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**Information technology — Programming
languages — Fortran — Enhanced data
type facilities**

*Technologies de l'information — Langages de programmation — Fortran —
Facilités de type de données améliorées*

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is still the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Technical Reports are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Attention is drawn to the possibility that some of the elements of this Technical Report may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC TR 15581, which is a Technical Report of type 2, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 22, *Programming languages, their environments and system software interfaces*.

This second edition cancels and replaces the first edition (ISO/IEC TR 15581:1998), which has been technically revised.

Annex A of this Technical Report is for information only.

This Technical Report specifies an extension to the data type facilities of the programming language Fortran. Fortran is specified by the international standard ISO/IEC 1539-1. This document has been prepared by ISO/IEC JTC1/SC22/WG5, the technical working group for the Fortran language.

It is the intention of ISO/IEC JTC1/SC22/WG5 that the semantics and syntax specified by this Technical Report be included in the next revision of the Fortran standard (ISO/IEC 1539-1) without change unless experience in the implementation and use of this feature identifies any errors that need to be corrected, or changes are required to achieve proper integration, in which case every reasonable effort will be made to minimize the impact of such changes on existing commercial implementations.

Introduction

There are many situations when programming in Fortran where it is necessary to allocate and deallocate arrays of variable size but the full power of pointer arrays is unnecessary and undesirable. In such situations the abilities of a pointer array to alias other arrays and to have non-unit (and variable at execution time) strides are unnecessary, and they are undesirable because this limits optimization, increases the complexity of the program, and increases the likelihood of memory leakage. The ALLOCATABLE attribute solves this problem but can currently only be used for locally stored arrays, a very significant limitation. The most pressing need is for this to be extended to array components; without allocatable array components it is overwhelmingly difficult to create opaque data types with a size that varies at runtime without serious performance penalties and memory leaks.

A major reason for extending the ALLOCATABLE attribute to include dummy arguments and function results is to avoid introducing further irregularities into the language. Furthermore, allocatable dummy arguments improve the ability to hide inessential details during problem decomposition by allowing the allocation and deallocation to occur in called subprograms, which is often the most natural position. Allocatable function results ease the task of creating array functions whose shape is not determined initially on function entry, without negatively impacting performance.

This extension is being defined by means of a Technical Report in the first instance to allow early publication of the proposed definition. This is to encourage early implementation of important extended functionalities in a consistent manner and will allow extensive testing of the design of the extended functionality prior to its incorporation into the language by way of the revision of ISO/IEC 1539-1.

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Information technology - Programming languages - Fortran - Enhanced data type facilities

1 General

1.1 Scope

This Technical Report specifies an extension to the data-type facilities of the programming language Fortran. The current Fortran language is specified by ISO/IEC 1539-1 : 1997. The proposed extension allows dummy arguments, function results, and components of derived types to be allocatable arrays.

Clause 2 of this Technical Report contains a general informal but precise description of the proposed extended functionalities. Clause 3 contains detailed editorial changes which if applied to the current International Standard would implement the revised language specification.

1.2 Normative Reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this Technical Report. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/IEC 1539-1 : 1997 *Information technology - Programming languages - Fortran - Part 1: Base language.*

2 Requirements

The following subclauses contain a general description of the extensions required to the syntax and semantics of the current Fortran language to provide facilities for regularization of the ALLOCATABLE attribute.

2.1 Allocatable Attribute Regularization

In order to avoid irregularities in the language, the ALLOCATABLE attribute needs to be allowed for all data entities for which it makes sense. Thus, this attribute which was previously limited to locally stored array variables is now allowed on

- array components of structures,
- dummy arrays, and
- array function results.

Allocatable entities remain forbidden from occurring in all places where they may be storage-associated (COMMON blocks and EQUIVALENCE statements). Allocatable array components may appear in SEQUENCE types, but objects of such types are then prohibited from COMMON and EQUIVALENCE.

