



WebAssembly Spec Addendum: Legacy Exception Handling

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1 Introduction

This document describes an extension of the official WebAssembly standard developed by its [W3C Community Group](#)¹ with additional instructions for exception handling. These instructions were never standardized and are deprecated, but they may still be available in some engines, especially in web browsers.

2 Structure

2.1 Instructions

¹ <https://www.w3.org/community/webassembly/>

Control Instructions

The set of recognised instructions is extended with the following:

```
instr ::= ...
| try blocktype instr* (catch tagidx instr*)* (catch_all instr*)? end
| try blocktype instr* delegate labelidx
| rethrow labelidx
```

The instructions `try` and `rethrow`, are concerned with exceptions. The `try` instruction installs an exception handler, and may either handle exceptions in the case of `catch` and `catch_all`, or rethrow them in an outer block in the case of `delegate`.

The `rethrow` instruction is only allowed inside a `catch` or `catch_all` clause and allows rethrowing the caught exception by lexically referring to a the corresponding `try`.

When `try-delegate` handles an exception, it also behaves similar to a forward jump, effectively rethrowing the caught exception right before the matching `end`.

3 Validation

3.1 Conventions

Contexts

The context is enriched with an additional flag on label types:

$$\begin{aligned} \text{labeltype} &::= \text{catch}^? \text{ resulttype} \\ C &::= \{\dots, \text{labels } \text{labeltype}^*, \dots\} \end{aligned}$$

Existing typing rules are adjusted as follows:

- All rules that extend the context with new labels use an absent catch flag.
- All rules that inspect the context for a label ignore the presence of a catch flag.

Note

This flag is used to distinguish labels bound by `catch` clauses, which can be targeted by `rethrow`.

3.2 Instructions

Control Instructions

`try blocktype instr1* (catch x instr2*)* (catch_all instr3)? end`

- The block type must be valid as some function type $[t_1^*] \rightarrow [t_2^*]$.
- Let C' be the same `context` as C , but with the `label type` $[t_2^*]$ prepended to the labels vector.
- Under context C' , the instruction sequence $instr_1^*$ must be valid with type $[t_1^*] \rightarrow [t_2^*]$.
- Let C'' be the same `context` as C , but with the `label type` `catch` $[t_2^*]$ prepended to the labels vector.
- For every x_i and $instr_{2i}^*$ in $(\text{catch } x \text{ } instr_{2i}^*)^*$:
 - The tag $C.\text{tags}[x_i]$ must be defined in the context C .
 - Let $[t_{3i}^*] \rightarrow [t_{4i}^*]$ be the tag type $C.\text{tags}[x_i]$.
 - The result type $[t_{4i}^*]$ must be empty.
 - Under context C'' , the instruction sequence $instr_{2i}^*$ must be valid with type $[t_{3i}^*] \rightarrow [t_2^*]$.
- If $(\text{catch_all } instr_3^*)?$ is not empty, then:

- Under context C'' , the instruction sequence $instr_3^*$ must be valid with type $[] \rightarrow [t_2^*]$.
- Then the compound instruction is valid with type $[t_1^*] \rightarrow [t_2^*]$.

$$\frac{C \vdash blocktype : [t_1^*] \rightarrow [t_2^*] \quad C, \text{labels}[t_2^*] \vdash instr_1^* : [t_1^*] \rightarrow [t_2^*] \\ (C.\text{tags}[x] = [t^*] \rightarrow [])^* \\ C, \text{labels}(\text{catch } [t_2^*]) \vdash instr_2^* : [t^*] \rightarrow [t_2^*])^* \\ (C, \text{labels}(\text{catch } [t_2^*]) \vdash instr_3^* : [] \rightarrow [t_2^*])?}{C \vdash \text{try } blocktype \ instr_1^* (\text{catch } x \ instr_2^*)^* (\text{catch_all } instr_3^*)? \text{ end} : [t_1^*] \rightarrow [t_2^*]}$$

Note

The notation $C, \text{labels}(\text{catch } [t^*])$ inserts the new label type at index 0, shifting all others.

try blocktype instr delegate l*

- The label $C.\text{labels}[l]$ must be defined in the context.
- The block type must be valid as some function type $[t_1^*] \rightarrow [t_2^*]$.
- Let C' be the same [context](#) as C , but with the result type $[t_2^*]$ prepended to the [labels](#) vector.
- Under context C' , the instruction sequence $instr^*$ must be valid with type $[t_1^*] \rightarrow [t_2^*]$.
- Then the compound instruction is valid with type $[t_1^*] \rightarrow [t_2^*]$.

