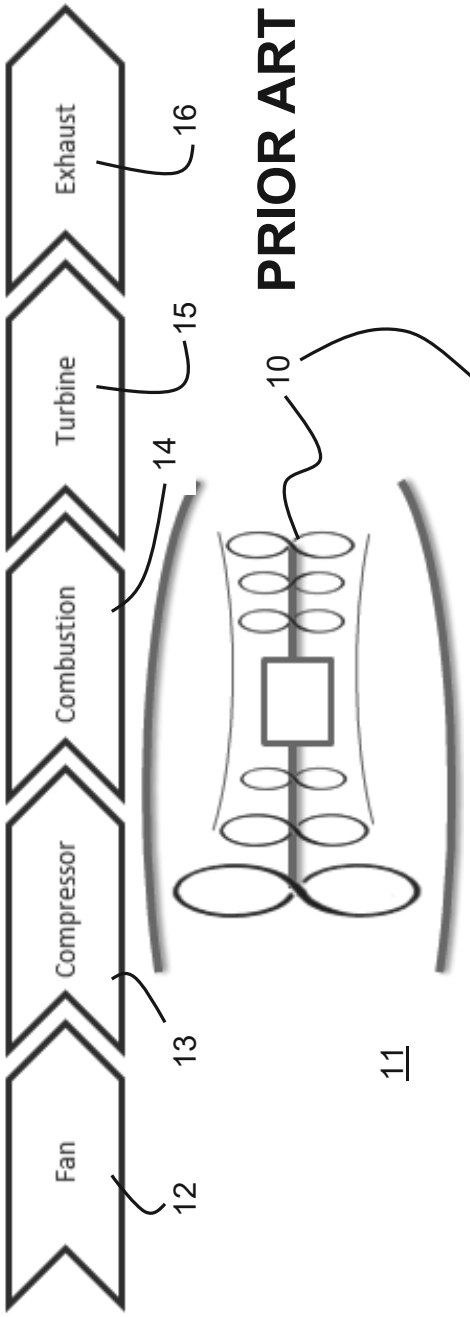

Fan
Compressor
Combustion
Turbine
Exhaust
12
13
14
15
16
10
11
PRIOR ART

FIG. 1

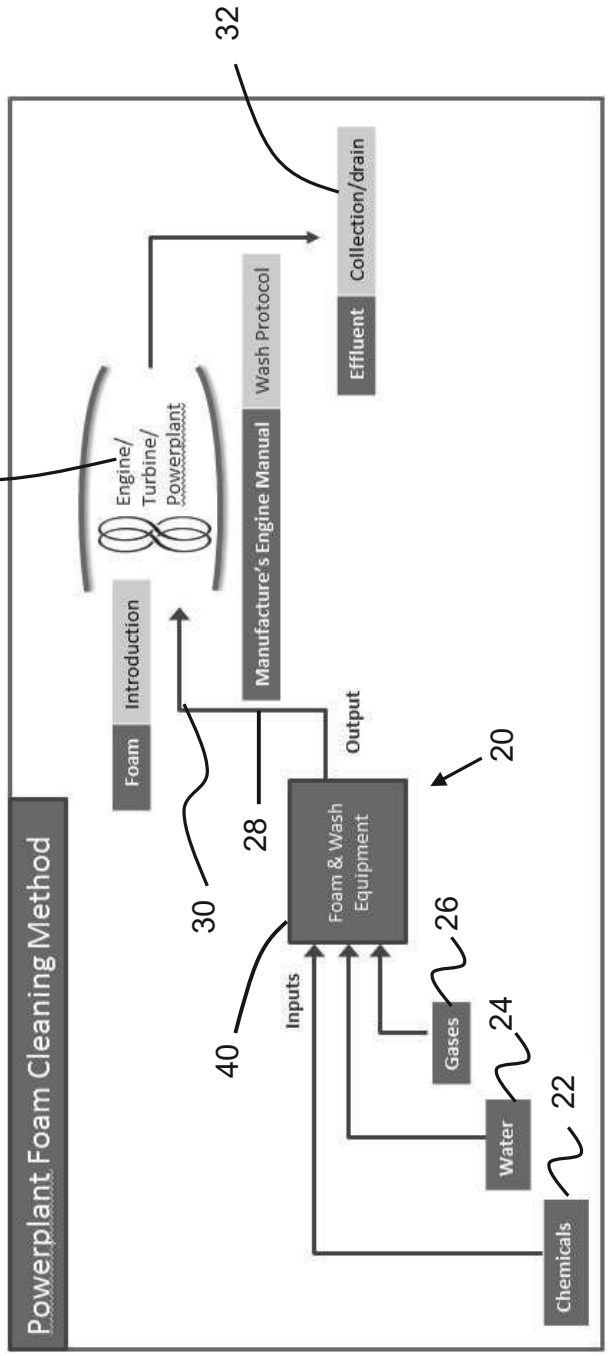

Powerplant Foam Cleaning Method
Foam
Introduction
Engine/
Turbine/
Powerplant
Manufacture's Engine Manual
Wash Protocol
Effluent
Collection/drain
Output
Foam & Wash
Equipment
Inputs
Gases
Water
Chemicals
20
22
24
26
28
30
32
40

