FIG. 1

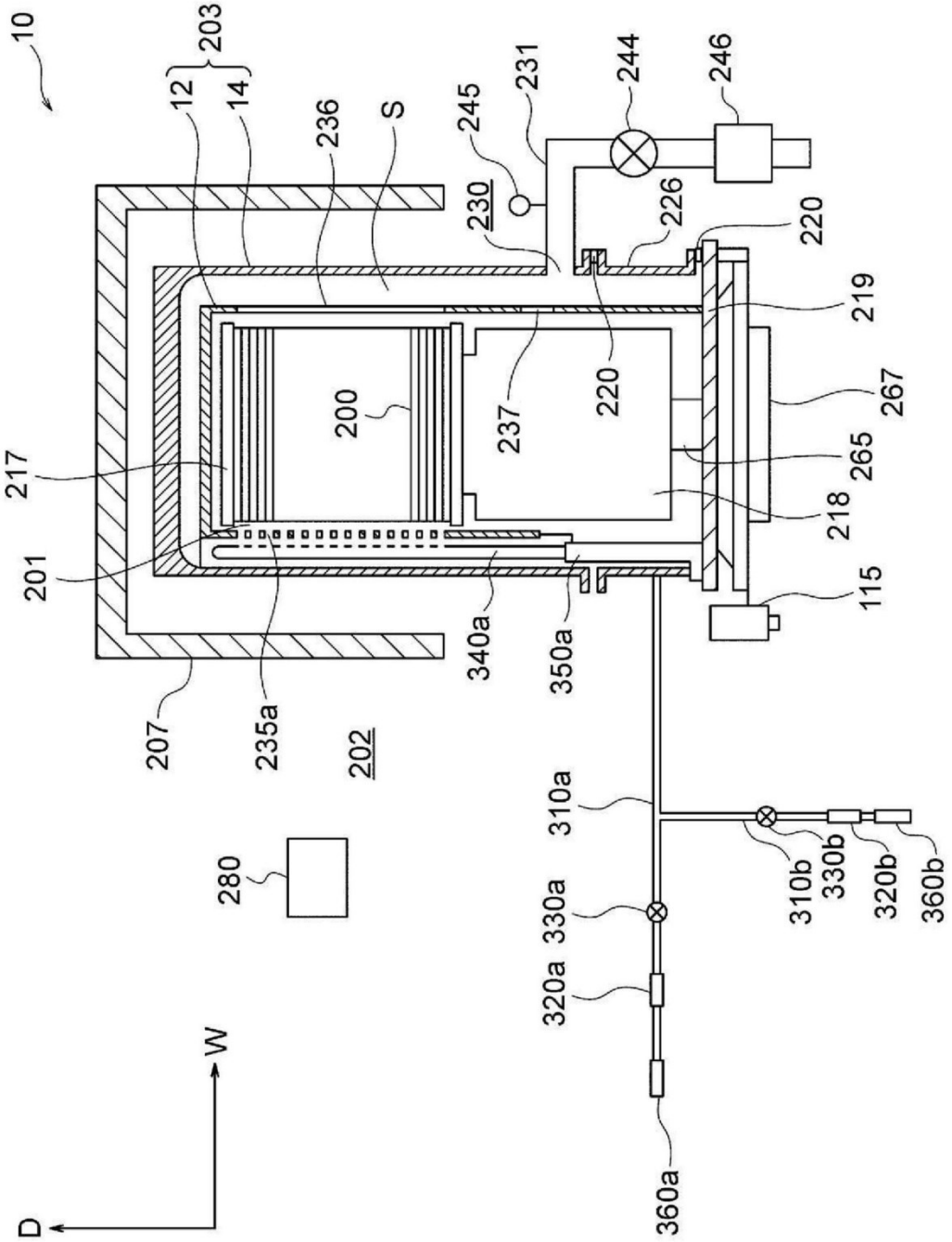

10
203
12
14
236
S
245
231
244
246
230
226
220
219
267
265
218
115
200
237
220
217
201
207
235a
202
340a
350a
280
310a
330a
320a
360a
310b
330b
320b
360b
D
W

