BS ISO/IEC 9075-15:2023

BSI Standards Publication

Information technology — Database languages SQL

Part 15: Multidimensional arrays (SQL/ MDA)

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee IST/40, Data management and interchange.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Published by BSI Standards Limited 2023

ISBN 978 0 539 21713 1

ICS 35.060

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2023.

Amendments/corrigenda issued since publication

Date	Text affected

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INTERNATIONAL STANDARD

ISO/IEC 9075-15

Second edition
2023-06

Information technology — Database languages SQL —

Part 15: Multidimensional arrays (SQL/MDA)

Technologies de l'information — Langages de base de données SQL —

Partie 15: Tableaux multi-dimensionnels (SQL/MDA)

Reference number
ISO/IEC 9075-15:2023(E)

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Published in Switzerland

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

ISO and IEC draw attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO and IEC take no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO and IEC have not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents and https://patents.iec.ch. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html. In the IEC, see www.iec.ch/understanding-standards.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 32, *Data management and interchange*.

This second edition cancels and replaces the first edition (ISO/IEC 9075-15:2019), which has been technically revised. It also incorporates the Technical Corrigendum ISO/IEC 9075-15:2019/Cor.1:2022.

The main changes are as follows:

— improve the presentation and accuracy of the summaries of implementation-defined and implementation-dependent aspects of this document;

— introduction of several digital artifacts;

— alignment with updated ISO house style and other guidelines for creating standards.

This second edition of ISO/IEC 9075-15 is designed to be used in conjunction with the following editions of other parts of the ISO/IEC 9075 series, all published in 2023:

— ISO/IEC 9075-1, sixth edition;

— ISO/IEC 9075-2, sixth edition;

— ISO/IEC 9075-3, sixth edition;

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— ISO/IEC 9075-4, seventh edition;

— ISO/IEC 9075-9, fifth edition;

— ISO/IEC 9075-10, fifth edition;

— ISO/IEC 9075-11, fifth edition;

— ISO/IEC 9075-13, fifth edition;

— ISO/IEC 9075-14, sixth edition;

— ISO/IEC 9075-16, first edition.

A list of all parts in the ISO/IEC 9075 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

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Introduction

This document was developed in response to industry demand for the ability to store and manipulate data in the form of multidimensional arrays within databases managed using database language SQL.

The organization of this document is as follows:

1) Clause 1, "Scope", specifies the scope of this document.

2) Clause 2, "Normative references", identifies additional standards that, through reference in this document, constitute provisions of this document.

3) Clause 3, "Terms and definitions", defines the notations and conventions used in this document.

4) Clause 4, "Concepts", presents concepts used in the definition of multidimensional arrays.

5) Clause 5, "Lexical elements", defines a number of lexical elements used in the definition of multidimensional arrays.

6) Clause 6, "Scalar expressions", defines a number of scalar expressions used in the definition of multidimensional arrays.

7) Clause 7, "Query expressions", defines the elements of the language that produce rows and tables of data as used in multidimensional arrays.

8) Clause 8, "Predicates", defines the predicates used in the definition of multidimensional arrays.

9) Clause 9, "Additional common rules", specifies the rules for assignments that retrieve multidimensional array data from or store multidimensional array data into SQL-data, and formation rules for set operations.

10) Clause 10, "Additional common elements", defines additional common elements used in the definition of multidimensional arrays.

11) Clause 11, "Schema definition and manipulation", defines facilities for creating and managing a schema.

12) Clause 12, "SQL-client modules", defines SQL-client modules and externally-invoked procedures in the context of multidimensional arrays.

13) Clause 13, "Data manipulation", defines the data manipulation statements.

14) Clause 14, "Additional data manipulation rules", defines additional rules for data manipulation.

15) Clause 15, "Dynamic SQL", defines the facilities for executing SQL-statements dynamically in the context of multidimensional arrays.

16) Clause 16, "Embedded SQL", defines the host language embeddings in the context of multidimensional arrays.

17) Clause 17, "Call-Level Interface specifications", defines facilities for using SQL through a Call-Level Interface.

18) Clause 18, "Information Schema", defines the Information and Definition Schema objects associated with multidimensional arrays.

19) Clause 19, "Definition Schema", defines base tables on which the viewed tables containing schema information depend.

20) Clause 20, "Status codes", defines SQLSTATE values related to multidimensional arrays.

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21) Clause 21, "Conformance", defines the criteria for conformance to this document.

22) Annex A, "SQL conformance summary", is an informative Annex. It summarizes the conformance requirements of the SQL language.

23) Annex B, "Implementation-defined elements", is an informative Annex. It lists those features for which the body of this document states that the syntax, the meaning, the returned results, the effect on SQL-data and/or schemas, or other aspect is partly or wholly implementation-defined.

24) Annex C, "Implementation-dependent elements", is an informative Annex. It lists those features for which the body of this document states that the syntax, the meaning, the returned results, the effect on SQL-data and/or schemas, or other aspect is partly or wholly implementation-dependent.

25) Annex D, "SQL optional feature taxonomy", is an informative Annex. It identifies the optional features of the SQL language specified in this document by an identifier and a short descriptive name. This taxonomy is used to specify conformance.

26) Annex E, "Deprecated features", is an informative Annex. It lists features that the responsible Technical Committee intends not to include in a future edition of this document.

27) Annex F, "Incompatibilities with ISO/IEC 9075:2016", is an informative Annex. It lists incompatibilities with the previous version of this document.

28) Annex G, "Defect Reports not addressed in this edition of this document", is an informative Annex. It describes the Defect Reports that were known at the time of publication of this document. Each of these problems is a problem carried forward from the previous edition of the ISO/IEC 9075 series. No new problems have been created in the drafting of this edition of this document.

In the text of this document, in Clause 5, "Lexical elements", through Clause 21, "Conformance", Subclauses begin new pages. Any resulting blank space is not significant.

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Information technology — Database language SQL —

Part 15:
Multidimensional arrays (SQL/MDA)

1 Scope

This document defines ways in which Database Language SQL can be used in conjunction with multidimensional arrays.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 9075-1, *Information technology — Database languages — SQL — Part 1: Framework (SQL/Framework)*

ISO/IEC 9075-2, *Information technology — Database languages — SQL — Part 2: Foundation (SQL/Foundation)*

ISO/IEC 9075-3, *Information technology — Database languages — SQL — Part 3: Call-Level Interface (SQL/CLI)*

ISO/IEC 9075-11, *Information technology — Database languages — SQL — Part 11: Information and Definition Schemas (SQL/Schemata)*

Internet Engineering Task Force (IETF) RFC 2046 *Multipurpose Internet Mail Extensions (MIME), Part Two: Media Types*. Edited by: Freed, N. November 1996
Available at: https://tools.ietf.org/html/rfc2046

Internet Engineering Task Force (IETF) RFC 8259 *The JavaScript Object Notation (JSON) Data Interchange Format*. Edited by: Miller, Matthew December 2018
Available at: https://datatracker.ietf.org/doc/rfc8259/

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 9075-1, ISO/IEC 9075-2, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at `https://www.iso.org/obp`

— IEC Electropedia: available at `https://www.electropedia.org/`

3.1
coordinate
non-empty ordered list of integers

3.2
maximum MD-extent
<of an MD-array type or a site of MD-array type> *MD-extent* (3.6) of an MD-array type

Note 1 to entry: The term "maximum MD-extent" is used for the *MD-extent* (3.6) of an MD-array type because it defines the maximum MD-extent that a value of that MD-array type can have. The *MD-extent* (3.6) of an MD-array value must be within the maximum MD-extent of the value's type.

3.3
MD-array
ordered collection of elements of the same type associated with an *MD-extent* (3.6) where each element is 1:1 associated with some *coordinate* (3.1) within its *MD-extent* (3.6)

Note 1 to entry: A *coordinate* (3.1) is within an *MD-extent* (3.6) if every coordinate value from the integer list is greater than or equal to the lower limit, and less than or equal to the upper limit of the *MD-interval* (3.7) of the *MD-axis* (3.4) at the position in the *MD-extent* (3.6) as the coordinate value has within the *coordinate* (3.1).

3.4
MD-axis
named *MD-interval* (3.7)

3.5
MD-dimension
number of *MD-axes* (3.4) in the *MD-extent* (3.6) of an *MD-array* (3.3)

3.6
MD-extent
non-empty ordered collection of *MD-axes* (3.4) with no duplicate names

3.7
MD-interval
integer interval given by a pair of lower and upper integer limits such that the lower limit is less than or equal to the upper limit; the interval is closed, i.e., both limits are contained in it

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4 Concepts

This Clause modifies Clause 4, "Concepts", in ISO/IEC 9075-2.

