>* *(4.2)*

derived syntax: A *floating point literal* in which 1. a *digit sequence,* 2. an *exponent* is missing is derived syntax for a *literal* in which 1. the *digit sequence* is 0, 2. the *exponent* is E1.

semantics: A floating point literal delivers a floating point value, expressed as a decimal number in scientific notation.

A signed floating point literal delivers a value which is the additive inverse of that delivered by the *unsigned floating point literal* in it.

If the floating point literal lies between the **upper bound** and **lower bound** of one of the **predefined** floating point modes of the implementation but is not exactly representable, the floating point literal value is approximated to the value delivered by an implicit *representation conversion* to the **predefined** floating point mode chosen by the implementation for representing the *floating point literal*.

static properties: The class of a *floating point literal* is the *&FLOAT*-derived class. A *floating point literal* is **constant** and **literal**.

The **precision** of a *floating point literal* is the sum of the number of significant decimal digits delivered by the two *digit sequences* that form its mantissa.

static conditions: The value delivered by *floating point literal* must be one of the values defined by the *&FLOAT* mode.

examples:

10.0E1 *(1.1)*
-365.0E-5 *(1.1)*

5.2.4.4 Boolean literals

syntax:

<*boolean literal*> *::=* *(1)*
<*boolean literal name*> *(1.1)*

predefined names: The names *FALSE* and *TRUE* are predefined as **boolean literal** names.

semantics: A boolean literal delivers a boolean value.

static properties: The class of a *boolean literal* is the *BOOL*-derived class. A *boolean literal* is **constant** and **literal**.

example:

5.42 *FALSE* *(1.1)*

5.2.4.5 Character literals

syntax:

<*character literal*> *::=* *(1)*
' { <*character*> | <*control sequence*>} ' *(1.1)*

<*control sequence*> *::=* *(2)*
^ (<*integer literal expression*> { , <*integer literal expression*> }*) *(2.1)*
| ^ <*non-special character*> *(2.2)*
| ^^ *(2.3)*

semantics: A character literal delivers a character value.

Apart from the printable representation, the *control sequence* representation may be used. A *control sequence* in which the circumflex character (^) is followed by an open parenthesis denotes the sequence of characters whose representations are the *integer literal expression* in it; otherwise if it is followed by another circumflex character it denotes itself, otherwise it denotes the character whose representation is obtained by logically negating the b7 of the internal representation of the *non-special character* in it (see 12.4.4 and Appendix I).

static properties: The class of a *character literal* is the *CHAR*-derived class. A *character literal* is **constant** and **literal**.

static conditions: A *control sequence* in a *character literal* must denote only one character.

The value delivered by an *integer literal expression* in a *control sequence* must belong to the range of values defined by the representations of the characters in the CHILL character set (see Appendix I).

example:

7.9 *'M'* *(1.1)*

5.2.4.6 Set literals

syntax:

<*set literal*> *::=* *(1)*
[<*mode name*> .] <*set element name*> *(1.1)*

semantics: A set literal delivers a set value. A set literal is a name defined in a set mode.

static properties: The class of a *set literal* is the M-value class, where M is the *mode name*, if specified. Otherwise, M depends upon the context where the *set literal* occurs, according to the following list:

- if the *set literal* is used in a place where a *tuple* without the *mode name* can be used, then M is derived following the same rules defined for the *tuple* (see 5.2.5);
- if the *set literal* is used as a value in a *tuple*, then M is the mode of that value;
- if the *set literal* is used in a *literal range* to define a *discrete range mode* of the form:

  <*discrete mode name*> *(* <*literal range*> *)*

  then M is the *discrete mode* name;

- if the *set literal* is the *usage expression*, the *where expression*, the *index expression* or the *write expression* in a built-in routine for input output (see 7.4), then M is respectively *USAGE*, *WHERE*, the **index** mode of the *access location* or of the *text location*, the **record** mode of the *access location*;
- if the *set literal* is used in a *conditional expression*, then M is derived in the same way as for the *expression* in which it is contained;
- if the *set literal* is the *upper index* in a *parameterised array mode*, then M is the corresponding *index mode* of the origin array mode;
- if the *set literal* is an *expression* in a *parameterised structure mode*, then M is the **root** mode of the corresponding *tag field name* in the origin variant structure mode;
- if the *set literal* is used in an *array element* or *array slice*, then M is the corresponding *index mode* in the *array mode*;
- if the *set literal* is used in a *case label*, then M is derived from the mode of the corresponding *tag field name* (for *structure mode*), from the mode of the corresponding selector in the *case selector list* (for *case action* or *conditional expression*), or from the *index mode* (for *tuple*);
- if the *set literal* is used as the *lower bound* or the *upper bound* and a *discrete mode name* is specified in the *literal range* in which it is contained, then M is the *discrete mode name*.

A *set literal* is **constant** and **literal**.

static conditions: The optional *mode name* may be omitted only in the contexts specified above.

The *set element name* must belong to the set of **set element** names of M.

examples:

6.51	*dec*	*(1.1)*
11.78	*king*	*(1.1)*

5.2.4.7 Emptiness literal

syntax:

<emptiness literal> ::=	*(1)*
<emptiness literal name>	*(1.1)*

predefined names: The name *NULL* is predefined as an **emptiness literal** name.

semantics: The emptiness literal delivers either the empty reference value, i.e. a value which does not refer to a location, the empty procedure value, i.e. a value which does not indicate a procedure, or the empty instance value, i.e. a value which does not identify a process.

static properties: The class of the *emptiness literal* is the **null** class. An *emptiness literal* is **constant**.

example:

10.43	*NULL*	*(1.1)*

5.2.4.8 Character string literals

syntax:

<character string literal> ::=	*(1)*
” { <non-reserved character> | <quote> | <control sequence>} ”*	*(1.1)*
<quote> ::=	*(2)*
””	*(2.1)*

semantics: A character string literal delivers a character string value that may be of length 0. It is a list of values for the elements of the string; the values are given for the elements in increasing order of their index from left to right. To represent the character quote (”) within a character string literal, it has to be written twice (””).

static properties: The **string length** of a *character string literal* is the number of *non-reserved character*, *quote* and characters denoted by *control sequence* occurrences.

The class of a *character string literal* is the **CHARS** *(n)*-derived class, where *n* is the **string length** of the *character string literal*. A *character string literal* is **constant**.

example:

8.20 ”A-B<ZAA9K’ ” *(1.1)*

5.2.4.9 Bit string literals

syntax:

<bit string literal> ::= *(1)*
<binary bit string literal> *(1.1)*
| *<octal bit string literal>* *(1.2)*
| *<hexadecimal bit string literal>* *(1.3)*

<binary bit string literal> ::= *(2)*
{ B | b } ’ { 0 | 1 | _ }* ’ *(2.1)*

<octal bit string literal> ::= *(3)*
{ O | o } ’ { *<octal digit>* | _ }* ’ *(3.1)*

<hexadecimal bit string literal> ::= *(4)*
{ H | h } ’ { *<hexadecimal digit>* | _ }* ’ *(4.1)*

semantics: A bit string literal delivers a bit string value that may be of length 0. Binary, octal or hexadecimal notations may be used. The underline character (_) is insignificant, i.e. it serves only for readability and does not influence the indicated value.

A bit string literal is a list of values for the elements of the string; the values are given for the elements in increasing order of their index from left to right.

static properties: The **string length** of a *bit string literal* is either the number of *0* and *1* occurrences in a *binary bit string literal*, three times the number of *octal digit* occurrences in an *octal bit string literal* or four times the number of *hexadecimal digit* occurrences in a *hexadecimal bit string literal*.

The class of a *bit string literal* is the **BOOLS** *(n)*-derived class, where *n* is the **string length** of the *bit string literal*. A *bit string literal* is **constant**.

examples:

B’101011_110100’ *(1.1)*
O’53_64’ *(1.2)*
H’AF4’ *(1.3)*

5.2.5 Tuples

syntax:

<tuple> ::= *(1)*
[*<mode name>*] (: { *<powerset tuple>* |
<array tuple> | *<structure tuple>* } :) *(1.1)*

<powerset tuple> ::= *(2)*
[{ *<expression>* | *<range>*} { , { *<expression>* | *<range>*} }*] *(2.1)*

<range> ::= *(3)*
<expression> : *<expression>* *(3.1)*

<array tuple> ::= *(4)*
<unlabelled array tuple> *(4.1)*
| *<labelled array tuple>* *(4.2)*

<unlabelled array tuple> ::= *(5)*
<value> { , *<value>*}* *(5.1)*

<labelled array tuple> ::= *(6)*
<case label list> : *<value>* { , *<case label list>* : *<value>*}* *(6.1)*

<structure tuple> ::= *(7)*
<unlabelled structure tuple> *(7.1)*
| *<labelled structure tuple>* *(7.2)*

<unlabelled structure tuple> ::= *(8)*
<value> { , *<value>*}* *(8.1)*

<labelled structure tuple> ::= *(9)*
<field name list> : *<value>* { , *<field name list>* : *<value>*}* *(9.1)*

<field name list> ::= *(10)*
. *<field name>* { , . *<field name>* }* *(10.1)*

derived syntax: The tuple opening and closing brackets, [and], are derived syntax for *(:* and *:)*, respectively. This is not indicated in the syntax to avoid confusion with the use of square brackets as meta symbols.

semantics: A tuple delivers either a powerset value, an array value or a structure value.

If it is a powerset value, it consists of a list of expressions and/or ranges denoting those member values which are in the powerset value. A range denotes those values which lie between or are one of the values delivered by the expressions in the range. If the second expression delivers a value which is less than the value delivered by the first expression, the range is empty, i.e. it denotes no values. The powerset tuple may denote the empty powerset value.

If it is an array value, it is a (possibly labelled) list of values for the elements of the array; in the unlabelled array tuple, the values are given for the elements in increasing order of their index; in the labelled array tuple, the values are given for the elements whose indices are specified in the case label list labelling the value. It can be used as a shorthand for large array tuples where many values are the same. The label **ELSE** denotes all the index values not mentioned explicitly. The label ∗ denotes all index values (for further details, see 12.3).

If it is a structure value, it is a (possibly labelled) set of values for the fields of the structure. In the unlabelled structure tuple, the values are given for the fields in the same order as they are specified in the attached structure mode. In the labelled structure tuple, the values are given for the fields whose field names are specified in the field name list for the value.

The order of evaluation of the expressions and values in a tuple is undefined and they may be considered as being evaluated in any order.

static properties: The class of a *tuple* is the M-value class, where M is the *<u>mode</u> name*, if specified. Otherwise M depends upon the context where the *tuple* occurs, according to the following list:

- if the *tuple* is the *value* or *<u>constant</u> value* in an *initialisation* in a *location declaration*, then M is the *mode* in the *location declaration*;
- if the *tuple* is the right-hand side *value* in a *single assignment action*, then M is the (possibly dynamic) mode of the left-hand side *location*;
- if the *tuple* is the *<u>constant</u> value* in a *synonym definition* with a specified *mode*, then M is that *mode*;
- if the *tuple* is used in an *operand-2* and one of the operands is **strong**, then M is the mode of the **strong** operand;
- if the *tuple* is an *actual parameter* in a *procedure call* or in a *start expression* where **DYNAMIC** is not specified in the corresponding *parameter spec*, then M is the mode in the corresponding *parameter spec*;
- if the *tuple* is the *value* in a *return action* or a *result action*, then M is the mode of the **result spec** of the **procedure** name of the *result action* or *return action* (see 6.8);
- if the *tuple* is a *value* in a *send action*, then it is the associated mode specified in the signal definition of the *<u>signal</u> name* or the **buffer element** mode of the mode of the *<u>buffer</u> location*;
- if the *tuple* is an *expression* in an *array tuple*, then M is the **element** mode of the mode of the *array tuple*;
- if the *tuple* is an *expression* in an *unlabelled structure tuple* or a *labelled structure tuple* where the associated *field name list* consists of only one *field name*, then M is the mode of the field in the *structure tuple* for which the tuple is specified;
- if the *tuple* is the *value* in a *GETSTACK* or *ALLOCATE* built-in routine call, then M is the mode denoted by *mode argument*.

A *tuple* is **constant** if, and only if, each *value* or *expression* occurring in it is **constant**.

static conditions: The optional <u>*mode*</u> *name* may be omitted only in the contexts specified above. Depending on whether a *powerset tuple*, *array tuple* or *structure tuple* is specified, the following compatibility requirements must be fulfilled:

a) *Powerset tuple:*

1) The mode of the *tuple* must be a powerset mode.

2) The class of each *expression* must be **compatible** with the **member** mode of the mode of the *tuple*.

3) For a **constant** powerset tuple the value delivered by each *expression* must be one of the values defined by that **member** mode.

b) *Array tuple:*

1) The mode of the *tuple* must be an array mode.

2) The class of each *value* must be **compatible** with the **element** mode of the mode of the *tuple*.

3) In the case of an *unlabelled array tuple*, there must be as many occurrences of *value* as the **number of elements** of the array mode of the *tuple*.

4) In the case of a *labelled array tuple*, the case selection conditions must hold for the list of *case label list* occurrences (see 12.3). The **resulting class** of the list must be **compatible** with the **index** mode of the mode of the *tuple*. The list of case label specifications must be **complete**.

5) In the case of a *labelled array tuple*, the values explicitly indicated by each case label in a *case label list* must be values defined by the **index** mode of the *tuple*.

6) In an *unlabelled array tuple*, at least one *value* occurrence must be an *expression*.

7) For a **constant** *array tuple*, where the **element** mode of the mode of the *tuple* is a discrete mode, each specified *value* must deliver a value defined by that **element** mode, unless it is an **undefined** value.

c) *Structure tuple:*

1) The mode of the tuple must be a structure mode.

2) This mode must not be a structure mode which has **field** names which are **invisible** (see 12.2.5).

In the case of an *unlabelled structure tuple*:

– If the mode of the *tuple* is neither a **variant** structure mode nor a **parameterised** structure mode, then:

3) There must be as many occurrences of *value* as there are **field** names in the list of **field** names of the mode of the *tuple*.

4) The class of each *value* must be **compatible** with the mode of the corresponding (by position) **field** name of the mode of the *tuple*.

– If the mode of the *tuple* is a **tagged variant** structure mode or a **tagged parameterised** structure mode, then:

5) Each *value* specified for a **tag** field must be a <u>*discrete literal*</u> *expression*.

6) There must be as many occurrences of *value* as there are **field** names indicated as existing by the value(s) delivered by the <u>*discrete literal*</u> *expression* occurrences specified for the **tag** fields.

7) The class of each *value* must be **compatible** with the mode of the corresponding **field** name.

– If the mode of the *tuple* is a **tag-less variant** structure mode or a **tag-less parameterised** structure mode,

8) No unlabelled structure tuple is allowed.

In the case of a labelled structure tuple:

– If the mode of the *tuple* is neither a **variant** structure mode nor a **parameterised** structure mode, then:

9) Each **field** name of the list of **field** names of the mode of the *tuple* must be mentioned once and only once in the *tuple*.

10) The class of each *value* must be **compatible** with the mode of every **field** name specified in the *field name list* labelling that *value*. The modes of all **field** names in the *field name list* must be **equivalent**.

– If the mode of the *tuple* is a **tagged variant** structure mode or a **tagged parameterised** structure mode, then:

11) Each *value* that is specified for a **tag** field must be a <u>*discrete literal*</u> *expression*.

12) Each **field** name that denotes a fixed field or a field indicated as existing by the value(s) delivered by the <u>*discrete literal*</u> *expression* occurrences specified for the **tag** fields must be mentioned once and only once in the *tuple*.

13) The class of each *value* must be **compatible** with the mode of any **field** name specified in the *field name list* labelling that *value*.

– If the mode of the *tuple* is a **tag-less variant** structure mode or a **tag-less parameterised** structure mode, then:

14) Each **field** name must be mentioned at most once in the tuple. All the **fixed field** names must be mentioned. **Field** names mentioned in the tuple, which are defined in the same alternative field, must all be defined in the same variant alternative or all be defined after **ELSE**. All **field** names of an alternative field in each variant alternative or all **field** names defined after **ELSE** must be mentioned.

15) The class of each *value* must be **compatible** with the mode of any **field** name specified in the *field name list* labelling that *value*.

16) If the mode of the *tuple* is a **tagged parameterised** structure mode, the list of values delivered by the <u>*discrete literal*</u> *expression* occurrences specified for the **tag** fields must be the same as the list of values of the mode of the *tuple*.

17) For a **constant** *structure tuple*, each *value* specified for a field with a discrete mode must deliver a value defined by the **field** mode, unless it is an **undefined** value.

18) At least one *value* occurrence must be an *expression*.

No *tuple* may have two *value* occurrences in it, such that one is **extra-regional** and the other is **intra-regional** (see 11.2.2).

dynamic conditions: The assignment conditions of any value with respect to the **member** mode, **element** mode or associated **field** mode, in the case of *powerset tuple*, *array tuple* or *structure tuple*, respectively (see 6.2) apply [refer to conditions a) 2), b) 2), c) 4), c) 7), c) 10), c) 13) and c) 15)].

If the *tuple* has a dynamic array mode, the *RANGEFAIL* exception occurs if any of the conditions b) 3) or b) 5) are not satisfied.

If the *tuple* has a dynamic **parameterised** structure mode, the *TAGFAIL* exception occurs if any of the conditions c) 14) or c) 16) are not satisfied.

The value delivered by a *tuple* must not be **undefined**.

examples:

9.6	*number_list [ ]^ (1.1)*	
9.7	*[2:max]*	*(2.1)*
8.26	*[('A'):3,('B','K','Z'):1,(***ELSE***):0]*	*(6.1)*
17.5	*[(*):' ']*	*(6.1)*

12.35 *(:NULL,NULL,536:)* *(7.1)*
11.18 *[.status:occupied,.p:[white,rook]]* *(9.1)*

5.2.6 Value string elements

syntax:

<value string element> ::= *(1)*
 <string primitive value> (*<start element>*) *(1.1)*

NOTE – If the *string primitive value* is a *string location*, the syntactic construct is ambiguous and will be interpreted as a *string element* (see 4.2.6).

semantics: A value string element delivers a value which is the element of the specified string value indicated by *start element*.

static properties: The class of the *value string element* is the M-value class, where M is the **element** mode of the mode of the *string primitive value*.

A *value string element* is **constant** if, and only if, *string primitive value* and *start element* are **constant**.

dynamic conditions: The value delivered by a *value string element* must not be **undefined**.

The *RANGEFAIL* exception occurs if the following relation does not hold:

$0 \leq NUM\ (start\ element) \leq L - 1$

where *L* is the **actual length** of the *string primitive value*.

5.2.7 Value string slices

syntax:

<value string slice> ::= *(1)*
 <string primitive value> (*<left element>* : *<right element>*) *(1.1)*
 | *<string primitive value>* (*<start element>* **UP** *<slice size>*) *(1.2)*

NOTE – If the *string primitive value* is a *string location*, the syntactic construct is ambiguous and will be interpreted as a *string slice* (see 4.2.7).

semantics: A value string slice delivers a (possibly dynamic) string value which is the part of the specified string value indicated by *left element* and *right element* or *start element* and *slice size*. The (possibly dynamic) length of the string slice is determined from the specified expressions.

A *string slice* in which the *right element* delivers a value which is less than that delivered by the *left element* or in which *slice size* delivers a non-positive value, denotes an empty string.

static properties: The (possibly dynamic) class of a *value string slice* is the M-value class if the *string primitive value* is **strong** and otherwise the M-derived class, where M is a **parameterised** string mode constructed as:

&name (string size)

where *&name* is a virtual **synmode** name **synonymous** with the (possibly dynamic) **root** mode of the *string primitive value* if it is a **fixed** string mode, otherwise with the **component** mode, and where *string size* is either

$NUM\ (right\ element) - NUM\ (left\ element) + 1$

or:

$NUM\ (slice\ size)$

However, if an empty string is denoted, *string size* is 0. The class of a *value string slice* is static if *string size* is **literal**, i.e. *left element* and *right element* are **literal** or *slice size* is **literal**; otherwise the class is dynamic.

A *value string slice* is **constant** if, and only if, *string primitive value* and *string size* are **constant**.

static conditions: The following relations must hold:

$0 \leq NUM\ (left\ element) \leq L - 1$

$0 \leq NUM\ (right\ element) \leq L - 1$

$0 \leq NUM\ (start\ element) \leq L - 1$

$NUM\ (start\ element) + NUM\ (slice\ size) \leq L$

where L is the **actual length** of the *string primitive value*. If L and the value all *integer expressions* are known statically, the relations can be checked statically.

dynamic conditions: The value delivered by a *value string slice* must not be **undefined**.

The *RANGEFAIL* exception occurs if a dynamic part of the check of the relations above fails.

5.2.8 Value array elements

syntax:

<value array element> ::=	*(1)*
<*array primitive value*> (<*expression list*>)	*(1.1)*

NOTE – If the *array primitive value* is an *array location*, the syntactic construct is ambiguous and will be interpreted as an *array element* (see 4.2.8).

derived syntax: See 4.2.8.

semantics: A value array element delivers a value which is the element of the specified array value indicated by *expression*.

static properties: The class of the *value array element* is the M-value class, where M is the **element** mode of the mode of the *array primitive value*.

A *value array element* is **constant** if, and only if, *array primitive value* and *expression* are **constant**.

static conditions: The class of the *expression* must be **compatible** with the **index** mode of the mode of the *array primitive value*.

dynamic conditions: The value delivered by a *value array element* must not be **undefined**.

The *RANGEFAIL* exception occurs if the following relation does not hold:

$L \leq expression \leq U$

where L and U are the **lower bound** and (possibly dynamic) **upper bound** of the mode of the *array primitive value*, respectively.

5.2.9 Value array slices

syntax:

<value array slice> ::=	*(1)*
<*array primitive value*> (<*lower element*> : <*upper element*>)	*(1.1)*
| <*array primitive value*> (<*first element*> **UP** <*slice size*>)	*(1.2)*

NOTE – If the *array primitive value* is an *array location*, the syntactic construct is ambiguous and will be interpreted as an *array slice* (see 4.2.9).

semantics: A value array slice delivers a (possibly dynamic) array value which is the part of the specified array value indicated by *lower element* and *upper element*, or *first element* and *slice size*. The **lower bound** of the value array slice is equal to the **lower bound** of the specified array value; the (possibly dynamic) **upper bound** is determined from the specified expressions.

static properties: The (possibly dynamic) class of a *value array slice* is the M-value class, where M is a **parameterised** array mode constructed as:

&*name (upper index)*

where &*name* is a virtual **synmode** name **synonymous** with the (possibly dynamic) mode of the *array primitive value* and *upper index* is either an expression whose class is **compatible** with the classes of *lower element* and *upper element* and delivers a value such that:

$NUM\ (upper\ index) = NUM\ (L) + NUM\ (upper\ element) - NUM\ (lower\ element)$

or is an expression whose class is **compatible** with the class of *first element* and delivers a value such that:

NUM (*upper index*) = *NUM* (*L*) + *NUM* (*slice size*) – 1

where *L* is the **lower bound** of the mode of the *array primitive value*.

The class of a *value array slice* is static if *upper index* is **literal**, i.e. *lower element* and *upper element* both are **literal** or *slice size* is **literal**; otherwise the class is dynamic.

static conditions: The classes of *lower element* and *upper element* or the class of *first element* must be **compatible** with the **index** mode of the *array primitive value*.

The following relations must hold:

L ≤ *NUM* (*lower element*) ≤ *NUM* (*upper element*) ≤ *U*

1 ≤ *NUM* (*slice size*) ≤ *NUM* (*U*) – *NUM* (*L*) + 1

NUM (*L*) ≤ *NUM* (*first element*) ≤ *NUM* (*first element*) + *NUM* (*slice size*) – 1 ≤ *NUM* (*U*)

where *L* and *U* are, respectively, the **lower bound** and **upper bound** of the mode of the *array primitive value*. If *U* and the value of all *expressions* are known statically, the relations can be checked statically.

A *value array slice* is **constant** if, and only if, *array primitive value* and *upper index* are **constant**.

dynamic conditions: The value delivered by a *value array slice* must not be **undefined**.

The *RANGEFAIL* exception occurs if a dynamic part of the check of the relations above fails.

5.2.10 Value structure fields

syntax:

<value structure field> ::=	*(1)*
<structure primitive value> . <field name>	*(1.1)*

NOTE – If the *structure primitive value* is a *structure location*, the syntactic construct is ambiguous and will be interpreted as a *structure field* (see 4.2.10).

semantics: A value structure field delivers a value which is the field of the specified structure value indicated by *field name*. If the *structure primitive value* has a **tag-less variant** structure mode and the *field name* is a **variant field** name, the semantics are implementation defined.

static properties: The class of *value structure field* is the M-value class, where M is the mode of the *field name*.

A *value structure field* is **constant** if, and only if, *structure primitive value* is **constant**.

static conditions: The *field name* must be a name from the set of **field** names of the mode of the *structure primitive value*.

dynamic conditions: The value delivered by a *value structure field* must not be **undefined**.

A value must not denote:

- a **tagged variant** structure mode value in which the associated **tag** field value(s) indicate(s) that the denoted field does not exist;
- a dynamic **parameterised** structure mode value in which the associated list of values indicates that the field does not exist.

The above-mentioned conditions are called the variant field access conditions for the value (note that the conditions do not include the occurrence of an exception). The *TAGFAIL* exception occurs if they are not satisfied for the *structure primitive value*.

example:

11.140	*b (lin)(col).status*	*(1.1)*

5.2.11 Expression conversion

syntax:

<expression conversion> ::= *(1)*
<*mode name*> # (<*expression*>) *(1.1)*

NOTE – If the *expression* is a *static mode location*, the syntactic construct is ambiguous and will be interpreted as a *location conversion* (see 4.2.13).

semantics: An expression conversion overrides the CHILL mode checking and compatibility rules. It explicitly attaches a mode to the expression without any change in the internal representation.

static properties: The class of the *expression conversion* is the M-value class, where M is the *mode name*. An *expression conversion* is **constant** if, and only if, the *expression* is **constant**.

static conditions: The *mode name* must not have the **non-value property**. The size of the **root** mode of the *expression* and the size of *mode name* must be equal.

5.2.12 Representation conversion

syntax:

<representation conversion> ::= *(1)*
<*mode name*> (<*expression*>) *(1.1)*

semantics: A representation conversion overrides the CHILL mode checking and compatibility rules. It explicitly attaches a mode to the expression and may change the internal representation of the value delivered by the expression itself. If the mode of the *mode name* is a discrete mode and the class of the value delivered by the expression is discrete, then the value delivered by the representation conversion is such that:

NUM (*mode name* (*expression*)) = *NUM* (*expression*)

A representation conversion in which *mode name* and the **root** mode of the class of the expression are respectively:

- an integer mode and a floating point mode;
- a floating point mode and an integer mode;
- a floating point mode and another floating point mode with different **root** modes,

may involve an approximation. If the value delivered by expression is exactly representable in the set of values of *mode name*, the result of the representation conversion is the value of expression itself, otherwise it is one of the two values belonging to the set of values of *mode name* that delimit the smallest interval in which the value delivered by expression is contained. A representation conversion in which *mode name* is an integer mode and the **root** mode of the class of the expression is a duration mode, delivers an integer value which represents in milliseconds the value delivered by expression.

A representation conversion in which *mode name* or the **root** mode of the class of the expression is a structure mode, and the other one is a **parameterised** structure mode whose **origin** structure mode is **similar** to it, delivers a structure value in which the values of the fields are equal to the corresponding ones of the expression, if present. Otherwise the result is implementation defined.

Note that for **tag-less variant** structure values and for **tagged variant** structure values in which the list of tag values is different from that of the **parameterised** structure mode, the result of the representation conversion is implementation defined.

A representation conversion in which the mode M of the *mode name* is a reference mode and the class of the expression is the **null** class, the result of the representation conversion is **null**, if M is **compatible** with the class of
-> ((*expression*) ->), then the result is equal to it, otherwise the result is implementation defined.

Otherwise the value delivered by the representation conversion is implementation defined and may depend on the internal representation of values.

static properties: The class of the *representation conversion* is the M-value class, where M is the *mode name*. A *representation conversion* is **constant** if, and only if, the *expression* is **constant**.

static conditions: The *mode name* must not have the **non-value property**. An implementation may impose additional static conditions.

dynamic conditions: In the case of an *expression* that is not **constant**:

- a *RANGEFAIL* exception occurs if *mode name* is a duration mode and the **root** mode of the class of the *expression* is an integer mode (or vice versa), and the value delivered by *representation conversion* does not belong to the set of values defined for *mode name*;
- an *OVERFLOW* exception occurs if:
  - the class of the value delivered by *expression* is discrete and the mode of *mode name* is a discrete mode which does not define a value with an internal representation equal to *NUM* (*expression*);
  - the mode of *mode name* and the **root** mode of the class of the *expression* are, independently, an integer mode or a floating point mode, and the *expression* delivers a value that does not lie between the bounds of the **root** mode of *mode name*;
- an *UNDERFLOW* exception occurs if the *mode name* and the **root** mode of the class of the *expression* are floating point modes, and the value delivered by *expression* is greater than the **negative lower limit** and less than the **positive lower limit** of the *mode name*, and is different from zero.

An implementation may impose additional dynamic conditions that, when violated, cause an exception defined by the implementation.

5.2.13 Value procedure calls

syntax:

<value procedure call> ::=	*(1)*
<value procedure call>	*(1.1)*

semantics: A value procedure call delivers the value returned from a procedure.

static properties: The class of the *value procedure call* is the M-value class, where M is the mode of the **result spec** of the *value procedure call*.

dynamic conditions: The *value procedure call* must not deliver an **undefined** value (see 5.3.1 and 6.8).

examples:

6.50	*julian_day_number([10,dec,1979])*	*(1.1)*
11.63	*ok_bishop(b,m)*	*(1.1)*

5.2.14 Value built-in routine calls

syntax:

<value built-in routine call> ::=	*(1)*
<value built-in routine call>	*(1.1)*

semantics: A value built-in routine call delivers the value returned by the built-in routine.

static properties: The class attached to the *value built-in routine call* is the class of the *value built-in routine call*.

dynamic conditions: The *value built-in routine call* must not deliver an **undefined** value (see 5.3.1 and 6.8).

5.2.15 Start expressions

syntax:

<start expression> ::=	*(1)*
START *<process name>* ([*<actual parameter list>*])	*(1.1)*

semantics: The evaluation of the start expression creates and activates a new process whose definition is indicated by the *process name* (see clause 11). The start expression delivers the instance value identifying the created process. Parameter passing is analogous to procedure parameter passing; however, additional actual parameters may be given with an implementation defined meaning.

static properties: The class of the *start expression* is the *INSTANCE*-derived class.

static conditions: The number of *actual parameter* occurrences in the *actual parameter list* must not be less than the number of *formal parameter* occurrences in the *formal parameter list* of the process definition of the *process name*. If the number of actual parameters is *m* and the number of formal parameters is n ($m \geq n$), the compatibility and **regionality** requirements for the first *n* actual parameters are the same as for procedure parameter passing (see 6.7). The static conditions for the rest of the actual parameters are implementation defined.

dynamic conditions: For parameter passing, the assignment conditions of any actual value with respect to the mode of its associated formal parameter apply (see 6.7).

The *start expression* causes the *SPACEFAIL* exception if storage requirements cannot be satisfied.

example:

15.35 **START** *counter()* *(1.1)*

5.2.16 Zero-adic operator

syntax:

<zero-adic operator> ::= *(1)*
THIS *(1.1)*

semantics: The zero-adic operator delivers the unique instance value identifying the process executing it.

static properties: The class of the *zero-adic operator* is the *INSTANCE*-derived class.

5.2.17 Parenthesised expression

syntax:

<parenthesised expression> ::= *(1)*
(*<expression>*) *(1.1)*

semantics: A parenthesised expression delivers the value delivered by the evaluation of the expression.

static properties: The class of the *parenthesised expression* is the class of the *expression*.

A *parenthesised expression* is **constant** (**literal**) if, and only if, the *expression* is **constant** (**literal**).

example:

5.10 *(a1* **OR** *b1)* *(1.1)*

5.3 Values and expressions

5.3.1 General

syntax:

<value> ::= *(1)*
<expression> *(1.1)*
| *<undefined value>* *(1.2)*

<undefined value> ::= *(2)*
* *(2.1)*
| *<undefined synonym name>* *(2.2)*

semantics: A value is either an **undefined** value or a (CHILL defined) value delivered as the result of the evaluation of an expression.

Except where explicitly indicated to the contrary, the order of evaluation of the constituents of an expression and their sub-constituents, etc., is undefined and they may be considered as being evaluated in any order. They need only be evaluated to the point that the value to be delivered is determined uniquely. If the context requires a **constant** or **literal** expression, the evaluation is assumed to be done prior to run time and cannot cause an exception. An implementation will define ranges of allowed values for **literal** and **constant** expressions and may reject a program if such a prior-to-run-time evaluation delivers a value outside the implementation defined bounds.

static properties: The class of a *value* is the class of the *expression* or *undefined value*, respectively.

The class of the *undefined value* is the **all** class if the *undefined value* is a *; otherwise the class is the class of the *undefined synonym name*.

A *value* is **constant** if, and only if, it is an *undefined value* or an *expression* which is **constant**. A *value* is **literal** if, and only if, it is an *expression* which is **literal**.

dynamic properties: A value is said to be **undefined** if it is denoted by the *undefined value* or when explicitly indicated in this Recommendation | International Standard. A composite value is **undefined** if, and only if, all its sub-components (i.e. substring values, element values, field values) are **undefined**.

example:

6.40 *(146_097*c)/4+(1_461*y)/4*
*+(153*m+2)/5+day+1_721_119* *(1.1)*

5.3.2 Expressions

syntax:

<expression> ::= *(1)*
<operand-0> *(1.1)*
| *<conditional expression>* *(1.2)*

<conditional expression> ::= *(2)*
| **IF** *<boolean expression> <then alternative>*
<else alternative> **FI** *(2.1)*
| **CASE** *<case selector list>* **OF** { *<value case alternative>*}$^+$
[**ELSE** *<sub expression>*] **ESAC** *(2.2)*

<then alternative> ::= *(3)*
THEN *<sub expression>* *(3.1)*

<else alternative> ::= *(4)*
ELSE *<sub expression>* *(4.1)*
| **ELSIF** *<boolean expression>*
<then alternative> <else alternative> *(4.2)*

<sub expression> ::= *(5)*
<expression> *(5.1)*

<value case alternative> ::= *(6)*
<case label specification> : *<sub expression> ;* *(6.1)*

semantics: If **IF** is specified, the *boolean expression* is evaluated and if it yields *TRUE*, the result is the value delivered by the *sub expression* in the *then alternative*, otherwise it is the value delivered by the *else alternative*.

The value delivered by an *else alternative* is the value of the *sub expression* if **ELSE** is specified, otherwise the *boolean expression* is evaluated and if it yields *TRUE*, it is the value delivered by the *sub expression* in the *then alternative*, otherwise it is the value delivered by the *else alternative*.

If **CASE** is specified, the *sub expressions* in the *case selector list* are evaluated and if a *case label specification* matches, the result is the value delivered by the corresponding *sub expression*, otherwise it is the value delivered by the *sub expression* following **ELSE** (which will be present).

Unused *sub expressions* in a *conditional expression* are not evaluated.

static properties: If an *expression* is an *operand-0*, the class of the *expression* is the class of the *operand-0*. If it is a *conditional expression*, the class of the *expression* is the M-value class, where M is the mode which depends on the context where the *conditional expression* occurs according to the same rules that define the mode of the class of a tuple without a *mode name* (see 5.2.5).

An *expression* is **constant** (**literal**) if, and only if, it is either an *operand-0* which is **constant** (**literal**), or a *conditional expression* in which all *boolean expression* or *case selector list* in it are **constant** (**literal**) and in which all *sub expressions* in it are **constant** (**literal**).

static conditions: If an *expression* is a *conditional expression*, the following conditions apply:

- a *conditional expression* may occur only in the contexts in which a tuple without a *mode name* in front of it may occur;

- each *sub expression* must be **compatible** with the mode that is derived from the context with the same rules as for tuples. However, the dynamic part of the compatibility relation applies only to the selected *sub expression*;
- if **CASE** is specified, the case selection conditions must be fulfilled (see 12.3), and the same completeness, consistency and compatibility requirements must hold as for the case action (see 6.4);
- no *conditional expression* may have two *sub expression* occurrences in it, such that one is **extra-regional** and the other is **intra-regional** (see 11.2.2).

dynamic conditions: In the case of a *conditional expression*, the assignment conditions of the value delivered by the selected *sub expression* with respect to the mode M derived from the context apply.

5.3.3 Operand-0

syntax:

<operand-0> ::=	*(1)*
<operand-1>	*(1.1)*
| *<sub operand-0>* { **OR** | **ORIF** | **XOR** >} *<operand-1>*	*(1.2)*
<sub operand-0> ::=	*(2)*
<operand-0>	*(2.1)*

semantics: If **OR**, **ORIF** or **XOR** is specified, *sub operand-0* and *operand-1* deliver:

- boolean values, in which case **OR** and **XOR** denote the logical operators “inclusive disjunction” and “exclusive disjunction”, respectively, delivering a boolean value. If **ORIF** is specified and *operand-0* delivers the boolean value *TRUE*, then this is the result, otherwise the result is the value delivered by *operand-1*;
- bit string values, in which case **OR** and **XOR** denote the logical operations on corresponding element of the bit strings, delivering a bit string value;
- powerset values, in which case **OR** denotes the union of both powerset values and **XOR** denotes the powerset value consisting of those member values which are in only one of the specified powerset values (e.g. *A* **XOR** *B = A–B* **OR** *B–A*).

static properties: If an *operand-0* is an *operand-1*, the class of *operand-0* is the class of *operand-1*. If **OR**, **ORIF** or **XOR** is specified, the class of *operand-0* is the **resulting class** of the classes of *sub operand-0* and *operand-1*.

An *operand-0* is **constant** (**literal**) if, and only if, it is either an *operand-1* which is **constant** (**literal**), or built up from an *operand-0* and an *operand-1* which are both **constant** (**literal**).

static conditions: If **OR**, **ORIF** or **XOR** is specified, the class of *sub operand-0* must be **compatible** with the class of *operand-1*. If **ORIF** is specified, both classes must have a boolean **root** mode, otherwise both classes must have a boolean, powerset or bit string **root** mode, in which case the **actual length** of *sub operand-0* and *operand-1* must be the same. This check is dynamic if one or both modes is (are) dynamic or **varying** string modes.

dynamic conditions: In the case of **OR** or **XOR**, a *RANGEFAIL* exception occurs if one or both operands have a dynamic class and the dynamic part of the above-mentioned compatibility check fails.

examples:

10.31	*i<min*	*(1.1)*
10.31	*i<min* **OR** *i>max*	*(1.2)*

5.3.4 Operand-1

syntax:

<operand-1> ::=	*(1)*
<operand-2>	*(1.1)*
| *<sub operand-1>* { **AND** | **ANDIF** >} *<operand-2>*	*(1.2)*
<sub operand-1> ::=	*(2)*
<operand-1>	*(2.1)*

semantics: If **AND** or **ANDIF** is specified, *sub operand-1* and *operand-2* deliver:

- boolean values, in which case **AND** denotes the logical “conjunction” operation, delivering a boolean value. If **ANDIF** is specified and *sub operand-1* delivers the boolean value *FALSE*, then this is the result, otherwise the result is the value delivered by *operand-2*;
- bit string values, in which case **AND** denotes the logical operation on corresponding element of the bit strings, delivering a bit string value;
- powerset values, in which case **AND** denotes the “intersection” operation of powerset values delivering a powerset value as a result.

static properties: If an *operand-1* is an *operand-2*, the class of *operand-1* is the class of *operand-2*.

If **AND** or **ANDIF** is specified, the class of *operand-1* is the **resulting class** of the classes of *sub operand-1* and *operand-2*.

An *operand-1* is **constant** (**literal**) if, and only if, it is either an *operand-2* which is **constant** (**literal**), or built up from an *operand-1* and an *operand-2* which are both **constant** (**literal**).

static conditions: If **AND** or **ANDIF** is specified, the class of *sub operand-1* must be **compatible** with the class of *operand-2*. If **ANDIF** is specified, both classes must have a boolean **root** mode, otherwise both classes must have a boolean, powerset or **bit** string **root** mode, in which case the **actual length** of *sub operand-1* and *operand-2* must be the same. This check is dynamic if one or both modes is (are) dynamic or **varying** string modes.

dynamic conditions: In the case of **AND**, a *RANGEFAIL* exception occurs if one or both operands have a dynamic class and the dynamic part of the above-mentioned compatibility check fails.

examples:

5.10 *(a1* **OR** *b1)* *(1.1)*
5.10 **NOT** *k2* **AND** *(a1* **OR** *b1)* *(1.2)*

5.3.5 Operand-2

syntax:

<operand-2> ::= *(1)*
<operand-3> *(1.1)*
| *<sub operand-2> <operator-3> <operand-3>* *(1.2)*

<sub operand-2> ::= *(2)*
<operand-2> *(2.1)*

<operator-3> ::= *(3)*
<relational operator> *(3.1)*
| *<membership operator>* *(3.2)*
| *<powerset inclusion operator>* *(3.3)*

<relational operator> ::= *(4)*
= | /= | > | >= | < | <= *(4.1)*

<membership operator> ::= *(5)*
IN *(5.1)*

<powerset inclusion operator> ::= *(6)*
<= | >= | < | > *(6.1)*

semantics: The equality (=) and inequality (/=) operators are defined between all values of a given mode. The other relational operators (less than: <, less than or equal to: <=, greater than: >, greater than or equal to: >=) are defined between values of a given discrete, timing, string or floating point mode. All the relational operators deliver a boolean value as result.

The membership operator is defined between a member value and a powerset value. The operator delivers *TRUE* if the member value is in the specified powerset value, otherwise *FALSE*.

The powerset inclusion operators are defined between powerset values and they test whether or not a powerset value is contained in: <=, is properly contained in: <, contains: >= or properly contains: > the other powerset value. A powerset inclusion operator delivers a boolean value as result.

static properties: If an *operand-2* is an *operand-3*, the class of *operand-2* is the class of *operand-3*. If an *operator-3* is specified, the class of *operand-2* is the *BOOL*-derived class.

An *operand-2* is **constant** (**literal**) if, and only if, it is either an *operand-3* which is **constant** (**literal**) or built up from a *sub operand-2* and an *operand-3* which are both **constant** (**literal**).

static conditions: If an *operator-3* is specified, the following compatibility requirements between the class of *sub operand-2* and the class of *operand-3* must be fulfilled:

- if *operator-3* is = or /=, both classes must be **compatible**;
- if *operator-3* is a *relational operator* other than = or /=, both classes must be **compatible** and must have a discrete, timing, string or floating point **root** mode;
- if *operator-3* is a *membership operator*, the class of *operand-3* must have a powerset **root** mode and the class of *sub operand-2* must be **compatible** with the **member** mode of that **root** mode;
- if *operator-3* is a *powerset inclusion operator*, both classes must be **compatible** and must have a powerset **root** mode.

dynamic conditions: In the case of a *relational operator*, a *RANGEFAIL* or *TAGFAIL* exception occurs if one or both operands have a dynamic class and the dynamic part of the above-mentioned compatibility check fails. The *TAGFAIL* exception occurs if, and only if, a dynamic class is based upon a dynamic **parameterised** structure mode.

examples:

10.50	*NULL*	*(1.1)*
10.50	*last=NULL*	*(1.2)*

5.3.6 Operand-3

syntax:

```
<operand-3> ::=                                              (1)
        <operand-4>                                          (1.1)
      | <sub operand-3> <operator-4> <operand-4>             (1.2)

<sub operand-3> ::=                                          (2)
        <operand-3>                                          (2.1)

<operator-4> ::=                                             (3)
        <arithmetic additive operator>                       (3.1)
      | <string concatenation operator>                      (3.2)
      | <powerset difference operator>                       (3.3)

<arithmetic additive operator> ::=                           (4)
        + | –                                                (4.1)

<string concatenation operator> ::=                          (5)
        //                                                   (5.1)

<powerset difference operator> ::=                           (6)
        –                                                    (6.1)
```

semantics: If *operator-4* is an arithmetic additive operator, both operands deliver either integer values or floating point values and the resulting integer value or floating point value respectively is the sum (+) or difference (–) of the two values.

If *operator-4* is a string concatenation operator, both operands deliver either bit string values or character string values; the resulting value consists of the concatenation of these values. Boolean (character) values are also allowed; they are regarded as bit (character) string values of length 1.

If *operator-4* is the powerset difference operator, both operands deliver powerset values and the resulting value is the powerset value consisting of those member values which are in the value delivered by *sub operand-3* and not in the value delivered by *operand-4*.

If the class of operand-3 has a floating point **root** mode, the result is the floating point value that approximates, using the same criterion used for representation conversion, the result of the exact mathematical operation.

static properties: If an *operand-3* is an *operand-4*, the class of *operand-3* is the class of *operand-4*. If an *operator-4* is specified, the class of *operand-3* is determined by *operator-4* as follows:

- If *operator-4* is a *string concatenation operator*, the class of *operand-3* is dependent on the classes of *operand-4* and *sub operand-3*, in which an operand that is a boolean or a character value is regarded as a value whose class is a **BOOLS** *(1)*-derived class or **CHARS** *(1)*-derived class, respectively:
  - if none of them is **strong**, the class is the **BOOLS** *(n)*-derived class or **CHARS** *(n)*-derived class, depending on whether both operands are bit or character strings, where *n* is the sum of the **string lengths** of the **root** modes of both classes;
  - otherwise the class is the &*name(n)*-value class, where &*name* is a virtual **synmode** name **synonymous** with the **root** mode of the **resulting class** of the classes of the operands and *n* is the sum of the **string lengths** of the **root** modes of both classes.

    (This class is dynamic if one or both operands have a dynamic class).
- If *operator-4* is an *arithmetic additive operator* or *powerset difference operator*, the class of *operand-3* is the **resulting class** of the classes of *operand-4* and *sub operand-3*.

An *operand-3* is **constant** (**literal**) if, and only if, it is either an *operand-4* which is **constant** (**literal**), or built up from an *operand-3* and an *operand-4* which are both **constant** (**literal**) and *operator-4* is either the *arithmetic additive operator* or the *powerset difference operator*.

If *operator-4* is the *string concatenation operator*, an *operand-3* is **constant** if it is built up from an *operand-3* and *operand-4* which are both **constant**.

static conditions: If an *operator-4* is specified, the following compatibility requirements must be fulfilled:

- If *operator-4* is the *arithmetic additive operator*, the classes of both operands must be **compatible** and they must both have either an integer or a floating point **root** mode. Furthermore, if *operand-3* is not **constant**, the **root** mode of the class of *operand-3* must be a **predefined** integer mode or a **predefined** floating point mode.
- If *operator-4* is the *string concatenation operator*, then:
  - the classes of both operands must be **compatible** and they must both have a **bit** string **root** mode or both have a **character** string **root** mode; or
  - the classes of both operands must be **compatible** with the *BOOL* mode or both be **compatible** with the *CHAR* mode; or
  - the class of one operand must have a **bit** (**character**) string **root** mode and the other must be **compatible** with the *BOOL* (*CHAR*) mode.
- If *operator-4* is the *powerset difference operator*, the classes of both operands must be **compatible** and both must have a powerset **root** mode.

dynamic conditions: In the case of an *operand-3* that is not **constant**, if *operator-4* is an *arithmetic additive operator*, an *OVERFLOW* exception occurs if an addition (+) or a subtraction (–) gives rise to a value that is not one of the values defined by the **root** mode of the class of *operand-3*, or one or both operands do not belong to the set of values of the **root** mode of *operand-3*.