FIG. 2

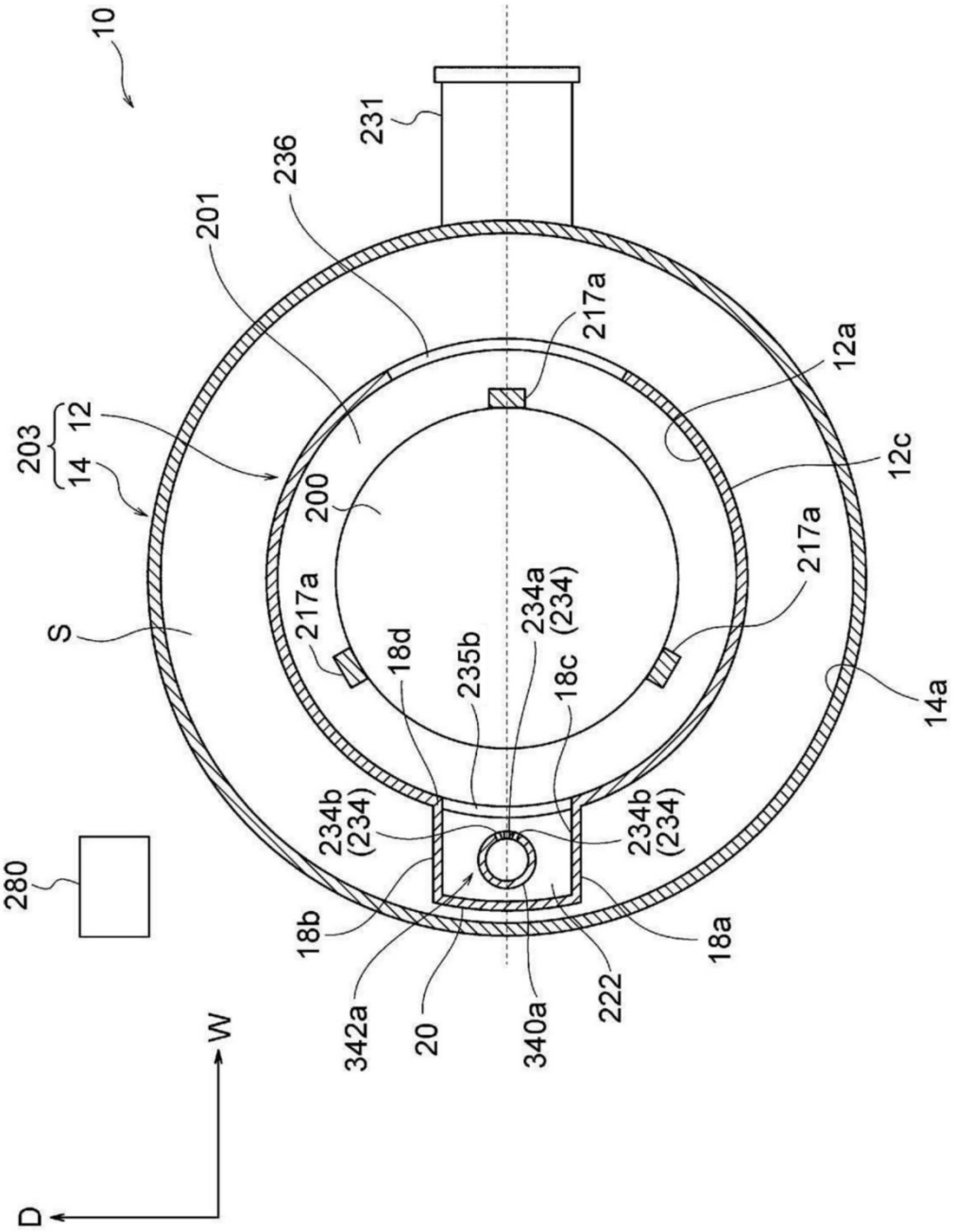

10
231
236
201
217a
12a
203
12
14
200
12c
217a
S
217a
18d
235b
234a
(234)
18c
14a
234b
(234)
234b
(234)
280
18b
18a
342a
20
340a
222
W
D

FIG. 3

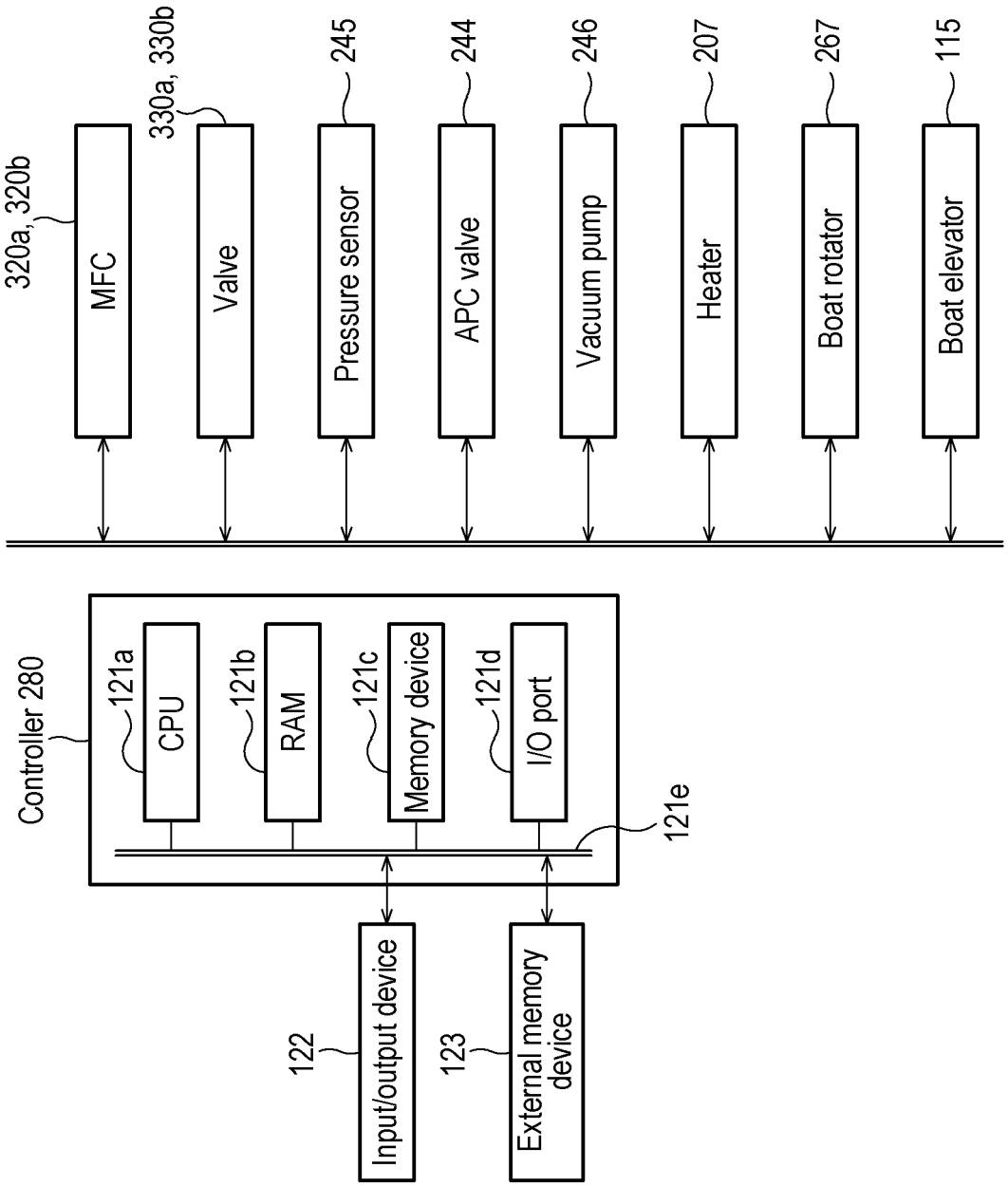

320a, 320b
MFC
330a, 330b
Valve
245
Pressure sensor
244
APC valve
246
Vacuum pump
207
Heater
267
Boat rotator
115
Boat elevator
Controller 280
121a
CPU
121b
RAM
121c
Memory device
121d
I/O port
121e
122
Input/output device
123
External memory device

