

A proposal to add `std::byte`-based IO to C++

Document #: DXXXXR0
Date: 2019-11-19
Project: Programming Language C++
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1 Motivation

C++ has text streams for a long time. However, there is no comfortable way to read and write binary data. One can argue that it is possible to [ab]use `char`-based text streams that provide unformatted IO but it has many drawbacks:

- The API still works in terms of `char` which means `reinterpret_cast` if you use `std::byte` in your code base.
- Streams operate in terms of `std::char_traits` which makes no sense when doing binary IO. In particular, `std::ios::pos_type` is a very painful type to work with but is required in many IO operations.
- Stream open mode doesn't make a lot of sense and you'd always want to make sure to force it to have `std::ios_base::binary`.
- Stream objects carry a lot of text formatting flags that are irrelevant when doing binary IO. This leads to wasted memory.
- By default, stream operations don't throw exceptions. This usually means some wrapper code to force exceptions.
- If you want to do IO in memory, you're stuck with string streams that operate using `std::string`. Most binary data is stored in `std::vector` which leads to awful performance due to unnecessary copies.
- There is no agreed standard for customization points for binary IO.

This proposal tries to fix all mentioned issues.

2 Prior art

This proposal is based on `ftz` Serialization library which was initially written in 2010 targeting C++98 and was gradually updated to C++20. In particular, the following problems were encountered:

- There was no portable way to determine the native endianness, especially since sizes of all fundamental types can be 1 and all fixed-width types are optional. This was fixed by `std::endian` in C++20.
- There was no easy way to convert integers from native representation to two's complement and vice versa. This was fixed by requiring all integers to be two's complement in C++20.
- There is no easy way to convert integers from native endianness to specific endianness and vice versa. There is an `std::byteswap` proposal but it doesn't solve the general case because C++ allows systems that are neither big nor little endian.
- There is no easy way to convert floating point number from native representation to ISO/IEC/IEEE 60559 and vice versa. This makes portable serialization of floating point numbers very hard on non-IEC platforms. [P1468](#) should fix this.

While the author thinks that having endianness and floating point conversion functions available publicly is a good idea, they leave them as implementation details in this paper.

Thoughts on [Boost.Serialization](#):

- It uses confusing operator overloading akin to standard text streams which leads to several problems such as unnecessary complexity of >> and << returning a reference to the archive.
- It doesn't support portable serialization of floating point values.
- It tries to do too much by adding version number to customization points, performing magic on pointers, arrays, several standard containers and general purpose boost classes.
- Unfortunate macro to split `load` and `save` customization points.
- It still uses standard text streams as archives.

Thoughts on [Cereal](#)

- It decided to inherit several Boost problems for the sake of compatibility.
- Strange `operator()` syntax for IO.
- Will not compile if `CHAR_BIT > 8`.
- Undefined behavior when detecting native endianness due to strict aliasing violation.
- Doesn't support portable serialization of floating point values, but gives helpful `static_assert` in case of non-IEC platform.
- Still uses standard text streams as archives.

3 Design goals

- Always use `std::byte` instead of `char` when meaning raw bytes. Avoid `char*`, `unsigned char*` and `void*`.
- Do not do any text processing or hold any text-related data inside stream classes, even as template parameters.
- Provide intuitive customization points.
- Support different endiannesses and floating point formats.
- Stream classes should efficiently map to OS API in case of file IO.

4 Design decisions

- It was chosen to put all new types into separate namespace `std::io`. This follows the model ranges took where they define more modern versions of old facilities inside a new namespace.
- The inheritance heirarchy of legacy text streams has been changed to concepts. Legacy base class templates have become the following concepts:
 - `std::ios_base` and `std::basic_ios` -> `std::io::stream_base`.
 - `std::basic_istream` -> `std::io::input_stream`.
 - `std::basic_ostream` -> `std::io::output_stream`.
 - `std::basic_stream` -> `std::io::stream`.
- Concrete class templates have been renamed as follows:
 - `std::basic_istringstream` -> `std::io::basic_input_memory_stream`.
 - `std::basic_ostringstream` -> `std::io::basic_output_memory_stream`.
 - `std::basic_stringstream` -> `std::io::basic_memory_stream`.
 - `std::basic_ifstream` -> `std::io::input_file_stream`.
 - `std::basic_ofstream` -> `std::io::output_file_stream`.
 - `std::basic_fstream` -> `std::io::file_stream`.
- The `streambuf` part of legacy text streams has been dropped.
- Fixed size streams have been added:
 - `std::io::input_span_stream`.
 - `std::io::output_span_stream`.
 - `std::io::span_stream`.

- Since the explicit goal of this proposal is to do IO in terms of `std::byte`, `CharT` and `Traits` template parameters have been removed.
- All text formatting flags have been removed. A new class `std::io::format` has been introduced for binary format. The separate class is used in order to make the change of stream format atomic.
- Parts of legacy text streams related to `std::ios_base::iostate` have been removed. It is better to report any specific errors via exceptions and since binary files usually have fixed layout and almost always start chunks of data with size, any kind of IO error is usually unrecoverable.
- Since there is no more buffering because of lack of `streambuf` and operating systems only expose a single file position that is used both for reading and writing, the interface has been changed accordingly:
 - `tellg` and `tellp` -> `get_position`.
 - Single argument versions of `seekg` and `seekp` -> `set_position`.
 - Double argument versions of `seekg` and `seekp` -> `seek_position`.
 - `peek`, `putback`, `unget` and `flush` member functions were removed.
- `std::basic_ios::pos_type` has been replaced with `std::streamoff`.
- `std::basic_ios::off_type` has been replaced with `std::streamoff`.
- `std::ios_base::seekdir` has been replaced with `std::io::base_position`.
- `getline` and `ignore` member functions were removed because they don't make sense during binary IO.
- Since it is not always possible to read or write all requested bytes in one system call (especially during networking), the interface has been changed accordingly:
 - `std::io::input_stream` requires `read_some` member function that reads zero or more bytes from the stream and returns amount of bytes read.
 - `std::io::output_stream` requires `write_some` member function that writes one or more bytes to the stream and returns amount of bytes written.
 - `gcount` became the return value of `read_some`.
 - `get`, `read`, `put` and `write` member functions were removed in favor of `read_some` and `write_some`.
- `operator>>` and `operator<<` have been replaced with `std::io::read` and `std::io::write` customization points.