4.1 Notations and conventions

This Subclause modifies Subclause 4.1, "Notations and conventions", in ISO/IEC 9075-2.

4.1.1 Notations

This Subclause modifies Subclause 4.1.1, "Notations", in ISO/IEC 9075-2.

The notations used in this document are defined in ISO/IEC 9075-1.

The syntax defined in this document is available from the ISO website as a "digital artifact". See `https://standards.iso.org/iso-iec/9075/-15/ed-2/en/` to download digital artifacts for this document. To download the syntax defined in a plain-text format, select the file named `ISO_IEC_9075-15(E)_MDA.bnf.txt`. To download the syntax defined in an XML format, select the file named `ISO_IEC_9075-15(E)_MDA.bnf.xml`.

4.2 Data types

This Subclause modifies Subclause 4.2, "Data types", in ISO/IEC 9075-2.

4.2.1 General introduction to data types

This Subclause modifies Subclause 4.2.1, "General introduction to data types", in ISO/IEC 9075-2.

Insert into the 4th paragraph, in the 1st list item, after the last list item:

— MD-array type: MDARRAY

Insert into the 5th paragraph, after the last list item:

— MD-array types.

4.2.2 Data type terminology

This Subclause modifies Subclause 4.2.4, "Data type terminology", in ISO/IEC 9075-2.

Insert after the 11th paragraph: A data type *TY* is a *collection-containing type* if exactly one of the following is true:

— *TY* is a collection type;

— *TY* is a row type, and the declared type of some field of *TY* is a collection-containing type;

— *TY* is distinct type, and the source type of *TY* is a collection-containing type;

— *TY* is a structured type and the declared type of some attribute of *TY* is a collection-containing type.

Insert into the 11th paragraph, after the last list item:

— A type *T* is *MD-array-ordered* if *T* is *S*-ordered, where *S* is the set of MD-array types.

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4.3 Numbers

This Subclause modifies Subclause 4.5, "Numbers", in ISO/IEC 9075-2.

4.3.1 Operations involving numbers

This Subclause modifies Subclause 4.5.3, "Operations involving numbers", in ISO/IEC 9075-2.

Insert into the 1st paragraph, after the last list item:

— <md-array axis index function> (see Subclause 4.5.4.3, "Operators that operate on MD-array values and return numbers") operates on an MD-array argument and an MD-axis name, and returns an integer denoting its index position in the MD-extent of the MD-array.

— <md-array dimension> (see Subclause 4.5.4.3, "Operators that operate on MD-array values and return numbers") operates on an MD-array argument and returns an integer denoting its MD-dimension.

— <md-array lower axis limit> (see Subclause 4.5.4.3, "Operators that operate on MD-array values and return numbers") operates on an MD-array argument and an MD-axis name or index, and returns the lower limit of an MD-axis.

— <md-array upper axis limit> (see Subclause 4.5.4.3, "Operators that operate on MD-array values and return numbers") operates on an MD-array argument and an MD-axis name or index, and returns the upper limit of an MD-axis.

4.4 User-defined types

This Subclause modifies Subclause 4.9, "User-defined types", in ISO/IEC 9075-2.

4.4.1 Distinct types

This Subclause modifies Subclause 4.9.2, "Distinct types", in ISO/IEC 9075-2.

Insert after the 4th paragraph: *CT* shall not be an MD-array type.

4.5 Collection types

This Subclause modifies Subclause 4.12, "Collection types", in ISO/IEC 9075-2.

4.5.1 Introduction to collection types

This Subclause modifies Subclause 4.12.1, "Introduction to collection types", in ISO/IEC 9075-2.

Insert into the 1st paragraph, after the 1st list item:

— MD-arrays

Augment the 2nd paragraph by adding "MDARRAY" the list of alternatives for KC.

Insert after the 2nd paragraph: A maximum MD-extent is mandatory for MD-arrays.

Insert into the 5th paragraph, after the 1st list item:

— MDARRAY (MD-array type).

Insert into the 5th paragraph, after the 2nd list item:

— If *CT* is an MD-array type, the MD-axis descriptors of each dimension of the MD-array.

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Insert after the 5th paragraph: An MD-axis descriptor describes a dimension of an MD-array type. The MD-axis descriptor includes:

— The name of the MD-axis.

— The ordinal position of the MD-axis in the MD-extent of the MD-array type.

— The lower limit of the MD-axis.

— The upper limit of the MD-axis.

Insert into the 7th paragraph, after the last list item:

— MD-array-returning external function

4.5.2 MD-arrays

An MD-array A is a collection where each element is uniquely identified by a d-dimensional coordinate that is an element of the Cartesian product of the d MD-intervals of A's MD-extent. d is the MD-dimension of A.

The MD-extent of A is a non-empty array of MD-axis elements. The MD-axis at position i, with 1 (one) $\leq i \leq d$, consists of a name N_i unique within this MD-extent and a closed MD-interval given by a *lower limit* LO_i and an *upper limit* HI_i. A LO_i or HI_i that is the null value in a maximum MD-extent indicates that the MD-axis has no lower or upper limit, respectively.

Each MD-axis of an MD-extent can be uniquely identified through either its name or its position i within the MD-extent, where 1 (one) $\leq i \leq d$. The *extent* of an MD-axis AE_i is defined as the length of the MD-interval of AE_i : $HI_i - LO_i + 1$ (one). An MD-extent D is denoted as [N_1 (LO_1 : HI_1), ..., N_d (LO_d : HI_d)]. The *cardinality* of an MD-extent DC is the product of the extents of the MD-axes of D: $AE_1 \times ... \times AE_d$.

An MD-extent D, denoted as [DN_1 (DLO_1 : DHI_1), ..., DN_d (DLO_d : DHI_d)], is *within* another MD-extent E, denoted as [EN_1 (ELO_1 : EHI_1), ..., EN_e (ELO_e : EHI_e)], if $d \leq e$, and, for all i, 1 (one) $\leq i \leq d$, all of the following are true:

— ELO_i is the null value or $DLO_i \geq ELO_i$.

— EHI_i is the null value or $DHI_i \leq EHI_i$.

If D is within E and $d = e$, then D is *strictly within* E.

If $d = e$, DLO_i is not distinct from ELO_i and DHI_i is not distinct from EHI_i, then D is *interval-equal* to E. If D and E are interval-equal, and additionally $DN_i = EN_i$, then D is *equal* to E.

If $d = e$ and $DN_i = EN_i$, then the *union* of D and E is defined as [DN_1 (MIN (DLO_1, ELO_1) : MAX (DHI_1, EHI_1)), ..., DN_d (MIN (DLO_d, ELO_d) : MAX (DHI_d, EHI_d)]. The union U of a non-empty set of N MD-extents D_1, ..., D_N is defined as defined in this list.

— If N is 1 (one), then U is D_1.

— If N is 2, then U is the union of D_1 and D_2.

— Otherwise, let $TMPD$ be the union of D_1 and D_2. For all i, $3 \leq i \leq N$, let $TMPD$ be the union of $TMPD$ and D_i. U is $TMPD$.

A site AS of MD-array type has a maximum MD-extent D. The MD-extent E of an MD-array occupying AS is constrained to be strictly within D.

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An *MD-array type* is a <collection type> whose element type *EDT* is not a collection-containing type. If *AT* is some MD-array type with element type *EDT* and maximum MD-extent *D*, then every value of *AT* is an MD-array with element type *EDT* and maximum MD-extent *D*.

Two MD-arrays *A* and *B* are identical if and only if both *A* and *B* have the same MD-extent *D*, and if, for every coordinate *P* in *D*, the element at coordinate *P* in *A* is identical to the element at coordinate *P* in *B*.

4.5.3 Collection comparison and assignment

This Subclause modifies Subclause 4.12.4, "Collection comparison and assignment", in ISO/IEC 9075-2.

Insert after the 4th paragraph: A value of an MD-array type *AT* with MD-extent *D* is assignable to a site of an MD-array type *AS* with maximum MD-extent *E* if *D* is strictly within *E*.

MD-array values are not comparable.

4.5.4 Operations involving MD-arrays

4.5.4.1 Operators that operate on MD-array values and return MD-array values

<md-array subset> is an operation that returns an MD-array value consisting of only those elements from its input MD-array *A* whose coordinates are within the MD-extent defined by the subset. The subset MD-extent can be defined as:

— a list of <md-axis limits named> and <md-axis slice named>, corresponding to specific MD-axes;

— a list of <md-axis limits positional> and <md-axis slice positional>, listed for every MD-axis in turn;

— an <md-extent> function, which allows subsetting an MD-array to the MD-extent of another MD-array.

