Unevaluated strings

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Reply-to:	Corentin Jabot <corentin.jabot@gmail.com>
	Aaron Ballman <aaron.ballman@gmail.com>

Abstract

*string-literal*s can appear in a context where they are not used to initialize a character array, but are used at compile time for diagnostic messages, preprocessing, and other implementation-defined behaviors. This paper clarifies how compilers should handle these strings.

Motivation

A *string-literal* can appear in `_Pragma`, `asm`, `extern`, `static_assert`, `[[deprecated]]` and `[[nodiscard]]` attributes...

In all of these cases, the strings are exclusively used at compile time by the compiler, and are as such not evaluated in phase 6. This means they should not be converted to the narrow encoding or any literal encoding specified by an encoding prefix (L, u, U, u8).

Their encoding should therefore not be constrained or otherwise specified, except that these strings can contain any Unicode characters.

This proposal aims to identify contexts in which strings are not evaluated so that they can be handled consistently by compilers.

Revisions

R5

- Re-specify `asm` declarations to accept any *balanced-token-seq* rather than trying to put constraints on the *string-literal* they are currently specified to accept. This simplifies the specification and more closely matches existing practices. **Following EWG review, additional wording has been added to make it clear that an implementation does not have to support `asm` statements or any grammar therein**. The intent of the proposal is to allow implementer to either allow any kind of grammar they want in `asm` statements, or allow no grammar whatsoever; No implementation would have to change its handling of `asm` statements with this proposal. Further work to remove [decl.asm]

entierly wile leaving the `asm` keyword reserved for vendor extensions could be the object of a separate paper.

- Fix a number of typos.

R4

- Rebase the wording and wording tweaks.

R3

- Improve wording by not making *unevaluated-string* preprocessing token as preprocessing tokens should not be context dependent. Fix the wording of `#line` and `_Pragma` accordingly.
- Append null-terminator during evaluation of string-literals to make it clear that *unevaluated-string* are not null-terminated.
- Adapt the grammar of *literal-operator-id*
- Adapt the wording of `extern` to clarify that the likage specification denotes unicode characters.
- Allow numeric escape sequences in asm statements.

R2

- *unevaluated-string-literal* to *unevaluated-string*.
- Add a note about not disallowing non-printable characters
- Add a note about *unevaluated-string* not being expressions.
- Fix typos.
- Improve wording.

Proposal

Unevaluated string literals can appear in

- `_Pragma`
- `#line` directives
- `[[nodiscard]]` and `[[deprecated]]` attributes
- `extern` linkage specifications
- `asm` statements
- `static_assert`

- literal operator

We propose that in all of these cases:

- No prefix is allowed
- The string is not converted to the execution encoding.
- `universal-character-name` and `simple-escape-sequence` (except `\0`) are replaced by the corresponding Unicode codepoints, and other escape sequences are ill-formed.

This last point is important. Because the encoding the compiler will convert these strings to is not known, and because UCNs can represent any Unicode characters, numeric-escape-sequences have no use beyond forcing the compiler to contend with invalid code units in diagnostic messages.

All of these changes are breaking changes. However, a survey of open source projects tends to show that none of the restrictions added impact existing code.

This proposal does not specify how unevaluated strings are presented in diagnostic messages.

Non-printable characters and escape sequences

This proposal does not attempt to restrict further the characters allowed in unevaluated strings. In particular, they may contain all matter of space, control characters, invisible characters, and alert. The handling of these characters in diagnostic messages is left as quality of implementation, mostly for simplicity. The alternative would be to only allow graphic characters (General_Category L, M, N, P, S + spaces).

Alternative considered

Allowing and ignoring any prefix

This is arguably the status quo. The issue is that it is hard to teach. Users should be able to expect for example that L"X" is always in the wide execution encoding. It could be argued that `"foo"` not being in the narrow-encoding is also confusing, however, there is precedence for that in headers names (which are already not *string-literal*s).

Allowing prefixes and encode all strings using that prefix

This is both implementer- and user-hostile. It would force users to use any of u, u8, U on all of their `static_assert` which contain non-ASCII characters as it is the only way to obtain a portable encoding. It has the advantage of being mostly consistent (all strings except those in headers names would be encoded using the encoding associated with their prefix) but would break existing code using non-ASCII characters in `static_assert` and attributes and litter C++ code with these prefixes, which seems to be a net negative.