FIG. 4

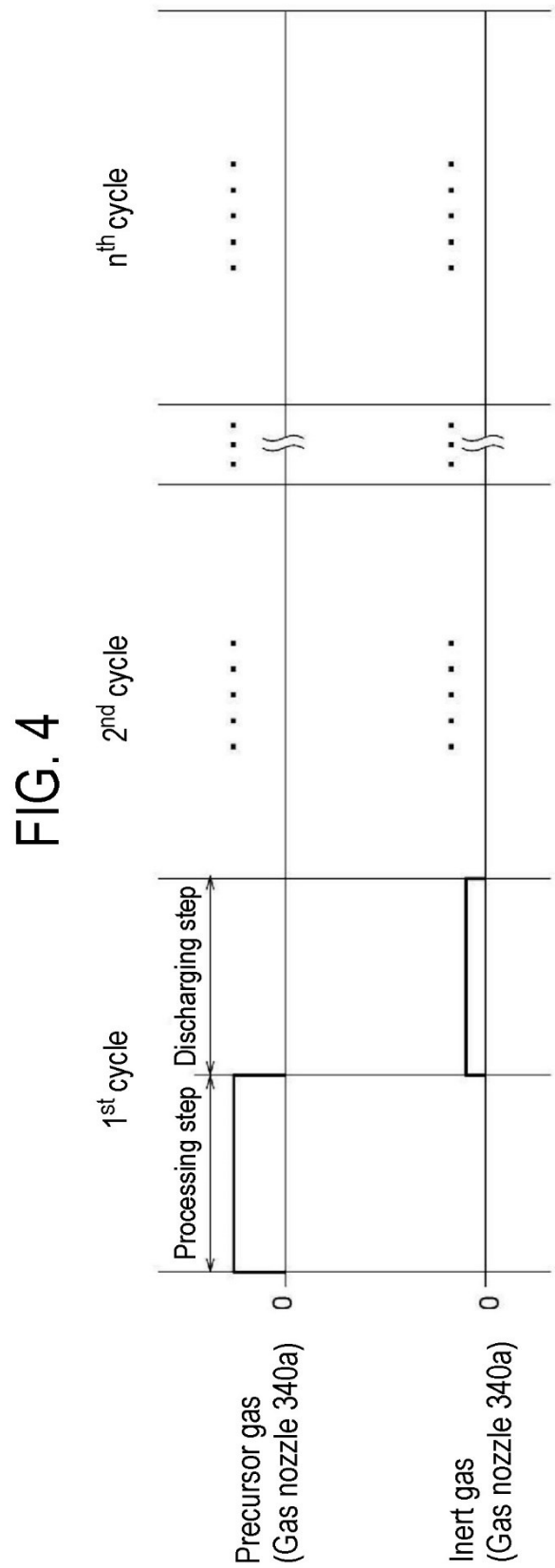

1st cycle
2nd cycle
nth cycle
Processing step
Discharging step
Precursor gas
(Gas nozzle 340a)
Inert gas
(Gas nozzle 340a)
0
0

FIG. 5

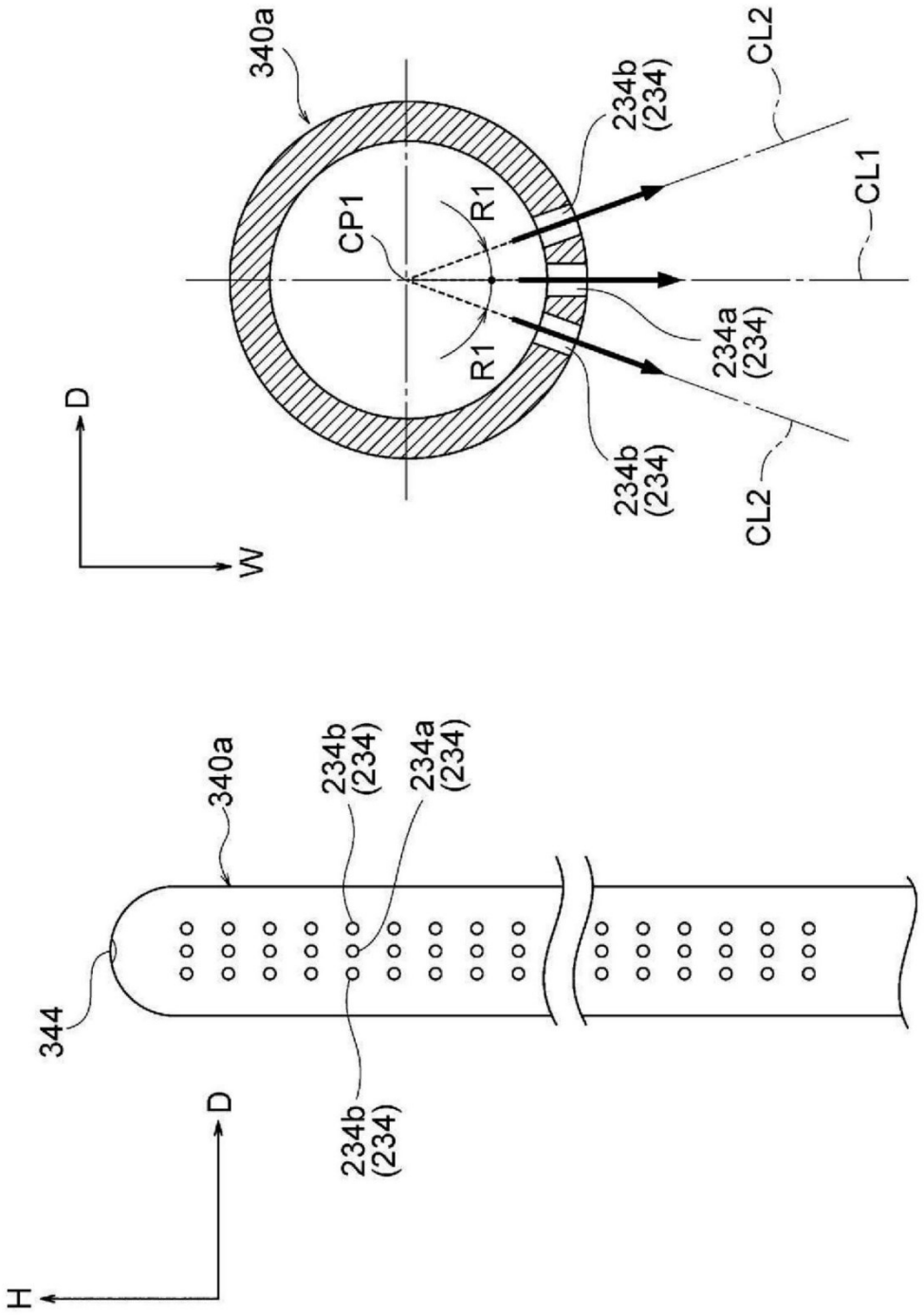

340a
234b (234)
CL2
CL1
CP1
R1
R1
234a (234)
234b (234)
CL2
D
W
340a
234b (234)
234a (234)
344
234b (234)
D
H

