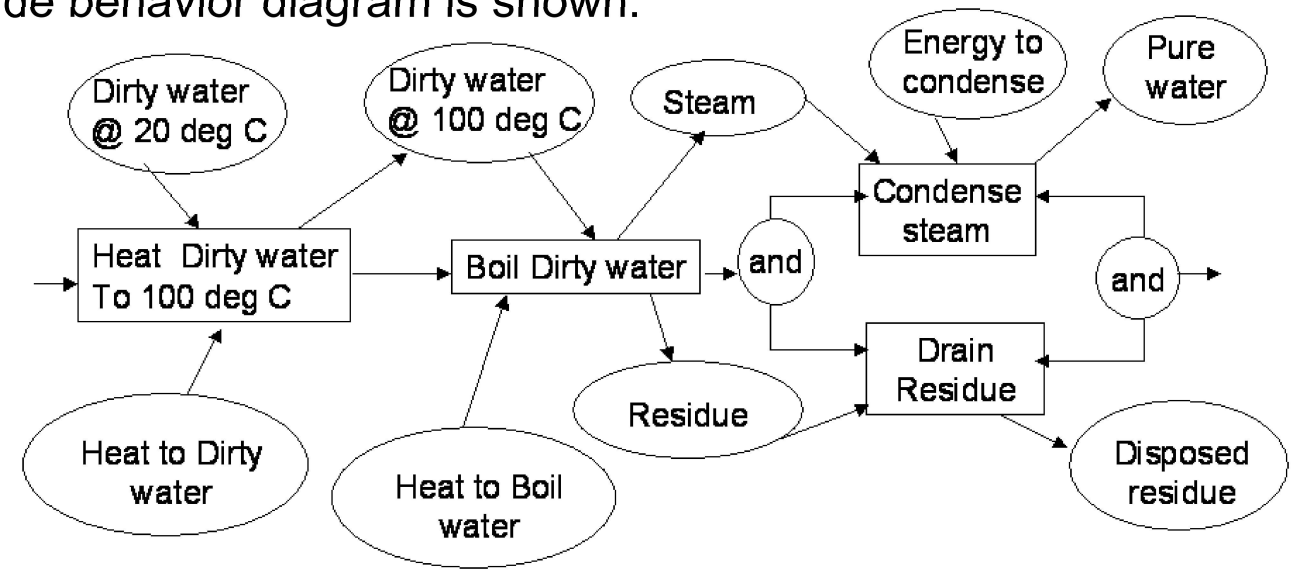
Distiller Sample Problem

Refer to Chapter 15

“A Practical Guide to SysML”

Distiller Problem Statement

- The following problem was posed to the SysMLteam in Dec '05 by D. Oliver:
- Describe a system for purifying dirty water.
  - Heat dirty water and condense steam are performed by a Counter Flow Heat Exchanger
  - Boil dirty water is performed by a Boiler
  - Drain residue is performed by a Drain
  - The water has properties: vol = 1 liter, density 1 gm/cm3, temp 20 deg C, specific heat 1cal/gm deg C, heat of vaporization 540 cal/gm.
- A crude behavior diagram is shown.



What are the real requirements?
How do we design the system?

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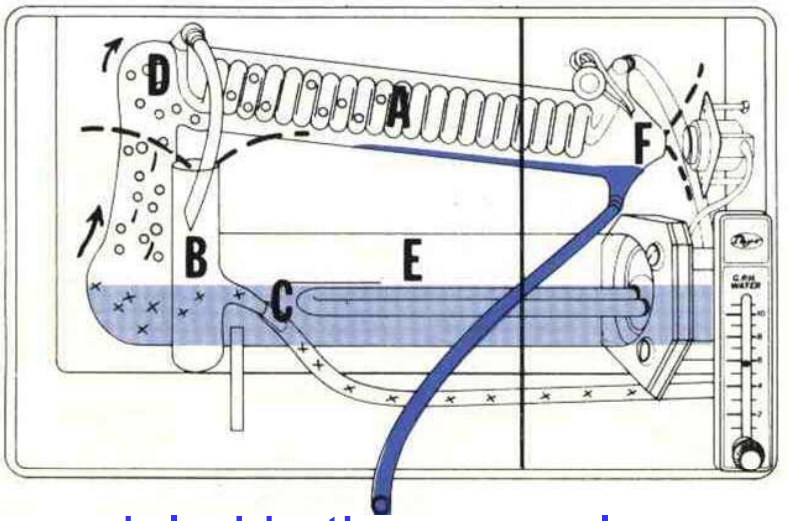
Distiller Types

Batch Distiller

Continuous Distiller



Note: Not all aspects of the distiller are modeled in the example

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Distiller Problem – Process Used

- Organize the model, identify libraries needed
- List requirements and assumptions
- Model behavior
  - In similar form to problem statement
  - Elaborate as necessary
- Model structure
  - Capture implied inputs and outputs
    - segregate I/O from behavioral flows
  - Allocate behavior onto structure, flow onto I/O
- Capture and evaluate parametric constraints
  - Heat balance equation
- Modify design as required to meet constraints
- Model the user interaction
- Modify design to reflect user interaction

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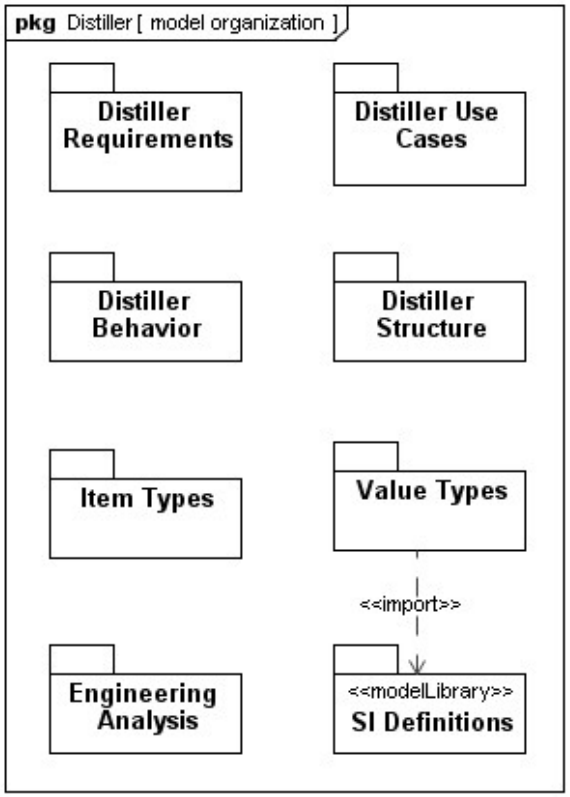
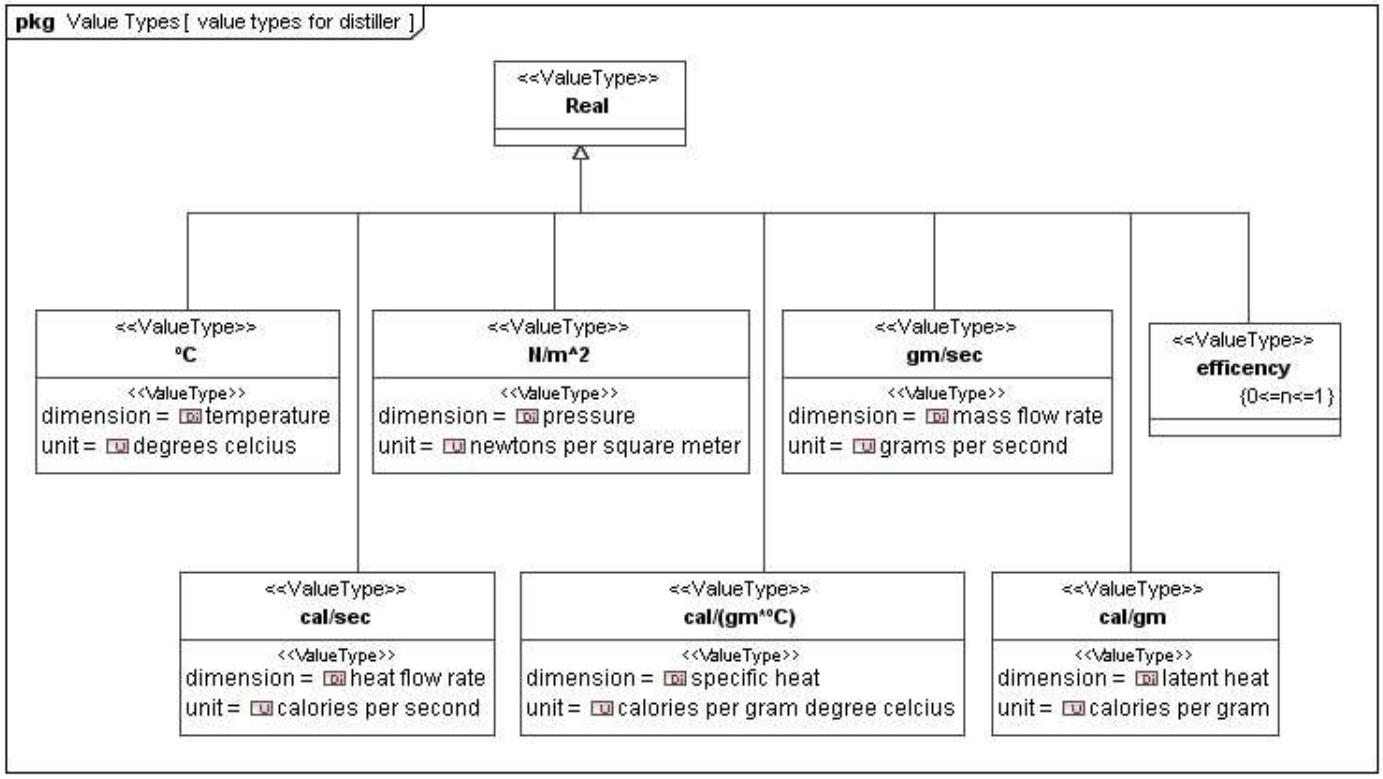
Distiller Problem – Package Diagram: Model Structure and Libraries