The semantics for the allocation status of an allocatable entity remain unchanged:

- If it is in a main program or has the SAVE attribute, it has an initial allocation status of not currently allocated. Its allocation status changes only as a result of ALLOCATE and DEALLOCATE statements.
- If it is a module variable without the SAVE attribute, the initial allocation status is not currently allocated and the allocation status may become not currently allocated (by automatic deallocation) whenever execution of a RETURN or END statement results in no active procedure having access to the module.
- If it is a local variable (not accessed by use or host association) and does not have the SAVE attribute, the allocation status becomes not currently allocated on entry to the procedure. On exit from this procedure, if it is currently allocated it is automatically deallocated and the allocation status changes to not currently allocated.

Since an allocatable entity cannot be an alias for an array section (unlike pointer arrays), it may always be stored contiguously.

2.2 Allocatable Arrays as Dummy Arguments

An allocatable dummy argument array shall have associated with it an actual argument which is also an allocatable array.

On procedure entry the allocation status of an allocatable dummy array becomes that of the associated actual argument. If the dummy argument is INTENT(OUT) and the associated actual argument is currently allocated, the actual argument is deallocated on procedure invocation so that the dummy argument has an allocation status of not currently allocated. If the dummy argument is not INTENT(OUT) and the actual argument is currently allocated, the value of the dummy argument is that of the associated actual argument.

While the procedure is active, an allocatable dummy argument array that does not have INTENT(IN) may be allocated, deallocated, defined, or become undefined. If any of these events occur no reference to the associated actual argument via another alias is permitted.

On exit from the routine the actual argument has the allocation status of the allocatable dummy argument (there is no change, of course, if the allocatable dummy argument has INTENT(IN)). The usual rules apply for propagation of the value from the dummy argument to the actual argument.

No automatic deallocation of the allocatable dummy argument occurs as a result of execution of a RETURN or END statement in the procedure of which it is a dummy argument.

Note that an INTENT(IN) allocatable dummy argument array cannot have its allocation status altered within the called procedure. Thus the main difference between such a dummy argument and a normal dummy array is that it might be unallocated on entry (and throughout execution of the procedure).

Example

```

SUBROUTINE LOAD(ARRAY, FILE)
  REAL, ALLOCATABLE, INTENT(OUT) :: ARRAY(:, :, :)
  CHARACTER(LEN=*), INTENT(IN) :: FILE
  INTEGER UNIT, N1, N2, N3
  INTEGER, EXTERNAL :: GET_LUN
  UNIT = GET_LUN()      ! Returns an unused unit number
  OPEN(UNIT, FILE=FILE, FORM='UNFORMATTED')
  READ(UNIT) N1, N2, N3
  ALLOCATE(ARRAY(N1, N2, N3))
  READ(UNIT) ARRAY
  CLOSE(UNIT)
END SUBROUTINE LOAD

```

2.3 Allocatable Array Function Results

An allocatable array function shall have an explicit interface.

On entry to an allocatable array function, the allocation status of the result variable becomes not currently allocated.

The function result variable may be allocated and deallocated any number of times during the execution of the function; however, it shall be currently allocated and have a defined value on exit from the function. Automatic deallocation of the result variable does not occur immediately on exit from the function, but after execution of the statement in which the function reference occurs.¹

Example

```

FUNCTION INQUIRE_FILES_OPEN() RESULT(OPENED_STATUS)
  LOGICAL,ALLOCATABLE :: OPENED_STATUS(:)
  INTEGER I,J
  LOGICAL TEST
  DO I=1000,0,-1
    INQUIRE(UNIT=I,OPENED=TEST,ERR=100)
    IF (TEST) EXIT
100 CONTINUE
  END DO
  ALLOCATE(OPENED_STATUS(0:I))
  DO J=0,I
    INQUIRE(UNIT=J,OPENED=OPENED_STATUS(J))
  END DO
END FUNCTION INQUIRE_FILES_OPEN

```

2.4 Allocatable Array Components

Allocatable array components are defined to be **ultimate components** just as pointer components are, because the value (if any) is stored separately from the rest of the structure and this storage does not exist (because the array is unallocated) when the structure is created. As with ultimate pointer components, variables containing ultimate allocatable array components are forbidden from appearing directly in input/output lists - the user shall list any allocatable array or pointer component for i/o.