In the case of an *operand-3* that is not **constant**, an *UNDERFLOW* exception occurs if the class of *operand-3* has a floating point **root** mode and the exact mathematical addition (+) or subtraction (–) give rise to a value that is greater than the **negative upper limit** and less than the **positive lower limit** of the **root** mode of *operand-3*, and is different from zero.

examples:

1.6	*j*	*(1.1)*
1.6	*i+j*	*(1.2)*

5.3.7 Operand-4

syntax:

<operand-4> ::= *(1)*

	<operand-5>	*(1.1)*
|	*<sub operand-4> <arithmetic multiplicative operator> <operand-5>*	*(1.2)*

<sub operand-4> ::= *(2)*
<operand-4> *(2.1)*

<arithmetic multiplicative operator> ::= *(3)*
∗ | / | **MOD** | **REM** *(3.1)*

semantics: If the arithmetic multiplicative operator is either the product (∗) or the quotient operator (/), then both *sub operand-4* and *operand-5* deliver either integer values or floating point values and the resulting integer value or floating point value respectively is the product or quotient of both values.

If the arithmetic multiplicative operator is either the modulo (**MOD**) or division remainder (**REM**) operator, then both *sub operand-4* and *operand-5* deliver integer values, and the resulting integer value is the modulo or division remainder of both values.

The modulo operation is defined such that i **MOD** j delivers the unique integer value k, $0 \leq k < j$ such that there is an integer value n such that $i = n * j + k$; j must be greater than 0.

The quotient operation is defined such that all relations:

$$ABS\ (x/y) = ABS\ (x)\ /\ ABS\ (y) \text{ and}$$
$$\text{sign}\ (x/y) = \text{sign}\ (x)\ /\ \text{sign}\ (y) \text{ and}$$
$$ABS\ (x) - (ABS\ (x)\ /\ ABS\ (y)) * ABS\ (y) = ABS\ (x)\ \mathbf{MOD}\ ABS\ (y)$$

yield *TRUE* for all integer values x and y, where sign $(x) = -1$ if $x < 0$, otherwise sign $(x) = 1$.

The remainder operation is defined such that x **REM** $y = x - (x/y) * y$ yields *TRUE* for all integer values x and y.

If the class of operand-4 has a floating point **root** mode, the result is the floating point value that approximates, using the same criterion used for representation conversion, the result of the exact mathematical operation.

static properties: If *operand-4* is an *operand-5*, the class of *operand-4* is the class of *operand-5*; otherwise the class of *operand-4* is the **resulting class** of the classes of *sub operand-4* and *operand-5*.

An *operand-4* is **constant** (**literal**) if, and only if, it is either an *operand-5* which is **constant** (**literal**), or built up from an *operand-4* and an *operand-5* which are both **constant** (**literal**).

static conditions: If an *arithmetic multiplicative operator* is specified between integer or floating point operands, then the classes of *operand-5* and *sub operand-4* must be **compatible** and both must have an integer **root** mode or a floating point **root** mode respectively. Furthermore, if *operand-4* is not **constant**, the **root** mode of the class of *operand-4* must be a **predefined** integer mode or a **predefined** floating point mode.

dynamic conditions: In the case of an *operand-4* that is not **constant**, if an *arithmetic multiplicative operator* is specified, an *OVERFLOW* exception occurs if a multiplication (∗), a division (/), a modulo (**MOD**), or a remainder (**REM**) operation gives rise to a value that is not one of the values defined by the **root** mode of the class of *operand-4* or is performed on operand values for which the operator is mathematically not defined, i.e. division or remainder with an *operand-5* delivering 0 or a modulo operation with an *operand-5* delivering a non-positive integer value, or one or both operands do not belong to the set of values of the **root** mode of *operand-4*.

In the case of an *operand-4* that is not **constant**, an *UNDERFLOW* exception occurs if the class of *operand-4* has a floating point **root** mode and the exact mathematical multiplication (∗) or division (/) give rise to a value that is greater than the **negative upper limit** and less than the **positive lower limit** of the **root** mode of *operand-4*, and is different from zero.

examples:

6.15	*1_461*	*(1.1)*
6.15	*(4 ∗ d + 3) / 1_461*	*(1.2)*

5.3.8 Operand-5

syntax:

<operand-5> ::=	*(1)*
<operand-6>	*(1.1)*
| *<sub operand-5> <exponentiation operator> <operand-6>*	*(1.2)*
<sub operand-5> ::=	*(2)*
<operand-5>	*(2.1)*
<exponentiation operator> ::=	*(3)*
**	*(3.1)*

semantics: If the *exponentiation operator* is specified, *sub operand-5* and *operand-6* deliver a floating point value or an integer value. The resulting value is that obtained by raising the value delivered by *sub operand-5* to the power of that delivered by *operand-6*.

If the class of operand-5 has a floating point **root** mode, the result is the floating point value that approximates, using the same criterion used for representation conversion, the result of the exact mathematical operation.

static properties: If the *operand-5* is an *operand-6*, the class of the *operand-5* is the class of *operand-6*.

If the *exponentiation operator* is specified, the class of the *operand-5* is that of the *sub operand-5*.

An *operand-5* is **constant** (**literal**) if, and only if, it is either an *operand-6* which is **constant** (**literal**), or built up from an *operand-5* and *operand-6* which are both **constant** (**literal**).

static conditions: If an *exponentiation operator* is specified:

- if the class of *sub operand-5* has a floating point **root** mode, the class of *operand-6* must have an integer **root** mode or a floating point **root** mode;
- otherwise the class of *sub operand-5* must have an integer **root** mode and the class of *operand-6* must have an integer **root** mode.

dynamic conditions: In the case of an *operand-5* which is not **constant**, an *OVERFLOW* exception occurs if an exponentiation operation gives rise to a value outside the range of the **root** mode of the class of the *operand-5*.

In the case of an *operand-5* that is not **constant**, an *UNDERFLOW* exception occurs if the class of *operand-5* has a floating point **root** mode and the exact mathematical exponentiation gives rise to a value that is less than the **positive lower limit** of the **root** mode of *operand-5*.

If an *exponentiation operator* is specified and the class of *operand-5* has an integer **root** mode, then if *operand-6* is not **constant**, its value must be greater than or equal to zero.

example:

*r ** 4*	*(1.2)*

5.3.9 Operand-6

syntax:

<operand-6> ::=	*(1)*
[*<monadic operator>*] *<operand-7>*	*(1.1)*
| *<signed integer literal>*	*(1.2)*
| *<signed floating point literal>*	*(1.3)*
<monadic operator> ::=	*(2)*
– | **NOT**	*(2.1)*
| *<string repetition operator>*	*(2.2)*
<string repetition operator> ::=	*(3)*
(*<<u>integer literal</u> expression>*)	*(3.1)*

NOTE – If the *monadic operator* is the change sign operator (-) and the *operand-7* is an *unsigned integer literal* or an *unsigned floating point literal*, the syntactic construct is ambiguous and will be interpreted as a *signed integer literal* or a *signed floating point literal* respectively.

semantics: If the monadic operator is a change-sign operator (-), *operand-7* delivers an integer value or a floating point value and the resulting integer value or floating point value is the previous integer value or floating point value with its sign changed.

If the monadic operator is **NOT**, *operand-7* delivers a boolean value, a bit string value, or a powerset value. In the first two cases the logical negation of the boolean value or of the elements of the bit string value is delivered. In the latter case, the set complement value, i.e. the set of those member values which are not in the operand powerset value, is delivered.

If the monadic operator is a string repetition operator, *operand-7* is a *character string literal* or a *bit string literal*. If the <u>*integer literal*</u> *expression* delivers 0, the result is the empty string value; otherwise the result is the string value formed by concatenating the string with itself as many times as specified by the value delivered by the <u>*integer literal*</u> *expression* minus 1.

static properties: If *operand-6* is an *operand-7*, the class of *operand-6* is the class of *operand-7*.

If a *monadic operator* is specified, the class of *operand-6* is:

- if the *monadic operator* is – or **NOT**, then the **resulting class** of *operand-7*;
- if the *monadic operator* is the *string repetition operator*, then it is the **CHARS** *(n)*- or **BOOLS** *(n)*-derived class (depending on whether the literal was a *character string literal* or *bit string literal*) where $n = r * l$, where *r* is the value delivered by the <u>*integer literal*</u> *expression* and *l* is the **string length** of the string literal.

An *operand-6* is **constant** if, and only if, the *operand-7* is **constant**. An *operand-6* is **literal** if, and only if, the *operand-7* is **literal** and the *monadic operator* is – or **NOT**.

static conditions: If *monadic operator* is –, the class of *operand-7* must have an integer **root** mode or a floating point **root** mode. Furthermore, if *operand-6* is not **constant**, the **root** mode of the class of *operand-6* must be a **predefined** integer mode or a **predefined** floating point mode.

If *monadic operator* is **NOT**, the class of *operand-7* must have a boolean, **bit** string or powerset **root** mode.

If *monadic operator* is the *string repetition operator*, *operand-7* must be a *character string literal* or a *bit string literal*. The <u>*integer literal*</u> *expression* must deliver a non-negative integer-value.

dynamic conditions: If *operand-6* is not **constant**, an *OVERFLOW* exception occurs if a change sign (–) operation gives rise to a value which is not one of the values defined by the **root** mode of the class of the *operand-6*.

In the case of an *operand-6* that is not **constant**, an *UNDERFLOW* exception occurs if the class of *operand-6* has a floating point **root** mode and the exact mathematical change sign operation (–) gives rise to a value that is greater than the **negative upper limit** and less than the **positive lower limit** of the **root** mode of *operand-6*, and is different from zero.

examples:

5.10	**NOT** *k2*	*(1.1)*
7.54	*(6)" "*	*(1.1)*
7.54	*(6)*	*(2.2)*

5.3.10 Operand-7

syntax:

```
<operand-7> ::=                                   (1)
        <referenced location>                     (1.1)
      | <primitive value>                         (1.2)

<referenced location> ::=                         (2)
        –> <location>                             (2.1)
```

semantics: A referenced location delivers a reference to the specified location.

static properties: The class of an *operand-7* is the class of the *referenced location* or *primitive value*, respectively. The class of the *referenced location* is the M-reference class where M is the mode of the *location*.

An *operand-7* is **constant** if, and only if, the *primitive value* is **constant** or the *referenced location* is **constant**. A *referenced location* is **constant** if, and only if, the *location* is **static**. An *operand-7* is **literal** if, and only if, the *primitive value* is **literal**.

static conditions: The *location* must be **referable**.

example:

8.25 *-> c* *(2.1)*

6 Actions

6.1 General

syntax:

<action statement> ::= *(1)*
[*<defining occurrence>* :] *<action>* [*<handler>*] [*<simple name string>*] *;* *(1.1)*
| *<module>* *(1.2)*
| *<spec module>* *(1.3)*
| *<context module>* *(1.4)*

<action> ::= *(2)*
<bracketed action> *(2.1)*
| *<assignment action>* *(2.2)*
| *<call action>* *(2.3)*
| *<exit action>* *(2.4)*
| *<return action>* *(2.5)*
| *<result action>* *(2.6)*
| *<goto action>* *(2.7)*
| *<assert action>* *(2.8)*
| *<empty action>* *(2.9)*
| *<start action>* *(2.10)*
| *<stop action>* *(2.11)*
| *<delay action>* *(2.12)*
| *<continue action>* *(2.13)*
| *<send action>* *(2.14)*
| *<cause action>* *(2.15)*

<bracketed action> ::= *(3)*
<if action> *(3.1)*
| *<case action>* *(3.2)*
| *<do action>* *(3.3)*
| *<begin-end block>* *(3.4)*
| *<delay case action>* *(3.5)*
| *<receive case action>* *(3.6)*
| *<timing action>* *(3.7)*

semantics: Action statements constitute the algorithmic part of a CHILL program. Any action statement may be labelled. Those actions that have no exception defined may not have a handler appended.

static properties: A *defining occurrence* in an *action statement* defines a **label** name.

static conditions: The *simple name string* may only be given after an *action* which is a *bracketed action* or if a *handler* is specified, and only if a *defining occurrence* is specified. The *simple name string* must be the same name string as the *defining occurrence*.

6.2 Assignment action

syntax:

<assignment action> ::= *(1)*
<single assignment action> *(1.1)*
| *<multiple assignment action>* *(1.2)*

<single assignment action> ::= *(2)*
<location> *<assignment symbol>* *<value>* *(2.1)*
| *<location>* *<assigning operator>* *<expression>* *(2.2)*

<multiple assignment action> ::= *(3)*
<location> { , *<location>* }$^{+}$ *<assignment symbol>* *<value>* *(3.1)*

<assigning operator> ::= *(4)*
<closed dyadic operator> *<assignment symbol>* *(4.1)*

<closed dyadic operator> ::= *(5)*
OR | **XOR** | **AND** *(5.1)*
| *<powerset difference operator>* *(5.2)*
| *<arithmetic additive operator>* *(5.3)*
| *<arithmetic multiplicative operator>* *(5.4)*
| *<string concatenation operator>* *(5.5)*

<assignment symbol> ::= *(6)*
:= *(6.1)*

semantics: An assignment action stores a value into one or more locations.

If an assignment symbol is used, the value yielded by the right hand side is stored into the location(s) specified at the left hand side.

If an assigning operator is used, the value contained in the location is combined with the right hand side value (in that order) according to the semantics of the specified closed dyadic operator, and the result is stored back into the same location.

The evaluation of the left hand side location(s), of the right hand side value, and of the assignment themselves are performed in any order. Any assignment may be performed as soon as the value and a location have been evaluated.

If the location (or any of the locations) is the **tag** field of a variant structure, the semantics for the variant fields that depend on it are implementation defined.

static conditions: The modes of all *location* occurrences must be **equivalent** and they must have neither the **read-only property** nor the **non-value property**. Each mode must be **compatible** with the class of the *value*. The checks are dynamic in the case where dynamic mode locations and/or a value with a dynamic class are involved.

The *value* must be **regionally safe** for every *location* (see 11.2.2).

If any *location* has a **fixed** string mode, then the **string length** of the mode and the **actual length** of the value must be the same; otherwise, if it has a **varying** string mode, then the **string length** of the mode must not be less than the **actual length** of the value. This check is dynamic if one or both modes is (are) dynamic or **varying** string modes. This condition is called the string assignment condition.

dynamic conditions: The *RANGEFAIL* or *TAGFAIL* exception occurs if the mode of the location and/or that of the value are dynamic modes and the dynamic part of the above mentioned compatibility checks fails.

The *RANGEFAIL* exception occurs if the mode of the location and/or that of the value are **varying** string modes and the dynamic part of the above mentioned compatibility checks fails.

The *RANGEFAIL* exception occurs if any *location* has a discrete range mode (floating point range mode) and the value delivered by the evaluation of *value* is neither one of the values defined by the discrete range mode (floating point range mode) nor the **undefined** value.

The above mentioned dynamic conditions together with the string assignment condition are called the assignment conditions of a value with respect to a mode.

In the case of an *assigning operator*, the same exceptions are caused as if the expression:

<location> <closed dyadic operator> (<expression>)

were evaluated and the delivered value stored into the specified location (note that the location is evaluated once only).

examples:

4.12	*a := b+c*	*(1.1)*
10.25	*stackindex- := 1 (2.1)*	
19.19	*x->.prev, x->.next := NULL*	*(3.1)*
10.25	*- :=*	*(4.1)*

6.3 If action

syntax:

<*if action*> *::=* *(1)*
IF <*boolean expression*> <*then clause*> [<*else clause*>] **FI** *(1.1)*

<*then clause*> *::=* *(2)*
THEN <*action statement list*> *(2.1)*

<*else clause*> *::=* *(3)*
ELSE <*action statement list*> *(3.1)*
| **ELSIF** <*boolean expression*> <*then clause*> [<*else clause*>] *(3.2)*

derived syntax: The notation:

ELSIF <*boolean expression*> <*then clause*> [<*else clause*>]

is derived syntax for:

ELSE IF <*boolean expression*> <*then clause*> [<*else clause*>] **FI**;

semantics: An if action is a conditional two-way branch. If the *boolean expression* yields *TRUE*, the action statement list following **THEN** is entered; otherwise the action statement list following **ELSE**, if present, is entered.

dynamic conditions: The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

examples:

```
7.22     IF n >= 50 THEN rn(r) := 'L';
            n- := 50;
            r+ := 1;
         FI                                  (1.1)
10.50    IF last = NULL
            THEN first,last := p;
            ELSE last->.succ := p;
            p->.pred := last;
            last := p;
         FI                                  (1.1)
```

6.4 Case action

syntax:

<*case action*> *::=* *(1)*
CASE <*case selector list*> **OF** [<*range list*> *;*] { <*case alternative*> }$^+$
[**ELSE** <*action statement list*>] **ESAC** *(1.1)*

<*case selector list*> *::=* *(2)*
<*discrete expression*> { , <*discrete expression*> }* *(2.1)*

<*range list*> *::=* *(3)*
<*discrete mode name*> { , <*discrete mode name*> }* *(3.1)*

<*case alternative*> *::=* *(4)*
<*case label specification*> : <*action statement list*> *(4.1)*

semantics: A case action is a multiple branch. It consists of the specification of one or more discrete expressions (the case selector list) and a number of labelled action statement lists (case alternatives). Each action statement list is labelled with a case label specification which consists of a list of case label list specifications (one for each case selector). Each case label list defines a set of values. The use of a list of discrete expressions in the case selector list allows selection of an alternative based on multiple conditions.

The case action enters that action statement list for which values given in the case label specification match the values in the case selector list; if no value match, the *action statement list* following **ELSE** is entered.

The expressions in the case selector list are evaluated in any order. They need be evaluated only up to the point where a case alternative is uniquely determined.

static conditions: For the list of *case label specification* occurrences, the case selection conditions apply (see 12.3).

The number of discrete *expression* occurrences in the *case selector list* must be equal to the number of classes in the **resulting list of classes** of the list of *case label list* occurrences and, if present, to the number of discrete mode *name* occurrences in the *range list*.

The class of any discrete *expression* in the *case selector list* must be **compatible** with the corresponding (by position) class of the **resulting list of classes** of the *case label list* occurrences and, if present, **compatible** with the corresponding (by position) discrete mode *name* in the *range list*. The latter mode must also be **compatible** with the corresponding class of the **resulting list of classes**.

Any value delivered by a discrete literal *expression* or defined by a *literal range* or by a discrete mode *name* in a *case label* (see 12.3) must lie in the range of the corresponding discrete mode *name* of the *range list*, if present, and also in the range defined by the mode of the corresponding discrete *expression* in the *case selector list*, if it is a **strong** discrete *expression*. In the latter case, the values defined by the corresponding discrete mode *name* of the *range list*, if present, must also lie in that range.

The optional **ELSE** part according to the syntax may only be omitted if the list of *case label list* occurrences is **complete** (see 12.3).

dynamic conditions: The *RANGEFAIL* exception occurs if a *range list* is specified and the value delivered by a discrete *expression* in the *case selector list* does not lie within the bounds specified by the corresponding discrete mode *name* in the *range list*.

The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

examples:

```
4.11    CASE order OF
          (1):  a := b+c;
                RETURN;
          (2):  d := 0;
          (ELSE): d := 1;
        ESAC                                          (1.1)
11.43   starting.p.kind, starting.p.color             (2.1)
11.58   (rook),(*):
          IF NOT ok_rook(b,m)
            THEN
              CAUSE illegal;
          FI;                                         (4.1)
```

6.5 Do action

6.5.1 General

syntax:

```
<do action> ::=                                                   (1)
        DO [ <control part> ; ] <action statement list> OD        (1.1)

<control part> ::=                                                (2)
          <for control> [ <while control> ]                       (2.1)
        | <while control>                                         (2.2)
        | <with part>                                             (2.3)
```

semantics: A do action has one out of three different forms: the do-for and the do-while versions, both for looping, and the do-with version as a convenient short hand notation for accessing structure fields in an efficient way. If no control part is specified, the action statement list is entered once, each time the do action is entered.

When the do-for and the do-while versions are combined, the while control is evaluated after the for control, and only if the do action is not terminated by the for control.

If the specified control part is a for control and/or while control, then for as long as control stays inside the reach of the do action, the action statement list is entered according to the control part, but the do reach is not re-entered for each execution of the action statement list.

dynamic conditions: The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

examples:

```
4.17     DO FOR i := 1 TO c;
           op(a,b,d,order-1);
           d := a;
         OD                                   (1.1)
15.58    DO WITH each;
           IF this_counter = counter
             THEN
               status := idle;
               EXIT find_counter;
           FI;
         OD                                   (1.1)
```

6.5.2 For control

syntax:

<for control> ::=		*(1)*
	FOR { *<iteration>* { , *<iteration>* }* | **EVER** }	*(1.1)*
<iteration> ::=		*(2)*
	<value enumeration>	*(2.1)*
	| *<location enumeration>*	*(2.2)*
<value enumeration> ::=		*(3)*
	<step enumeration>	*(3.1)*
	| *<range enumeration>*	*(3.2)*
	| *<powerset enumeration>*	*(3.3)*
<step enumeration> ::=		*(4)*
	<loop counter> <assignment symbol> *<start value>* [*<step value>*] [**DOWN**] *<end value>*	*(4.1)*
<loop counter> ::=		*(5)*
	<defining occurrence>	*(5.1)*
<start value> ::=		*(6)*
	<discrete expression>	*(6.1)*
<step value> ::=		*(7)*
	BY *<integer expression>*	*(7.1)*
<end value> ::=		*(8)*
	TO *<discrete expression>*	*(8.1)*
<range enumeration> ::=		*(9)*
	<loop counter> [**DOWN**] **IN** *<discrete mode name>*	*(9.1)*
<powerset enumeration> ::=		*(10)*
	<loop counter> [**DOWN**] **IN** *<powerset expression>*	*(10.1)*
<location enumeration> ::=		*(11)*
	<loop counter> [**DOWN**] **IN** *<composite object>*	*(11.1)*
<composite object> ::=		*(12)*
	<array location>	*(12.1)*
	| *<array expression>*	*(12.2)*
	| *<string location>*	*(12.3)*
	| *<string expression>*	*(12.4)*

NOTE – If the *composite object* is a *string location* or an *array location*, the syntactic ambiguity is resolved by interpreting *composite object* as a *location* rather than an *expression*.

semantics: The for control may mention several loop counters. The loop counters are evaluated each time in an unspecified order, before entering the action statement list, and they need be evaluated only up to the point that it can be decided to terminate the do action. The do action is terminated if at least one of the loop counters indicates termination.

1) **do for ever:**

The action list is indefinitely repeated. The do action can only terminate by a transfer of control out of it.

2) **value enumeration:**

The action statement list is repeatedly entered for the set of specified values of the loop counters. The set of values is either specified by a *discrete mode name* (range enumeration), or by a powerset value (powerset enumeration), or by a start value, step value and end value (step enumeration).

The loop counter implicitly defines a name which denotes its value or location inside the action statement list.

range enumeration:

In the case of range enumeration without (with) DOWN specification, the initial value of the loop counter is the smallest (greatest) value in the set of values defined by the *discrete mode name*. For subsequent executions of the action statement list, the *next value* will be evaluated as:

SUCC (previous value) (*PRED (previous value))*

Termination occurs if the action statement list has been executed for the greatest (smallest) value defined by the *discrete mode name*.

powerset enumeration:

In the case of powerset enumeration without (with) **DOWN** specification, the initial value of the loop counter is the smallest (highest) member value in the denoted powerset value. If the powerset value is empty, the action statement list will not be executed. For subsequent executions of the action statement list, the next value will be the next greater (smaller) member value in the powerset value. Termination occurs if the action statement list has been executed for the greatest (smallest) value. When the do action is executed, the **powerset** expression is evaluated only once.

step enumeration:

In the case of step enumeration without (with) **DOWN** specification, the set of values of the loop counter is determined by a start value, an end value, and possibly a step value. When the do action is executed, these expressions are evaluated only once in any order. The step value is always positive. The test for termination is made before each execution of the action statement list. Initially, a test is made to determine whether the start value of the loop counter is greater (smaller) than the end value. For subsequent executions, *next value* will be evaluated as:

previous value + step value (*previous value – step value*)

in the case of *step value* specification; otherwise as:

SUCC (previous value) (*PRED (previous value))*

Termination occurs if the evaluation yields a value which is greater (smaller) than the end value or would have caused an *OVERFLOW* exception.

3) **location enumeration:**

In the case of a location enumeration without (with) **DOWN** specification, the action statement list is repeatedly entered for a set of locations which are the elements of the array location denoted by *array location* or the components of the string location denoted by *string location*. If an *array expression* or a *string expression* is specified that is not a location, a location containing the specified value will be implicitly created. The lifetime of the created location is the do action. The mode of the created location is dynamic if the value has a dynamic class. The semantics are as if before each execution of the action statement list the loc-identity declaration:

DCL <*loop counter*> <*mode*> **LOC** := <*composite object*> *(<index>);*

were encountered, where *mode* is the element mode of the array location or &*name(1)* such that &*name* is a virtual **synmode** name **synonymous** with the mode of the string location if it is a **fixed** string mode, otherwise with the **component** mode, and where *index* is initially set to the **lower bound** (**upper bound**) of the mode of location and *index* before each subsequent execution of the action statement list is set to *SUCC (index)* (*PRED (index)*). The action statement list will not be executed if the **actual length** of the <u>string</u> *location* equals 0. The do action is terminated if *index* just after an execution of the action statement list is equal to the **upper bound** (**lower bound**) of the mode of location. When the do action is executed, the *composite object* is evaluated only once.

static properties: A loop counter has a name string attached which is the name string of its *defining occurrence*.

value enumeration:

The name defined by the *loop counter* is a **value enumeration** name.

step enumeration:

The class of the name defined by a *loop counter* is the **resulting class** of the classes of the *start value*, the *step value*, if present, and the *end value*.

range enumeration:

The class of the name defined by the *loop counter* is the M-value class, where M is the <u>*discrete mode*</u> *name*.

powerset enumeration:

The class of the name defined by the *loop counter* is the M-value class, where M is the **member** mode of the mode of the (**strong**) <u>*powerset*</u> *expression*.

location enumeration:

The name defined by the *loop counter* is a **location enumeration** name. Its mode is the **element** mode of the mode of the <u>*array*</u> *location* or <u>*array*</u> *expression* or the string mode *&name*(1), where *&name* is a virtual **synmode** name **synonymous** with the mode of <u>*string*</u> *location* or the **root** mode of the <u>*string*</u> *expression*.

A **location enumeration** name is **referable** if the element layout of the mode of the <u>*array*</u> *location* is **NOPACK**.

static conditions: The classes of *start value*, *end value* and *step value*, if present, must be pairwise **compatible**.

The **root** mode of the class of a *loop counter* in a *value enumeration* must not be a **numbered** set mode.

If the **root** mode of the class of a *loop counter* is an integer mode, there must exist a **predefined** integer mode that contains all the values delivered by *start value*, *end value* and *step value*, if present.

dynamic conditions: A *RANGEFAIL* exception occurs if the value delivered by *step value* is not greater than 0. This exception occurs outside the block of the do action.

examples:

4.17	**FOR** *i := 1* **TO** *c*	*(1.1)*
15.37	**FOR EVER**	*(1.1)*
4.17	*i := 1* **TO** *c*	*(3.1)*
9.12	*j := MIN (sieve)* **BY** *MIN (sieve)* **TO** *max*	*(3.1)*
14.28	*i* **IN** *INT (1:100) (3.2)*	

6.5.3 While control

syntax:

<while control> ::=	*(1)*
WHILE <<u>*boolean*</u> *expression*>	*(1.1)*

semantics: The boolean expression is evaluated just before entering the action statement list (after the evaluation of the for control, if present). If it yields *TRUE*, the action statement list is entered; otherwise the do action is terminated.

examples:

7.35 **WHILE** *n >= 1* *(1.1)*

6.5.4 With part

syntax:

<with part> ::= *(1)*
WITH *<with control>* { , *<with control>* }* *(1.1)*

<with control> ::= *(2)*
<structure location> *(2.1)*
| *<structure primitive value>* *(2.2)*

NOTE – If the *with control* is a *structure location*, the syntactic ambiguity is resolved by interpreting *with control* as a *location* rather than a *primitive value*.

semantics: The (**visible**) field names of the mode of the structure locations or structure value specified in each *with control* are made available as direct accesses to the fields.

The visibility rules are as if a field name defining occurrence were introduced for each **field** name attached to the mode of the location or primitive value and with the same name string as the field name.

If a *structure location* is specified, access names with the same name string as the field names of the mode of the *structure location* are implicitly declared, denoting the sub-locations of the structure location.

If a *structure primitive value* is specified, value names with the same name string as the field names of the mode of the (**strong**) *structure primitive value* are implicitly defined, denoting the sub-values of the structure value.

When the do action is entered, the specified structure locations and/or structure values are evaluated once only on entering the do action, in any order.

static properties: The (virtual) defining occurrence introduced for a **field** name has the same name string as the *field name defining occurrence* of that **field** name.

If a *structure primitive value* is specified, a (virtual) defining occurrence in a *with part* defines a **value do-with** name. Its class is the M-value class, where M is the mode of that **field** name of the structure mode of the *structure primitive value* which is made available as **value do-with** name.

If a *structure location* is specified, a (virtual) defining occurrence in a *with part* defines a **location do-with** name. Its mode is the mode of that **field** name of the mode of the *structure location* which is made available as **location do-with** name. A **location do-with** name is **referable** if the field layout of the associated **field** name is **NOPACK**.

examples:

15.58 **WITH** *each* *(1.1)*

6.6 Exit action

syntax:

<exit action> ::= *(1)*
EXIT *<label name>* *(1.1)*

semantics: An exit action is used to leave a bracketed action statement or a module. Execution is resumed immediately after the closest surrounding bracketed action statement or module labelled with the *label name*.

static conditions: The *exit action* must lie within the bracketed action statement or module of which the *defining occurrence* in front has the same name string as *label name*.

If the *exit action* is placed within a procedure or process definition, the exited bracketed action statement or module must also lie within the same procedure or process definition (i.e. the exit action cannot be used to leave procedures or processes).

No *handler* may be appended to an *exit action*.

examples:

15.62 **EXIT** *find_counter* *(1.1)*

6.7 Call action

syntax:

```
<call action> ::=                                                          (1)
        <procedure call>                                                   (1.1)
      | <built-in routine call>                                            (1.2)
      | <moreta component procedure call>                                  (1.3)

<procedure call> ::=                                                       (2)
        { <procedure name> | <procedure primitive value> }
        ( [ <actual parameter list> ] )                                    (2.1)

<actual parameter list> ::=                                                (3)
        <actual parameter> { , <actual parameter> }*                       (3.1)

<actual parameter> ::=                                                     (4)
        <value>                                                            (4.1)
      | <location>                                                         (4.2)

<built-in routine call> ::=                                                (5)
        <built-in routine name> ( [ <built-in routine parameter list> ] )  (5.1)

<built-in routine parameter list> ::=                                      (6)
        <built-in routine parameter> { , <built-in routine parameter> }*   (6.1)

<built-in routine parameter> ::=                                           (7)
        <value>                                                            (7.1)
      | <location>                                                         (7.2)
      | <non-reserved name> [ ( <built-in routine parameter list> ) ]      (7.3)

<moreta component procedure call> ::=                                      (8)
        <moreta location> . <moreta component procedure call> [<priority>] (8.1)
      | <bound reference moreta location primitive value> -> .
        <moreta component procedure call> [<priority>]                     (8.2)
      | <moreta component procedure call> [<priority> ]                    (8.3)
```

NOTE – If the *actual parameter* or *built-in routine parameter* is a *location*, the syntactic ambiguity is resolved by interpreting it as a *location* rather than a *value*.

derived syntax: A procedure call **P(...)** of a *moreta component procedure* **P** is derived syntax for **SELF.P(...)**.

semantics: A call action causes the call of either a procedure, a built-in routine, or a moreta component procedure. A procedure call causes a call of the **general** procedure indicated by the value delivered by the *procedure primitive value* or the procedure indicated by the *procedure name*. A *moreta component procedure call* **L.name(...)** causes the call of that moreta component procedure which is identified by name in the mode of **L**. **L** is passed as an initial location parameter to the procedure. The actual values and locations specified in the actual parameter list are passed to the procedure.

A *built-in routine call* is either a *CHILL built-in routine call* or an implementation *built-in routine call* (see 6.20 and 13.1, respectively).

A value, a location, or any program defined name that is not a **reserved** simple name string may be passed as *built-in routine parameter*. The built-in routine call may return a value or a location.

A built-in routine may be generic, i.e. its class (if it is a **value** built-in routine call) or its mode (if it is a **location** built-in routine call) may depend not only on the *built-in routine name* but also on the static properties of the actual parameters passed and the static context of the call.

A moreta component procedure call has always the structure "location . procedure call". This is characterised by the expression "the procedure call is applied to the location".

For a moreta component procedure call, the following steps are performed:

a) *The called procedure is applied to a module mode location:*

   1) evaluation of the actual parameters;

   2) check of the precondition;

   3) check of the complete invariant;

   4) execution of the body of the procedure;

   5) check of the complete invariant;

   6) check of complete postcondition;

   7) return to the calling point.

b) *The called procedure is applied to a region mode location RL:*

   1) evaluation of the actual parameters;

   2) wait until RL is free and lock RL;

   3) check of the precondition;

   4) check of the complete invariant;

   5) execution of the body of the procedure;

   6) check of the complete invariant;

   7) check of complete postcondition;

   8) release RL;

   9) return to the calling point.

c) *The called procedure is applied to a task mode location TL:*

   the caller performs the following steps:

   1) evaluation of the actual parameters;

   2) send procedure identification, actual parameters and priority to TL;

   3) continue with next action.

   TL performs the following steps:

   1) receive procedure identification and actual parameters according to priority;

   2) check of the precondition;

   3) check of the complete invariant;

   4) execution of the body of the procedure;

   5) check of the complete invariant;

   6) check of complete postcondition.

static properties: A *procedure call* has the following properties attached: a list of **parameter specs**, possibly a **result spec**, a possibly empty set of exception names, a **generality**, a **recursivity**, and possibly it is **intra-regional** (the latter is only possible with a *<u>procedure</u> name*, see 11.2.2). These properties are inherited from the *<u>procedure</u> name, <u>moreta component procedure</u> name* or any mode **compatible** with the class of the *<u>procedure</u> primitive valu*e (in the latter case, the generality is always **general**).

A *procedure call* with a **result spec** is a *<u>location</u> procedure call* if, and only if, **LOC** is specified in the **result spec**; otherwise it is a *<u>value</u> procedure call*.

A *<u>built-in routine</u> name* is a CHILL or an implementation defined name that is considered to be defined in the reach of the imaginary outermost process definition or in any context (see 10.8).

A *built-in routine call* is a **location** *built-in routine call* if it delivers a location; it is a **value** *built-in routine call* if it delivers a value.

static conditions: A *priority* can only be used in a call of a procedure applied to a task location.

The number of *actual parameter* occurrences in the *procedure call* must be the same as the number of its parameter specs. The compatibility requirements for the *actual parameter* and corresponding (by position) parameter spec of the *procedure call* are:

- If the parameter spec has the **IN** attribute (default), the *actual parameter* must be a *value* whose class is **compatible** with the mode in the corresponding parameter spec. The latter mode must not have the **non-value property**. The *actual parameter* is a *value* which must be **regionally safe** for the *procedure call*.

- If the parameter spec has the **INOUT** or **OUT** attribute, the *actual parameter* must be a *location*, whose mode must be **compatible** with the M-value class, where M is the mode in the corresponding parameter spec. The mode of the (actual) *location* must be static and must not have the **read-only property** nor the **non-value property**. The *actual parameter* is a *location*. It can be viewed as a *value* which must be **regionally safe** for the *procedure call*.

- If the parameter spec has the **INOUT** attribute, the mode in the parameter spec must be **compatible** with the M-value class where M is the mode of the *location*.

- If the parameter spec has the **LOC** attribute specified without **DYNAMIC**, the *actual parameter* must be a *location* which is both **referable** and such that the mode in the parameter spec is **read-compatible** with the mode of the (actual) *location*, or the *actual parameter* must be a *value* which is not a *location* but whose class is **compatible** with the mode in the parameter spec.

- If the parameter spec has the **LOC** attribute with **DYNAMIC** specified, the *actual parameter* must be a *location* which is both **referable** and such that the mode in the parameter spec is **dynamic read-compatible** with the mode of the (actual) *location*, or the *actual parameter* must be a *value* which is not a *location* but whose class is **compatible** with a parameterised version of this mode.

- If the parameter spec has the **LOC** attribute then:

  – if the *actual parameter* is a *location*, it must have the same **regionality** as the *procedure call*;

  – if the *actual parameter* is a *value*, then it must be **regionally safe** for the *procedure call*.

dynamic conditions: A *call action* can cause any of the exceptions from the attached set of exception names. A *procedure call* causes the *EMPTY* exception if the <u>*procedure*</u> *primitive value* delivers *NULL*. A *call action* causes the *SPACEFAIL* exception if storage requirements cannot be satisfied. If the **recursivity** of the procedure is **non-recursive**, then the procedure must not call itself either directly or indirectly.

Parameter passing can cause the following exceptions:

- If the parameter spec has the **IN** or **INOUT** attribute, the assignment conditions of the (actual) value with respect to the mode of the parameter spec apply at the point of the call (see 6.2) and the possible exceptions are caused before the procedure is called.

- If the parameter spec has the **INOUT** or **OUT** attribute, the assignment conditions of the local value of the formal parameter with respect to the mode of the (actual) location apply at the point of return (see 6.2) and possible exceptions are caused after the procedure has returned.

- If the parameter spec has the **LOC** attribute and the *actual parameter* is a *value* which is not a *location*, the assignment conditions of the (actual) *value* with respect to the mode of the parameter spec apply at the point of the call and the possible exceptions are caused before the procedure is called (see 6.2).

Assertion checking can cause the following exceptions:

- If the precondition evaluates to *FALSE* the exception *PREFAIL* is caused – The search for an appropriate handler begins at the end of the procedure body and continues according to 8.3.

- If the postcondition evaluates to *FALSE* the exception *POSTFAIL* is caused – The search for an appropriate handler begins at the end of the procedure body and continues according to 8.3.
- If the invariant evaluates to *FALSE* the exception *INVFAIL* is caused – The search for an appropriate handler begins at the end of the body of the corresponding moreta mode and continues according to 8.3.

The *procedure primitive value* must not deliver a procedure defined within a process definition whose activation is not the same as the activation of the process executing the procedure call (other than the imaginary outermost process) and the lifetime of the denoted procedure must not have ended.

If a call is applied to a task location TL, then TL must not be ended.

examples:

4.18	*op(a,b,d,order-1)*	*(1.1)*

6.8 Result and return action

syntax:

<return action> ::= *(1)*
RETURN [*<result>*] *(1.1)*

<result action> ::= *(2)*
RESULT *<result>* *(2.1)*

<result> ::= *(3)*
<value> *(3.1)*
| *<location>* *(3.2)*

derived syntax: The *return action* with *result* is derived from **DO RESULT** *<result> ;* **RETURN***;* **OD**.

semantics: A result action serves to establish the result to be delivered by a procedure call. This result may be a location or a value. A return action causes the return from the invocation of the procedure within whose definition it is placed. If the procedure returns a result, this result is determined by the latest executed result action. If no result action has been executed, the procedure call delivers an **undefined** location or **undefined** value, respectively.

static properties: A *result action* and a *return action* have a **procedure** name attached, which is the name of the closest surrounding procedure definition.

static conditions: A *return action* and a *result action* must be textually surrounded by a procedure definition. A *result action* may only be specified if its **procedure** name has a **result spec**.

A *handler* must not be appended to a *return action* (without *result*).

If **LOC** (**LOC DYNAMIC**) is specified in the **result spec** of the **procedure** name of the *result action*, the *result* must be a *location*, such that the mode in the **result spec** is **read-compatible** (**dynamic read-compatible**) with the mode of the *location*. The *location* must be **referable** if **NONREF** is not specified in the **result spec**. The *result* is a *location* which must have the same **regionality** as the **procedure** name attached to the *result action*.

If **LOC** is not specified in the **result spec** of the **procedure** name of the *result action*, the *result* must be a *value*, whose class is **compatible** with the mode in the **result spec**. The *result* is a *value* which must be **regionally safe** for the **procedure** name attached to the *result action*.

dynamic conditions: If **LOC** is not specified in the **result spec** of the **procedure** name, the assignment conditions of the *value* in the *result action* with respect to the mode in the **result spec** of its **procedure** name apply.

examples:

4.21	**RETURN**	*(1.1)*
1.6	**RESULT** *i+j*	*(2.1)*
5.19	*c*	*(3.1)*

6.9 Goto action

syntax:

<goto action> ::= *(1)*
GOTO *<label name>* *(1.1)*

semantics: A goto action causes a transfer of control. Execution is resumed with the action statement labelled with the *label name*.

static conditions: If a *goto action* is placed within a procedure or process definition, the label indicated by the *label name* must also be defined within the definition (i.e. it is not possible to jump outside a procedure or process invocation).

A *handler* must not be appended to a *goto action*.

6.10 Assert action

syntax:

<assert action> ::= *(1)*
ASSERT *<boolean expression>* *(1.1)*

semantics: An assert action provides a means of testing a condition.

dynamic conditions: The *ASSERTFAIL* exception occurs if the *boolean expression* delivers *FALSE*.

examples:

4.7 **ASSERT** *b>0* **AND** *c>0* **AND** *order>0* *(1.1)*

6.11 Empty action

syntax:

<empty action> ::= *(1)*
<empty> *(1.1)*

<empty> ::= *(2)*

semantics: An empty action causes no action.

static conditions: A *handler* must not be appended to an *empty action*.

6.12 Cause action

syntax:

<cause action> ::= *(1)*
CAUSE *<exception name>* *(1.1)*

semantics: A cause action causes the exception whose name is indicated by *exception name* to occur.

static conditions: A *handler* must not be appended to a *cause action*.

examples:

4.9 **CAUSE** *wrong_input* *(1.1)*

6.13 Start action

syntax:

<start action> ::= *(1)*
<start expression> *(1.1)*

semantics: A start action evaluates the start expression (see 5.2.15) without using the resulting instance value.

examples:

14.45 **START** *call_distributor ( )* *(1.1)*

6.14 Stop action

syntax:

<stop action> ::= *(1)*
STOP *(1.1)*

semantics: A stop action terminates the process executing it (see 11.1).

static conditions: A *handler* must not be appended to a *stop action*.

6.15 Continue action

syntax:

<continue action> ::= *(1)*
CONTINUE <<u>*event*</u> *location*> *(1.1)*

semantics: A continue action evaluates the <u>*event*</u> *location*.

If the event location has a non-empty set of delayed processes attached, one of these, with the highest priority, will be re-activated. If there are several such processes, one will be selected in an implementation defined way. If there are no such processes, the continue action has no further effect.

If a process becomes re-activated, it is removed from all sets of delayed processes of which it was a member.

examples:

13.25 **CONTINUE** *resource_freed* *(1.1)*

6.16 Delay action

syntax:

<delay action> ::= *(1)*
DELAY <<u>*event*</u> *location*> [<*priority*>] *(1.1)*

<priority> ::= *(2)*
PRIORITY <<u>*integer literal*</u> *expression*> *(2.1)*

semantics: A delay action evaluates the <u>*event*</u> *location*.

Then a *DELAYFAIL* exception occurs (see below) or the executing process becomes delayed.

If the executing process becomes delayed, it becomes a member with a priority of the set of delayed processes attached to the specified event location. The priority is the one specified, if any, otherwise 0 (lowest).

dynamic properties: A process executing a delay action becomes **timeoutable** when it reaches the point of execution where it may become delayed. It ceases to be **timeoutable** when it leaves that point.

static conditions: The <u>*integer literal*</u> *expression* must not deliver a negative value.

dynamic conditions: The *DELAYFAIL* exception occurs if the <u>*event*</u> *location* has a mode with an **event length** attached which is equal to the number of processes already delayed on the event location.

The lifetime of the <u>*event*</u> *location* must not end while the executing process is delayed on it.

examples:

13.18 **DELAY** *resource_freed* *(1.1)*

6.17 Delay case action

syntax:

<delay case action> ::= *(1)*
DELAY CASE [**SET** <*instance* location> [<*priority*>] *;* | <*priority*> *;*]
{ <*delay alternative*> }+
ESAC *(1.1)*

<delay alternative> ::= *(2)*
(<*event list*>) : <*action statement list*> *(2.1)*

<event list> ::= *(3)*
<*event location*> { , <*event location*> }* *(3.1)*

semantics: A delay case action evaluates, in any order, the *instance* location, if present, and all *event* locations specified in a *delay alternative*.

Then a *DELAYFAIL* exception occurs (see below) or the executing process becomes delayed.

If the executing process becomes delayed, it becomes a member with a priority of the set of delayed processes attached to each of the specified event locations. The priority is the one specified, if any, otherwise 0 (lowest).

If the delayed process becomes re-activated by another process executing a continue action on an event location, the corresponding *action statement list* is entered. If several *delay alternatives* specify the same event location, the choice between them is not specified. Prior to entering, if an instance location is specified, the instance value identifying the process that has executed the continue action is stored in it.

dynamic properties: A process executing a delay case action becomes **timeoutable** when it reaches the point of execution where it may become delayed. It ceases to be **timeoutable** when it leaves that point.

static conditions: The mode of the *instance location* must not have the **read-only property**. The *integer literal expression* in *priority* must not deliver a negative value.

dynamic conditions: The DELAYFAIL exception occurs if any *event location* has a mode with an **event length** attached which is equal to the number of processes already delayed on that event location.

The lifetime of none of the *event locations* must end while the executing process is delayed on them.

The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

examples:

14.26 **DELAY CASE**
(operator_is_ready): / some actions */*
(switch_is_closed): **DO FOR** i **IN** *INT (1:100);*
CONTINUE *operator_is_ready;*
/ empty the queue */*
OD;
ESAC *(1.1)*

6.18 Send action

6.18.1 General

syntax:

<send action> ::= *(1)*
<*send signal action*> *(1.1)*
| <*send buffer action*> *(1.2)*

semantics: A send action initiates the transfer of synchronisation information from a sending process. The detailed semantics depend on whether the synchronisation object is a signal or a buffer.

6.18.2 Send signal action

syntax:

<send signal action> ::= *(1)*
SEND <*signal name*> [(<*value*> { , <*value*> }*)]
[**TO** <*instance primitive value*>] [<*priority*>] *(1.1)*

semantics: A send signal action evaluates, in any order, the list of *values*, if present, and the *instance primitive value*, if present.

The signal specified by *signal name* is composed for transmission from the specified values and a priority. The priority is the one specified, if any, otherwise 0 (lowest).