FIG. 2

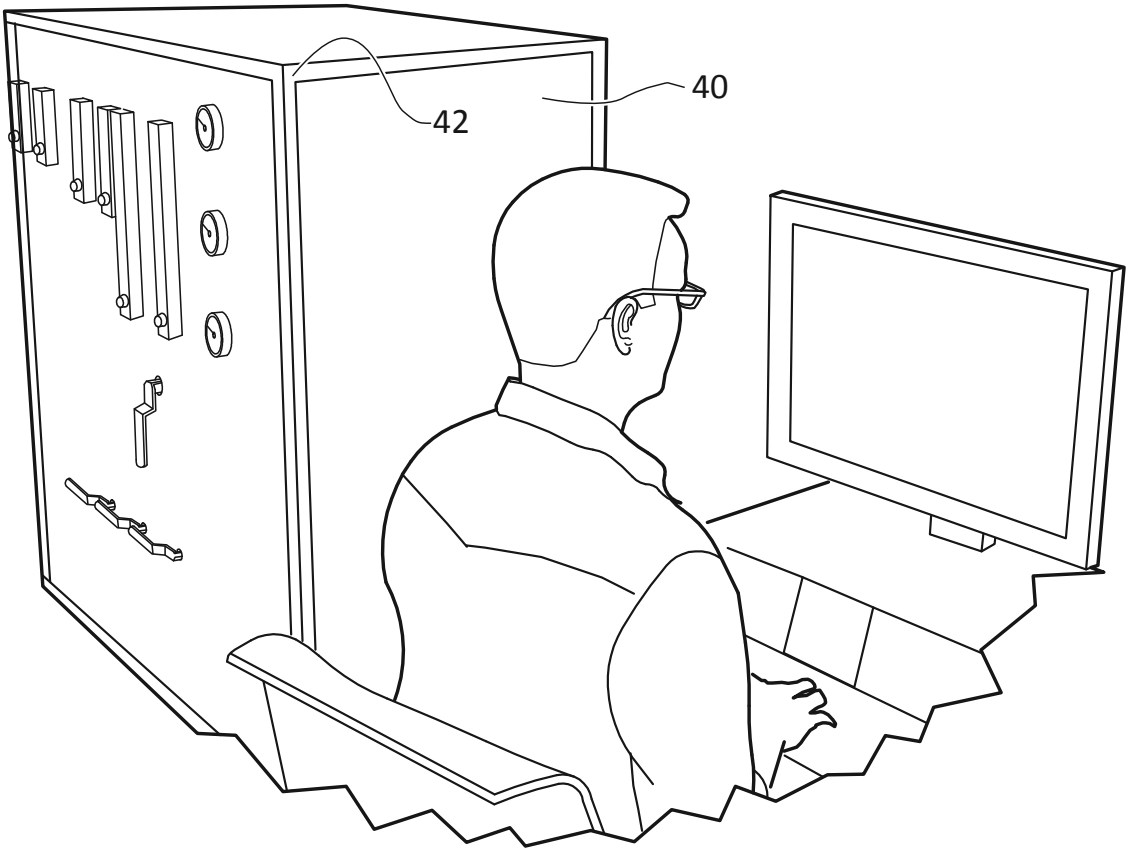


FIG. 3A

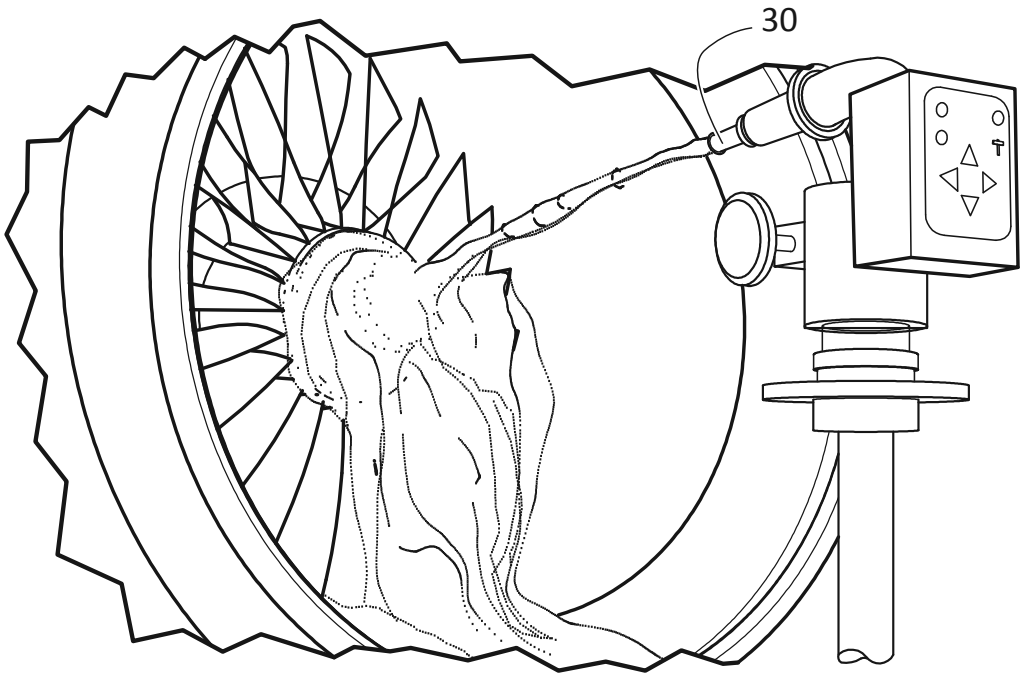


FIG. 3B

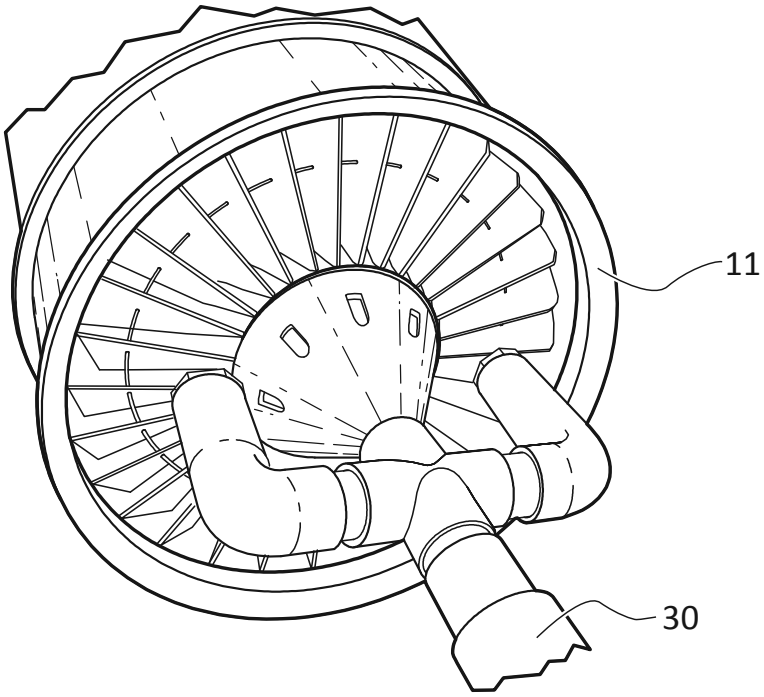


FIG. 3C

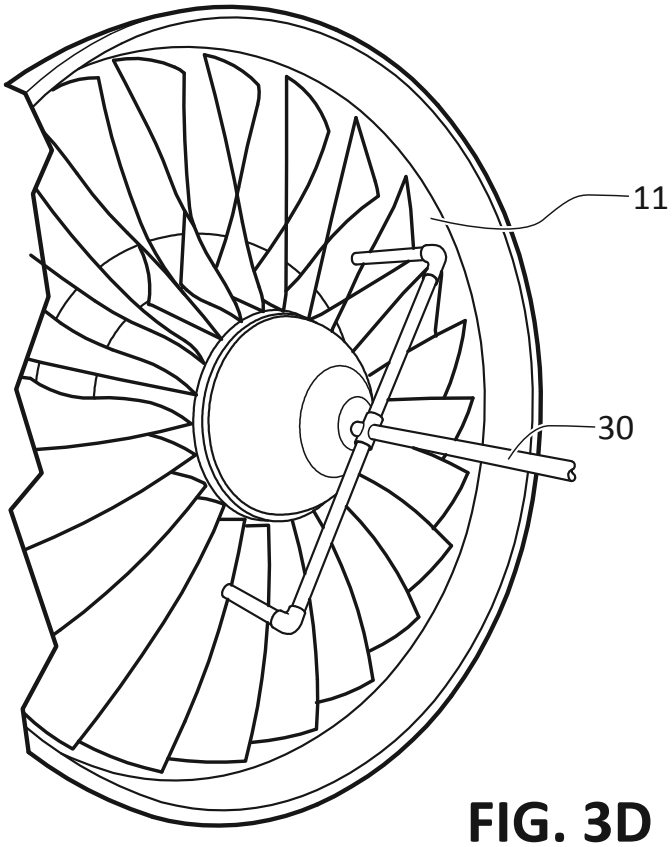


FIG. 3D

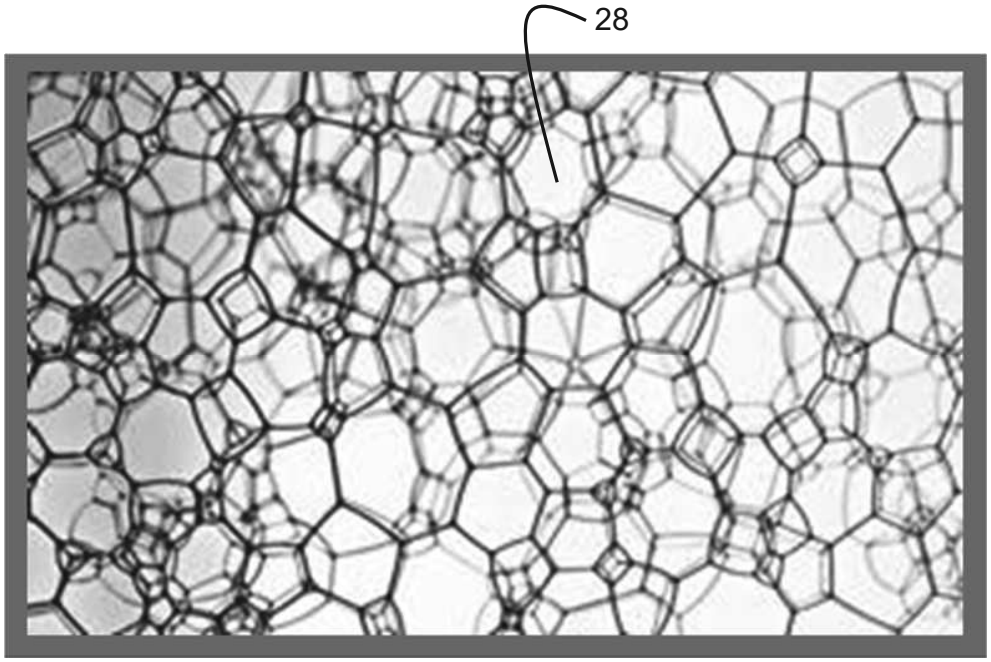

28

FIG. 4

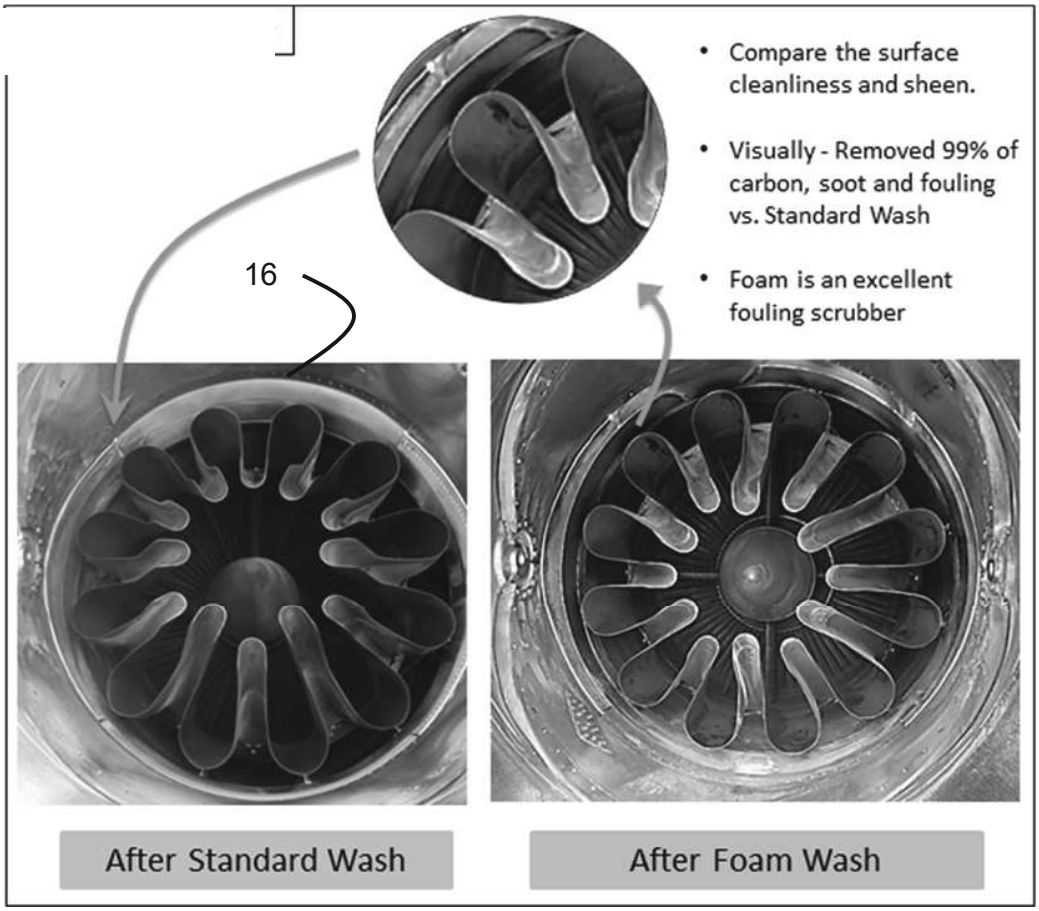