5 Tutorial

5.1 Example 1: Writing integer with default format

```
#include <io>
#include <iostream>

int main()
{
    unsigned int value = 42;

    // Create a stream. This stream will write to dynamically allocated memory.
    std::io::output_memory_stream s;

    // Write the value to the stream.
    std::io::write(s, value);

    // Get reference to the buffer of the stream.
    const auto& buffer = s.get_buffer();

    // Print the buffer.
    for (auto byte : buffer)
    {
        std::cout << std::to_integer<int>(byte) << ' ';
    }
}
```

```
std::cout << '\n';
}
```

The result is implementation defined because by default the bytes of the integer are being copied as-is without any processing. This is the fastest. You don't pay for what you don't use. The output would depend on `CHAR_BIT`, `sizeof(unsigned int)` and `std::endian::native`. On AMD64 this will print:

```
42 0 0 0
```

This is because `CHAR_BIT` is 8, `sizeof(unsigned int)` is 4 and `std::endian::native == std::endian::little`. We can be more strict and have more portable layout:

5.2 Example 2: Writing integer with specific layout

```
#include <cstdint>
#include <io>
#include <iostream>

// Do not compile on systems with non-8-bit bytes.
static_assert(CHAR_BIT == 8);

int main()
{
    std::uint32_t value = 42;

    // Create a specific binary format.
    // Here we want our data in the stream to be in big endian byte order.
    std::io::format f{std::endian::big};

    // Create a stream with our format.
    std::io::output_memory_stream s{f};

    // Write the value to the stream.
    // This will perform endianness conversion on non-big-endian systems.
    std::io::write(s, value);

    const auto& buffer = s.get_buffer();

    for (auto byte : buffer)
    {
        std::cout << std::to_integer<int>(byte) << ' ';
    }
    std::cout << '\n';
}
```

This will either fail to compile on systems where `CHAR_BIT != 8` or print:

```
0 0 0 42
```

5.3 Example 3: Working with floating point numbers

TODO

5.4 Example 4: Working with user defined type

```
#include <io>
#include <iostream>

struct MyType
{
    int a;
    float b;

    void read(std::io::input_stream auto& stream)
    {
        std::io::read(stream, a);
        std::io::read(stream, b);
    }

    void write(std::io::output_stream auto& stream) const
    {
        std::io::write(stream, a);
        std::io::write(stream, b);
    }
};

int main()
{
    MyType t{1, 2.0f};
    std::io::output_memory_stream s;

    // std::io::write will automatically pickup "write" member function if it
    // has a valid signature.
    std::io::write(s, t);

    const auto& buffer = s.get_buffer();

    for (auto byte : buffer)
    {
        std::cout << std::to_integer<int>(byte) << ' ';
    }
    std::cout << '\n';
}
```

5.5 Example 5: Working with user defined type (another approach)

```
#include <io>
#include <iostream>

struct VendorType // Can't modify interface.
{
    int a;
    float b;
};

// Add "read" and "write" as free functions. They will be picked up
// automatically.
```

```

void read(std::io::input_stream auto& stream, VendorType& vt)
{
    std::io::read(stream, vt.a);
    std::io::read(stream, vt.b);
}

void write(std::io::output_stream auto& stream, const VendorType& vt)
{
    std::io::write(stream, vt.a);
    std::io::write(stream, vt.b);
}

int main()
{
    VendorType vt{1, 2.0f};
    std::io::output_memory_stream s;

    // std::io::write will automatically pickup "write" non-member function if
    // it has a valid signature.
    std::io::write(s, t);

    const auto& buffer = s.get_buffer();

    for (auto byte : buffer)
    {
        std::cout << std::to_integer<int>(byte) << ' ';
    }
    std::cout << '\n';
}

```

5.6 Example 6: Working with enums

Enumerations are essentially strong integers. Therefore, serializing them is the same as integers and is done out-of-the-box by `std::io::write`. However, reading is not so simple since there is no language-level mechanism to iterate the valid values. For now you have to write non-member `read` function that will read the integer and manually check if it has a legal value. It is hopeful that the need to write such boilerplate code will be resolved by reflection in the future.

```

enum class MyEnum
{
    Foo,
    Bar
};

void read(std::io::input_stream auto& stream, MyEnum& my_enum)
{
    // Create a raw integer that is the same type as underlying type of our
    // enumeration.
    std::underlying_type_t<MyEnum> raw;

    // Read the integer from the stream.
    std::io::read(stream, raw);

    // Cast it to our enumeration.
}

```

```

my_enum = static_cast<MyEnum>(raw);

// Check the value of enumeration.
switch (my_enum)
{
    case MyEnum::Foo:
    case MyEnum::Bar:
    {
        // The value is legal.
        return;
    }
    default:
    {
        // The value is illegal.
        throw /* ... */
    }
}
}

```

5.7 Example 7: Resource Interchange File Format

There are 2 flavors of RIFF files: little-endian and big-endian. Endianness is determined by the ID of the first chunk. ASCII “RIFF” means little-endian, ASCII “RIFX” means big-endian. We can just read the chunk ID as sequence of bytes, set the format of the stream to the correct endianness and read the rest of the file as usual.

```

#include <io>
#include <array>
#include <vector>

namespace RIFF // Put things into separate namespace to save typing long names.
{

// Describes a single RIFF chunk. It starts with 4 byte ID, then size as 32-bit
// unsigned integer followed by the data of the chunk. The size doesn't include
// ID and size fields, only the size of raw data. If size is odd, there is 1
// byte padding so all chunks are aligned at even offsets.
struct Chunk
{
    using ID = std::array<std::byte, 4>;
    using Size = std::uint32_t;

    ID id;
    std::vector<std::byte> data;

    template <typename S>
    requires std::io::input_stream<S> && std::io::seekable_stream<S>
    Chunk(S& stream)
    {
        this->read(stream);
    }

    template <typename S>
    requires std::io::input_stream<S> && std::io::seekable_stream<S>
    void read(S& stream)

```



```

{
    // Read the ID of the chunk.
    std::io::read(stream, id);
    // Read the size of the chunk.
    Size size;
    std::io::read(stream, size);
    // Read the data of the chunk.
    data.resize(size);
    std::io::read(stream, data);
    // Skip padding.
    if (size % 2 == 1)
    {
        stream.seek_position(std::io::base_position::current, 1);
    }
}

void write(std::io::output_stream auto& stream) const
{
    // Write the ID of the chunk.
    std::io::write(stream, id);
    // Write the size of the chunk.
    Size size = std::size(data); // Production code would make sure there is
    // no overflow here.
    std::io::write(stream, size);
    // Write the data of the chunk.
    std::io::write(stream, data);
    // Write padding.
    if (size % 2 == 1)
    {
        std::io::write(stream, std::byte{0});
    }
}

// Returns the full size of the chunk when serializing.
Size GetSize() const noexcept
{
    Size size = 8 + std::size(data);
    if (size % 2 == 1)
    {
        ++size;
    }
    return size;
}
};

// C++ doesn't have ASCII literals but we can use UTF-8 literals instead.
constexpr Chunk::ID LittleEndianFile{
    std::byte{u8'R'}, std::byte{u8'I'}, std::byte{u8'F'}, std::byte{u8'F'}};
constexpr Chunk::ID BigEndianFile{
    std::byte{u8'R'}, std::byte{u8'I'}, std::byte{u8'F'}, std::byte{u8'X'}};

class File
{

```

```

public:
    template <typename S>
    requires std::io::input_stream<S> && std::io::seekable_stream<S>
    File(S& stream)
    {
        this->read(stream);
    }

    template <typename S>
    requires std::io::input_stream<S> && std::io::seekable_stream<S>
    void read(S& stream)
    {
        // Read the main chunk ID.
        Chunk::ID chunk_id;
        std::io::read(stream, chunk_id);
        if (chunk_id == LittleEndianFile)
        {
            // We have little endian file.
            m_endianness = std::endian::little;
        }
        else if (chunk_id == BigEndianFile)
        {
            // We have big endian file.
            m_endianness = std::endian::big;
        }
        else
        {
            throw /* ... */
        }
        // Set stream format to correct endianness.
        auto format = stream.get_format();
        format.set_endianness(m_endianness);
        stream.set_format(format);
        // We have set correct endianness based on the 1st chunk ID.
        // The rest of the file will be deserialized correctly according to
        // our format.
        Chunk::Size file_size;
        // Read the size of the file.
        std::io::read(stream, file_size);
        // Now we can determine where the file ends.
        std::streamoff end_position = stream.get_position() + file_size;
        // Read the form type of the file.
        std::io::read(stream, m_form_type);
        // Read all the chunks.
        while (stream.get_position() < end_position)
        {
            m_chunks.emplace_back(stream);
        }
    }

    void write(std::io::output_stream auto& stream) const
    {
        // Set the endianness of the stream.
        auto format = stream.get_format();
    }