If the **signal** name has a **process** name attached, only processes with that name may receive the signal; if an *instance primitive value* is specified, only that process may receive the signal. Otherwise any process may receive the signal.

If the signal has a non-empty set of delayed processes attached, in which one or more may receive the signal, one of these will be re-activated. If there are several such processes, one will be selected in an implementation defined way. If there are no such processes, the signal becomes pending.

If a process becomes re-activated, it is removed from all sets of delayed processes of which it was a member.

static conditions: The number of *value* occurrences must be equal to the number of modes of the *signal name*. The class of each *value* must be **compatible** with the corresponding mode of the *signal name*. No *value* occurrence may be **intra-regional** (see 11.2.2). The *integer literal expression* in *priority* must not deliver a negative value.

dynamic conditions: The assignment conditions of each *value* with respect to its corresponding mode of the *signal name* apply.

The *EMPTY* exception occurs if the *instance primitive value* delivers *NULL*.

The lifetime of the process indicated by the value delivered by the *instance primitive value* must not have ended at the point of the execution of the send signal action.

The *SENDFAIL* exception occurs if the *signal name* has a **process** name attached which is not the name of the process indicated by the value delivered by the *instance primitive value*.

examples:

15.78 **SEND** *ready* **TO** *received_user* *(1.1)*
15.86 **SEND** *readout(count)* **TO** *user* *(1.1)*

6.18.3 Send buffer action

syntax:

<send buffer action> ::= *(1)*
SEND <*buffer location*> (<*value*>) [<*priority*>] *(1.1)*

semantics: A send buffer action evaluates the *buffer location* and the *value* in any order.

If the buffer location has a non-empty set of delayed processes attached, one of these will be re-activated. If there are several such processes, one will be selected in an implementation defined way. If there are no such processes and the capacity of the buffer location is exceeded, the executing process becomes delayed with a priority. Otherwise, the value is stored with a priority. The priority is the one specified, if any, otherwise 0 (lowest). The capacity of the buffer is exceeded if the *buffer location* has a mode with a **buffer length** attached which is equal to the number of values already stored in the buffer location.

If the executing process becomes delayed, it becomes a member of the set of delayed sending processes attached to the buffer location. If a process becomes re-activated, it is removed from all sets of delayed processes of which it was a member.

dynamic properties: A process executing a send buffer action becomes **timeoutable** when it reaches the point of execution where it may become delayed. It ceases to be **timeoutable** when it leaves that point.

static conditions: The class of the *value* must be **compatible** with the **buffer element** mode of the mode of the *buffer location*. The *value* must not be **intra-regional** (see 11.2.2). The *integer literal expression* in *priority* must not deliver a negative value.

dynamic conditions: The assignment conditions of the *value* with respect to the **buffer element** mode of the mode of the *buffer location* apply; the possible exceptions occur before the process may become delayed.

The lifetime of the *buffer location* must not end while the executing process is delayed on it.

examples:

16.123 **SEND** *user->([ready, ->counter_buffer]) ;* *(1.1)*

6.19 Receive case action

6.19.1 General

syntax:

<receive case action> ::= *(1)*
<receive signal case action> *(1.1)*
| *<receive buffer case action>* *(1.2)*

semantics: A receive case action receives synchronisation information transmitted by a send action. The detailed semantics depend on the synchronisation object used, which is either a signal or a buffer. Entering a receive case action does not necessarily result in a delaying of the executing process (see clause 11 for further details).

6.19.2 Receive signal case action

syntax:

<receive signal case action> ::= *(1)*
RECEIVE CASE [**SET** *<instance location> ;*]
{ *<signal receive alternative>* }$^+$
[**ELSE** *<action statement list>*] **ESAC** *(1.1)*
| **RECEIVE** [**SET** *<instance location>*]
(*<signal name>* [**IN** *<location list>*]) *(1.2)*

<location list> ::= *(2)*
<location> { , *<location>* }* *(2.1)*

<signal receive alternative> ::= *(3)*
(*<signal name>* [**IN** *<defining occurrence list>*]) : *<action statement list>* *(3.1)*

derived syntax: The notation (1.2) is derived syntax for

RECEIVE CASE [**SET** *<instance location>;*]
(*<signal name>* [**IN** *<&name>*$_1$, …, *<&name>*$_n$]):
<location>$_1$:= *<&name>*$_1$*;* … *<location>*$_n$:= *<&name>*$_n$*;* **ESAC**,
where *<&name>*$_1$, …, *<&name>*$_n$ are virtually introduced **value receive** names, and
<location>$_1$, …, *<location>*$_n$ are the *locations* in the *location list*.

semantics: A receive signal case action evaluates the *instance location*, if present.

Then the executing process: (immediately) receives a signal or, if **ELSE** is specified, enters the corresponding *action statement list*, otherwise becomes delayed. The executing process immediately receives a signal if one of a *signal name* specified in a *signal receive alternative* is pending and may be received by the process. If more than one signal may be received, one with the highest priority will be selected in an implementation defined way.

If the executing process becomes delayed, it becomes a member of the set of delayed processes attached to each of the specified signals. If the delayed process becomes re-activated by another process executing a send signal action, it receives a signal.

If the executing process receives a signal, the corresponding *action statement list* is entered. Prior to entering, if an *instance location* is specified, the instance value identifying the process that has sent the received signal is stored in it. If the **signal** name of the received signal has a list of modes attached, a list of **value receive** names is specified; the signal carries a list of values, and the **value receive** names denote their corresponding value in the entered *action statement list*.

static properties: A *defining occurrence* in the *defining occurrence list* of a *signal receive alternative* defines a **value receive** name. Its class is the M-value class, where M is the corresponding mode in the list of modes attached to the *signal name* in front of it.

dynamic properties: A process executing a receive signal case action becomes **timeoutable** when it reaches the point of execution where it may become delayed. It ceases to be **timeoutable** when it leaves that point.

static conditions: The mode of the *instance location* must not have the **read-only property**.

All *signal name* occurrences must be different.

The optional **IN** and the *defining occurrence list* in the *signal receive alternative* must be specified if, and only if, the *signal name* has a non-empty set of modes. The number of names in the *defining occurrence list* must be equal to the number of modes of the *signal name*.

The assignment conditions of the values delivered by $\&name_1$, …, $\&name_n$ with respect to the modes of $location_1$, …, $location_n$ apply.

dynamic conditions: The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

examples:

15.83 **RECEIVE CASE**
(advance): count + := 1;
(terminate):
SEND *readout(count)* **TO** *user;*
EXIT *work_loop;*
ESAC *(1.1)*

6.19.3 Receive buffer case action

syntax:

<receive buffer case action> ::= *(1)*
RECEIVE CASE [**SET** <*instance location*> *;*]
{ <*buffer receive alternative*> }$^+$
[**ELSE** <*action statement list*>]
ESAC *(1.1)*
| **RECEIVE** [**SET** <*instance location*>]
(<*buffer location* > **IN** <*location*>) *(1.2)*

<buffer receive alternative> ::= *(2)*
(<*buffer location*> **IN** <*defining occurrence*>) : <*action statement list*> *(2.1)*

derived syntax: The notation (1.2) is derived syntax for

RECEIVE CASE [**SET** <*instance location*>*;*]
(<*buffer location*> **IN** <*&name*>): <*location*> := <*&name*>*;*
where <*&name*> is a virtually introduced **value receive** name.

semantics: A receive buffer case action evaluates, in any order, the *instance location*, if present, and all *buffer locations* specified in a *buffer receive alternative*.

Then the executing process: (immediately) receives a value or, if **ELSE** is specified, enters the corresponding *action statement list*, otherwise becomes delayed. The executing process immediately receives a value if one is stored in, or a sending process delayed on, one of the specified buffer locations. If more than one value may be received, one with the highest priority will be selected in an implementation defined way.

If the executing process becomes delayed, it becomes a member of the set of delayed processes attached to each of the specified buffer locations. If the delayed process becomes re-activated by another process executing a send buffer action, it receives a value.

If the executing process receives a value, the corresponding *action statement list* is entered. If several *buffer receive alternatives* specify the same buffer location, the choice between them is not specified. Prior to entering, if an *instance* *location* is specified, the instance value identifying the process that has sent the received value is stored in it. The specified **value receive** name denotes the received value in the entered *action statement list*.

Another process becomes re-activated if the executing process receives a value from a buffer location, the attached set of delayed sending processes of which is not empty. The re-activated process is one with the highest priority attached, if the received value was stored in the buffer location, otherwise the one sending the received value. In the former case, the value to be sent by the re-activated process is stored in the buffer location (the capacity of which remains exceeded), and if more than one process may be re-activated, one will be selected in an implementation defined way. The re-activated process is removed from the set of delayed sending processes attached to the buffer location.

static properties: A *defining occurrence* in a *buffer receive alternative* defines a **value receive** name. Its class is the M-value class, where M is the **buffer element** mode of the mode of the *buffer location* labelling the *buffer receive alternative*.

dynamic properties: A process executing a receive buffer case action becomes **timeoutable** when it reaches the point of execution where it may become delayed. It ceases to be **timeoutable** when it leaves that point.

static conditions: The mode of the *instance location* must not have the **read-only property**.

The assignment conditions of the value denoted by *&name* with respect to the mode of the *location* apply.

dynamic conditions: The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

The lifetime of none of the *buffer locations* must end while the executing process is delayed on them.

6.20 CHILL built-in routine calls

syntax:

<CHILL built-in routine call> ::=	*(1)*
<CHILL simple built-in routine call>	*(1.1)*
| *<CHILL location built-in routine call>*	*(1.2)*
| *<CHILL value built-in routine call>*	*(1.3)*

predefined names: The CHILL built-in routine names are predefined as **built-in routine** names (see 6.7).

semantics: A *CHILL built-in routine call* is either a *CHILL simple built-in routine call*, which delivers no results (see 6.20.1), a *CHILL location built-in routine call*, which delivers a location (see 6.20.2), or a *CHILL value built-in routine call*, which delivers a value (see 6.20.3).

static properties: A *CHILL built-in routine call* is a **location** *built-in routine call* if it is a *CHILL location built-in routine call*; it is a **value** *built-in routine call* if it is a *CHILL value built-in routine call*.

6.20.1 CHILL simple built-in routine calls

syntax:

<CHILL simple built-in routine call> ::=	*(1)*
<terminate built-in routine call>	*(1.1)*
| *<io simple built-in routine call>*	*(1.2)*
| *<timing simple built-in routine call>*	*(1.3)*

semantics: A *CHILL simple built-in routine call* is a *built-in routine call* which delivers neither a value nor a location. The simple built-in routines for input output are defined in clause 7. The simple built-in routines for timing are defined in clause 9.

6.20.2 CHILL location built-in routine calls

syntax:

<CHILL location built-in routine call> ::=	*(1)*
<io location built-in routine call>	*(1.1)*

semantics: A *CHILL location built-in routine call* is a *built-in routine call* that delivers a location. The location built-in routines for input output are defined in clause 7.

6.20.3 CHILL value built-in routine calls

syntax:

<CHILL value built-in routine call> ::= (1)

NUM (<discrete expression>) (1.1)

| PRED (<discrete expression>) (1.2)

| SUCC (<discrete expression>) (1.3)

| ABS (<numeric expression>) (1.4)

| CARD (<powerset expression>) (1.5)

| MAX (<powerset expression>) (1.6)

| MIN (<powerset expression>) (1.7)

| SIZE ({ <location> | <mode argument> }) (1.8)

| UPPER (<upper lower argument>) (1.9)

| LOWER (<upper lower argument>) (1.10)

| LENGTH (<length argument>) (1.11)

| <allocate built-in routine call> (1.12)

| <io value built-in routine call> (1.13)

| <time value built-in routine call> (1.14)

| SIN (<floating point expression>) (1.15)

| COS (<floating point expression>) (1.16)

| TAN (<floating point expression>) (1.17)

| ARCSIN (<floating point expression>) (1.18)

| ARCCOS (<floating point expression>) (1.19)

| ARCTAN (<floating point expression>) (1.20)

| EXP (<floating point expression>) (1.21)

| LN (<floating point expression>) (1.22)

| LOG (<floating point expression>) (1.23)

| SQRT (<floating point expression>) (1.24)

<numeric expression> ::= (2)

<integer expression> (2.1)

| <floating point expression> (2.2)

<mode argument> ::= (3)

<mode name> (3.1)

| <array mode name> (<expression>) (3.2)

| <string mode name> (<integer expression>) (3.3)

| <variant structure mode name> (<expression list>) (3.4)

<upper lower argument> ::= (3)

<array location> (4.1)

| <array expression> (4.2)

| <array mode name> (4.3)

| <string location> (4.4)

| <string expression> (4.5)

| <string mode name> (4.6)

| <discrete location> (4.7)

| <discrete expression> (4.8)

| <discrete mode name> (4.9)

| <floating point location> (4.10)

| <floating point expression> (4.11)

| <floating point mode name> (4.12)

| <access location> (4.13)

| <access mode name> (4.14)

| <text location> (4.15)

| <text mode name> (4.16)

<length argument> ::= (5)

<string location> (5.1)

| <string expression> (5.2)

| <string mode name> (5.3)

| <event location> (5.4)

| <event mode name> (5.5)

| *<<u>buffer</u> location>* *(5.6)*
| *<<u>buffer mode</u> name>* *(5.7)*
| *<<u>text</u> location>* *(5.8)*
| *<<u>text mode</u> name>* *(5.9)*

NOTE – If the upper lower argument is an <u>array</u> location, a <u>string</u> location, a <u>discrete</u> location or a <u>floating point</u> location, the syntactic ambiguity is resolved by interpreting upper lower argument as a location rather than an expression or primitive value. If the length argument is a <u>string</u> location, the syntactic ambiguity is resolved by interpreting length argument as a location rather than an expression.

semantics: A *CHILL value built-in routine call* is a *built-in routine call* that delivers a value.

NUM delivers an integer value with the same internal representation as the value delivered by its argument.

PRED and *SUCC* deliver respectively the next lower and higher discrete value of their argument.

ABS is defined on numeric values, i.e. integer values and floating point values, delivering the corresponding absolute value.

CARD, *MAX* and *MIN* are defined on powerset values. *CARD* delivers the number of element values in its argument.

MAX and *MIN* deliver respectively the greatest and smallest element value in their argument.

SIZE is defined on **referable** locations and (possibly dynamic) modes. In the first case, it delivers the number of addressable memory units occupied by that location; in the second case, the number of addressable memory units that a **referable** location of that mode will occupy. The mode is static if the *mode argument* is a *<u>mode</u> name*, otherwise it is a dynamically parameterised version of it, with parameters as specified in the *mode argument*. In the first case, the *location* will not be evaluated at run time.

UPPER and *LOWER* are defined on (possibly dynamic):

- array, string, discrete, floating point, access and text locations, delivering the **upper bound** and **lower bound** of the mode of the location;
- array and string expressions, delivering the **upper bound** and **lower bound** of the mode of the value’s class;
- **strong** discrete and floating point expressions, delivering the **upper bound** and **lower bound** of the mode of the value’s class;
- array, string, discrete, floating point, access and text **mode** names, delivering the **upper bound** and **lower bound** of the mode.

LENGTH is defined on (possibly dynamic):

- string and text locations and string expressions delivering the actual value of them;
- event locations delivering the **event length** of the mode of the locations;
- buffer locations delivering the **buffer length** of the mode of the locations;
- string **mode** names delivering the **string length** of the mode;
- text **mode** names delivering the **text length** of the mode;
- buffer **mode** names delivering the **buffer length** of the mode;
- event **mode** names delivering the **event length** of the mode.

SIN delivers the sine of its argument (interpreted in radians).

COS delivers the cosine of its argument (interpreted in radians).

TAN delivers the tangent of its argument (interpreted in radians).

ARCSIN delivers the $\sin^{-1}$ function of its argument in the range $-\pi/2 : \pi/2$.

ARCCOS delivers the $\cos^{-1}$ function of its argument in the range $0 : \pi$.

ARCTAN delivers the $\tan^{-1}$ function of its argument in the range $-\pi/2 : \pi/2$.

EXP delivers the e^{x} function, where *x* is its argument.

LN delivers the natural logarithm of its argument.

LOG delivers the base 10 logarithm of its argument.

SQRT delivers the square root of its argument.

The same rules for the evaluation of the result of *built-in routine call* with **constant** arguments as that of **constant** *expression* apply (see 5.3.1).

static properties: The class of a *NUM* built-in routine call is the *&INT*-derived class. The built-in routine call is **constant** (**literal**) if, and only if, the argument is **constant** (**literal**).

The class of a *PRED* or *SUCC* built-in routine call is the **resulting class** of the argument. The built-in routine call is **constant** (**literal**) if, and only if, the argument is **constant** (**literal**).

The class of an *ABS* built-in routine call is the **resulting class** of the argument. The built-in routine call is **constant** (**literal**) if, and only if, the argument is **constant** (**literal**).

The class of a *CARD* built-in routine call is the *&INT*-derived class. The built-in routine call is **constant** if, and only if, the argument is **constant**.

The class of a *MAX* or *MIN* built-in routine call is the M-value class, where M is the **member** mode of the mode of the *powerset expression*. The built-in routine call is **constant** if, and only if, the argument is **constant**.

The class of a *SIZE* built-in routine call is the *&INT*-derived class. The built-in routine call is **constant** if the mode of the argument is static.

The class of an *UPPER* and *LOWER* built-in routine call is:

- the M-value class if *upper lower argument* is an *array location*, *array expression* or *array mode name*, where M is the **index** mode of *array location*, *array expression* or *array mode name*, respectively;
- the *&INT*-derived class if *upper lower argument* is a *string location*, *string expression* or *string mode name*;
- the M-value class if *upper lower argument* is a *discrete location*, *discrete expression* or *discrete mode name*, where M is the mode of *discrete location*, or *discrete expression*, or *discrete mode name*, respectively;
- the M-value class if *upper lower argument* is a *floating point location*, *floating point expression*, or *floating point mode name*, where M is the mode of the *floating point location*, *floating point expression*, or *floating point mode name*, respectively;
- the M-value class if *upper lower argument* is an *access location* or *access mode name*, where M is the **index** mode of the mode of the *access location* or *access mode name*, respectively;
- the M-value class if *upper lower argument* is a *text location* or *text mode name*, where M is the **index** mode of the mode of the *text location* or *text mode name*, respectively.

An *UPPER* or *LOWER* built-in routine call is **literal** if the *upper lower argument* is an *array mode name*, a *string mode name*, a *discrete mode name*, a *floating point mode name*, an *access mode name*, or a *text mode name*, if the mode of the *array location* or *string location* is static, if the *array expression* or *string expression* has a static class, or if the *upper lower argument* is a *discrete location*, a *discrete expression*, a *floating point location*, a *floating point expression*, an *access location*, or a *text location*.

The class of a *LENGTH* built-in routine call is the *&INT*-derived class. The built-in routine call is **literal** if the *length argument* is a *string location* with a static mode, a *string expression* with a static class, an *event location*, or a *buffer location*, or if it is a *string mode name*, an *event mode name*, a *buffer mode name*, or a *text mode name*.

The class of a *TAN, EXP, LN, LOG* or *SQRT* built-in routine call is the **resulting class** of its argument.

The class of *SIN*, *COS*, *ARCSIN*, *ARCCOS*, *ARCTAN* is the 1. N-derived class, 2. N-value class if the class of the argument is 1. an N-derived class, 2. an N-value class, where N is a mode constructed as follows:

- for *SIN*: &**RANGE** (-1.0 : 1.0, *S*);
- for *COS*: &**RANGE** (-1.0 : 1.0, *S*);
- for *ARCSIN*: &**RANGE** (-π/2 : π/2, *S*);
- for *ARCCOS*: &**RANGE** (0 : π, *S*);
- for *ARCTAN*: &**RANGE** (-π/2 : π/2, *S*);

where S is the **precision** of N, and the **novelty** is that of N.

A *SIN*, *COS*, *TAN*, *ARCSIN*, *ARCCOS*, *ARCTAN*, *EXP*, *LN*, *LOG* or *SQRT* built-in routine call is **constant** (**literal**) if, and only if, the argument is **constant** (**literal**).

static conditions: If the argument of a *PRED* or *SUCC* built-in routine call is **constant**, it must not deliver, respectively, the smallest or greatest discrete value defined by the **root** mode of the class of the argument. The **root** mode of the *discrete expression* argument of *PRED* and *SUCC* must not be a **numbered** set mode.

If the argument of a *MAX* or *MIN* built-in routine call is **constant**, it must not deliver the empty powerset value.

The *location* argument of *SIZE* must be **referable**.

The *discrete expression* and *floating point expression* as arguments of *UPPER* and *LOWER* must be **strong**.

If the *upper lower argument* is an *access mode name* or an *access location*, the corresponding access mode must have an **index** mode.

If the *upper lower argument* is a *text mode name* or a *text location*, the corresponding text mode must have an **index** mode.

The following compatibility requirements hold for a *mode argument* which is not a single *mode name*:

- The class of the *expression* must be **compatible** with the **index** mode of the *array mode name*.
- The *variant structure mode name* must be **parameterisable** and there must be as many expressions in the *expression list* as there are classes in its list of classes and the class of each expression must be **compatible** with the corresponding class in the list of classes.

dynamic conditions: *PRED* and *SUCC* that are not **constant** cause the *OVERFLOW* exception if they are applied to the smallest or greatest discrete value defined by the **root** mode of the class of the argument.

NUM and *CARD* that are not **constant** cause the *OVERFLOW* exception if the resulting value is outside the set of values defined by *&INT*.

MAX and *MIN* cause the *EMPTY* exception if they are applied to empty powerset values.

ABS that is not **constant** causes the *OVERFLOW* exception if the resulting value is outside the bounds defined by the **root** mode of the class of the argument.

The *RANGEFAIL* exception occurs if in the *mode argument*:

- the *expression* delivers a value which does not belong to the set of values defined by the **index** mode of the *array mode name*;
- the *integer expression* delivers a negative value or a value which is greater than the **string length** of the *string mode name*;
- any expression in the *expression list* for which the corresponding class in the list of classes of the *variant structure mode name* is an M-value class (i.e. is **strong**) delivers a value which is outside the set of values defined by M.

ARCSIN and *ARCCOS* that are not **constant** cause the *OVERFLOW* exception if the argument does not lie in the range *–1.0 : 1.0*.

LN and *LOG* that are not **constant** cause the *OVERFLOW* exception if the argument is not greater than zero.

SQRT that is not **constant** causes the *OVERFLOW* exception if the argument is not greater than or equal to zero.

SIN, *COS*, *TAN*, *ARCSIN*, *ARCTAN*, *LN* and *LOG* that are not **constant** cause the *OVERFLOW* exception if the resulting value is greater than the **upper bound** or less than the **lower bound** of the **root** mode of the class of the argument. In the case of an exact mathematical resulting value that is greater than the **negative upper limit** and less than the **positive lower limit** of the **root** mode of the argument, and is different from zero, an *UNDERFLOW* exception occurs.

ARCCOS, *EXP* and *SQRT* that are not **constant** cause the *OVERFLOW* exception if the resulting value is greater than the **upper bound** or less than the **lower bound** of the **root** mode of the class of the argument. In the case of an exact mathematical resulting value that is greater than zero and less than the **positive lower limit** of the **root** mode of the argument, an *UNDERFLOW* exception occurs.

examples:

9.12	*MIN (sieve)*	*(1.7)*
11.47	*PRED (col_1)*	*(1.2)*
11.47	*SUCC (col_1)*	*(1.3)*

6.20.4 Dynamic storage handling built-in routines

syntax:

<*allocate built-in routine call*> *::=* *(1)*
GETSTACK (<*mode argument*> [, <*value*> |
([<*<u>constructor</u> actual parameter list*>])]) *(1.1)*
| *ALLOCATE* (<*mode argument*> [, <*value*> |
([<*<u>constructor</u> actual parameter list*>])]) *(1.2)*

<*terminate built-in routine call*> *::=* *(2)*
TERMINATE (<*<u>reference</u> primitive value*>) *(2.1)*

semantics: *GETSTACK* and *ALLOCATE* create a location of the specified mode and deliver a reference value for the created location. *GETSTACK* creates this location on the stack (see 10.9). A location whose mode is that of the *mode argument* is created and a value referring to it is delivered. The created location is initialised with the value of *value*, if present; otherwise with the **undefined** value (see 4.1.2) if the mode argument is not a *moreta mode*.

If the *mode argument* is a *moreta mode*, first all initialisations in the components are performed in textual order. If a (possibly empty) parameter list is specified, the corresponding **constructor** of the *mode argument* is applied to the newly created location. If the *mode argument* is a *task mode*, the task belonging to the newly created location is started.

TERMINATE ends the lifetime of the location referred to by the value delivered by *<u>reference</u> primitive value*. An implementation might as a consequence, release the storage occupied by this location, and if the *<u>reference</u> primitive value* is a location which is not **read-only**, assign the **undefined** value to the location.

If the *<u>reference</u> primitive value* refers to a **region** or a **task** location **L**, the following steps are performed sequentially:

a) **L** is closed. If a location is closed, no more external calls of the **public** component procedures in **L** are accepted.

b) The thread executing the *TERMINATE* waits until **L** is empty.

c) If the mode of **L** contains a **destructor**, that **destructor** is applied to **L**.

static properties: The class of a *GETSTACK* or *ALLOCATE* built-in routine call is the M-reference class, where M is the mode of *mode argument*. M is either the *mode name* or a **parameterised** mode constructed as:

&<*array mode name*> (<*expression*>); or

&<*string mode name*> (<*integer expression*>); or

&<*variant structure mode name*> (<*expression list*>),

respectively.

A *GETSTACK* or *ALLOCATE* built-in routine call is **intra-regional** if it is surrounded by a region, otherwise it is **extra-regional**.

static conditions: The class of the *value*, if present, in the *GETSTACK* and *ALLOCATE* built-in routine call must be **compatible** with the mode of *mode argument*; this check is dynamic in case the mode of *mode argument* is a dynamic mode.

If the mode of *mode argument* has the **read-only property**, the second argument must be present.

The *value*, if present, in the *GETSTACK* and *ALLOCATE* built-in routine call, must be **regionally safe** for the created location.

dynamic properties: A reference value is an **allocated** reference value if, and only if, it is returned by an *ALLOCATE* built-in routine call.

dynamic conditions: *GETSTACK* causes the *SPACEFAIL* exception if storage requirements cannot be satisfied.

ALLOCATE causes the *ALLOCATEFAIL* exception if storage requirements cannot be satisfied.

For *GETSTACK* and *ALLOCATE* the assignment conditions of the value delivered by *value* with respect to the mode of *mode argument* apply.

TERMINATE causes the *EMPTY* exception if the *reference primitive value* delivers the value *NULL*.

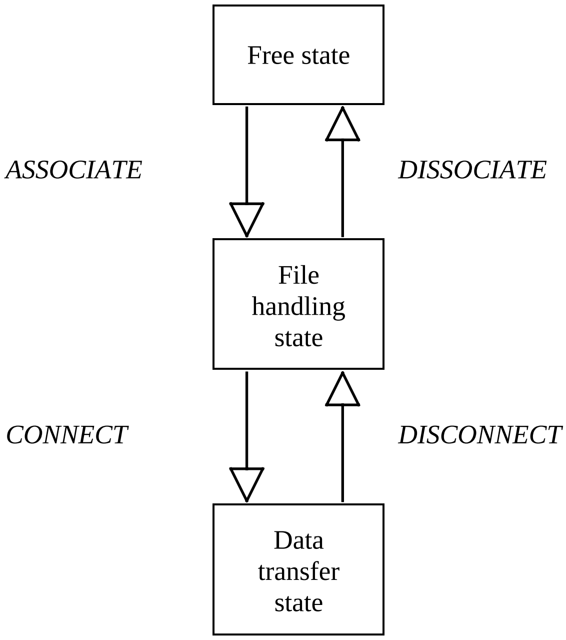
The *reference primitive value* must deliver an **allocated** reference value. The lifetime of the referenced location must not have ended.

7 Input and Output

7.1 I/O reference model

A model is used for the description of the input/output facilities in an implementation independent way; it distinguishes three states for a given association location: a free state, a file handling state and a data transfer state.

The diagram shows the three states and the possible transitions between the states.



The association location contains no value. No relation to an outside world object.

The association location contains an association. Operations like create and delete a file, or change its properties.

An access location is connected to the association location. Transfer data to/from a file: read and write operations.

The model assumes that objects, in implementations often referred to as datasets, files or devices, exist in the outside world, i.e. the external environment of a CHILL program. Such an outside world object is called a file in the model. A file can be a physical device, a communication line or just a file in a file management system; in general, a file is an object that can produce and/or consume data.

Manipulating a file in CHILL requires an association; an association is created by the associate operation and it identifies a file. An association has attributes; these attributes describe the properties of a file that is or could be attached to the association.

In the free state, there is no interaction or relation between the CHILL program and outside world objects. The associate operation changes the state of the model from the free state into the file handling state. This operation takes as one argument an association location and an implementation defined denotation for an outside world object for which an association must be created; additional arguments may be used to indicate the kind of association for the object and the initial values for the attributes of the association. A particular association also implies an (implementation dependent) set of operations that may be applied on the file that is attached to that association.

In the file handling state, it is possible to manipulate a file and its properties via an association, provided that the association enables the particular operation; for operations that change the properties of a file, an exclusive association for the file will be necessary in general.

The model assumes associations in general are exclusive, i.e. only one association exists at the same time for a given outside world object. However, implementations may allow the creation of more associations for the same object, provided that the object can be shared among different users (programs) and/or among different associations within the same program. All operations in the file handling state take an association as an argument.

The dissociate operation is used to end an association for an outside world object; this operation causes transition from the file handling state back to the free state.

Transferring data to or from a file is possible only in the data transfer state; transfer operations require an access location to be connected to an association for that file. The connect operation connects an access location to an association and changes the state of the model into the data transfer state. The operation takes an association location and an access location as arguments; the association location contains an association for the file to, or from, which data can be transferred via the access location. Additional arguments of the connect operation denote for which type of transfer operations the access location must be connected, and to which record the file must be positioned. At most one access location can be connected to an association location at any one time.

The disconnect operation takes an access location as argument and disconnects it from the association it is connected to; it changes the state of the model back to the file handling state.

In the data transfer state, an access location must be used as an argument of a transfer operation; there are two transfer operations provided, namely, a read operation to transfer data from a file to the program and a write operation to transfer data from the program to a file. The transfer operations use the record mode of the access location to transform CHILL values into records of the file, and vice versa.

A file is viewed in the model as an array of values; each element of this array relates to a record of the file. The element mode of this array is determined by the connect operation to be the record mode of the access location being connected. An index value is assigned to each record of the file; this value uniquely identifies each record of the file. In the description of the connect and transfer operations, three special index values will be used, namely, a **base** index, a **current** index and a **transfer** index. The **base** index is set by the connect operation and remains unchanged until a subsequent connect operation; it is used to calculate the **transfer** index in transfer operations and the **current** index in a connect operation. The **transfer** index denotes the position in the file where a transfer will take place; the **current** index denotes the record to which the file currently is positioned.

7.2 Association values

7.2.1 General

An association value reflects the properties of a file that is or could be attached to it. A particular association value also implies an (implementation dependent) set of operations on the file that is possibly attached to it.

Association values have no denotation but are contained in locations of association mode; there exists no expression denoting a value of association mode. Association values can only be manipulated by built-in routines that take an association location as parameter.

7.2.2 Attributes of association values

An association value has attributes; the attributes describe the properties of the association and the file that may or could be attached to it.

The following attributes are language defined:

- **existing**: indicating that a (possibly empty) file is attached to the association;
- **readable**: indicating that read operations are possible for the file when it is attached to the association;
- **writeable**: indicating that write operations are possible for the file when it is attached to the association;
- **indexable**: indicating that the file, when it is attached to the association, allows for random access to its records;
- **sequencible**: indicating that the file, when it is attached to the association, allows for sequential access to its records;
- **variable**: indicating that the **size** of the records of the file, when it is attached to the association, may vary within the file.

These attributes have a boolean value; the attributes are initialised when the association is created and may be updated as a consequence of particular operations on the association. This list comprises the language defined attributes only; implementations may add attributes according to their own needs.

7.3 Access values

7.3.1 General

Access values are contained in locations of access mode. An access location is necessary to transfer data from or to a file in the outside world.

Access values have no denotation but are contained in locations of access mode; there exists no expression denoting a value of access mode. Access values can only be manipulated by built-in routines that take an access location as parameter.

7.3.2 Attributes of access values

Access values have attributes that describe their dynamic properties, the semantics of transfer operations, and the conditions under which exceptions can occur.

CHILL defines the following attributes:

- **usage**: indicating for which transfer operation(s) the access location is connected to an association; the attribute is set by the connect operation;
- **outoffile**: indicating whether or not the **transfer** index calculated by the last read operation was in the file; the attribute is initialised to *FALSE* by the connect operation and is set by every read operation.

7.4 Built-in routines for input output

7.4.1 General

Language defined built-in routines are defined for operations on association locations and access locations, and for inspecting and changing the attributes of their values.

The built-in routines will be described in the following subclauses.

syntax:

<io value built-in routine call> ::=		*(1)*
	<association attr built-in routine call>	*(1.1)*
	| *<isassociated built-in routine call>*	*(1.2)*
	| *<access attr built-in routine call>*	*(1.3)*
	| *<readrecord built-in routine call>*	*(1.4)*
	| *<gettext built-in routine call>*	*(1.5)*
<io simple built-in routine call> ::=		*(2)*
	<dissociate built-in routine call>	*(2.1)*
	| *<modification built-in routine call>*	*(2.2)*
	| *<connect built-in routine call>*	*(2.3)*
	| *<disconnect built-in routine call>*	*(2.4)*
	| *<writerecord built-in routine call>*	*(2.5)*
	| *<text built-in routine call>*	*(2.6)*
	| *<settext built-in routine call>*	*(2.7)*
<io location built-in routine call> ::=		*(3)*
	<associate built-in routine call>	*(3.1)*

static conditions: A *built-in routine parameter* in an io built-in routine that is an <u>*association*</u> *location*, an <u>*access*</u> *location* or a <u>*text*</u> *location* must be **referable**.

7.4.2 Associating an outside world object

syntax:

<associate built-in routine call> ::=		*(1)*
	ASSOCIATE (*<<u>association</u> location>* [, *<associate parameter list>*])	*(1.1)*
<isassociated built-in routine call> ::=		*(2)*
	ISASSOCIATED (*<<u>association</u> location>*)	*(2.1)*
<associate parameter list> ::=		*(3)*
	<associate parameter> { , *<associate parameter>* }*	*(3.1)*
<associate parameter> ::=		*(4)*
	<location>	*(4.1)*
	| *<value>*	*(4.2)*

semantics: *ASSOCIATE* creates an association to an outside world object. It initialises the <u>*association*</u> *location* with the created association. It initialises the attributes of the created association. The association location is also returned as a result of the call. The particular association that is created is determined by the locations and/or values occurring in the *associate parameter list*; the modes (classes) and the semantics of these locations (values) are implementation defined.

ISASSOCIATED returns *TRUE* if <u>*association*</u> *location* contains an association and *FALSE* otherwise.

static properties: The class of an *ISASSOCIATED* built-in routine call is the *BOOL*-derived class. The mode of an *ASSOCIATE* built-in routine call is the mode of the <u>*association*</u> *location*.

The **regionality** of an *ASSOCIATE* built-in routine call is that of the <u>*association*</u> *location*.

static conditions: The mode and the class of each *associate parameter* is implementation defined.

dynamic conditions: *ASSOCIATE* causes the *ASSOCIATEFAIL* exception if the *association location* already contains an association or if the association cannot be created due to implementation defined reasons.

examples:

20.21 *ASSOCIATE (file_association,"DSK:RECORDS.DAT");* *(1.1)*

7.4.3 Dissociating an outside world object

syntax:

<dissociate built-in routine call> ::= *(1)*
DISSOCIATE (*<association location>*) *(1.1)*

semantics: *DISSOCIATE* terminates an association to an outside world object. An access location that is still connected to the association contained in an association location is disconnected before the association is terminated.

dynamic conditions: *DISSOCIATE* causes the *NOTASSOCIATED* exception if *association location* does not contain an association.

examples:

22.38 *DISSOCIATE (association);* *(1.1)*

7.4.4 Accessing association attributes

syntax:

<association attr built-in routine call> ::= *(1)*
EXISTING (*<association location>*) *(1.1)*
| *READABLE* (*<association location>*) *(1.2)*
| *WRITEABLE* (*<association location>*) *(1.3)*
| *INDEXABLE* (*<association location>*) *(1.4)*
| *SEQUENCIBLE* (*<association location>*) *(1.5)*
| *VARIABLE* (*<association location>*) *(1.6)*

semantics: *EXISTING*, *READABLE*, *WRITEABLE*, *INDEXABLE*, *SEQUENCIBLE* and *VARIABLE* return respectively the value of the **existing**-, **readable**-, **writeable**-, **indexable**-, **sequencible**- and **variable**-attribute of the association contained in *association location*.

static properties: The class of an *association attr built-in routine call* is the *BOOL*-derived class.

dynamic conditions: The *association attr built-in routine call* causes the *NOTASSOCIATED* exception if *association location* does not contain an association.

7.4.5 Modifying association attributes

syntax:

<modification built-in routine call> ::= *(1)*
CREATE (*<association location>*) *(1.1)*
| *DELETE* (*<association location>*) *(1.2)*
| *MODIFY* (*<association location>* [, *<modify parameter list>*]) *(1.3)*

<modify parameter list> ::= *(2)*
<modify parameter> { , *<modify parameter>* }* *(2.1)*

<modify parameter> ::= *(3)*
<value> *(3.1)*
| *<location>* *(3.2)*

semantics: *CREATE* creates an empty file and attaches it to the association denoted by the *association location*. The **existing**-attribute of the indicated association is set to *TRUE* if the operation succeeds.

DELETE detaches a file from the association denoted by *association location* and deletes the file. The **existing**-attribute of the indicated association is set to *FALSE* if the operation succeeds.

MODIFY provides the means of changing properties of an outside world object for which an association exists and that is denoted by *association location*; the locations and/or values that occur in *modify parameter list* describe how the properties must be modified. The modes (classes) and the semantics of these locations (values) are implementation defined.

dynamic conditions: *CREATE*, *DELETE* and *MODIFY* cause the *NOTASSOCIATED* exception if the *association location* does not contain an association.

CREATE causes the *CREATEFAIL* exception if one of the following conditions occurs:

- the **existing**-attribute of the association is *TRUE*;
- the creation of the file fails (implementation defined).

DELETE causes the *DELETEFAIL* exception if one of the following conditions occurs:

- the **existing**-attribute of the association is *FALSE*;
- the deletion of the file fails (implementation defined).

MODIFY causes the *MODIFYFAIL* exception if the properties, defined by *modify parameter list* cannot or may not be modified; the conditions under which this exception can occur are implementation defined.

examples:

21.39	*CREATE (outassoc);*	*(1.1)*
21.69	*DELETE (curassoc);*	*(1.2)*

7.4.6 Connecting an access location

syntax:

```
<connect built-in routine call> ::=                                              (1)
        CONNECT ( <transfer location> , <association location> ,
        <usage expression> [ , <where expression> [ , <index expression> ] ] )   (1.1)

<transfer location> ::=                                                          (2)
        <access location>                                                        (2.1)
      | <text location>                                                          (2.2)

<usage expression> ::=                                                           (3)
        <expression>                                                             (3.1)

<where expression> ::=                                                           (4)
        <expression>                                                             (4.1)

<index expression> ::=                                                           (5)
        <expression>                                                             (5.1)
```

predefined names: To control the connect operation, performed by the built-in routine *CONNECT*, two **synmode** names are predefined in the language, namely, *USAGE* and *WHERE*; their **defining** modes are **SET** (*READONLY*, *WRITEONLY*, *READWRITE*) and **SET** (*FIRST*, *SAME*, *LAST*), respectively.

Values of the mode *USAGE* indicate for which type of transfer operations the access location must be connected to an association, while values of the mode *WHERE* indicate how the file that is attached to an association must be positioned by the connect operation.

semantics: *CONNECT* connects the access location denoted by *transfer location* to the association that is contained in *association location*; there must be a file attached to the denoted association; i.e. the association's **existing**-attribute must be *TRUE*.

The access location denoted by *transfer location* is the location itself if it is an *access location*; otherwise the **access** sub-location of the *text location*.

The value that is delivered by *usage expression* indicates for which type of transfer operations the access location must be connected to the file. If the expression delivers *READONLY*, the connection is prepared for read operations only; if it delivers *WRITEONLY*, the connection is set up for write operations only; if it delivers *READWRITE*, the connection is prepared for both read and write operations.

The **indexable**-attribute of the denoted association must be *TRUE* if the access location has an **index** mode, while the **sequencible**-attribute must be *TRUE* if the location has no **index** mode.

CONNECT (re)positions the file that is attached to the denoted association; i.e. it establishes a (new) **base** index and **current** index in the file. The (new) **base** index depends upon the value that is delivered by *where expression*:

- if *where expression* delivers *FIRST* or is not specified, the **base** index is set to 0; i.e. the file is positioned before the first record;

- if *where expression* delivers *SAME*, the **base** index is set to the **current** index in the file; i.e. the file position is not changed;
- if *where expression* delivers *LAST*, the **base** index is set to N, where N denotes the number of records in the file; i.e. the file is positioned after the last record.

After a **base** index is set, a **current** index will be established by *CONNECT*. This **current** index depends upon the optional specification of an *index expression*:

- if no *index expression* is specified, the **current** index is set to the (new) **base** index;
- if an *index expression* is specified, the **current** index is set to:

  base index + *NUM* (*v*) – *NUM* (*l*)

  where *l* denotes the **lower bound** of the access location's **index** mode and *v* denotes the value that is delivered by *index expression*.

If the access location is being connected for sequential write operations (i.e. the access location has no **index** mode and the *usage expression* delivers *WRITEONLY*), then those records in the file that have an index greater than the (new) **current** index will be removed from the file; i.e. the file may be truncated or emptied by *CONNECT*.

An access location that has no index mode cannot be connected to an association for read and write operations at the same time.

Any access location to which the denoted association may be connected will be disconnected implicitly before the association is connected to the location that is denoted by *transfer location*.

CONNECT initialises the **outoffile**-attribute of the access location to *FALSE* and sets the **usage**-attribute according to the value that is delivered by *usage expression*.

static properties: The mode attached to a *transfer location* is the mode of the <u>access</u> *location* or the **access** mode of the <u>text</u> *location*, respectively.

static conditions: The mode of *transfer location* must have an **index** mode if an *index expression* is specified; the class of the value delivered by *index expression* must be **compatible** with that **index** mode. The *transfer location* must have the same **regionality** as the <u>association</u> *location*.

The class of the value delivered by *usage expression* must be **compatible** with the *USAGE*-derived class.

The class of the value delivered by *where expression* must be **compatible** with the *WHERE*-derived class.

dynamic conditions: *CONNECT* causes the *NOTASSOCIATED* exception if <u>association</u> *location* does not contain an association.

CONNECT causes the *CONNECTFAIL* exception if one of the following conditions occurs:

- the association's **existing**-attribute is *FALSE*;
- the association's **readable**-attribute is *FALSE* and *usage expression* delivers *READONLY* or *READWRITE*;
- the association's **writeable**-attribute is *FALSE* and *usage expression* delivers *WRITEONLY* or *READWRITE*;
- the association's **indexable**-attribute is *FALSE* and access location has an **index** mode;
- the association's **sequencible**-attribute is *FALSE* and access location has no **index** mode;
- *where expression* delivers *SAME*, while the association contained in <u>association</u> *location* is not connected to an access location;
- the association's **variable**-attribute is *FALSE* and the access location has a **dynamic record** mode, while *usage expression* delivers *WRITEONLY* or *READWRITE*;
- the association's **variable**-attribute is *TRUE* and the access location has a **static record** mode, while *usage expression* delivers *READONLY* or *READWRITE*;
- the access location has no **index** mode, while *usage expression* delivers *READWRITE*;
- the association contained in <u>association</u> *location* cannot be connected to the access location, due to implementation defined conditions.

CONNECT causes the *RANGEFAIL* exception if the **index** mode of access location is a discrete range mode and the *index expression* delivers a value which lies outside the bounds of that discrete range mode.

The *EMPTY* exception occurs if the **access reference** of the *text location* delivers the value *NULL*.

examples:

20.22 *CONNECT (record_file, file_association, READWRITE);* *(1.1)*
20.22 *READWRITE* *(3.1)*

7.4.7 Disconnecting an access location

syntax:

<disconnect built-in routine call> ::= *(1)*
DISCONNECT (*<transfer location>*) *(1.1)*

semantics: *DISCONNECT* disconnects the access location denoted by *transfer location* from the association it is connected to.

dynamic conditions: *DISCONNECT* causes the *NOTCONNECTED* exception if the access location denoted by *transfer location* is not connected to an association.

7.4.8 Accessing attributes of access locations

syntax:

<access attr built-in routine call> ::= *(1)*
GETASSOCIATION (<transfer location>) *(1.1)*
| *GETUSAGE (<transfer location>)* *(1.2)*
| *OUTOFFILE (<transfer location>)* *(1.3)*

semantics: *GETASSOCIATION* returns a reference value to the association location that the access location denoted by *transfer location* is connected to; it returns *NULL* if the access location is not connected to an association.

GETUSAGE returns the value of the **usage**-attribute, i.e. *READONLY* (*WRITEONLY*) if the access location is connected only for read (write) operations, or *READWRITE* if the access location is connected for both read and write operations.

OUTOFFILE returns the value of the **outoffile**-attribute of access location, i.e. *TRUE* if the last read operation calculated a **transfer** index that was not in the file, *FALSE* otherwise.

static properties: The class of a *GETASSOCIATION* built-in routine call is the *ASSOCIATION*-reference class. The **regionality** of an *GETASSOCIATION* built-in routine call is that of the *transfer location*.

The class of an *OUTOFFILE* built-in routine call is the *BOOL*-derived class.

The class of a *GETUSAGE* built-in routine call is the *USAGE*-derived class.

dynamic conditions: *GETUSAGE* and *OUTOFFILE* cause the *NOTCONNECTED* exception if the access location is not connected to an association.

examples:

21.47 *OUTOFFILE (infiles (FALSE))* *(1.3)*

7.4.9 Data transfer operations

syntax:

<readrecord built-in routine call> ::= *(1)*
READRECORD (*<access location>* [, *<index expression>*]
[, *<store location>*]) *(1.1)*

<writerecord built-in routine call> ::= *(2)*
WRITERECORD (*<access location>* [, *<index expression>*] ,
<write expression>) *(2.1)*

<store location> ::= *(3)*
<static mode location> *(3.1)*

<write expression> ::= *(4)*
<expression> *(4.1)*

NOTE – If the *access location* has an **index** mode, the syntactic ambiguity is resolved by interpreting the second argument as an *index expression* rather than a *store location*.

semantics: For the transfer of data to or from a file, the built-in routines *WRITERECORD* and *READRECORD* are defined. The *access location* must have a **record** mode, and it must be connected to an association in order to transfer data to or from the file that is attached to that association. The transfer direction must not be in contradiction with the value of the *access location*'s **usage**-attribute.