• Compare the surface cleanliness and sheen.
• Visually - Removed 99% of carbon, soot and fouling vs. Standard Wash
• Foam is an excellent fouling scrubber
16
After Standard Wash
After Foam Wash

FIG. 5

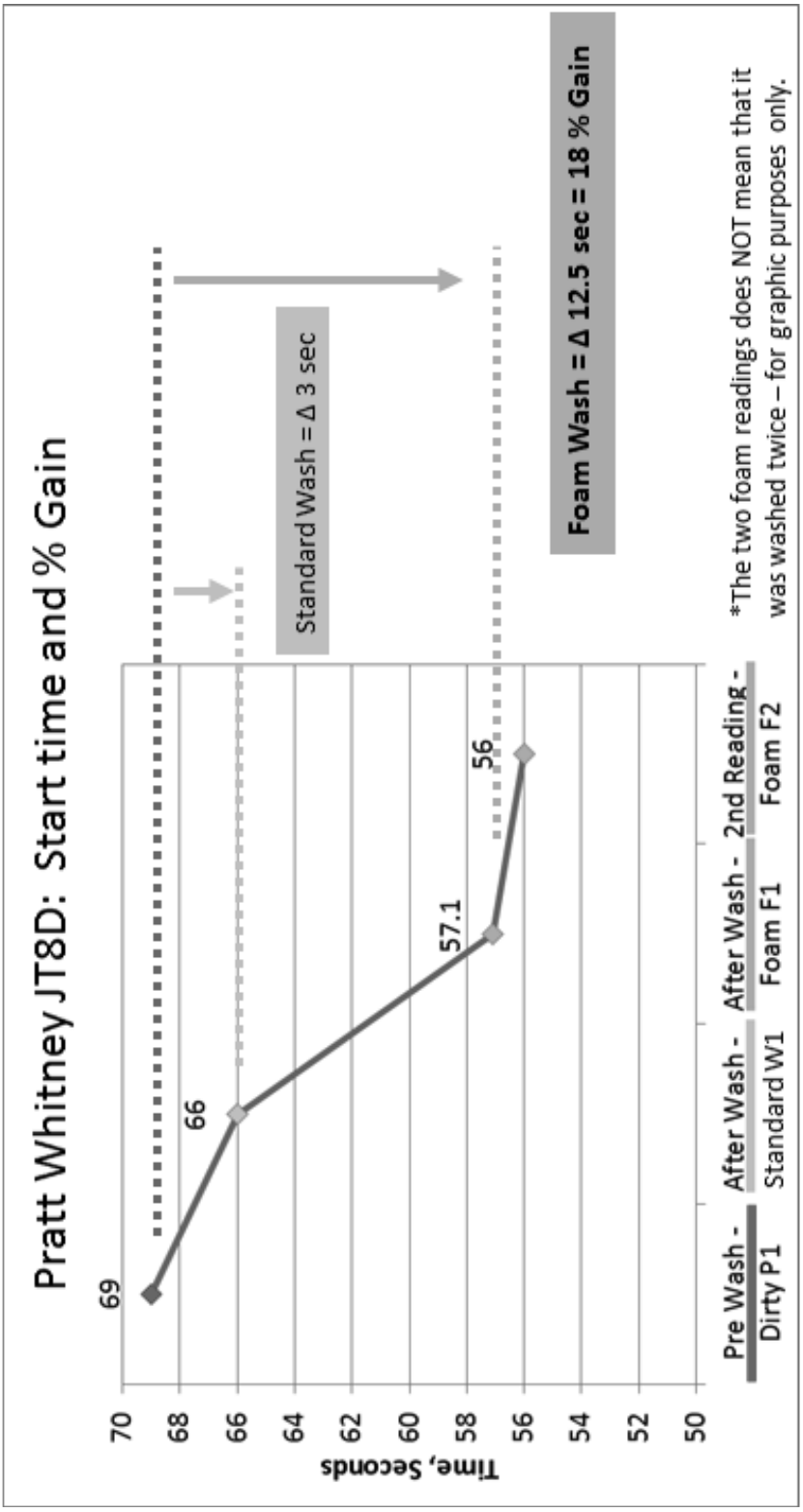

Pratt Whitney JT8D: Start time and % Gain
Time, Seconds
70
68
66
64
62
60
58
56
54
52
50
69
66
57.1
56
Standard Wash = Δ 3 sec
Foam Wash = Δ 12.5 sec = 18 % Gain
Pre Wash - Dirty P1
After Wash - Standard W1
After Wash - Foam F1
2nd Reading - Foam F2
*The two foam readings does NOT mean that it was washed twice – for graphic purposes only.