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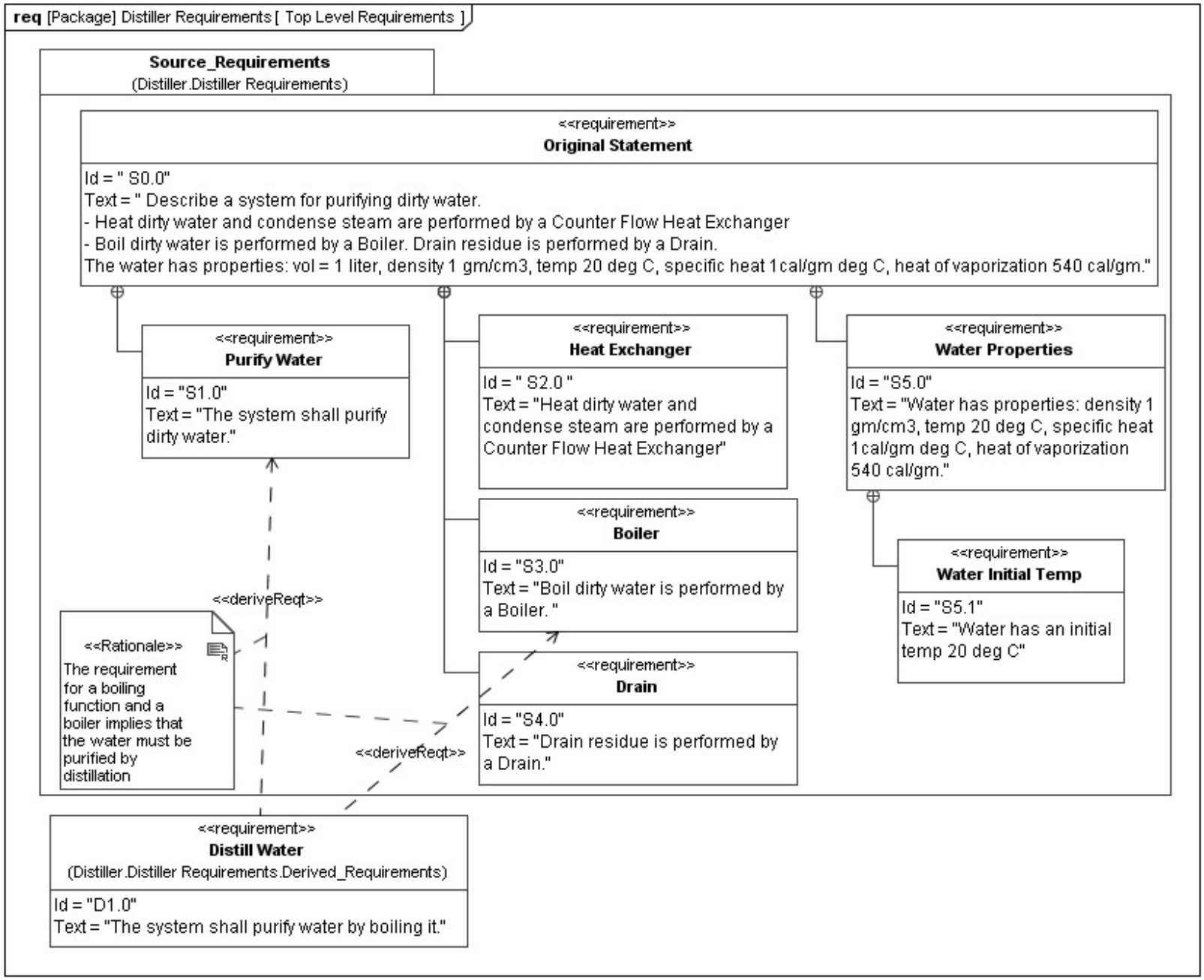
Distiller Example Requirements Diagram



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Distiller Example: Requirements Tables

table [requirement] OriginalStatement [Decomposition of OriginalStatement]

id	name	text
S0.0	OriginalStatement	Describe a system for purifying dirty water. …
S1.0	PurifyWater	The system shall purify dirty water.
S2.0	HeatExchanger	Heat dirty water and condense steam are performed by a …
S3.0	Boiler	Boil dirty water is performed by a Boiler.
S4.0	Drain	Drain residue is performed by a Drain.
S5.0	WaterProperties	water has properties: density 1 gm/cm3, temp 20 deg C, …
S5.1	WaterInitialTemp	water has an initial temp 20 deg C

table [requirement] PurifyWater [Requirements Tree]

id	name	relation	id	name	Rationale
S1.0	PurifyWater	deriveReqt	D1.0	DistillWater	The requirement for a boiling function and a boiler implies that the water must be purified by distillation

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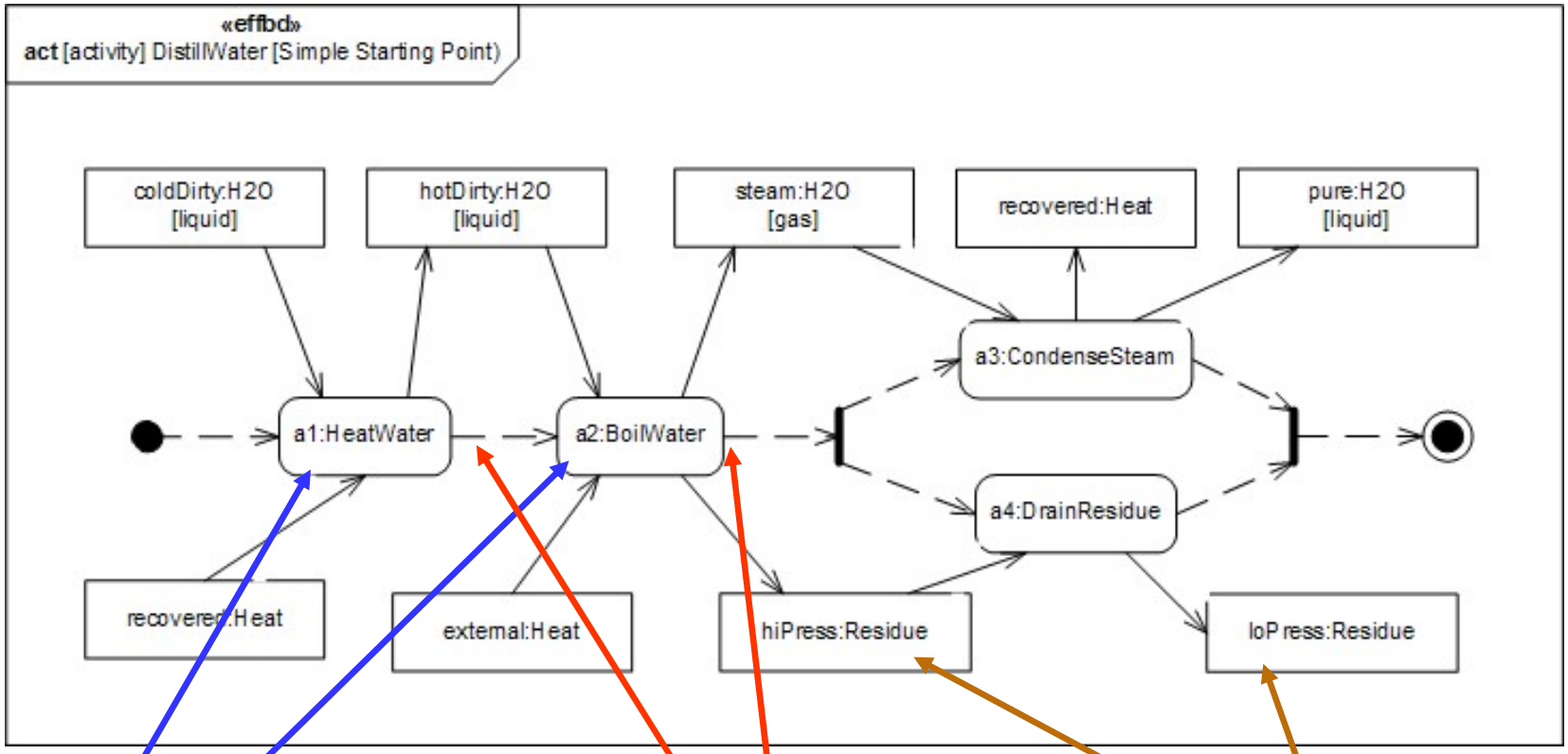
Distiller Example – Activity Diagram: Initial Diagram for DistillWater

- This activity diagram applies the SysML EFFBD profile, and formalizes the diagram in the problem statement.