Before a transfer takes place, the **transfer** index, i.e. the position in the file of the record to be transferred, is calculated. If the *access location* has no **index** mode, the **transfer** index is the **current** index incremented by 1; if the *access location* has an **index** mode, the **transfer** index is calculated as follows:

transfer index := **base** index + *NUM* (*v*) – *NUM* (*l*) + 1

where *l* is the **lower bound** of the mode of the *access location*'s **index** mode and *v* denotes the value that is delivered by *index expression*. If the transfer of the record with the calculated **transfer** index has been performed successfully, the **current** index becomes the **transfer** index.

The read operation:

READRECORD transfers data from a file in the outside world to the CHILL program.

If the calculated **transfer** index is not in the file, the **outoffile**-attribute is set to *TRUE*; otherwise the file is positioned, the record is read, and the **outoffile**-attribute is set to *FALSE*.

The record that is read must not deliver an **undefined** value; the effect of the read operation is implementation defined if the record being read from the file is not a legal value according to the **record** mode of the *access location*.

If a *store location* is specified, then the value of the record that was read is assigned to this location. If no *store location* is specified, the value will be assigned to an implicitly created location; the lifetime of this location ends when the *access location* is disconnected or reconnected. Whether the referenced location is created only once by the connect operation, or every time a read operation is performed, is not defined.

READRECORD returns in both cases a reference value that refers to the (possibly dynamic mode) location to which the value was assigned.

If the **outoffile**-attribute is set to *TRUE* as a result of the built-in routine call, then the *NULL* value is returned as a result of the call.

The write operation:

WRITERECORD transfers data from the CHILL program to a file in the outside world. The file is positioned to the record with the calculated index and the record is written.

After the record has been written successfully, the number of records is set to the **transfer** index, if the latter is greater than the actual number of records.

The record written by *WRITERECORD* is the value delivered by *write expression*.

static properties: The class of the value that was read by *READRECORD* is the M-value class, where M is the **record** mode of the *access location*, if it has a **static record** mode, or a dynamically parameterised version of it, if the location has a **dynamic record** mode; the parameters of such a dynamically parameterised record mode are:

- the dynamic **string length** of the string value that was read in case of a string mode;
- the dynamic **upper bound** of the array value that was read in case of an array mode;
- the list of (tag) values associated with the mode of the structure value that was read in case of a **variant** structure.

The class of the *READRECORD* built-in routine call is the M-reference class if *store location* is not specified, otherwise it is the S-reference class, where S is the mode of the *store location*.

The **regionality** of a *READRECORD* built-in routine call is that of the *store location* if it is specified, otherwise it is that of the *access location*.

static conditions: The *access location* must have a **record** mode.

An *index expression* may not be specified if *access location* has no **index** mode and must be specified if *access location* has an **index** mode; the class of the value delivered by *index expression* must be **compatible** with that **index** mode.

The *store location* must be **referable**.

The mode of *store location* must not have the **read-only property**.

If *store location* is specified, then the mode of *store location* must be **equivalent** with the **record** mode of the *access location*, if it has a **static record** mode or a **varying** string **record** mode, otherwise a dynamically parameterised version of it; the parameters of such a dynamically parameterised mode are those of the value that has been read.

The class of the value delivered by *write expression* must be **compatible** with the **record** mode of the *access location*, if it has a **static record** mode or a **varying** string **record** mode; otherwise there should exist a dynamically parameterised version of **record** mode that is **compatible** with the class of *write expression*. The assignment conditions of the value of *write expression* with respect to the above mentioned mode apply.

dynamic conditions: The *RANGEFAIL* or *TAGFAIL* exceptions occur if the dynamic part of the above mentioned compatibility check fails.

The *READRECORD* and *WRITERECORD* built-in routine call cause the *NOTCONNECTED* exception if the *access location* is not connected to an association.

The *READRECORD* or *WRITERECORD* built-in routine call cause the *RANGEFAIL* exception if the **index** mode of *access location* is a discrete range mode and the *index expression* delivers a value that lies outside the bounds of that discrete range mode.

The *READRECORD* built-in routine call causes the *READFAIL* exception if one of the following conditions occurs:

- the value of the **usage**-attribute is *WRITEONLY*;
- the value of the **outoffile**-attribute is *TRUE* and the *access location* is connected for sequential read operations;
- the reading of the record with the calculated index fails, due to outside world conditions.

The *WRITERECORD* built-in routine call causes the *WRITEFAIL* exception if one of the following conditions occurs:

- the value of the **usage**-attribute is *READONLY*;
- the writing of the record with the calculated index fails, due to outside world conditions.

If the *RANGEFAIL* exception or the *NOTCONNECTED* exception occur, then it occurs before the value of any attribute is changed and before the file is positioned.

examples:

0.24	*READRECORD (record_file, curindex, record_buffer);*	*(1.1)*
22.25	*READRECORD (fileaccess);*	*(1.1)*
20.32	*WRITERECORD (record_file, curindex, record_buffer);*	*(2.1)*
21.61	*WRITERECORD (outfile, buffers(flag));*	*(2.1)*
20.24	*record_buffer*	*(3.1)*
21.61	*buffers(flag)*	*(4.1)*

7.5 Text input output

7.5.1 General

Text output operations allow the representation of CHILL values in a human-readable form; text input operations perform the opposite transformation.

Text transfer operations are defined on top of the basic CHILL input/output model and operate on files that may be accessed either sequentially or randomly and whose records may have a fixed or variable length.

The model assumes that every record has a (possibly empty) positioning information attached, in implementations often referred to as carriage control or control characters.

Manipulating a text file in CHILL requires an association; transferring data to or from a text file requires a **text** location to be connected to an association for that file.

Text transfer operations can be applied to CHILL values that may become records of some text file, as well as to CHILL locations that are not necessarily related to any i/o activity of the program.

The possibility to recover from a piece of text the same CHILL values that originated it cannot be guaranteed in general, but rather it depends on the specific representation that has been used.

Text values are contained in locations of text mode. A text location is necessary to transfer data in human-readable form.

Text values have no denotation but are contained in locations of text mode; there exists no expression denoting a value of text mode. Text values can only be manipulated by built-in routines that take a text location as parameter.

7.5.2 Attributes of text values

Text values have attributes that describe their dynamic properties. The following attributes are defined:

- **actual index**: indicating the next character position of the **text record** to be read or written. It has a mode which is ***RANGE** (0:L-1)*, where *L* is the **text length** of the value's mode. It is initialised to 0 when a text location is created;
- **text record reference**: indicating a reference value to the **text record** sub-location of the text location. It has a mode which is **REF** *M*, where *M* is the **text record** mode of the value's mode;
- **access reference**: indicating a reference value to the **access** sub-location of the text location. It has a mode which is **REF** *M*, where *M* is the **access** mode of the value's mode.

7.5.3 Text transfer operations

syntax:

```
text built-in routine call> ::=                                      (1)
        READTEXT ( <text io argument list> )                         (1.1)
      | WRITETEXT ( <text io argument list> )                        (1.2)

<text io argument list> ::=                                          (2)
        <text argument> [ , <index expression> ] ,
        <format argument> [ , <io list> ]                            (2.1)

<text argument> ::=                                                  (3)
        <text location>                                              (3.1)
      | <character string location>                                  (3.2)
      | <character string expression>                                (3.3)

<format argument> ::=                                                (4)
        <character string expression>                                (4.1)

<io list> ::=                                                        (5)
        <io list element> { , <io list element> }*                   (5.1)

<io list element> ::=                                                (6)
        <value argument>                                             (6.1)
      | <location argument>                                          (6.2)

<location argument> ::=                                              (7)
        <discrete location>                                          (7.1)
| <floating point location>                                          (7.2)
      | <string location>                                            (7.3)

<value argument> ::=                                                 (8)
        <discrete expression>                                        (8.1)
| <floating point expression>                                        (8.2)
      | <string expression>                                          (8.3)
```

NOTE – If the *io list element* is a location, the syntactic ambiguity is resolved by interpreting the *io list element* as a *location argument* rather than a *value argument*.

semantics: *READTEXT* applies the conversion, editing and i/o control functions contained in the *format argument* to the **text record** denoted by the *text argument*; this (possibly) produces a list of values that are assigned to the elements of the *io list* in the sequence in which they are specified. *WRITETEXT* performs the opposite operation. No implicit i/o operations are performed.

If the *text argument* is a <u>character string</u> *location* or a <u>character string</u> *expression*, then the conversion and editing functions are applied without any relation with the external world. In this case the **actual index** denotes a location that is implicitly created at the beginning of the built-in routine call and initialised to 0. The **text record** is the character string denoted by <u>character string</u> *location* or <u>character string</u> *expression* and the **text length** its **string length**.

The elements of the *io list* may be either:

- *value arguments* and *location arguments*; or
- **variable** *clause widths* as described below.

Relationships between a format argument and an io list

The value delivered by a *format argument* must have the form of a *format control string* (see 7.5.4).

During the execution of a text i/o built-in routine call the *format control string* (see 7.5.4) denoted by the *format argument* and the *io list* are scanned from left to right. Each occurrence of a *format text* and *format specification* is interpreted and the appropriate action is taken as follows:

a) *Format text:*

   In *READTEXT* the **text record** should contain at the **actual index** position a string slice which is equal to the string delivered by *format text*. In *WRITETEXT*, the string delivered by *format text* is transferred to the **text record**. The semantics are the same as if a *format specification* which is *%C* and an *io list element* that delivers the same string value as that delivered by *format text* were encountered.

b) *Format specification:*

   If the *format specification* contains a *repetition factor*, then it is equivalent to a sequence of as many *format element* occurrences as the number denoted by *repetition factor*.

   If the *format specification* is a *format clause*, then it contains a *control code*. If the *control code* is a *conversion clause*, then an *io list element* is taken from the *io list* and the conversion function selected by the *conversion code*, *conversion qualifiers* and *clause width* is applied to it (see 7.5.5). If the *control code* is an *editing clause* or an *io clause*, then the editing or io function selected by the *editing code* or *io code* and *clause width* is applied to the *text argument* without reference to the *io list* (see 7.5.6 and 7.5.7).

   If the *clause width* is **variable**, then a value is taken from the list, which denotes the **width** parameter of the conversion or editing control function.

   If the *format specification* is a *parenthesised clause*, then the *format control string* that is contained in it is scanned.

The interpretation of the *format control string* terminates when the end of the string delivered by *format control string* has been reached.

The *io list elements* of the *io list* are scanned in the order that they are specified.

static conditions: If the *text argument* is a <u>string</u> *location*, its mode must be a **varying** string mode.

An *index expression* may not be specified if the *text argument* is not a <u>text</u> *location* or if it is and its **access** mode has no **index** mode and must be specified if the **access** mode has an **index** mode; the class of the value delivered by *index expression* must be **compatible** with that **index** mode.

A *text argument* in a *WRITETEXT* built-in routine call must be a location.

A <u>string</u> *location* in a *text argument* must be **referable**.

dynamic conditions: The *TEXTFAIL* exception occurs if:

- the string value delivered by the *format argument* cannot be derived as a terminal production of the *format control string*; or
- an attempt to assign to the **actual index** a value which is less than 0 or greater than **text length** is made; or
- during the interpretation, the end of the *format control string* has been reached and the *io list* is not completely scanned, or no more elements can be taken from the *io list* and the *format control string* contains more *conversion codes* or **variable** *clause widths*; or

- an *io clause* is encountered and the *text argument* is not a *text location*; or
- a *format text* is encountered in *READTEXT* and the **text record** does not contain at the **actual index** position a string which is equal to the string delivered by *format text*.

Any exception defined for the *READRECORD* and *WRITERECORD* built-in routine call can occur if an i/o control function is executed and any one of the dynamic conditions defined is violated.

examples:

26.18 WRITETEXT (output,"%B%/",10) (1.2)

7.5.4 Format control string

syntax:

format control string> ::= (1)
[<*format text*>] { <*format specification*> [<*format text*>] }* (1.1)

<*format text*> ::= (2)
{ <*non-percent character*> | <*percent*> }* (2.1)

<*percent*> ::= (3)
% % (3.1)

<*format specification*> ::= (4)
% [<*repetition factor*>] <*format element*> (4.1)

<*repetition factor*> ::= (5)
{ <*digit*> }+ (5.1)

<*format element*> ::= (6)
<*format clause*> (6.1)
| <*parenthesised clause*> (6.2)

<*format clause*> ::= (7)
<*control code*> [% .] (7.1)

<*control code*> ::= (8)
<*conversion clause*> (8.1)
| <*editing clause*> (8.2)
| <*io clause*> (8.3)

<*parenthesised clause*> ::= (9)
(<*format control string*> %) (9.1)

NOTE – A *format specification* is terminated by the first character that cannot be part of the *format element*. Spaces and format effectors may not be used within *format elements*. A period (.) may be used to terminate a *format clause*. It belongs to the *format clause* and it has only a delimiting effect. To represent the character percent (%) within a *format text*, it has to be written twice (*%%*).

semantics: A *format control string* specifies the external form of the values being transferred and the layout of data within the records. A *format control string* is composed of *format text* occurrences, which denote fixed parts of the records and of *format specification* occurrences, which denote the external representations of CHILL values, allowing the editing of the **text record** or controlling the actual i/o operations.

If a *format specification* contains a *repetition factor* and a *format clause*, then it is equivalent to as many identical *format specification* occurrences of the *format clause* as the number delivered by *repetition factor*. A *repetition factor* can be 0, in which case the *format specification* is not considered. E.g. *"%3C4"* is equivalent to *"%C4%C4%C4"*.

The decimal notation is assumed for the *digits* in a *repetition factor*.

A *format control string* in a *parenthesised clause* is repeatedly scanned according to the *repetition factor*. If none is specified, *1* is assumed by default.

examples:

26.20 size = %C%/ (1.1)

7.5.5 Conversion

syntax:

conversion clause> ::= (1)
<*conversion code*> { <*conversion qualifier*> }*
[<*clause width*>] (1.1)

<*conversion code*> *::=* (2)
B | O | H | C | F (2.1)

<*conversion qualifier*> *::=* (3)
L | E | P <*character*> (3.1)

<*clause width*> *::=* (4)
{ { <*digit*> }* | V } [<*fractional width*>] [<*exponent width*>] (4.1)

<*fractional width*> *::=* (5)
. { <*digit*> }+ (5.1)

<*exponent width*> *::=* (6)
: { <*digit*> }+ (6.1)

derived syntax: A *conversion clause* in which a *clause width* is not present is derived syntax for a *conversion clause* in which a *clause width* that is 0 is specified.

semantics: A conversion in a *READTEXT* built-in routine call transforms a string which is an external representation into a CHILL value. A conversion in a *WRITETEXT* built-in routine call performs the opposite transformation. The *conversion code* together with the *conversion qualifier* specify the type of the conversion and the details of the requested operation such as justification, overflow handling and padding.

The external representation is a string whose length usually depends on the value being converted. That string may contain the minimum number of characters that are necessary to represent the CHILL value (free format) or may have a given length (fixed format).

In the fixed format a slice of **width** size starting from the **actual index** position is read from or written into the **text record** according to the justification and padding selected by *conversion qualifiers*, as follows:

- In *READTEXT*: All padding characters (to the left or to the right according to the justification), if any, are removed. However, when characters or **fixed** character strings are being read, the maximum number *N* of padding characters that are removed is **width** -*L* , where *L* is 1 or **string length**, respectively. No characters are removed if $N < 0$. The remaining characters are taken as the external representation.

- In *WRITETEXT*: If the length of the external representation is less than or equal to **width**, then the characters are justified to the left or to the right in the slice (according to the justification). The unused string elements, if any, are filled with the padding character. Otherwise the string is truncated (on the left if the justification to the right is selected, otherwise on the right), or **width** “overflow” indicator characters (*) are transferred, if the qualifier *E* is present. The truncation is applied to the external representation, including the minus sign, the period (.) and the *E* (scientific representation), if any.

In the free format the following holds:

- In *READTEXT*: Padding characters, if any, are skipped except when a character or a character string is being read and the *conversion qualifier P* is not specified. Then, the external representation is taken as the longest slice of characters that starts at the **actual index** and is made of all the subsequent characters that may lexically belong to it as defined below.

- In *WRITETEXT*: The string delivered by the conversion is inserted starting from the **actual index** position.

In *WRITETEXT* the string which is the external representation is transferred to the **text record** without regard to its **actual length**. After the transfer, the **actual index** is automatically advanced to the next available character position and the **actual length** is set to the maximum value between the **actual index** and the (old) **actual length**.

A *clause width* is **constant** if it is made of *digits*. The decimal notation is assumed. Otherwise it is **variable**.

If the **width** is zero, then the free format is chosen, otherwise the **width** is the length of the fixed format.

If the **width** is too small to contain the string, the appropriate action is taken depending on the *conversion qualifier*.

In a *READTEXT* the external representation that is applied is the one defined below for the mode of the *location argument*.

In a *WRITETEXT* the external representation that is applied is the one defined below for the mode M of the M-value or M-derived class of the value delivered by the *value argument*.

Conversion codes

Conversion codes are represented as single letters. The following *conversion codes* are defined:

B: Binary representation.

O: Octal representation.

H: Hexadecimal representation.

C: Conversion – Indicates the default external representation of CHILL values, which depends on the mode of the value being converted (see below).

F: Scientific representation, i.e. the representation of floating point values with mantissa and exponent.

The external representation depends on the *conversion code* and the mode of the value being converted.

Conversion qualifiers

Conversion qualifiers are represented as single letters. The following *conversion qualifiers* are defined:

L: Left justification – Right justification is assumed if it is not present. In the free format the qualifier has no effect.

E: Overflow evidence – In *WRITETEXT* the overflow indication is selected; if the qualifier is not present, then truncation is performed. In *READTEXT* or in the free format this qualifier has no effect.

P: Padding – The character that follows the qualifier specifies the padding character. If *P* is not present, then the padding character is assumed to be space by default. In *READTEXT* if the free format is selected, then spaces and HT (Horizontal Tabulation) are considered as the same character for skipping purposes, either when specified after the qualifier or when applied by default.

External representation

The external representation of CHILL values is defined as follows:

a) *Integers*

Integer values are lexically represented as one or more digits in a decimal default base without leading zeroes and with a leading sign if negative. Underline characters, a leading plus sign and leading zeroes are discarded in *READTEXT*. The following *conversion codes* are available: *B*, *O*, *C* and *H*. The *conversion code C* selects the decimal representation. The digits that may belong to the representation are only those that are selected by the conversion code.

b) *Floating point*

Floating point values can be represented in two ways:

- fixed point representation (selected by *C conversion code*);
- scientific representation (selected by *F conversion code*).

In the fixed point representation the floating point value is lexically represented by a sequence of one or more digits (integer part) followed by an optional sequence of one or more digits (fractional part) separated from the integer part by a period (.). A leading minus sign is present if the value is negative.

In the scientific representation the floating point value is represented by mantissa and exponent. The mantissa is lexically represented as a fixed point value with the integer part consisting of only one digit, greater than zero. The exponent is lexically represented by an *E* followed by a possible sign and a sequence of one or more digits. For both representations a leading plus sign and zeros are discarded in *READTEXT*.

If *fractional width* is present, the value delivered by *digits* contained in it indicates the length of the fractional part extended with trailing zeros if necessary, otherwise the fractional part contains the minimum number of digits that are necessary to represent it.

If *exponent width* is present, the value delivered by *digits* contained in it indicates the minimum number of digits to use to represent the exponent, including leading zeros if necessary, otherwise a default value of 3 is assumed.

The following *conversion codes* are available: *C*, *F*.

c) *Booleans*

Boolean values are lexically represented as *simple name string*, that are *TRUE* and *FALSE* [in upper case (e.g. *TRUE*) or lower case (e.g. *true*) depending on the representation chosen by the implementation for the **special** simple name strings]. The following *conversion code* is available: *C*.

d) *Characters*

Character values are lexically represented as strings of length *1*. The following *conversion code* is available: *C*.

e) *Sets*

Set mode values are lexically represented as simple name strings, that are the set literals. The following *conversion code* is available: *C*.

f) *Ranges*

Range values have the same representation as the values of their **root** mode. However, only the representations of those values defined by the discrete range mode or floating point range mode belong to the set of external representations associated to the discrete range mode or floating point range mode.

g) *Character strings*

Character string values are lexically represented as strings of characters of length *L*. In *WRITETEXT L* is the **actual length**. In *READTEXT L* is the **string length** if the string is a **fixed** string, otherwise it is a **varying** string and *L* is the **string length**, unless there are less characters available in the (slice of) **text record** at the **actual index** position, in which case *L* is the number of available characters. The following *conversion code* is available: *C*.

h) *Bit strings*

Bit string values are lexically represented as strings of binary digits. The same rules as for character strings apply to determine the number of digits. The following *conversion code* is available: *C*.

dynamic properties: A *clause width* has a **width**, which is the value delivered by *digits* or by a value from the *io list* if the *clause width* is **variable**, otherwise it is zero if none is specified.

Dynamic conditions: The *TEXTFAIL* exception occurs if:

- in *READTEXT* the **text record** does not contain a string slice starting at the **actual index** that (after the removal or skipping of padding characters, see above) can be interpreted as an external representation of one of the values of the mode of the current *location argument* (including an attempt to read a non-empty external representation from a **text record** when **actual index** = **actual length**); or
- in *WRITETEXT* a string slice that is the external representation of the current *value argument* cannot be transferred to the **text record** starting at the **actual index**; or
- in *READTEXT* a *conversion code* is encountered and the current element in the *io list* is not a location, or the mode of the location has the **read-only property**; or
- the same *conversion qualifier* is specified more than once; or

- a **variable** *clause width* is encountered and the corresponding *io list element* in the *io list* does not have an integer class or it is less than 0;
- a *clause width* has a *fractional width* or an *exponent width* and the corresponding *io list element* in the *io list* does not have a floating point class, or it has an *exponent width* and the *conversion code* is not *F*.

examples:

26.21 *CL6* *(1.1)*

7.5.6 Editing

syntax:

<*editing clause*> *::=* *(1)*
<*editing code*> [<*clause width*>] *(1.1)*

<*editing code*> *::=* *(2)*
X | < | > | T *(2.1)*

derived syntax: An *editing clause* in which a *clause width* is not present is derived syntax for an *editing clause* in which a *clause width* that is *1* is specified if the *editing code* is not *T*, otherwise 0, respectively.

semantics: The following editing functions are defined:

X: space – **width** space characters are inserted or skipped.

>: skip right – The **actual index** is moved rightward for **width** positions.

<: skip left – The **actual index** is moved leftward for **width** positions.

T: tabulation – The **actual index** is moved to the position **width**.

In *WRITETEXT*, if the **actual index** is moved to a position which is greater than the **actual length**, then a string of *N* space characters, where *N* is the difference between the **actual index** and the (old) **actual length** is appended to the **text record**. The **actual length** is set to the maximum value between the **actual index** and the (old) **actual length**.

dynamic conditions: The *TEXTFAIL* exception occurs if:

- the **actual index** is moved to a position which is less than 0 or greater than **text length**; or
- in *READTEXT* the **actual index** is moved to a position which is greater than the **actual length**; or
- in *READTEXT* the *editing code X* is specified and a string of **width** space or HT (Horizontal Tabulation) characters is not present in the **text record** at the **actual index** position.

examples:

26.22 *X* *(1.1)*

7.5.7 I/O control

syntax:

<*io clause*> *::=* *(1)*
<*io code*> *(1.1)*

<*io code*> *::=* *(2)*
/ | – | + | ? | ! | = *(2.1)*

semantics: The i/o control functions (except *%=*) perform an i/o operation. They allow precise control over the transfer of the **text record**. In *READTEXT*, all the functions have the same effect, to read the next record from the file. In *WRITETEXT*, the **text record** and the appropriate representation of the carriage control information are transferred. The initial position of the carriage at the time the *text location* is connected is such that the first character of the first **text record** is printed at the beginning of the first unoccupied line (regardless of any positioning information attached to the **text record**).

The carriage placement is described by means of the following abstract operations on the current column, line and page (x, y, z) considering columns as being numbered from zero starting at the left margin, and lines from zero starting at the top margin.

nl(w): the carriage is moved w lines downward, at the beginning of the line [new position: (0, (y + w) mod p, z + (y + w) / p, where p is the number of lines per page)];

np(w): the carriage is moved w pages downward at the beginning of the line [new position: (0, 0, z + w)].

The following control functions are provided:

/: Next record – The record is printed on the next line (nl(1), print record, nl(0)).

+: Next page – The record is printed on the top of the next page (np(1), print record, nl(0)).

-: Current line – The record is printed on the current line (print record, nl(0)).

?: Prompt – The record is printed on the next line. The carriage is left at the end of the line [nl(1), print record].

!: Emit – No carriage control is performed (print record).

=: End page – Defines the positioning of the next record, if any, to be at the top of the next page (this overrides the positioning performed before the printing of the record). It does not cause any i/o operation.

The I/O transfer is performed as follows:

- In *READTEXT* the semantics are as if a *READRECORD (A, I, R)*, where *A* is the **access** sub-location of the *text location*, *I* is the *index expression* (if any) and *R* denotes the **text record**, were executed. After the I/O transfer **actual index** is set to 0 and **actual length** to the **string length** of the string value that was read.
- In *WRITETEXT* the semantics are as if a *WRITERECORD (A, I, R)*, where *A* is the **access** sub-location of the *text location, I* is the *index expression* (if any) and *R* denotes the **text record**, were executed. The associated positioning information is also transferred. If the **record** mode of the access is not **dynamic**, then the **text record** is filled at the end with space characters and its **actual length** is set to **text length** before the transfer takes place. After the I/O transfer **actual index** and **actual length** are set to 0.

examples:

26.21 / (1.1)

7.5.8 Accessing the attributes of a text location

syntax:

<gettext built-in routine call> ::= (1)
GETTEXTRECORD (<text location>) (1.1)
| GETTEXTINDEX (<text location>) (1.2)
| GETTEXTACCESS (<text location>) (1.3)
| EOLN (<text location>) (1.4)

<settext built-in routine call> ::= (2)
SETTEXTRECORD (<text location> , <character string location>) (2.1)
| SETTEXTINDEX (<text location> , <integer expression>) (2.2)
| SETTEXTACCESS (<text location> , <access location>) (2.3)

semantics: *GETTEXTRECORD* returns the **text record reference** of *text location*.

GETTEXTINDEX returns the **actual index** of *text location*.

GETTEXTACCESS returns the **access reference** of *text location*.

EOLN delivers *TRUE* if no more characters are available in the **text record** (i.e. if the **actual index** equals the **actual length**).

SETTEXTRECORD stores a reference to the location delivered by *character string location* into the **text record reference** of the *text location*.

SETTEXTINDEX has the same semantics as an *editing clause* in *WRITETEXT* in which *editing code* is *T* and *clause width* delivers the same value as *integer expression*, applied to the **text record** denoted by *text location*.

SETTEXTACCESS stores a reference to the location delivered by *access location* into the **access reference** of the *text location*.

static properties: The class of the *GETTEXTRECORD* built-in routine call is the M-reference class, where M is the **text record** mode of the *text location*.

The class of the *GETTEXTINDEX* built-in routine call is the *&INT*-derived class.

The class of the *GETTEXTACCESS* built-in routine call is the M-reference class, where M is the **access** mode of the *text location*.

The class of the *EOLN* built-in routine call is the *BOOL*-derived class.

A *GETTEXTRECORD* or *GETTEXTACCESS* built-in routine call has the same **regionality** as the *text location*.

static conditions: The mode of the *character string location* argument of *SETTEXTRECORD* must be **read-compatible** with the **text record** mode of the *text location*.

The mode of the *access location* argument of *SETTEXTACCESS* must be **read-compatible** with the **access** mode of the *text location*.

The *location* argument in *SETTEXTRECORD* and *SETTEXTACCESS* must have the same **regionality** as the *text location*.

dynamic conditions: The *TEXTFAIL* exception occurs if the *integer expression* argument of *SETTEXTINDEX* delivers a value that is less than 0 or greater than the **text length** of the *text location*.

examples:

26.23 *GETTEXTINDEX (output)* *(1.2)*

8 Exception handling

8.1 General

An exception is either a language defined exception, in which case it has a language defined exception name, a user defined exception, or an implementation defined exception. A language defined exception will be caused by the dynamic violation of a dynamic condition. Any exception can be caused by the execution of a cause action.

When an exception is caused, it may be handled, i.e. an action statement list of an appropriate handler will be executed.

Exception handling is defined such that at any statement it is statically known which exceptions might occur (i.e. it is statically known which exceptions cannot occur) and for which exceptions an appropriate handler can be found or which exceptions may be passed to the calling point of a procedure. If an exception occurs and no handler for it can be found, the program is in error.

When an exception occurs at an action statement or a declaration statement, the execution of the statement is performed up to an unspecified extent, unless stated otherwise in the appropriate section.

8.2 Handlers

syntax:

<*handler*> *::=* *(1)*
ON { <*on-alternative*> }* [**ELSE** <*action statement list*>] **END** *(1.1)*

<*on-alternative*> *::=* *(2)*
(<*exception list*>) : <*action statement list*> *(2.1)*

semantics: A handler is entered if it is appropriate for an exception E according to 8.3. If E is mentioned in an *exception list* in an *on-alternative* in the *handler*, the corresponding *action statement list* is entered; otherwise **ELSE** is specified and the corresponding *action statement list* is entered.

When the end of the chosen *action statement list* is reached, the *handler* and the construct to which the *handler* is appended are terminated.

static conditions: All the *exception names* in all the *exception list* occurrences must be different.

dynamic conditions: The *SPACEFAIL* exception occurs if an action statement list is entered and storage requirements cannot be satisfied.

examples:

10.47 **ON**
(*ALLOCATEFAIL*): **CAUSE** *overflow*;
END *(1.1)*

8.3 Handler identification

When an exception E occurs at an action or module A, or a data statement or region D, the exception may be handled by an appropriate handler; i.e. an action statement list in the handler will be executed or the exception may be passed to the calling point of a procedure; or, if neither is possible, the program is in error.

For any action or module A, or data statement or region D, it can be statically determined whether for a given exception E at A or D, an appropriate handler can be found or whether the exception may be passed to the calling point.

An appropriate handler for A or D with respect to an exception with exception name E is determined as follows:

1) if a handler which mentions E in an *exception list* or which specifies **ELSE** is appended to or included in A or D, and E occurs in the reach directly enclosing the handler, then that handler is the appropriate one with respect to E;

2) otherwise, if A or D is directly enclosed by a bracketed action, a module or a region, the appropriate handler (if present) is the appropriate handler for the bracketed action, module or region with respect to E;

3) otherwise, if A or D is placed in the reach of a procedure definition then:

   - if a handler which mentions E in an exception list or specifies **ELSE**, is appended to the procedure definition, then that handler is the appropriate handler;
   - otherwise, if E is mentioned in the exception list of the procedure definition, then E is caused at the calling point;
   - otherwise there is no user-defined handler; however, in this situation an implementation defined handler may be appropriate (see 13.5);

4) otherwise, if A or D is placed in the reach of a process definition, then:

   - if a handler which mentions E in an exception list or specifies **ELSE**, is appended to the process definition, then that handler is the appropriate handler;
   - otherwise there is no user-defined handler; however, in this situation an implementation defined handler may be appropriate (see 13.5);

5) otherwise, if A is an action of an action statement list in a handler, then the appropriate handler is the appropriate handler for the action A' or data statement or region D' with respect to E which the handler is appended to or included in but considered as if that handler were not specified.

If an exception is caused and the transfer of control to the appropriate handler implies exiting from blocks, local storage will be released when exiting from the block.

9 Time supervision

9.1 General

It is assumed that a concept of time exists externally to a CHILL program (system). CHILL does not specify the precise properties of time, but provides mechanisms to enable a program to interact with the external world's view of time.

9.2 Timeoutable processes

The concept of a **timeoutable** process exists in order to identify the precise points during program execution where a time interrupt may occur, that is, when a time supervision may interfere with the normal execution of a process.

A process becomes **timeoutable** when it reaches a well-defined point in the execution of certain actions. CHILL defines a process to become **timeoutable** during the execution of specific actions; an implementation may define a process to become **timeoutable** during the execution of further actions.

9.3 Timing actions

syntax:

<timing action> ::=		*(1)*
	<relative timing action>	*(1.1)*
	| *<absolute timing action>*	*(1.2)*
	| *<cyclic timing action>*	*(1.3)*

semantics: A timing action specifies time supervisions of the executing process. A time supervision may be initiated, it may expire and it may cease to exist. Several time supervisions may be associated with a single process because of the cyclic timing action and because a timing action can itself contain other actions whose execution can initiate time supervisions.

A time interrupt occurs when a process is **timeoutable** and at least one of its associated time supervisions has expired. The occurrence of a time interrupt implies that the first expired time supervision ceases to exist; furthermore, it leads to the transfer of control associated with that time supervision in the supervised process. If the supervised process was delayed, it becomes reactivated.

Time supervisions also cease to exist when control leaves the timing action that initiated them.

Note that if the transfer of control causes the process to leave a region, the region will be released (see 11.2.1).

9.3.1 Relative timing action

syntax:

<relative timing action> ::=		*(1)*
	AFTER <*duration primitive value*> [**DELAY**] **IN**	
	<action statement list> <timing handler> **END**	*(1.1)*
<timing handler> ::=		*(2)*
	TIMEOUT *<action statement list>*	*(2.1)*

semantics: The *duration primitive value* is evaluated, a time supervision is initiated, and then the *action statement list* is entered.

If **DELAY** is specified, the time supervision is initiated when the executing process becomes **timeoutable** at the point of execution specified by the *action statement* in the *action statement list*, otherwise it is initiated before the *action statement list* is entered.

If **DELAY** is specified, the time supervision ceases to exist if it has been initiated and the executing process ceases to be **timeoutable**.

The time supervision expires if it has not ceased to exist when the specified period of time has elapsed since initiation.

The transfer of control associated with the time supervision is to the *action statement list* of the *timing handler*.

static conditions: If **DELAY** is specified, the *action statement list* must consist of precisely one *action statement* that may itself cause the executing process to become **timeoutable**.

dynamic conditions: The *TIMERFAIL* exception occurs if the initiation of the time supervision fails for an implementation defined reason.

9.3.2 Absolute timing action

syntax:

<*absolute timing action*> *::=* *(1)*
AT <<u>*absolute time*</u> *primitive value*> **IN**
<*action statement list*> <*timing handler*> **END** *(1.1)*

semantics: The <u>*absolute time*</u> *primitive value* is evaluated, a time supervision is initiated, and then the *action statement list* is entered.

The time supervision expires if it has not ceased to exist at (or after) the specified point in time.

The transfer of control associated with the time supervision is to the *action statement list* of the *timing handler*.

dynamic condition: The *TIMERFAIL* exception occurs if the initiation of the time supervision fails for an implementation defined reason.

9.3.3 Cyclic timing action

syntax:

<*cyclic timing action*> *::=* *(1)*
CYCLE <<u>*duration*</u> *primitive value*> **IN**
<*action statement list*> **END** *(1.1)*

semantics: The cyclic timing action is intended to ensure that the executing process enters the action statement list at precise intervals without cumulated drifts (this implies that the execution time for the *action statement list* on average should be less than the specified duration value). The <u>*duration*</u> *primitive value* is evaluated, a relative time supervision is initiated, and then the *action statement list* is entered.

The time supervision expires if it has not ceased to exist when the specified period of time has elapsed since initiation. Indivisibly with the expiration, a new time supervision with the same duration value is initiated.

The transfer of control associated with the time supervision is to the beginning of the *action statement list*.

Note that the cyclic timing action can only terminate by a transfer of control out of it.

dynamic properties: The executing process becomes **timeoutable** if and when control reaches the end of the *action statement list*.

dynamic conditions: The *TIMERFAIL* exception occurs if any initiation of a time supervision fails for an implementation defined reason.

9.4 Built-in routines for time

syntax:

<*time value built-in routine call*> *::=* *(1)*
<*duration built-in routine call*> *(1.1)*
| <*absolute time built-in routine call*> *(1.2)*

semantics: Implementations are likely to have quite different requirements and capabilities in terms of precision and range of time values. The built-in routines defined below are intended to accommodate these differences in a portable manner.

9.4.1 Duration built-in routines

syntax:

<duration built-in routine call> ::=	*(1)*
MILLISECS (*<integer expression>*)	*(1.1)*
| *SECS* (*<integer expression>*)	*(1.2)*
| *MINUTES* (*<integer expression>*)	*(1.3)*
| *HOURS* (*<integer expression>*)	*(1.4)*
| *DAYS* (*<integer expression>*)	*(1.5)*

semantics: A duration built-in routine call delivers a duration value with implementation defined and possibly varying precision (i.e. *MILLISECS (1000)* and *SECS (1)* may deliver different duration values); this value is the closest approximation in the chosen precision to the indicated period of time. The argument of *MILLISECS*, *SECS*, *MINUTES*, *HOURS* and *DAYS* indicate a point in time expressed in milliseconds, seconds, minutes, hours and days respectively.

static properties: The class of a duration built-in routine call is the *DURATION*-derived class.

dynamic conditions: The *RANGEFAIL* exception occurs if the implementation cannot deliver a duration value denoting the indicated period of time.

9.4.2 Absolute time built-in routine

syntax:

<absolute time built-in routine call> ::=	*(1)*
ABSTIME ([[[[[[*<year expression>* ,] *<month expression>* ,] *<day expression>* ,] *<hour expression>* ,] *<minute expression>* ,] *<second expression>*])	*(1.1)*
<year expression> ::=	*(2)*
<integer expression>	*(2.1)*
<month expression> ::=	*(3)*
<integer expression>	*(3.1)*
<day expression> ::=	*(4)*
<integer expression>	*(4.1)*
<hour expression> ::=	*(5)*
<integer expression>	*(5.1)*
<minute expression> ::=	*(6)*
<integer expression>	*(6.1)*
<second expression> ::=	*(7)*
<integer expression>	*(7.1)*

semantics: The *ABSTIME* built-in routine call delivers an absolute time value denoting the point in time in the Gregorian calendar indicated in the parameter list. The parameters indicate the components of time in the following order: the year, the month, the day, the hour, the minute and the second. When higher order parameters are omitted, the point in time indicated is the next one that matches the low order parameters present [e.g. *ABSTIME (15,12,00,00)*] denotes noon on the 15th in this or the next month.

When no parameters are specified, an absolute time value denoting the present point in time is delivered.

static properties: The class of the absolute time built-in routine call is the *TIME*-derived class.

dynamic conditions: The *RANGEFAIL* exception is caused if the implementation cannot deliver an absolute time value denoting the indicated point in time.

9.4.3 Timing built-in routine call

syntax:

<timing simple built-in routine call> ::= *(1)*
WAIT ( ) *(1.1)*
| *EXPIRED* ( ) *(1.2)*
| *INTTIME* (*<absolute time primitive value>* , [[[[*<year location>*
<month location> ,] *<day location>* ,]
<hour location> ,] *<minute location>* ,]
<second location>) *(1.3)*

<year location> ::= *(2)*
<integer location> *(2.1)*

<month location> ::= *(3)*
<integer location> *(3.1)*

<day location> ::= *(4)*
<integer location> *(4.1)*

<hour location> ::= *(5)*
<integer location> *(5.1)*

<minute location> ::= *(6)*
<integer location> *(6.1)*

<second location> ::= *(7)*
<integer location> *(7.1)*

semantics: *WAIT* unconditionally makes the executing process **timeoutable**: its execution can only terminate by a time interrupt. (Note that the process remains active in the CHILL sense).

EXPIRED makes the executing process **timeoutable** if one of its associated time supervisions has expired; otherwise it has no effect.

INTTIME assigns to the specified integer locations an integer representation of the point in time in the Gregorian calendar specified by the *absolute time primitive value*. The locations passed as arguments receive the components of time in the following order: the year, the month, the day, the hour, the minute and the second.

static conditions: All specified integer locations must be **referable** and their modes may not have the **read-only property**.

dynamic properties: *WAIT* makes the executing process **timeoutable**.

EXPIRED makes the executing process **timeoutable** if there is an expired time supervision associated with it.

10 Program Structure

10.1 General

The *if action*, *case action*, *do action*, *delay case action*, *begin-end block*, *module*, *region*, *spec module*, *spec region*, *context*, *receive case action*, *procedure definition* and *process definition* determine the program structure; i.e. they determine the scope of names and the lifetime of locations created in them.

- The word block is used to denote:
  - the *action statement list* in a *do action* including any *loop counter* and *while control*;
  - the *action statement list* in a *then clause* in an *if action*;
  - the *action statement list* in a *case alternative* in a *case action*;
  - the *action statement list* in a *delay alternative* in a *delay case action*;
  - a *begin-end block*;
  - a *procedure definition* excluding the *result spec* and *parameter spec* of all *formal parameters* of the *formal parameter list*;
  - a *process definition* excluding the *parameter spec* of all *formal parameters* of the *formal parameter list*;
  - the *action statement list* in a *buffer receive alternative* or in a *signal receive alternative*, including any *defining occurrences* in a *defining occurrence list* after **IN**;
  - the *action statement list* after **ELSE** in an *if action* or *case action* or a *receive case action* or *handler*;
  - the *on-alternative* in a *handler*;
  - the *action statement list* in a *relative timing action*, an *absolute timing action*, a *cyclic timing action* or in a *timing handler*.
- The word modulion is used to denote:
  - a *module* or *region*, excluding the *context list* and *defining occurrence*, if any;
  - a *spec module* or *spec region*, excluding the *context list*, if any;
  - a *context*;
  - the specification together with the corresponding body of a *moreta mode*;
  - a *template* together with the corresponding body.
- The word group denotes either a block or a modulion.
- The word reach or reach of a group denotes that part of the group that is not surrounded (see 10.2) by an inner group. If BM is a moreta mode and DM is a direct successor of BM, then $BM_P - BM_{CD} \cup DM_P$ form one reach. For the visibility of the internal components of moreta modes, the reach of a successor is nested immediately in the specification part of its direct predecessor; this nesting occurs at the end of the specification part.

A group influences the scope of each name created in its reach. Names are created by *defining occurrences*:

- A *defining occurrence* in the *defining occurrence list* of a *declaration*, *mode definition* or *synonym definition* or appearing in a *signal definition* creates a name in the reach where the *declaration, mode definition, synonym definition* or *signal definition*, respectively, is placed.
- A *defining occurrence* in a *set mode* creates a name in the reach directly enclosing the *set mode*.
- A *defining occurrence* appearing in the *defining occurrence list* in a *formal parameter list* creates a name in the reach of the associated *procedure definition* or *process definition*.
- A *defining occurrence* in front of a colon followed by an *action*, *region*, *procedure definition*, or *process definition* creates a name in the reach where the *action, region, procedure definition, process definition*, respectively, is placed.

- A (virtual) *defining occurrence* introduced by a *with part* or in a *loop counter* creates a name in the reach of the block of the associated *do action*.
- A *defining occurrence* in the *defining occurrence list* of a *buffer receive alternative* or a *signal receive alternative* creates a name in the reach of the block of the associated *buffer receive alternative* or *signal receive alternative*, respectively.
- A (virtual) *defining occurrence* for a language predefined or an implementation defined name creates a name in the reach of the imaginary outermost process (see 10.8).

The places where a name is used are called applied occurrences of the name. The name binding rules associate a *defining occurrence* with each applied occurrence of the name (see 12.2.2).

A name has a certain scope, i.e. that part of the program where its definition or declarations can be seen and, as a consequence, where it may be freely used. The name is said to be **visible** in that part. Locations and procedures have a certain lifetime, i.e. that part of the program where they exist. Blocks determine both visibility of names and the lifetime of the locations created in them. Modulions determine only visibility; the lifetime of locations created in the reach of a modulion will be the same as if they were created in the reach of the first surrounding block. Modulions allow for restricting the visibility of names. For instance, a name created in the reach of a module will not automatically be **visible** in inner or outer modules, although the lifetime might allow for it.

10.2 Reaches and nesting

syntax:

<begin-end body> ::= (1)
<data statement list> <action statement list> (1.1)

<proc body> ::= (2)
<data statement list> <action statement list> (2.1)

<process body> ::= (3)
<data statement list> <action statement list> (3.1)

<module body> ::= (4)
{ <data statement> | <visibility statement> | <region> |
<spec region> }* <action statement list> (4.1)

<region body> ::= (5)
{ <data statement> | <visibility statement> }* (5.1)

<spec module body> ::= (6)
{ <quasi data statement> | <visibility statement> |
<spec module> | <spec region> }* (6.1)

<spec region body> ::= (7)
{ <quasi data statement> | <visibility statement> }* (7.1)

<context body> ::= (8)
{ <quasi data statement> | <visibility statement> |
<spec module> | <spec region> }* (8.1)

<action statement list> ::= (9)
{ <action statement> }* (9.1)

<data statement list> ::= (10)
{ <data statement> }* (10.1)

<data statement> ::= (11)
<declaration statement> (11.1)
| <definition statement> (11.2)

<definition statement> ::= (12)
<synmode definition statement> (12.1)
| <newmode definition statement> (12.2)
| <synonym definition statement> (12.3)
| <procedure definition statement> (12.4)
| <process definition statement> (12.5)

| *<signal definition statement>* *(12.6)*
| *<template>* *(12.7)*
| *<empty> ;* *(12.8)*

semantics: When a reach of a block is entered, all the lifetime-bound initialisations of the locations created when entering the block, are performed. Subsequently, the reach-bound initialisations in the block reach, the possibly dynamic evaluations in the loc-identity declarations, the reach-bound initialisations in the regions and the actions are performed in the order they are textually specified.

When a reach of a modulion is entered, the reach-bound initialisations, the possibly dynamic evaluations in the loc-identity declarations, the reach-bound initialisations in the regions and the actions (if the modulion is a module) that are in the modulion reach are performed in the order they are textually specified.

A data statement, action, module or region, is terminated either by completing it, or by terminating a handler appended to it.

When a reach-bound initialisation, loc-identity declaration, action, module, region, procedure or process is terminated, execution is resumed as follows, depending on the statement or the kind of termination:

- if the statement is terminated by completing the execution of a handler, then the execution is resumed with the subsequent statement;
- otherwise, if it is an action that implies a transfer of control, the execution is resumed with the statement defined for that action (see 6.5, 6.6, 6.8, 6.9);
- otherwise, if it is a procedure, control is returned to the calling point (see 10.4);
- otherwise, if it is a process, the execution of that process (or the program, if it is the outermost process) ends (see 11.1) and execution is (possibly) resumed with another process;
- otherwise control will be given to the subsequent statement.

static properties: Any reach is directly enclosed in zero or more groups as follows:

- If the reach is the reach of a *do action*, *begin-end block*, *procedure definition*, *process definition*, then it is directly enclosed in the group in whose reach the *do action*, *begin-end block*, *procedure definition* or *process definition*, respectively, is placed, and only in that group.
- If the reach is the *action statement list* of a *timing action* or *timing handler*, or one of the *action statement lists* of an *if action*, *case action* or *delay case action*, then it is directly enclosed in the group in whose reach the *timing action*, *timing handler*, *if action*, *case action* or *delay case action* is placed, and only in that group.
- If the reach is the *action statement list*, or a *buffer receive alternative*, or *signal receive alternative*, or the *action statement list* following **ELSE** in a *receive buffer case action* or *receive signal case action*, then it is directly enclosed in the group in whose reach the *receive buffer case action* or *receive signal case action* is placed, and only in that group.
- If the reach is the *action statement list* in an *on-alternative* or the *action statement list* following **ELSE** in a *handler* which is not appended to a group, then it is directly enclosed in the group in whose reach the statement to which the *handler* is appended is placed, and only in that group.
- If the reach is an *on-alternative* or *action statement list* after **ELSE** of a *handler* which is appended to a group, then it is directly enclosed in the group to which the *handler* is appended, and only in that group.
- If the reach is a *module*, *region*, *spec module* or *spec region*, then it is directly enclosed in the group in whose reach it is placed, and also directly enclosed in the *context* directly in front of the *module*, *region*, *spec module* or *spec region*, if any. This is the only case where a reach has more than one directly enclosing group.
- If the reach is a *context*, then it is directly enclosed in the *context* directly in front of it. If there is no such *context*, it has no directly enclosing group.