```

```

format.set_endianness(m_endianness);
stream.set_format(format);
// Write the ID of the main chunk.
if (m_endianness == std::endian::little)
{
    std::io::write(stream, LittleEndianFile);
}
else if (m_endianness == std::endian::big)
{
    std::io::write(stream, BigEndianFile);
}
else
{
    throw /* ... */
}
// Calculate the size of the file. For that we need to sum up the size
// of form type and sizes of all the chunks.
Chunk::Size file_size = 4;
for (const auto& chunk : m_chunks)
{
    file_size += chunk.GetSize();
}
// Write the size of the file.
std::io::write(stream, file_size);
// Write the form type of the file.
std::io::write(stream, m_form_type);
// Write all the chunks.
for (const auto& chunk : m_chunks)
{
    std::io::write(stream, chunk);
}
}
private:
    std::endian m_endianness;
    ChunkID m_form_type;
    std::vector<Chunk> m_chunks;
}
}

```

TODO: More tutorials? More explanations.

6 Implementation experience

The reference implementation is here: <https://github.com/Lyberta/cpp-io-impl>

Most of the proposal can be implemented in ISO C++. Low level conversions inside `std::io::read` and `std::io::write` require knowledge of implementation defined format of integers and floating point numbers. File IO requires calling operating system API. The following table provides some examples:

Function	POSIX	Windows	UEFI
Constructor	open	CreateFile	EFI_FILE_PROTOCOL.Open
Destructor	close	CloseHandle	EFI_FILE_PROTOCOL.Close
get_position	lseek	SetFilePointerEx	EFI_FILE_PROTOCOL.GetPosition

Function	POSIX	Windows	UEFI
set_position	lseek	SetFilePointerEx	EFI_FILE_PROTOCOL.SetPosition
seek_position	lseek	SetFilePointerEx	No 1:1 mapping
read_some	read	ReadFile	EFI_FILE_PROTOCOL.Read
write_some	write	WriteFile	EFI_FILE_PROTOCOL.Write

7 Future work

It is hopeful that `std::io::format` will be used to handle Unicode encoding schemes during file and network IO so Unicode layer will only need to handle encoding forms.

This proposal doesn't rule out more low-level library that exposes complex details of modern operating systems. However, the design of this library has been intentionally kept as simple as possible to be novice-friendly.

8 Open issues

- `std::io::format` as part of the stream class or as separate argument to `std::io::read` and `std::io::write`.
- Error handling using `throws + std::error`.
- `std::filesystem::path_view`
- Remove `std::io::floating_point_format` if P1468 is accepted.

9 Wording

All text is relative to [n4830](#).

Move clauses 29.1 - 29.10 into a new clause 29.2 “Legacy text IO”.

Add a new clause 29.1 “Binary IO”.

9.1 29.1.? General [io.general]

TODO

9.2 29.1.? Header <io> synopsis [io.syn]

```
namespace std
{
    namespace io
    {

        enum class floating_point_format
        {
            iec559,
            native
        };

        class format;

        enum class io_errc
        {
            bad_file_descriptor = implementation-defined,
```

```

    invalid_argument = implementation-defined,
    value_too_large = implementation-defined,
    reached_end_of_file = implementation-defined,
    interrupted = implementation-defined,
    physical_error = implementation-defined,
    file_too_large = implementation-defined
};

}

template <> struct is_error_code_enum<io::io_errc> : public true_type { };

namespace io
{
    // Error handling
    error_code make_error_code(io_errc e) noexcept;
    error_condition make_error_condition(io_errc e) noexcept;

    const error_category& category() noexcept;

    class io_error;

    enum class base_position
    {
        beginning,
        current,
        end
    };

    // Stream concepts
    template <typename T>
    concept stream_base = see below;
    template <typename T>
    concept seekable_stream = see below;
    template <typename T>
    concept input_stream = see below;
    template <typename T>
    concept output_stream = see below;
    template <typename T>
    concept stream = see below;

    // IO concepts
    template <typename T, typename S>
    concept customly_readable_from = see below;
    template <typename T, typename S>
    concept customly_writable_to = see below;

    // Customization points
    inline constexpr unspecified read = unspecified;
    inline constexpr unspecified write = unspecified;

    // Span streams
    class input_span_stream;

```

```

class output_span_stream;
class span_stream;

// Memory streams
template <typename Container>
class basic_input_memory_stream;
template <typename Container>
class basic_output_memory_stream;
template <typename Container>
class basic_memory_stream;

using input_memory_stream = basic_input_memory_stream<vector<byte>>;
using output_memory_stream = basic_output_memory_stream<vector<byte>>;
using memory_stream = basic_memory_stream<vector<byte>>;

// File streams

enum class open_mode
{
    read,
    write
};

class file_stream_base;
class input_file_stream;
class output_file_stream;
class file_stream;

}
}

```

9.3 29.1.? Class format [io.format]

```

class format final
{
public:
    // Constructor
    constexpr format(endian endianness = endian::native,
                     floating_point_format float_format = floating_point_format::native)
        noexcept;

    // Member functions
    constexpr endian get_endianness() const noexcept;
    constexpr void set_endianness(endian new_endianness) noexcept;
    constexpr floating_point_format get_floating_point_format() const noexcept;
    constexpr void set_floating_point_format(floating_point_format new_format)
        noexcept;

    // Equality
    friend constexpr bool operator==(const format& lhs, const format& rhs)
        noexcept = default;
private:
    endian endianness_; // exposition only

```

```
    floating_point_format float_format_; // exposition only
};
```

TODO

9.3.1 29.1.?? Constructor [io.format.cons]

```
constexpr format(endian endianness = endian::native,
    floating_point_format float_format = floating_point_format::native)
    noexcept;
```

Ensures: endianness_ == endianness and float_format_ == float_format.

9.3.2 29.1.?? Member functions [io.format.members]

```
constexpr endian get_endianness() const noexcept;
```

Returns: endianness_.

```
constexpr void set_endianness(endian new_endianness) noexcept;
```

Ensures: endianness_ == new_endianness.

```
constexpr floating_point_format get_floating_point_format() const noexcept;
```

Returns: float_format_.

```
constexpr void set_floating_point_format(floating_point_format new_format)
    noexcept;
```

Ensures: float_format_ == new_format.

9.4 29.1.? Error handling [io.errors]

```
const error_category& category() noexcept;
```

Returns: A reference to an object of a type derived from class `error_category`. All calls to this function shall return references to the same object.