FIG. 6

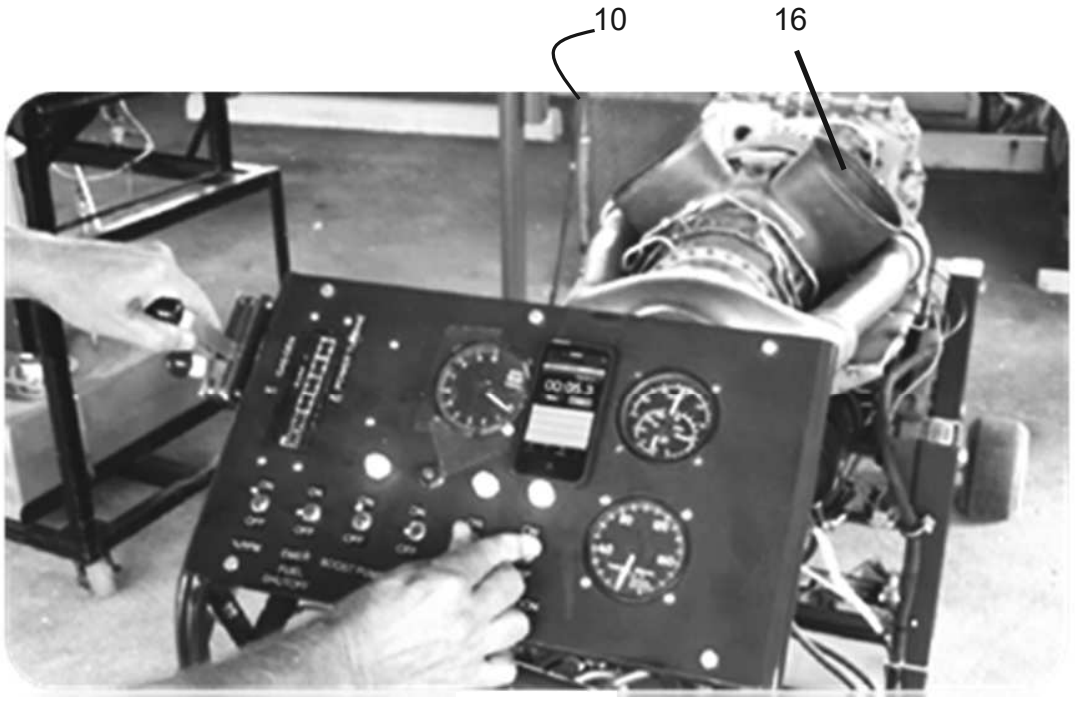


FIG. 7



FIG. 8

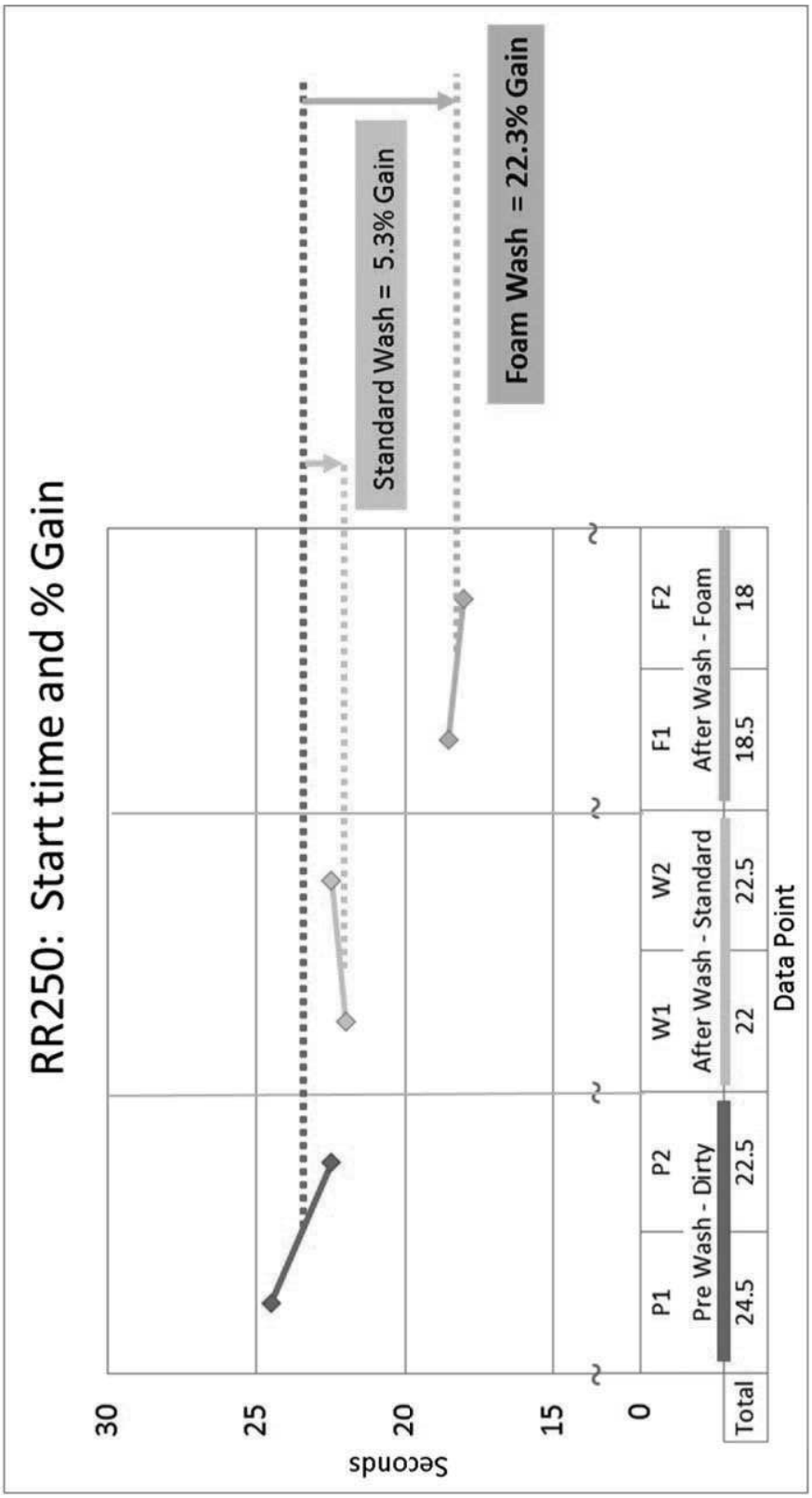

RR250: Start time and % Gain
Standard Wash = 5.3% Gain
Foam Wash = 22.3% Gain
Seconds
30
25
20
15
0
Pre Wash - Dirty
After Wash - Standard
After Wash - Foam
P1
P2
W1
W2
F1
F2
Total
24.5
22.5
22
22.5
18.5
18
Data Point