A reach has directly enclosing reaches that are the reaches of the directly enclosing groups. A statement has a unique directly enclosing group, namely, the group in which the statement is placed. A reach is said to directly enclose a group (reach) if, and only if, the reach is a directly enclosing reach of the group (reach).

A statement (reach) is said to be surrounded by a group if, and only if, either the group is the directly enclosing group of the statement (reach) or a directly enclosing reach is surrounded by the group.

A reach is said to be entered when:

- Module reach: The module is executed as an action (e.g. the module is not said to be entered when a goto action transfers control to a **label** name defined inside the module).
- Begin-end reach: The begin-end block is executed as an action.
- Region reach: The region is encountered (e.g. the region is not said to be entered when one of its **critical** procedures is called).
- Procedure reach: The procedure is entered via a procedure call.
- Process reach: The process is activated via the evaluation of a start expression.
- Do reach: The do action is executed as an action after the evaluation of the expressions or locations in the control part.
- Buffer-receive alternative reach, signal receive alternative reach: The alternative is executed on reception of a buffer value or signal.
- On-alternative reach: The on-alternative is executed on the cause of an exception.
- Other block reaches: The action statement list is entered.

An action statement list is said to be entered when, and only when, its first action, if present, receives control from outside the action statement list.

A reach is a **quasi** reach if it is the one of a *spec module, spec region* or *context*, otherwise it is a **real** reach.

A *defining occurrence* is a **quasi** *defining occurrence* if:

- it is surrounded by a *context* and not by a module or region; or
- it is surrounded by a *simple spec module* or a *simple spec region*; or
- it is not surrounded by one of the above mentioned groups and it is surrounded by a *module spec* or a *region spec* and it is contained in a *quasi declaration*, a *quasi procedure definition statement* or a *quasi process definition statement,*

otherwise it is a **real** *defining occurrence*.

10.3 Begin-end blocks

syntax:

<*begin-end block*> *::=* *(1)*
  BEGIN <*begin-end body*> **END** *(1.1)*

semantics: A begin-end block is an action, possibly containing local declarations and definitions. It determines both visibility of locally created names and the lifetimes of locally created locations (see 10.9 and 12.2).

dynamic conditions: The *SPACEFAIL* exception occurs if storage requirements cannot be satisfied.

examples: see 15.73 - 15.90

10.4 Procedure specifications and definitions

syntax:

<*procedure definition statement*> *::=* *(1)*
  <*defining occurrence*> : <*procedure definition*>
  [<*handler*>] [<*simple name string*>] *;* *(1.1)*
 | <*generic procedure instantiation*> *(1.2)*

<procedure definition> ::= *(2)*
PROC ([*<formal parameter list>*]) [*<result spec>*]
[**EXCEPTIONS** (*<exception list>*)] *<procedure attribute list> ;*
<proc body> **END** *(2.1)*

<formal parameter list> ::= *(3)*
<formal parameter> { , *<formal parameter>* }* *(3.1)*

<formal parameter> ::= *(4)*
<defining occurrence list> <parameter spec> *(4.1)*

<procedure attribute list> ::= *(5)*
[*<generality>*] *(5.1)*

<generality> ::= *(6)*
GENERAL *(6.1)*
| **SIMPLE** *(6.2)*
| **INLINE** *(6.3)*

<guarded procedure specification statement> ::= *(7)*
<defining occurrence> **:**
<guarded procedure specification> [*<simple name string>*] *;* *(7.1)*

<guarded procedure specification> ::= *(8)*
PROC ([*<formal parameter list>*] **)** [*<result spec>*]
[**EXCEPTIONS (** *<exception list>* **)**] *<guarded procedure attribute list>* **END** *(8.1)*

<guarded procedure definition statement> ::= *(9)*
<defining occurrence> **:** *<guarded procedure definition>*
[*<handler>*] [*<simple name string>*] *;* *(9.1)*

<guarded procedure definition> ::= *(10)*
PROC ([*<formal parameter list>*] **)** [*<result spec>*]
[**EXCEPTIONS (** *<exception list>* **)**] *<guarded procedure attribute list> ;*
<proc body> **END** *(10.1)*

<guarded procedure attribute list> ::= *(11)*
[**GENERAL**] *(11.1)*
| [**SIMPLE**] [*<simple component procedure attribute list>*] *<assertion part>* *(11.2)*
| [**INLINE**] [*<inline component procedure attribute list>*] *(11.3)*

<simple component procedure attribute list> ::= *(12)*
<inline component procedure attribute list> *(12.1)*
| **DESTR** *(12.2)*
| [**INCOMPLETE**] [**REIMPLEMENT**] *(12.3)*

<inline component procedure attribute list> ::= *(13)*
CONSTR *(13.1)*

<assertion part> ::= *(14)*
[**PRE (** *<boolean expression>*)]
[**POST** (*<boolean expression>*)] *(14.1)*

derived syntax: A *formal parameter*, where *defining occurrence list* consists of more than one *defining occurrence*, is derived from several *formal parameter* occurrences, separated by commas, one for each *defining occurrence* and each with the same *parameter spec*. E.g. *i, j INT* **LOC** is derived from *i INT* **LOC**, *j INT* **LOC**.

semantics: A procedure definition statement defines a (possibly) parameterised sequence of actions that may be called from different places in the program. The procedure is terminated and control is returned to the calling point either by executing a return action or by reaching the end of the *proc body* or by terminating a handler appended to the procedure definition (falling through). Different degrees of complexity of procedures may be specified as follows:

a) **simple** procedures (**SIMPLE**) are procedures that cannot be manipulated dynamically. They are not treated as values, i.e. they cannot be stored in a procedure location nor can they be passed as parameters to or returned as result from a procedure call;

b) **general** procedures (**GENERAL**) do not have the restrictions of **simple** procedures and may be treated as procedure values;

c) **inline** procedures (**INLINE**) have the same restrictions as **simple** procedures and they are not **recursive**. They have the same semantics as normal procedures, but the compiler may insert the generated object code at the point of invocation rather than generating code for actually calling the procedure.

Only **simple** and **general** procedures are **recursive**.

A guarded procedure definition statement defines a (possibly) parameterised sequence of actions that may be called from different places in the program. The procedure is terminated and control is returned to the calling point either by executing a *return action* or by reaching the end of the *proc body* or by terminating a *handler* appended to the procedure definition (falling through).

When the procedure is defined in a *moreta mode*, it is called a **component procedure**. Different kinds of **simple** and **inline** component procedures defined in moreta modes may be specified as follows:

a) a **constr** component procedure (**CONSTR**) is a constructor which can be used to initialise moreta locations automatically when they are created statically or dynamically;

b) a **destr** component procedure (**DESTR**) is a destructor which can be used to finalise moreta locations when they are destroyed statically or dynamically;

c) an **incomplete** component procedure (**INCOMPLETE**) has only a specification but no body;

d) a **reimplement** component procedure (**REIMPLEMENT**) which is given a new body and possibly new assertions.

Different kinds of *assertion part* may be specified for **simple** component procedures:

a) a **pre** assertion part (**PRE**) which is checked automatically before the body of the corresponding procedure is executed;

b) a **post** assertion part (**POST**) which is checked automatically after the body of the corresponding procedure has been executed and before the return to the calling point.

Only **simple** (except for *component procedures* with the attributes **constr** or **destr** or with **public** visibility in a **region** mode) and **general** procedures are **recursive**.

A procedure may return a value or it may return a location (indicated by the **LOC** attribute in the result spec).

The *defining occurrence* in front of the procedure definition defines the name of the procedure.

parameter passing:

There are basically two parameter passing mechanisms: the “pass by value” (**IN**, **OUT** and **INOUT**) and the “pass by location” (**LOC**).

pass by value

In pass by value parameter passing, a value is passed as a parameter to the procedure and stored in a local location of the specified parameter mode. The effect is as if, at the beginning of the procedure call, the location declaration:

DCL *<defining occurrence> <mode> := <actual parameter>;*

were encountered for the *defining occurrences* of the *formal parameter*. However, the procedure is entered after the actual parameters have been evaluated. Optionally, the keyword **IN** may be specified to indicate pass by value explicitly.

If the attribute **INOUT** is specified, the actual parameter value is obtained from a location and just before returning the current value of the formal parameter, is restored in the actual location.

The effect of **OUT** is the same as for **INOUT** with the exception that the initial value of the actual location is not copied into the formal parameter location upon procedure entry; therefore, the formal parameter has an **undefined** initial value. The store-back operation need not be performed if the procedure causes an exception at the calling point.

pass by location

In pass by location parameter passing, a (possibly dynamic mode) location is passed as a parameter to the procedure body. Only **referable** locations can be passed in this way. The effect is as if at the entry point of the procedure the loc-identity declaration statement:

> **DCL** <*defining occurrence*> <*mode*>
> **LOC** [**DYNAMIC**] *:=* <*actual parameter*> *;*

were encountered for the *defining occurrences* of the *formal parameter*. However the procedure is entered after the actual parameters have been evaluated.

If a *value* is specified that is not a *location*, a location containing the specified value will be implicitly created and passed at the point of the call. The lifetime of the created location is the procedure call. The mode of the created location is dynamic if the value has a dynamic class.

result transmission:

Both a value and a location may be returned from the procedure. In the first case, a *value* is specified in any *result action*, in the latter case, a *location* (see 6.8). If the attribute **NONREF** is not given in the *result spec*, the *location* must be **referable**. The returned value or location is determined by the most recently executed result action before returning. If a procedure with a result spec returns without having executed a result action, the procedure returns an **undefined** value or an **undefined** location. In this case the procedure call may not be used as a location procedure call (see 4.2.11) nor as a value procedure call (see 5.2.13), but only as a call action (see 6.7).

static properties: A *defining occurrence* in a *procedure definition statement* defines a **procedure** name.

A **procedure** name has a *procedure definition* attached that is the *procedure definition* in the statement in which the **procedure** name is defined.

A **procedure** name has the following properties attached, as defined by its *procedure definition*:

- It has a list of **parameter specs** that are defined by the *parameter spec* occurrences in the *formal parameter list*, each parameter consisting of a mode and possibly a parameter attribute.
- It has possibly a **result spec**, consisting of a mode and an optional result attribute.
- It has a possibly empty list of exception names, which are the names mentioned in *exception list*.
- It has a **generality** that is, if *generality* is specified, either **general** or **simple** or **inline**, depending on whether **GENERAL**, **SIMPLE** or **INLINE** is specified; otherwise an implementation default specifies **general** or **simple**. If the **procedure** name is defined inside a block or a region, its **generality** is **simple**. If a procedure is defined in a moreta mode and has **public** visibility, its generality is **simple** or **inline**.
- It has a **recursivity** which is **recursive**. However, if the **generality** is **inline** or if the **procedure** name is **critical** (see 11.2.1) the **recursivity** is **non-recursive**.
- A component procedure has the generality **inline** if the attribute **INLINE** is specified. Otherwise it has the generality **SIMPLE** by default.

A **procedure** name that is **general** is a **general procedure** name. A **general procedure** name has a procedure mode attached, formed as:

> **PROC** *(* [<*parameter list*>] *)* [<*result spec*>]
> [**EXCEPTIONS** *(* <*exception list*> *)*]

where <*result spec*>, if present, and <*exception list*> are the same as in its *procedure definition* and *parameter list* is the sequence of <*parameter spec*> occurrences in the *formal parameter list*, separated by commas.

A name defined in a *defining occurrence list* in the *formal parameter* is a **location** name if, and only if, the *parameter spec* in the *formal parameter* does not contain the **LOC** attribute. If it does contain the **LOC** attribute, it is a **loc-identity** name. Any such a **location** name or **loc-identity** name is **referable**.

A moreta mode component procedure of a moreta mode M has a complete postcondition CPM which is defined as follows:

a) if M has no immediate base mode then CPM = **post** part;

b) if M has the immediate base mode B then CPM = CPB $\wedge$ **post** part, where CPB is the complete postcondition of B.

static conditions: If a **procedure** name is **intra-regional** (see 11.2.2) or is a public procedure of a moreta mode, its procedure definition must not specify **GENERAL**.

If a **procedure** name is **critical** (see 11.2.1), its definition may not specify **GENERAL**.

If a **simple** component procedure has any *assertion part*, the name of the procedure must have **public** visibility.

The defining occurrence of a **constr** component procedure must be the same as that of its attached **moreta** mode. A **constr** component procedure must not specify a *result spec* and must be **non-recursive.**

The defining occurrence of a **destr** component procedure must be the same as that of its attached **moreta** mode. A **destr** component procedure must neither specify a *formal parameter list* nor a *result spec* and must be **non-recursive**.

If specified, the *simple name string* must be equal to the name string of the *defining occurrence* in front of the *procedure definition*.

Only if **LOC** is specified in the *parameter spec* or *result spec* may the mode in it have the **non-value property**.

All exception names mentioned in *exception list* must be different.

If P1 and P2 are component procedures or component processes, then P1 matches P2 if, and only if:

a) P1 and P2 are of the same kind; and

b) P1 and P2 have the same simple name string; and

c) the formal parameter lists of P1 and P2 are syntactically and semantically equivalent, and

d) the result specs of P1 and P2 are syntactically and semantically equivalent.

If P is a component procedure or a component process, then P_B *corresponds* to P_S if, and only if:

a) P_B matches P_S; and

b) the exception lists of P_S and P_B are syntactically and semantically equivalent; and

c) the attribute lists of P_S and P_B are syntactically and semantically equivalent.

examples:

```
1.4     add:
        PROC (i,j INT) RETURNS (INT) EXCEPTIONS (OVERFLOW);
          RESULT i+j;
        END add;        (1.1)

        put :
        PROC(p RANGE(1:10)) PRE((p > 0) AND (p < 11));
        ...;
        END put;                                          (10.1)
```

10.5 Process specifications and definitions

syntax:

<process definition statement> ::=		*(1)*
	<defining occurrence> : *<process definition>* [*<handler>*] [*<simple name string>*] *;*	*(1.1)*
|	*<generic process instantiation> ;*	*(1.2)*
<process definition> ::=		*(2)*
	PROCESS ([*<formal parameter list>*]) *<process body>* **END**	*(2.1)*

semantics: A process definition statement defines a possibly parameterised sequence of actions that may be started for concurrent execution from different places in the program (see clause 11).

static properties: A *defining occurrence* in a *process definition statement* defines a **process** name.

A **process** name has the following property attached, as defined by its *process definition*:

- It has a list of **parameter specs** that are defined by the *parameter spec* occurrences in the *formal parameter list*, each parameter consisting of a mode and possibly a parameter attribute.

static conditions: If specified, the *simple name string* must be equal to the name string of the *defining occurrence* in front of the *process definition*.

A *process definition statement* must not be surrounded by a region or by a block other than the imaginary outermost process definition (see 10.8).

The parameter attributes in the *formal parameter list* must not be **INOUT** nor **OUT**.

Only if **LOC** is specified in the *parameter spec* in a *formal parameter* in the *formal parameter list*, may the mode in it have the **non-value property**.

examples:

```
14.13    PROCESS ();
           wait:
           PROC (x INT);
           /*some wait action*/
           END wait;
           DO FOR EVER;
           wait(10 /* seconds */ );
           CONTINUE operator_is_ready;
           OD;
         END                                        (2.1)
```

10.6 Modules

syntax:

<module> ::= *(1)*

[*<context list>*] [*<defining occurrence>* :]
MODULE [**BODY**] *<module body>* **END**
[*<handler>*] [*<simple name string>*] *;* *(1.1)*
| *<remote modulion>* *(1.2)*
| *<generic module instantiation>* *(1.3)*

semantics: A module is an action statement possibly containing local declarations and definitions. A module is a means of restricting the visibility of name strings; it does not influence the lifetime of the locally declared locations.

The detailed visibility rules for modules are given in 12.2.

static properties: A *defining occurrence* in a *module* defines a **module** name as well as a **label** name. The name has the *module* (seen as a modulion, i.e. excluding the *context list* and *defining occurrence*, if any) attached.

A *module* is developed piecewisely if, and only if, a *context list* is specified.

A *module* is a **module body** if, and only if, **BODY** is specified.

static conditions: If specified, the *simple name string* must be equal to the name string of the *defining occurrence*.

A *remote modulion* in a *module* must refer to a *module*.

examples:

```
7.48     MODULE
           SEIZE convert;
           DCL n INT INIT:= 1979;
           DCL rn CHARS (20) INIT:= (20)" ";
           GRANT n,rn;
           convert();
```

ASSERT *rn = "MDCCCCLXXVIIII"//(6)" ";*
END *(1.1)*

10.7 Regions

syntax:

<region> ::= *(1)*
[*<context list>*] [*<defining occurrence>* :]
REGION [**BODY**] *<region body>* **END**
[*<handler>*] [*<simple name string>*] *;* *(1.1)*
| *<remote modulion>* *(1.2)*
| *<generic region instantiation>* *(1.3)*

semantics: A region is a means of providing mutually exclusive access to its locally declared data objects for the concurrent executions of processes (see clause 11). It determines visibility of locally created names in the same way as a module.

static properties: A *defining occurrence* in a *region* defines a **region** name. It has the region (seen as a modulion, i.e. excluding the *context list* and *defining occurrence*, if any) attached.

A *region* is developed piecewisely if, and only if, a *context list* is specified.

A *region* is a **region body** if, and only if, **BODY** is specified.

static conditions: If specified, the *simple name string* must be equal to the name string of the *defining occurrence*.

A *region* must not be surrounded by a block other than the imaginary outermost process definition.

A *remote modulion* in a *region* must refer to a *region*.

examples: see 13.1 - 13.28

10.8 Program

syntax:

<program> ::= *(1)*
{ *<module>* | *<spec module>* | *<region>* | *<spec region>*
| *<moreta declaration statement>*
| *<moreta synmode definition statement>*
| *<moreta newmode definition statement>*
| *<template>*}$^+$ *(1.1)*

semantics: A program consists of a list of program units (as given in the syntax rule) surrounded by an imaginary outermost process definition.

The definitions of the CHILL pre-defined names (see III.2) and the implementation defined built-in routines and integer modes are considered, for lifetime purposes, to be defined in the reach of the imaginary outermost process definition. For their visibility see 12.2.

10.9 Storage allocation and lifetime

The time during which a location or procedure exists within its program is its lifetime.

A location is created by a declaration or by the execution of a *GETSTACK* or an *ALLOCATE* built-in routine call.

The lifetime of a location declared in the reach of a block is the time during which control lies in that block or in a procedure whose call originated from that block, unless it is declared with the attribute **STATIC**. The lifetime of a location declared in the reach of a modulion is the same as if it were declared in the reach of the closest surrounding block of the modulion. The lifetime of a location declared with the attribute **STATIC** is the same as if it were declared in the reach of the imaginary outermost process definition. This implies that for a location declaration with the attribute **STATIC** storage allocation is made only once, namely, when starting the imaginary outermost process. If such a declaration appears inside a procedure definition or process definition, only one location will exist for all invocations or activations.

The lifetime of a location created by executing a *GETSTACK* built-in routine call ends when the directly enclosing block terminates.

The lifetime of a location created by an *ALLOCATE* built-in routine call is the time starting from the *ALLOCATE* call until the time that the location cannot be accessed anymore by any CHILL program. The latter is always the case if a *TERMINATE* built-in routine is applied to an **allocated** reference value that references the location.

The lifetime of an access created in a loc-identity declaration is the directly enclosing block of the loc-identity declaration.

The lifetime of a procedure is the directly enclosing block of the procedure definition.

static properties: A *location* is said to be **static** if, and only if, it is a *static mode location* of one of the following kinds:

- A *location name* that is declared with the attribute **STATIC** or whose definition is not surrounded by a block other than the imaginary outermost process definition.
- A *string element* or *string slice* where the *string location* is **static** and either the *left element* and *right element*, or *start element* and *slice size* are **constant**.
- An *array element* where the *array location* is **static** and the *expression* is **constant**.
- An *array slice* where the *array location* is **static** and either the *lower element* and *upper element* or the *first element* and *slice size* are **constant**.
- A *structure field* where the *structure location* is **static**.
- A *location conversion* where the *location* occurring in it is **static**.

10.10 Constructs for piecewise programming

Modules and regions are the elementary units (pieces) in which a complete CHILL program that is developed piecewisely can be subdivided. The text of such pieces is indicated by remote constructs (see 10.10.1). CHILL defines the syntax and semantics of complete programs, in which all occurrences of remote pieces have been virtually replaced by the referred text.

10.10.1 Remote pieces

syntax:

<remote modulion> ::= *(1)*
  [*<simple name string>* :] **REMOTE** *<piece designator> ;* *(1.1)*

<remote spec> ::= *(2)*
  [*<simple name string>* :] **SPEC REMOTE** *<piece designator> ;* *(2.1)*

<remote context> ::= *(3)*
  CONTEXT REMOTE *<piece designator>*
  [*<context body>*] **FOR** *(3.1)*

<context module> ::= *(4)*
  CONTEXT MODULE REMOTE *<piece designator> ;* *(4.1)*

<piece designator> ::= *(5)*
  <character string literal> *(5.1)*
  | *<text reference name>* *(5.2)*
  | *<empty>* *(5.3)*

<remote program unit> ::= *(6)*
  [*<simple name string>* :] **REMOTE** *<piece designator> ;* *(6.1)*

derived syntax: The notation:

CONTEXT MODULE REMOTE *<piece designator>*

is derived syntax for:

> **CONTEXT REMOTE** <*piece designator*> **FOR**
> **MODULE SEIZE ALL***;* **END***;*

NOTE – This construct is redundant but can be used for consistence checking.

semantics: *Remote modulions*, *remote specs*, *remote contexts*, *context modules,* and *remote program units* are means to represent the source text of a program as a set of (interconnected) files.

A *piece designator* refers in an implementation defined way to a description of a piece of CHILL source text, as follows:

- If the *piece designator* is empty, the source text is retrieved from a place determined by the structure of the program.
- If the *piece designator* contains a *character string literal*, the *character string literal* is used to retrieve the source text.
- If the *piece designator* contains a *text reference name*, the *text reference name* is interpreted in an implementation defined way to retrieve the source text.

A program with: 1. *remote modulions*, 2. *remote specs*, 3. *remote program units* is equivalent to the program built by replacing each: 1. *remote modulion*, 2. *remote spec*, 3. *remote program unit* by the piece of CHILL text referred to by its *piece designator*.

A program with *remote contexts* is equivalent to the program built by replacing each *remote context* by the piece of CHILL text referred to by its *piece designator* in which the *context body* has been virtually inserted immediately after the last occurrence of *context body* in the *context list* referred to by the *piece designator*.

If the designated piece is not available as CHILL text, then the *piece designator* in it is considered to refer to an equivalent piece of CHILL text which is introduced virtually.

Although the semantics of a remote piece is defined in terms of replacement, CHILL does not imply any textual substitution.

static conditions: The *piece designator* in a: 1. *remote modulion*, 2. *remote spec*, 3. *remote context*, 4. *context module*, 5. *remote program unit*, must refer to a description of a piece of source text which is a terminal production of a: 1. *module* or *region* that is not a *remote modulion*, 2. *spec module* or *spec region* that is not a *remote spec*, 3., 4. *context list* which is not a *remote context*, 5. a *program unit* which is not remote.

When the source text referred to by the *piece designator* in a *remote modulion* starts with a *defining occurrence*, then the *remote modulion* must start with a *simple name string* which is the name string of that *defining occurrence*.

When the source text referred to by the *piece designator* in a *remote spec* starts with a *simple name string*, then the *remote spec* must start with the same *simple name string*.

When the source text referred to by the *piece designator* in a *remote program unit* starts with a *simple name string*, then the first defining occurrence in the *remote program unit* must be the same *simple name string*.

examples:

25.9	*stack:* **REMOTE** *”example 27 or 28”;*	*(1.1)*
25.9	*”example 27 or 28”*	*(5.1)*

10.10.2 Spec modules, spec regions and contexts

syntax:

<*spec module*> *::=*	*(1)*
<*simple spec module*>	*(1.1)*
| <*module spec*>	*(1.2)*
| <*remote spec*>	*(1.3)*
<*simple spec module*> *::=*	*(2)*
[<*context list*>] [<*simple name string*> :] **SPEC MODULE**	
<*spec module body*> **END** [<*simple name string*>] *;*	*(2.1)*

<module spec> ::= *(3)*
[*<context list>*] *<simple name string>* : **MODULE SPEC**
<spec module body> **END** [*<simple name string>*] *;* *(3.1)*

<spec region> ::= *(4)*
<simple spec region> *(4.1)*
| *<region spec>* *(4.2)*
| *<remote spec>* *(4.3)*

<simple spec region> ::= *(5)*
[*<context list>*] [*<simple name string>* :] **SPEC REGION**
<spec region body> **END** [*<simple name string>*] *;* *(5.1)*

<region spec> ::= *(6)*
[*<context list>*] *<simple name string>* : **REGION SPEC**
<spec region body> **END** [*<simple name string>*] *;* *(6.1)*

<context list> ::= *(7)*
<context> { *<context>* }* *(7.1)*
| *<remote context>* *(7.2)*

<context> ::= *(8)*
CONTEXT *<context body>* **FOR** *(8.1)*

semantics: *Simple spec modules*, *simple spec regions* and *contexts* are used to specify static properties of names. They may be redundant but they can be used for piecewise programming.

Simple name strings in *spec modules* and *spec regions* are not names, they are not **bound**, and they have no visibility rules.

1. *spec modules*, 2. *spec regions* in a **real** reach indicate the properties of one or more 1. *modules*, 2. *regions* that are piecewisely compiled and that are considered to be enclosed in that reach. The texts of such: 1. *modules*, 2. *regions*, are indicated by occurrences of *remote modulions*. A *context list* indicates the surrounding reaches (note that a module or a region that is developed piecewisely always has a *context list* in front of it).

For each *name string OP ! NS* **visible** in the reach of a: 1. *module spec*, 2. *region spec* and **linked** there to a **quasi s** defining occurrence and that is granted into a **real** reach as *NP ! NS*, a (virtual) grant statement with the same **old** *name string OP ! NS* and **new** *name string NP ! NS*, is considered to be introduced in the reach of the corresponding: 1. **module body**, 2. **region body**.

static conditions: In a *spec module* or a *spec region*, the optional *simple name string* following **END** may only be present if the optional *simple name string* before **SPEC** is present. When both are present, they must have equal name strings.

A *context* which has no directly enclosing group may not contain visibility statements.

A **real** reach that contains a: 1. *spec module*, 2. *spec region*, must also contain at least a *remote modulion* and vice versa.

If a **real r reach** contains a: 1. *module* which is a **module body**, 2. *region* which is a **region body**, then it must contain also a: 1. *module spec*, 2. *region spec* such that the *simple name strings* in front of them have equal name strings. The: 1. *module spec*, 2. *region spec*, is said to have a **corresponding**: 1. **module body**, 2. **region body**.

A *remote spec* in a: 1. *spec module*, 2. *spec region*, must refer to a: 1. *spec module*, 2. *spec region*.

A *spec module* or a *spec region* may not be surrounded by a block other than the imaginary outermost process definition.

examples:

```
23.2    letter_count:
        SPEC MODULE
          SEIZE max;
          count: PROC (input ROW CHARS (max) IN,
            output ARRAY ('A':'Z') INT OUT) END;
          GRANT count;
        END letter_count;                                   (1.1)
```

10.10.3 Quasi statements

syntax:

<quasi data statement> ::= *(1)*
<quasi declaration statement> *(1.1)*
| *<quasi definition statement>* *(1.2)*

<quasi declaration statement> ::= *(2)*
DCL *<quasi declaration>* { , *<quasi declaration>* }* *;* *(2.1)*

<quasi declaration> ::= *(3)*
<quasi location declaration> *(3.1)*
| *<quasi loc-identity declaration>* *(3.2)*

<quasi location declaration> ::= *(4)*
<defining occurrence list> <mode> *(4.1)*

<quasi loc-identity declaration> ::= *(5)*
<defining occurrence list> <mode>
LOC [**NONREF**] [**DYNAMIC**] *(5.1)*

<quasi definition statement> ::= *(6)*
<synmode definition statement> *(6.1)*
| *<newmode definition statement>* *(6.2)*
| *<synonym definition statement>* *(6.3)*
| *<quasi synonym definition statement>* *(6.4)*
| *<quasi procedure definition statement>* *(6.5)*
| *<quasi process definition statement>* *(6.6)*
| *<quasi signal definition statement>* *(6.7)*
| *<signal definition statement>* *(6.8)*
| *<empty> ;* *(6.9)*

<quasi synonym definition statement> ::= *(7)*
SYN *<quasi synonym definition>* { , *<quasi synonym definition>* }* *;* *(7.1)*

<quasi synonym definition> ::= (8)
<defining occurrence list> { *<mode>* = [*<constant value>*] |
[*<mode>*] = *<literal expression>* } *(8.1)*

<quasi procedure definition statement> ::= *(9)*
<defining occurrence> : **PROC** ([*<quasi formal parameter list>*])
[*<result spec>*] [**EXCEPTIONS** (*<exception list>*)]
<procedure attribute list> [**END** [*<simple name string>*]] *;* *(9.1)*

<quasi formal parameter list> ::= *(10)*
<quasi formal parameter> { , *<quasi formal parameter>* }* *(10.1)*

<quasi formal parameter> ::= *(11)*
<simple name string> { , *<simple name string>* }* *<parameter spec>* *(11.1)*

<quasi process definition statement> ::= *(12)*
<defining occurrence> : **PROCESS** ([*<quasi formal parameter list>*])
[**END** [*<simple name string>*]] *;* *(12.1)*

<quasi signal definition statement> ::= *(13)*
SIGNAL *<quasi signal definition>* { , *<quasi signal definition>* }* *;* *(13.1)*

<quasi signal definition> ::= *(14)*
<defining occurrence> [= (*<mode>* { , *<mode>* }*)] [**TO**] *(14.1)*

semantics: Quasi statements are used in *spec modules*, *spec regions* and *contexts* to specify static properties of names. *Spec modules*, *spec regions* and *contexts* may contain quasi statements and real statements. Quasi statements may be redundant, but are used for piecewise programming.

An implementation that cannot guarantee the equality of the values between **quasi constant synonym** names and the corresponding **real** ones may disallow the indication of the *constant value*.

Note that in CHILL no **quasi** *defining occurrences* exist for **label** names.

static properties: Quasi statements are restricted forms of the corresponding *statements*, and have the same static properties.

The name defined by a *defining occurrence* in a *quasi loc-identity declaration* is **referable** if **NONREF** is not specified.

static conditions: Quasi statements are restricted forms of the corresponding statements and are subject to their static conditions.

A *quasi synonym definition statement* or a *quasi signal definition statement* may only be directly enclosed in a *simple spec module*, *simple spec region* or *context*. A *synonym definition statement* or a *signal definition statement* in a *quasi definition statement* may only be directly enclosed in a *module spec* or *region spec*.

10.10.4 Matching between quasi defining occurrences and defining occurrences

Two *defining occurrences* are said to **match** if they have identical semantic categories and:

- If they are **synonym** names, then they must have the same **regionality** and value, the **root** mode of their classes must be **alike**, they must both have an M-value, M-derived, M-reference, **null** or **all** class, and if the one which is quasi is **literal**, then so the other one must be.
- If they are **newmode** names or **synmode** names, then their modes must be **alike**.
- If they are **location** names or **loc-identity** names, then they must have the same **regionality**, they both must be or both not be **referable**, and their modes must be **alike**.
- If they are **procedure** names, then they must have the same **regionality** and **generality**, they both must be or both not be **critical**, they must satisfy the same conditions of alikeness as procedure modes, and corresponding (by position) *simple name strings* in the *formal parameter list* and *quasi formal parameter list* must be the same.
- If they are **process** names, then the parameters of their process definitions must satisfy the same conditions of matching and alikeness as the parameters of **procedure** names.
- If they are **signal** names, then they must both specify or both not specify **TO**, their lists of modes must have the same number of modes, and corresponding modes must be **alike**.

If two structure modes are **novelty bound** in a reach R, then they must have the same set of **visible** field names in R.

The following rules apply:

- If a *name string* in a reach that is not the reach of a *spec module*, *spec region* or *context* is **bound** to a **quasi** *defining occurrence*, then it must also be **bound** to a *defining occurrence* which is not a **quasi** *defining occurrence*, and further:
  - Let a *name string* be **bound** to a **quasi** *defining occurrence* QD and be **bound** also to a **real** *defining occurrence* RD in reach R, then:
    1) QD and RD must **match** as defined above; and
    2) RD and QD must both be enclosed in an enclosed group of R or both not be enclosed in the group of R or, if R is the reach of a *module* or *region* which is a **module body** or **region body**, then QD must be enclosed in the group of the **corresponding** *module spec* or *region spec* and RD must be enclosed in the group of R.
  - If a *name string* in a **real** reach R is **bound** to a **quasi** *defining occurrence* that is enclosed in the group of R (i.e. surrounded by a spec modulion), then it must also be **bound** to a **real** *defining occurrence* that is surrounded by the group of a *module* or *region* that are indicated by a *remote modulion* directly enclosed in R (informally, if the interface grants, so must the implementation). If the **quasi** *defining occurrence* is enclosed in the group of a *module spec* or a *region spec*, then the **real** one must be enclosed in the group of the **corresponding** modulion.
  - For each *name string* in the reach Q of a *spec module* or *spec region* directly enclosed in a **real** reach R that is **bound** to a *defining occurrence* not surrounded by Q, there must be an identical *name string* in the reach of a *module* or *region* that is indicated by a *remote modulion* directly enclosed in

R that is **bound** to the same *defining occurrence* (informally, if the interface seizes, so must the implementation).

- If two *name strings* are **bound** to the same: 1. **real**, 2. **quasi** *defining occurrence* in a reach, then both *name strings* must be **bound** to the same: 1. **quasi**, 2. **real** *defining occurrence*, or both not be further **bound**.
- A **real novelty** may not be **novelty bound** to two **quasi novelties** in any reach.

  Let a **quasi novelty** QN and a **real novelty** RN be **novelty bound** to each other in a reach R; then RN and QN must both be enclosed in an enclosed group of R or both not be enclosed in the group of R, or if R is the reach of a *module* or *region* which is a **module body** or **region body**, then RN must be enclosed in the group of R and QN must be enclosed in the group of the **corresponding** *module spec* or *region spec*.

10.11 Genericity

Many algorithms solve problems on similarly structured data items whose component modes are different. Genericity provides a means to implement such algorithms as program schemes which are instantiated by substituting formal mode definitions by actual ones.

syntax:

<template> ::= (1)
  <generic module template> (1.1)
  | *<generic region template>* (1.2)
  | *<generic procedure template>* (1.3)
  | *<generic process template>* (1.4)
  | *<generic module mode template>* (1.5)
  | *<generic region mode template>* (1.6)
  | *<generic task mode template>* (1.7)
  | *<remote program unit>* (1.8)

<generic module template> ::= (2)
  [*<context list>*] [*<defining occurrence>* :]
  <generic part> **MODULE** [**BODY**] *<module body>* **END**
  [*<handler>*] [*<simple name string>*] *;* (2.1)

<generic region template> ::= (3)
  [*<context list>*] [*<defining occurrence>* :]
  <generic part> **REGION** [**BODY**] *<region body>* **END**
  [*<handler>*] [*<simple name string>*] *;* (3.1)

<generic procedure template> ::= (4)
  <defining occurrence> : *<generic part> <procedure definition>*
  [*<handler>*] [*<simple name string>*] *;* (4.1)

<generic process template> ::= (5)
  <defining occurrence> : *<generic part> <process definition>*
  [*<handler>*] [*<simple name string>*] *;* (5.1)

<generic module mode template> ::= (6)
  <generic part> <module mode specification> (6.1)

<generic region mode template> ::= (7)
  <generic part> <region mode specification> (7.1)

<generic task mode template> ::= (8)
  <generic part> <task mode specification> (8.1)

<generic part> ::= (9)
  GENERIC { *<seize statement>* }* *<formal generic parameter list>* (9.1)

<formal generic parameter list> ::= (10)
  { *<formal generic parameter>* }* (10.1)

<formal generic parameter> ::= (11)
  SYN *<formal generic synonym list> ;* (11.1)

| **MODE** *<formal generic mode list> ;* *(11.2)*
| **PROC** *<formal generic procedure spec> ;* *(11.3)*

<formal generic synonym list> ::= *(12)*
<formal generic synonym> { ,*<formal generic synonym>* }* *(12.1)*

<formal generic mode list> ::= *(13)*
<formal generic mode> { ,*<formal generic mode>* }* *(13.1)*

<formal generic synonym> ::= *(14)*
<defining occurrence list> =
{ *<mode>* **| ANY_DISCRETE | ANY_INT | ANY_REAL** } *(14.1)*

<formal generic mode> ::= *(15)*
<defining occurrence list> = *<formal generic mode indication>* *(15.1)*

<formal generic mode indication> ::= *(16)*
ANY *(16.1)*
| **ANY_ASSIGN** *(16.2)*
| **ANY_DISCRETE** *(16.3)*
| **ANY_INT** *(16.4)*
| **ANY_REAL** *(16.5)*
| *<moreta mode name>* *(16.6)*

<formal generic procedure spec> ::= *(17)*
<simple name string> ([*<formal parameter list>*]) [*<result spec>*]
[**EXCEPTIONS** (*<exception list>*)] *(17.1)*

<generic module instantiation> ::= *(18)*
<simple name string>: **MODULE** = **NEW** *<generic module name>*
{ *<seize statement>* }*
<actual generic parameter list> **END** [*<simple name string>*] *;* *(18.1)*

<generic region instantiation> ::= *(19)*
<simple name string>: **REGION** = **NEW** *<generic region name>*
{ *<seize statement>* }*
<actual generic parameter list> **END** [*<simple name string>*] *;* *(19.1)*

<generic procedure instantiation> ::= *(20)*
<simple name string>: **PROC** = **NEW** *<generic procedure name>*
{ *<seize statement>* }*
<actual generic parameter list> **END** [*<simple name string>*] *;* *(20.1)*

<generic process instantiation> ::= *(21)*
<simple name string>: **PROCESS** = **NEW** *<generic process name>*
{ *<seize statement>* }*
<actual generic parameter list> **END** [*<simple name string>*] **;** *(21.1)*

<generic moreta mode instantiation> ::= *(22)*
NEW *<generic moreta mode name>*
{ *<seize statement>* }*
<actual generic parameter list> **END** [*<simple name string>*] *;* *(22.1)*

<actual generic parameter list> ::= *(23)*
<actual generic parameter> { *<actual generic parameter>* }* *(23.1)*

<actual generic parameter> ::= *(24)*
<synonym definition statement> *(24.1)*
| *<synmode definition statement>* *(24.2)*
| *<newmode definition statement>* *(24.3)*
| *<actual generic procedure>* *(24.4)*

<actual generic procedure> ::= *(25)*
PROC *<defining occurrence list>* = *<procedure name> ;* *(25.1)*

semantics: The word *unit* means either a module, a region, a procedure, a process, or a moreta mode.

A generic unit is a unit which contains a generic part.

A generic unit is a template from which non-generic units may be obtained by a process called generic instantiation.

A generic unit may contain formal generic parameters. During generic instantiation a copy of the generic unit is made and the formal generic parameters are replaced by the actual generic parameters throughout the whole unit. After this replacement, the generic part is deleted and thus a non-generic unit is obtained.

static properties: The formal generic synonyms are characterised by two properties:

a) the properties which a formal generic parameter has inside the generic unit;

b) the properties which a corresponding actual generic parameter must have to be accepted:

mode:	formal prop:	properties of the given mode which must not have the **non-value** property.
	act prop:	value of the actual generic parameter must be a value of the mode.
ANY_DISCRETE:	formal prop:	operations available: :=, relational, PRED, SUCC, NUM, SIZE.
	act prop:	value of the actual generic parameter must be a value of a discrete mode.
ANY_INT:	formal prop:	ANY_DISCRETE and +, -, *, /, mod, abs, rem.
	act prop:	value of the actual generic parameter must be a value of an integer mode.
ANY_REAL:	formal prop:	operations available: ANY_ASSIGN and relational, +, -, *, /.
	act prop:	value of the actual generic parameter must be a value of a real mode.

The formal generic modes are characterised by two properties:

a) the properties which a formal generic parameter has inside the generic unit;

b) the properties which a corresponding actual generic parameter must have to be accepted:

ANY:	formal prop:	SIZE; cannot be used as the mode of a location or of a parameter; (can be used as a referenced mode).
	actual prop:	any mode acceptable.
ANY_ASSIGN:	formal prop:	operations available: :=, comparison, SIZE.
	act prop:	mode must posses formal prop.
ANY_DISCRETE:	formal prop:	operations available: :=, relational, PRED, SUCC, NUM, SIZE.
	act prop:	mode must posses formal prop.
ANY_INT:	formal prop:	ANY_DISCRETE and +, -, *, /, mod, abs, rem.
	act prop:	mode must posses formal prop.
ANY_REAL:	formal prop:	operations available: ANY_ASSIGN and relational, +, -, *, /.
	act prop:	mode must posses formal prop.
moreta mode name:	formal prop:	those of the mode.
	act prop:	same mode or any successor.

The formal generic procedures are characterised by two properties:

a) the properties which a formal generic parameter has inside the generic unit;

b) the properties which a corresponding actual generic parameter must have to be accepted:

formal prop:	according to the given formal generic procedure spec.
act prop:	the given formal generic procedure spec must be **compatible** with the class of the actual generic parameter.

static conditions: For derivation involving generic moreta mode templates, the following restrictions apply: if the base is a template then any derived entity must also be a template. If the base is not a template, a derived entity may be a template.

In a generic instantiation there must be exactly one actual generic parameter for each formal generic parameter of the generic unit being instantiated.

For templates the restrictions on nesting are given in the following table. The table defines which templates may occur immediately in which groups.

Template/ Instantiation Group	MODULE	REGION	PROC	PROCESS	Module mode	Region mode	Task mode
Begin-End	Yes	No	Yes	No	Yes	No	No
PROC	Yes	No	Yes	No	Yes	No	No
PROCESS	Yes	No	Yes	No	Yes	No	No
MODULE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
REGION	Yes	Yes	Yes	No	Yes	Yes	No
Module Mode	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region Mode	Yes	Yes	Yes	No	Yes	Yes	No
Task Mode	Yes	No	Yes	No	Yes	No	No
Program	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table is based on the following correspondence between templates and entities of CHILL92. For a template in the left column, the restrictions of the corresponding entity in the right column apply:

generic module template	procedure definition statement
generic region template	region
generic procedure template	procedure definition statement
generic process template	process definition statement
generic module mode template	procedure definition statement
generic region mode template	region
generic task mode template	process definition statement

11 Concurrent execution

11.1 Processes, tasks, threads and their definitions

A thread is either a process or a task.

A process is the sequential execution of a series of statements. It may be executed concurrently with other threads. The behaviour of a process is described by a process definition (see 10.5), that describes the objects local to a process and the series of action statements to be executed sequentially.

A process is created by the evaluation of a start expression (see 5.2.15). It becomes active (i.e. under execution) and is considered to be executed concurrently with other threads. The created process is an activation of the definition indicated by the **process** name of the process definition. An unspecified number of processes with the same definition may be created and may be executed concurrently. Each process is uniquely identified by an instance value, yielded as the result of the start expression or the evaluation of the **THIS** operator. The creation of a process causes the creation of its locally declared locations, except those declared with the attribute **STATIC** (see 10.9), and of locally defined values and procedures. The locally declared locations, values and procedures are said to have the same activation as the created process to which they belong. The imaginary outermost process (see 10.8), which is the whole CHILL program under execution, is considered to be created by a start expression executed by the system under whose control the program is executing. At the creation of a process, its formal parameters, if present, denote the values and locations as delivered by the corresponding actual parameters in the start expression.

A process is terminated by the execution of a stop action, by reaching the end of the process body or by terminating a handler specified at the end of the process definition (falling through). If the imaginary outermost process executes a stop action or falls through, the termination will be completed when, and only when, all other threads in the program are terminated.

A task is a sequential execution of a series of statements. It may be executed concurrently with other threads. The behaviour of a task is described by a task mode definition.

A task is created as part of the creation and initialisation of a task mode location (see 4.1). It is called to belong to this task mode location. A task is terminated if its task mode location is destroyed (see 10.2).

A thread is, at the CHILL programming level, always in one of two states: it is either active (i.e. under execution) or delayed (see 11.3). The transition from active to delayed is called the delaying of the thread; the transition from delayed to active is called the re-activation of the thread.

11.2 Mutual exclusion and regions

11.2.1 General

Regions (see 10.7) and region locations (see 3.15) are a means of providing threads with mutually exclusive indirect access to locations declared inside the regions or region locations by granted procedures. Static context conditions (see 11.2.2) are made such that accesses by a thread other than the imaginary outermost process to locations declared inside a region can be made only by calling procedures that are defined inside the region or region mode and granted by the region or region mode.

NOTE – The only situation when the locations declared inside a region or region location can be directly accessed by a thread T is when the region or the region location is entered and its reach-bound initialisations (if any) are performed by T.

A **procedure** name is said to denote a **critical** procedure (and it is a **critical procedure** name) if it is defined inside a region and granted by the region.

A **component procedure** name is said to denote a **critical** component procedure (and it is a **critical component procedure** name) if it is defined inside a region mode and granted by the region mode.

A region is said to be free if, and only if, control lies in none of its **critical** procedures or in the region itself performing reach-bound initialisations.

A region location is said to be free if, and only if, control lies in none of its **critical** component procedures or in the region location itself performing reach-bound initialisations.

The region will be locked (to prevent concurrent execution) if:

- The region is entered (note that because regions are not surrounded by a block, no concurrent attempts can be made to enter the region).

- A **critical** procedure of the region is called.
- A process, delayed in the region, is re-activated.

The region location will be locked (to prevent concurrent execution) if:

- The region location is entered.
- A critical component procedure of the region location is called.
- A thread, which is delayed in the region location, is re-activated.

The region will be released, becoming free again, if:

- The region is left after having its reach-bound initialisations performed.
- A **critical** procedure returns.
- A **critical** procedure executes an action that causes the executing process to become delayed (see 11.3). In the case of dynamically nested **critical** procedure calls, only the latest locked region will be released.
- A process executing a **critical** procedure terminates. In the case of dynamically nested **critical** procedure calls, all the regions locked by the process will be released.