Remarks: The object's `default_error_condition` and `equivalent` virtual functions shall behave as specified for the class `error_category`. The object's `name` virtual function shall return a pointer to the string "io".

```
error_code make_error_code(io_errc e) noexcept;
```

Returns: `error_code(static_cast<int>(e), io::category())`.

```
error_condition make_error_condition(io_errc e) noexcept;
```

Returns: `error_condition(static_cast<int>(e), io::category())`.

9.5 29.1.? Class `io_error` [ioerr.ioerr]

```
class io_error : public system_error
{
public:
    io_error(const string& message, error_code ec);
    io_error(const char* message, error_code ec);
};
```

TODO

9.6 29.1.? Stream concepts [stream.concepts]

9.6.1 29.1.??? Concept `stream_base` [stream.concept.base]

```
template <typename T>
concept stream_base = requires(const T s)
{
    {s.get_format()} -> same_as<format>;
} && requires(T s, format f)
{
    s.set_format(f);
};
```

TODO

9.6.1.1 29.1.??? Format [stream.base.format]

```
format get_format() const noexcept;
```

Returns: Stream format.

```
void set_format(format f) noexcept;
```

Effects: Sets the stream format to f.

9.6.2 29.1.??? Concept `seekable_stream` [stream.concept.seekable]

```
template <typename T>
concept seekable_stream = requires(const T s)
{
    {s.get_position()} -> same_as<streamoff>;
} && requires(T s, streamoff position, base_position base)
{
    s.set_position(position);
    s.seek_position(base, position);
};
```

TODO

9.6.2.1 29.1.??? Position [seekable.stream.position]

```
streamoff get_position();
```

Returns: Current position of the stream.

```
void set_position(streamoff position);
```

Effects: Sets the position of the stream to the given value.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative and the stream doesn't support that.
- `value_too_large` - if position is greater than the maximum size supported by the stream.


```
void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative and the stream doesn't support that.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or is greater than the maximum size supported by the stream.

9.6.3 29.1.?? Concept `input_stream` [`stream.concept.input`]

```
template <typename T>
concept input_stream = stream_base<T> && requires(T s, span<byte> buffer)
{
    {s.read_some(buffer);} -> same_as<streamsize>;
};
```

TODO

9.6.3.1 29.1.???.? Reading [`input.stream.read`]

```
streamsize read_some(span<byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. Otherwise reads zero or more bytes from the stream and advances the position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: `io_error` in case of error.

Error conditions:

- `value_too_large` - if starting position is equal or greater than maximum value supported by the implementation.
- `interrupted` - if reading was interrupted due to the receipt of a signal.
- `physical_error` - if physical I/O error has occurred.

9.6.4 29.1.?? Concept `output_stream` [`stream.concept.output`]

```
template <typename T>
concept output_stream = stream_base<T> && requires(T s, span<const byte> buffer)
{
    {s.write_some(buffer);} -> same_as<streamsize>;
};
```

TODO

9.6.4.1 29.1.???.? Writing [`output.stream.write`]

```
streamsize write_some(span<const byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. Otherwise writes one or more bytes to the stream and advances the position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: `io_error` in case of error.

Error conditions:

- `file_too_large` - tried to write past the maximum size supported by the stream.
- `interrupted` - if writing was interrupted due to the receipt of a signal.
- `physical_error` - if physical I/O error has occurred.

9.6.5 29.1.?? Concept `stream` [`stream.concept.stream`??]

```
template <typename T>
concept stream = input_stream<T> && output_stream<T>;
```

TODO

9.7 29.1.? IO concepts [`io.concepts`]

9.7.1 29.1.?? Concept `customly_readable_from` [`io.concept.readable`]

```
template <typename T, typename S>
concept customly_readable_from =
    input_stream<S> &&
    requires(T object, S& s)
{
    object.read(s);
};
```

TODO

9.7.2 29.1.?? Concept `customly_writable_to` [`io.concept.writable`]

```
template <typename T, typename S>
concept customly_writable_to =
    output_stream<S> &&
    requires(const T object, S& s)
{
    object.write(s);
};
```

TODO

9.8 29.1.? Customization points [??]

9.8.1 29.1.?.1 `io::read` [`io.read`]

The name `read` denotes a customization point object. The expression `io::read(S, E)` for some subexpression `S` with type `U` and subexpression `E` with type `T` has the following effects:

- If `U` is not `input_stream`, `io::read(S, E)` is ill-formed.
- If `T` is `byte`, reads one byte from the stream and assigns it to `E`.
- If `T` is `bool`, reads 1 byte from the stream, contextually converts its value to `bool` and assigns the result to `E`.
- If `T` is `integral`, reads `sizeof(T)` bytes from the stream, performs conversion of bytes from stream endianness to native endianness and assigns the result to object representation of `E`.
- If `T` is `floating_point`, reads `sizeof(T)` bytes from the stream and:
 - If stream floating point format is `native`, assigns the bytes to the object representation of `E`.
 - If stream floating point format is `iec559`, performs conversion of bytes treated as an ISO/IEC/IEEE 60559 floating point representation in stream endianness to native format and assigns the result to the object representation of `E`.

- If `T` is a span of bytes, reads `ssize(E)` bytes from the stream and assigns them to `E`.
- If `T` and `U` satisfy `customly_readable_from<T, U>`, calls `E.read(S)`.

9.8.2 29.1.?.2 `io::write` [`io.write`]

The name `write` denotes a customization point object. The expression `io::write(S, E)` for some subexpression `S` with type `U` and subexpression `E` with type `T` has the following effects:

- If `U` is not `output_stream`, `io::write(S, E)` is ill-formed.
- If `T` is `byte`, writes it to the stream.
- If `T` is `bool`, writes a single byte whose value is the result of integral promotion of `E` to the stream.
- If `T` is `integral` or an enumeration type, performs conversion of object representation of `E` from native endianness to stream endianness and writes the result to the stream.
- If `T` is `floating_point` and:
 - If stream floating point format is `native`, writes the object representation of `E` to the stream.
 - If stream floating point format is `iec559`, performs conversion of object representation of `E` from native format to ISO/IEC/IEEE 60559 format in stream endianness and writes the result to the stream.
- If `T` is a span of bytes, writes `ssize(E)` bytes to the stream.
- If `T` and `U` satisfy `customly_writable_to<T,U>`, calls `E.write(S)`.

9.9 29.1.? Span streams [`span.streams`]

9.9.1 29.1.?.1 Class `input_span_stream` [`input.span.stream`]

```
class input_span_stream final
{
public:
    // Constructors
    constexpr input_span_stream(format f = {}) noexcept;
    constexpr input_span_stream(span<const byte> buffer, format f = {})
        noexcept;

    // Format
    constexpr format get_format() const noexcept;
    constexpr void set_format(format f) noexcept;

    // Position
    constexpr streamoff get_position() const noexcept;
    constexpr void set_position(streamoff position);
    constexpr void seek_position(base_position base, streamoff offset);

    // Reading
    constexpr streamsize read_some(span<byte> buffer);

    // Buffer management
    constexpr span<const byte> get_buffer() const noexcept;
    constexpr void set_buffer(span<const byte> new_buffer) noexcept;
private:
    format format_; // exposition only
    span<const byte> buffer_; // exposition only
    ptrdiff_t position_; // exposition only
};
```

TODO

9.9.1.1 29.1.?.?.? Constructors [input.span.stream.cons]

```
constexpr input_span_stream(format f = {}) noexcept;
```

Ensures:

- `get_format() == f`,
- `empty(buffer_) == true`,
- `position_ == 0`.