$$\frac{C \vdash blocktype : [t_1^*] \rightarrow [t_2^*] \quad C, \text{labels}[t_2^*] \vdash instr^* : [t_1^*] \rightarrow [t_2^*] \quad C.\text{labels}[l] = [t_0^*]}{C \vdash \text{try } blocktype \ instr^* \text{ delegate } l : [t_1^*] \rightarrow [t_2^*]}$$

Note

The label index space in the [context](#) C contains the most recent label first, so that $C.\text{labels}[l]$ performs a relative lookup as expected.

rethrow l

- The label $C.\text{labels}[l]$ must be defined in the context.
- Let $(\text{catch}^? [t^*])$ be the [label type](#) $C.\text{labels}[l]$.
- The catch must be present in the [label type](#) $C.\text{labels}[l]$.
- Then the instruction is valid with type $[t_1^*] \rightarrow [t_2^*]$, for any sequences of value types t_1^* and t_2^* .

$$\frac{C.\text{labels}[l] = \text{catch } [t^*]}{C \vdash \text{rethrow } l : [t_1^*] \rightarrow [t_2^*]}$$

Note

The [rethrow](#) instruction is stack-polymorphic.

4 Execution

4.1 Runtime Structure

Stack

Exception Handlers

Legacy exception handlers are installed by try instructions. Instead of branch labels, their catch clauses have instruction blocks associated with them. Furthermore, a delegate handler is associated with a label index to implicitly rethrow to:

```
catch ::= ...
| catch tagidx instr*
| catch_all tagidx instr*
| delegate labelidx
```

Administrative Instructions

Administrative instructions are extended with the caught instruction that models exceptions caught by legacy exception handlers.

```
instr ::= ...
| caughtn{exnaddr} instr*
```

Block Contexts

Block contexts are extended to include caught instructions:

```
Bk ::= ...
| caughtn{exnaddr} Bk end
```

Throw Contexts

Throw contexts are also extended to include caught instructions:

```
T ::= ...
| caughtn{exnaddr} T end
```

4.2 Instructions

Control Instructions

```
try blocktype instr1* (catch x instr2*)* (catch_all instr3)? end
```

1. Assert: due to validation, $\text{expand}_F(\text{blocktype})$ is defined.
2. Let $[t_1^m] \rightarrow [t_2^n]$ be the function type $\text{expand}_F(\text{blocktype})$.
3. Let L be the label whose arity is n and whose continuation is the end of the try instruction.
4. Assert: due to validation, there are at least m values on the top of the stack.
5. Pop the values val^m from the stack.
6. Let F be the current frame.
7. For each catch clause ($\text{catch } x_i \text{ instr}_{2i}^*$) do:
 - a. Assert: due to validation, $F.\text{module}.\text{tagaddrs}[x_i]$ exists.
 - b. Let a_i be the tag address $F.\text{module}.\text{tagaddrs}[x_i]$.
 - c. Let catch_i be the catch clause ($\text{catch } a_i \text{ instr}_{2i}^*$).

8. If there is a catch-all clause (`catch_all instr3*`), then:
 - a. Let $catch'^?$ be the handler (`catch_all instr3*`).
9. Else:
 - a. Let $catch'^?$ be empty.
10. Let $catch^*$ be the concatenation of $catch_i$ and $catch'^?$.
11. Enter the block $val^m \ instr_1^*$ with label L and exception handler $\text{handler}_n\{catch^*\}^*$.

$$F; val^m (\text{try } bt \ instr_1^* (\text{catch } x \ instr_2^*)^* (\text{catch_all } instr_3^*)? \text{ end}) \hookrightarrow \\ F; \text{label}_n\{\epsilon\} (\text{handler}_n\{(\text{catch } a_x \ instr_2^*)^* (\text{catch_all } instr_3^*)?\} val^m \ instr_1^* \text{ end}) \text{ end} \\ (\text{if expand}_F(bt) = [t_1^m] \rightarrow [t_2^n] \wedge (F.\text{module}.tagaddrs[x] = a_x)^*))$$