FIG. 6

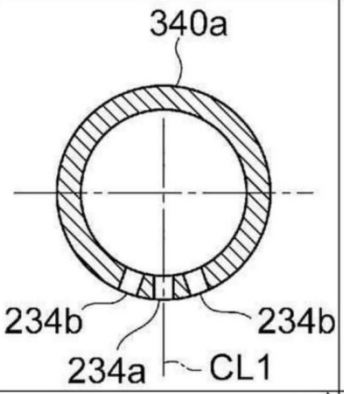
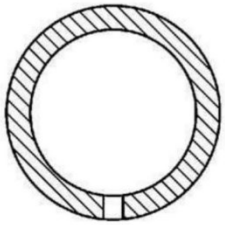
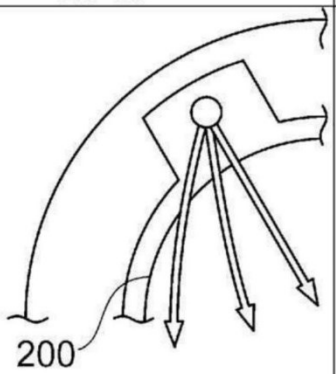
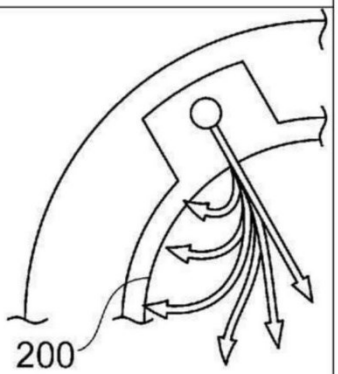
	Present embodiment	Conventional
Gas nozzle cross section		
Gas flow		
Gas partial pressure	1.5Pa	5.7Pa

FIG. 7

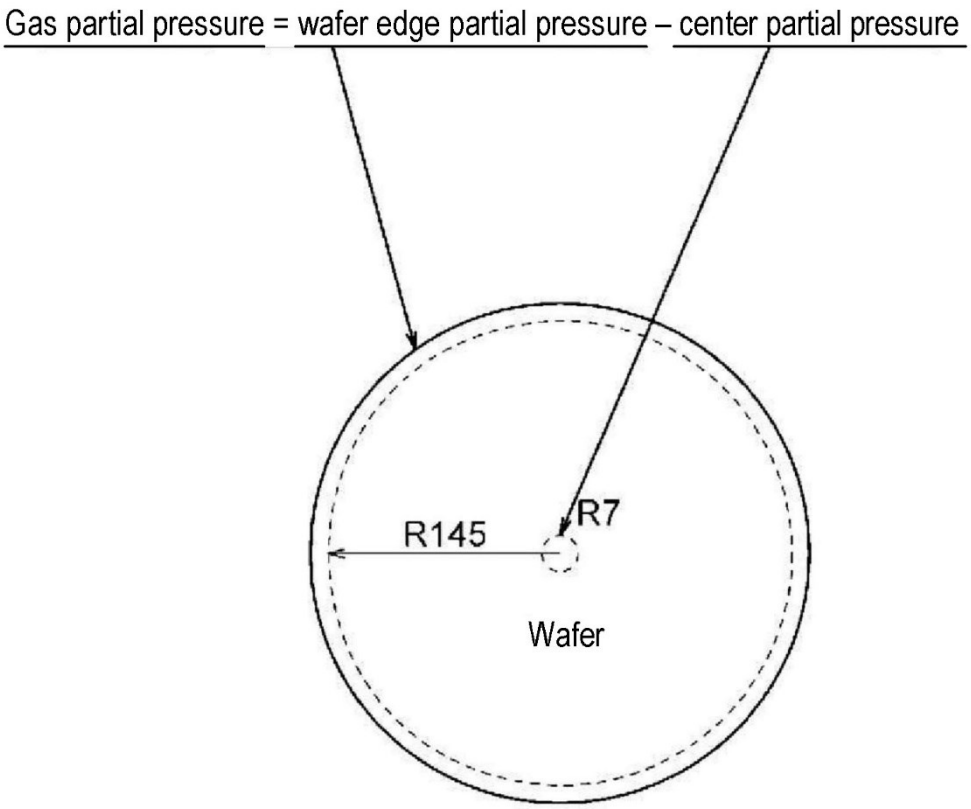

Gas partial pressure = wafer edge partial pressure – center partial pressure
R145
R7
Wafer

FIG. 8

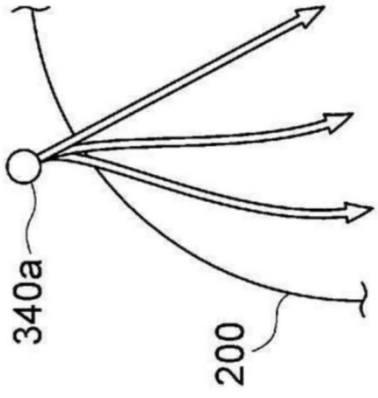
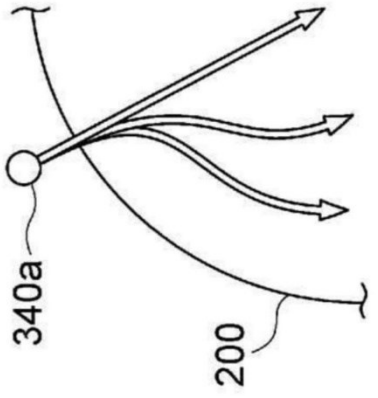
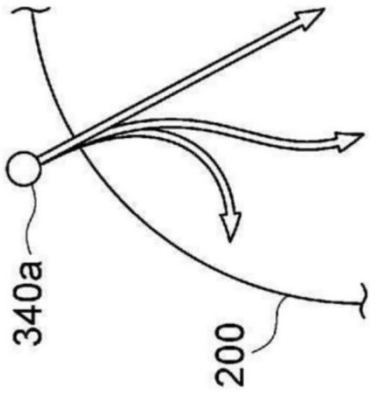
	Evaluation Example 1			Evaluation Example 2			Evaluation Example 3		
Hole diameter ratio	1:1:1			0.85:1:0.85			0.75:1:0.75		
	Second opening	First opening	Second opening	Second opening	First opening	Second opening	Second opening	First opening	Second opening
Gas flow									
Wafer region Return flow	No			No			Yes		

FIG. 9

	Evaluation Example 1			Evaluation Example 2			Evaluation Example 3		
Hole diameter ratio	1:1:1			0.85:1:0.85			0.75:1:0.75		
Cross-sectional area ratio of opening	Second opening	First opening	Second opening	Second opening	First opening	Second opening	Second opening	First opening	Second opening
	1	1	1	0.7	1	0.7	0.5	1	0.5
Wafer region Return flow	No			No			Yes		
Flow rate ratio	0.99	0.97	1	0.69	1	0.69	0.49	1	0.49
Gas partial pressure	1.5 Pa			2.7 Pa			4.0 Pa		