```
constexpr input_span_stream(span<const byte> buffer, format f = {}) noexcept;
```

Ensures:

- `get_format() == f`,
- `data(buffer_) == data(buffer)`,
- `size(buffer_) == size(buffer)`,
- `position_ == 0`.

9.9.1.2 29.1.?.?.? Format [input.span.stream.format]

```
constexpr format get_format() const noexcept;
```

Returns: `format_`.

```
constexpr void set_format(format f) noexcept;
```

Ensures: `format_ == f`.

9.9.1.3 29.1.?.?.? Position [input.span.stream.position]

```
constexpr streamoff get_position() const noexcept;
```

Returns: `position_`.

```
constexpr void set_position(streamoff position);
```

Ensures: `position_ == position`.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative.
- `value_too_large` - if position cannot be represented as type `ptrdiff_t`.

```
constexpr void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or `ptrdiff_t`.

9.9.1.4 29.1.?.?.? Reading [input.span.stream.read]

```
constexpr streamsize read_some(span<byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= ssize(buffer_)`, returns 0. If `position_ == numeric_limits<streamoff>::max()`, throws exception. Otherwise determines the amount of bytes to read so that it satisfies the following constraints:

- Must be less than or equal to `ssize(buffer)`.
- Must be representable as `streamsize`.
- Position after the read must be less than or equal to `ssize(buffer_)`.
- Position after the read must be representable as `streamoff`.

After that reads that amount of bytes from the stream to the given buffer and advances stream position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: `io_error` in case of error.

Error conditions:

- `value_too_large` - if `!empty(buffer)` and `position_ == numeric_limits<streamoff>::max()`.

9.9.1.5 29.1.?.?.? Buffer management [`input.span.stream.buffer`]

```
constexpr span<const byte> get_buffer() const noexcept;
```

Returns: `buffer_`.

```
constexpr void set_buffer(span<const byte> new_buffer) noexcept;
```

Ensures:

- `data(buffer_) == data(new_buffer)`,
- `size(buffer_) == size(new_buffer)`,
- `position_ == 0`.

9.9.2 29.1.?.2 Class `output_span_stream` [`output.span.stream`]

```
class output_span_stream final
{
public:
    // Constructors
    constexpr output_span_stream(format f = {}) noexcept;
    constexpr output_span_stream(span<byte> buffer, format f = {}) noexcept;

    // Format
    constexpr format get_format() const noexcept;
    constexpr void set_format(format f) noexcept;

    // Position
    constexpr streamoff get_position() const noexcept;
    constexpr void set_position(streamoff position);
    constexpr void seek_position(base_position base, streamoff offset);

    // Writing
    constexpr streamsize write_some(span<const byte> buffer);

    // Buffer management
    constexpr span<byte> get_buffer() const noexcept;
    constexpr void set_buffer(span<byte> new_buffer) noexcept;
private:
    format format_; // exposition only
    span<byte> buffer_; // exposition only
```

```
    ptrdiff_t position_; // exposition only
};
```

TODO

9.9.2.1 29.1.?.?.? Constructors [output.span.stream.cons]

```
constexpr output_span_stream(format f = {}) noexcept;
```

Ensures:

- `get_format() == f`,
- `empty(buffer_) == true`,
- `position_ == 0`.

```
constexpr output_span_stream(span<byte> buffer, format f = {}) noexcept;
```

Ensures:

- `get_format() == f`,
- `data(buffer_) == data(buffer)`,
- `size(buffer_) == size(buffer)`,
- `position_ == 0`.

9.9.2.2 29.1.?.?.? Format [output.span.stream.format]

```
constexpr format get_format() const noexcept;
```

Returns: `format_`.

```
constexpr void set_format(format f) noexcept;
```

Ensures: `format_ == f`.

9.9.2.3 29.1.?.?.? Position [output.span.stream.position]

```
constexpr streamoff get_position() const noexcept;
```

Returns: `position_`.

```
constexpr void set_position(streamoff position);
```

Ensures: `position_ == position`.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative.
- `value_too_large` - if position cannot be represented as type `ptrdiff_t`.

```
constexpr void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or `ptrdiff_t`.

9.9.2.4 29.1.?.?.? Writing [output.span.stream.write]

```
constexpr streamsize write_some(span<const byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= ssize(buffer_)` or `position_ == numeric_limits<streamoff>::max()` throws exception. Otherwise determines the amount of bytes to write so that it satisfies the following constraints:

- Must be less than or equal to `ssize(buffer)`.
- Must be representable as `streamsize`.
- Position after the write must be less than or equal to `ssize(buffer_)`.
- Position after the write must be representable as `streamoff`.

After that writes that amount of bytes from the given buffer to the stream and advances stream position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: `io_error` in case of error.

Error conditions:

- `file_too_large` - if `!empty(buffer) && ((position_ == ssize(buffer_)) || (position_ == numeric_limits<streamoff>::max()))`.

9.9.2.5 29.1.?.?.? Buffer management [output.span.stream.buffer]

```
constexpr span<byte> get_buffer() const noexcept;
```

Returns: `buffer_`.

```
constexpr void set_buffer(span<byte> new_buffer) noexcept;
```

Ensures:

- `data(buffer_) == data(new_buffer)`,
- `size(buffer_) == size(new_buffer)`,
- `position_ == 0`.

9.9.3 29.1.?.?.? Class `span_stream` [span.stream]

```
class span_stream final
{
public:
    // Constructors
    constexpr span_stream(format f = {}) noexcept;
    constexpr span_stream(span<byte> buffer, format f = {}) noexcept;

    // Format
    constexpr format get_format() const noexcept;
    constexpr void set_format(format f) noexcept;

    // Position
    constexpr streamoff get_position() const noexcept;
    constexpr void set_position(streamoff position);
    constexpr void seek_position(base_position base, streamoff offset);

    // Reading
    constexpr streamsize read_some(span<byte> buffer);
```

```

    // Writing
    constexpr streamsize write_some(span<const byte> buffer);

    // Buffer management
    constexpr span<byte> get_buffer() const noexcept;
    constexpr void set_buffer(span<byte> new_buffer) noexcept;
private:
    format format_; // exposition only
    span<byte> buffer_; // exposition only
    ptrdiff_t position_; // exposition only
};

```

TODO

9.9.3.1 29.1.??? Constructors [span.stream.cons]

```
constexpr span_stream(format f = {}) noexcept;
```

Ensures:

- `get_format() == f`,
- `empty(buffer_) == true`,
- `position_ == 0`.

```
constexpr span_stream(span<byte> buffer, format f = {}) noexcept;
```

Ensures:

- `get_format() == f`,
- `data(buffer_) == data(buffer)`,
- `size(buffer_) == size(buffer)`,
- `position_ == 0`.

9.9.3.2 29.1.??? Format [span.stream.format]

```
constexpr format get_format() const noexcept;
```

Returns: `format_`.

```
constexpr void set_format(format f) noexcept;
```

Ensures: `format_ == f`.

9.9.3.3 29.1.??? Position [output.span.stream.position]

```
constexpr streamoff get_position() const noexcept;
```

Returns: `position_`.