As per allocatable arrays currently, they are forbidden from storage association contexts (so any variable containing an ultimate allocatable array component cannot appear in COMMON or EQUIVALENCE); this maintains the clarity and optimizability of allocatable arrays. However, allocatable array components are permitted in SEQUENCE types, which allows the same type to be defined separately in more than one scoping unit.

¹ This storage can thus be reclaimed at the same time as that of array temporaries and the results of *explicit-shape-spec* functions referenced in the expression.

Deallocation of a variable containing an ultimate allocatable array component automatically deallocates all such components of the variable that are currently allocated.

In a structure constructor for a derived type containing an allocatable array component, the expression corresponding to the allocatable array component must be one of the following:

- an argumentless reference to the intrinsic function `NULL ()`; the allocatable array component receives the allocation status of not currently allocated.
- a variable that is itself an allocatable array; the allocatable array component receives the allocation status of the variable, and, if allocated, the bounds and value of the variable.
- any other array expression; the allocatable array component receives the allocation status of currently allocated with the same bounds and value as the expression.

For intrinsic assignment of objects of a derived type containing an allocatable array component, the allocatable array component of the variable on the left-hand-side receives the allocation status and, if allocated, the bounds and value of the corresponding component of the expression. This occurs as if the following sequence of steps is carried out:²

1. If the component of the variable is currently allocated, it is deallocated.
2. If the corresponding component of the expression is currently allocated, the component of the variable is allocated with the same bounds. The value of the component of the expression is then assigned to the corresponding component of the variable using intrinsic assignment.

Note that this definition of assignment facilitates certain optimizations when the allocatable array component of the expression is allocated. In particular:

1. If the corresponding component of the variable is allocated with the same (or larger) size, its storage can be re-used without the overhead of an additional allocation or deallocation;
2. If the expression is a function reference, the processor can simply copy the descriptor instead of the allocatable array contents and omit the deallocation of this component.

An allocated ultimate allocatable array component of an actual argument that is associated with an `INTENT(OUT)` dummy argument is deallocated on procedure entry so that the corresponding component of the dummy argument has an allocation status of not currently allocated.

² This ensures that any pointers that point to the previous contents of the allocatable array component of the variable become undefined. Implementations are thus free to skip the allocation-deallocation (or not) when the component of the variable happens to be allocated with the same shape as the corresponding component of the expression, whichever is most efficient.

Example

```

MODULE REAL_POLYNOMIAL_MODULE
  TYPE REAL_POLYNOMIAL
    REAL, ALLOCATABLE :: COEFF(:)
  END TYPE
  INTERFACE OPERATOR(+)
    MODULE PROCEDURE RP_ADD_RP, RP_ADD_R
  END INTERFACE
CONTAINS
  FUNCTION RP_ADD_R(P1,R)
    TYPE(REAL_POLYNOMIAL) RP_ADD_R, P1
    REAL R
    INTENT(IN) P1,R
    ALLOCATE(RP_ADD_R%COEFF(SIZE(P1%COEFF)))
    RP_ADD_R%COEFF = P1%COEFF
    RP_ADD_R%COEFF(1) = P1%COEFF(1) + R
  END FUNCTION
  FUNCTION RP_ADD_RP(P1,P2)
    TYPE(REAL_POLYNOMIAL) RP_ADD_RP, P1, P2
    INTENT(IN) P1, P2
    INTEGER M
    ALLOCATE(RP_ADD_RP%COEFF(MAX(SIZE(P1%COEFF), SIZE(P2%COEFF))))
    M = MIN(SIZE(P1%COEFF), SIZE(P2%COEFF))
    RP_ADD_RP%COEFF(:M) = P1%COEFF(:M) + P2%COEFF(:M)
    IF (SIZE(P1%COEFF)>M) THEN
      RP_ADD_RP%COEFF(M+1:) = P1%COEFF(M+1:)
    ELSE IF (SIZE(P2%COEFF)>M) THEN
      RP_ADD_RP%COEFF(M+1:) = P2%COEFF(M+1:)
    END IF
  END FUNCTION
END MODULE

PROGRAM EXAMPLE
  USE REAL_POLYNOMIAL_MODULE
  TYPE(REAL_POLYNOMIAL) P, Q, R
  P = REAL_POLYNOMIAL(/4,2,1/) ! Set P to (X**2+2X+4)
  Q = REAL_POLYNOMIAL(/-1,1/) ! Set Q to (X-1)
  R = P + Q ! Polynomial addition
  PRINT *, 'Coefficients are: ', R%COEFF
END