Actions (Functions) **Control (Sequence)** **Things that flow (ObjectNodes)**

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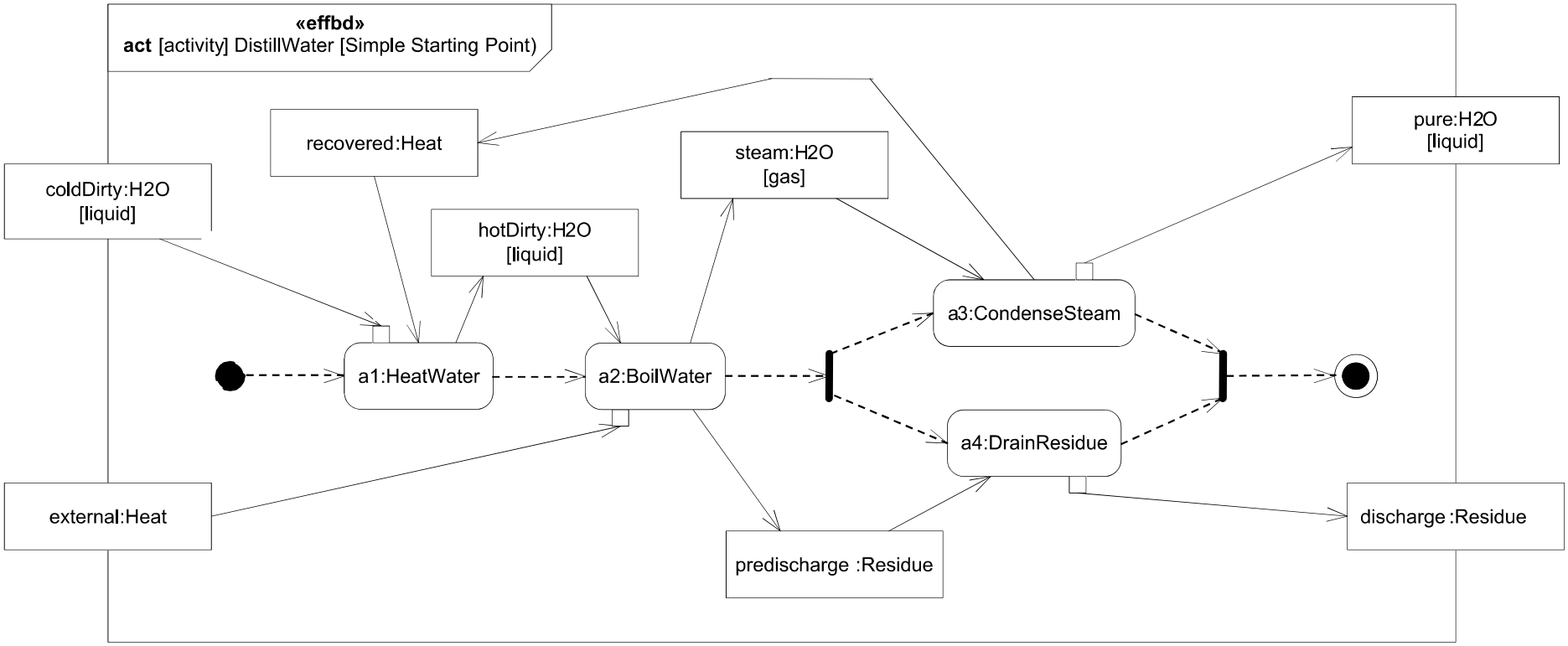
Distiller Example – Activity Diagram: Control-Driven: Serial Behavior



Continuous Distiller Here

Batch Distiller

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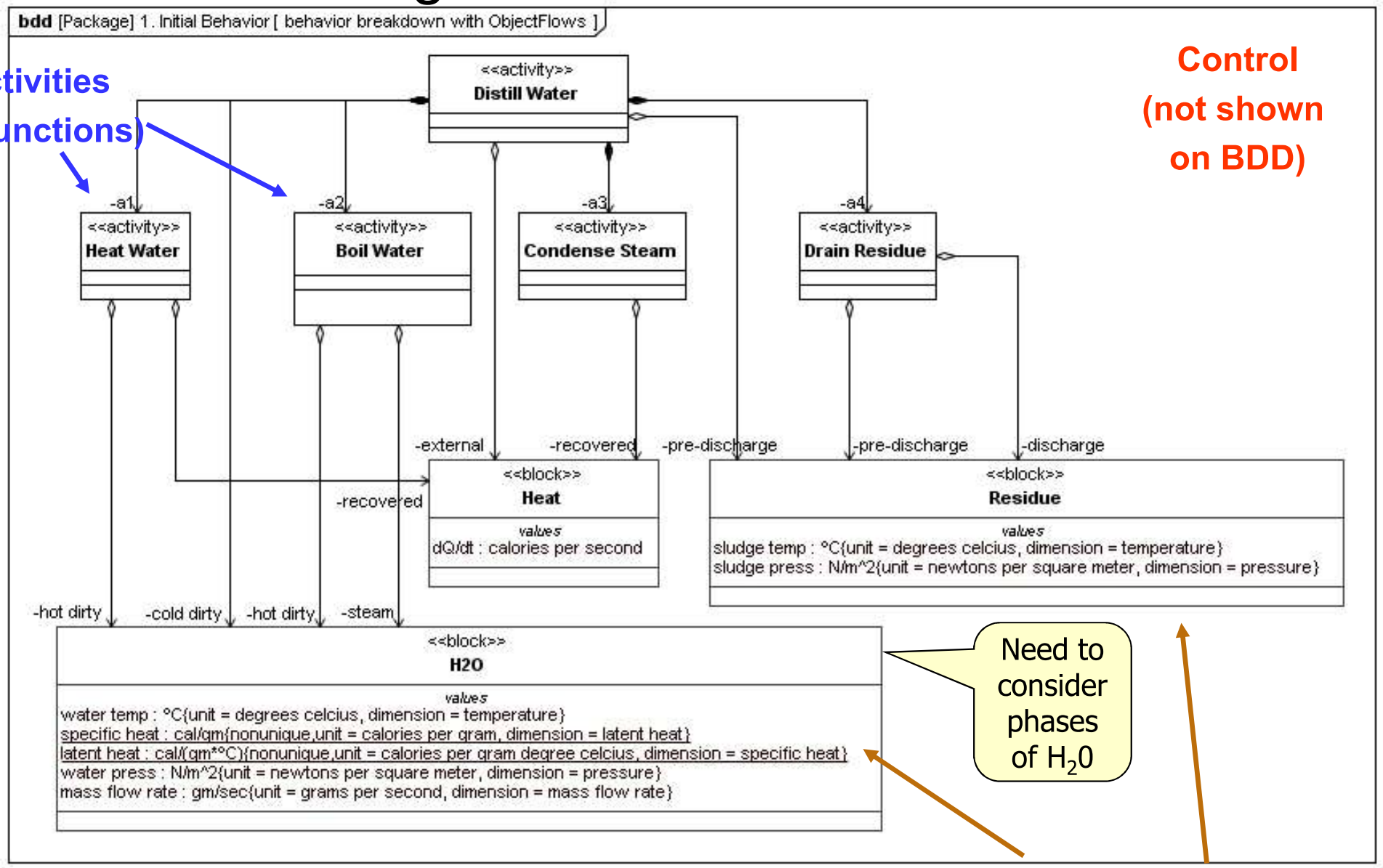
Distiller Example – Block Definition Diagram: DistillerBehavior



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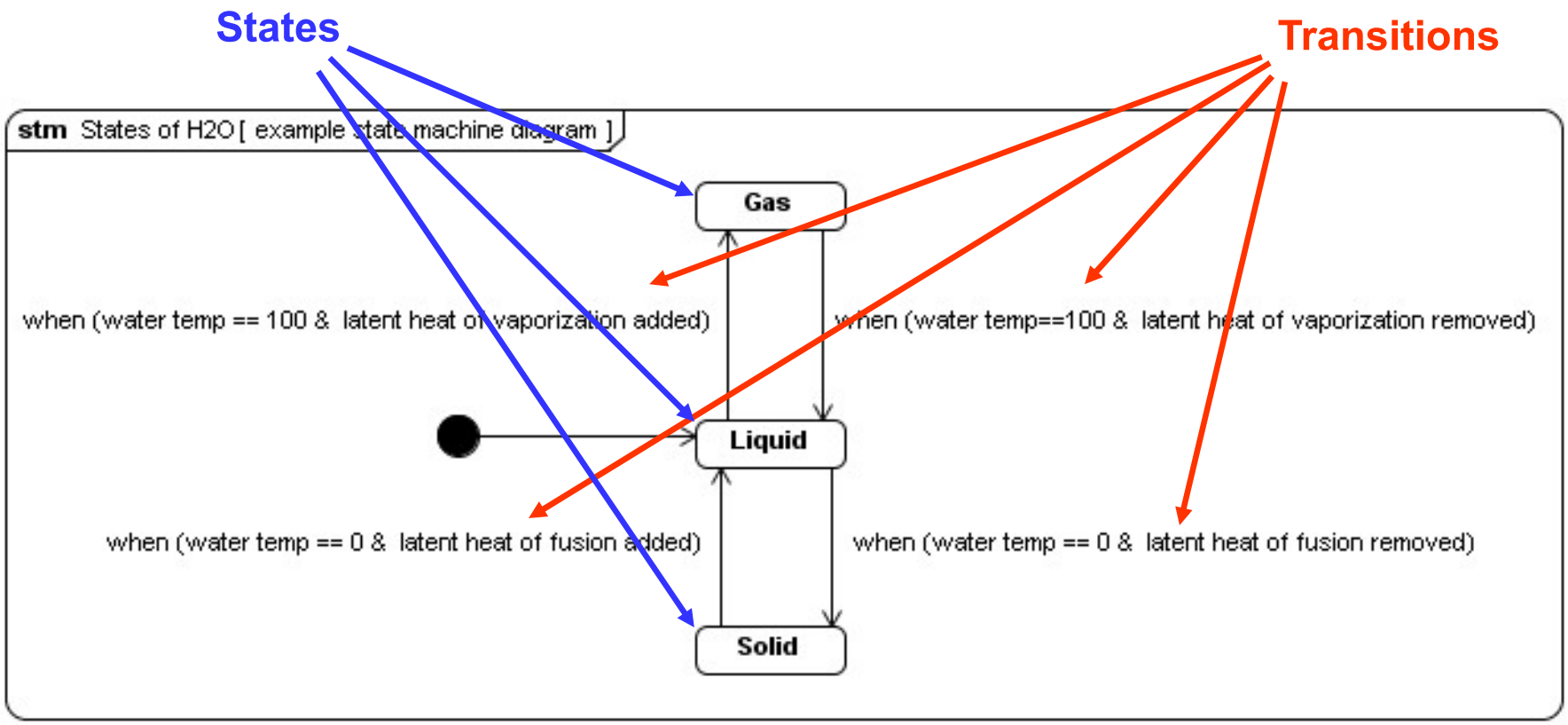
Distiller Example – State Machine Diagram: States of H2O