```
constexpr void set_position(streamoff position);
```

Ensures: `position_ == position`.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative.
- `value_too_large` - if position cannot be represented as type `ptrdiff_t`.


```
constexpr void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or `ptrdiff_t`.

9.9.3.4 29.1.?.?.? Reading [span.stream.read]

```
constexpr streamsize read_some(span<byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= ssize(buffer_)`, returns 0. If `position_ == numeric_limits<streamoff>::max()`, throws exception. Otherwise determines the amount of bytes to read so that it satisfies the following constraints:

- Must be less than or equal to `ssize(buffer)`.
- Must be representable as `streamsize`.
- Position after the read must be less than or equal to `ssize(buffer_)`.
- Position after the read must be representable as `streamoff`.

After that reads that amount of bytes from the stream to the given buffer and advances stream position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: `io_error` in case of error.

Error conditions:

- `value_too_large` - if `!empty(buffer)` and `position_ == numeric_limits<streamoff>::max()`.

9.9.3.5 29.1.?.?.? Writing [span.stream.write]

```
constexpr streamsize write_some(span<const byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= ssize(buffer_)` or `position_ == numeric_limits<streamoff>::max()`, throws exception. Otherwise determines the amount of bytes to write so that it satisfies the following constraints:

- Must be less than or equal to `ssize(buffer)`.
- Must be representable as `streamsize`.
- Position after the write must be less than or equal to `ssize(buffer_)`.
- Position after the write must be representable as `streamoff`.

After that writes that amount of bytes from the given buffer to the stream and advances stream position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: `io_error` in case of error.

Error conditions:

- `file_too_large` - if `!empty(buffer) && ((position_ == ssize(buffer_)) || (position_ == numeric_limits<streamoff>::max()))`.

9.9.3.6 29.1.?.?.? Buffer management [span.stream.buffer]

```
constexpr span<byte> get_buffer() const noexcept;
```

Returns: `buffer_`.

```
constexpr void set_buffer(span<byte> new_buffer) noexcept;
```

Ensures:

- `data(buffer_) == data(new_buffer)`,
- `size(buffer_) == size(new_buffer)`,
- `position_ == 0`.

9.10 29.1.? Memory streams [memory.streams]

9.10.1 29.1.?.1 Class template `basic_input_memory_stream` [input.memory.stream]

```
template <typename Container>
class basic_input_memory_stream final
{
public:
    // Constructors
    constexpr basic_input_memory_stream(format f = {});
    constexpr basic_input_memory_stream(const Container& c, format f = {});
    constexpr basic_input_memory_stream(Container&& c, format f = {});

    // Format
    constexpr format get_format() const noexcept;
    constexpr void set_format(format f) noexcept;

    // Position
    constexpr streamoff get_position() const noexcept;
    constexpr void set_position(streamoff position);
    constexpr void seek_position(base_position base, streamoff offset);

    // Reading
    constexpr streamsize read_some(span<byte> buffer);

    // Buffer management
    constexpr const Container& get_buffer() const & noexcept;
    constexpr Container& get_buffer() && noexcept;
    constexpr void set_buffer(const Container& new_buffer);
    constexpr void set_buffer(Container&& new_buffer);
    constexpr void reset_buffer() noexcept;
private:
    format format_; // exposition only
    Container buffer_; // exposition only
    typename Container::difference_type position_; // exposition only
};
```

TODO

9.10.1.1 29.1.?.?.? Constructors [input.memory.stream.cons]

```
constexpr basic_input_memory_stream(format f = {});
```

Ensures:

- `get_format() == f`,
- `buffer_ == Container{}`,
- `position_ == 0`.

```
constexpr basic_input_memory_stream(const Container& c, format f = {});
```

Effects: Initializes `buffer_` with `c`.

Ensures:

- `get_format() == f`,
- `position_ == 0`.

```
constexpr basic_input_memory_stream(Container&& c, format f = {});
```

Effects: Initializes `buffer_` with `move(c)`.

Ensures:

- `get_format() == f`,
- `position_ == 0`.

9.10.1.2 29.1.???.? Format [input.memory.stream.format]

```
constexpr format get_format() const noexcept;
```

Returns: `format_`.

```
constexpr void set_format(format f) noexcept;
```

Ensures: `format_ == f`.

9.10.1.3 29.1.???.? Position [input.memory.stream.position]

```
constexpr streamoff get_position() const noexcept;
```

Returns: `position_`.

```
constexpr void set_position(streamoff position);
```

Ensures: `position_ == position`.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative.
- `value_too_large` - if position if position cannot be represented as type `typename Container::difference_type`.

```
constexpr void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or `typename Container::difference_type`.

9.10.1.4 29.1.?.?.? Reading [input.memory.stream.read]

```
constexpr streamsize read_some(span<byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= ssize(buffer_)`, returns 0. If `position_ == numeric_limits<streamoff>::max()`, throws exception. Otherwise determines the amount of bytes to read so that it satisfies the following constraints:

- Must be less than or equal to `ssize(buffer)`.
- Must be representable as `streamsize`.
- Position after the read must be less than or equal to `ssize(buffer_)`.
- Position after the read must be representable as `streamoff`.

After that reads that amount of bytes from the stream to the given buffer and advances stream position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: `io_error` in case of error.

Error conditions:

- `value_too_large` - if `!empty(buffer)` and `position_ == numeric_limits<streamoff>::max()`.

9.10.1.5 29.1.?.?.? Buffer management [input.memory.stream.buffer]

```
constexpr const Container& get_buffer() const & noexcept;
```

Returns: `buffer_`.

```
constexpr Container get_buffer() && noexcept;
```

Returns: `move(buffer_)`.

```
constexpr void set_buffer(const Container& new_buffer);
```

Ensures:

- `buffer_ == new_buffer`.
- `position_ == 0`.

```
constexpr void set_buffer(Container&& new_buffer);
```

Effects: Move assigns `new_buffer` to `buffer_`.

Ensures: `position_ == 0`.

```
constexpr void reset_buffer() noexcept;
```

Effects: Equivalent to `buffer_.clear()`.

Ensures: `position_ == 0`.

9.10.2 29.1.?.2 Class template `basic_output_memory_stream` [output.memory.stream]

```
template <typename Container>
class basic_output_memory_stream final
{
public:
    // Constructors
    constexpr basic_output_memory_stream(format f = {});
    constexpr basic_output_memory_stream(const Container& c, format f = {});
    constexpr basic_output_memory_stream(Container&& c, format f = {});
```

```

// Format
constexpr format get_format() const noexcept;
constexpr void set_format(format f) noexcept;

// Position
constexpr streamoff get_position() const noexcept;
constexpr void set_position(streamoff position);
constexpr void seek_position(base_position base, streamoff offset);

// Writing
constexpr streamsize write_some(span<const byte> buffer);

// Buffer management
constexpr const Container& get_buffer() const & noexcept;
constexpr Container get_buffer() && noexcept;
constexpr void set_buffer(const Container& new_buffer);
constexpr void set_buffer(Container&& new_buffer);
constexpr void reset_buffer() noexcept;
private:
    format format_; // exposition only
    Container buffer_; // exposition only
    typename Container::difference_type position_; // exposition only
};

```

TODO

9.10.2.1 29.1.?.?.? Constructors [output.memory.stream.cons]

```
constexpr basic_output_memory_stream(format f = {});
```

Ensures:

- `get_format() == f`,
- `buffer_ == Container{}`,
- `position_ == 0`.

```
constexpr basic_output_memory_stream(const Container& c, format f = {});
```

Effects: Initializes `buffer_` with `c`.