FIG. 9

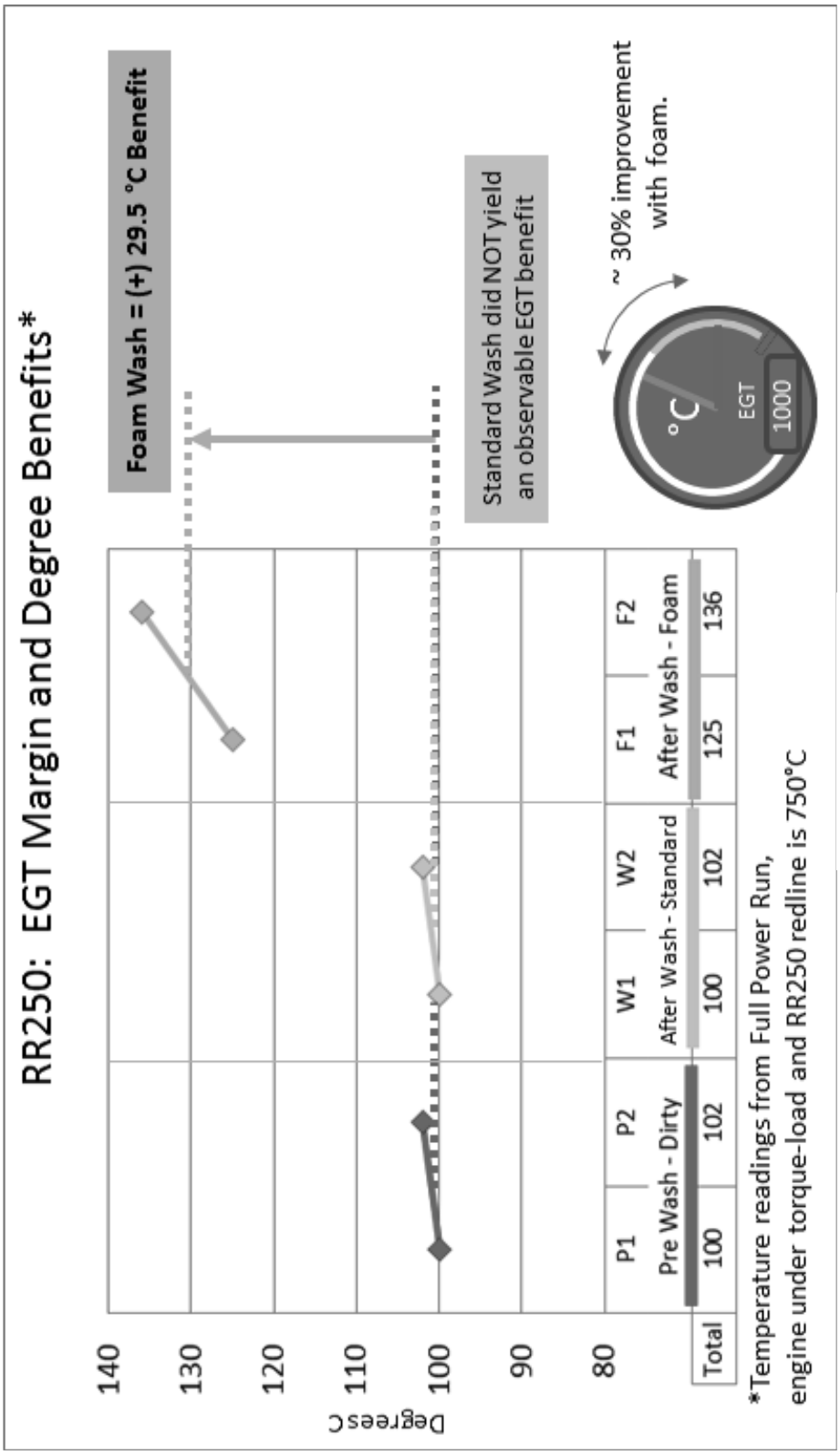

RR250: EGT Margin and Degree Benefits*
Foam Wash = (+) 29.5 °C Benefit
Standard Wash did NOT yield an observable EGT benefit
~ 30% improvement with foam.
°C
EGT
1000
Degrees C
140
130
120
110
100
90
80
Total
100
P1
P2
102
Pre Wash - Dirty
W1
100
W2
102
After Wash - Standard
F1
125
F2
136
After Wash - Foam
*Temperature readings from Full Power Run,
engine under torque-load and RR250 redline is 750°C