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Distiller Example – Activity Diagram: I/O Driven: Continuous Parallel Behavior

act Distill Water(cold dirty : H2O, external : Heat, pure : H2O, discharge : Residue) [4. parallel continuous]

a3 : Condense Steam

pure : H2O {stream}

<<continuous>> pure : H2O {stream}

recovered : Heat {stream}

steam : H2O {stream}

<<continuous>> cold dirty : H2O {stream}

recovered : Heat {stream}

steam : H2O {stream}

discharge : Residue {stream}

cold dirty : H2O {stream}

a1 : Heat Water

hot dirty : H2O {stream}

a2 : Boil Water

a4 : Drain Residue

<<continuous>> discharge : Residue {stream}

hot dirty : H2O {stream}

external : Heat {stream}

pre-discharge : Residue {stream}

pre-discharge : Residue {stream}

<<continuous>> external : Heat {stream}

Continuous Distiller

Batch Distiller Here

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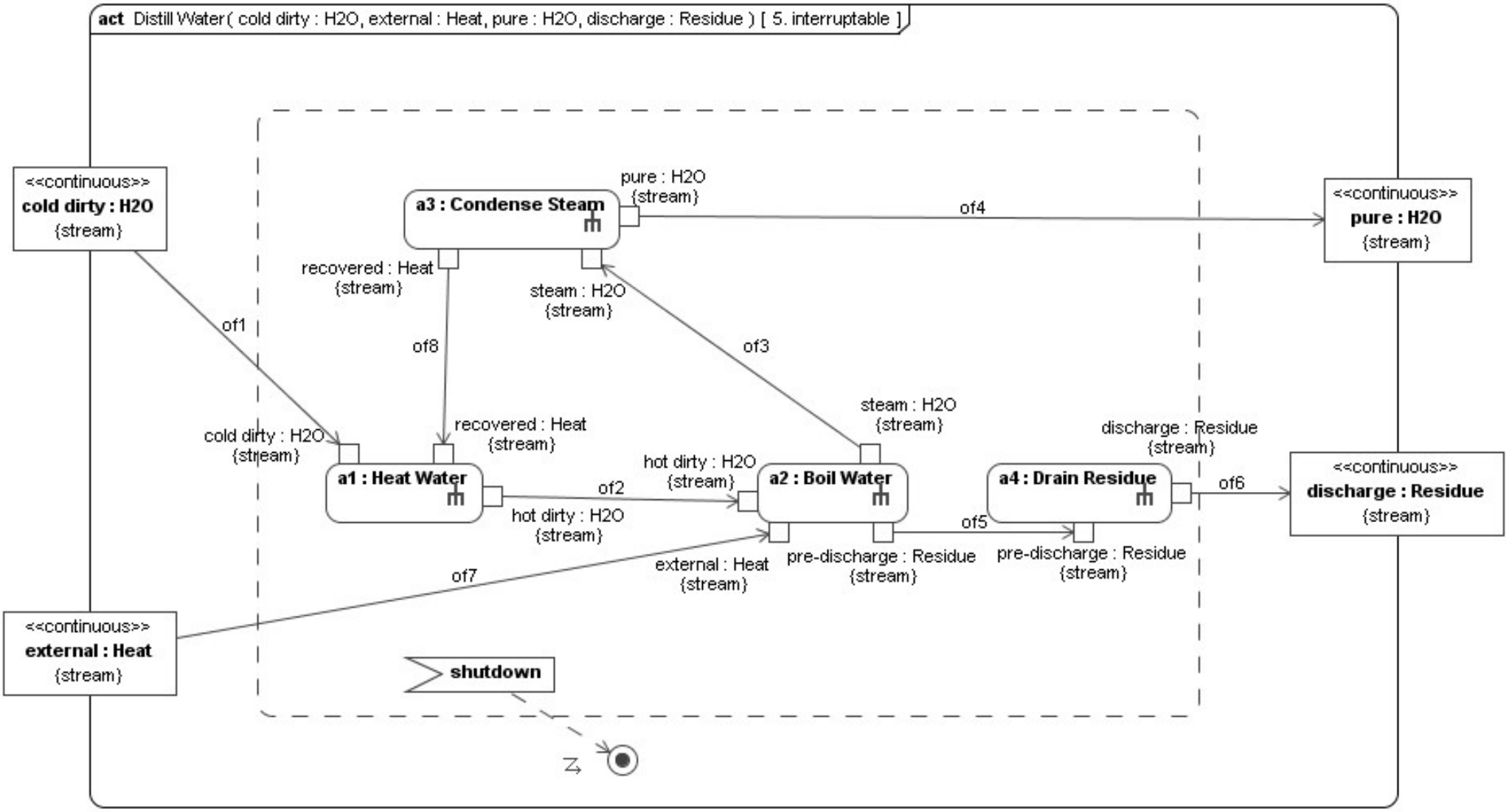
Distiller Example – Activity Diagram: No Control Flow, ActionPin Notation, Simultaneous Behavior



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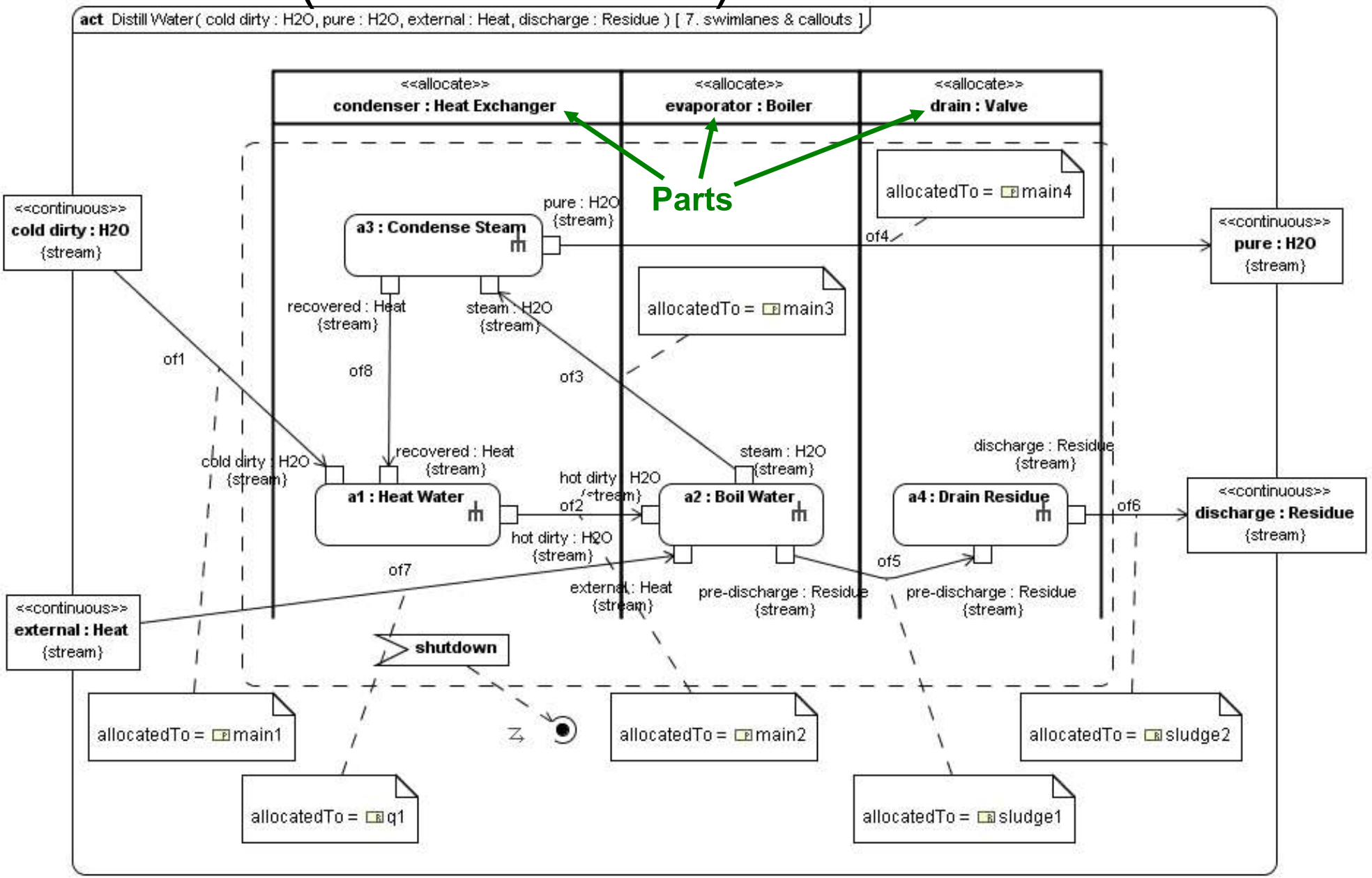
Distiller Example – Activity Diagram (with Swimlanes): DistillWater