FIG. 10

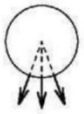
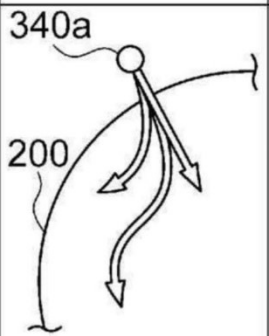
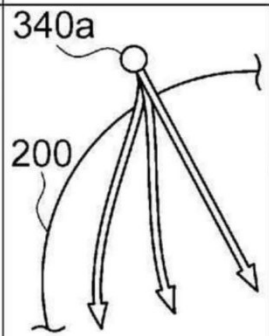
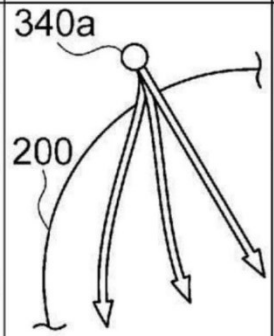
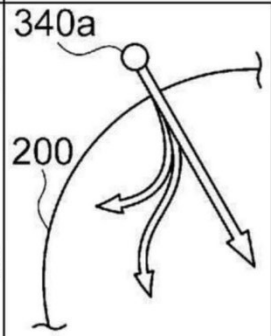
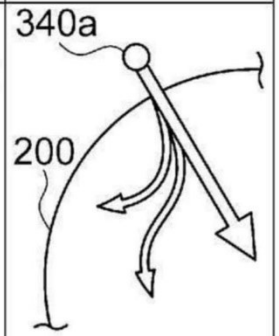
	Evaluation Example 4	Evaluation Example 5	Evaluation Example 6	Evaluation Example 7	Evaluation Example 8
Hole diameter	φ2.7-2.7-2.7				
Inclination angle R1	20°	25°	30°	35°	40°
	20° inclined 	25° inclined 	30° inclined 	35° inclined 	40° inclined 
Gas flow					
Wafer region Return flow	No	No	No	Yes	Yes
Gas partial pressure	2.6 Pa	2.9 Pa	3.1 Pa	7.8 Pa	9.7 Pa

FIG. 11

Evaluation Example 9	HCD flow rate:3slm →	Analysis result	Second opening	First opening	Second opening
		Flow rate ratio	0.997	0.976	1
		Flow rate uniformity ±%	±1.20%		
Evaluation Example 10	HCD flow rate:5.9slm →	Analysis result	Second opening	First opening	Second opening
		Flow rate ratio	0.993	0.970	1
		Flow rate uniformity ±%	±1.52%		
Evaluation Example 11	HCD flow rate:12slm →	Analysis result	Second opening	First opening	Second opening
		Flow rate ratio	0.989	0.984	1
		Flow rate uniformity ±%	±0.81%		

FIG. 12

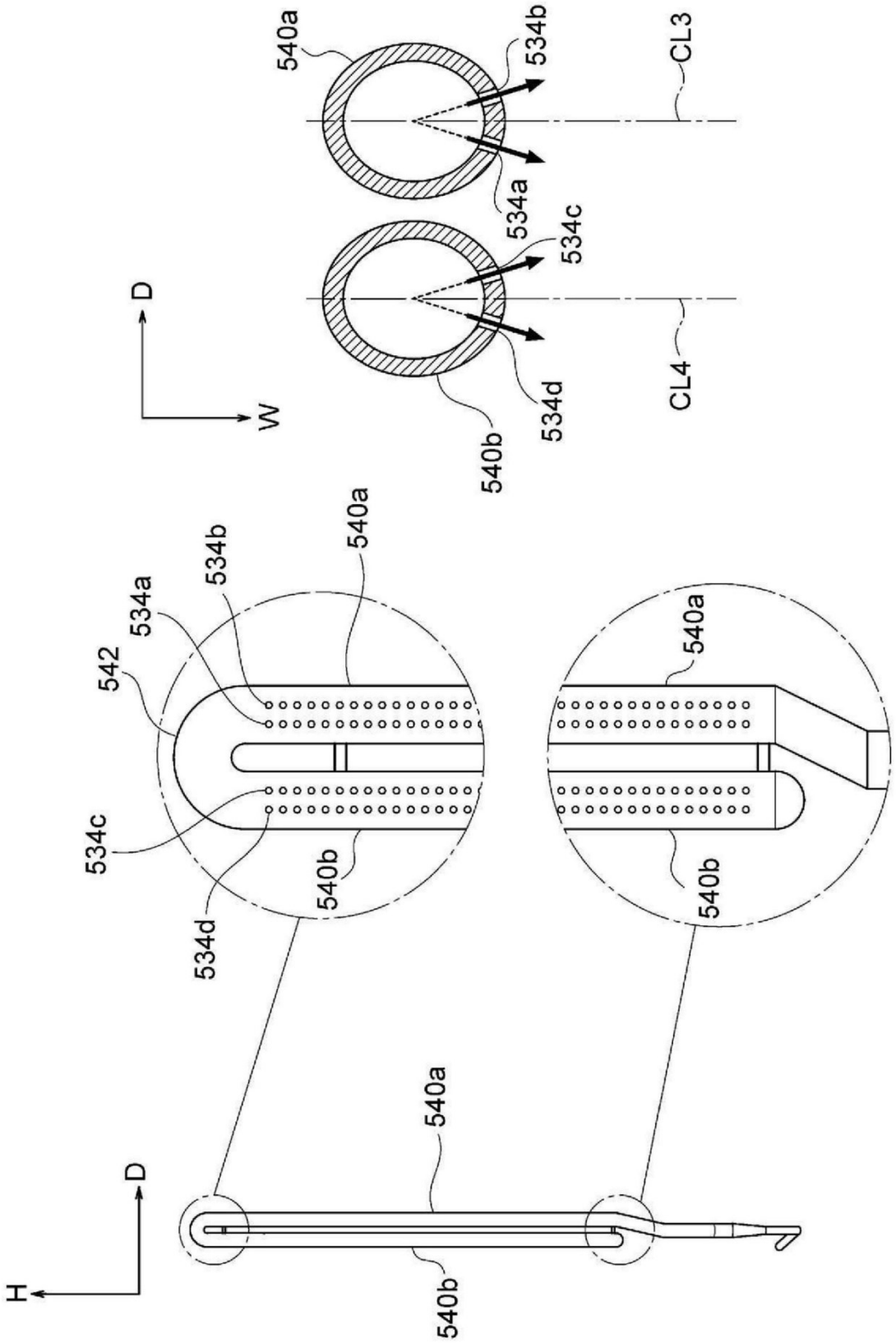

540a
534b
CL3
534a
534c
CL4
534d
540b
D
W
540a
534b
534a
542
534c
534d
540b
540a
540b
540a
D
H
540b