```

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3 Required editorial changes to ISO/IEC 1539-1 : 1997

The following subclauses contain the editorial changes to ISO/IEC 1539-1 : 1997 required to include these extensions in a revised definition of the International Standard for the Fortran language.

Note, where new syntax rules are inserted they are numbered with a decimal addition to the rule number that precedes them. In the actual document these will have to be properly numbered in the revised sequence.

Comments about each edit to the standard appear within braces { }.

Page and line number references for these edits appear within brackets [].

- 4.4, first paragraph, list item (2) [37:42]
 Change “nonpointer component that is of derived type,”
 To: “component that is of derived type and is not a pointer or allocatable array,”
 {The direct component tree stops at allocatable arrays, just as with pointers.}
- 4.4, second paragraph [38:2]
 Insert “allocatable arrays or” before “pointers”.
 {This makes allocatable array components into **ultimate** components, just as pointer components.}
- 4.4.1, R426 *component-attr-spec* [38:42+]
 add new production to rule: “**or** ALLOCATABLE”.
 {Allow ALLOCATABLE attribute in *component-def-stmt*.}
- R427, sixth constraint [39:13]
 change “the POINTER attribute is not”
 to “neither the POINTER attribute nor the ALLOCATABLE attribute is”
 {Do not require an *explicit-shape-spec-list* when ALLOCATABLE is specified.}
- Two new constraints at end of list [39:16+]
 Add:
 “Constraint: If the ALLOCATABLE attribute is specified for a component, the component shall be a deferred-shape array.
 Constraint: POINTER and ALLOCATABLE shall not both appear in the same *component-def-stmt*.
 {Require ALLOCATABLE components to be deferred-shape arrays. Ensure POINTER and ALLOCATABLE are exclusive.}

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R428 *component-initialization*

[39:29+]

Add new constraint to end of list:

“Constraint: If the ALLOCATABLE attribute appears in the *component-attr-spec-list*, *component-initialization* shall not appear.”

{Forbid default initialization - allocatable array components are already effectively default-initialized to “not currently allocated”.}

4.4.1, paragraph beginning “If the **SEQUENCE statement** is”

[39:38-39]

add “or allocatable arrays”

after both occurrences of “are not pointers”.

{Allocatable array components, like pointer components, stop a SEQUENCE type from being a standard (numeric or character) sequence type.}

4.4.1, after Note 4.25,

[42:20+]

add new example:

“Note 4.25.1

A derived type may have a component that is an allocatable array. For example:

```
TYPE STACK
  INTEGER :: INDEX
  INTEGER, ALLOCATABLE :: CONTENTS(:)
END TYPE STACK
```

For each scalar variable of type STACK, the shape of component CONTENTS is determined by execution of an ALLOCATE statement or assignment statement, or by argument association.”