<md-axis limits named> and <md-axis limits positional> specify lower and upper trim limits for an MD-axis. A wildcard operator * provided in the lower and/or upper trim limits expands to the current limits of the MD-axis. Trimming does not change the MD-dimension of the result MD-array.

<md-axis slice named> and <md-axis slice positional> specify a single coordinate on the selected MD-axis. Slicing reduces the dimension of the result MD-array by one, i.e., for *N* <md-axis slice named> in an <md-array subset> on *A*, the MD-dimension *d* of the result is $d = \text{MDDIMENSION}(A) - N$.

<md-axis limits named> and <md-axis slice named> allow positionally-independent addressing of MD-axes through their unique names, in contrast to <md-axis limits positional> and <md-axis slice positional>.

<md-array value expression> covers the usual arithmetic, comparison, and logical operations where at least one operand is an MD-array. The MD-extents of MD-arrays *A* and *B* in an <md-array value expression> of the form *A op B* shall be equal. The result is an MD-array value with an MD-extent equal to the MD-extent(s) of the input MD-array(s).

<md-array reshape function> is an operation that, given an MD-array with MD-extent *D* and an MD-extent *E* such that $\text{MDDIMENSION}(D) = \text{MDDIMENSION}(E)$, returns an MD-array with the same elements as the input MD-array at coordinates within *E* that are also within *D*, plus additional elements with null values at those coordinates within *E* that are not within *D*. The result MD-array value has an MD-extent *E*.

<md-array shift function> is an operation that, given an MD-array with MD-extent *D* and an offset coordinate of MD-dimension equal to $\text{MDDIMENSION}(D)$, returns an MD-array with an MD-extent *D* and the same elements as the input MD-array, such that each element at coordinate *P* is shifted by the offset coordinate.

<md-array scale function> is an operation that returns an MD-array with the target MD-extent indicated and elements obtained by using nearest-neighbor interpolation to fit the input MD-array elements at coordinates within the MD-extent of the result MD-array.

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<md-array absolute value expression> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <absolute value expression> to the element at the same coordinate in the input.

<md-array natural logarithm> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <natural logarithm> to the element at the same coordinate in the input.

<md-array common logarithm> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <common logarithm> to the element at the same coordinate in the input.

<md-array exponential function> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <exponential function> to the element at the same coordinate in the input.

<md-array square root> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <square root> to the element at the same coordinate in the input.

<md-array floor function> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <floor function> to the element at the same coordinate in the input.

<md-array ceiling function> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <ceiling function> to the element at the same coordinate in the input.

<md-array trigonometric function> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-array, where the element at each coordinate in the result is derived by applying <trigonometric function> to the element at the same coordinate in the input.

<md-array power function> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-arrays, where the element at each coordinate in the result is derived by applying <power function> to the element at the same coordinate in the input and the second argument of the function.

<md-array modulus expression> is a function that returns an MD-array with an MD-extent equal to the MD-extent of its input MD-arrays, where the element at each coordinate in the result is derived by applying <modulus expression> to the element at the same coordinate in the input and the second argument of the function.

<md-array concatenation> is an operation that returns the MD-array value made by joining its MD-array value operands in the order given along a specified MD-axis.

4.5.4.2 Operators that operate on MD-array values and return tables

<md-array extent> is an operation that returns the MD-extent *D* of a given MD-array value *A* as a table of cardinality *CAR* equal to the MD-dimension of *A* and four columns. The row with value *i*, 1 (one) ≤ *i* ≤ *CAR*, in the first column contains the name, lower limit, and upper limit of the *i*-th MD-axis in *D* in the second, third, and fourth column, respectively.

<md-array max extent> is an operation that returns the maximum MD-extent *MD* with the declared type of a given MD-array value *A* as a table of cardinality *CAR* equal to the MD-dimension of *A* and four columns. The row with value *i*, 1 (one) ≤ *i* ≤ *CAR*, in the first column contains the name, lower limit, and upper limit of the *i*-th MD-axis in *MD* in the second, third, and fourth column, respectively.

<collection derived table> allows converting an <md-array value expression> *AVE* with element type *ET* and MD-dimension *d* to a table. The resulting table has *d* columns holding the coordinate values of each element, and, if *ETM* is not a row type, one column, or, if *ET* is a row type of degree *N*, *N* columns for the

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element values of *AVE*. If WITH ORDINALITY is specified, then the resulting table has an additional ordinality column holding the values from 1 (one) to the cardinality of *AVE*.

4.5.4.3 Operators that operate on MD-array values and return numbers

<md-array axis index function> is an operation that, for a given MD-array and an MD-axis name, returns the index position of the MD-axis with the specified name in the MD-extent of the MD-array.

<md-array dimension> is an operation that returns the dimension of the MD-array as an exact numeric with scale 0 (zero).

<md-array lower axis limit> is an operation that, for a given MD-array and an MD-axis identified by its position or its name, returns the lower limit the MD-axis as an exact numeric with scale 0 (zero).

<md-array upper axis limit> is an operation that, for a given MD-array and an MD-axis identified by its position or its name, returns the upper limit the MD-axis as an exact numeric with scale 0 (zero).

4.5.4.4 Operators that operate on MD-array values and return character strings

<md-array axis name function> is an operation that, for a given MD-array and an MD-axis identified by its position, returns the name of the MD-axis as a character string.

4.5.4.5 Operators that operate on MD-array values and return numbers or Boolean values

<md-array aggregation expression> is an operation that returns an aggregated value obtained from iterating over all coordinates in the MD-extent indicated in its <md-extent alternative>, evaluating the <value expression primary> at each particular coordinate that satisfies the optional <search condition>, and aggregating the result by applying the <md-array aggregation operator>.

<md-array aggregation function> is an operation that returns a value aggregating all elements of the input MD-array. Table 1, "Table aggregation operators", lists all predefined aggregation functions. Let *A* be an MD-array of numeric element type, let *B* be an MD-array of Boolean element type, and let *C* be an MD-array of any element type.

Table 1 — Table aggregation operators

Operation	Meaning
MDSUM(*A*)	Sum of all elements in *A*
MDAVG(*A*)	Average of all elements in *A*
MDMIN(*A*)	Minimum of all elements in *A*
MDMAX(*A*)	Maximum of all elements in *A*
MDCOUNT(*C*)	Number of non-NULL elements in *C*
MDCOUNT_TRUE(*B*)	Number of *True* non-NULL elements in *B*
MDCOUNT_FALSE(*B*)	Number of *False* non-NULL elements in *B*
MDCOUNT_UNKNOWN(*B*)	Number of *Unknown* elements in *B*
MDANY(*B*)	Is there any element in *B* with value true?
MDALL(*B*)	Do all elements in *B* have value true?

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4.5.4.6 Operators that operate on MD-array values and return character or binary strings

<md-array encode function> is an operation that accepts an MD-array and returns a character string or a binary string containing the MD-array encoded in the data format indicated by its media type (specified in RFC 2046). MD-arrays can be encoded using JSON (media type "application/json" according to RFC 8259). Support for encoding to further media types is implementation-defined (IA096).

4.5.4.7 Operators that construct new MD-array values

<md-array value constructor by decoding> is an operation that accepts a character string or a binary string and returns an MD-array containing the elements at their respective coordinates, determined by decoding the character or binary string. Such a character or binary string contains a JSON encoding (media type "application/json" RFC 8259) of the MD-array to be decoded. Optional support for decoding from further media types is implementation-defined (IA095).

<md-array value constructor by enumeration> is an operation that returns an MD-array with the MD-extent specified by <md-extent alternative> and elements enumerated by <md-array element list>.

<md-array value constructor by query> returns an MD-array with the MD-extent specified by <md-extent alternative> and elements provided by the result of <table subquery>.

<md-array value constructor by iteration> returns an MD-array with the MD-extent specified by <md-extent alternative> and each element as the result of <md-array element>. The <md-array element> expression may contain MD-axis variables that allow referencing the element's coordinate.

<md-array value constructor by join> performs a join on two or more MD-arrays of equal MD-extents based on their coordinates. An element in the resulting MD-array is a row value constructed from the corresponding elements of each input MD-array, in the order in which they have been specified. The field names of each element in the result can be explicitly specified or implicitly generated.