`try blocktype instr* delegate l`

1. Assert: due to validation, $\text{expand}_F(blocktype)$ is defined.
2. Let $[t_1^m] \rightarrow [t_2^n]$ be the function type $\text{expand}_F(blocktype)$.
3. Let L be the label whose arity is n and whose continuation is the end of the try instruction.
4. Let H be the exception handler l , targeting the l -th surrounding block.
5. Assert: due to validation, there are at least m values on the top of the stack.
6. Pop the values val^m from the stack.
7. Enter the block $val^m \ instr^*$ with label L and exception handler $HANDLER_n\{DELEGATE-l\}$.

$$F; val^m (\text{try } bt \ instr^* \text{ delegate } l) \hookrightarrow F; \text{label}_n\{\epsilon\} (\text{handler}_n\{\text{delegate } l\} val^m \ instr^* \text{ end}) \text{ end} \\ (\text{if expand}_F(bt) = [t_1^m] \rightarrow [t_2^n])$$

`throw_ref`

1. Let F be the current frame.
2. Assert: due to validation, a reference is on the top of the stack.
3. Pop the reference ref from the stack.
4. If ref is `ref.null ht`, then:
 - a. Trap.
5. Assert: due to validation, ref is an exception reference.
6. Let ref.exn ea be ref .
7. Assert: due to validation, $S.\text{exns}[ea]$ exists.
8. Let exn be the exception instance $S.\text{exns}[ea]$.
9. Let a be the tag address $exn.tag$.
10. While the stack is not empty and the top of the stack is not an exception handler, do:
 - a. Pop the top element from the stack.
11. Assert: the stack is now either empty, or there is an exception handler on the top of the stack.
12. If the stack is empty, then:
 - a. Return the exception ($\text{ref.exn } a$) as a result.
13. Assert: there is an exception handler on the top of the stack.
14. Pop the exception handler $\text{handler}_n\{catch^*\}$ from the stack.

15. If $catch^*$ is empty, then:

- a. Push the exception reference $\text{ref.exn } ea$ back to the stack.
- b. Execute the instruction throw_ref again.

16. Else:

- a. Let $catch_1$ be the first catch clause in $catch^*$ and $catch'^*$ the remaining clauses.
- b. If $catch_1$ is of the form $\text{catch } x \ l$ and the exception address a equals $F.\text{module.tagaddrs}[x]$, then:
 - i. Push the values exn.fields to the stack.
 - ii. Execute the instruction $\text{br } l$.
- c. Else if $catch_1$ is of the form $\text{catch_ref } x \ l$ and the exception address a equals $F.\text{module.tagaddrs}[x]$, then:
 - i. Push the values exn.fields to the stack.
 - ii. Push the exception reference $\text{ref.exn } ea$ to the stack.
 - iii. Execute the instruction $\text{br } l$.
- d. Else if $catch_1$ is of the form $\text{catch_all } l$, then:
 - i. Execute the instruction $\text{br } l$.
- e. Else if $catch_1$ is of the form $\text{catch_all_ref } l$, then:
 - i. Push the exception reference $\text{ref.exn } ea$ to the stack.
 - ii. Execute the instruction $\text{br } l$.
- f. Else if $catch_1$ is of the form $\text{catch } x \ instr^*$ and the exception address a equals $F.\text{module.tagaddrs}[x]$, then:
 - i. Push the caught exception $\text{caught}_n\{ea\}$ to the stack.
 - ii. Push the values exn.fields to the stack.
 - iii. Enter the catch block $instr^*$.
- g. Else if $catch_1$ is of the form $\text{catch_all } instr^*$, then:
 - i. Push the caught exception $\text{caught}_n\{ea\}$ to the stack.
 - ii. Enter the catch block $instr^*$.
- h. Else if $catch_1$ is of the form $\text{delegate } l$, then:
 - i. Assert: due to validation, the stack contains at least l labels.
 - ii. Repeat l times:
 - While the top of the stack is not a label, do:
 - Pop the top element from the stack.
 - iii. Assert: due to validation, the top of the stack now is a label.
 - iv. Pop the label from the stack.
 - v. Push the exception reference $\text{ref.exn } ea$ back to the stack.
 - vi. Execute the instruction throw_ref again.
- i. Else:
 1. Push the modified handler $\text{handler}_n\{catch'^*\}$ back to the stack.
 2. Push the exception reference $\text{ref.exn } ea$ back to the stack.
 3. Execute the instruction throw_ref again.