Allocated **ibd**

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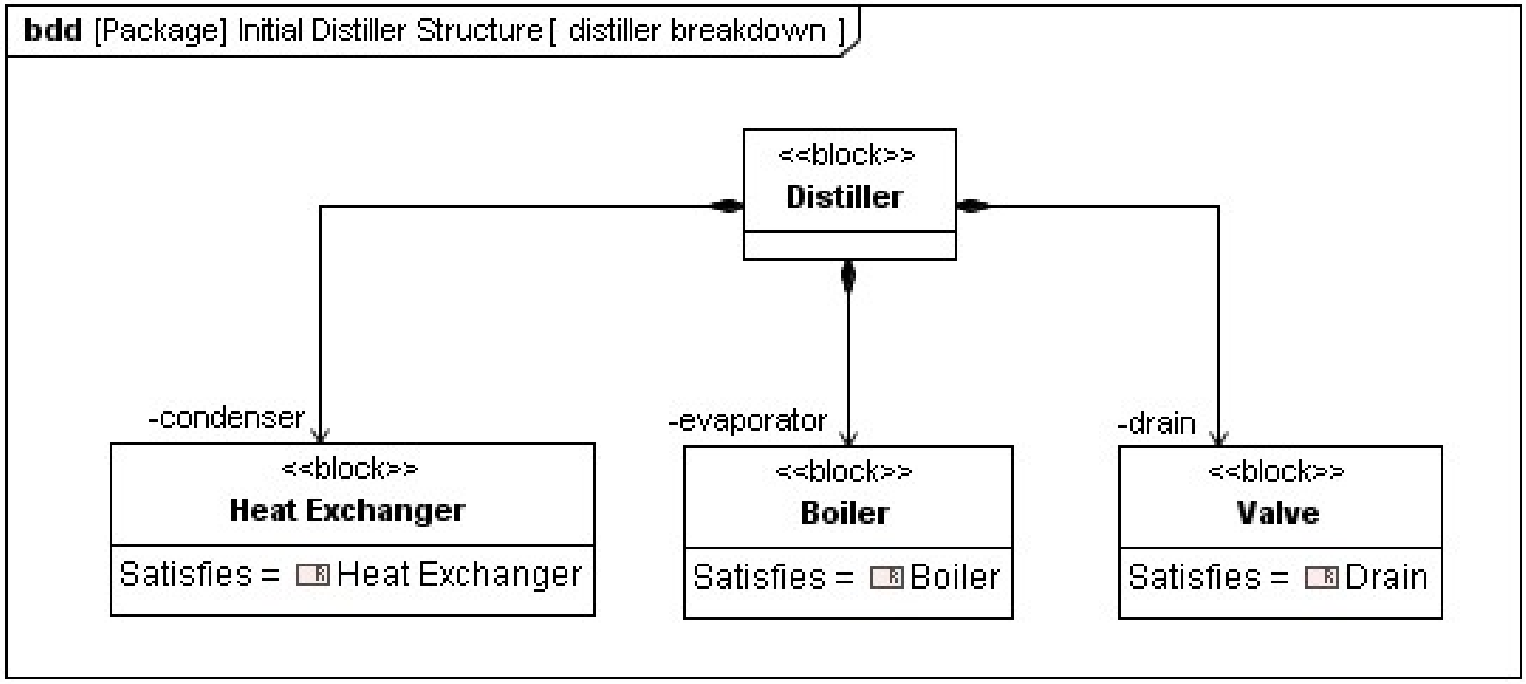
Distiller Example – Block Definition Diagram: DistillerStructure



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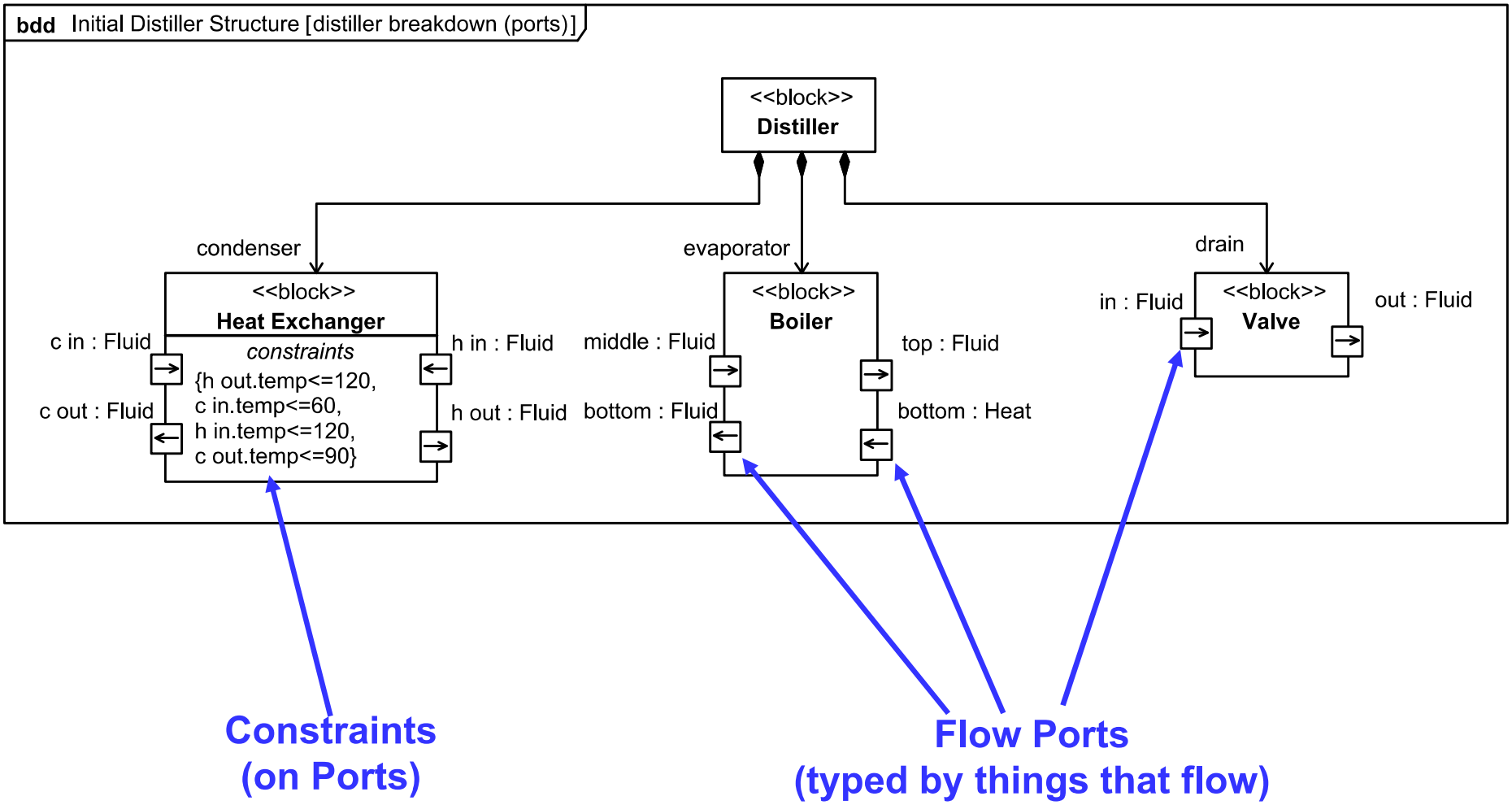
Distiller Example – Block Definition Diagram: Heat Exchanger Flow Ports



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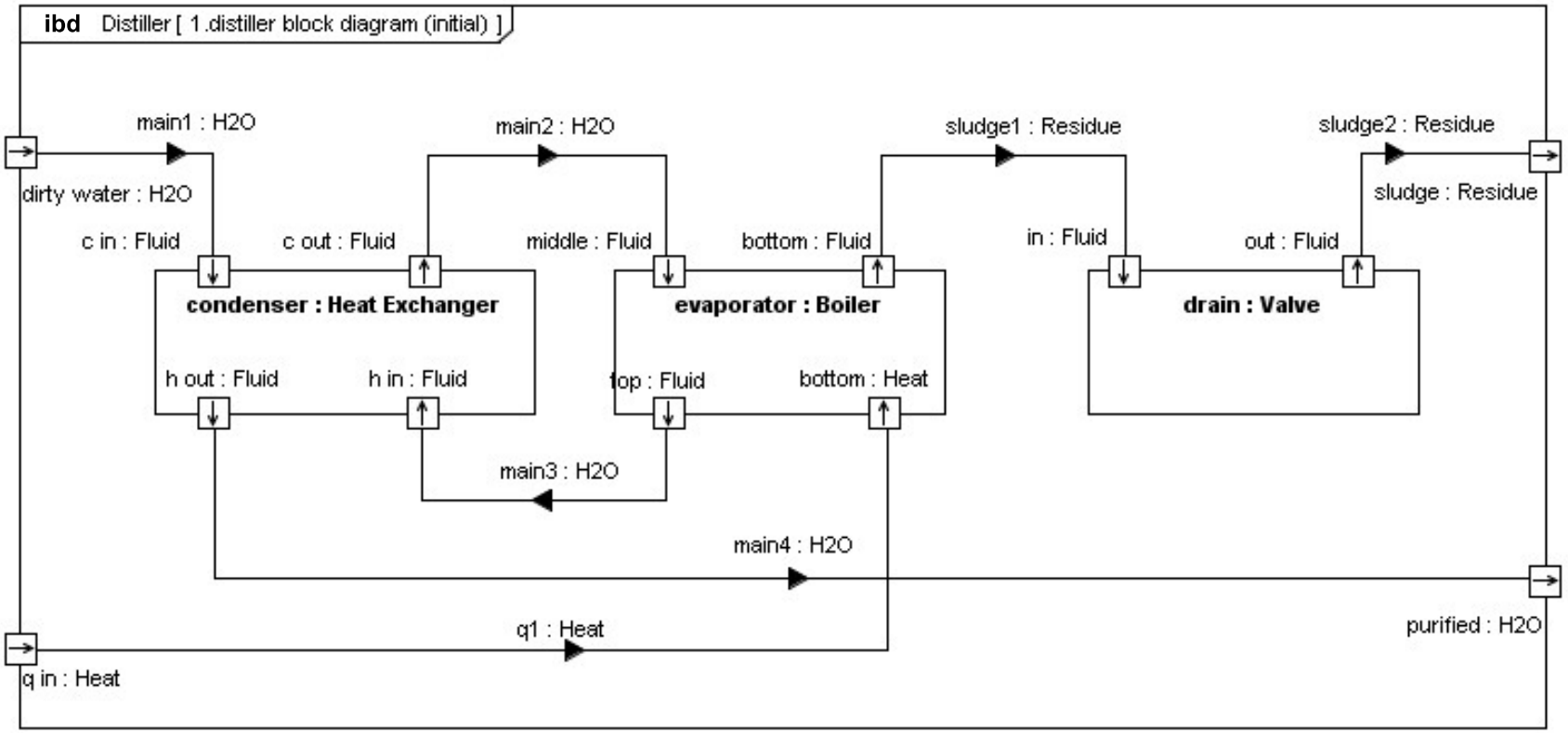
Distiller Example – Internal Block Diagram: Distiller Initial Design