FIG. 13

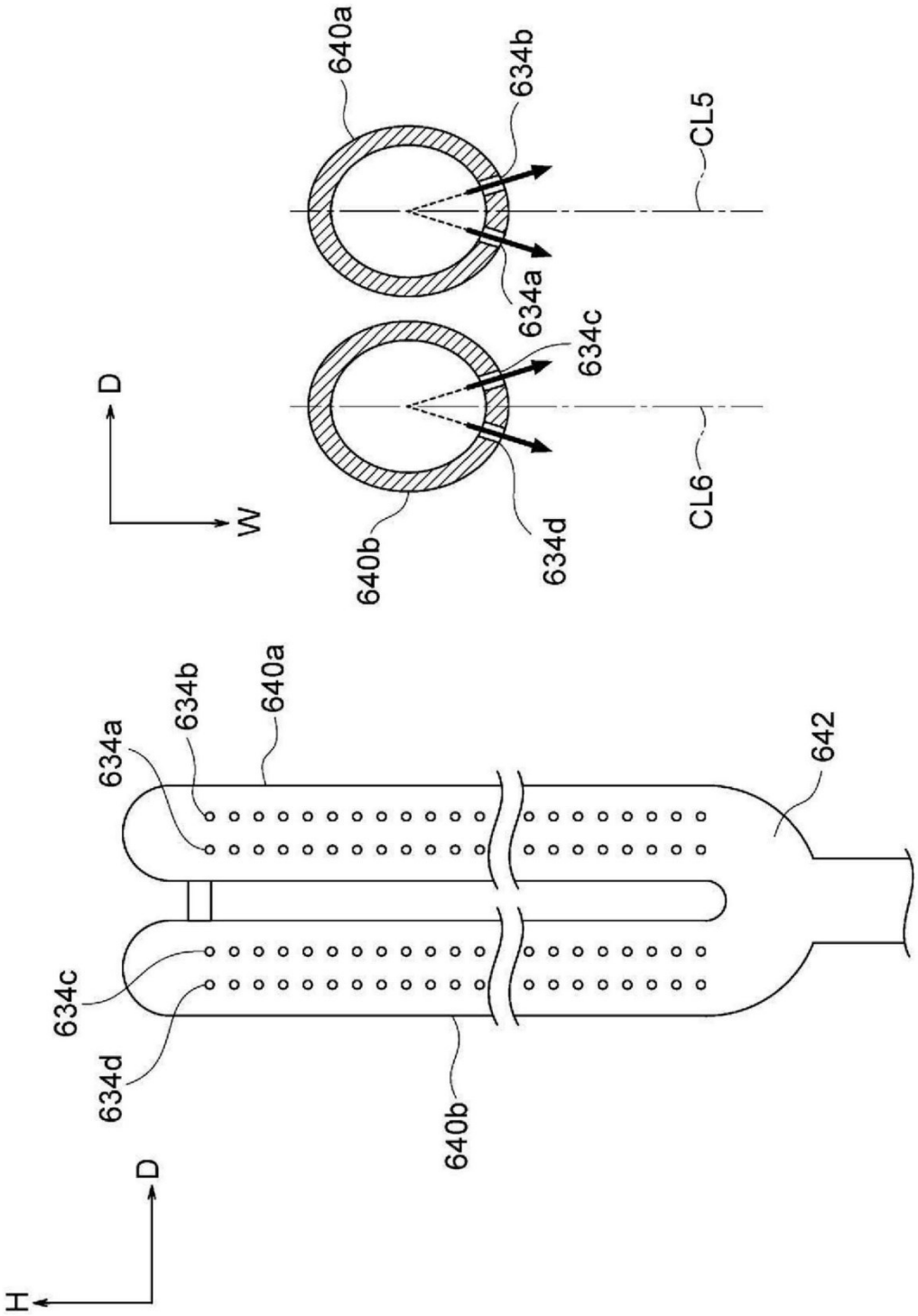

640a
634b
CL5
634a
634c
CL6
640b
634d
D
W
634a
634b
640a
642
634c
634d
640b
D
H

FIG. 14

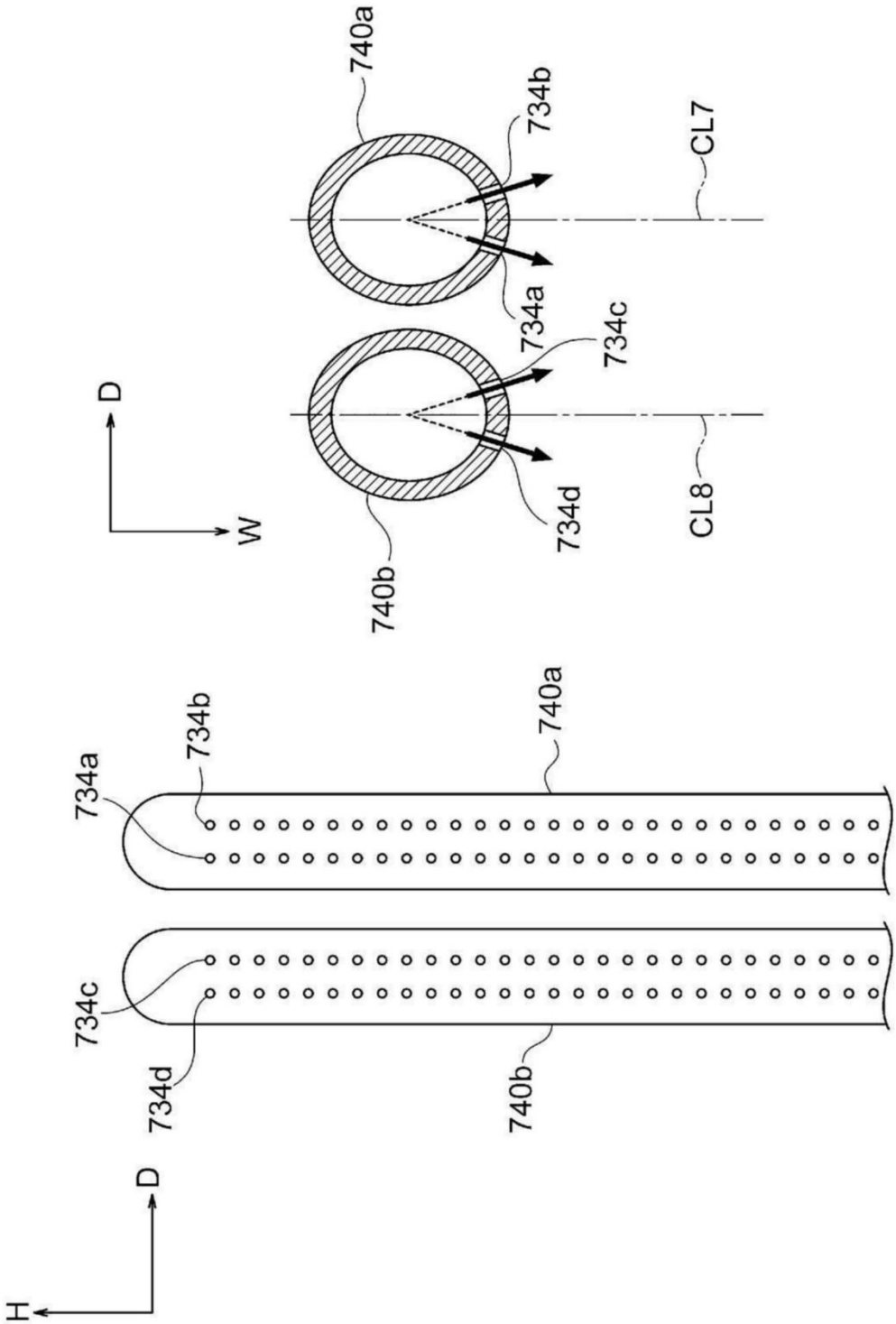

740a
734b
CL7
734a
734c
D
W
CL8
734d