4.5.4.8 Operators that operate on MD-array values and return MD-array elements

<md-array element reference> is an operation that returns the MD-array element at a specific coordinate within the MD-extent of the MD-array.

4.5.5 MD-axis variables

An <md-array aggregation expression> or an <md-array value constructor by iteration> are operations that specify *MD-axis variables* for every MD-axis in the MD-extent specified by the <md-extent alternative>. The name of each MD-axis variable is equivalent to the name of the corresponding MD-axis, and its value, when referenced by its name, ranges from the lower to the upper limit of the MD-axis.

An MD-axis variable is specified by <md-axis variable>.

Every MD-axis variable has a *scope*. In <md-array value constructor by iteration>, the scope of an MD-axis variable is the immediately contained <md-array element>. In <md-array aggregation expression>, the scope of an MD-axis variable is the immediately contained <value expression primary> and <search condition>, if specified. Two MD-axis variables that are equivalent are nevertheless distinct if they have different scope.

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5 Lexical elements

This Clause modifies Clause 5, "Lexical elements", in ISO/IEC 9075-2.

5.1 <token> and <separator>

This Subclause modifies Subclause 5.2, "<token> and <separator>", in ISO/IEC 9075-2.

Function

Specify lexical units (tokens and separators) that participate in SQL language.

Format

```
<reserved word> ::=
    !! All alternatives from ISO/IEC 9075-2

  | MDAGGREGATE | MDALL | MDANY | MDARRAY | MDAVG | MDAXIS_HIGH | MDAXIS_INDEX | MDAXIS_LOW
  | MDAXIS_NAME | MDAXIS_NAMES | MDCONCAT | MDCOUNT | MDCOUNT_FALSE
  | MDCOUNT_TRUE | MDCOUNT_UNKNOWN | MDDECODE | MDDIMENSION | MDENCODE | MDEXTENT
  | MDJOIN | MDMAX | MDMAX_EXTENT | MDMIN | MDRESHAPE | MDSCALE | MDSHIFT | MDSUM

<non-reserved word> ::=
    !! All alternatives from ISO/IEC 9075-2
  | ELEMENTS
```

Syntax Rules

No additional Syntax Rules.

Access Rules

No additional Access Rules.

General Rules

No additional General Rules.

Conformance Rules

No additional Conformance Rules.

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5.2 Names and identifiers

This Subclause modifies Subclause 5.4, "Names and identifiers", in ISO/IEC 9075-2.

Function

Specify names.

Format

```
<md-axis variable> ::=
  <identifier>
```

Syntax Rules

No additional Syntax Rules.

Access Rules

No additional Access Rules.

General Rules

1) Insert after the last GR: An <md-axis variable> identifies an MD-axis variable associated with an MD-axis whose name is equivalent to the <md-axis variable>.

Conformance Rules

No additional Conformance Rules.

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6 Scalar expressions

This Clause modifies Clause 6, "Scalar expressions", in ISO/IEC 9075-2.

6.1 <data type>

This Subclause modifies Subclause 6.1, "<data type>", in ISO/IEC 9075-2.

Function

Specify a data type.

Format

```
<collection type> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array type>

<md-array type> ::=
  <data type> MDARRAY <maximum md-extent>

<maximum md-extent> ::=
    <left bracket or trigraph> <maximum md-axis list> <right bracket or trigraph>
  | <left bracket or trigraph> <maximum md-axis list anonymous> <right bracket or trigraph>

<maximum md-axis list> ::=
  <maximum md-axis> [ { <comma> <maximum md-axis> }... ]

<maximum md-axis list anonymous> ::=
  <maximum md-axis anonymous> [ { <comma> <maximum md-axis anonymous> }... ]

<maximum md-axis> ::=
  <md-axis name> [ <left paren>
      <maximum md-axis lower limit> <colon> <maximum md-axis upper limit>
      <right paren> ]

<maximum md-axis anonymous> ::=
  <maximum md-axis lower limit> <colon> <maximum md-axis upper limit>

<maximum md-axis lower limit> ::=
  <md-axis limit>

<maximum md-axis upper limit> ::=
  <md-axis limit>

<md-axis limit> ::=
    <md-axis limit fixed>
  | <asterisk>

<md-axis limit fixed> ::=
  <signed numeric literal>

<md-axis name> ::=
  <identifier>
```

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Syntax Rules

1) Insert after SR 47): The element type of an <array type> shall not be an MD-array type.

2) Insert after SR 47): An <md-array type> *AT* specifies an *MD-array type*. The <data type> *DT* immediately contained in *AT* is the *element type* of the MD-array type. *DT* shall not be a collection-containing type.

   a) If <maximum md-extent> *EU* immediately contains <maximum md-axis list> *MAL* and any <maximum md-axis> immediately contained in *MAL* specifies an <md-axis name> but does not specify <maximum md-axis lower limit> and <maximum md-axis upper limit>, then *EU* is equivalent to *MN*(* : *).

   b) If any <maximum md-axis lower limit> *ALL* simply contained in *AT* is an <asterisk>, then *ALL* is is the null value.

   c) If any <maximum md-axis upper limit> *AUL* simply contained in *AT* is an <asterisk>, then *AUL* is the null value.

   d) The declared type of <md-axis limit fixed> and <md-axis limit> is an implementation-defined (IV201) exact numeric type with scale 0 (zero).

   e) The minimum value of <md-axis limit fixed> is implementation-defined (IL013). <md-axis limit fixed> shall not be smaller than this value.

   f) The maximum value of <md-axis limit fixed> is implementation-defined (IL014). <md-axis limit fixed> shall not be greater than this value.

   g) Case:

      i) If *EU* immediately contains <maximum md-axis list>, then let *d* be the number of <maximum md-axis> simply contained in *EU*.

      ii) Otherwise, let *d* be the number of <maximum md-axis anonymous> simply contained in *EU*.

   h) *d* is the MD-dimension of *AT*. *d* shall be less than or equal to an implementation-defined (IL017) maximum value.

   i) For *i*, 1 (one) $\leq i \leq d$,

      i) Case:

         1) If *EU* immediately contains <maximum md-axis list>, then let AU_i be the *i*-th <maximum md-axis> simply contained in *EU*. Let MN_i be the value of <md-axis name> immediately contained in AU_i.

         2) Otherwise, let AU_i be the *i*-th <maximum md-axis anonymous> simply contained in *EU* and let SEQ_i be the <unsigned integer> numeric literal with no leading zeros corresponding to *i*. The Syntax Rules of Subclause 9.15, "Indexed name", are applied with *d* as *LASTINDEX*, SEQ_i as *INDEX*, and 'D' as *PREFIX*; let MN_i be the *INDEXEDNAME* returned from the application of those Syntax Rules.

      ii) Let MLO_i be the <maximum md-axis lower limit> and let MHI_i be the <maximum md-axis upper limit> specified or implied by AU_i.

   j) Let *MD* be [MN_1 (MLO_1 : MHI_1), ..., MN_d (MLO_d : MHI_d)]. *MD* is the maximum MD-extent of a site with data type *AT*.

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i) For all i, 1 (one) $\leq i \leq d$, if neither MLO_i or MHI_i are the null value, then MLO_i shall be less than or equal to MHI_i.

ii) For all i and j, 1 (one) $\leq i, j \leq d$, $i \neq j$, MN_i shall not be equivalent to MN_j.

iii) The value of MLO_i is the value of the corresponding <maximum md-axis lower limit>.

iv) The value of MHI_i is the value of the corresponding <maximum md-axis upper limit>.

3) Insert after SR 47): The element type of a <multiset type> shall not be an MD-array type.

Access Rules

No additional Access Rules.

General Rules

1) Insert after GR 20)a): If *KC* is MDARRAY, then the collection type descriptor additionally includes a set of MD-axis descriptors, each of which, for 1 (one) $\leq i \leq d$, contains the name MN_i, the ordinal position i, the lower limit MLO_i, and the upper limit MHI_i for the i-th MD-axis of the MD-array type.

Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain an <md-array type>.

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6.2 <value expression primary>

This Subclause modifies Subclause 6.3, "<value expression primary>", in ISO/IEC 9075-2.

Function

Specify a value that is syntactically self-delimited.

Format

```
<non-parenthesized value expression primary> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array aggregation expression>
  | <md-axis variable>
  | <md-array element reference>

<collection value constructor> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array value constructor>
```

Syntax Rules

1) Augment SR 1) by adding "<md-array element reference>, <md-axis variable> and <md-array aggregation expression>" to the list of simply contained BNF non-terminals.

2) Insert after the last SR: The declared type of an <md-axis variable> is exact numeric with scale 0 (zero).