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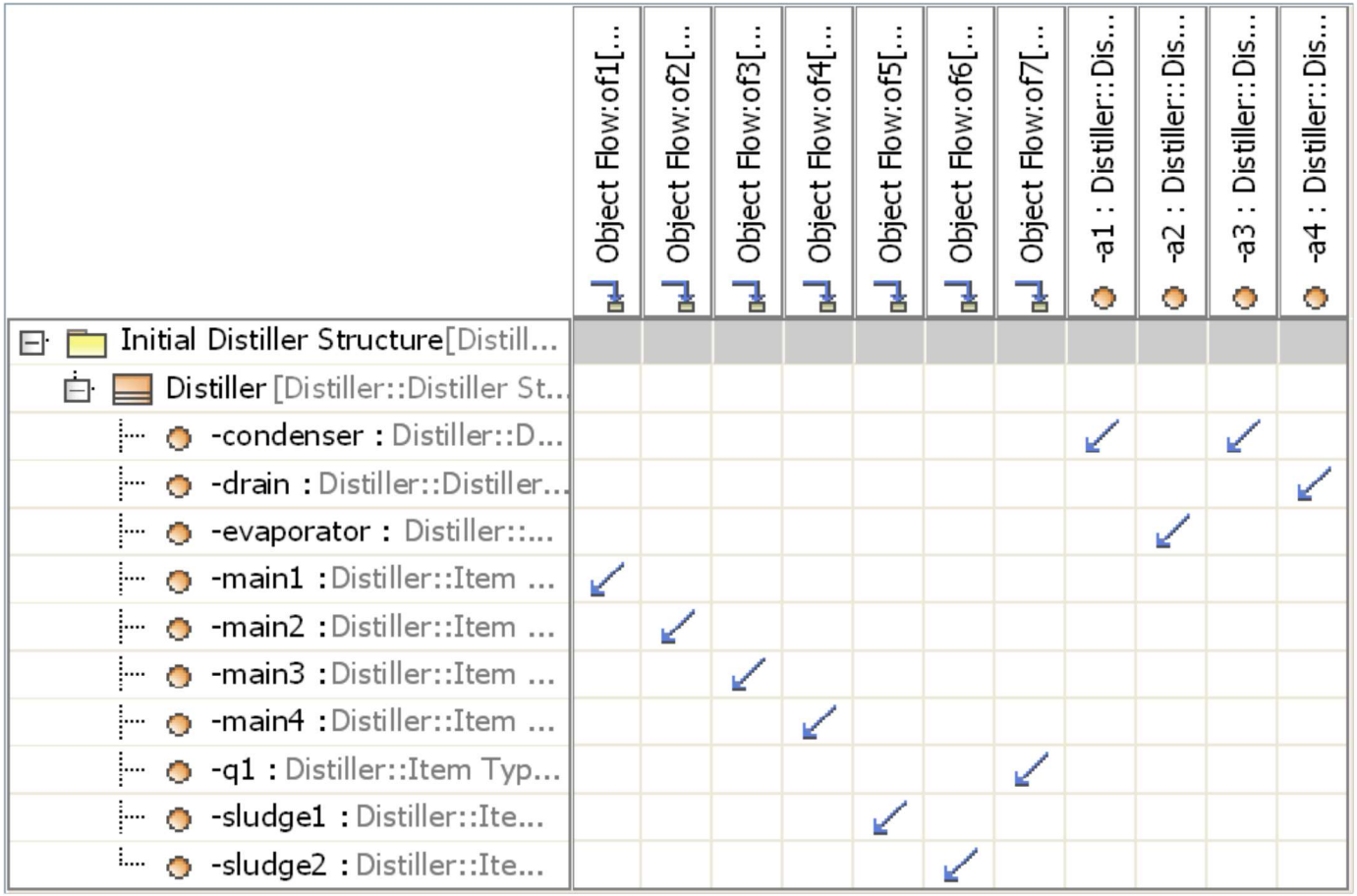
Distiller Example –Table: Functional Allocation



Exercise for student:
Is allocation complete?
Where is "«objectFlow»of8"?

Swimlane Diagram

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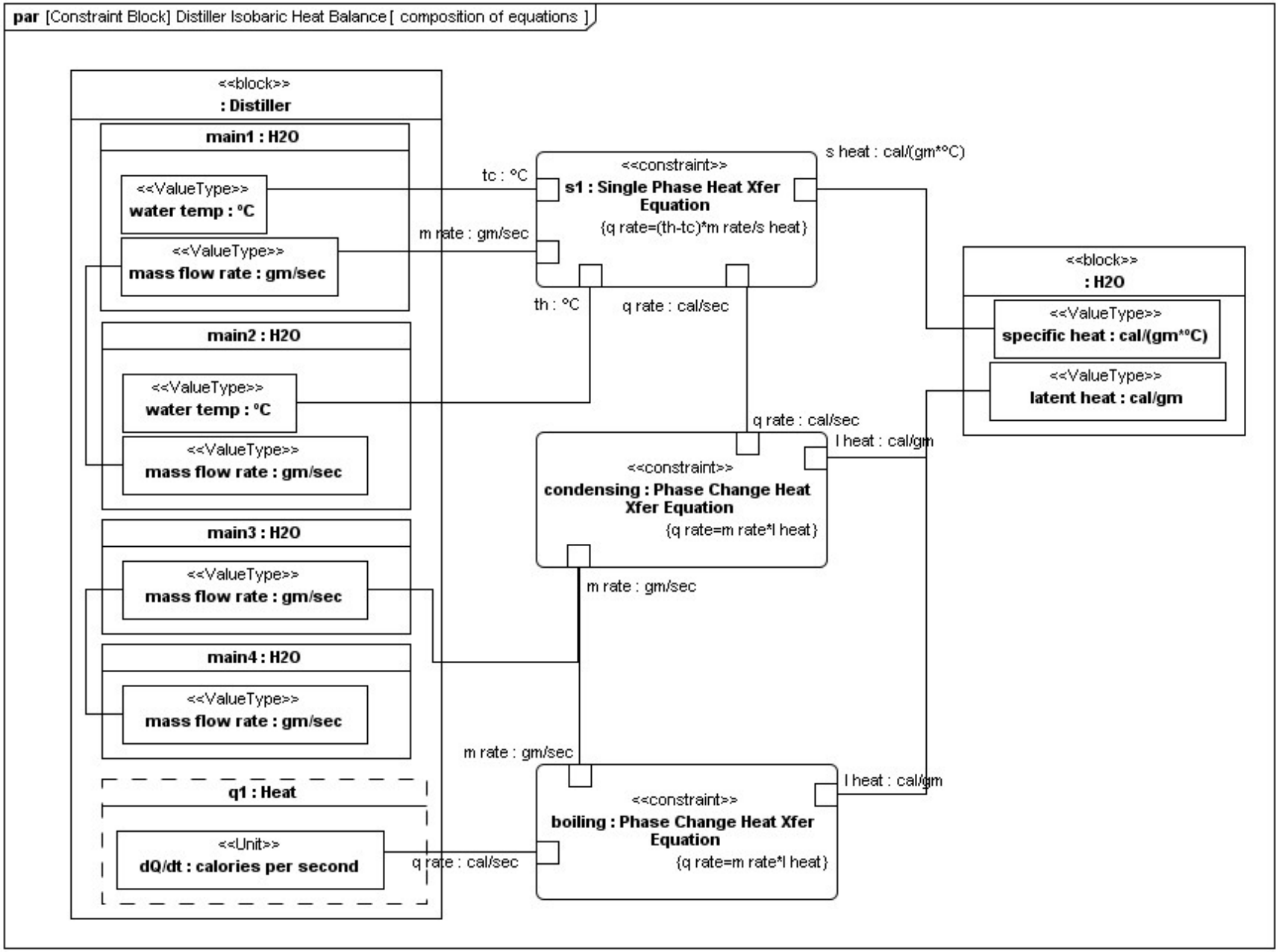
Parametric Diagram: Heat Balance



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Distiller Example – Heat Balance Results

table IsobaricHeatBalance1 [Results of Isobaric Heat Balance]

		main1 : H2O	main2 : H2O frm condenser	main2 : H2O into evap	main3 : H2O	main4 : H2O
specific heat cal/gm-°C	**1**					
latent heat cal/cm	**540**					
mass flow rate gm/sec		6.8	**6.8**	1	1	1
temp °C		20	100	100	100	100

Satisfies «requirement» WaterSpecificHeat

Satisfies «requirement» WaterHeatOfVaporization

Satisfies «requirement» WaterInitialTemp

dQ/dt cooling water cal/sec	540
dQ/dt steam-condensate cal/sec	540
condenser efficency	1
heat deficit	0

dQ/dt condensate-steam cal/sec	540
boiler efficiency	1
dQ/dt in boiler cal/sec	540

Note: Cooling water needs to have 6.75x flow of steam! Need bypass between hx_water_out and bx_water_in!