740b
734a
734b
740a
734c
734d
740b
D
H

FIG. 15

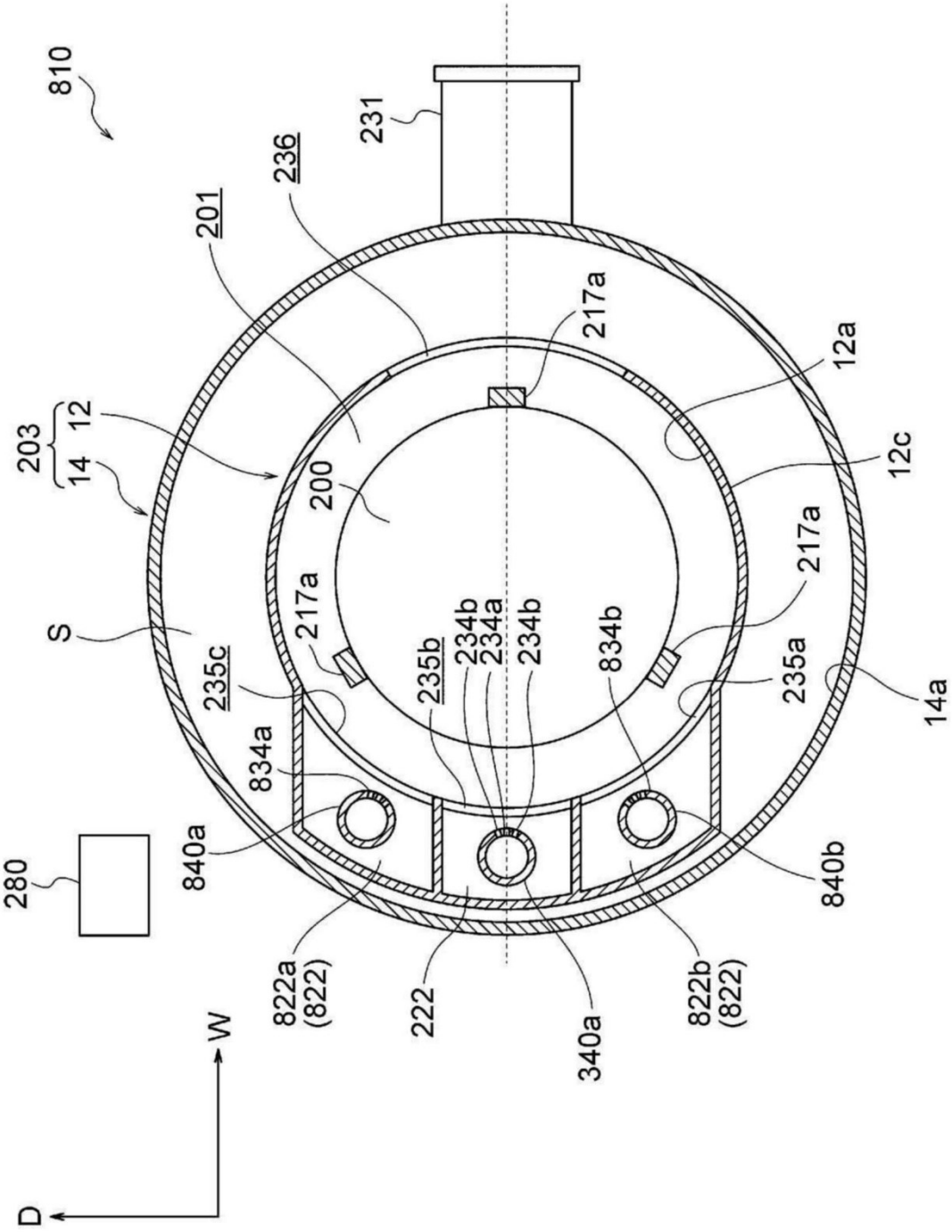

810
231
236
201
203
12
14
200
217a
12a
12c
S
235c
234b
234a
235b
834b
235a
14a
834a
840a
840b
280
822a
(822)
222
340a
822b
(822)
W
D