3) Augment SR 3) by adding "<md-array value constructor>" to the list of simply contained BNF non-terminals.

Access Rules

No additional Access Rules.

General Rules

1) Augment GR 1) by adding "<md-array element reference>, <md-axis variable> and <md-array aggregation expression>" to the list of simply contained BNF non-terminals.

2) Augment GR 2) by adding "<md-array value constructor>" to the list of simply contained BNF non-terminals.

Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain a <non-parenthesized value expression primary> that simply contains an <md-axis variable>.

2) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain a <collection value constructor> that simply contains an <md-array value constructor>.

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3) Insert after the last CR: Without Feature A010, “Multi-dimensional array support”, conforming SQL language shall not contain a <non-parenthesized value expression primary> that simply contains an <md-array aggregation expression>.

4) Insert after the last CR: Without Feature A010, “Multi-dimensional array support”, conforming SQL language shall not contain a <non-parenthesized value expression primary> that simply contains an <md-array element reference>.

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6.3 <md-array subset>

Function

Returns a subset of an MD-array.

Format

```
<md-array subset> ::=
  <md-array value expression>
      <left bracket or trigraph> <md-axis subset list> <right bracket or trigraph>

<md-axis subset list> ::=
    <md-axis subset list named>
  | <md-axis subset list positional>
  | <md-array subset extent>

<md-axis subset list named> ::=
  <md-axis subset named> [ { <comma> <md-axis subset named> }... ]

<md-axis subset list positional> ::=
  <md-axis subset positional> [ { <comma> <md-axis subset positional> }... ]

<md-axis subset named> ::=
    <md-axis limits named>
  | <md-axis slice named>

<md-axis subset positional> ::=
    <md-axis limits positional>
  | <md-axis slice positional>

<md-axis limits named> ::=
  <md-axis name> <left paren> <md-interval expression> <right paren>

<md-axis limits positional> ::=
  <md-interval expression>

<md-interval expression> ::=
  <md-axis lower limit expression> <colon> <md-axis upper limit expression>

<md-axis lower limit expression> ::=
  <md-axis limit expression>

<md-axis upper limit expression> ::=
  <md-axis limit expression>

<md-axis limit expression> ::=
    <numeric value expression>
  | <asterisk>

<md-axis slice named> ::=
  <md-axis name> <left paren> <md-axis slice positional> <right paren>

<md-axis slice positional> ::=
  <numeric value expression>

<md-array subset extent> ::=
  MDEXTENT <left paren> <md-array value expression> <right paren>
```


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Syntax Rules

1) Let *AS* be the <md-array subset>, let *AVE* be the <md-array value expression> immediately contained in *AS*, and let *ASL* be the <md-axis subset list> immediately contained in *AS*.

2) Let *MDT* be the declared type of *AVE*.

3) The Syntax Rules of Subclause 9.16, "MD-array subset", are applied with *MDT* as *MDARRAY TYPE* and *ASL* as *MDAXIS SUBSET LIST*; let *TMD* be the *TARGET MAXIMUM MDEXTENT* and let *EQ* be the *EQUIVALENCE* returned from the application of those Syntax Rules.

   Case:

   a) If *EQ* is not a zero-length character string, then <md-array subset> is equivalent to *AVE EQ*.

   b) Otherwise:

      i) Let *EDT* be the element type of *AVE*.

      ii) The declared type of *AS* is an MD-array type of element type *EDT* and maximum MD-extent *TMD*.

Access Rules

No additional Access Rules.

General Rules

1) Let *AS* be the <md-array subset>, let *AVE* be the <md-array value expression> immediately contained in *AS*, and let *ASL* be the <md-axis subset list> immediately contained in *AS*. Let *AV* be the value of *AVE*.

2) If *AV* is the null value, then the result of *AS* is the null value and no further General Rules of this Subclause are applied.

3) The General Rules of Subclause 9.16, "MD-array subset", are applied with *AV* as *MDARRAY VALUE* and *ASL* as *MDAXIS SUBSET LIST*; let *SMD* be the *SOURCE MDEXTENT*, let *TMD* be the *TARGET MDEXTENT*, and let *SLICEDAXES* be the *SLICED MDAXES* returned from the application of those General Rules.

4) Let *D* be the MD-extent of *AV*, let *d* be the number of MD-axes in *D*, and let *t* be the number of MD-axes in *TMD*.

5) If *SMD* is not within *D*, then an exception condition is raised: *data exception — MD-array subset not within MD-extent (2203L)*.

6) Let *TV* be the MD-array value with element type *EDT* and MD-extent *TMD* constructed in the following way. For each coordinate *R* within *SMD*:

   a) Let RP_i be the *i*-th element of *R*, 1 (one) $\leq i \leq d$.

   b) Let *j* be 1 (one).

   c) For all *k*, 1 (one) $\leq k \leq d$, such that *k* is not an element of *SLICEDAXES*:

      i) Let TP_j be RP_k.

      ii) *j* is increased by 1 (one).

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d) Let Q be the coordinate denoted by [TP_1, ..., TP_t].

NOTE 1 — There are t non-*SLICEDAXES*.

e) The element in *TV* at coordinate Q is the element in *AV* at coordinate R.

7) *TV* is the value of *AS*.

Conformance Rules

1) Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain an <md-array subset>.

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6.4 <identifier chain>

This Subclause modifies Subclause 6.6, "<identifier chain>", in ISO/IEC 9075-2.

Function

Disambiguate a period-separated chain of identifiers.

Format

No additional Format items.

Syntax Rules

1) Insert after SR 9)a)ii)1)C): The scope of an MD-axis variable equivalent to I_1.

2) Insert after SR 9)a)ii)2)B): If *IPST* is an <md-array aggregation expression> or an <md-array value constructor by iteration>, then let *SV* be the MD-axis variable equivalent to I_1. PIC_1 is the basis of *IC*, the basis length is 1 (one), the basis scope is the scope of *SP*, and the basis referent is *SV*.

Access Rules

No additional Access Rules.

General Rules

1) Insert after GR 4): If *BIC* is an MD-axis variable, then *BIC* references the MD-axis *SV* of a given execution of the <md-array aggregation expression> or an <md-array value constructor by iteration> whose <md-extent> contains *SV*.

Conformance Rules

No additional Conformance Rules.

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6.5 <md-array aggregation expression>

Function

Aggregate MD-array values into a single value.

Format

```
<md-array aggregation expression> ::=
  MDAGGREGATE <md-array aggregation operator>
      OVER <md-extent alternative>
      USING <value expression primary>
      [ WHERE <search condition> ]

<md-array aggregation operator> ::=
    <plus sign> | AND | OR | MAX | MIN
```

Syntax Rules

1) The declared type of <md-array aggregation expression> *AAE* is the declared type of the immediately contained <value expression primary> *VE*. Let *op* be the immediately contained <md-array aggregation operator>.

   Case:

   a) If *op* is <plus sign>, then the declared type of *VE* shall be numeric.

   b) If *op* is AND or OR, then the declared type of *VE* shall be Boolean.

   c) Otherwise, *VE* is an operand of an ordering operation.

      i) The Syntax and Conformance Rules of Subclause 9.11, "Ordering operations", are applied.

      ii) The declared type of *VE* shall not be row-ordered.