$$\begin{aligned}
 \text{handler}_n\{(\text{catch } x \text{ instr}^*) \text{ catch}^*\} T[(\text{ref.exn } a) \text{ throw_ref}] \text{ end} &\xrightarrow{\dots} \text{caught}_n\{a\} \text{ exn.fields } \text{instr}^* \text{ end} \\
 &\quad (\text{if } \text{exn} = S.\text{exns}[a] \\
 &\quad \wedge \text{exn.tag} = F.\text{module.tagaddrs}[x]) \\
 \text{handler}_n\{(\text{catch_all } \text{instr}^*) \text{ catch}^*\} T[(\text{ref.exn } a) \text{ throw_ref}] \text{ end} &\xrightarrow{\dots} \text{caught}_n\{a\} \text{ instr}^* \text{ end} \\
 B^l[\text{handler}_n\{(\text{delegate } l) \text{ catch}^*\} T[(\text{ref.exn } a) \text{ throw_ref}] \text{ end}] &\xrightarrow{\dots} (\text{ref.exn } a) \text{ throw_ref}
 \end{aligned}$$

`rethrow l`

1. Assert: due to validation, the stack contains at least $l + 1$ labels.
2. Let L be the l -th label appearing on the stack, starting from the top and counting from zero.
3. Assert: due to validation, L is a catch label, i.e., a label of the form $(\text{catch } [t^*])$, which is a label followed by a caught exception in an active catch clause.
4. Let a be the caught exception address.
5. Push the value `ref.exn a` onto the stack.
6. Execute the instruction `throw_ref`.

$$\text{caught}_n\{a\} B^l[\text{rethrow } l] \text{ end} \xrightarrow{\dots} \text{caught}_n\{a\} B^l[(\text{ref.exn } a) \text{ throw_ref}] \text{ end}$$

Entering a catch block

1. Jump to the start of the instruction sequence instr^* .

Exiting a catch block

When the end of a catch block is reached without a jump, thrown exception, or trap, then the following steps are performed.

1. Let val^m be the values on the top of the stack.
2. Pop the values val^m from the stack.
3. Assert: due to validation, a caught exception is now on the top of the stack.
4. Pop the caught exception from the stack.
5. Push val^m back to the stack.
6. Jump to the position after the end of the administrative instruction associated with the caught exception.

$$\text{caught}_n\{a\} \text{ val}^m \text{ end} \xrightarrow{\dots} \text{val}^m$$

Note

A caught exception can only be rethrown from the scope of the administrative instruction associated with it, i.e., from the scope of the catch or catch_all block of a legacy try instruction. Upon exit from that block, the caught exception is discarded.

5 Binary Format

5.1 Instructions

Control Instructions

```

instr ::= ...
| 0x06 bt:blocktype (in1:instr)*
  (0x07 x:tagidx (in2:instr)*)*
  (0x19 (in3:instr)?)? 0x0B      ⇒ try bt in1* (catch x in2)* (catch_all in3)? end
| 0x06 bt:blocktype (in:instr)*
  0x18 l:labelidx                  ⇒ try bt in* delegate l
| 0x09 l:labelidx                 ⇒ rethrow l

```

6 Text Format

6.1 Instructions

Control Instructions

The label identifier on a structured control instruction may optionally be repeated after the corresponding `end`, `else`, `catch`, `catch_all`, and `delegate` pseudo instructions, to indicate the matching delimiters.

```

blockinstrI ::= ...
| 'try' I':labelI bt:blocktype (in1:instrI')*
  ('catch' id1? x:tagidxI (in2:instrI'))*?
  ('catch_all' id1? (in3:instrI'))?
  'end' id2?                   ⇒ try bt in1* (catch x in2)* (catch_all in3)? end
  (if id1? = ε ∨ id1? = label, id2? = ε ∨ id2? = label)
| 'try' I':labelI bt:blocktype (in1:instrI')*
  'delegate' l:labelidxI l:labelidxI           ⇒ try bt in1* delegate l      (if id? = ε ∨ id? = label)
plaininstrI ::= ...
| 'rethrow' l:labelidxI    ⇒ rethrow l

```

7 Index of Instructions

| Instruction | Binary Opcode | Type | Validation | Execution |
|-------------------|---------------|--|------------------------|----------------------|
| try <i>bt</i> | 0x06 | [t ₁]* → [t ₂] | validation, validation | execution, execution |
| catch <i>x</i> | 0x07 | | validation | execution |
| rethrow <i>n</i> | 0x09 | [t ₁]* → [t ₂] | validation | execution |
| delegate <i>l</i> | 0x18 | | validation | execution |
| catch_all | 0x19 | | validation | execution |