FIG. 16A

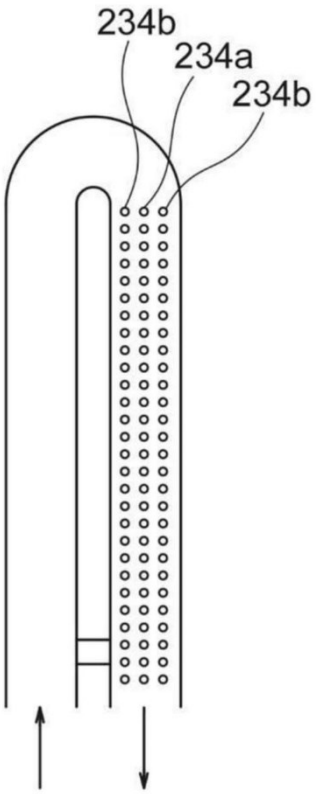


FIG. 16B

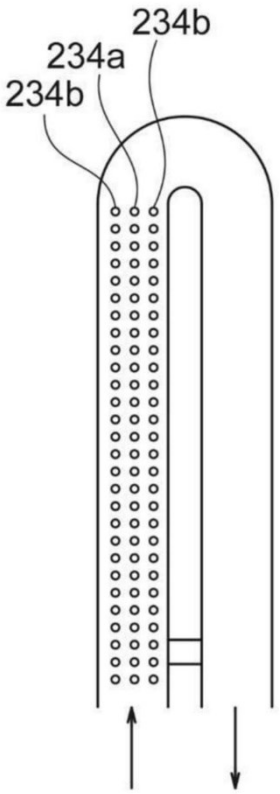


FIG. 17

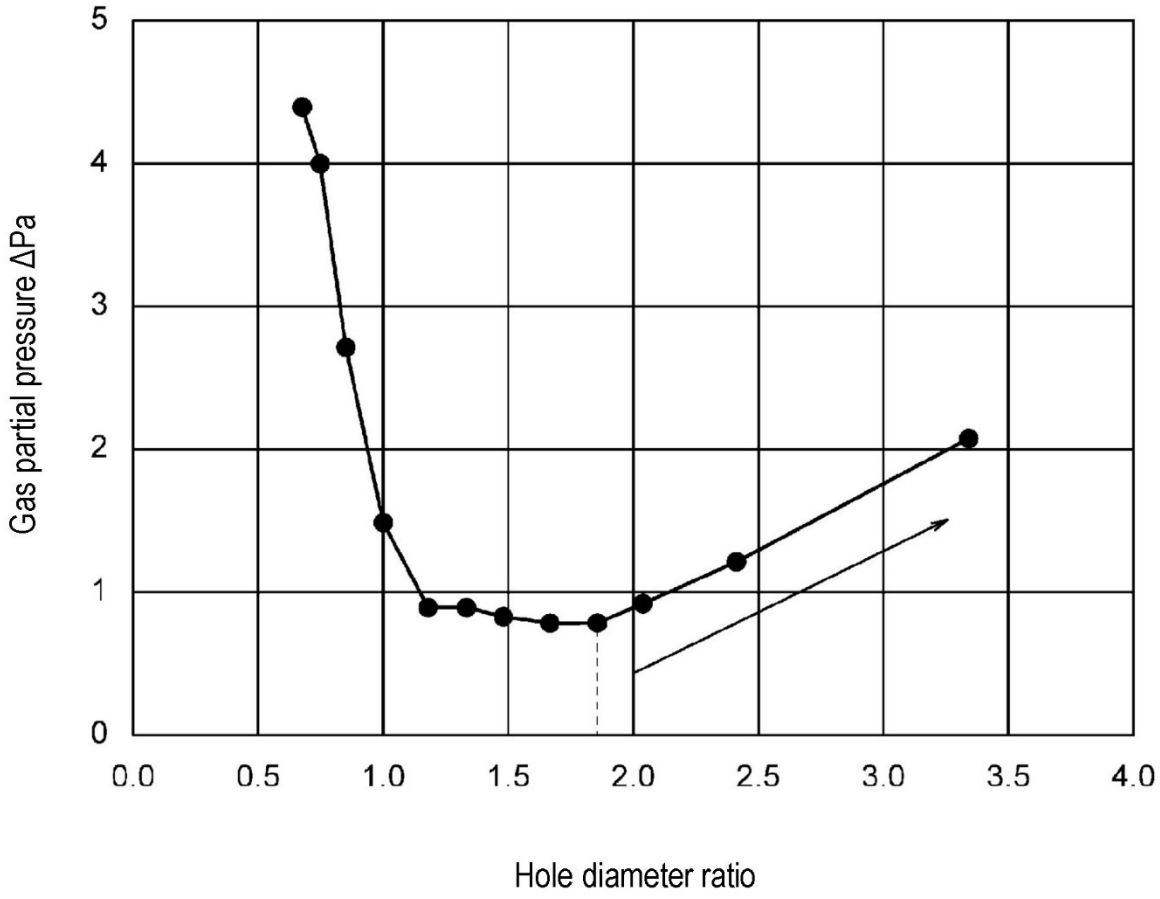
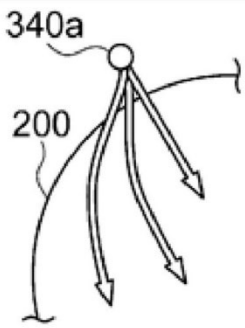
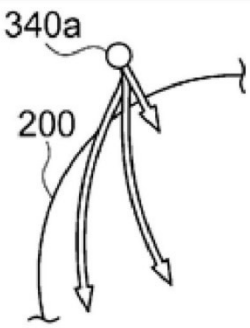
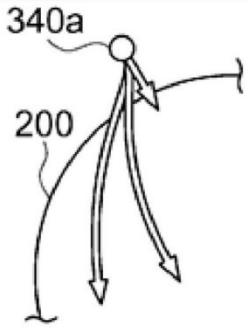
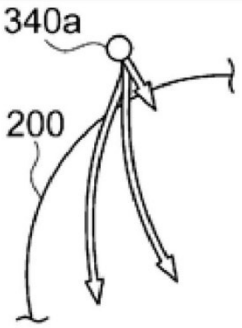

Gas partial pressure ΔPa
5
4
3
2
1
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Hole diameter ratio

FIG. 18

	Evaluation example 12			Evaluation example 13			Evaluation example 14			Evaluation example 15		
Hole diameter ratio	1.19:1:1.19			1.85:1:1.85			2.41:1:2.41			3.33:1:3.33		
Gas flow ratio	Second opening	First opening	Second opening	Second opening	First opening	Second opening	Second opening	First opening	Second opening	Second opening	First opening	Second opening
	1.68	1	1.67	5.79	1	5.51	13.92	1	13.65	48.99	1	47.27
Cross-sectional area ratio of opening	1.4:1:1.4			3.4:1:3.4			5.8:1:5.8			11.1:1:11.1		
Gas flow												
Wafer region return flow	No			No			No			No		
Gas partial pressure	0.9 Pa			0.8 Pa			1.2 Pa			2.1 Pa		