2) If the <md-extent alternative> immediately contained in *AAE* is an <md-array extent> *EA*, then:

   a) Let *AVE1* be the <md-array value expression> immediately contained in *EA* and let *e* be the MD-dimension of *AVE1*.

   b) Case:

      i) If <search condition> *SC* is immediately contained in *AAE*, then *AEE* is equivalent to

```
MDAGGREGATE op
  OVER [ MDAXIS_NAME(AVE1, 1) ( MDAXIS_LOW(AVE1, 1) : MDAXIS_HIGH(AVE1, 1)
),
         ...,
         MDAXIS_NAME(AVE1, e) ( MDAXIS_LOW(AVE1, e) : MDAXIS_HIGH(AVE1, e)
)
       ]
USING  VE
WHERE  VE IS NOT NULL AND SC
```

      ii) Otherwise, *AEE* is equivalent to

```
MDAGGREGATE op
  OVER [ MDAXIS_NAME(AVE1, 1) ( MDAXIS_LOW(AVE1, 1) : MDAXIS_HIGH(AVE1, 1)
),
```


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```
            ...,
            MDAXIS_NAME(AVE1, e) ( MDAXIS_LOW(AVE1, e) : MDAXIS_HIGH(AVE1, e)
)
        ]
USING   VE
WHERE   VE IS NOT NULL
```

3) Let *MD* be the maximum MD-extent specified by <md-extent> and let *d* be the number of MD-axes in *MD*. For 1 (one) $\leq i \leq d$, let AV_i be an <md-axis variable> whose name is equivalent to the name of the i-th MD-axis in *MD*. The scope of AV_i is *VE* and the <search condition> immediately contained in <md-array aggregation expression>, if specified.

Access Rules

None.

General Rules

1) Let *D* be the MD-extent specified by <md-extent>, let *d* be the number of MD-axes in *D*, and let N_i, LO_i, and HI_i, be the name, lower limit, and upper limit, respectively, of the *i*-th MD-axis in the maximum MD-extent of *D*, 1 (one) $\leq i \leq d$.

2) Let *S* be the union of all coordinates [P_1, ..., P_d], such that $LO_1 \leq P_1 \leq HI_1$, ..., $LO_d \leq P_d \leq HI_d$, (that is, *S* is the Cartesian product of all MD-intervals in *D*).

3) Let *op* be <md-array aggregation operator>. Let *AGG* be

   Case:

   a) If *op* is <plus sign>, then 0 (zero).

   b) If *op* is MAX, then an implementation-defined (IL067) minimum value of a type comparable to the <value expression primary>.

   c) If *op* is MIN, then an implementation-defined (IL068) maximum value of a type comparable to the <value expression primary>.

   d) If *op* is AND, then *True*.

   e) If *op* is OR, then *False*.

4) Let *NULLRES* be *True*.

5) For every coordinate [P_1, ..., P_d] in *S*,

   a) Let *BV* be *True*.

   b) If <search condition> *BVE* is specified, then the value of any AV_i contained in *BVE*, 1 (one) $\leq i \leq d$, is equal to P_i. Let *BV* then be the result of evaluating *BVE*.

   c) Case:

      i) If *BV* is *True*, then the value of any AV_i contained in *VE*, 1 (one) $\leq i \leq d$, is equal to P_i. Let *NULLRES* be *False*. Let the value of *VE* be *TEMP*.

         Case:

         1) If *op* is MIN, then let *AGG* be the lesser of *AGG* and *TEMP*.

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2) If *op* is MAX, then let *AGG* be the greater of *AGG* and *TEMP*.

3) If *op* is AND or OR, then let *AGG* be the value of *AGG op TEMP*.

4) Otherwise, *op* is <plus sign>; let *TP* be the declared type of <md-array aggregation expression>.

Case:

A) If *TP* is exact numeric and the mathematical result of *AGG op TEMP* is not exactly representable with the precision and scale of *TP*, then an exception condition is raised: *data exception — numeric value out of range (22003)*.

B) If *TP* is approximate numeric and the exponent of the approximate mathematical result of *AGG op TEMP* is not within the implementation-defined (IL202) exponent range for *TP*, then an exception condition is raised: *data exception — numeric value out of range (22003)*.

C) If *TP* is the decimal floating point type, then the result is an implementation-defined (IV240) value *IV* of *TP* such that no other value of *TP* is strictly between *IV* and the mathematical result of *AGG op TEMP*. If the exponent of *IV* is not within the implementation-defined (IL202) exponent range for *TP*, then an exception condition is raised: *data exception — numeric value out of range (22003)*.

D) Otherwise, let *AGG* be the value of *AGG op TEMP*.

ii) Otherwise, *VE* is not evaluated for this coordinate.

6) Case:

a) If *NULLRES* is *False* then the result of <md-array aggregation expression> is *AGG*.

b) Otherwise, the result of <md-array aggregation expression> is the null value.

Conformance Rules

1) Without Feature A010, “Multi-dimensional array support”, conforming SQL language shall not contain <md-array aggregation expression>.

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6.6 <case expression>

This Subclause modifies Subclause 6.12, "<case expression>", in ISO/IEC 9075-2.

Function

Specify a conditional value.

Format

```
<searched when clause> ::=
    !! All alternatives from ISO/IEC 9075-2
  | WHEN <md-array boolean expression> THEN <result>
```

Syntax Rules

1) Insert after SR 2): If a <case specification> specifies a <searched case>, then:

   a) Let N be the number of <searched when clause>s.

   b) For each i between 1 (one) and N, let SWC_i be the i-th <searched when clause>, let SC_i be the immediately contained <search condition> or <md-array boolean expression> of SWC_i, and let R_i be the <result> immediately contained in SWC_i.

   c) Case:

      i) If <else clause> is specified, then let M be $N + 1$. Let R_M be the <result> immediately contained in the <else clause>.

      ii) Otherwise, let M be N.

   d) Either every SC_i, 1 (one) $\leq i \leq N$, shall be an <md-array boolean expression>, or no SC_i, 1 (one) $\leq i \leq N$, shall be an <md-array boolean expression>.

   e) If every SC_i is an <md-array boolean expression> MBE_i, then let MDT_i be the declared type of MBE_i and let d_i be the MD-dimension of MDT_i. For all j and k, $j \neq k$ and 1 (one) $\leq j, k \leq N$, d_j shall be equal to d_k. Let MN_i be the name of the i-th MD-axis in the maximum MD-extent of MDT_1, 1 (one) $\leq i \leq d_1$.

      i) <case specification> shall not generally contain a <routine invocation> whose subject routine is an SQL-invoked routine that is possibly non-deterministic or that possibly modifies SQL-data.

      ii) <case specification> shall not generally contain a <table primary> that contains a <data change delta table>.

      iii) For all j, 1 (one) $\leq j \leq M$:

         Case:

         1) If R_j is of MD-array type, then let MDT be the declared type of R_j, and let e be the MD-dimension of MDT. e shall be equal to d_1. Let RA_j be R_j.

         2) Otherwise, let e be d_1. RA_j is equivalent to

            MDARRAY [MN_1 (MDAXIS_LOW (SC_1, 1) : MDAXIS_HIGH (SC_1, 1)), ...,

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```
                    MN_e ( MDAXIS_LOW (SC_1, e) : MDAXIS_HIGH (SC_1, e) ) ]
ELEMENTS R_j
```

Access Rules

None.

General Rules

1) Insert before GR 2)a): If the value of every SC_i, 1 (one) $\le i \le N$, is an MD-array value, then:

   a) Let D_i be the MD-extent of the value of SC_i. For all j and k, $j \ne k$ and 1 (one) $\le j, k \le N$, if D_j is not equal to D_k, then an exception condition is raised: *data exception — MD-array operands with non-matching MD-extents (2203R)*.

   b) For all j, 1 (one) $\le j \le M$, let E_j be the MD-extent of the value of RA_j. If E_j is not equal to D_1, then an exception condition is raised: *data exception — MD-array operands with non-matching MD-extents (2203R)*.

   c) If <else clause> is specified, then let *CEEC* be equivalent to ELSE RA_M[N_1, ..., N_d]; otherwise, let *CEEC* be a character string of length 0 (zero).

   d) Let d be d_1, and let N_i, LO_i, and HI_i, be the name, lower limit, and upper limit, respectively, of the i-th MD-axis in the MD-extent of the value of SC_1, 1 (one) $\le i \le d$.

   e) The value of the <case specification> is the value of:

```
MDARRAY [ N_1 ( LO_1 : HI_1 ), ...,
          N_d ( LO_d : HI_d ) ]
ELEMENTS
CASE WHEN SC_1[ N_1, ..., N_d ] THEN RA_1[ N_1, ..., N_d ]
     ...
     WHEN SC_N[ N_1, ..., N_d ] THEN RA_N[ N_1, ..., N_d ]
     CEEC END
```

Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", in conforming SQL language, a <case expression> shall not support operands of MD-array type.

2) Insert after the last CR: Without Feature A011, "MD-array BOOLEAN element type", conforming SQL language shall not contain a <searched when clause> that immediately contains an <md-array boolean expression>.

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6.7 <cast specification>

This Subclause modifies Subclause 6.13, "<cast specification>", in ISO/IEC 9075-2.

Function

Specify a data conversion.