`asm` declarations

Several people in SG22, as well as an implementer, raised concerns about banning numeric escape sequences in asm statement as supposedly an implementation could do "something" here. Given the implementation-defined, conditionally supported nature of `asm` declarations, and existing practice, we decided to modify the grammar to accept any balanced token sequence (which includes string literals). This is consistent with GCC's "extended asm" syntax, notably. Implementations that support a single string literal in `asm` declarations can, of course, continue to do so with no change required to their implementation and are free to put whichever requirements they need on them. This does not requires an implementation to be able to parse arbitrary *balanced-token-seq* either. The intent is that any *balanced-token-seq* not recognized by an implementation that would otherwise support `asm` statements can be ill-formed.

Compilers survey

_Pragma

In `_Pragma` directives, the standard specifies that the `L` prefix is ignored. In C, all encoding prefixes are ignored. This divergence is highlighted in CWG897 [2]. MSVC does not support `_Pragma(L"")`. Only Clang supports other prefixes in `_Pragma`.

Out of the 90 million lines of code of the 1300+ open source projects available on vcpkg, a single use of that feature was found within clang's lexer test suite, for a total of 2000 uses of `_Pragma`. Similarly, the only uses of `_Pragma (u8"")`, `_Pragma (u"")`, `_Pragma (U"")`, etc were found in Clang's test suite (both because these are valid C and because neither GCC nor Clang are conforming, only `L""` is described as valid by the C++ standard).

Attributes

Clang does not support strings with an encoding prefix in attributes, other compilers accept them.

`static_assert`

All compilers support strings with an encoding prefix in static assert. MSVC appears to convert the string to the encoding associated with that prefix before displaying it, producing mojibake if a string cannot be represented in the literal encoding. The following diagnostics are emmited by MSVC with `/execution-charset:ascii`:

```
static_assert(false, "Your code is on 🔥");

<source>(1): warning C4566: character represented by universal-character-name
'\u00F0'  cannot be represented in the current code page (20127)
<source>(1): warning C4566: character represented by universal-character-name
```

```
'\u0178'  cannot be represented in the current code page (20127)
<source>(1): warning C4566: character represented by universal-character-name
'\u201D' cannot be represented in the current code page (20127)
<source>(1): warning C4566: character represented by universal-character-name
'\u00A5' cannot be represented in the current code page (20127)
<source>(1): error C2338: ????

static_assert(false, u8"Your code is on 🔥");
<source>(1): error C2002: invalid wide-character constant
```

`extern` & `asm`

No compiler support strings with an encoding prefix in extern and asm statements.

`#line`

GCC and Clang do not support encoding prefix in `#line` directives.

Future direction

This proposal does not prevent supporting constant expression in `static_assert` or attributes in the future; we can imagine the following grammar:

static_assert-declaration:
`static_assert` (*constant-expression*) ;
`static_assert` (*constant-expression* , *unevaluated-string*) ;
`static_assert` (*constant-expression* , *constant-expression*) ;

Those may make `static_assert(true, u8"foo");` valid again as `u8"foo"` would be a valid constant expression.

Implementability

This proposal requires implementations to keep around a non-encoded string for diagnostic purposes. This has recently come up in a clang patch to support EBCDIC as the literal encoding. To support diagnostics in this context, especially on a non-EBCDIC platform the original sequence of characters must be retained. This proposal offers a well-specified, portable mechanism to solve this problem.

Wording Challenges

Strings are handled in phases 5 and 6 before the program is parsed, which might force us to have a ”reversal” of these phases. *string-literal* and *unevaluated-string-literal* only differ by the context in which they may appear.

It is important to note that *unevaluated-string*, by virtue of not being evaluated, are not C++ expressions. They are purposefully left out of the *literal* grammar. Not being literal, and not being expressions, *unevaluated-string* do not have a value category.

Previous works

P2246R1 [1] removes wording specific to attributes mandating that diagnostic with characters from the basic characters are displayed in diagnostic messages, which was not implementable.

Wording

[Editor's note: Add after "[lex.string]/p10"]

🔲 Unevaluated strings [lex.string.unevaluated]

unevaluated-string:
string-literal

An *unevaluated-string* shall have no *encoding-prefix*.

Each *universal-character-name* and each *simple-escape-sequence* in an *unevaluated-string* is replaced by the member of the translation character set it denotes. An *unevaluated-string* which contains a *numeric-escape-sequence* or a *conditional-escape-sequence* is ill-formed.

An *unevaluated-string* is never evaluated and its interpretation depends on the context in which it appears.

[Editor's note: "translation set" is defined in P2314R2 [3] in [lex.phases]]

🔲 Declarations [dcl.dcl]

🔲 Preamble [dcl.pre]

simple-declaration:
decl-specifier-seq init-declarator-list$_{opt}$;
attribute-specifier-seq decl-specifier-seq init-declarator-list ;
attribute-specifier-seq$_{opt}$ *decl-specifier-seq ref-qualifier*$_{opt}$ `[` *identifier-list* `]` *initializer* ;

static_assert-declaration:
`static_assert` `(` *constant-expression* `)` ;
`static_assert` `(` *constant-expression* , *unevaluated-string* ~~*literal*~~ `)` ;

[...]