{Example needed.}

4.4.4, add new paragraphs to end of clause:

[45:19+]

“If a component of a derived type is an allocatable array, the corresponding constructor expression shall either be a reference to the intrinsic function NULL() with no arguments, an allocatable array, or shall evaluate to an array. If the expression is a reference to the intrinsic function NULL(), the corresponding component of the constructor has a status of not currently allocated. If the expression is an allocatable array, the corresponding component of the constructor has the same allocation status as that allocatable array and, if it is allocated, the same bounds and value. With any other expression that evaluates to an array the corresponding component of the constructor has an allocation status of currently allocated with the same bounds and value as the expression.

Note 4.34.1:

When the constructor is an actual argument, the allocation status of the allocatable array component is available through the associated dummy argument.

If a derived type contains an ultimate component that is an allocatable array, its constructor shall not appear as a *data-stmt-constant* in a DATA statement (5.2.9), as an *initialization-expr* in an *entity-decl* (5.1), or as an *initialization-expr* in a *component-initialization* (4.4.1).”

{Allow structure constructors for derived types with allocatable array components, and define their semantics.}

5.1, R501-R506, third constraint

[48:1-2]

Delete “that is not a dummy argument or function result”

- 5.1, eighth constraint, begins “The PARAMETER attribute shall not”: [48:12]
 After “allocatable arrays,”
 Add “derived-type objects with an ultimate component that is an allocatable array,”
 {forbid such objects from having the PARAMETER attribute. }
- 5.1, third-last constraint, begins “*initialization* shall not appear”: [48:33]
 after “an allocatable array,”
 add “a derived-type object containing an ultimate component that is an allocatable array,”
 {forbid such types from having =*initialization*. }
- 5.1.2.4.3, second paragraph [55:12]
 After “An **allocatable array** is”, change “a named array” to “an array”.
 {Do not insist on allocatable arrays being simple names, i.e. allow components. }
- 5.1.2.4.3, third paragraph, begins “The ALLOCATABLE attribute may be”: [55:15-19]
 Replace paragraph with:
 “The ALLOCATABLE attribute may be specified for an array in a type declaration statement, a component definition statement, or an ALLOCATABLE statement (5.2.6). An array with the ALLOCATABLE attribute shall be declared with a *deferred-shape-spec-list* in a type declaration statement, an ALLOCATABLE statement, a component definition statement, a DIMENSION statement (5.2.5), or a TARGET statement (5.2.8). The type and type parameters may be specified in a type declaration statement or a component definition statement.”
- 5.2.10, R533-R537, following the third constraint [61:42+]
 Add new constraint:
 “Constraint: A *data-i-do-object*, or a *variable* that appears as a *data-stmt-object*, shall not be of a derived type containing an allocatable array as an ultimate component.”
 {Forbid initialization of allocatable arrays via the DATA statement. }
- 5.4, R545 first constraint [66:2-3]
 After: “, a pointer,”
 Insert “an allocatable array, or”
 After “is a pointer”
 Delete “”
 {Do not allow derived types containing allocatable arrays in NAMELIST. }
- 5.5.1, R548 first constraint [66:40]
 After “an allocatable array,”
 Insert “an object of a derived type containing an allocatable array as an ultimate component,”
 {Do not allow derived types containing allocatable arrays in EQUIVALENCE. }
- 5.5.2, R550 second constraint [69:1]
 After “allocatable array,”
 Insert “an object of a derived type containing an allocatable array as an ultimate component,”
 {Do not allow derived types containing allocatable arrays in COMMON. }

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6.1.2, R612-R613, fourth constraint

[75:14]

Change “POINTER” to “ALLOCATABLE or POINTER”.

{We do not want to have arrays of allocatable array elements, one from each allocatable array component. }

6.3.1.1, new paragraph at end of clause

[80:29+]

“If an object of derived type is created by an ALLOCATE statement, any ultimate allocatable components have an allocation status of not currently allocated.”