Format

```
<cast target> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array cast>
  | <md-array base type cast>
  | <md-array maximum md-extent cast>

<md-array cast> ::=
  <data type> MDARRAY <md-array axis names>

<md-array base type cast> ::=
  <data type> MDARRAY

<md-array maximum md-extent cast> ::=
  MDARRAY <maximum md-extent cast alternative>

<maximum md-extent cast alternative> ::=
    <maximum md-extent>
  | <md-array axis names>

<md-axis explicit name list> ::=
  <left bracket or trigraph> <md-axis name>
      [ { <comma> <md-axis name> }... ] <right bracket or trigraph>

<md-array axis names> ::=
  MDAXIS_NAMES <left paren> <md-array value expression> <right paren>
```

Syntax Rules

1) Insert before SR 1)a): If <cast target> immediately contains an <md-array cast>, <md-array base type cast>, <md-array maximum md-extent cast>, or <data type> *TD* that is an <md-array type>, then:

   a) Neither <cast operand> nor <cast target> shall generally contain a <routine invocation> whose subject routine is an SQL-invoked routine that is possibly non-deterministic or that possibly modifies SQL-data.

   b) Neither <cast operand> nor <cast target> shall generally contain a <table primary> that contains a <data change delta table>.

   c) The <cast operand> shall be an <md-array value expression>. Let *AVE* be the <cast operand>. Let *MDT* be the declared type of *AVE*, let *EDT* be the element type of *MDT*, let *d* be the MD-dimension of *MDT*, and let MN_i be the name of the *i*-th MD-axis in the maximum MD-extent of *MDT*, 1 (one) $\leq i \leq d$.

      Case:

      i) If an <md-array cast> *AC* is specified, then let *TEDT* be the data type identified by the <data type> immediately contained in *AC* and let *ANC* be the <md-array axis names>

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immediately contained in *AC*. *TEDT* shall not be a collection-containing type. The <cast specification> is equivalent to

```
CAST(CAST(AVE AS TEDT MDARRAY) AS ANC)
```

ii) If *TD* is an <md-array type>, then let *TEDT* be the <data type> immediately contained in *TD*, and let *ANC* be the <maximum md-extent> immediately contained in *TD*. *TEDT* shall not be a collection-containing type. The <cast specification> is equivalent to

```
CAST(CAST(AVE AS TEDT MDARRAY) AS MDARRAY ANC)
```

iii) If an <md-array base type cast> *ABTC* is specified, then let *TEDT* be the data type identified by the <data type> immediately contained in *ABTC*. The <cast specification> is equivalent to

```
MDARRAY [ MN1 ( MDAXIS_LOW (AVE, 1) : MDAXIS_HIGH (AVE, 1) ), ...,
          MNd ( MDAXIS_LOW (AVE, d) : MDAXIS_HIGH (AVE, d) ) ]
ELEMENTS CAST(AVE[ MN1, ..., MNd ] AS TEDT)
```

iv) Otherwise, an <md-array maximum md-extent cast> *MMC* is specified. Let *MMCA* be the <maximum md-extent cast alternative> immediately contained in *MMC*.

Case:

1) If *MMCA* is a <maximum md-extent> *TMD*, then the MD-dimension of *TMD* shall be equal to *d*. *TMD* is the *maximum MD-extent* of *TD*.

2) Otherwise, let *AVE1* be the <md-array value expression> immediately contained in the <md-array axis names>immediately contained in *MMCA*, and let *e* be the MD-dimension of *AVE1*. *e* shall be equal to *d*. The <cast specification> is equivalent to:

```
CAST(AVE AS MDARRAY [ MDAXIS_NAME(AVE1, 1) ( MDAXIS_LOW(AVE1, 1) :
MDAXIS_HIGH(AVE1, 1) ),
                      ...,
                      MDAXIS_NAME(AVE1, e) ( MDAXIS_LOW(AVE1, e) :
MDAXIS_HIGH(AVE1, e) ) ] )
```

Access Rules

No additional Access Rules.

General Rules

1) Insert before GR 7): If <cast target> simply contains a <maximum md-extent>, then:

a) Let LO_i and HI_i, 1 (one) $\leq i \leq d$, be the lower limit and upper limit, respectively, of the *i*-th MD-axis in the MD-extent of the value of *AVE*. Let TMN_i, be the name of the *i*-th MD-axis in *TMD*.

b) Let *D* be the MD-extent denoted by [TMN_1 (LO_1 : HI_1), ..., TMN_d (LO_d : HI_d)].

Case:

i) If *D* is not strictly within *TMD*, then an exception condition is raised: *data exception — MD-array source MD-extent not strictly within maximum target MD-extent (2203Q)*.

ii) Otherwise, *TV* is the value of *AVE* with MD-extent *D*.

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Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain a <cast target> that immediately contains an <md-array cast>, an <md-array base type cast>, or an <md-array maximum md-extent cast>.

2) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", in conforming SQL language, <cast specification> shall not support <cast operand>s of MD-array type.

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6.8 <value expression>

This Subclause modifies Subclause 6.29, "<value expression>", in ISO/IEC 9075-2.

Function

Specify a value.

Format

```
<collection value expression> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array value expression>
```

Syntax Rules

1) Augment SR 5) by adding "<md-array value expression>" to the list of BNF non-terminals.

Access Rules

No additional Access Rules.

General Rules

1) Augment GR 4) by adding "<md-array value expression>" to the list of BNF non-terminals.

Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain a <collection value expression> that immediately contains an <md-array value expression>.

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6.9 <numeric value function>

This Subclause modifies Subclause 6.31, "<numeric value function>", in ISO/IEC 9075-2.

Function

Specify a function yielding a value of type numeric.

Format

```
<numeric value function> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array dimension>
  | <md-array axis index function>
  | <md-array lower axis limit>
  | <md-array upper axis limit>
  | <md-array aggregation function>

<md-array dimension> ::=
  MDDIMENSION <left paren> <md-array value expression> <right paren>

<md-array axis index function> ::=
  MDAXIS_INDEX <left paren>
      <md-array value expression> <comma> <md-axis name>
      <right paren>

<md-array lower axis limit> ::=
  MDAXIS_LOW <left paren> <md-array md-axis> <right paren>

<md-array upper axis limit> ::=
  MDAXIS_HIGH <left paren> <md-array md-axis> <right paren>

<md-array aggregation function> ::=
  <md-array aggregation function name>
      <left paren> <md-array value expression> <right paren>

<md-array aggregation function name> ::=
    MDALL
  | MDANY
  | MDAVG
  | MDCOUNT
  | MDCOUNT_FALSE
  | MDCOUNT_TRUE
  | MDCOUNT_UNKNOWN
  | MDMAX
  | MDMIN
  | MDSUM
```

Syntax Rules

1) Insert after the last SR: If <md-array dimension>, <md-array axis index function>, <md-array lower axis limit>, <md-array upper axis limit>, or <md-array aggregation function> is specified, then let *AVE* be the simply contained <md-array value expression>. Let *MDT* be the declared type of *AVE*, let *EDT* be the element type of *MDT*, let *d* be the MD-dimension of *MDT*, and let MN_i be the name of the *i*-th MD-axis in the maximum MD-extent of *MDT*, 1 (one) $\leq i \leq d$.

2) Insert after the last SR: If <md-array dimension> is specified, then the declared type of the result is an implementation-defined (IV241) exact numeric type with scale 0 (zero).

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3) Insert after the last SR: If <md-array axis index function> *AIF* is specified, then the declared type of the result is an implementation-defined (IV242) exact numeric type with scale 0 (zero). The <md-axis name> immediately contained in *AIF* shall be equivalent to MN_{idx} for some *idx*, 1 (one) ≤ *idx* ≤ *d*.

4) Insert after the last SR: If <md-array lower axis limit> or <md-array upper axis limit> is specified, then the declared type of the result is an implementation-defined (IV243) exact numeric type with scale 0 (zero). Let *AD* be the index specified by <md-array md-axis>.

5) Insert after the last SR: If <md-array aggregation function> *MAF* is specified, then *MAF* shall not generally contain a <routine invocation> whose subject routine is an SQL-invoked routine that is possibly non-deterministic or that possibly modifies SQL-data, and *MAF* shall not generally contain a <table primary> that contains a <data change delta table>.