The region location will be released, becoming free again, if:

- The region location is left after having its reach-bound initialisations performed.
- A critical component procedure returns.
- A critical component procedure executes an action that causes the executing thread to become delayed (see 11.3). In the case of dynamically nested critical procedure calls, only the latest locked region will be released.
- A thread executing a critical component procedure terminates. In the case of dynamically nested critical component procedure calls, all the region locations locked by the thread will be released.

If, while the region is locked, a thread attempts to call one of its **critical** procedures or a thread delayed in the region is re-activated, the thread is suspended until the region is released (note that the thread remains active in the CHILL sense).

If, while the region location is locked, a thread attempts to call one of its **critical** component procedures or a thread delayed in the region location is re-activated, the thread is suspended until the region location is released (note that the thread remains active in the CHILL sense).

When a region is released and more than one thread has been suspended while attempting to call one of its **critical** procedures or to be re-activated in one of its **critical** procedures, only one thread will be selected to lock the region according to an implementation defined scheduling algorithm.

When a region location is released and more than one thread has been suspended while attempting to call one of its **critical** component procedures or to be re-activated in one of its **critical** component procedures, only one thread will be selected to lock the region location according to an implementation defined scheduling algorithm.

11.2.2 Regionality

To allow for checking statically that a location declared in a region can only be accessed by calling **critical** procedures or by entering the region for performing reach-bound initialisations, the following static context conditions are enforced:

- the **regionality** requirements mentioned in the appropriate sections (assignment action, procedure call, send action, result action, etc.);
- **intra-regional** procedures are not **general** (see 10.4);
- **critical** procedures are neither **general** nor **recursive** (see 10.4).

To allow for checking statically that a component location declared in a region location can only be accessed by calling **critical component** procedures or by entering the region location for performing reach-bound initialisations, the following static context conditions are enforced:

- the regionality requirements mentioned in the appropriate sections (assignment action, procedure call, send action, result action, etc.);
- intra-regional component procedures are not general (see 10.4);

- critical component procedures are neither general nor recursive (see 10.4);
- critical component procedures are also not **inline** (see 3.15).

A *location* and *procedure call* have a **regionality** which is **intra-regional** or **extra-regional**. A *value* has a **regionality** which is **intra-regional** or **extra-regional** or **nil**. These properties are defined as follows:

1) **Location**

A *location* is **intra-regional** if, and only if, any of the following conditions are fulfilled:

- It is an *access name* that is either:
  - a <u>*location*</u> *name* declared textually inside a *region* or *spec region* and not defined in a *formal parameter* of a **critical** procedure;
  - a <u>*location*</u> *name* declared textually inside a *region mode* and not defined in a *formal parameter* of a **critical** component procedure;
  - a <u>*loc-identity*</u> *name*, where the *location* in its declaration is **intra-regional** or that is defined in a *formal parameter* of an **intra-regional** procedure;
  - a <u>*loc-identity*</u> *name*, where the *location* in its declaration is **intra-regional** or that is defined in a *formal parameter* of an **intra-regional** component procedure;
  - a <u>*location enumeration*</u> *name*, where the <u>*array*</u> *location* or <u>*string*</u> *location* in the associated *do action* is **intra-regional**;
  - a <u>*location do-with*</u> *name*, where the <u>*structure*</u> *location* in the associated *do action* is **intra-regional**.
- It is a *dereferenced bound reference*, where the <u>*bound reference*</u> *primitive value* in it is **intra-regional**.
- It is a *dereferenced free reference*, where the <u>*free reference*</u> *primitive value* in it is **intra-regional**.
- It is a *dereferenced row*, where the <u>*row*</u> *primitive value* in it is **intra-regional**.
- It is an *array element* or *array slice*, where the <u>*array*</u> *location* in it is **intra-regional**.
- It is a *string element* or *string slice*, where the <u>*string*</u> *location* in it is **intra-regional**.
- It is a *structure field*, where the <u>*structure*</u> *location* in it is **intra-regional**.
- It is a *location procedure call*, where in the <u>*location*</u> *procedure call* a <u>*procedure*</u> *name* is specified which is **intra-regional**.
- It is a <u>*location*</u> *built-in routine call*, that the CHILL definition or the implementation specifies to be **intra-regional**.
- It is a *location conversion*, where the <u>*static mode*</u> *location* in it is **intra-regional**.

A *location* which is not **intra-regional** is **extra-regional**.

2) **Value**

A *value* has a **regionality** depending on its class. If it has the M-derived class or the **all** class or the **null** class, then it has **regionality nil**. Otherwise it has the M-value class or the M-reference class and it has a **regionality** depending on the mode M as follows:

If the *value* has the M-value class and M does not have the **referencing property**, then the **regionality** is **nil**; otherwise the *value* is an *operand-7* (and has the **referencing property**) or a *conditional expression*:

If it is a *primitive value* then:

- If it is a *location contents* that is a *location*, then it is that of the *location*.
- If it is a *component location contents* that is a *component location*, then it is that of the component *location*.
- If it is a *value name*, then:
  - if it is a <u>*synonym*</u> *name*, then it is that of the <u>*constant*</u> *value* in its definition;

   – if it is a <u>value do-with</u> *name*, then it is that of the <u>structure</u> *primitive value* in the associated do action;

   – if it is a <u>value receive</u> *name*, then it is **extra-regional**.

- If it is a *tuple*, then if one of the *value* occurrences in it has **regionality** not **nil**, then it is that of that *value* (it does not matter which choice is made, see 5.2.5 static conditions); otherwise it is **nil**.
- If it is a *value array element* or a *value array slice*, then it is that of the <u>array</u> *primitive value* in it.
- If it is a *value structure field*, then it is that of the <u>structure</u> *primitive value* in it.
- If it is an *expression conversion*, then it is that of the *expression* in it.
- If it is a *value procedure call*, then it is that of the *procedure call* in it.
- If it is a *value component procedure call*, then it is that of the *component procedure call* in it.
- If it is a <u>value</u> *built-in routine call* that the CHILL definition or the implementation specifies to be **intra-regional** or **extra-regional**.

If it is a *referenced location*, then it is that of the *location* in it.

If it is a *conditional expression*, then if one of the *sub expression* occurrences in it has **regionality** not **nil**, then it is that of that *sub expression* (it does not matter which choice is made, see 5.3.2 static conditions); otherwise it is **nil**.

3) **Procedure name**

A <u>procedure</u> *name* is **intra-regional** if, and only if, it is defined inside a *region* or *spec region* and it is not **critical** (i.e. not granted by the region). Otherwise it is **extra-regional**.

A <u>component procedure</u> *name* is **intra-regional** if, and only if, it is defined inside a *region mode* and it is not **critical** (i.e. not granted by the region mode). Otherwise it is **extra-regional**.

4) **Procedure call**

A *procedure call* is **intra-regional** if it contains a <u>procedure</u> *name* which is **intra-regional**; otherwise it is **extra-regional**.

A *component procedure call* is **intra-regional** if it contains a <u>component procedure</u> *name* which is intra-regional; otherwise it is **extra-regional**.

A *value* is **regionally safe** for a non-terminal (used only for *location*, *procedure call* and <u>procedure</u> *name*) if, and only if:

- the non-terminal is **extra-regional** and the *value* is not **intra-regional**;
- the non-terminal is **intra-regional** and the *value* is not **extra-regional**;
- the non-terminal has **regionality nil**.

11.3 Delaying of a thread

An active thread may become delayed by executing one of the following actions:

- delay action (see 6.16);
- delay case action (see 6.17);
- receive signal case action (see 6.19.2);
- receive buffer case action (see 6.19.3);
- send buffer action (see 6.18.3);
- call action to a component procedure of a region location (see 3.15.3);
- call action to a component procedure of a task location in case there is not enough storage to perform step 6) 2) in 6.7 (see 3.15.4).

When a thread becomes delayed while its control lies within a **critical** procedure or a **critical component** procedure, the associated region is released. The dynamic context of the thread is retained until it is re-activated. The thread then attempts to lock the region or the region location again, which may cause it to be suspended.

11.4 Re-activation of a thread

A delayed thread may become re-activated if it is time supervised and a time interrupt occurs (see clause 9). It may also become re-activated if another thread executes one of the following actions:

- continue action (see 6.15);
- send signal action (see 6.18.2);
- send buffer action (see 6.18.3);
- receive buffer case action (see 6.19.3);
- release of a region location (see 3.15.3);
- at the beginning of the execution of an externally called component procedure of a task location (see 3.15.4).

When a thread, while having locked a region or region location, re-activates another thread, it remains active, i.e. it will not release the region or region location at that point.

11.5 Signal definition statements

syntax:

<signal definition statement> ::= *(1)*
SIGNAL <*signal definition*> { , <*signal definition*> }* *;* *(1.1)*

<*signal definition*> *::=* *(2)*
<*defining occurrence*> [= (<*mode*> { , <*mode*> }*)] [**TO** <<u>*process*</u> *name*>] *(2.1)*

semantics: A signal definition defines a composing and decomposing function for values to be transmitted between processes. If a signal is sent, the specified list of values is transmitted. If no process is waiting for the signal in a receive case action, the values are kept until a process receives the values.

static properties: A *defining occurrence* in a *signal definition* defines a **signal** name.

A **signal** name has the following properties:

- It has an optional list of modes attached, that are the modes mentioned in the *signal definition*.
- It has an optional **process** name attached that is the <u>*process*</u> *name* specified after **TO**.

static conditions: No *mode* in a *signal definition* may have the **non-value property**.

examples:

15.27 **SIGNAL** *initiate* = (*INSTANCE*),
terminate; *(1.1)*

12 General semantic properties

12.1 Mode rules

12.1.1 Properties of modes and classes

12.1.1.1 Read-only property

Informal

A mode has the **read-only property** if it is a **read-only** mode or contains a component or a sub-component, etc. which is a **read-only** mode.

Definition

A mode has the **read-only property** if, and only if, it is:

- an array mode with an **element** mode that has the **read-only property**;
- a structure mode where at least one of its **field** modes has the **read-only property**, where the field is not a **tag** field with an implicit **read-only** mode of a **parameterised structure** mode;
- a **read-only** mode.

12.1.1.2 Parameterisable modes

Informal

A mode is **parameterisable** if it can be parameterised.

Definition

A mode is **parameterisable** if, and only if, it is:

- a string mode;
- an array mode;
- a **parameterisable variant** structure mode.

12.1.1.3 Referencing property

Informal

A mode has the **referencing property** if it is a reference mode or contains a component or a sub-component, etc. which is a reference mode.

Definition

A mode has the **referencing property** if, and only if, it is:

- a reference mode;
- an array mode with an **element** mode that has the **referencing property**;
- a structure mode where at least one of its **field** modes has the **referencing property**.

12.1.1.4 Tagged parameterised property

Informal

A mode has the **tagged parameterised property** if it is a **tagged parameterised** structure mode or contains a component or a sub-component etc. which is a **tagged parameterised** structure mode.

Definition

A mode has the **tagged parameterised property** if, and only if, it is:

- an array mode with an **element** mode which has the **tagged parameterised property**;
- a structure mode where at least one of its **field** modes has the **tagged parameterised property**;
- a **tagged parameterised** structure mode.

12.1.1.5 Non-value property

Informal

A mode has the **non-value property** if no expression or primitive value denotation exists for the mode.

Definition

A mode has the **non-value property** if, and only if, it is:

- an event mode, a buffer mode, an access mode, an association mode or a text mode;
- an array mode with an **element** mode that has the **non-value property**;
- a structure mode where at least one of its **field** modes has the **non-value property**;
- a **not_assignable** moreta mode;
- an **abstract** moreta mode;
- a moreta mode where at least one of its components has the **non-value property**.

12.1.1.6 Root mode

Any mode M has a **root** mode defined as:

- if M is not a discrete range mode nor a floating point range mode;
- the **parent** mode of M, if M is a discrete range mode or a floating point range mode.

Any M-value class or M-derived class has a **root** mode which is the **root** mode of M.

12.1.1.7 Resulting class

Given two **compatible** classes (see 12.1.2.16), where the first one is either the **all** class, an M-value class or an M-derived class, where M and N are either a discrete mode, a floating point mode, a powerset mode or a string mode, the **resulting class** is defined as:

- the **resulting class** of the M-value class and the N-value class is the R-value class;
- the **resulting class** of the M-value class and the N-derived class or the **all** class is the P-value class;
- the **resulting class** of the M-derived class and the N-derived class is the R-derived class;
- the **resulting class** of the M-derived class and the **all** class is the P-derived class;
- the **resulting class** of the **all** class and the **all** class is the **all** class,

where R is the **resulting** mode of M and N, and P is the **root** mode of M.

Given two **similar** modes M and N, the **resulting** mode R is defined as:

- if the **root** mode of one is a **fixed** string mode and the other one is a **varying** string mode, then it is the **root** mode of the one (between M and N) whose **root** mode is a **varying** string mode;
- otherwise it is P.

Given a list C_i of pairwise **compatible** classes (i=1,…,n), the **resulting class** of the list of classes is recursively defined as the **resulting class** of the **resulting class** of the list C_i (i=1,…,n–1) and the class C_n if n > 1; otherwise as the **resulting class** of C_1 and C_1.

12.1.2 Relations on modes and classes

12.1.2.1 General

In the following subclauses, the compatibility relations are defined between modes, between classes, and between modes and classes. These relations are used throughout the document to define static conditions.

The compatibility relations themselves are defined in terms of other relations which are mainly used in this clause for the above mentioned purpose.

12.1.2.2 Equivalence relations on modes

Informal

The following equivalence relations play a role in the formulation of the compatibility relations:

- Two modes are **similar** if they are of the same kind, i.e. they have the same hereditary properties.
- Two modes are **v-equivalent** (value-equivalent) if they are **similar** and also have the same **novelty**.
- Two modes are **equivalent** if they are **v-equivalent** and also possible differences in value representation in storage or minimum storage size are taken into account.
- Two modes are **l-equivalent** (location-equivalent) if they are **equivalent** and also have the same **read-only** specification.
- Two modes are **alike** if they are indistinguishable, i.e. if all operations that can be applied to objects of one of the modes can be applied to the other one as well, provided that **novelty** is not taken into account.
- Two modes are **novelty bound** if they are **alike** and have equal **novelty** specification.

Definition

In the following subclauses, the equivalence relations on modes are given in the form of a (partial) set of relations. The full equivalence algorithms are obtained by taking the symmetric, reflexive and transitive closure of this set of relations. The modes mentioned in the relations may be virtually introduced or dynamic. In the latter case, the complete equivalence check can only be performed at run time. Check failure of the dynamic part will result in the *RANGEFAIL* or *TAGFAIL* exception (see appropriate subclauses).

Checking two recursive modes for any equivalence, requires the checking of associated modes in the corresponding paths of the set of recursive modes by which they are defined. Equivalence between the modes holds if no contradiction is found. (As a consequence, a path of the checking algorithm stops successfully if two modes which have been compared before, are compared.)

12.1.2.3 The relation similar

Two modes are **similar** if and only if:

- they are integer modes;
- they are floating point modes;
- they are boolean modes;
- they are character modes;
- they are set modes such that:
  1) they define the same **number of values**;
  2) for each **set element** name defined by one mode there is a **set element** name defined by the other mode which has the same name string and the same representation value;
  3) they both are **numbered** set modes or both are **unnumbered** set modes;
- they are discrete range modes with **similar parent** modes;
- they are floating point range modes;
- one is a discrete range mode or a floating point range mode whose **parent** mode is **similar** to the other mode;

- they are powerset modes such that their **member** modes are **equivalent**;
- they are bound reference modes such that their **referenced** modes are **equivalent**;
- they are free reference modes;
- they are row modes such that their **referenced origin** modes are **equivalent**;
- they are procedure modes such that:
  1) they have the same number of **parameter specs** and corresponding (by position) **parameter specs** have **l-equivalent** modes and the same parameter attributes, if present;
  2) they both have or both do not have a **result spec**. If present, the **result specs** must have **l-equivalent** modes and the same attributes, if present;
  3) they have the same list of **exception** names;
  4) they have the same **recursivity**;
- they are instance modes;
- they are event modes such that they both have no **event length** or both have the same **event length**;
- they are buffer modes such that:
  1) they both have no **buffer length** or both have the same **buffer length**;
  2) they have **l-equivalent buffer element** modes;
- they are association modes;
- they are access modes such that:
  1) they both have no **index** mode or both have **index** modes which are **equivalent**;
  2) at least one has no **record** mode, or both have **record** modes that are **l-equivalent** and that are both **static record** modes or both **dynamic record** modes;
- they are text modes such that:
  1) they have the same **text length**;
  2) they have **l-equivalent text record** modes;
  3) they have **l-equivalent access** modes;
- they are duration modes;
- they are absolute time modes;
- they are string modes such that their **element** modes are **equivalent**;
- they are array modes such that:
  1) their **index** modes are **v-equivalent**;
  2) their **element** modes are **equivalent**;
  3) their **element layouts** are **equivalent**;
  4) they have the same **number of elements**. This check is dynamic if one or both modes is (are) dynamic. Check failure will result in the *RANGEFAIL* exception;
- they are structure modes which are not **parameterised** structure modes such that:
  1) in the strict syntax, they have the same number of *fields* and corresponding (by position) *fields* are **equivalent**;
  2) if they are both **parameterisable variant** structure modes, their lists of classes must be **compatible**;
- they are **parameterised** structure modes such that:
  1) their **origin variant** structure modes are **similar**;
  2) their corresponding (by position) values are the same. This check is dynamic if one or both modes is (are) dynamic. Check failure will result in the *TAGFAIL* exception.

12.1.2.4 The relation v-equivalent

Two modes are **v-equivalent** if, and only if, they are **similar** and have the same **novelty**.

12.1.2.5 The relation equivalent

Two modes are **equivalent** if, and only if, they are **v-equivalent** and:

- if one is a discrete range mode, the other must also be a discrete range mode and both **upper bounds** must be equal and both **lower bounds** must be equal;
- if one is a floating point range mode, the other must also be a floating point range mode and both **upper bounds** must be equal and both **lower bounds** must be equal and they must have the same **precision**;
- if one is a **fixed** string mode, the other one must also be a **fixed** string mode, and they must have the same **string length**. This check is dynamic in the case that one or both modes is (are) dynamic. Check failure will result in the *RANGEFAIL* exception;
- if one is a **varying** string mode, the other one must also be a **varying** string mode, and they must have the same **string length**. This check is dynamic in the case that one or both modes is (are) dynamic. Check failure will result in the *RANGEFAIL* exception.

12.1.2.6 The relation l-equivalent

Two modes are **l-equivalent** if, and only if, they are **equivalent** and if one is a **read-only** mode, the other must also be a **read-only** mode, and:

- if they are bound reference modes, their **referenced** modes must be **l-equivalent**;
- if they are row modes, their **referenced origin** modes must be **l-equivalent**;
- if they are array modes, their **element** modes must be **l-equivalent**;
- if they are structure modes which are not **parameterised** structure modes, corresponding (by position) *fields* in the strict syntax must be **l-equivalent**; if they are **parameterised** structure modes, their **origin variant** structure modes must be **l-equivalent**.

12.1.2.7 The relations equivalent and l-equivalent for fields

Two *fields* (both *fields* in the context of two given structure modes) are: 1. **equivalent**, 2. **l-equivalent** if, and only if, both *fields* are *fixed fields* which are: 1. **equivalent**, 2. **l-equivalent** or both are *alternative fields* which are: 1. **equivalent**, 2. **l-equivalent**.

The relations **equivalent** and **l-equivalent** are recursively defined for corresponding *fixed fields*, *variant fields*, *alternative fields* and *variant alternatives*, respectively, in the following way:

- *Fixed fields* and *variant fields:*
  1) Both *fixed fields* or *variant fields* must have **equivalent field layout**.
  2) Both **field** modes must be: 1. **equivalent**, 2. **l-equivalent**.
- *Alternative fields:*
  1) Both *alternative fields* have *tag lists* or both have no *tag lists*. In the former case, the *tag lists* must have the same number of **tag field** names and corresponding (by position) **tag field** names must denote corresponding *fixed fields*.
  2) Both must have the same number of *variant alternatives* and corresponding (by position) *variant alternatives* must be: 1. **equivalent**, 2. **l-equivalent**.
  3) Both must have no **ELSE** specified or both must have **ELSE** specified. In the latter case, the same number of *variant fields* must follow and corresponding (by position) *variant fields* must be: 1. **equivalent**, 2. **l-equivalent**.
- *Variant alternatives:*
  1) Both *variant alternatives* must have the same number of *case label lists* and corresponding (by position) *case label lists* must either be both *irrelevant*, or both define the same set of values.

2) Both *variant alternatives* must have the same number of *variant fields* and corresponding (by position) *variant fields* must be: 1. **equivalent**, 2. **l-equivalent**.

12.1.2.8 The relation equivalent for layout

In the rest of the section, it will be assumed that each *pos* is of the form:

POS *(<number>,<start bit>,<length>)*

and that each *step* is of the form:

STEP *(<pos>,<step size>)*

Subclause 3.13.5 gives the appropriate rules to bring *pos* or *step* in the required form:

- *Field layout*:

  Two **field layouts** are **equivalent** if they are both **NOPACK**, or both **PACK**, or both *pos*. In the latter case the one *pos* must be **equivalent** to the other one (see below).

- *Element layout*:

  Two **element layouts** are **equivalent** if they are both **NOPACK**, both **PACK**, or both *step*. In the latter case the *pos* in the one *step* must be **equivalent** to the *pos* in the other one (see below) and *step size* must deliver the same values for the two **element layouts**.

- *Pos*:

  A *pos* is **equivalent** to another *pos* if, and only if, both *word* occurrences deliver the same value, both *start bit* occurrences deliver the same value and both *length* occurrences deliver the same value.

12.1.2.9 The relation alike

Two modes are **alike** if, and only if, they both are or both are not **read-only** modes and they both have **novelty nil** or both have the same **novelty** and:

- they are integer modes;
- they are boolean modes;
- they are character modes;
- they are **similar** set modes;
- they are discrete range modes with equal **upper bounds** and equal **lower bounds**;
- they are floating point range modes with equal **upper bounds**, equal **lower bounds** and equal **precision**;
- they are powerset modes such that their **member** modes are **alike**;
- they are bound reference modes such that their **referenced** modes are **alike**;
- they are free reference modes;
- they are row modes such that their **referenced origin** modes are **alike**;
- they are procedure modes such that:

  1) they have the same number of **parameter specs** and corresponding (by position) **parameter specs** have **alike** modes and the same parameter attributes, if present;

  2) they both have or both do not have a **result spec**. If present, the **result specs** must have **alike** modes and the same attributes, if present;

  3) they have the same list of **exception** names;

  4) they have the same **recursivity**;

- they are instance modes;
- they are event modes such that they both have no **event length** or both have the same **event length**;
- they are buffer modes such that:

   1) they both have no **buffer length** or both have the same **buffer length**;
   2) they have **buffer element** modes which are **alike**;
- they are association modes;
- they are access modes such that:
   1) they both have no **index** mode or both have **index** modes that are **alike**;
   2) at least one has no **record** mode or both have **record** modes that are **alike** and that are both **static record** modes or both **dynamic record** modes;
- they are text modes such that:
   1) they have the same **text length**;
   2) their **text record** modes are **alike**;
   3) their **access** modes are **alike**;
- they are duration modes;
- they are absolute time modes;
- they are string modes such that:
   1) their **element** modes are **alike**;
   2) they have the same **string length**;
   3) they both are **fixed** string modes or both are **varying** string modes;
- they are array modes such that:
   1) their **index** modes are **alike**;
   2) their **element** modes are **alike**;
   3) their **element layouts** are **equivalent**;
   4) they have the same **number of elements**;
- they are structure modes that are not **parameterised** structure modes such that:
   1) in the strict syntax they have the same number of *fields* and corresponding (by position) *fields* are **alike**;
   2) if they are both **parameterisable variant** structure modes, their lists of classes must be **compatible**;
- they are **parameterised** structure modes such that:
   1) their **origin variant** structure modes are **alike**;
   2) their corresponding (by position) values are the same.

12.1.2.10 The relation alike for fields

Two *fields* (both *fields* in the context of two given structure modes) are **alike** if, and only if, both *fields* are *fixed fields* which are **alike** or both are *alternative fields* which are **alike**.

The relation **alike** is recursively defined for corresponding *fixed fields*, *variant fields*, *alternative fields* and *variant alternatives*, respectively, in the following way:

- *Fixed fields* and *variant fields*:
   1) Both *fixed fields* or *variant fields* must have **equivalent field layout**.
   2) Both **field** modes must be **alike**.
   3) Both *fixed fields* or *variant fields* must have the same *name string* attached.

- *Alternative fields*:
  1) Both *alternative fields* have *tag lists* or both have no *tag lists*. In the former case, the *tag lists* must have the same number of **tag field** names and corresponding (by position) **tag field** names must denote corresponding *fixed fields*.
  2) Both must have the same number of *variant alternatives* and corresponding (by position) *variant alternatives* must be **alike**.
  3) Both must have no **ELSE** specified or both must have **ELSE** specified. In the latter case, the same number of *variant fields* must follow and corresponding (by position) *variant fields* must be **alike**.
- *Variant alternatives*:
  1) Both *variant alternatives* must have the same number of *case label lists* and corresponding (by position) *case label lists* must either be both *irrelevant*, or both define the same set of values.
  2) Both *variant alternatives* must have the same number of *variant fields* and corresponding (by position) *variant fields* must be **alike**.

12.1.2.11 The relation novelty bound

Informal

In a program, each **quasi** newmode must represent at most one **real** newmode. This is established as follows: when a *name string* is **bound** to both a **real** and a **quasi** *defining occurrence*, all the newmodes involved are paired. The relation **novelty bound** is then established between **novelties**.

Definition

The relation **novelty paired** applies between two modes and a reach. For each *name string* **bound** in a reach R to both a **real** and a **quasi** *defining occurrence*:

- if they are **synonym** names, then the **root** modes of their classes are **novelty paired** in R;
- if they are **location** or **loc-identity** names, then their location modes are **novelty paired** in R;
- if they are **procedure** names, then the modes of the **parameter specs** and **result spec**, if present, are **novelty paired** in R;
- if they are **process** names, then the modes of the **parameter specs** are **novelty paired** in R;
- if they are **signal** names, then the modes in the list of modes are **novelty paired** in R.

If two modes are **novelty paired** in a reach R, then:

- if they are powerset modes, their **member** modes are **novelty paired** in R;
- if they are bound reference modes, their **referenced** modes are **novelty paired** in R;
- if they are row modes, their **referenced origin** modes are **novelty paired** in R;
- if they are procedure modes, the modes of their **parameter specs** and **result spec**, if present, are **novelty paired** in R;
- if they are buffer modes, their **buffer element** modes are **novelty paired** in R;
- if they are access modes, their **index** modes, if present, and **record** modes, if present, are **novelty paired** in R;
- if they are text modes, their **index** modes, if present, are **novelty paired** in R;
- if they are array modes, their **index** modes and **element** modes are **novelty paired** in R;
- if they are **parameterised** structure modes, their **origin variant** structure modes are **novelty paired** in R;
- if they are **parameterisable variant** structure modes, their **field** modes and the modes of the classes in their list of classes are **novelty paired** in R;
- otherwise if they are structure modes, their **field** modes are **novelty paired** in R.

If two modes are **novelty paired** in a reach R and their **novelties** are not equal, then the **real** and **quasi novelties** of the modes are **novelty bound** to each other in R.

Two **novelties** are considered the same if they are:

- the same **real novelty**; or
- a **real novelty** and a **quasi novelty** that are **novelty bound**.

12.1.2.12 The relation read-compatible

Informal

The relation **read-compatible** is relevant for **equivalent** modes. A mode M is said to be **read-compatible** with a mode N if it or its possible (sub-)components have equal or more restrictive **read-only** specifications and, if they are reference modes, refer to **l-equivalent** locations. This relation is therefore non-symmetric.

Example:

READ REF READ *CHAR* is **read-compatible** with **REF READ** *CHAR*

Definition

A mode M is said to be **read-compatible** with a mode N (a non-symmetric relation) if, and only if, M and N are **equivalent** and, if N is a **read-only** mode, then M must also be a **read-only** mode and further:

- if M and N are bound reference modes, the **referenced** mode of M must be **l-equivalent** with the **referenced** mode of N;
- if M and N are row modes, the **referenced origin** mode of M must be **l-equivalent** with the **referenced origin** mode of N;
- if M and N are array modes, the **element** mode of M must be **read-compatible** with the **element** mode of N;
- if M and N are structure modes which are not **parameterised** structure modes, any **field** mode of M must be **read-compatible** with the corresponding **field** mode of N. If M and N are **parameterised** structure modes, the **origin variant** structure mode of M must be **read-compatible** with the **origin variant** structure mode of N.

12.1.2.13 The relations dynamic equivalent and read-compatible

Informal

The relations: 1. **dynamic equivalent**, 2. **dynamic read-compatible**, are relevant only for modes that can be dynamic, i.e. string, array and **variant** structure modes. A **parameterisable** mode M is said to be: 1. **dynamic equivalent**, 2. **dynamic read-compatible** with a (possibly dynamic) mode N, if there exists a dynamically parameterised version of M which is: 1. **equivalent**, 2. **Read-compatible** with N.

Definition

A mode M is: 1. **dynamic equivalent** to a mode N, 2. **dynamic read-compatible** with a mode N (a non-symmetric relation) if, and only if, one of the following holds:

- M and N are string modes such that M(p) is: 1. **equivalent**, 2. **read-compatible** with N, where p is the (possibly dynamic) length of N. The value p must not be greater than the **string length** of M. This check is dynamic if N is a dynamic mode. Check failure will result in a *RANGEFAIL* exception;
- M and N are array modes such that M(p) is: 1. **equivalent**, 2. **read-compatible** with N, where p is such that *NUM* (p) – *LOWER* (M) + 1 is the (possibly dynamic) **number of elements** of N. The value p must not be greater than the **upper bound** of M. This check is dynamic if N is a dynamic mode. Check failure will result in a *RANGEFAIL* exception;
- M is a **parameterisable variant** structure mode and N is a **parameterised** structure mode such that M($p_1,\ldots,p_n$) is: 1. **equivalent**, 2. **read-compatible** with N, where $p_1,\ldots,p_n$ denote the list of values of N.

12.1.2.14 The relation restrictable

Informal

The relation **restrictable** is relevant for **equivalent** modes with the **referencing property**. A mode M is said to be **restrictable** to a mode N if it or its possible (sub-)components refer to locations with equal or more restrictive **read-only** specification than those referenced by N. This relation is therefore non-symmetric.

Example:

REF READ *INT* is **restrictable** to **REF** *INT***STRUCT** *(P **REF READ** BOOL)* is **restrictable** to **STRUCT** *(Q **REF** BOOL)*

Definition

A mode M is **restrictable** to a mode N (a non-symmetric relation) if, and only if, M and N are **equivalent** and further:

- if M and N are bound reference modes, the **referenced** mode of M must be **read-compatible** with the **referenced** mode of N;
- if M and N are row modes, the **referenced origin** mode of M must be **read-compatible** with the **referenced origin** mode of N;
- if M and N are array modes, the **element** mode of M must be **restrictable** to the **element** mode of N;
- if M and N are structure modes, each **field** mode of M must be **restrictable** to the corresponding **field** mode of N.

12.1.2.15 Compatibility between a mode and a class

- Any mode M is **compatible** with the **all** class.
- A mode M is **compatible** with the **null** class if, and only if, M is a reference mode or a procedure mode or an instance mode.
- A mode M is **compatible** with the N-reference class if, and only if, M is a reference mode and one of the following conditions is fulfilled:
  1) N is a static non-moreta mode and M is a bound reference mode whose **referenced** mode is **read-compatible** with N;
  2) N is a static moreta mode and M is a bound reference mode REF-MM and either MM = N or N is a successor of MM;
  3) N is a static mode and M is a free reference mode;
  4) M is a row mode whose **referenced origin** mode is **dynamic read-compatible** with N.
- A mode M is **compatible** with the N-derived class if, and only if, M and N are **similar**.
- A mode M is **compatible** with the N-value class if, and only if, one of the following holds:
  1) if M does not have the **referencing property**, M and N must be **v-equivalent**;
  2) if M does have the **referencing property**, M must be **restrictable** to N.

12.1.2.16 Compatibility between classes

- Any class is **compatible** with itself.
- The **all** class is **compatible** with any other class.
- The **null** class is **compatible** with any M-reference class.
- The **null** class is **compatible** with the M-derived class or M-value class if, and only if, M is a reference mode, procedure mode or instance mode.
- The M-reference class is **compatible** with the N-reference class if, and only if, M and N are **equivalent**. If M and/or N is (are) a dynamic mode, the dynamic part of the equivalence check is ignored, i.e. no exceptions can occur.
- The M-reference class is **compatible** with the N-value class if, and only if, N is a reference mode and one of the following conditions is fulfilled:
  1) M is a static mode and N is a bound reference mode whose **referenced** mode is **equivalent** to M;
  2) M is a static mode and N is a free reference mode;
  3) N is a row mode whose **referenced origin** mode is **dynamic equivalent** with M;

- the M-derived class is **compatible** with the N-derived class or N-value class if, and only if, M and N are **similar**;
- the M-value class is **compatible** with the N-value class if, and only if, M and N are **v-equivalent**.

Two lists of classes are **compatible** if, and only if, both lists have the same number of classes and corresponding (by position) classes are **compatible**.

12.1.3 Definitions for moreta modes

If M is a moreta mode, then:

M_S is the specification part of M (also the set of components in this part);
M_B is the body part of M (also the set of components in this part);
M_P is the set of public components of M_S defined directly in M_S;
M_{P+} is the set of all public components of M_S (including the inherited ones);
M_I is the set of internal components of M_S;
M_{I+} is the set of all internal components of M_S (including the inherited ones);
M_R is the set of private components of M_B;
M_{R+} is the set of all private components of M_S (including the inherited ones);
M_{CD} is the set of constructors and destructors of M_S;
M_{inv} is the invariant of M_S;
M_O is the set of components (logically) contained in a location of mode M.

If P is a component procedure of a moreta mode, then:

PS is the specification part of P;
PD is the (complete) definition of P;
PPre is the precondition of P;
PPost is the postcondition of P;
PE is the set of exceptions specified in PS.

If X is a procedure or a moreta mode then:

attr(X, A)	$\equiv$ X contains the attribute A, e.g. attr(P, INLINE);
prop(X, P)	$\equiv$ X has the property P, e.g. prop(P, assignable);
GRANTed	$\equiv$ explicitly exported;
granted	$\equiv$ GRANTed $\vee$ implicitly exported.

Qualified names of components of moreta modes and moreta locations.

If M is the simple name string of a moreta mode, L is the simple name string of a moreta location, and C is the simple name of a component of M or of a public component of L, then the name M.C or L.C can be used as a unique name for C in order to distinguish C from components with the same simple name string. If necessary the qualified name is assumed.

A moreta mode DM is a direct successor of a moreta mode BM if, and only if, BM is mentioned in the inheritance clause of DM.

A moreta mode DM is a successor of a moreta mode BM if, and only if, DM is a direct successor of BM or if DM is a successor of a direct successor of BM.

The relation “predecessor” is the inverse of “successor”.

12.2 Visibility and name binding

The definition of visibility and name binding is based on the following terminology:

- *name string*: denotes a terminal string that has attached a **canonical** name string (see 2.7) and visibility properties;
- name: denotes a *simple name string* associated with the *defining occurrence* that has created it (see 10.1);

- *name*: denotes an applied occurrence of a name (with a possibly prefixed name string).

12.2.1 Degrees of visibility

The binding rules are based on the visibility of *name strings* in the reaches of a program. Within a reach, each *name string* has one of the following degrees of visibility.

Table 1 – Degrees of visibility

Visibility	Properties (informal)
directly visible	*Name string* is **visible** by creation, granting or seizing or inheritance from spec to body.
indirectly visible	*Name string* is predefined or inherited via block nesting.
invisible	*Name string* may not be applied.
publicly visible	*Name string* is name of a public component of a *moreta mode* and is used in a moreta component name, or name string is name of a component of a moreta mode M and is used in a moreta component name which occurs inside M or any successor of M.

A *name string* is said to be **visible** in a reach if it is either **directly visible** or **indirectly visible** in that reach. Otherwise the *name string* is said to be **invisible** in that reach. The program structuring statements and visibility statements determine uniquely to which visibility class each *name string* belongs.

When a *name string* is **visible** in a reach, it can be **directly linked** to another *name string* in another reach, or **directly linked** to a *defining occurrence* in the program. The rules for **direct linkage** are in 12.2.3. Notice that any application of a rule introduces a new **direct linkage** for a *name string*.

Based on **direct linkage**, the notion of (not necessarily **direct**) **linkage** is defined as follows:

A *name string* N_1, **visible** in reach R_1, is said to be **linked** to *name string* N_2 in reach R_2 or to *defining occurrence* D, if, and only if, one of the following conditions holds:

- N_1 in R_1 is **directly linked** to N_2 in R_2 or to D. However, if N_1 is **directly linked** to more than one *defining occurrence* in R_1, then all but one of these *defining occurrences* are superfluous, and N_1 is **linked** to an arbitrary one of them in R_1. This does not apply if N_1 is the name string of a simple guarded procedure specification statement in a moreta mode specification.
- N_1 in R_1 is **directly linked** to some N in some R, and N in R is **linked** to N_2 in R_2 or to D.

12.2.2 Visibility conditions and name binding

In each reach of a program, the following conditions must be satisfied:

- If a *name string* is **visible** in a reach and has more than one **direct linkage**, then it must be **linked** to exactly one **real** *defining occurrence* and one **quasi** *defining occurrence*, or to exactly one **real** *defining occurrence* in a **simple** guarded procedure specification statement and exactly one **real** defining occurrence in a corresponding **simple** guarded procedure definition statement.

A *name string* NS, **visible** in reach R, is said to be **bound** in R to several *defining occurrences* according to the following rules:

- If NS is **visible** in R, NS is **bound** to the *defining occurrences* to which it is **linked** in R (as a **visible** *name string*). If it is **bound** both to a **quasi** *defining occurrence* and a **real** *defining occurrence*, then the **quasi** one is redundant and does not participate further to visibility and name binding (i.e. it is not seized, granted nor inherited).
- Otherwise NS is not **bound** in R.

static condition: The *name string* attached to each *name* directly enclosed in a reach must be **bound** in that reach.

binding of names: A *name* N with attached *name string* NS in a reach R is **bound** to the *defining occurrences* to which NS is **bound** in R.

12.2.3 Visibility in reaches

12.2.3.1 General

A *name string* is **directly visible** in a reach according to the following rules:

- The *name string* is seized into the reach (see 12.2.3.5).
- The *name string* is granted into the reach (see 12.2.3.4).
- There is a *defining occurrence* with that *name string* in the reach. In that case, the *name string* in the reach is **directly linked** to the *defining occurrence*. (Note that the *name string* may be **directly linked** to several *defining occurrences* in the reach.)
- Inside a constructor or destructor CD of a moreta mode M the name string of M is not hidden by the defining occurrence of the same name string in the definition of CD (but it may still be hidden by other defining occurrences of the same name string).

  At a place inside a constructor or destructor CD of a moreta mode M, where the name string S of M is not hidden, S denotes either M or CD depending on the context.
- The reach is a: 1. *module body*, 2. *region body* and the *name string* is **directly visible** in the reach of a **corresponding**: 1. *module spec*, 2. *region spec*. The *name string* is **directly linked** to the *name string* in the corresponding reach.

A *name string* which is not **directly visible** in a reach is **indirectly visible** in it, according to the following rules:

- The reach is a block, and the *name string* is **visible** in the directly enclosing reach. The *name string* is said to be inherited by the block, and is **directly linked** to the same *name string* in the directly enclosing reach.
- The reach is not a block in which the *name string* is inherited and the *name string* is a language (see III.2) or implementation defined *name string*. The *name string* is considered to be **directly linked** to a *defining occurrence* in the reach of the imaginary outermost process definition for its predefined meaning.

12.2.3.2 Visibility statements

syntax:

<visibility statement> ::=		*(1)*
	<grant statement>	*(1.1)*
|	*<seize statement>*	*(1.2)*

semantics: Visibility statements are only allowed in modulion reaches and moreta mode reaches, and control the visibility of the *name strings* mentioned in them.

static properties: A *visibility statement* has one or two **origin** reaches (see 10.2) and one or two **destination** reaches attached, defined as follows:

- If the *visibility statement* is a *seize statement*, its **destination** reach is the reach directly enclosing the *seize statement*, and its **origin** reaches are the reaches directly enclosing that reach.
- If the *visibility statement* is a *grant statement*, then its **origin** reach is the reach directly enclosing the *grant statement*, and its **destination** reaches are the reaches directly enclosing that reach.
- If the *visibility statement* is a *grant statement* in a *moreta mode specification*, then its **origin** reach is the reach directly enclosing the *grant statement*, and its **destination** reaches are not the reaches directly enclosing that reach.

12.2.3.3 Prefix rename clause

syntax:

<prefix rename clause> ::=		*(1)*
	(*<old prefix>* –> *<new prefix>*) ! *<postfix>*	*(1.1)*
<old prefix> ::=		*(2)*
	<prefix>	*(2.1)*
|	*<empty>*	*(2.2)*

<new prefix> ::= *(3)*
<prefix> *(3.1)*
| *<empty>* *(3.2)*

<postfix> ::= *(4)*
*<seize postfix> { , <seize postfix> }** *(4.1)*
| *<grant postfix> { , <grant postfix> }** *(4.2)*

derived syntax: A *prefix rename clause* where the *postfix* consists of more than one *seize postfix* (*grant postfix*) is derived syntax for several *prefix rename clauses*, one for each *seize postfix* (*grant postfix*), separated by commas, with the same *old prefix* and *new prefix*.

For example:

GRANT *(p –> q) ! a , b ;*

is derived syntax for:

GRANT *(p –> q) ! a , (p –> q) ! b ;*

semantics: Prefix rename clauses are used in visibility statements to express change of prefix in prefixed name strings that are granted or seized. (Since prefix rename clauses can be used without prefix changes - when both the *old prefix* and the *new prefix* are empty - they are taken as the semantic base for visibility statements).

static properties: A *prefix rename clause* has one or two **origin** reaches attached, which are the **origin** reaches of the *visibility statement* in which it is written.

A *prefix rename clause* has one or two **destination** reaches attached, which are the **destination** reaches of the *visibility statement* in which it is written.

A *postfix* has a set of *name strings* attached, which is the set of *name strings* attached to its *seize postfix* or the set of *name strings* attached to its *grant postfix*. These *name strings* are the postfix *name strings* of the *prefix rename clause*.

A *prefix rename clause* has a set of **old** *name strings* and a set of **new** *name strings* attached. Each postfix *name string* attached to the *prefix rename clause* gives both an **old** *name string* and a **new** *name string* attached to the *prefix rename clause*, as follows: the **new** *name string* is obtained by prefixing the postfix *name string* with the *new prefix*; the **old** *name string* is obtained by prefixing the postfix *name string* with the *old prefix*.

When a **new** *name string* and an **old** *name string* are obtained from the same postfix *name string*, the **old** *name string* is said to be the source of the **new** *name string*.

visibility rules: The **new** *name strings* attached to a *prefix rename clause* are **visible** in their **destination** reaches and are **directly linked** in those reaches to their sources in the **origin** reaches. If the *prefix rename clause* is part of a *seize statement* (*grant statement*) , those *name strings* are seized (granted) in their **destination** reach (reaches).

A *name string* NS is said to be **seizable** by modulion M directly enclosed in reach R if, and only if, it is **visible** in R and it is neither **linked** in R to any *name string* in the reach of M nor **directly linked** to the *defining occurrence* of a predefined *name string*.

A *name string* NS is said to be **grantable** by modulion M directly enclosed in reach R if, and only if, it is **visible** in the reach of M and it is neither **linked** in it to any *name string* in R nor **directly linked** in it to the *defining occurrence* of a predefined *name string*.

static conditions: If a *prefix rename clause* is in a *seize statement* directly enclosed in the reach of modulion M, then each of its **old** *name strings* must be:

- **bound** to several *defining occurrences* in the reach directly enclosing the reach of M; and
- **seizable** by M.

If a *prefix rename clause* is in a *grant statement* directly enclosed in the reach of modulion M, then each of its **old** *name strings* must be:

- **bound** to several *defining occurrences* in the reach of M; and
- **grantable** by M.

A *prefix rename clause* that occurs in a *grant statement* (*seize statement*) must have a *postfix* that is a *grant postfix* (*seize postfix*).

examples:

25.35 *(stack ! int -> stack)!* **ALL** *(1.1)*

12.2.3.4 Grant statement

syntax:

<grant statement> ::= *(1)*
GRANT *<prefix rename clause>* { , *<prefix rename clause>* }* *;* *(1.1)*
| **GRANT** *<grant window>* [*<prefix clause>*] *;* *(1.2)*

<grant window> ::= *(2)*
<grant postfix> { , *<grant postfix>* }* *(2.1)*

<grant postfix> ::= *(3)*
<name string> [(*<formal parameter list>*) [[**RETURNS**] (*<result spec>*)]] *(3.1)*
| *<newmode name string>* *<forbid clause>* *(3.2)*
| [*<prefix>* !] **ALL** *(3.3)*

<prefix clause> ::= *(4)*
PREFIXED [*<prefix>*] *(4.1)*

<forbid clause> ::= *(5)*
FORBID { *<forbid name list>* | **ALL** } *(5.1)*

<forbid name list> ::= *(6)*
(*<field name>* { , *<field name>* }*) *(6.1)*

semantics: Grant statements are a means of extending the visibility of name strings in a modulion reach into the directly enclosing reaches. **FORBID** can be specified only for **newmode** names which are structure modes. It means that all locations and values of that mode have fields which may be selected only inside the granting modulion, not outside.

The following visibility rules apply:

- If the *grant statement* contains *prefix rename clause(s)*, the *grant statement* has the effect of its *prefix rename clause(s)* (see 12.2.3.3).
- If the *grant statement* contains *grant windows*, it is shorthand notation for a set of *grant statements* with *prefix rename clauses* constructed as follows:
  – for each *grant postfix* in the *grant window*, there is a corresponding *grant statement*;
  – the *old prefix* in their *prefix rename clause* is empty;
  – the *new prefix* in their *prefix rename clause* is the *prefix* attached to the *prefix clause* in the *grant statement*, or it is empty if there is no *prefix clause* in the original *grant statement*;
  – the *postfix* in the *prefix rename clause* is the corresponding *postfix* in the *grant window*.
- The notation **FORBID ALL** is shorthand notation for forbidding all the *field names* of the **newmode** name (see 12.2.5).
- If a *prefix rename clause* in a *grant statement* has a *grant postfix* which contains a *prefix* and **ALL**, then it is of the form:

  (OP–>NP) ! P ! **ALL**

  where *OP* and *NP* are the possibly empty *old prefix* and *new prefix*, respectively, and *P* is the *prefix* in the *grant postfix*. The *prefix rename clause* is then shorthand notation for a clause of the form:

  (OP ! P–>NP ! P) ! **ALL**

static properties: A *prefix clause* has a *prefix* attached, defined as follows:

- If the *prefix clause* contains a *prefix*, then that *prefix* is attached.