Ensures:

- `get_format() == f`,
- `position_ == 0`.

```
constexpr basic_output_memory_stream(Container&& c, format f = {});
```

Effects: Initializes `buffer_` with `move(c)`.

Ensures:

- `get_format() == f`,
- `position_ == 0`.

9.10.2.2 29.1.?.?.? Format [output.memory.stream.format]

```
constexpr format get_format() const noexcept;
```

Returns: `format_`.

```
constexpr void set_format(format f) noexcept;
```

Ensures: `format_ == f`.

9.10.2.3 29.1.?.?.? Position [output.memory.stream.position]

```
constexpr streamoff get_position() const noexcept;
```

Returns: `position_`.

```
constexpr void set_position(streamoff position);
```

Ensures: `position_ == position`.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative.
- `value_too_large` - if position cannot be represented as type `typename Container::difference_type`.

```
constexpr void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or `typename Container::difference_type`.

9.10.2.4 29.1.?.?.? Writing [output.memory.stream.write]

```
constexpr streamsize write_some(span<const byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= buffer_.max_size()` or `position_ == numeric_limits<streamoff>::max()`, throws exception. If `position_ < ssize(buffer_)`:

- Determines the amount of bytes to write so that it satisfies the following constraints:
 - Must be less than or equal to `ssize(buffer)`.
 - Must be representable as `streamsize`.
 - Position after the write must be less than or equal to `ssize(buffer_)`.
 - Position after the write must be representable as `streamoff`.
- Writes that amount of bytes from the given buffer to the stream and advances stream position by the amount of bytes written.

Otherwise:

- Determines the amount of bytes to write so that it satisfies the following constraints:
 - Must be less than or equal to `ssize(buffer)`.
 - Must be representable as `streamsize`.
 - Position after the write must be less than or equal to `buffer_.max_size()`.
 - Position after the write must be representable as `streamoff`.
- Resizes the stream buffer so it has enough space to write the chosen amount of bytes. If any exceptions are thrown during resizing of stream buffer, they are propagated outside.
- Writes chosen amount of bytes from the given buffer to the stream and advances stream position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: `io_error` in case of error.

Error conditions:

- `file_too_large` - if `!empty(buffer) && ((position_ == buffer_.max_size()) || (position_ == numeric_limits<streamoff>::max()))`.

9.10.2.5 29.1.?.?.? Buffer management [output.memory.stream.buffer]

```
constexpr const Container& get_buffer() const & noexcept;
```

Returns: `buffer_`.

```
constexpr Container get_buffer() && noexcept;
```

Returns: `move(buffer_)`.

```
constexpr void set_buffer(const Container& new_buffer);
```

Ensures:

- `buffer_ == new_buffer`.
- `position_ == 0`.

```
constexpr void set_buffer(Container&& new_buffer);
```

Effects: Move assigns `new_buffer` to `buffer_`.

Ensures: `position_ == 0`.

```
constexpr void reset_buffer() noexcept;
```

Effects: Equivalent to `buffer_.clear()`.

Ensures: `position_ == 0`.

9.10.3 29.1.?.3 Class template `basic_memory_stream` [memory.stream]

```
template <typename Container>
class basic_memory_stream final
{
public:
    // Constructors
    constexpr basic_memory_stream(format f = {});
    constexpr basic_memory_stream(const Container& c, format f = {});
    constexpr basic_memory_stream(Container&& c, format f = {});

    // Format
    constexpr format get_format() const noexcept;
    constexpr void set_format(format f) noexcept;

    // Position
    constexpr streamoff get_position() const noexcept;
    constexpr void set_position(streamoff position);
    constexpr void seek_position(base_position base, streamoff offset);

    // Reading
    constexpr streamsize read_some(span<byte> buffer);
```

```

    // Writing
    constexpr streamsize write_some(span<const byte> buffer);

    // Buffer management
    constexpr const Container& get_buffer() const & noexcept;
    constexpr Container get_buffer() && noexcept;
    constexpr void set_buffer(const Container& new_buffer);
    constexpr void set_buffer(Container&& new_buffer);
    constexpr void reset_buffer() noexcept;
private:
    format format_; // exposition only
    Container buffer_; // exposition only
    typename Container::difference_type position_; // exposition only
};

```

TODO

9.10.3.1 29.1.?.?.? Constructors [memory.stream.cons]

```
constexpr basic_memory_stream(format f = {});
```

Ensures:

- get_format() == f,
- buffer_ == Container{},
- position_ == 0.

```
constexpr basic_memory_stream(const Container& c, format f = {});
```

Effects: Initializes buffer_ with c.

Ensures:

- get_format() == f,
- position_ == 0.

```
constexpr basic_memory_stream(Container&& c, format f = {});
```

Effects: Initializes buffer_ with move(c).

Ensures:

- get_format() == f,
- position_ == 0.

9.10.3.2 29.1.?.?.? Format [memory.stream.format]

```
constexpr format get_format() const noexcept;
```

Returns: format_.

```
constexpr void set_format(format f) noexcept;
```

Ensures: format_ == f.

9.10.3.3 29.1.?.?.? Position [memory.stream.position]

```
constexpr streamoff get_position();
```

Returns: position_.


```
constexpr void set_position(streamoff position);
```

Ensures: `position_ == position`.

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if position is negative.
- `value_too_large` - if position cannot be represented as type `typename Container::difference_type`.

```
constexpr void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: `io_error` in case of error.

Error conditions:

- `invalid_argument` - if resulting position is negative.
- `value_too_large` - if resulting position cannot be represented as type `streamoff` or `typename Container::difference_type`.

9.10.3.4 29.1.?.?.? Reading [`memory.stream.read`]

```
constexpr streamsize read_some(span<byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= ssize(buffer_)`, returns 0. If `position_ == numeric_limits<streamoff>::max()`, throws exception. Otherwise determines the amount of bytes to read so that it satisfies the following constraints:

- Must be less than or equal to `ssize(buffer)`.
- Must be representable as `streamsize`.
- Position after the read must be less than or equal to `ssize(buffer_)`.
- Position after the read must be representable as `streamoff`.

After that reads that amount of bytes from the stream to the given buffer and advances stream position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: `io_error` in case of error.

Error conditions:

- `value_too_large` - if `!empty(buffer)` and `position_ == numeric_limits<streamoff>::max()`.