1. Set these (steady state)
2. Solve for these

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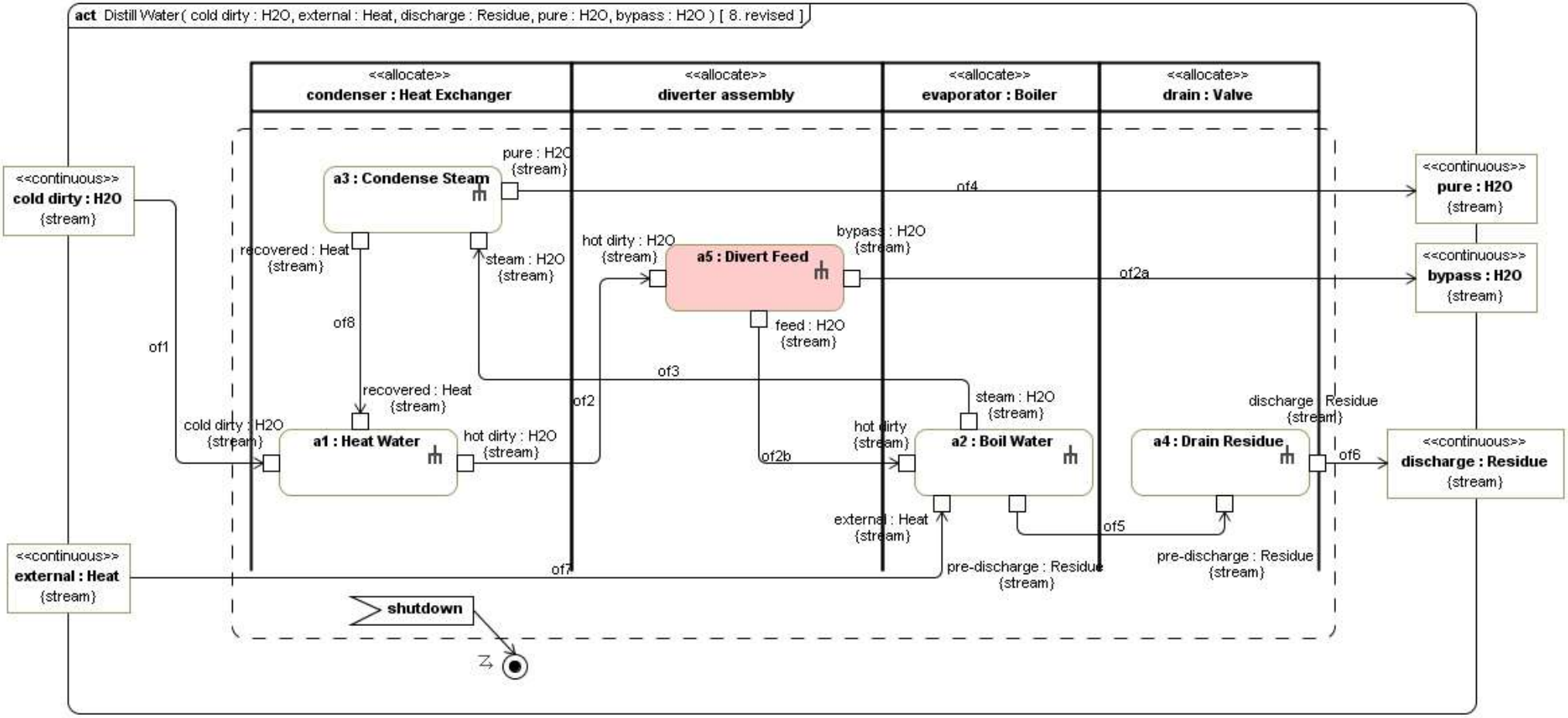
Distiller Example – Activity Diagram: Updated DistillWater



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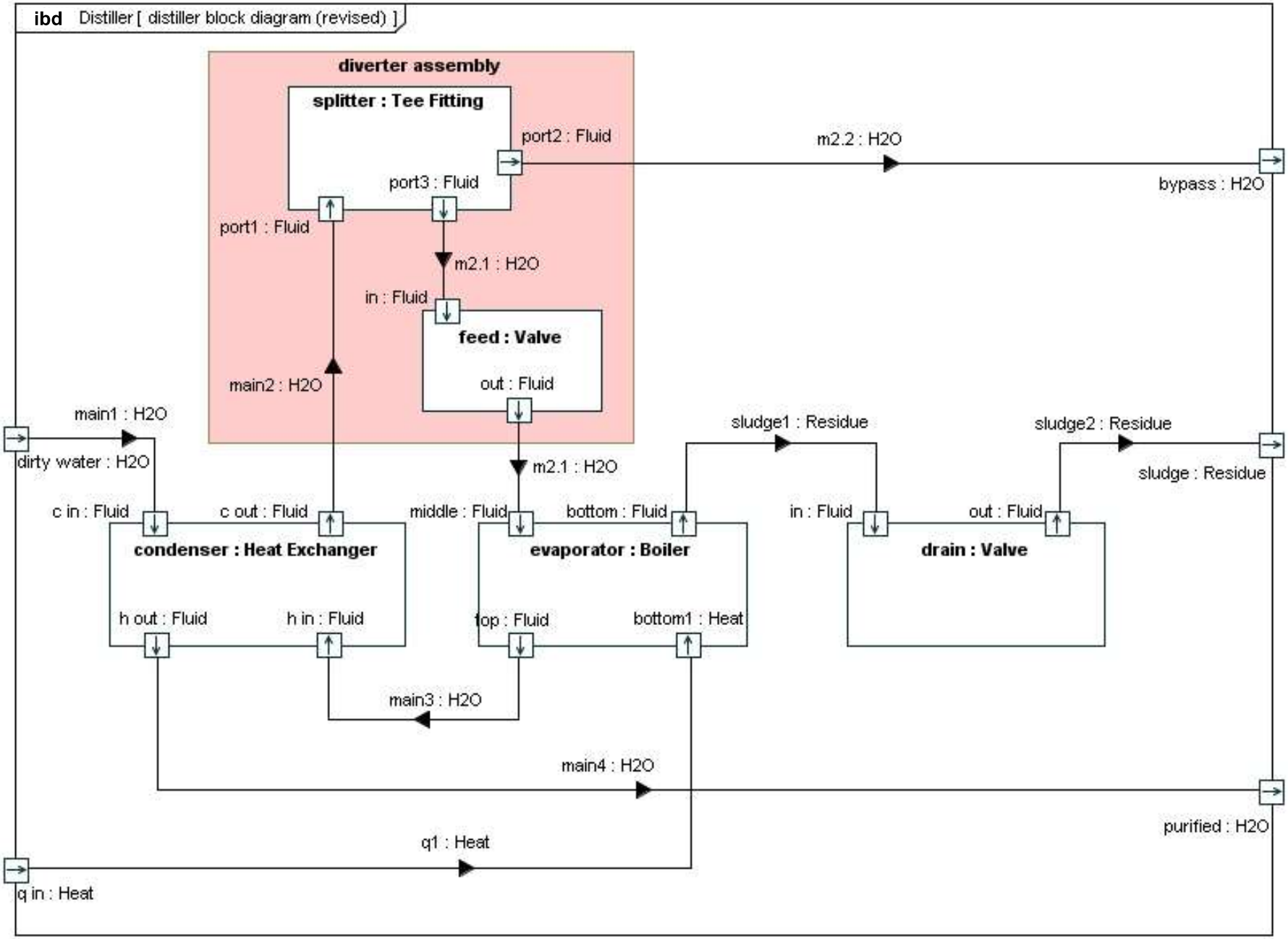
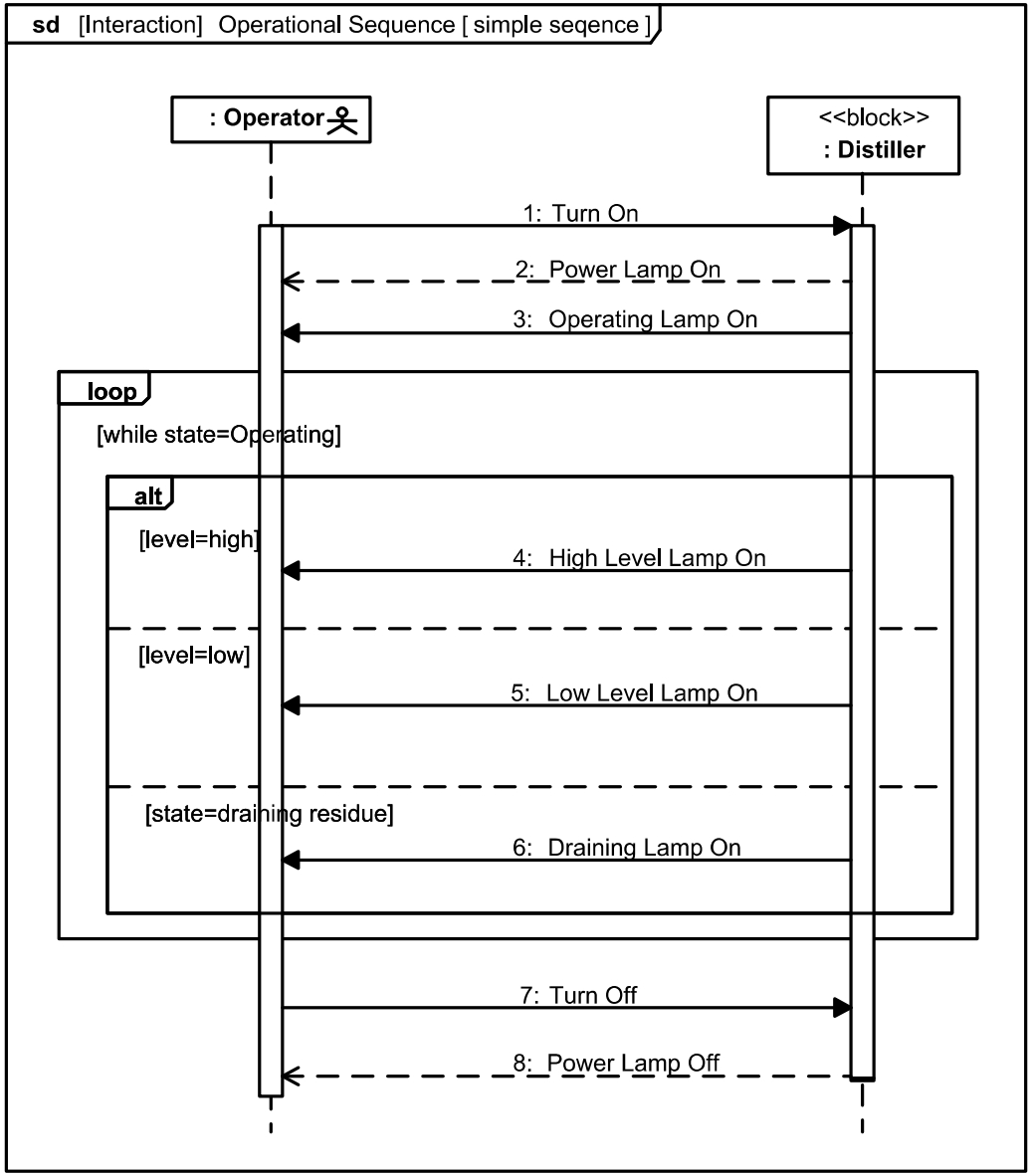
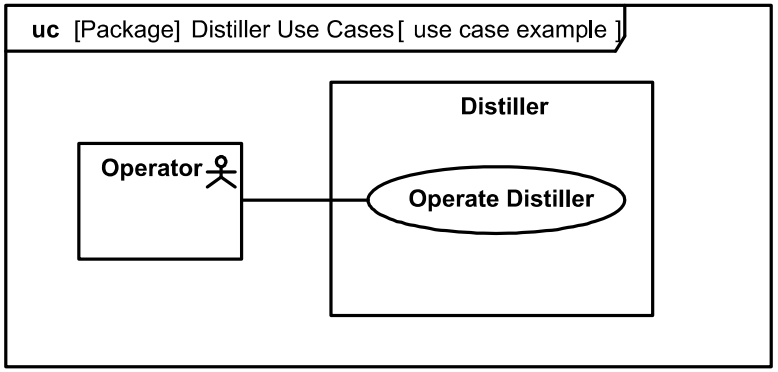
Distiller Example – Internal Block Diagram: Updated Distiller