- Otherwise the attached *prefix* is a *simple prefix* whose *name string* is determined as follows:
  - if the reach directly enclosing the *prefix* is a *module* or *region*, then the *name string* is the same as the one of the **module** name or **region** name of that modulion;
  - if the reach directly enclosing the *prefix* is a *spec region* or *spec module*, then the name string is the name string in front of **SPEC**.

A *grant postfix* has a set of *name strings* attached, defined as follows:

- If it is a *name string*, or contains a <u>newmode</u> *name string*, then the set contains only that *name string*.
- Otherwise, let *OP* be the (possibly empty) *old prefix* of the *prefix rename clause* in which the *grant postfix* is placed, the set contains all *name strings* of the form *OP ! N* (i.e. obtained by prefixing *N* with *OP*) for any *name string N* such that *OP ! N* is **visible** in the reach of the modulion in which the *grant postfix* is placed and **grantable** by this modulion.

static conditions: The <u>newmode</u> *name string* with *forbid clause* must be **visible** in the reach *R* of the modulion in which the *grant statement* is placed. The <u>newmode</u> *name string* must be **bound** in *R* to the *defining occurrence* of a newmode which must be a structure mode, and each *field name* in the *forbid name list* must be a **field** name of that mode. The newmode *defining occurrence* must be directly enclosed in *R*. All *field names* in a *forbid name list* must have different name strings.

If the *grant statement* is placed in the reach of a *region* or *spec region*, it must not grant a *name string* which is **bound** in that reach to the *defining occurrence* of:

- a **location** name; or
- a **loc-identity** name, where the *location* in its declaration is **intra-regional**; or
- a **synonym** name whose *value* is **intra-regional**.

The *prefix rename clause* in a *grant statement* must have a *grant postfix*.

If a *grant statement* contains a *prefix clause* which does not contain a *prefix*, then its directly enclosing modulion must not be a *context* and:

- if its directly enclosing modulion is a *module* or *region*, then it must be named (i.e. it must be headed by a *defining occurrence* followed by a colon);
- if its directly enclosing modulion is a *spec module* or a *spec region*, then it must be headed by a *simple name string*.

If the grant statement occurs immediately inside a moreta specification, then no prefixing must occur.

examples:

25.7	**GRANT** *(-> stack ! char) !* **ALL**;	*(1.1)*
6.44	*gregorian_date, julian_day_number*	*(2.1)*

12.2.3.5 Seize statement

syntax:

<seize statement> ::=	*(1)*
SEIZE *<prefix rename clause>* { , *<prefix rename clause>* }* *;*	*(1.1)*
| **SEIZE** *<seize window>* [*<prefix clause>*] *;*	*(1.2)*
<seize window> ::=	*(2)*
<seize postfix> { , *<seize postfix>* }*	*(2.1)*
<seize postfix> ::=	*(3)*
<name string> [(*<formal parameter list>*) [[**RETURNS**] (*<result spec>*)]]	*(3.1)*
| [*<prefix>* !] **ALL**	*(3.2)*

semantics: Seize statements are a means of extending the visibility of name strings in group reaches into the reaches of directly enclosed modulions.

The following visibility rules apply:

- If the *seize statement* contains *prefix rename clause(s)*, the *seize statement* has the effect of its *prefix rename clause(s)* (see 12.2.3.3).
- If the *seize statement* contains a *seize window*, it is shorthand notation for a set of *seize statements* with *prefix rename clauses* constructed as follows:
  - for each *seize postfix* in the *seize window*, there is a corresponding *seize statement*;
  - the *old prefix* in their *prefix rename clause* is the *prefix* attached to the *prefix clause* in the *seize statement*, or is empty if there is no *prefix clause* in the original *seize statement*;
  - the *new prefix* in their *prefix rename clause* is empty;
  - the *postfix* in their *prefix rename clause* is the corresponding *postfix* of the *seize window*.
- If a *prefix rename clause* in a *seize statement* has a *seize postfix* which contains a *prefix* and **ALL**, then it is of the form:

  (OP–>NP) ! P ! **ALL**

  where *OP* and *NP* are the possibly empty *old prefix* and *new prefix*, respectively, and *P* is the *prefix* in the *seize postfix*. The *prefix rename clause* is then shorthand notation for a clause of the form:

  (OP ! P–>NP ! P) ! **ALL**

static properties: A *seize postfix* has a set of *name strings* attached, defined as follows:

- If the *seize postfix* is a *name string*, the set contains only the *name string*.
- Else, if the *seize postfix* is **ALL**, let *OP* be the (possibly empty) *old prefix* of the *prefix rename clause* of which the *seize postfix* is part, the set contains all *name strings* of the form *OP ! S*, for any *name string S*, such that:
  - OP!S is **visible** in the reach directly enclosing the modulion in which the *seize statement* is placed; and
  - it is **seizable** by this modulion; and
  - it is **bound** to a **quasi** *defining occurrence* if this modulion has a *context* in front of it.

static conditions: The *prefix rename clause* in a *seize statement* must have a *seize postfix*.

If a *seize statement* contains a *prefix clause* which does not contain a *prefix*, then its directly enclosing modulion must not be a *context* and:

- if its directly enclosing modulion is a *module* or *region*, then it must be named (i.e. it must be headed by a *defining occurrence* followed by a colon);
- if its directly enclosing modulion is a *spec module* or a *spec region*, then it must be headed by a *simple name string*.

examples:

25.35 **SEIZE** *(stack ! int -> stack) !* **ALL**; *(1.1)*

12.2.4 Visibility of set element names

A *set element name* may occur only in the context of a *set literal*.

If a <u>set mode</u> *name* is specified in the *set literal*, then the *name string* of a *set element name* can be **bound** to a *set element name defining occurrence* in the mode of the class of the *set literal*.

Otherwise, a <u>set mode</u> *name* is not specified, and then the *name string* can be **bound** to a *set element name defining occurrence* only if it is not **visible** in the reach in which the *set literal* is placed.

12.2.5 Visibility of field names

Field names may occur only in the following contexts:

- *structure fields* and *value structure fields*;
- *labelled structure tuples*;

- *forbid clauses* in *grant statements*.

Note that a *field name* may not occur in a *grant postfix* or in a *seize postfix*.

In each of these cases, the *name string* of the *field name* can be **bound** to a *field name defining occurrence* in the mode M or in the **defining** mode of M, obtained as follows:

- M is the mode of the <u>*structure*</u> *location* or (**strong**) <u>*structure*</u> *primitive value*;
- M is the mode of the *structure tuple*;
- M is the mode of the *defining occurrence* to which the <u>*newmode*</u> *name string* is **bound** in the reach in which the *forbid clause* is placed.

However, if the **novelty** of M is a *defining occurrence* that defines a **newmode** name that has been granted by a *grant statement* in a modulion as a *grant postfix* with a *forbid clause*, then the field names mentioned in the forbid name list are only **visible**:

- in the group of the granting modulion;
- if the **novelty** of M is **novelty bound** to a **quasi novelty** N, then in the group of the reach in which N is directly enclosed;
- if the modulion is a *module spec* or *region spec*, then in the reach of the **corresponding** modulion.

Outside these reaches, the *field names* mentioned in the *forbid name list* are **invisible** and cannot be used.

12.3 Case selection

syntax:

<case label specification> ::=		*(1)*
	<case label list> { , *<case label list>* }*	*(1.1)*
<case label list> ::=		*(2)*
	(*<case label>* { , *<case label>* }*)	*(2.1)*
	| *<irrelevant>*	*(2.2)*
<case label> ::=		*(3)*
	<<u>discrete literal</u> expression>	*(3.1)*
	| *<literal range>*	*(3.2)*
	| *<<u>discrete mode</u> name>*	*(3.3)*
	| **ELSE**	*(3.4)*
<irrelevant> ::=		*(4)*
	(∗)	*(4.1)*

semantics: Case selection is a means of selecting an alternative from a list of alternatives. The selection is based upon a specified list of selector values. Case selection may be applied to:

- alternative fields (see 3.13.4), in which case a list of variant fields is selected;
- labelled array tuples (see 5.2.5), in which case an array element value is selected;
- conditional expressions (see 5.3.2), in which case an expression is selected;
- case action (see 6.4), in which case an action statement list is selected.

In the first, third and fourth situations, each alternative is labelled with a case label specification; in the labelled array tuple, each value is labelled with a case label list. For ease of description, the case label list in the labelled array tuple will be considered in this subclause as a case label specification with only one case label list occurrence.

Case selection selects that alternative which is labelled by the case label specification which matches the list of selector values. (The number of selector values will always be the same as the number of case label list occurrences in the case label specification.) A list of values is said to match a case label specification if, and only if, each value matches the corresponding (by position) case label list in the case label specification.

A value is said to match a case label list if, and only if:

- the case label list consists of case labels and the value is one of the values explicitly indicated by one of the case labels or implicitly indicated in the case of **ELSE**;
- the case label list consists of *irrelevant*.

The values explicitly indicated by a case label are the values delivered by any *discrete literal expression*, or defined by the *literal range* or *discrete mode name*. The values implicitly indicated by **ELSE** are all the possible selector values which are not explicitly indicated by any associated case label list (i.e. belonging to the same selector value) in any case label specification.

static properties:

- An *alternative fields* with *case label specification*, a *labelled array tuple*, a *conditional expression*, or a *case action* has a list of case label specifications attached, formed by taking the *case label specification* in front of each *variant alternative*, *value* or *case alternative*, respectively.
- A *case label* has a class attached, which is, if it is a *discrete literal expression*, the class of the *discrete literal expression*; if it is a *literal range*, the **resulting class** of the classes of each *discrete literal expression* in the *literal range*; if it is a *discrete mode name*, the **resulting class** of the M-value class where M is the *discrete mode name*; if it is **ELSE**, the **all** class.
- A *case label list* has a class attached, which is, if it is *irrelevant*, the **all** class, otherwise the **resulting class** of the classes of each *case label*.
- A *case label specification* has a list of classes attached, which are the classes of the case label lists.
- A list of case label specifications has a **resulting list of classes** attached. This **resulting list of classes** is formed by constructing, for each position in the list, the **resulting class** of all the classes that have that position.

A list of case label specifications is **complete** if, and only if, for all lists of possible selector values, a case label specification is present, which matches the list of selector values. The set of all possible selector values is determined by the context as follows:

- For a **tagged variant** structure mode, it is the set of values defined by the mode of the corresponding **tag** field.
- For a **tag-less variant** structure mode, it is the set of values defined by the **root** mode of the corresponding **resulting class** (this class is never the **all** class, see 3.13.4).
- For an array tuple, it is the set of values defined by the **index** mode of the mode of the array tuple.
- For a case action with a range list, it is the set of values defined by the corresponding discrete mode in the range list.
- For a case action without a range list, or a conditional expression, it is the set of values defined by M where the class of the corresponding selector is the M-value class or the M-derived class.

static conditions: For each *case label specification*, the number of *case label list* occurrences must be equal.

For any two *case label specification* occurrences, their lists of classes must be **compatible**.

The list of *case label specification* occurrences must be **consistent**, i.e. each list of possible selector values matches at most one case label specification.

If the **root** mode of the class of a *case label list* is an integer mode, there must exist a **predefined** integer mode that contains all the values delivered by each *case label*.

examples:

11.9	*(occupied)*	*(2.1)*
11.58	*(rook),(∗)*	*(1.1)*
8.26	*(***ELSE***)*	*(2.1)*

12.4 Definition and summary of semantic categories

This subclause gives a summary of all semantic categories which are indicated in the syntax description by means of an underlined part. If these categories are not defined in the appropriate clauses, the definition is given here, otherwise the appropriate subclause will be referenced.

12.4.1 Names

Mode names

absolute time mode name:	a *name* defined to be an absolute time mode.
access mode name:	a *name* defined to be an access mode.
array mode name:	a *name* defined to be an array mode.
association mode name:	a *name* defined to be an association mode.
boolean mode name:	a *name* defined to be a boolean mode.
bound reference mode name:	a *name* defined to be a bound reference mode.
buffer mode name:	a *name* defined to be a buffer mode.
character mode name:	a *name* defined to be a character mode.
discrete mode name:	a *name* defined to be a discrete mode.
discrete range mode name:	a *name* defined to be a discrete range mode.
duration mode name:	a *name* defined to be a duration mode.
event mode name:	a *name* defined to be an event mode.
floating point mode name:	a *name* defined to be a floating point mode.
floating point range mode name:	a *name* defined to be a floating point range mode.
free reference mode name:	a *name* defined to be a free reference mode.
generic moreta mode name:	a *name* defined to be a generic moreta mode.
instance mode name:	a *name* defined to be an instance mode.
integer mode name:	a *name* defined to be an integer mode.
mode name:	see 3.2.1.
module mode name:	a *name* defined to be a module mode.
moreta mode name:	a *name* defined to be a moreta mode.
parameterised array mode name:	a *name* defined to be a **parameterised** array mode.
parameterised string mode name:	a *name* defined to be a **parameterised** string mode.
parameterised structure mode name:	a *name* defined to be a **parameterised** structure mode.
powerset mode name:	a *name* defined to be a powerset mode.
procedure mode name:	a *name* defined to be a procedure mode.
region mode name:	a *name* defined to be a region mode.
row mode name:	a *name* defined to be a row mode.
set mode name:	a *name* defined to be a set mode.
string mode name:	a *name* defined to be a string mode.
structure mode name:	a *name* defined to be a structure mode.
task mode name:	a *name* defined to be a task mode.
variant structure mode name:	a *name* defined to be a **variant** structure mode.

Access names

location name:	see 4.1.2.
location do-with name:	see 6.5.4.
location enumeration name:	see 6.5.2.
loc-identity name:	see 4.1.3.

Value names

boolean literal name:	see 5.2.4.4.
emptiness literal name:	see 5.2.4.7.
synonym name:	see 5.1.
value do-with name:	see 6.5.4.
value enumeration name:	see 6.5.2.
value receive name:	see 6.19.2, 6.19.3.

Miscellaneous names

built-in routine name:	any CHILL or implementation defined name denoting a built-in routine.
general procedure name:	a *procedure name* whose generality is **general**.
generic module name:	see 10.11.
generic procedure name:	see 10.11.
generic process name:	see 10.11.
generic region name:	see 10.11.
label name:	see 6.1, 10.6.
newmode name string:	a *name string* **bound** to the *defining occurrence* of a **newmode** name.
non-reserved name:	a *name* which is none of the reserved names mentioned in III.1.
procedure name:	see 10.4.
process name:	see 10.5.
set element name:	see 3.4.5.
signal name:	see 11.5.
tag field name:	see 3.13.4.
undefined synonym name:	see 5.1.

12.4.2 Locations

access location:	a *location* with an access mode.
array location:	a *location* with an array mode.
association location:	a *location* with an association mode.
buffer location:	a *location* with a buffer mode.
character string location:	a *location* with a **character** string mode.
discrete location:	a *location* with a discrete mode.
event location:	a *location* with an event mode.
floating point location:	a *location* with a floating point mode.
instance location:	a *location* with an instance mode.
integer location:	a *location* with an integer mode.
moreta location:	a *location* with a moreta mode.
static mode location:	a *location* with a static mode.
string location:	a *location* with a string mode.
structure location:	a *location* with a structure mode.
text location:	a *location* with a text mode.

12.4.3 Expressions and values

absolute time primitive value:	a *primitive value* whose class is **compatible** with an absolute time mode.
array expression:	an *expression* whose class is **compatible** with an array mode.
array primitive value:	a *primitive value* whose class is **compatible** with an array mode.
boolean expression:	an *expression* whose class is **compatible** with a boolean mode.
bound reference moreta location primitive value:	see 6.7.
bound reference primitive value:	a *primitive value* whose class is **compatible** with a bound reference mode.
character string expression:	an *expression* whose class is **compatible** with a **character** string mode.
constant value:	a *value* which is **constant**.
discrete expression:	an *expression* whose class is **compatible** with a discrete mode.
discrete literal expression:	a *discrete expression* which is **literal**.
duration primitive value:	a *primitive value* whose class is **compatible** with a duration mode.

<u>*floating point*</u> *expression*:	an *expression* whose class is **compatible** with a floating point mode.
<u>*floating point literal*</u> *expression*:	a <u>*floating point*</u> *expression* which is **literal**.
<u>*free reference*</u> *primitive value*:	a *primitive value* whose class is **compatible** with a free reference mode.
<u>*instance*</u> *primitive value*:	a *primitive value* whose class is **compatible** with an instance mode.
<u>*integer*</u> *expression*:	an *expression* whose class is **compatible** with an integer mode.
<u>*integer literal*</u> *expression*:	an <u>*integer*</u> *expression* which is **literal**.
<u>*literal*</u> *expression*:	an *expression* which is **literal**.
<u>*powerset*</u> *expression*:	an *expression* whose class is **compatible** with a powerset mode.
<u>*procedure*</u> *primitive value*:	a *primitive value* whose class is **compatible** with a procedure mode.
<u>*reference*</u> *primitive value*:	a *primitive value* whose class is **compatible** with either a bound reference mode, a free reference mode or a row mode.
<u>*row*</u> *primitive value*:	a *primitive value* whose class is **compatible** with a row mode.
<u>*string*</u> *expression*:	an *expression* whose class is **compatible** with a string mode.
<u>*string*</u> *primitive value*:	a *primitive value* whose class is **compatible** with a string mode.
<u>*structure*</u> *primitive value*:	a *primitive value* whose class is **compatible** with a structure mode.

12.4.4 Miscellaneous semantic categories

<u>*array*</u> *mode*:	a *mode* in which the *composite mode* is an *array mode*.
<u>*constructor*</u> *actual parameter list*:	see 4.1.2.
<u>*discrete*</u> *mode*:	a *mode* in which the *non-composite mode* is a *discrete mode*.
<u>*inline*</u> *guarded procedure definition statement*:	see 10.4.
<u>*location*</u> *built-in routine call*:	see 6.7.
<u>*location*</u> *procedure call*:	see 6.7.
<u>*moreta component*</u> *procedure call*:	see 2.7.
<u>*moreta*</u> *declaration statement*:	see 3.15.
<u>*moreta*</u> *newmode definition statement*:	see 3.15.
<u>*moreta*</u> *synmode definition statement*:	see 3.15.
<u>*non-percent*</u> *character*:	a *character* which is not a percent (%).
<u>*non-reserved*</u> *character*:	a *character* which is neither a quote (”) nor a circumflex (^).
<u>*non-special*</u> *character*:	a *character* which is neither a circumflex (^) nor an open parenthesis (().
<u>*simple*</u> *guarded procedure definition statement*:	see 10.4.
<u>*simple*</u> *guarded procedure specification statement*:	see 10.4.
<u>*string*</u> *mode*:	a *mode* in which the *composite mode* is a *string mode*.
<u>*value*</u> *built-in routine call*:	see 6.7.
<u>*value*</u> *procedure call*:	see 6.7.

13 Implementation options

13.1 Implementation defined built-in routines

semantics: An implementation may provide for a set of implementation defined built-in routines in addition to the set of language defined built-in routines.

The parameter passing mechanism is implementation defined.

predefined names: The name of an implementation defined built-in routine is predefined as a **built-in routine** name.

static properties: A **built-in routine** name may have a set of implementation defined exception names attached. A *built-in routine call* is a **value** (**location**) *built-in routine call* if, and only if, the implementation specifies that for a given choice of static properties of the parameters and the given static context of the call, the built-in routine call delivers a value (location).

The implementation specifies also the **regionality** of the value (location).

13.2 Implementation defined integer modes

An implementation defines the **upper bound** and **lower bound** of the integer mode *INT*. An implementation may define integer modes other than the ones defined by *INT*, e.g. short integers, long integers, unsigned integers. These integer modes must be denoted by implementation defined integer **mode** names. These names are considered to be **newmode** names, **similar** to *INT*. Their value ranges are implementation defined. These integer modes may be defined as **root** modes of appropriate classes.

13.3 Implementation defined floating point modes

An implementation defines the **upper bound** and the **lower bound**, the **negative upper limit** and the **positive lower limit**, the **precision** of the floating point mode *FLOAT*. An implementation may define floating point modes other than the ones defined by *FLOAT*, e.g. short float, long float. These floating point modes must be denoted by implementation defined floating point **mode** names. These names are considered to be **newmode** names, **similar** to *FLOAT*. Their values ranges, lower limits and **precision** are implementation defined. These floating point modes may be defined as **root** modes of appropriate classes.

13.4 Implementation defined process names

An implementation may define a set of implementation defined **process** names, i.e. **process** names whose definition is not specified in CHILL. The definition is considered to be placed in the reach of the imaginary outermost process or in any context. Processes of this name may be started and instance values denoting such processes may be manipulated.

13.5 Implementation defined handlers

An implementation may specify that an implementation defined handler is appended to a process or procedure definition; such a handler may handle any exception.

13.6 Implementation defined exception names

An implementation may define a set of exception names.

13.7 Other implementation defined features

- Static check of dynamic conditions (see 2.1.2);

- *implementation directive* (see 2.6);
- case of **special** simple name strings;
- *text reference name* (see 2.7 and 10.10.1);
- default **generality** (see 10.4);
- set of values of duration modes (see 3.12.2);
- set of values of absolute time modes (see 3.12.3);
- default **element layout** (see 3.13.3);
- comparison of **tag-less variant** structure values (see 3.13.4);
- number of bits in a word (see 3.13.5);
- minimum bit occupancy (see 3.13.5);
- additional **referable** (sub-)locations (see 4.2.1);
- semantics of a *location do-with name* and *value do-with name* which is a **variant** field of a **tag-less variant** structure location (see 4.2.2 and 5.2.3);
- semantics of **variant** fields of **tag-less variant** structures (see 4.2.10, 5.2.14 and 6.2);
- semantics of *location conversion* (see 4.2.13);
- semantics of *expression conversion* and additional conditions (see 5.2.11);
- additional *actual parameters* in a *start expression* (see 5.2.15);
- ranges of values for **literal** and **constant** expressions (see 5.3.1);
- scheduling algorithm (see 6.15, 6.18.2, 6.18.3, 6.19.2, 6.19.3 and 11.2.1);
- releasing of storage in *TERMINATE* (see 6.20.4);
- denotation for files (see 7.1);
- operations on associations (see 7.1 and 7.2.1);
- non-exclusive associations (see 7.1);
- additional attributes of association values (see 7.2.2);
- semantics of *associate parameters* (see 7.4.2);
- *ASSOCIATEFAIL* exception (see 7.4.2);
- semantics of *modify parameters* (see 7.4.5);
- *CREATEFAIL*, *DELETEFAIL* and *MODIFYFAIL* exception (see 7.4.5);
- *CONNECTFAIL* exception (see 7.4.6);
- semantics of reading of records that are not legal values according to the record mode (see 7.4.9);
- additional **timeoutable** actions (see 9.2);
- *TIMERFAIL* exception (see 9.3.1, 9.3.2 and 9.3.3);
- precision of duration values (see 9.4.1 and 9.4.2);
- indication of **constant** value in *quasi synonym definitions* (see 10.10.3);
- **regionality** of built-in routines (see 11.2.2).

Appendix I

Character set for CHILL

The character set of CHILL is an extension of the CCITT Alphabet No. 5, International Reference Version, Recommendation V3. For the values whose representations are greater than 127, no graphical representation is defined.

The integer representation is the binary number formed by bits b8 to b1, where b1 is the least significant bit.

<table>
<tr><td></td><td>$b_7b_6b_5$</td><td>000</td><td>001</td><td>010</td><td>011</td><td>100</td><td>101</td><td>110</td><td>111</td></tr>
<tr><td>$b_4b_3b_2b_1$</td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>0000</td><td>0</td><td>NUL</td><td>TC$_7$
(DLE)</td><td>SP</td><td>0</td><td>@</td><td>P</td><td>‘</td><td>p</td></tr>
<tr><td>0001</td><td>1</td><td>TC$_1$
(SOH)</td><td>DC$_1$</td><td>!</td><td>1</td><td>A</td><td>Q</td><td>a</td><td>q</td></tr>
<tr><td>0010</td><td>2</td><td>TC$_2$
(STX)</td><td>DC$_2$</td><td>”</td><td>2</td><td>B</td><td>R</td><td>b</td><td>r</td></tr>
<tr><td>0011</td><td>3</td><td>TC$_3$
(ETX)</td><td>DC$_3$</td><td>#</td><td>3</td><td>C</td><td>S</td><td>c</td><td>s</td></tr>
<tr><td>0100</td><td>4</td><td>TC$_4$
(EOT)</td><td>DC$_4$</td><td>$</td><td>4</td><td>D</td><td>T</td><td>d</td><td>t</td></tr>
<tr><td>0101</td><td>5</td><td>TC$_5$
(ENQ)</td><td>TC$_8$
(NAK)</td><td>%</td><td>5</td><td>E</td><td>U</td><td>e</td><td>u</td></tr>
<tr><td>0110</td><td>6</td><td>TC$_6$
(ACK)</td><td>TC$_9$
(SYN)</td><td>&</td><td>6</td><td>F</td><td>V</td><td>f</td><td>v</td></tr>
<tr><td>0111</td><td>7</td><td>BEL</td><td>TC$_{10}$
(ETB)</td><td>’</td><td>7</td><td>G</td><td>W</td><td>g</td><td>w</td></tr>
<tr><td>1000</td><td>8</td><td>FE$_0$
(BS)</td><td>CAN</td><td>(</td><td>8</td><td>H</td><td>X</td><td>h</td><td>x</td></tr>
<tr><td>1001</td><td>9</td><td>FE$_1$
(HT)</td><td>EM</td><td>)</td><td>9</td><td>I</td><td>Y</td><td>i</td><td>y</td></tr>
<tr><td>1010</td><td>10</td><td>FE$_2$
(LF)</td><td>SUB</td><td>*</td><td>:</td><td>J</td><td>Z</td><td>j</td><td>z</td></tr>
<tr><td>1011</td><td>11</td><td>FE$_3$
(VT)</td><td>ESC</td><td>+</td><td>;</td><td>K</td><td>[</td><td>k</td><td>{</td></tr>
<tr><td>1100</td><td>12</td><td>FE$_4$
(FF)</td><td>IS$_4$
(FS)</td><td>,</td><td><</td><td>L</td><td>\</td><td>l</td><td>|</td></tr>
<tr><td>1101</td><td>13</td><td>FE$_5$
(CR)</td><td>IS$_3$
(GS)</td><td>-</td><td>=</td><td>M</td><td>]</td><td>m</td><td>}</td></tr>
<tr><td>1110</td><td>14</td><td>SO</td><td>IS$_2$
(RS)</td><td>.</td><td>></td><td>N</td><td>^</td><td>n</td><td>˜</td></tr>
<tr><td>1111</td><td>15</td><td>SI</td><td>IS$_1$
(US)</td><td>/</td><td>?</td><td>O</td><td>_</td><td>o</td><td>DEL</td></tr>
</table>

Appendix II

Special symbols

	Name	Use
;	semicolon	terminator for statements, etc.
,	comma	separator in various constructs
(	left parenthesis	opening parenthesis of various constructs
)	right parenthesis	closing parenthesis of various constructs
[	left square bracket	opening bracket of a tuple
]	right square bracket	closing bracket of a tuple
(:	left tuple bracket	opening bracket of a tuple
:)	right tuple bracket	closing bracket of a tuple
:	colon	label indicator, range indicator
.	dot	field selection symbol
:=	assignment symbol	assignment, initialisation
<	less than	relational operator
<=	less than or equal	relational operator
=	equal	relational operator, assignment, initialisation, definition indicator
/=	not equal	relational operator
>=	greater than or equal	relational operator
>	greater than	relational operator
+	plus	addition operator
-	minus	subtraction operator
*	asterisk	multiplication operator, undefined value, unnamed value, irrelevant symbol
/	solidus	division operator
//	double solidus	concatenation operator
->	arrow	referencing and dereferencing, prefix renaming
<>	diamond	start or end of a directive clause
/*	comment opening	bracket start of a comment
*/	comment closing	bracket end of a comment
’	apostrophe	start or end symbol in various literals
#	sharp	location and expression conversion
”	quote	start or end symbol in character string literals
!	prefixing operator	prefixing of names
B’	literal qualification	binary base for literal
D’	literal qualification	decimal base for literal
H’	literal qualification	hexadecimal base for literal
O’	literal qualification	octal base for literal
– –	line end	line end delimiter of in-line comments

Appendix III

Special simple name strings

III.1 Reserved simple name strings

ABSTRACT
ACCESS
AFTER
ALL
AND
ANDIF
ANY
ANY_ASSIGN
ANY_DISCRETE
ANY_INT
ANY_REAL
ARRAY
ASSIGNABLE
ASSERT
AT

BASED_ON
BEGIN
BIN
BODY
BOOLS
BUFFER
BY

CASE
CAUSE
CHARS
CONSTR
CONTEXT
CONTINUE
CYCLE

DCL
DELAY
DESTR
DO
DOWN
DYNAMIC

ELSE
ELSIF
END
ESAC
EVENT
EVER
EXCEPTIONS
EXIT

FI
FOR
FORBID

GENERAL
GENERIC
GOTO
GRANT

IF
IN
INCOMPLETE
INIT
INLINE
INOUT
INVARIANT

LOC

MOD
MODE
MODULE

NEW
NEWMODE
NONREF
NOT_ASSIGNABLE
NOPACK
NOT

OD
OF
ON
OR
ORIF
OUT

PACK
POS
POST
POWERSET
PRE
PREFIXED
PRIORITY
PROC
PROCESS

RANGE
READ
RECEIVE
REF
REGION
REIMPLEMENT
REM
REMOTE
RESULT
RETURN
RETURNS
ROW

SEIZE
SELF
SEND
SET
SIGNAL
SIMPLE
SPEC
START
STATIC
STEP
STOP
STRUCT
SYN
SYNMODE

TASK
TEXT
THEN
THIS
TIMEOUT
TO

UP

VARYING

WHILE
WITH

XOR

III.2 Predefined simple name strings

ABS
ABSTIME
ALLOCATE
ASSOCIATE
ASSOCIATION

BOOL

CARD
CHAR
CONNECT
CREATE

DAYS
DELETE
DISCONNECT
DISSOCIATE
DURATION

EOLN
EXISTING
EXPIRED

FALSE
FIRST
FLOAT

GETASSOCIATION
GETSTACK
GETTEXTACCESS
GETTEXTINDEX
GETTEXTRECORD
GETUSAGE

HOURS

INDEXABLE
INSTANCE
INT
INTTIME
ISASSOCIATED

LAST
LENGTH
LOWER

MAX
MILLISECS
MIN
MINUTES
MODIFY

NULL
NUM

OUTOFFILE

PRED
PTR

READABLE
READONLY
READRECORD
READTEXT
READWRITE

SAME
SECS
SEQUENCIBLE
SETTEXTACCESS
SETTEXTINDEX
SETTEXTRECORD
SIZE
SUCC

TERMINATE
TIME
TRUE

UPPER
USAGE

VARIABLE

WAIT
WHERE
WRITEABLE
WRITEONLY
WRITERECORD
WRITETEXT

III.3 Exception names

ALLOCATEFAIL
ASSERTFAIL
ASSOCIATEFAIL
CONNECTFAIL
CREATEFAIL
DELAYFAIL
DELETEFAIL
EMPTY
INVFAIL
MODIFYFAIL
NOTASSOCIATED
NOTCONNECTED
OVERFLOW
POSTFAIL
PREFAIL
RANGEFAIL
READFAIL
SENDFAIL
SPACEFAIL
TAGFAIL
TEXTFAIL
TIMERFAIL
UNDERFLOW
WRITEFAIL

Appendix IV

Program examples

1 Operations on integers

```
integer_operations:
MODULE

    add:
    PROC (i,j INT) RETURNS (INT) EXCEPTIONS (OVERFLOW);
            RESULT i+j;
    END add;

    mult:
    PROC (i,j INT) RETURNS (INT) EXCEPTIONS (OVERFLOW);
            RESULT i*j;
    END mult;

    GRANT add, mult;
    SYNMODE operand_mode=INT;
    GRANT operand_mode;
    SYN     neutral_for_add=0,
            neutral_for_mult=1;
    GRANT   neutral_for_add,
                neutral_for_mult;

END integer_operations;
```

2 Same operations on fractions

```
fraction_operations:
MODULE
    NEWMODE fraction=STRUCT (num,denum INT);

    add:
    PROC (f1,f2 fraction) RETURNS (fraction) EXCEPTIONS (OVERFLOW);
            RETURN [f1.num*f2.denum+f2.num*f1.denum,f1.denum*f2.denum];
    END add;

    mult:
    PROC (f1,f2 fraction) RETURNS (fraction) EXCEPTIONS (OVERFLOW);
            RETURN [f1.num*f2.num,f2.denum*f1.denum];
    END mult;

    GRANT add, mult;
    SYNMODE operand_mode=fraction;
    GRANT operand_mode;
    SYN     neutral_for_add fraction=[ 0,1 ],
            neutral_for_mult fraction=[ 1,1 ];
    GRANT   neutral_for_add,
                neutral_for_mult;

END fraction_operations;
```

3 Same operations on complex numbers

```
complex_operations:
MODULE
    NEWMODE complex=STRUCT (re,im FLOAT);
```

```

    add:
    PROC (c1,c2 complex) RETURNS (complex) EXCEPTIONS (OVERFLOW);
        RETURN [c1.re+c2.re,c1.im+c2.im];
    END add;

    mult:
    PROC (c1,c2 complex) RETURNS (complex) EXCEPTIONS (OVERFLOW);
        RETURN [c1.re*c2.re-c1.im*c2.im,c1.re*c2.im+c1.im*c2.re];
    END mult;

    GRANT add, mult;
    SYNMODE operand_mode=complex;
    GRANT operand_mode;
    SYN  neutral_for_add=complex [ 0.0,0.0 ],
         neutral_for_mult=complex [ 1.0,0.0 ];
    GRANT  neutral_for_add,
           neutral_for_mult;

END complex_operations;
```

4 General order arithmetic

```
general_order_arithmetic:  /* from collected algorithms from CACM no. 93 */
MODULE
    op:
    PROC (a INT INOUT, b,c,order INT)
        EXCEPTIONS (wrong_input);
      DCL d INT;
      ASSERT b>0 AND c>0 AND order>0
        ON (ASSERTFAIL):
          CAUSE wrong_input;
        END;
      CASE order OF
        (1):      a := b+c;
                  RETURN;
        (2):      d := 0;
        (ELSE):   d := 1;
      ESAC;
      DO FOR i := 1 TO c;
        op (a,b,d,order-1);
        d := a;
      OD;
      RETURN;
    END op;

    GRANT op;

END general_order_arithmetic;
```

5 Adding bit-by-bit and checking the result

```
add_bit_by_bit:
MODULE
    adder:
    PROC (a STRUCT (a2,a1 BOOL) IN, b STRUCT (b2,b1 BOOL) IN)
        RETURNS (STRUCT (c4,c2,c1 BOOL));
      DCL c STRUCT (c4,c2,c1 BOOL);
      DCL k2,x,w,t,s,r BOOL;
```

```
        DO WITH a,b,c;
            k2 := a1 AND b1;
            c1 := NOT k2 AND (a1 OR b1);
            x := a2 AND b2 AND k2;
            w := a2 OR b2 OR k2;
            t := b2 AND k2;
            s := a2 AND k2;
            r := a2 AND b2;
            c4 := r OR s OR t;
            c2 := x OR (w AND NOT c4);
        OD;
        RETURN c;
    END adder;
    GRANT adder;
END add_bit_by_bit;

exhaustive_checker:
MODULE
    SEIZE adder;
    SYNMODE res=ARRAY (1:16) STRUCT (c4,c2,c1 BOOL);
    DCL r INT, results res;
    r := 0;
    DO FOR a2 IN BOOL;
        DO FOR a1 IN BOOL;
            DO FOR b2 IN BOOL;
                DO FOR b1 IN BOOL;
                    r+ := 1;
                    results (r) := adder ([a2,a1], [b2,b1]);
                OD;
            OD;
        OD;
    OD;
    ASSERT
        results=res [  [FALSE,FALSE,FALSE ]    ,[FALSE,FALSE,TRUE ],
                       [FALSE,TRUE,FALSE ],[FALSE,TRUE,TRUE ],
                       [FALSE,FALSE,TRUE ],[FALSE,TRUE,FALSE ],
                       [FALSE,TRUE,TRUE ]      ,[TRUE,FALSE,FALSE ],
                       [FALSE,TRUE,FALSE ],[FALSE,TRUE,TRUE ],
                       [TRUE,FALSE,FALSE ],[TRUE,FALSE,TRUE ],
                       [FALSE,TRUE,TRUE ]      ,[TRUE,FALSE,FALSE ],
                       [TRUE,FALSE,TRUE ]      ,[TRUE,TRUE,FALSE ]];
END exhaustive_checker;
```

6 Playing with dates

```
playing_with_dates:
MODULE /* from collected algorithms from CACM no. 199 */
    SYNMODE  month=SET (jan,feb,mar,apr,may,jun,
                        jul,aug,sep,oct,nov,dec);
    NEWMODE date=STRUCT (day INT (1:31), mo month, year INT);

    gregorian_date:
    PROC (julian_day_number INT) RETURNS (date);
        DCL   j INT:= julian_day_number,
                d,m,y INT;
        j- := 1_721_119;
        y := (4 * j - 1) / 146_097;
        j := 4 * j - 1 - 146_097 * y;
        d := j / 4;
        j := (4 * d + 3) / 1_461;
        d := 4 * d + 3 - 1_461 * j;
        d := (d + 4) / 4;
        m := (5 * d - 3) / 153;
        d := 5 * d - 3 - 153 * m;
        d := (d + 5) / 5;
        y := 100 * y + j;
         IF m<10 THEN       m + := 3;
                  ELSE      m - := 9;
                            y + := 1;
        FI;
        RETURN [d,month (m-1), y];
    END gregorian_date;

    julian_day_number:
    PROC (d date) RETURNS (INT);
        DCL c,y,m INT;
        DO WITH d;
            m := NUM (mo)+1;
            IF m>2   THEN      m - := 3;
                     ELSE      m + := 9;
                               year - := 1;
            FI;
            c := year/100;
            y := year-100*c;
            RETURN    (146_097*c)/4+(1_461*y)/4
                      +(153*m+2)/5+day+1_721_119;
        OD;
    END julian_day_number;
    GRANT gregorian_date, julian_day_number;
END playing_with_dates;

test:
MODULE
    SEIZE gregorian_date, julian_day_number;
    ASSERT    julian_day_number ([ 10,dec,1979 ])= julian_day_number
              (gregorian_date(julian_day_number([ 10,dec,1979 ])));
END test;
```

7 Roman numerals

```
Roman:
MODULE
    SEIZE n,rn;
```

```
        GRANT convert;
        convert:
        PROC () EXCEPTIONS (string_too_small);
            DCL r INT:= 0;
            DO WHILE n>=1_000;
                rn(r) := ’M’;
                n - := 1_000;
                r + := 1;
            OD;
            IF n>500 THENrn(r) := ’D’;
                         n - := 500;
                         r + := 1;
            FI;
            DO WHILE n>=100;
                rn(r) := ’C’;
                n - := 100;
                r + := 1;
            OD;
            IF n>=50 THEN  rn(r) := ’L’;
                           n - := 50;
                           r + := 1;
            FI;
            DO WHILE n>=10;
                rn(r) := ’X’;
                n - := 10;
                r + := 1;
            OD;
            IF n>=5 THEN rn(r) := ’V’;
                         n - := 5;
                         r + := 1;
            FI;
            DO WHILE n>=1;
                rn(r) := ’I’;
                n - := 1;
                r + := 1;
            OD;
            RETURN;
        END ON (RANGEFAIL):  DO FOR i := 0 TO UPPER (rn);
                                 rn(i) := ’.’;
                             OD;
                             CAUSE string_too_small;
        END convert;
    END Roman;
    test:
    MODULE
        SEIZE convert;
        DCL n INT INIT:= 1979;
         DCL rn CHARS (20) INIT:= (20)” ”;
        GRANT n,rn;
        convert ();
        ASSERT rn=”MDCCCCLXXVIIII”//(6)” ”;
    END test;
```

8 Counting letters in a character string of arbitrary length

```
    letter_count:
    MODULE
        SEIZE max;
        DCL letter POWERSET CHAR INIT:= [’A’ : ’Z’];
```

```
        count:
        PROC (input ROW CHARS (max) IN, output ARRAY ('A':'Z') INT OUT);
            output := [(ELSE) : 0];
            DO FOR i := 0 TO UPPER (input ->);
                IF input -> (i) IN letter
                    THEN
                        output (input -> (i)) + := 1;
                FI;
            OD;
        END count;
        GRANT count;
    END letter_count;
    test:
    MODULE
        SYNMODE results=ARRAY ('A':'Z')INT;
        DCL c CHARS (10) INIT:= "A-B<ZAA9K' ";
        DCL output results;
        SYN max=10_000;
        GRANT max;
        SEIZE count;
        count (-> c,output);
        ASSERT output=results [('A') : 3,('B','K','Z') : 1, (ELSE) : 0];
    END test;
```

9 Prime numbers

```
    prime:
    MODULE

        SYN max = H'7FFF;
        NEWMODE number_list =POWERSET INT (2:max);
        SYN empty = number_list [ ];
        DCL sieve number_list INIT:= [ 2:max ],
            primes number_list INIT:= empty;
        GRANT primes;
        DO WHILE sieve/=empty;
            primes OR:= [MIN (sieve)];
            DO FOR j := MIN (sieve) BY MIN (sieve) TO max;
                sieve - := [j];
            OD;
        OD;
    END prime;
```

10 Implementing stacks in two different ways, transparent to the user

```
    stack: MODULE
        NEWMODE element =STRUCT (a INT, b BOOL);
        stacks_1:
        MODULE
            SEIZE element;
            SYN max=10_000,min=1;
            DCL   stack ARRAY (min : max) element,
                  stackindex INT INIT:= min;

            push:
            PROC (e element) EXCEPTIONS (overflow);
                IF stackindex=max
                    THEN CAUSE overflow;
                FI;
```

```
            stackindex + := 1;
            stack (stackindex) := e;
            RETURN;
        END push;

        pop:
        PROC () EXCEPTIONS (underflow);
            IF stackindex=min
                THEN CAUSE underflow;
            FI;
            stackindex - := 1;
            RETURN;
        END pop;

        elem:
        PROC (i INT) RETURNS (element LOC) EXCEPTIONS (bounds);
            IF i<min OR i>max
                THEN CAUSE bounds;
            FI;
            RETURN stack (i);
        END elem;

        GRANT push,pop,elem;
    END stacks_1;
    stacks_2:
    MODULE
        SEIZE element;
        NEWMODE cell=STRUCT (pred,succ REF cell,info element);
        DCL p,last,first REF cell INIT:= NULL;

        push:
        PROC (e element) EXCEPTIONS (overflow);
            p := ALLOCATE (cell) ON
                                  (ALLOCATEFAIL) : CAUSE overflow;
            END;
            IF last=NULL
                THEN    first := p;
                        last := p;
                ELSElast ->. succ := p;
                        p ->. pred := last;
                        last := p;
            FI;
            last ->. info := e;
            RETURN;
        END push;

        pop:
        PROC () EXCEPTIONS (underflow);
            IF last=NULL
                THEN CAUSE underflow;
            FI;
            p := last;
            last := last ->. pred;
            IF last = NULL
                THEN first := NULL;
                ELSE last ->. succ := NULL;
            FI;
            TERMINATE(p);
            RETURN;
        END pop;
```

```

            elem:
            PROC (i INT) RETURNS (element LOC) EXCEPTIONS (bounds);
                IF first=NULL
                    THEN CAUSE bounds;
                FI;
                p := first;
                DO FOR j := 2 TO i;
                    IF p ->. succ=NULL
                        THEN CAUSE bounds;
                    FI;
                    p := p ->. succ;
                OD;
                RETURN p ->. info;
            END elem;

            /* GRANT push,pop,elem; */
        END stacks_2;
    END stack;
```