FIG. 10

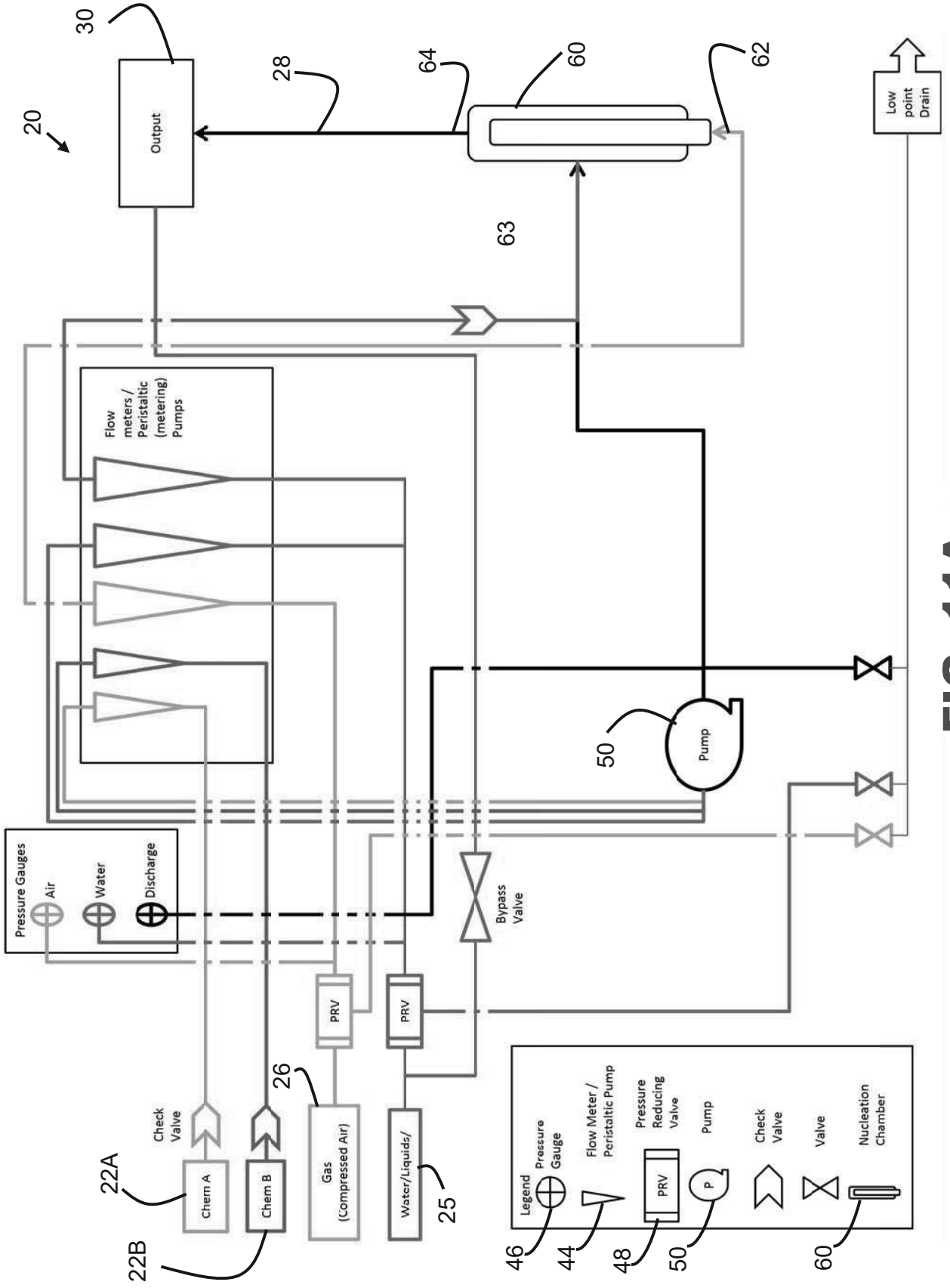

20
30
Output
28
64
60
62
63
Low point Drain
Flow meters / Peristaltic (metering) Pumps
50
Pump
Pressure Gauges
Air
Water
Discharge
Bypass Valve
PRV
PRV
Check Valve
Chem A
Chem B
26
Gas (Compressed Air)
Water/Liquids/
25
22A
22B
Legend
Pressure Gauge
Flow Meter / Peristaltic Pump
Pressure Reducing Valve
Pump
Check Valve
Valve
Nucleation Chamber
46
44
48
50
60