9.10.3.5 29.1.?.?.? Writing [`memory.stream.write`]

```
constexpr streamsize write_some(span<const byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. If `position_ >= buffer_.max_size()` or `position_ == numeric_limits<streamoff>::max()`, throws exception. If `position_ < ssize(buffer_)`:

- Determines the amount of bytes to write so that it satisfies the following constraints:
 - Must be less than or equal to `ssize(buffer)`.
 - Must be representable as `streamsize`.
 - Position after the write must be less than or equal to `ssize(buffer_)`.
 - Position after the write must be representable as `streamoff`.
- Writes that amount of bytes from the given buffer to the stream and advances stream position by the amount of bytes written.

Otherwise:

- Determines the amount of bytes to write so that it satisfies the following constraints:
 - Must be less than or equal to `ssize(buffer)`.
 - Must be representable as `streamsize`.
 - Position after the write must be less than or equal to `buffer_.max_size()`.
 - Position after the write must be representable as `streamoff`.
- Resizes the stream buffer so it has enough space to write the chosen amount of bytes. If any exceptions are thrown during resizing of stream buffer, they are propagated outside.
- Writes chosen amount of bytes from the given buffer to the stream and advances stream position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: `io_error` in case of error.

Error conditions:

- `file_too_large` - if `!empty(buffer) && ((position_ == buffer_.max_size()) || (position_ == numeric_limits<streamoff>::max()))`.

9.10.3.6 29.1.??? Buffer management [`memory.stream.buffer`]

```
constexpr const Container& get_buffer() const & noexcept;
```

Returns: `buffer_`.

```
constexpr Container get_buffer() && noexcept;
```

Returns: `move(buffer_)`.

```
constexpr void set_buffer(const Container& new_buffer);
```

Ensures:

- `buffer_ == new_buffer`.
- `position_ == 0`.

```
constexpr void set_buffer(Container&& new_buffer);
```

Effects: Move assigns `new_buffer` to `buffer_`.

Ensures: `position_ == 0`.

```
constexpr void reset_buffer() noexcept;
```

Effects: Equivalent to `buffer_.clear()`.

Ensures: `position_ == 0`.

9.11 29.1.? File streams [`file.streams.???`] (naming conflict)

9.11.1 29.1.??? Native handles [`file.streams.native`]

TODO

9.11.2 29.1.??? Class `file_stream_base` [`file.stream.base`]

```
class file_stream_base
{
public:
    using native_handle_type = implementation-defined;
```

```

// Format
format get_format() const noexcept;
void set_format(format f) noexcept;

// Position
streamoff get_position() const;
void set_position(streamoff position);
void seek_position(base_position base, streamoff offset);

// Native handle management
native_handle_type native_handle();
void assign(native_handle_type handle);
native_handle_type release();
protected:
// Construct/copy/destroy
file_stream_base(format f = {}) noexcept;
file_stream_base(const filesystem::path& file_name, open_mode mode,
    format f = {});
file_stream_base(native_handle_type handle, format f = {});
file_stream_base(const file_stream_base&) = delete;
file_stream_base(file_stream_base&&);
~file_stream_base();
file_stream_base& operator=(const file_stream_base&) = delete;
file_stream_base& operator=(file_stream_base&&);
private:
    format format_; // exposition only

```

TODO

9.11.2.1 29.1.???.? Constructors [file.stream.base.cons]

```
file_stream_base(format f = {}) noexcept;
```

Effects: TODO

Ensures: format_ == f.

```
file_stream_base(const filesystem::path& file_name, open_mode mode,
    format f = {});
```

Effects: TODO

Ensures: format_ == f.

Throws: TODO

```
file_stream_base(native_handle_type handle, format f = {});
```

Effects: TODO

Ensures: format_ == f.

Throws: TODO

9.11.2.2 29.1.???.? Format [file.stream.base.format]

```
format get_format() const noexcept;
```

Returns: format_.

```
void set_format(format f) noexcept;
```

Ensures: format_ == f.

9.11.2.3 29.1.?.?.? Position [file.stream.base.position]

```
streamoff get_position() const;
```

Returns: Current position of the stream.

Throws: TODO

```
void set_position(streamoff position);
```

Effects: Sets the position of the stream to the given value.

Throws: TODO

```
void seek_position(base_position base, streamoff offset);
```

Effects: TODO

Throws: TODO

9.11.3 29.1.?.? Class input_file_stream [input.file.stream]

```
class input_file_stream final : public file_stream_base
{
public:
    // Construct/copy/destroy
    input_file_stream(format f = {}) noexcept;
    input_file_stream(const filesystem::path& file_name, format f = {});
    input_file_stream(native_handle_type handle, format f = {});

    // Reading
    streamsize read_some(span<byte> buffer);
};
```

TODO

9.11.3.1 29.1.?.?.? Constructors [input.file.stream.cons]

```
input_file_stream(format f = {}) noexcept;
```

Effects: Initializes the base class with file_stream_base(f).

```
input_file_stream(const filesystem::path& file_name, format f = {});
```

Effects: Initializes the base class with file_stream_base(handle, open_mode::read, f).

```
input_file_stream(native_handle_type handle, format f = {});
```

Effects: Initializes the base class with file_stream_base(handle, f).

9.11.3.2 29.1.?.?.? Reading [input.file.stream.read]

```
streamsize read_some(span<byte> buffer);
```

Effects: If empty(buffer), returns 0. Otherwise reads zero or more bytes from the stream and advances the position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: TODO

9.11.4 29.1.?? Class output_file_stream [output.file.stream]

```
class output_file_stream final : public file_stream_base
{
public:
    // Construct/copy/destroy
    output_file_stream(format f = {}) noexcept;
    output_file_stream(const filesystem::path& file_name, format f = {});
    output_file_stream(native_handle_type handle, format f = {});

    // Writing
    streamsize write_some(span<const byte> buffer);
};
```

TODO

9.11.4.1 29.1.??? Constructors [output.file.stream.cons]

```
output_file_stream(format f = {}) noexcept;
```

Effects: Initializes the base class with file_stream_base(f).

```
output_file_stream(const filesystem::path& file_name, format f = {});
```

Effects: Initializes the base class with file_stream_base(handle, open_mode::write, f).

```
output_file_stream(native_handle_type handle, format f = {});
```

Effects: Initializes the base class with file_stream_base(handle, f).

9.11.4.2 29.1.??? Writing [output.file.stream.write]

```
streamsize write_some(span<const byte> buffer);
```

Effects: If empty(buffer), returns 0. Otherwise writes one or more bytes to the stream and advances the position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: TODO

9.11.5 29.1.?? Class file_stream [file.stream]

```
class file_stream final : public file_stream_base
{
public:
    // Construct/copy/destroy
    file_stream(format f = {}) noexcept;
    file_stream(const filesystem::path& file_name, format f = {});
    file_stream(native_handle_type handle, format f = {});

    // Reading
    streamsize read_some(span<byte> buffer);
};
```

```

    // Writing
    streamsize write_some(span<const byte> buffer);
};

```

TODO

9.11.5.1 29.1.?.?.? Constructors [file.stream.cons]

```
file_stream(format f = {}) noexcept;
```

Effects: Initializes the base class with `file_stream_base(f)`.

```
file_stream(const filesystem::path& file_name, format f = {});
```

Effects: Initializes the base class with `file_stream_base(handle, open_mode::write, f)`.

```
file_stream(native_handle_type handle, format f = {});
```

Effects: Initializes the base class with `file_stream_base(handle, f)`.

9.11.5.2 29.1.?.?.? Reading [file.stream.read]

```
streamsize read_some(span<byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. Otherwise reads zero or more bytes from the stream and advances the position by the amount of bytes read.

Returns: The amount of bytes read.

Throws: TODO

9.11.5.3 29.1.?.?.? Writing [file.stream.write]

```
streamsize write_some(span<const byte> buffer);
```

Effects: If `empty(buffer)`, returns 0. Otherwise writes one or more bytes to the stream and advances the position by the amount of bytes written.

Returns: The amount of bytes written.

Throws: TODO