Case:

a) If <md-array aggregation function name> is one of MDSUM, MDMAX, MDMIN, MDALL, or MDANY, then let *op* be <plus sign> for MDSUM, MAX for MDMAX, MIN for MDMIN, AND for MDALL, and OR for MDANY. <md-array aggregation function> is equivalent to:

```
MDAGGREGATE op
OVER [ MN1 ( MDAXIS_LOW (AVE, 1) : MDAXIS_HIGH (AVE, 1) ),
       ...,
       MNd ( MDAXIS_LOW (AVE, d) : MDAXIS_HIGH (AVE, d) ) ]
USING AVE[ MN1, ..., MNd ]
WHERE AVE[ MN1, ..., MNd ] IS NOT NULL
```

b) If <md-array aggregation function name> is MDCOUNT_TRUE, then <md-array aggregation function> is equivalent to:

```
MDAGGREGATE <plus sign>
OVER [ MN1 ( MDAXIS_LOW (AVE, 1) : MDAXIS_HIGH (AVE, 1) ),
       ...,
       MNd ( MDAXIS_LOW (AVE, d) : MDAXIS_HIGH (AVE, d) ) ]
USING CASE WHEN AVE[ MN1, ..., MNd ] THEN 1 ELSE 0 END
WHERE AVE[ MN1, ..., MNd ] IS NOT NULL
```

c) If <md-array aggregation function name> is MDCOUNT_FALSE, then <md-array aggregation function> is equivalent to:

```
MDCOUNT_TRUE( AVE IS FALSE )
```

d) If <md-array aggregation function name> is MDCOUNT_UNKNOWN, then <md-array aggregation function> is equivalent to:

```
MDCOUNT_TRUE( AVE IS UNKNOWN )
```

e) If <md-array aggregation function name> is MDCOUNT, then <md-array aggregation function> is equivalent to:

```
MDAGGREGATE <plus sign>
OVER [ MN1 ( MDAXIS_LOW (AVE, 1) : MDAXIS_HIGH (AVE, 1) ),
       ...,
       MNd ( MDAXIS_LOW (AVE, d) : MDAXIS_HIGH (AVE, d) ) ]
USING 1
WHERE AVE[ MN1, ..., MNd ] IS NOT NULL
```

f) Otherwise, <md-array aggregation function name> is MDAVG and <md-array aggregation function> is equivalent to:

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```
CASE WHEN MDCOUNT ( AVE ) = 0 THEN NULL
     ELSE MDSUM ( AVE ) / MDCOUNT ( AVE ) END
```

Access Rules

No additional Access Rules.

General Rules

1) Insert after the last GR: The result of <md-array dimension> is *d*.

2) Insert after the last GR: The result of <md-array axis index function> is *idx*.

3) Insert after the last GR: If <md-array lower axis limit> or <md-array upper axis limit> is specified, then:

   a) Let *VAVE* be the value of *AVE*.

   b) Case:

      i) If *VAVE* is the null value, then the result is the null value.

      ii) Otherwise, let LO_i and HI_i be the lower and upper limits of the *i*-th MD-axis of the MD-extent of *VAVE*.

      Case:

      1) If <md-array lower axis limit> is specified, then the result is LO_{AD}.

      2) Otherwise, the result is HI_{AD}.

Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain <md-array dimension>, <md-array lower axis limit>, <md-array upper axis limit>, or <md-array axis index function>.

2) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain <md-array aggregation function>.

3) Insert after the last CR: Without Feature A011, "MD-array BOOLEAN element type", conforming SQL language shall not contain an <md-array aggregation function name> that is MDALL, MDANY, MDCOUNT_FALSE, MDCOUNT_TRUE, or MDCOUNT_UNKNOWN.

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6.10 <string value function>

This Subclause modifies Subclause 6.33, "<string value function>", in ISO/IEC 9075-2.

Function

Specify a function yielding a value of type character string or binary string.

Format

```
<string value function> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array encode function>

<character value function> ::=
    !! All alternatives from ISO/IEC 9075-2
  | <md-array axis name function>

<md-array axis name function> ::=
  MDAXIS_NAME <left paren>
      <md-array value expression> <comma> <numeric value expression>
      <right paren>
```

Syntax Rules

1) Augment SR 1) by adding "<md-array encode function>" to the list of BNF non-terminals.

2) Augment SR 2) by adding "<md-array axis name function>" to the list of BNF non-terminals.

3) Insert after the last SR: If <md-array axis name function> *ANF* is specified, then:

   a) Let *MDT* be the declared type of the <md-array value expression> immediately contained in *ANF*, let *MD* be the maximum MD-extent of *MDT*, let *d* be the number of MD-axes in *MDT*, and let MN_i be the name of the *i*-th MD-axis in *MD*, 1 (one) $\leq i \leq d$.

   b) Let *NVE* be the <numeric value expression> immediately contained in *ANF*. The declared type of *NVE* shall be an exact numeric type with scale 0 (zero).

   c) Let *VL* be the implementation-defined (IL006) maximum length of variable-length character strings. The declared type of the result is variable-length character string type with maximum length equal to *VL*.

Access Rules

No additional Access Rules.

General Rules

1) Augment GR 1) by adding "<md-array encode function>" to the list of BNF non-terminals.

2) Augment GR 2) by adding "<md-array axis name function>" to the list of BNF non-terminals.

3) Insert after the last GR: The result of <md-array axis name function> is determined as follows:

   a) Let *NV* be the value of *NVE*.

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b) If *NV* is the null value, then the result is the null value and no further General Rules of this Subclause are applied.

c) If *NV* is less than 1 (one) or greater than *d*, then an exception condition is raised: *data exception — MD-array invalid MD-axis (2203T)*.

d) Let *AVE* be the value of the <md-array value expression>.

e) If *AVE* is the null value, then the result is the null value and no further General Rules of this Subclause are applied.

f) The result is MN_{NV}.

Conformance Rules

1) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain <md-array axis name function>.

2) Insert after the last CR: Without Feature A010, "Multi-dimensional array support", conforming SQL language shall not contain a <string value function> that is an <md-array encode function>.

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6.11 <md-array encode function>

Function

Convert an array to format-specific encoded string.

Format

```
<md-array encode function> ::=
  MDENCODE <left paren>
      <md-array value expression> <comma> <format identifier>
      [ <md-array encode returning clause> ]
  <right paren>

<format identifier> ::=
  <character string literal>

<md-array encode returning clause> ::=
  RETURNING <data type>
```

Syntax Rules

1) Let *AEF* be the <md-array encode function> and let *FID* be the value of <format identifier> immediately contained in *AEF*. *FID* shall be a valid media type as specified in RFC 2046.

2) If <md-array encode returning clause> is not specified, then

   Case:

   a) If *FID* is equivalent to 'application/json', then an implementation-defined (ID225) character string type is implicit.

   b) Otherwise, an implementation-defined (ID226) string type is implicit.

3) The <data type> *DT* immediately contained in the explicit or implicit <md-array encode returning clause> shall be a <predefined type> that identifies a character string data type or binary string data type.

4) The declared type of *AEF* is the data type specified by *DT*.

Access Rules

None.

General Rules

1) Let *AVE* be the value of the <md-array value expression> immediately contained in *AEF*.

2) If *AVE* is the null value, then the result of *AEF* is the null value and no further General Rules of this Subclause are applied.

3) Let *ET* be the element type of the declared type of *AVE*.

   Case:

   a) If *FID* is equivalent to 'application/json', then

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i) The function *F* transforming an MD-array *A* to JSON text is defined recursively as follows.

Let *N* be the value of MDAXIS_NAME(*A*, 1), let *LO* be the value of MDAXIS_LOW(*A*, 1), and let *HI* be the value of MDAXIS_HIGH(*A*, 1).

Case:

1) If MDDIMENSION(*A*) is equal to 1 (one), then

Case:

A) If *ET* is a row type, then let *DET* be the degree of *ET* and let FN_j be the name of the *j*-th field of *ET*, 1 (one) ≤ *j* ≤ *DET*. *F*(*A*) is the result of

```
JSON_ARRAY(
  JSON_OBJECT( FN1 : A[LO].FN1, ..., FNDET : A[LO].FNDET ),
  ...,
  JSON_OBJECT( FN1 : A[HI].FN1, ..., FNDET : A[HI].FNDET ),
)
```

B) Otherwise, *F*(*A*) is the result of

```
JSON_ARRAY( A[LO], ..., A[HI] )
```

2) Otherwise, let G_i be *F*(*A*[*N*(*i*)]), *LO* ≤ *i* ≤ *HI*. *F*(*A*) is the result of

```
JSON_ARRAY(GLO, ..., GHI)
```

ii) The result of *AEF* is JSON_OBJECT('data' VALUE *F*(*AVE*) FORMAT JSON).

b) Otherwise, the result of *AEF* is implementation-defined (IV244). If an encoding error occurs, then an exception condition is raised: *data exception — MD-array encoding error (2203Z)*.

Conformance Rules

1) Without Feature A014, “MDA encode/decode functions media type: application/json”, conforming SQL language shall not contain <md-array encode function>.

2) Without Feature A015, “MDA encode/decode functions with implementation-defined behavior”, conforming SQL language shall not contain an <md-array encode function> that contains a <format identifier> that is not equivalent to 'application/json'.

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