11 Fragment for playing chess

```
    chess_fragments:
    MODULE
        NEWMODE piece=STRUCT(color SET (white,black),
                             kind SET (pawn,rook,knight,bishop,queen,king));
        NEWMODE column=SET (a,b,c,d,e,f,g,h);
        NEWMODE line=INT (1 : 8);
        NEWMODE square=STRUCT   (status SET (occupied,free),
                                CASE status OF
                                (occupied) : p piece,
                                (free) :
                                ESAC);
        NEWMODE board=ARRAY (line) ARRAY (column) square;
        NEWMODE move=STRUCT(lin_1,lin_2 line,
                             col_1,col_2 column);

        initialise:
        PROC (bd board INOUT);
            bd := [   (1):    [   (a,h):    [.status: occupied, .p : [white,rook]],
                                  (b,g):    [.status: occupied, .p : [white,knight]],
                                  (c,f):    [.status: occupied, .p : [white,bishop]],
                                  (d):      [.status: occupied, .p : [white,queen]],
                                  (e):      [.status: occupied, .p : [white,king]]],
                      (2):    [   (ELSE):   [.status: occupied, .p : [white,pawn]]],
                      (3:6):  [   (ELSE):   [.status: free]],
                      (7):    [   (ELSE):   [.status: occupied, .p : [black,pawn]]],
                      (8):    [   (a,h):    [.status: occupied, .p : [black,rook]],
                                  (b,g):    [.status: occupied, .p : [black,knight]],
                                  (c,f):    [.status: occupied, .p : [black,bishop]],
                                  (d):      [.status: occupied, .p : [black,queen]],
                                  (e):      [.status: occupied, .p : [black,king]]]
                  ];
            RETURN;
        END initialise;
        register_move:
        PROC (b board LOC,m move) EXCEPTIONS (illegal);
            DCL   starting square LOC:= b (m.lin_1)(m.col_1),
                  arriving square LOC:= b (m.lin_2)(m.col_2);
```

```
          DO WITH m;
            IF starting.status=free THEN CAUSE illegal; FI;
            IF arriving.status/=free THEN
              IF arriving.p.kind=king THEN CAUSE illegal; FI;
            FI;
            CASE starting.p.kind, starting.p.color OF
              (pawn),(white):
              IF col_1 = col_2 AND (arriving.status/=free
                OR NOT (lin_2=lin_1+1 OR lin_2=lin_1+2 AND lin_2=2))
                OR (col_2=PRED (col_1) OR col_2=SUCC (col_1))
                AND arriving.status=free THEN CAUSE illegal; FI;
                IF arriving.status/=free THEN
                  IF arriving.p.color=white THEN CAUSE illegal; FI; FI;
              (pawn),(black):
              IF col_1=col_2 AND (arriving.status/=free
                OR NOT (lin_2=lin_1-1 OR lin_2=lin_1-2 AND lin_1=7))
                OR (col_2=PRED (col_1) OR col_2=SUCC (col_1))
                AND arriving.status=free THEN CAUSE illegal; FI;
                IF arriving.status/=free THEN
                  IF arriving.p.color=black THEN CAUSE illegal; FI; FI;
              (rook),(*):
              IF NOT ok_rook (b,m)
                THEN CAUSE illegal;
              FI;
              (bishop),(*):
              IF NOT ok_bishop (b,m)
                THEN CAUSE illegal;
              FI;
              (queen),(*):
              IF NOT ok_rook (b,m) AND NOT ok_bishop (b,m)
                THEN CAUSE illegal;
              FI;
              (knight),(*):
              IF ABS (  ABS (NUM (col_2)-NUM (col_1))
                        -ABS (lin_2- lin_1)) /= 1
                OR    ABS (NUM (col_2)-NUM (col_1))
                        +ABS (lin_2- lin_1) =/ 3 THEN CAUSE illegal; FI;
              IF arriving.status/=free THEN
                IF arriving.p.color=starting.p.color THEN
                CAUSE illegal; FI; FI;
              (king),(*):
              IF ABS (NUM (col_2)-NUM (col_1)) > 1
                OR ABS (lin_2- lin_1) > 1
                OR lin_2=lin_1 AND col_2=col_1 THEN CAUSE illegal; FI;
              IF arriving.status/=free THEN
                IF arriving.p.color=starting.p.color THEN
                CAUSE illegal; FI; FI;/* checking king moving to check not implemented */
            ESAC;
          OD;
          arriving := starting;
          starting := [.status:free];
          RETURN;
        END register_move;
        ok_rook:
        PROC (b board,m move) RETURNS (BOOL);
          DCL   starting square := b (m.lin_1)(m.col_1),
                arriving square := b (m.lin_2)(m.col_2);

          DO WITH m;
            IF NOT (col_2=col_1 OR lin_1=lin_2) THEN RETURN FALSE; FI;
```

```
            IF arriving.status/=free THEN
              IF arriving.p.color=starting.p.color THEN;
              RETURN FALSE; FI; FI;
            IF col_1=col_2
              THEN    IF lin_1<lin_2
                      THEN DO FOR lin := lin_1+1 TO lin_2-1;
                                IF  b (lin)(col_1).status/=free
                                  THEN RETURN FALSE;
                                FI;
                              OD;
                      ELSE DO FOR lin := lin_1-1 DOWN TO lin_2+1;
                                IF b (lin)(col_1).status/=free
                                  THEN RETURN FALSE;
                                FI;
                              OD;
                      FI;
            ELSIF col_1<col_2
              THEN DO FOR col := SUCC (col_1) TO PRED (col_2);
                      IF b (lin_1)(col).status/=free
                        THEN RETURN FALSE;
                      FI;
                    OD;
              ELSE DO FOR col := SUCC (col_2) DOWN TO PRED (col_1);
                      IF b (lin_1)(col).status/=free
                        THEN RETURN FALSE;
                      FI;
                    OD;
            FI;
            RETURN TRUE;
        OD;
    END ok_rook;
    ok_bishop:
    PROC (b board,m move) RETURNS (BOOL);
        DCL   starting square := b (m.lin_1)(m.col_1),
              arriving square := b (m.lin_2)(m.col_2),
              col column;

        DO WITH m;
            CASE lin_2>lin_1,col_2>col_1 OF
              (TRUE),(TRUE): col := col_1;
                        DO FOR lin := lin_1+1 TO lin_2-1;
                              col := SUCC (col);
                              IF b (lin)(col).status/=free
                                THEN RETURN FALSE;
                              FI;
                        OD;
                        IF SUCC (col)/=col_2
                                THEN RETURN FALSE;
                        FI;
              (TRUE),(FALSE): col := col_1;
                        DO FOR lin := lin_1+1 TO lin_2-1;
                              col := PRED (col);%
                              IF b (lin)(col).status/=free
                                THEN RETURN FALSE;
                              FI;
                        OD;
                        IF PRED (col)/=col_2
                                THEN RETURN FALSE;
                        FI;
              (FALSE),(TRUE): col := col_1;
```

```
                        DO FOR lin := lin_1-1 DOWN TO lin_2+1;
                            col := SUCC (col);
                            IF b (lin)(col).status/=free
                              THEN RETURN FALSE;
                            FI;
                        OD;
                        IF SUCC (col)/=col_2
                            THEN RETURN FALSE;
                        FI;
                (FALSE),(FALSE): col := col_1;
                        DO FOR lin := lin_1-1 DOWN TO lin_2+1;
                            col := PRED (col);
                            IF b (lin)(col).status/=free
                              THEN RETURN FALSE;
                            FI;
                        OD;
                        IF PRED (col)/=col_2
                            THEN RETURN FALSE;
                        FI;
        ESAC;
        IF arriving.status=free THEN RETURN TRUE;
        ELSE RETURN arriving.p.color/=starting.p.color; FI;
        OD;
    END ok_bishop;
    END chess_fragments;
```

12 Building and manipulating a circularly linked list

```
circular_list:
MODULE
    handle_list:
    MODULE
        GRANT insert, remove, node;
        NEWMODE node=STRUCT (pred, suc REF node, value INT);
        DCL pool ARRAY (1:1000)node;
        DCL head node := (: NULL,NULL,0 :);

        insert: PROC (new node);
            /* insert actions */
        END insert;

        remove: PROC ();
            /* remove actions */
        END remove;

        initialize_list:
        BEGIN
            DCL last REF node := ->head;
            DO FOR new IN pool;
                new.pred := last;
                last->.suc := ->new;
                last := ->new;
                new.value := 0;
            OD;
            head.pred := last;
            last->.suc := ->head;
        END initialize_list;

    END handle_list;
```

```
    manipulate:
    MODULE
        SEIZE node, remove, insert;
        DCL node_a node := (: NULL,NULL,536 :);
        remove();
        remove();
        insert(node_a);
    END manipulate;
END circular_list;
```

13 A region for managing competing accesses to a resource

```
allocate_resources:
REGION
    GRANT allocate, deallocate;
    NEWMODE resource_set = INT (0:9);
    DCL allocated ARRAY (resource_set)BOOL:= (: (resource_set): FALSE:);
    DCL resource_freed EVENT;

    allocate:
    PROC () RETURNS (resource_set);
        DO FOR EVER;
            DO FOR i IN resource_set;
                IF NOT allocated(i)
                    THEN
                        allocated(i) := TRUE;
                        RETURN i;
                FI;
            OD;
            DELAY resource_freed;
        OD;
    END allocate;

    deallocate:
    PROC (i resource_set);
        allocated(i) := FALSE;
        CONTINUE resource_freed;
    END deallocate;

END allocate_resources;
```

14 Queuing calls to a switchboard

```
switchboard:
MODULE
    /*  This example illustrates a switchboard which queues incoming calls
        and feeds them to the operator at an even rate. Every time the
        operator is ready one and only one call is let through. This is
        handled by a call distributor which lets calls through at fixed
        intervals. If the operator is not ready or there are other calls
        waiting, a new call must queue up to wait for its turn. */
    DCL   operator_is_ready,
          switch_is_closed EVENT;

    call_distributor:
    PROCESS ();
        wait:
        PROC (x INT);
            /*some wait action*/
```

```
          END wait;
          DO FOR EVER;
               wait(10 /*seconds*/);
               CONTINUE operator_is_ready;
          OD;
     END call_distributor;

     call_process:
     PROCESS ();
          DELAY CASE
          (operator_is_ready): /* some actions */ ;
          (switch_is_closed): DO FOR i IN INT (1:100);
                                        CONTINUE operator_is_ready;
                                        /* empty the queue*/
                                        OD;
          ESAC;
     END call_process;

     operator:
     PROCESS ();
          DCL time INT;
          DO FOR EVER;
               IF time = 1700
                    THEN CONTINUE switch_is_closed;
               FI;
          OD;
     END operator;

     START call_distributor();
     START operator();
     DO FOR i IN INT (1:100);
          START call_process();
     OD;
END switchboard;
```

15 Allocating and deallocating a set of resources

```
definitions:
MODULE
SIGNAL
     acquire,
     release=(INSTANCE),
     congested,
     ready,
     advance,
     readout=(INT);
     GRANT ALL;
END definitions;
counter_manager:
MODULE
/*   To illustrate the use of signals and the receive case, (buffers
     might have been used instead) we will look at an example where an
     allocator manages a set of resources, in this case a set of
     counters. The module is part of a larger system where there are
     users, that can request the services of the counter_manager. The
     module is made to consist of two process definitions, one for the
     allocation and one for the counters. Initiate and terminate
     are internal signals sent from the allocator
     to the counters. All the other signals are external, being sent
     from or to the users. */
```

```

SEIZE/* external signals */
    acquire, release, congested,ready,advance,readout;
SIGNAL  initiate = (INSTANCE),
            terminate;
allocator:
PROCESS ();
    NEWMODE no_of_counters = INT (1:100);
DCL counters ARRAY (no_of_counters)
                        STRUCT (counter INSTANCE, status SET (busy,idle));
DO FOR each IN counters;
    each := (: START counter(), idle :);
OD;
DO FOR EVER;
BEGIN
    DCL user INSTANCE;
    await_signals:
    RECEIVE CASE SET user;
    (acquire):
        DO FOR each IN counters;
            DO WITH each;
                IF status = idle
                    THEN
                        status := busy;
                        SEND initiate (user) TO counter;
                        EXIT await_signals;
                FI;
            OD;
        OD;
        SEND congested TO user;
    (release IN this_counter):
        SEND terminate TO this_counter;
        find_counter:
        DO FOR each IN counters;
            DO WITH each;
                IF this_counter = counter
                    THEN
                        status := idle;
                        EXIT find_counter;
                FI;
            OD;
        OD find_counter;
    ESAC await_signals;
END;
OD;
END allocator;
counter:
PROCESS ();
    DO FOR EVER;
    BEGIN
        DCL  user INSTANCE,
             count INT:= 0;
        RECEIVE CASE
            (initiate IN received_user):
                SEND ready TO received_user;
                user := received_user;
        ESAC;
        work_loop:
        DO FOR EVER;
            RECEIVE CASE
```

```
                    (advance): count + := 1;
                    (terminate):
                        SEND readout(count) TO user;
                        EXIT work_loop;
                ESAC;
            OD work_loop;
        END;
        OD;
    END counter;
    START allocator();
END counter_manager;
```

16 Allocating and deallocating a set of resources using buffers

```


user_world:
MODULE
/* This example is the same as no.15 except that buffers are
    used for communication instead of signals.
    The main difference is that processes are now identified
    by means of references to local message buffers rather than
    by instance values. There is one message buffer declared
    local to each process. There is one set of message types
    for each process definition. When started each process must
    identify its buffer address to the starting process.
    The user_world module sketches some of the environment in
    which the counter_manager is used. */

SEIZE allocator;
GRANT   user_buffers,user_messages,
            allocator_messages, allocator_buffers,
            counter_messages, counters_buffers;
NEWMODE
    user_messages =
        STRUCT (type SET (    congested, ready,
                        readout, allocator_id),
                    CASE type OF
                        (congested) : ,
                        (ready) : counter REF counters_buffers,
                        (readout) : count INT,
                        (allocator_id): allocator REF allocator_buffers
                    ESAC),
    user_buffers = BUFFER (1) user_messages,
    allocator_messages =
        STRUCT (type SET (acquire, release, counter_id),
                    CASE type OF
                        (acquire) : user REF user_buffers,
                        (release,
                        counter_id): counter REF counters_buffers
                    ESAC),
    allocator_buffers = BUFFER (1) allocator_messages,
    counter_messages =
        STRUCT (type SET (initiate, advance, terminate),
                    CASE type OF
                        (initiate) : user REF user_buffers,
                        (advance,
                        terminate):
                    ESAC),
    counters_buffers = BUFFER (1) counter_messages;
DCL   user_buffer user_buffers,
        allocator_buf REF allocator_buffers,
        counter_buf REF counters_buffers;
START allocator(->user_buffer);
RECEIVE CASE
     (user_buffer IN u_msg): allocator_buf := u_msg.allocator;
ESAC;
END user_world;
counter_manager:
MODULE
SEIZE     user_buffers,user_messages,
        allocator_messages, allocator_buffers,
        counter_messages, counters_buffers;
```

```
GRANT allocator;

allocator:
PROCESS (starter REF user_buffers);
    DCL allocator_buffer allocator_buffers;
    NEWMODE no_of_counters = INT (1:10);
    DCL  counters ARRAY   (no_of_counters)
                          STRUCT (counter REF counters_buffers,
                                  status SET (busy, idle)),
        message allocator_messages;
    SEND starter->([allocator_id, ->allocator_buffer]);
    DO FOR each IN counters;
        START counter(->allocator_buffer);
        RECEIVE CASE
            (allocator_buffer IN a_msg): each := [a_msg.counter, idle];
        ESAC;
    OD;
    DO FOR EVER;
        BEGIN
        DCL user REF user_buffers;
        RECEIVE (allocator_buffer IN message);
        handle_messages:
        CASE message.type OF
        (acquire):
             user := message.user;
             DO FOR each IN counters;
                 DO WITH each;
                     IF status= idle
                         THEN   status := busy;
                             SEND counter->([initiate, user]);
                             EXIT handle_messages;
                     FI;
                 OD;
             OD;
             SEND user->([congested]);
        (release):
             SEND message.counter->([terminate]);
             find_counter:
             DO FOR each IN counters;
                 DO WITH each;
                     IF message.counter = counter
                         THEN   status := idle;
                             EXIT find_counter;
                     FI;
                 OD;
             OD find_counter;
        (counter_id): ;
        ESAC handle_messages;
        END;
    OD;
END allocator;
counter:
PROCESS (starter REF allocator_buffers);
    DCL counter_buffer counters_buffers;
    SEND starter->([counter_id, ->counter_buffer]);
    DO FOR EVER;
        BEGIN
             DCL  user REF user_buffers,
                  count INT:= 0,
                  message counter_messages;
```

```
            RECEIVE (counter_buffer IN message);
            CASE message.type OF
                (initiate):      user := message.user;
                                 SEND user->([ready, ->counter_buffer]);
                ELSE/* some error action */
            ESAC;
        work_loop:
        DO FOR EVER;
            RECEIVE (counter_buffer IN message);
            CASE message.type OF
                (advance):       count + := 1;
                (terminate):     SEND user->([readout, count]);
                                 EXIT work_loop;
                ELSE/* some error action */
            ESAC;
        OD work_loop;
    END;
    OD;
END counter;
END counter_manager;
```

17 String scanner1

```
string_scanner1: /*    This program implements strings by means
                       of packed arrays of characters. */
MODULE
    SYN
        blanks ARRAY (0:9)CHAR PACK = [(*):' ' ], linelength = 132;
    SYNMODE
        stringptr = ROW ARRAY (lineindex)CHAR PACK,
        lineindex = INT (0:linelength-1);

scanner:
PROC    (string stringptr, scanstart lineindex INOUT,
        scanstop lineindex, stopset POWERSET CHAR)
        RETURNS (ARRAY (0:9)CHAR PACK);
    DCL count INT:= 0,
        res ARRAY (0:9)CHAR PACK:= blanks;
    DO
        FOR c IN string->(scanstart:scanstop)
        WHILE NOT (c IN stopset);
            count + := 1;
    OD;
    IF count>0
        THEN
            IF count>10
                THEN
                    count := 10;
            FI;
            res(0:count-1) := string->(scanstart:scanstart+count-1);
    FI;
    RESULT res;
    IF scanstart+count < scanstop
        THEN
            scanstart := scanstart+count+1;
    FI;
END scanner;

GRANT scanner;
```

```
END string_scanner1;
```

18 String scanner2

```
string_scanner2: /*    This example is the same as No.17 but it uses
                       character string instead of packed arrays */
MODULE
    SYN
        blanks = (10)" ", linelength = 132;
    SYNMODE
        stringptr = ROW CHARS (linelength),
        lineindex = INT (0:linelength-1);

    scanner:
        PROC    (string stringptr, scanstart lineindex INOUT,
                scanstop lineindex, stopset POWERSET CHAR)
                RETURNS (CHARS (10));
            DCL count INT:= 0;
            DO FOR i := scanstart TO scanstop
                WHILE NOT (string->(i) IN stopset);
                    count + := 1;
            OD;
            IF count>0
                THEN
                    IF count>=10
                        THEN
                            RESULT string->(scanstart UP 10);
                        ELSE
                            RESULT string->(scanstart:scanstart+count-1)
                                    //blanks(count:9);
                    FI;
                ELSE
                    RESULT blanks;
            FI;
            IF scanstart+count < scanstop
                THEN
                    scanstart := scanstart+count+1;
            FI;
        END scanner;

    GRANT scanner;

END string_scanner2;
```

19 Removing an item from a double linked list

```
queue: MODULE
    SYNMODE info=INT;
    queue_removal:
    MODULE
        SEIZE info;
        GRANT remove;
        remove:
        PROC    (p PTR) RETURNS (info) EXCEPTIONS (EMPTY);
                /*  This procedure removes the item referred to
                    by p from a queue and returns the information
                    contents of that queue element */
                SYNMODE  element = STRUCT (
```

```
                        i info POS (0,8:31),
                        prev PTR POS (1,0:15),
                        next PTR POS (1,16:31));
                DCL x REF element LOC:= element(p), prev, next PTR;
                prev := x->.prev;
                next := x->.next;
                x->.prev, x->.next := NULL;
                RESULT x->.i;
                p := prev;
                x->.next := next;
                p := next;
                x->.prev := prev;
        END remove;
    END queue_removal;
END queue;
```

20 Update a record of a file

```
read_modify_write:
MODULE

    /*  this example indicates how the CHILL i/o concepts can be used      */
    /*  to write an application where a record of a random accessible      */
    /*  file can be updated or added if not yet in use                     */

    NEWMODE
        index_set = INT (1:1000),
        record_type = STRUCT (
                            free    BOOL,
                            count   INT,
                            name    CHARS (20));

    DCL
        curindex            index_set,
        file_association    ASSOCIATION,
        record_file         ACCESS (index_set) record_type,
        record_buffer       record_type;

    ASSOCIATE (file_association,"DSK:RECORDS.DAT");     /* create association    */
    CONNECT (record_file,file_association,READWRITE);   /* connect to file       */
    curindex := 123;                                    /* position record       */
    READRECORD (record_file,curindex,record_buffer);    /* read the record       */
        IF record_buffer.free                           /* if record is free     */
        THEN                                            /* the claim and         */
            record_buffer.free := FALSE                 /* initialize it         */
            record_buffer.count := 0;
            record_buffer.name := "CHILL I/O concept    ";
        FI;
    record_buffer.count + := 1;                         /* increment its count   */
    WRITERECORD (record_file, curindex, record_buffer); /* write the record      */
    DISSOCIATE (file_association);                      /* end the association   */

END read_modify_write;
```

21 Merge two sorted files

```
merge_sorted_files:
MODULE

```

```
/* this example shows how two sorted files can be merged into one     */
/* new sorted file, where the field 'key' is used for sorting          */
/* the old sorted files are deleted after the merging has been done    */

NEWMODE
   record_type = STRUCT (
                          key     INT,
                          name    CHARS (50));

DCL
   flag          BOOL,
   infiles       ARRAY (BOOL) ACCESS record_type,
   outfile       ACCESS record_type,
   buffers     ARRAY (BOOL) record_type,
   innames       ARRAY (BOOL) CHARS (10) INIT:= ["FILE.IN.1 ","FILE.IN.2 "],
   outname       CHARS (10) INIT:= "FILE.OUT  ",
   inassocs      ARRAY (BOOL) ASSOCIATION,
   outassoc      ASSOCIATION;

/* associate both sorted input files, connect an access to them for input   */
/* and read their first record into a buffer                                 */

DO
   FOR  curfile IN infiles,
        curbuffer IN buffers,
        curassoc IN inassocs,
        curname IN innames;
      CONNECT (curfile, ASSOCIATE (curassoc,curname), READONLY);
      READRECORD (curfile, curbuffer);
OD;

/* associate the output file, create a file for the association     */
/* and connect an access to it for output                             */

ASSOCIATE (outassoc,outname);
CREATE (outassoc);
CONNECT (outfile, outassoc, WRITEONLY);
merge_files:
DO FOR EVER

   /* determine which file, if any at all, to process next      */
   /* 'flag' indicates the file                                  */

   CASE OUTOFFILE (infiles(FALSE)),OUTOFFILE (infiles(TRUE)) OF
      (TRUE),   (TRUE):                       /* both files are empty      */
                EXIT merge_files;
      (TRUE),   (FALSE):                      /* one file is empty         */
                flag := TRUE;
      (FALSE),  (TRUE):                       /* one file is empty         */
                flag := FALSE;
      (FALSE),  (FALSE):                      /* no file is empty          */
                flag := buffers(FALSE).key>buffers(TRUE).key;
   ESAC;

      /* output the buffer which currently contains a record with the     */
      /* smallest value for 'key', fill the buffer with a new record       */

      WRITERECORD (outfile,buffers(flag));
      READRECORD (infiles(flag), buffers(flag));
OD merge_files;
```

```

        /* delete the input files and close the output file */
        DO
        FOR curassoc IN inassocs;
            DELETE (curassoc);                    /* delete the file            */
            DISSOCIATE (curassoc);                /* and terminate association  */
        OD;
        DISSOCIATE (outassoc);                    /* disconnect and terminate */

    END merge_sorted_files;
```

22 Read a file with variable length records

```
    variable_length_records:
    MODULE

        /* This example shows how a file which consists of variable length     */
        /* records can be treated.                                              */
        /* The file consists of a number of strings of varying length; the      */
        /* algorithm will read a string, allocate an appropriate location       */
        /* for it, and put the reference to this location into a push down list */

        NEWMODE
            string = CHARS (80),
            link_record = STRUCT (
                                   next_record  REF link_record,
                                   string_row   ROW string);

        DCL
            pushdownlist    REF link_record INIT:= NULL,
            length              INT (1:80),
            temporaryrow        ROW string,
            fileaccess      string DYNAMIC,
            association         ASSOCIATION;
            filename            CHARS (20) VARYING INIT := "INPUT.DATA";
        ASSOCIATE (association,filename);                /* associate the input file     */
        CONNECT (fileaccess, association, READONLY);     /* connect access for input     */
        temporaryrow := READRECORD (fileaccess);         /* read the first record        */
        DO                                               /* while not end-of-file        */
            WHILE NOT(OUTOFFILE(fileaccess));
                pushdownlist := ALLOCATE (link_record,   /* get a new link record        */
                                [pushdownlist,NULL ]);   /* and initialize it            */
                length := 1 + UPPER (temporaryrow->);    /* determine length of string   */
            DO
                WITH pushdowlist->;                      /* add new string to list       */
                string_row := ALLOCATE (CHARS (length),  /* allocate space for string    */
                                        temporaryrow->); /* and fill it                  */
            OD;
            temporaryrow := READRECORD (fileaccess);     /* get next record in file      */
        OD;
        DISSOCIATE (association);                        /* end the association          */

    END variable_length_records;
```

23 The use of spec modules

```
        /* The examples 23 and 24 are example 8 divided in two pieces. */
    letter_count:
    SPEC MODULE
```

```
        /* This is a spec module for the corresponding module in example 8. */
        SEIZE max;
        count:
        PROC (input ROW CHARS (max) IN, output ARRAY ('A':'Z') INT OUT) END;
        GRANT count;
    END letter_count;
    letter_count: REMOTE "example 24";
    test:
    MODULE
        /* This is the module 'test' from example 8.            */
        /* It can now be piecewise compiled together with       */
        /* the above spec module                                */
        SYNMODE results = ARRAY ('A':'Z') INT;
        DCL c CHARS (10) INIT:= "A-B<ZAA9K' ";
        DCL output results;
        SYN max = 10_000;
        GRANT max;
        SEIZE count;
        count (-> c, output);
        ASSERT output = results [('A') : 3, ('B', 'K', 'Z') : 1, (ELSE) : 0 ];
    END test;
```

24 Example of a context

```
    CONTEXT
        /* This is a context for the module "letter_count"      */
        /* as used in example 23, allowing the piecewise        */
        /* compilation of "letter_count"                        */
        SYN max = 10_000;
    FOR
    letter_count:
    MODULE
        SEIZE max;
        DCL letter POWERSET CHAR INIT:= ['A' : 'Z'];
        count:
        PROC (input ROW CHARS (max) IN, output ARRAY ('A':'Z') INT OUT);
            output := [(ELSE) : 0];
            DO FOR i := 0 TO UPPER (input ->);
                IF input -> (i) IN letter THEN
                    output (input -> (i)) + := 1;
                FI;
            OD;
        END count;
        GRANT count;
    END letter_count;
```

25 The use of prefixing and remote modules

```
        /* This example uses the module 'stack' from example 27 or 28.    */
        /* It shows how prefixes can be used to prevent name clashes.     */
        /* It uses the remote construct to share the source code.         */
    char_stack:
    MODULE
        SYNMODE element = CHAR;
        GRANT (-> stack ! char) ! ALL;
        stack: SPEC REMOTE "example 29";
        stack: REMOTE           "example 27 or 28 for CHAR";
    END char_stack;
```

```
int_stack:
MODULE
    SYNMODE element = INT;
    GRANT (-> stack ! int) ! ALL;
    stack: SPEC REMOTE "example 29";
    stack: REMOTE            "example 27 or 28 for CHAR";
END int_stack;
    /* Here 'push', 'pop' and 'element' are visible but        */
    /* with prefixes 'stack ! char' and 'stack ! int' for      */
    /* the implementations with element = CHAR and             */
    /* element = INT, respectively.                            */
    /* Below are some possibilities of using the granted       */
    /* names inside modules.                                   */
MODULE
    SEIZE ALL PREFIXED stack ;
    DCL c CHAR;
    int ! push (123) ;
    char ! push ('a') ;
    int ! pop ( ) ;
    c := char ! elem (1) ;
END;

MODULE
    SEIZE (stack ! int -> stack) ! ALL;
    stack ! push (345) ;
    stack ! pop ( ) ;
END;
```

26 The use of text i/o

```
textio:
MODULE

    /* This example shows the use of the text i/o features. */

    DCL
        outfile   ASSOCIATION,
        output    TEXT (80) DYNAMIC,
        size      INT:= 12345,
        flag      BOOL:= FALSE,
        set       SET (a,b,c) := b,
        s1        CHARS (5) := "CHILL",
        s2        CHARS (5) VARYING:= "text";

    ASSOCIATE (outfile,"OUTPUT.DATA");           - - associate the output file
    CREATE (outfile);                               - - create it
    CONNECT (output,outfile,WRITEONLY);          - - then connect text location
    WRITETEXT (output,"%B%/",10);                   - - 1010
    WRITETEXT (output,"%C%/",set);                  - - b
    WRITETEXT (output,"size = %C%/",size);          - - size = 12345
    WRITETEXT (output,"%CL6%C i/o%/",s1,s2);        - - CHILL text i/o
    WRITETEXT (output,"flag =%X%C",flag);           - - flag = FALSE
    size := GETTEXTINDEX (output);                  - - 12
    DISSOCIATE (outfile);
END textio;
```

27 A generic stack

```
    /* This example implements a generic stack. Please         */
```

```
    /* note that the element mode has been left out.        */
    /* The element mode is defined in the surroundings.     */
    /* The context is a virtually introduced context,       */
    /* and it has no source.                                */
CONTEXT REMOTE FOR
stack:
MODULE
    SEIZE element;
    NEWMODE cell = STRUCT (pred,succ REF cell,info element);
    DCL p,last,first REF cell INIT:= NULL;

    push:
    PROC (e element) EXCEPTIONS (overflow)
        p := ALLOCATE (cell) ON (ALLOCATEFAIL): CAUSE overflow; END;
        IF last = NULL THEN
            first := p;
            last := p;
        ELSE
            last -> .succ := p;
            p -> .pred := last;
            last := p;
        FI;
        last -> .info := e;
        RETURN;
    END push;

    pop:
    PROC () EXCEPTIONS (underflow)
        IF last = NULL THEN
            CAUSE underflow;
        FI;
        p:= last;
        last := last -> .pred;
        IF last = NULL THEN
            first := NULL;
        ELSE
            last -> .succ := NULL;
        FI;
        TERMINATE (p);
        RETURN;
    END pop;

    elem:
    PROC (i INT) RETURNS (element LOC) EXCEPTIONS (bounds)
        IF first = NULL THEN
            CAUSE bounds;
        FI;
        p := first;
        DO FOR j := 2 TO i;
            IF p -> .succ = NULL THEN
                CAUSE bounds;
            FI;
            p := p -> .succ;
        OD;
        RETURN p -> .info;
    END elem;

    GRANT push,pop,elem;
END stack;
```

28 An abstract data type

```
     /* This example implements a stack with the same functionality         */
    /* of example 27, demonstrating how an abstract data type              */
    /* can be implemented in two different ways in CHILL.                  */
CONTEXT REMOTE FOR
stack:
MODULE
    SEIZE element;
    SYN max = 10_000, min = 1;
    DCL   stack ARRAY (min : max) element,

            stackindex INT INIT:= min-1;
    push:
    PROC (e element) EXCEPTIONS (overflow)
        IF stackindex = max THEN
             CAUSE overflow;
        FI;
        stackindex +:= 1;
        stack(stackindex) := e;
        RETURN;
    END push;
    pop:
    PROC () EXCEPTIONS (underflow)
        IF stackindex = min THEN
             CAUSE underflow;
        FI;
        stackindex-:= 1;
        RETURN;
    END pop;

    elem:
    PROC (i INT) RETURNS (element LOC) EXCEPTIONS (bounds)
        IF i < min OR i > max THEN
             CAUSE bounds;
        FI;
        RETURN stack(i);
    END elem;

    GRANT push,pop,elem;
END stacks;
```

29 Example of a spec module

```
    /* This SPEC MODULE defines the interface of examples 27 and 28. */
stack: SPEC MODULE
    SEIZE: element;
    push: PROC (e element) EXCEPTIONS (overflow) END;
    pop: PROC () EXCEPTIONS (underflow) END;
    elem: PROC (i INT) RETURNS (element LOC) EXCEPTIONS (bounds) END;
    GRANT push,pop,elem;
END stack;
```

30 Object-Orientation – Modes for Simple, Sequential Stacks

```
/*   The examples show the application of object-orientation to the well known stack data structure.
     Two different implementations of stack modes with identical interfaces are realized (Example 30).
    Based on these modes extended modes with an additional operation (e.g. Top; Example 31) or
    with other properties (e.g. mutual exclusive access to stacks (Example 32)) are realized.          */
```

```

SYNMODE   StackMode1 = MODULE SPEC      /* --------------    Definition of the interface    */
    GRANT ElementMode, Push, Pop;                              /* Simple, sequential stack   */
    NEWMODE  ElementMode  =  STRUCT (a  INT, b  BOOL);
    Push: PROC(Elem  ElementMode IN) EXCEPTIONS(Overflow) END Push;
    Pop:   PROC( ) RETURNS(ElementMode) EXCEPTIONS(Underflow) END Pop;
    SYN   Length = 10_000;
    DCL   StackData  ARRAY (1:Length)  ElementMode,           /* Array implementation*/
          TopOfStack  RANGE(0:Length) INIT := 0;              /* of the stack*/
END  StackMode1;

SYNMODE   StackMode1 = MODULE BODY     /* ----------------   Definition of the body */
    Push: PROC(Elem  ElementMode IN) EXCEPTIONS(Overflow)
        IF  TopOfStack = Length  THEN
            CAUSE  Overflow;
        ELSE
            TopOfStack +:= 1;
            StackData(TopOfStack) := Elem;
    FI;
    END Push;
    Pop: PROC( )  RETURNS(ElementMode) EXCEPTIONS(Underflow)
        IF TopOfStack = 0 THEN
            CAUSE  Underflow;
        ELSE
            RESULT(StackData(TopOfStack));
            TopOfStack  -:=  1;
        FI;
    END  Pop;
END  StackMode1;

MainProgram1:  MODULE
    SEIZE StackMode1;
    DCL Stack1  StackMode1;
    DCL Elem1  StackMode1!ElementMode;
    Elem1 := [10, TRUE];
    Stack1.Push(Elem1);
    Stack1.Push( [20, FALSE] );
END MainProgram1;

SYNMODE  StackMode2  =  MODULE SPEC      /* ---------------- Definition of the interface      */
    GRANT ElementMode, Push, Pop;                       /* Same interface as StackMode1    */
    NEWMODE  ElementMode  =  STRUCT (a  INT, b  BOOL);
    Push: PROC(Elem  ElementMode IN) EXCEPTIONS(Overflow) END Push;
    Pop:   PROC( ) RETURNS(ElementMode) EXCEPTIONS(Underflow) END Pop;

    NEWMODE  ListElem  =  STRUCT      (next  REF  ListElem,        /*  List implementation   */
                                          info  ElementMode);               /*  of the stack  */
    DCL  Stack   REF  ListElem  INIT := NULL;
END  StackMode2;

SYNMODE  StackMode2  =  MODULE BODY          /* ---------------- Definition of the body      */
    Push: PROC(Elem  ElementMode IN) EXCEPTIONS(Overflow)
        Stack := ALLOCATE (ListElem, [Stack, Elem])
            ON  (ALLOCATEFAIL) : CAUSE Overflow;  END;
    END Push;
    Pop:   PROC( ) RETURNS(ElementMode) EXCEPTIONS(Underflow)
        DCL Temp  REF ListElem;
        IF Stack = NULL THEN
            CAUSE  Underflow;
        ELSE
```

```
                RESULT (Stack->.info);
                Temp := Stack;
                Stack := Stack->.next;
                TERMINATE (Temp);
            FI;
        END  Pop;
    END  StackMode2;

    MainProgram2:  MODULE    /*  -----------------------  Essentially the same as MainProgram1  */
        SEIZE StackMode2;
        DCL Stack1  StackMode2;
        DCL Elem1  StackMode2!ElementMode;
        Elem1 := [10, TRUE];
        Stack1.Push(Elem1);
        Stack1.Push( [20, FALSE] );
    END MainProgram2;
```

31 Object-Orientation – Mode Extension – Simple, Sequential Stack with Operation “Top”

```

    SYNMODE  StackWithTopMode2  =      MODULE  SPEC        /*  BASED_ON  indicates    */
                                       BASED_ON  StackMode2  /*  mode derivation or    */
        GRANT  Top;                                          /*  inheritance           */
        Top: PROC( ) RETURNS (ElementMode)                 /*  Top is an additional operation  */
                    EXCEPTIONS (EmptyStack) END Top;
    END  StackWithTopMode2  ;

    SYNMODE  StackWithTopMode2  =  MODULE  BODY  BASED_ON  StackMode2
        Top: PROC( ) RETURNS (ElementMode) EXCEPTIONS (EmptyStack)
            IF Stack = NULL THEN
                CAUSE  EmptyStack;
            ELSE
                RETURN (Stack->.info);
            FI;
        END  Top;
    END  StackWithTopMode2  ;

    MainProgram3:  MODULE    /*  ---------------------------------  Very similar to  MainProgram2  */
        SEIZE StackWithTopMode2;
        DCL Stack1  StackWithTopMode2;
        DCL Elem1  StackWithTopMode2!ElementMode;
        Elem1 := [10, TRUE];
        Stack1.Push(Elem1);
        Stack1.Push( [20, FALSE] );
        Elem1 := Stack1.Top( );
    END MainProgram3;
```

32 Object-Orientation – Modes for Stacks with Access Synchronization

```
    /*  Based on the mode StackWithTopMode2 defined in example 31 the mode
        RegionStackWithTopMode1 is defined whose objects behave like regions:
        at any point in time at most one of the public procedures may be in execution.
        Apart from this, the behavior is essentially the same as for StackWithTopMode2:
        erroneous use of an object causes an exception. The second mode
        RegionStackWithTopMode2 uses the CHILL event mechanism to deal with
        erroneous use of a stack object.                                              */

    SYNMODE  RegionStackWithTopMode1  =  REGION  SPEC  BASED_ON  StackWithTopMode2
            /* Just put the base mode into a “region envelope”  */
```

```
            /* In case of an erroneous use same behaviour as StackWithTopMode2: cause an exception */
    END  RegionStackWithTopMode1 ;

    SYNMODE  RegionStackWithTopMode1  =  REGION  BODY  BASED_ON  StackWithTopMode2
    END  RegionStackWithTopMode1  ;

    MainProgram4:  MODULE
        SEIZE  RegionStackWithTopMode1;
        DCL Stack1  RegionStackWithTopMode1;
        Producer: PROCESS ( ) ;
            DCL Elem1  RegionStackWithTopMode1!ElementMode;
            DO  FOR  EVER
                /*  compute Elem1 */
                Stack1.Push(Elem1);
            OD;
        END Producer;
        Consumer: PROCESS ( ) ;
            DCL Elem1  RegionStackWithTopMode1!ElementMode;
            DO  FOR  EVER
                Elem1 :=  Stack1.Pop ( );
                /*  process  Elem1 */
            OD;
        END Consumer;
        START  Producer ( );
        START  Consumer ( );
    END MainProgram4;

    SYNMODE  RegionStackWithTopMode2  =   REGION  SPEC   BASED_ON  StackWithTopMode2
            /*  In case of an erroneous use different behaviour as StackWithTopMode2:
                use the event mechanism */
        GRANT Push, Pop, Top;
        Push:  PROC(Elem  ElementMode IN) REIMPLEMENT END Push;
        Pop:   PROC( ) RETURNS (ElementMode) REIMPLEMENT END Pop;
        Top:   PROC( ) RETURNS (ElementMode) REIMPLEMENT END Top;
        DCL  NotEmpty,  NotFull  EVENT;
    END  RegionStackWithTopMode2  ;

    SYNMODE  RegionStackWithTopMode2  =  REGION  BODY  BASED_ON  StackWithTopMode2
        Push: PROC(Elem  ElementMode IN) REIMPLEMENT
            PushLoop: DO
                BEGIN
                    StackWithTopMode2!Push(Elem);
                    EXIT PushLoop;
                END
                ON (Overflow): DELAY  NotFull;  END;
            OD  PushLoop;
            CONTINUE  NotEmpty;
        END Push;
        Pop:   PROC( ) RETURNS(ElementMode) REIMPLEMENT
            PopLoop: DO
                BEGIN
                    RESULT StackWithTopMode2!Pop( );
                    EXIT PopLoop;
                END
                ON (Underflow): DELAY  NotEmpty;  END;
            OD  PopLoop;
            CONTINUE  NotFull;
        END Pop;
        Top: PROC( ) RETURNS (ElementMode) REIMPLEMENT
            TopLoop: DO
```

```
                BEGIN
                    RESULT StackWithTopMode2!Top( );
                    EXIT TopLoop;
                END
                ON (EmptyStack): DELAY  NotEmpty;  END;
            OD  TopLoop;
            CONTINUE  NotFull;
        END Top;
    END  RegionStackWithTopMode2 ;

    MainProgram5:  MODULE    /*  -------------------------- Essentially the same as MainProgram4  */
        SEIZE  RegionStackWithTopMode2;
        DCL Stack1  RegionStackWithTopMode2;
        Producer: PROCESS ( ) ;
            DCL Elem1  RegionStackWithTopMode2!ElementMode;
            DO  FOR  EVER
                /*  compute Elem1 */
                Stack1.Push(Elem1);
            OD;
        END Producer;
        Consumer: PROCESS ( ) ;
            DCL Elem1  RegionStackWithTopMode2!ElementMode;
            DO  FOR  EVER
                Elem1 := Stack1.Pop (Elem1);
                /*  process  Elem1 */
            OD;
        END Consumer;
        START  Producer ( );
        START  Consumer ( );
    END MainProgram5;
```

Appendix V

Decommitted features

The features described in the following are not part of the present Recommendation Z.200, but were part of the Recommendation Z.200, 1984, *Red Book*, Volume VI - Fascicle VI.12 and Recommendation Z.200, 1988, *Blue Book*, Volume X - Fascicle X.6. In the following a brief description is given; for a complete definition of them, refer to the relevant subclauses of Recommendation Z.200, 1984, that are hereafter mentioned. These features may be supported by an implementation. If no indication is given, the references are made to Recommendation Z.200, 1984.

1 Free directive (see 2.6)

A free directive freed the **reserved** simple name strings specified in the *reserved simple name string list* so that they could be redefined.

2 Integer modes syntax (see 3.4.2)

BIN was derived syntax for *INT*.

3 Set modes with holes (see 3.4.5)

A set mode defined a set of named or unnamed values. A set mode was a set mode **with holes**, if, and only if, the number of its **set element** names was less than the **number of values** of the set mode.

4 Procedure modes syntax (see 3.7)

A *result spec* without the optional **reserved** simple name string **RETURNS** was derived syntax for the *result spec* with **RETURNS**.

5 String modes syntax (see 3.11.2)

The notation **CHAR** *(n)* and **BIT** *(n)* denoted character strings and bit strings respectively.

6 Array modes syntax (see 3.11.3)

The **reserved** simple name string **ARRAY** was optional.

7 Level structure notation (see 3.11.5)

A *level structure mode* was derived syntax for a *nested structure mode*. In the level structure notation, the fields were preceded by a level number. If a structure contained fields that were themselves structures or arrays of structures, a hierarchy of structures was formed and a level number could be associated with each field. Instead of writing nested structure modes, it was allowed in the *level structure mode* to write the level number in the front of the field name.

8 Map reference names (see 3.11.6)

Map reference names could be used to specify mapping in an implementation defined way.

9 Based declarations (see 4.1.4)

A based declaration without a *bound or free reference location name* was derived syntax for a synmode definition statement. A based declaration with a *bound or free reference location name* defined one or more access names. These names served as an alternative way of accessing a location by dereferencing the reference value contained in the specified reference location. This dereferencing operation was performed each time and only when an access was made via a declared **based** name.

10 Character string literals (see 5.2.4.6)

Character string literals were delimited by apostrophe characters. Apart from the printable representation, the hexadecimal representation could be used. Character string literals of length one served as character literals.

11 Receive expressions (see Rec. Z.200, 1988, 5.3.9)

Receive expressions were used to receive values from buffer locations. The executing process could become delayed and could re-activate another process, delayed on sending a value to the specified buffer location.

12 Addr notation (see 5.3.8)

ADDR *(<location>)* was derived syntax for -> *<location>*.

13 Assignment syntax (see 6.2)

The = symbol was derived syntax for the := symbol.

14 Case action syntax (see 6.4)

The *range list* of a *case action* could be specified more generally by a *<u>discrete</u> mode*, and not only by a *<u>discrete mode</u> name*.

15 Do-for action syntax (see 6.5.2)

The range in the *range enumeration* of a do-for action could be specified more generally by a *<u>discrete</u> mode*, and not only by a *<u>discrete mode</u> name*.

16 Explicit loop counters (see 6.5.2)

If an access name was visible in the reach where the *do action* was placed, which was equal to one of the names defined by a *loop counters*, then the *loop counter* was **explicit**; otherwise it was **implicit**. In the former case, the value of the loop counter was stored into the denoted location just prior to abnormal termination. A distinction was made between **normal** and **abnormal** termination. Normal termination occurred if the evaluation of at least one of the loop counters indicated termination. Abnormal termination occurred if the evaluation of while condition delivered *FALSE* or if the do action was left by a transfer of control out of it.

17 Call action syntax (see 6.7)

The **reserved** simple name string **CALL** was optional. A *call action* with **CALL** was derived from a *call action* without **CALL**.

18 RECURSEFAIL exception (see 6.7)

The *RECURSEFAIL* exception was caused when a **non-recursive** procedure called itself recursively.

19 Start action syntax (see 6.13)

The *start action* with the **SET** option was derived syntax for the single assignment action:
<*instance location*> *:=* <*start expression*>.

20 Explicit value receive names (see 6.19)

A receive signal case action and a receive buffer case action could introduce **value receive** names. If a name was visible in the reach where the *receive signal case action* was placed, which was equal to one of the names introduced after **IN**, then the **value receive** name was **explicit**; otherwise it was **implicit**. In the former case, the received value was stored into the denoted location immediately before the execution of the action statement list.

21 Blocks (see 8.1)

The *if action, case action, do action* and *delay case action* were not defined to be blocks.

22 Entry statement (see 8.4)

A procedure could have multiple entry points by means of entry statements. These statements were considered to be additional procedure definitions. The defining occurrence in the entry statement defined the name of the entry point in the procedure in which reach it was placed. The entry point was determined by the textual position of the entry statement.

23 Register names (see 8.4)

Register specification could be given in the formal parameter of the procedure and in the result spec. In the pass by value case, it meant that the actual value was contained in the specified register; in the pass by location case, it meant that the (hidden) pointer to the actual location was contained in the specified register. If the specification was in the result spec it meant that the returned value or the (hidden) pointer to the returned location was contained in the specified register.

24 Recursive attribute (see Rec. Z.200, 1988, 10.4)

The **recursivity** of procedures was an implementation default, unless the attribute **RECURSIVE** was specified in a procedure attribute list.

25 Quasi cause statements and quasi handlers (see 8.10.3)

Quasi cause statements indicated the presence of cause statements in remote modules or remote regions directly enclosed in the reach directly enclosing the reach of the spec module or spec region in which the quasi cause statement was placed. Quasi handlers indicated the presence of a handler in the program, reachable from the module, region or context directly enclosed in the context to which the quasi handler was appended.

26 Syntax of quasi statements (see Rec. Z.200, 1988, 10.10.3)

Quasi procedure and process definition statements were terminated by an **END** <*simple name string*>.

27 Weakly visible names and visibility statements (see Rec. Z.200, 1988, 12.2.1)

A *name string* which was not **strongly visible** in a reach was said to be **weakly visible** in it if it was **implied** by a *name string* which was **strongly visible** in the reach. The *name string* in the reach was **linked** to **implied** *defining* *occurrences*. If they did not define the same set element of **similar** set modes, a **weak clash** occurred, otherwise the *name string* was **bound** to them. Subclause 12.2.4 defined the **implied** *defining occurrences* for names.

28 Weakly visible names and visibility statements (see 10.2.4.3)

A *name string* NS weakly visible in reach R was said to be seizable by modulion M directly enclosed in R if NS was linked in R to a *defining occurrence* not surrounded by the reach of M. A *name string* NS weakly visible in reach R of modulion M was said to be grantable by M if NS was linked in R to a *defining occurrence* surrounded by R.

29 Pervasiveness (see 10.2.4.4)

When a *grant statement* contained (**DIRECTLY**) **PERVASIVE**, all name strings granted by it had the (directly) pervasive property in the surrounding reaches of the modulion M that directly enclosed the *grant statement*. The name strings:

- were **strongly visible** in a directly surrounding reach S of M;
- in case the name strings had the **directly pervasive** property in S, they had also the **directly pervasive** property in M;
- if they were not **directly strongly visible** in a reach R and were **strongly visible** in a reach that directly enclosed R and where they had the pervasive property, then they were **indirectly strongly visible** in R and had also the pervasive property in R.

30 Seizing by modulion name (see 10.2.4.5)

If a *prefix rename clause* in a *seize statement* had a *seize postfix* which contained a modulion *name string* and **ALL**, then the *prefix rename clause* was equivalent to a set of *seize statements*, for any name string that was strongly visible in the reach that directly enclosed the modulion in which the *seize statement* was placed and was seizable by this modulion, and was granted by the modulion attached to the <u>*modulion*</u> *name* in the reach directly enclosing the modulion in which the *seize statement* was placed.

31 Predefined simple name strings (see III.2)

AND, *NOT*, *OR*, *REM*, *MOD*, *THIS* and *XOR* were predefined simple name strings.

Appendix VI

Index of production rules

Index

Page numbers in boldface are references to the defining occurrences of an item; normal font refers to applied occurrences of indexed items.

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