In a *static_assert-declaration*, the *constant-expression* shall be a contextually converted constant expression of type `bool`. If the value of the expression when so converted is `true`, the declaration has no effect. Otherwise, the program is ill-formed, and the resulting diagnostic

message shall include the text of the *unevaluated-string~~-literal~~*, if one is supplied, except that characters not in the basic source character set are not required to appear in the diagnostic message. [*Example:*

```
static_assert(sizeof(int) == sizeof(void*), "wrong pointer size");
```

— end example]

🔲 The `asm` declaration [dcl.asm]

An `asm` declaration has the form

asm-declaration:
attribute-specifier-seq$_{opt}$ `asm` `(` ~~*string-literal*~~ *balanced-token-seq* `)` `;`

The `asm` declaration is conditionally-supported; any restrictions on the *balanced-token-seq* and its meaning ~~is~~ are implementation-defined. The optional *attribute-specifier-seq* in an *asm-declaration* appertains to the `asm` declaration. [*Note:* Typically it is used to pass information through the implementation to an assembler. *— end note*]

🔲 Linkage specifications [dcl.link]

All functions and variables whose names have external linkage and all function types have a *language linkage*. [*Note:* Some of the properties associated with an entity with language linkage are specific to each implementation and are not described here. For example, a particular language linkage might be associated with a particular form of representing names of objects and functions with external linkage, or with a particular calling convention, etc. *— end note*] The default language linkage of all function types, functions, and variables is C++ language linkage. Two function types with different language linkages are distinct types even if they are otherwise identical.

Linkage between C++ and non-C++ code fragments can be achieved using a *linkage-specification*:

linkage-specification:
`extern` *unevaluated-string~~-literal~~* `{` *declaration-seq*$_{opt}$ `}`
`extern` *unevaluated-string~~-literal~~* *declaration*

The *unevaluated-string~~-literal~~* indicates the required language linkage [*Note:* Escape sequences and *universal-character-name*s have been replaced in [lex.string.unevaluated] *— end note*] .

This document specifies the semantics for the unevaluated-string~~-literal~~ `"C"` and `"C++"`. Use of a unevaluated-string~~-literal~~ other than `"C"` or `"C++"` is conditionally-supported, with implementation-defined semantics. [*Note:* Therefore, a linkage-specification with a ~~*string-literal*~~ language linkage that is unknown to the implementation requires a diagnostic. *— end note*] [*Note:* It is recommended that the spelling of the ~~*string-literal*~~ language linkage be taken from the document defining that language. For example, `Ada` (not `ADA`) and `Fortran` or `FORTRAN`, depending on the vintage. *— end note*]

Every implementation shall provide for linkage to the C programming language, `"C"`, and C++, `"C++"`. [*Example:*

```
complex sqrt(complex);          // C++ language linkage by default
extern "C" {
    double sqrt(double);          // C language linkage
}
```

— *end example*]

// [...]

🔗 Attributes [dcl.attr]

🔗 Deprecated attribute [dcl.attr.deprecated]

The *attribute-token* `deprecated` can be used to mark names and entities whose use is still allowed, but is discouraged for some reason. [*Note:* In particular, `deprecated` is appropriate for names and entities that are deemed obsolescent or unsafe. — *end note*] It shall appear at most once in each *attribute-list*. An *attribute-argument-clause* may be present and, if present, it shall have the form:

(*unevaluated-string~~-literal~~*)

[*Note:* The *unevaluated-string~~-literal~~* in the *attribute-argument-clause* can be used to explain the rationale for deprecation and/or to suggest a replacing entity. — *end note*]

🔗 Nodiscard attribute [dcl.attr.nodiscard]

The *attribute-token* `nodiscard` may be applied to the *declarator-id* in a function declaration or to the declaration of a class or enumeration. It shall appear at most once in each *attribute-list*. An *attribute-argument-clause* may be present and, if present, shall have the form:

(*unevaluated-string~~-literal~~*)

A name or entity declared without the `nodiscard` attribute can later be redeclared with the attribute and vice-versa. [*Note:* Thus, an entity initially declared without the attribute can be marked as `nodiscard` by a subsequent redeclaration. However, after an entity is marked as `nodiscard`, later redeclarations do not remove the `nodiscard` from the entity. — *end note*] Redeclarations using different forms of the attribute (with or without the *attribute-argument-clause* or with different *attribute-argument-clause* s) are allowed.