Distiller Example – Use Case and Sequence Diagrams





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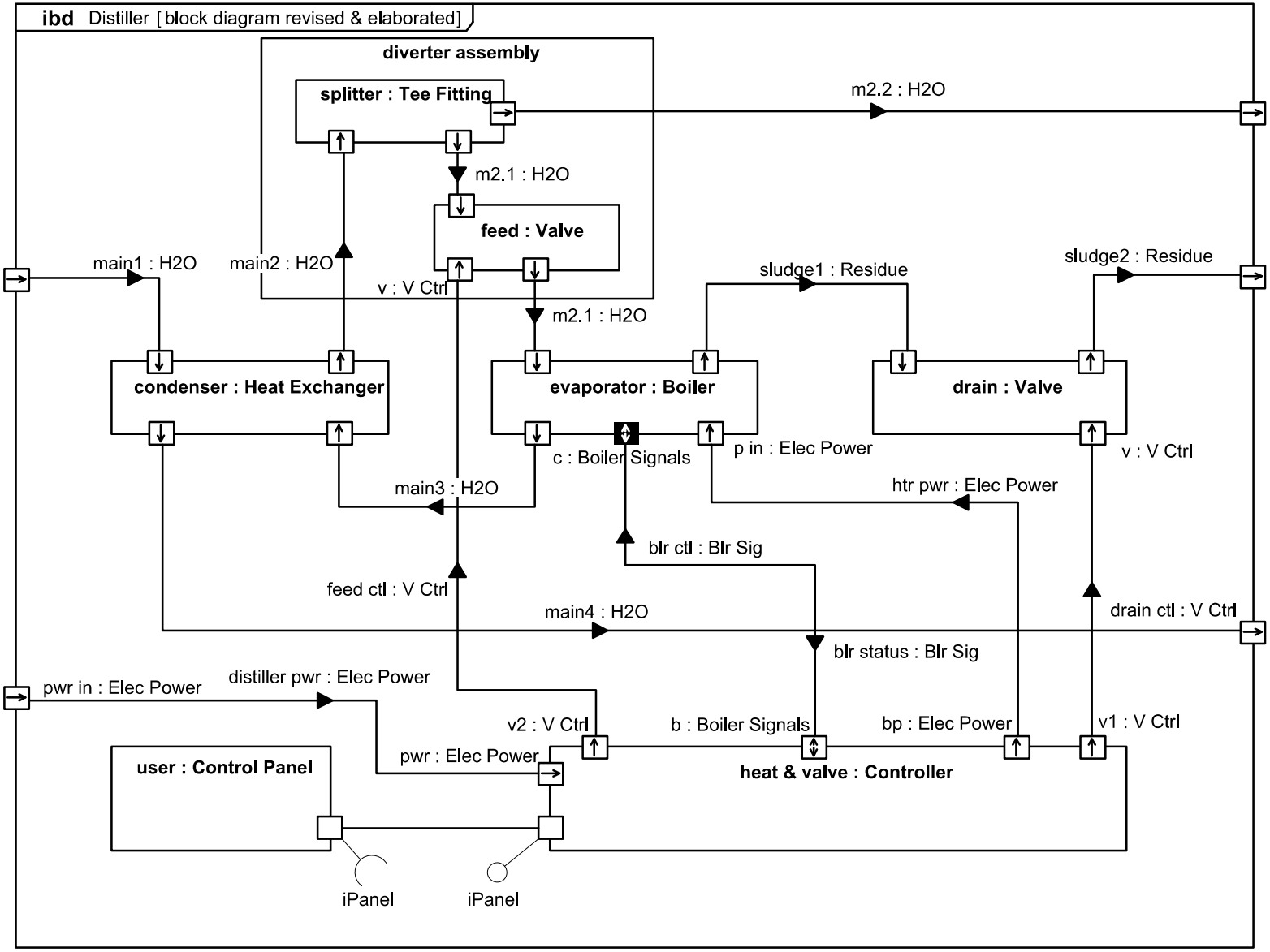
Distiller Example – Internal Block Diagram: Distiller Controller



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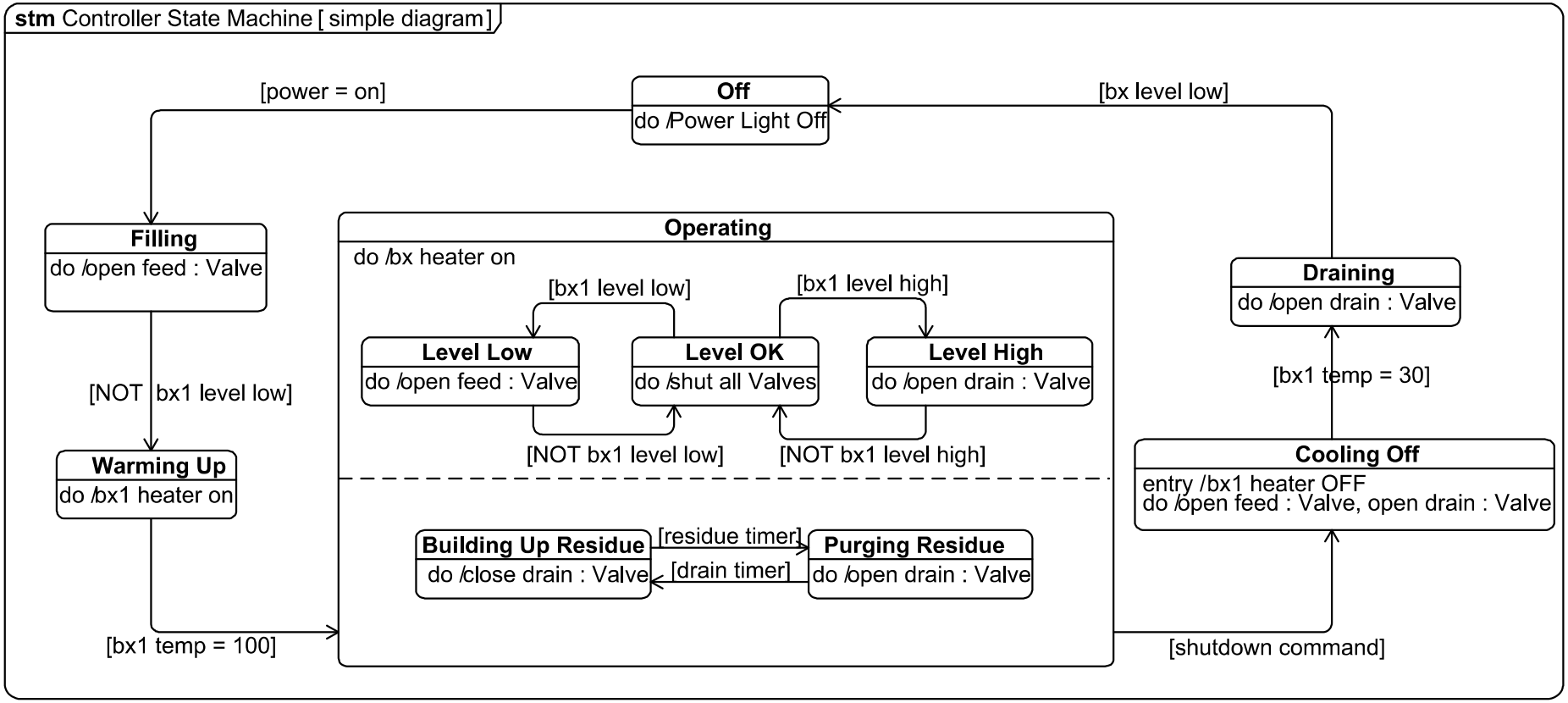
Distiller Example – State Machine Diagram: Distiller Controller



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