{Specify allocation status of allocatable array components created by an ALLOCATE statement. }

6.3.1.2, new paragraph following the second paragraph

[80:42+]

“An allocatable dummy array receives the allocation status of the actual argument with which it is associated on entry to the procedure. An allocatable array that is an ultimate component of a dummy argument that is not INTENT(OUT) receives the allocation status of the corresponding component of the actual argument on entry to the procedure. An allocated actual argument that is associated with an INTENT(OUT) allocatable dummy array is deallocated on procedure entry and the dummy array has an allocation status of not currently allocated. An allocated ultimate allocatable array component of an actual argument that is associated with an INTENT(OUT) dummy argument is deallocated on procedure entry and the corresponding component of the dummy argument has an allocation status of not currently allocated.”

{Specify initial status of allocatable dummy arrays and allocatable components of dummy arguments. }

6.3.1.2, third paragraph

[80:43]

After “that is a local variable of a procedure”

Insert “or an ultimate component thereof, that is not a dummy argument or a subobject thereof”

{Exclude allocatable dummy arrays from the initial “not currently allocated” status, and also from automatic deallocation. }

6.3.1.2, third paragraph

[81:1]

After “If the array”

Add “is not the result variable of the procedure or a subobject thereof and”

{Exclude allocatable function results from automatic deallocation. }

6.3.3.1, second paragraph

[83:10-13]

After “has the SAVE attribute,”

Add new list items and renumber rest of list:

(2) It is a dummy argument or an ultimate component thereof.

(3) It is a function result variable or an ultimate component thereof.

{Say that these cases retain their allocation status (and thus are excluded from automatic deallocation). }

6.3.3.1, before Note 6.18,

[83:18+]

Add new paragraph:

“When a variable of derived type is deallocated, any ultimate component that is a currently allocated allocatable array is deallocated (as if by a DEALLOCATE statement).”

{Prevent memory leaks from nested allocatable array components. }

6.3.3.1, before Note 6.18, after added paragraph above [83:18+]

Add another new paragraph:

“If a statement contains a reference to a function whose result is an allocatable array or a structure that contains an ultimate component that is an allocatable array, and the function reference is executed, an allocatable array result and any allocated ultimate components that are allocatable arrays in the result returned by the function are deallocated after execution of this statement.”

{Specify when a function result is deallocated. Needed in case the function result has the TARGET attribute. Also, prevents memory leaks.}

7.1.4.1, fifth paragraph [91:27]

After “returns a disassociated pointer”

Insert “or designates an unallocated allocatable array component of a structure constructor”

After “A disassociated pointer”

Insert “or unallocated allocatable array”

After “with the result”

[91:30]

Insert “or by the corresponding component in a structure constructor”

7.1.6.1. [94:6]

After “(3) A structure constructor where each component is an initialization expression”

Insert “and no component has the ALLOCATABLE attribute”

{Exclude structure constructors containing allocatable components from initialization expressions.}

7.5.1.5, paragraph after Note 7.43 [109:35-38]

After “nonpointer components” change “.” to

“that are not allocatable arrays. For allocatable array components the following sequence of operations is applied:

1. If the component of *variable* is currently allocated, it is deallocated.
2. If the component of *expr* is currently allocated, the corresponding component of *variable* is allocated with the same bounds. The value of the component of *expr* is then assigned to the corresponding component of *variable* using intrinsic assignment.”

{Specify semantics to be used for assignment of derived types containing allocatable array components. Note that because pointers to deallocated objects become undefined, this definition does not rule out optimising away the allocation-deallocation when the components are already allocated with the same shape.}

7.5.1.5, After Note 7.44 [110:5+]

Add new note:

“Note 7.44.1:

If an allocatable array component of *expr* is not currently allocated, the corresponding component of *variable* has an allocation status of not currently allocated after execution of the assignment.”

{Note that assignments containing unallocated components are allowed and have the expected effect.}

9.4.2, paragraph after Note 9.26 [149:6]

After “If a derived type ultimately contains a pointer component”

Insert “or an allocatable array component”

{Exclude objects of derived type containing ultimate array components from appearing in i/o statements.}