A *nodiscard type* is a (possibly cv-qualified) class or enumeration type marked `nodiscard` in a reachable declaration. A *nodiscard call* is either

- a function call expression that calls a function declared `nodiscard` in a reachable declaration or whose return type is a nodiscard type, or

- an explicit type conversion (**??**, **??**, **??**) that constructs an object through a constructor declared `nodiscard` in a reachable declaration, or that initializes an object of a nodiscard type.

Recommended Practice: Appearance of a nodiscard call as a potentially-evaluated discarded-value expression is discouraged unless explicitly cast to `void`. Implementations should issue a warning in such cases. [*Note:* This is typically because discarding the return value of a nodiscard call has surprising consequences. — *end note*] The *unevaluated-string* ~~*-literal*~~ in a `nodiscard` *attribute-argument-clause* should be used in the message of the warning as the rationale for why the result should not be discarded.

🔲 User-defined literals [over.literal]

literal-operator-id:
`operator` ~~*string-literal*~~ *unevaluated-string* *identifier*
`operator` *user-defined-string-literal*

The ~~*string-literal or*~~ *user-defined-string-literal* in a *literal-operator-id* shall have no *encoding-prefix* and shall contain no characters other than the implicit terminating `'\0'`. The *ud-suffix* of the *user-defined-string-literal* or the *identifier* in a *literal-operator-id* is called a *literal suffix identifier*. Some literal suffix identifiers are reserved for future standardization; see **??**. A declaration whose *literal-operator-id* uses such a literal suffix identifier is ill-formed, no diagnostic required.

🔲 Preprocessing directives [cpp]

[...]

🔲 Line control [cpp.line]

The *string-literal* of a `#line` directive, if present, shall ~~be a character string literal~~ satisfy the semantic constraints of an *unevaluated-string* [lex.string.unevaluated].

[Editor's note: *string-literal* is prexisting wording, but the grammar refers to a quoted sequence of s-char. This is arguably a bug that CWG may want to address as a drive-by when processing this paper.]

The *line number* of the current source line is one greater than the number of new-line characters read or introduced in translation phase 1 while processing the source file to the current token.

A preprocessing directive of the form `# line` *digit-sequence new-line*
causes the implementation to behave as if the following sequence of source lines begins with a source line that has a line number as specified by the digit sequence (interpreted as a decimal integer). If the digit sequence specifies zero or a number greater than 2147483647, the behavior is undefined.

A preprocessing directive of the form

`# line` *digit-sequence* " *s-char-sequence*$_{opt}$ " *new-line*

sets the presumed line number similarly and changes the presumed name of the source file to be the contents of the ~~character~~ string literal.

A preprocessing directive of the form

`# line` *pp-tokens new-line*

(that does not match one of the two previous forms) is permitted. The preprocessing tokens after `line` on the directive are processed just as in normal text (each identifier currently defined as a macro name is replaced by its replacement list of preprocessing tokens). If the directive resulting after all replacements does not match one of the two previous forms, the behavior is undefined; otherwise, the result is processed as appropriate.

🔲 Pragma operator [cpp.pragma.op]

The *string-literal* of a Pragma operator shall satisfy the semantic constraints of an *unevaluated-string* [lex.string.unevaluated].

A unary operator expression of the form:

`_Pragma (` *string-literal* `)`

is processed as follows: The *string-literal* is *destringized* by ~~deleting the `L` prefix, if present,~~ deleting the leading and trailing double-quotes,replacing each escape sequence `\"` by a double-quote, and replacing each escape sequence `\\` by a single backslash. The resulting sequence of characters is processed through translation phase 3 to produce preprocessing tokens that are executed as if they were the *pp-tokens* in a pragma directive. The original four preprocessing tokens in the unary operator expression are removed.

[*Example:*

```
#pragma listing on "..\listing.dir"
```

can also be expressed as:

```
_Pragma ( "listing on \"..\\listing.dir\"" )
```

The latter form is processed in the same way whether it appears literally as shown, or results from macro replacement, as in:

```
#define LISTING(x) PRAGMA(listing on #x)
#define PRAGMA(x) _Pragma(#x)

LISTING( ..\listing.dir )
```

— *end example*]

Acknowledgments

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References

[1] Aaron Ballman. P2246R1: Character encoding of diagnostic text. https://wg21.link/p2246r1, 1 2021.

[2] Daniel Krügler. CWG897: _pragma and extended string-literals. https://wg21.link/cwg897, 5 2009.

[3] Jens Maurer. P2314R2: Character sets and encodings. https://wg21.link/p2314r2, 5 2021.

[N4885] Thomas Köppe *Working Draft, Standard for Programming Language C++* https://wg21.link/N4885