FIG. 11A

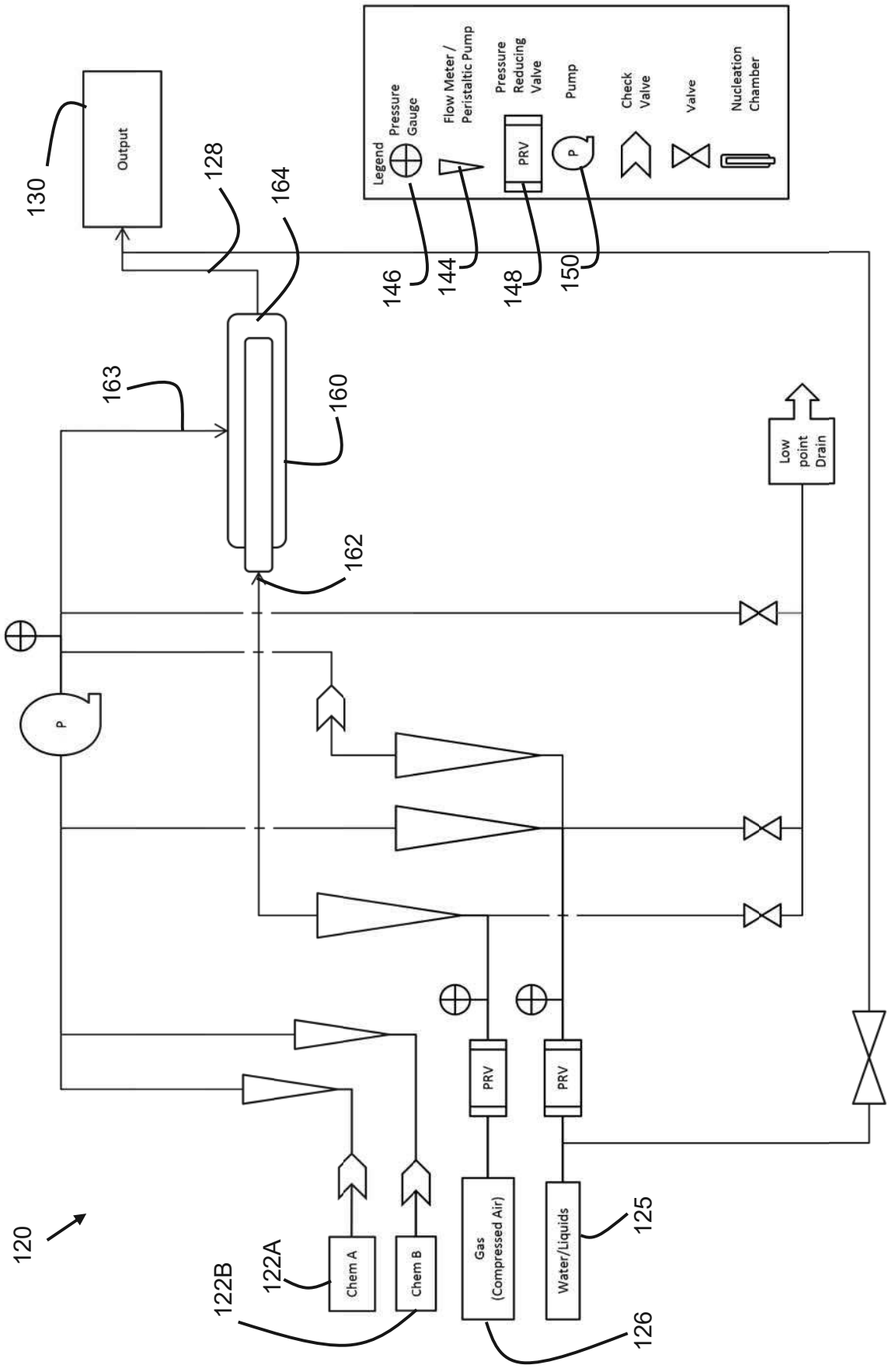

Legend
Pressure Gauge
Flow Meter / Peristaltic Pump
Pressure Reducing Valve
Pump
Check Valve
Valve
Nucleation Chamber
PRV
P
Output
130
128
164
146
144
148
150
163
160
162
Low point Drain
120
122A
122B
Chem A
Chem B
Gas (Compressed Air)
Water/Liquids
125
126

FIG. 11B

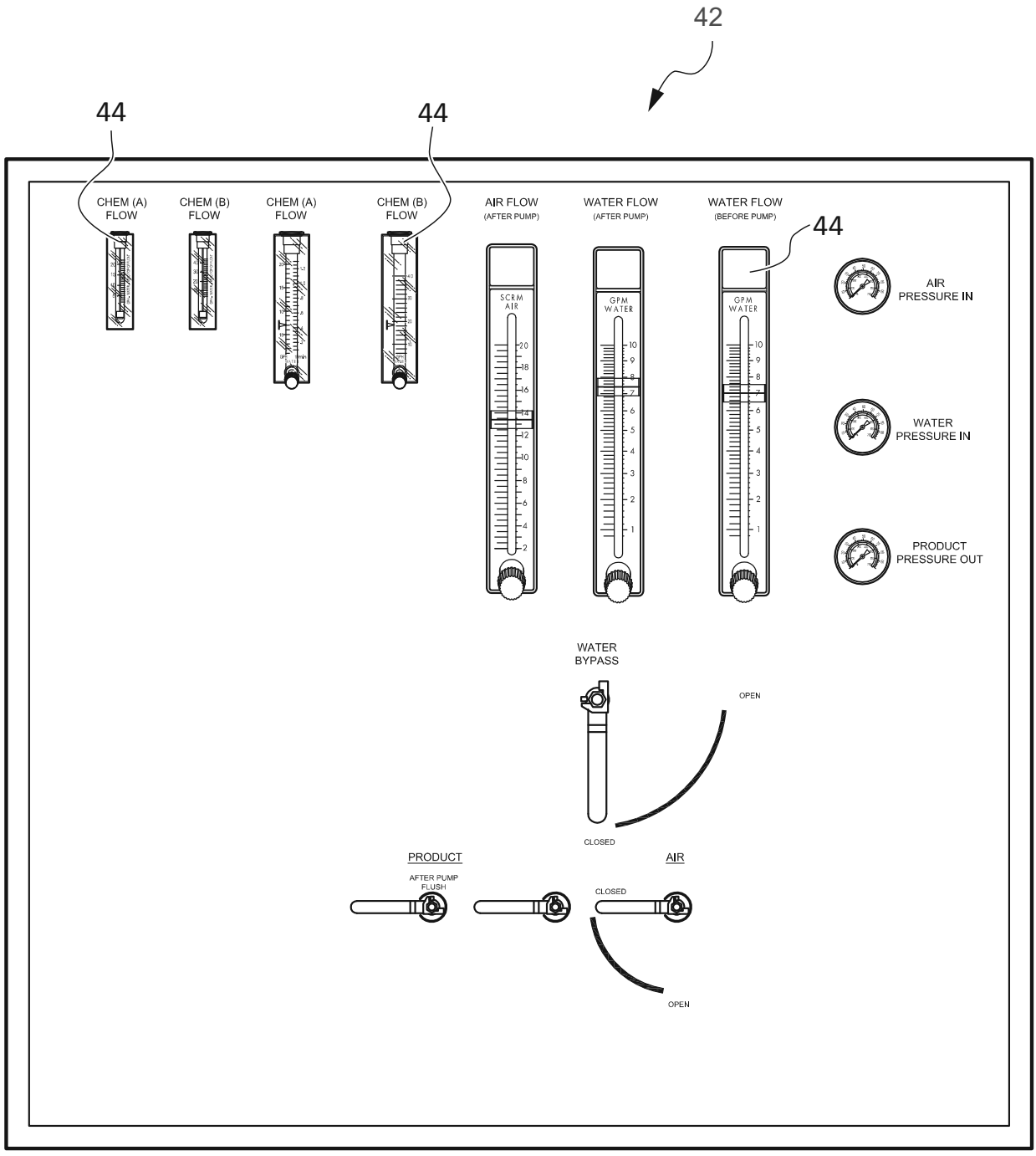

42
44
44
44
CHEM (A) FLOW
CHEM (B) FLOW
CHEM (A) FLOW
CHEM (B) FLOW
AIR FLOW (AFTER PUMP)
WATER FLOW (AFTER PUMP)
WATER FLOW (BEFORE PUMP)
SCFM AIR
GPM WATER
GPM WATER
AIR PRESSURE IN
WATER PRESSURE IN
PRODUCT PRESSURE OUT
WATER BYPASS
OPEN
CLOSED
PRODUCT
AFTER PUMP FLUSH
AIR
CLOSED
OPEN

FIG. 12A

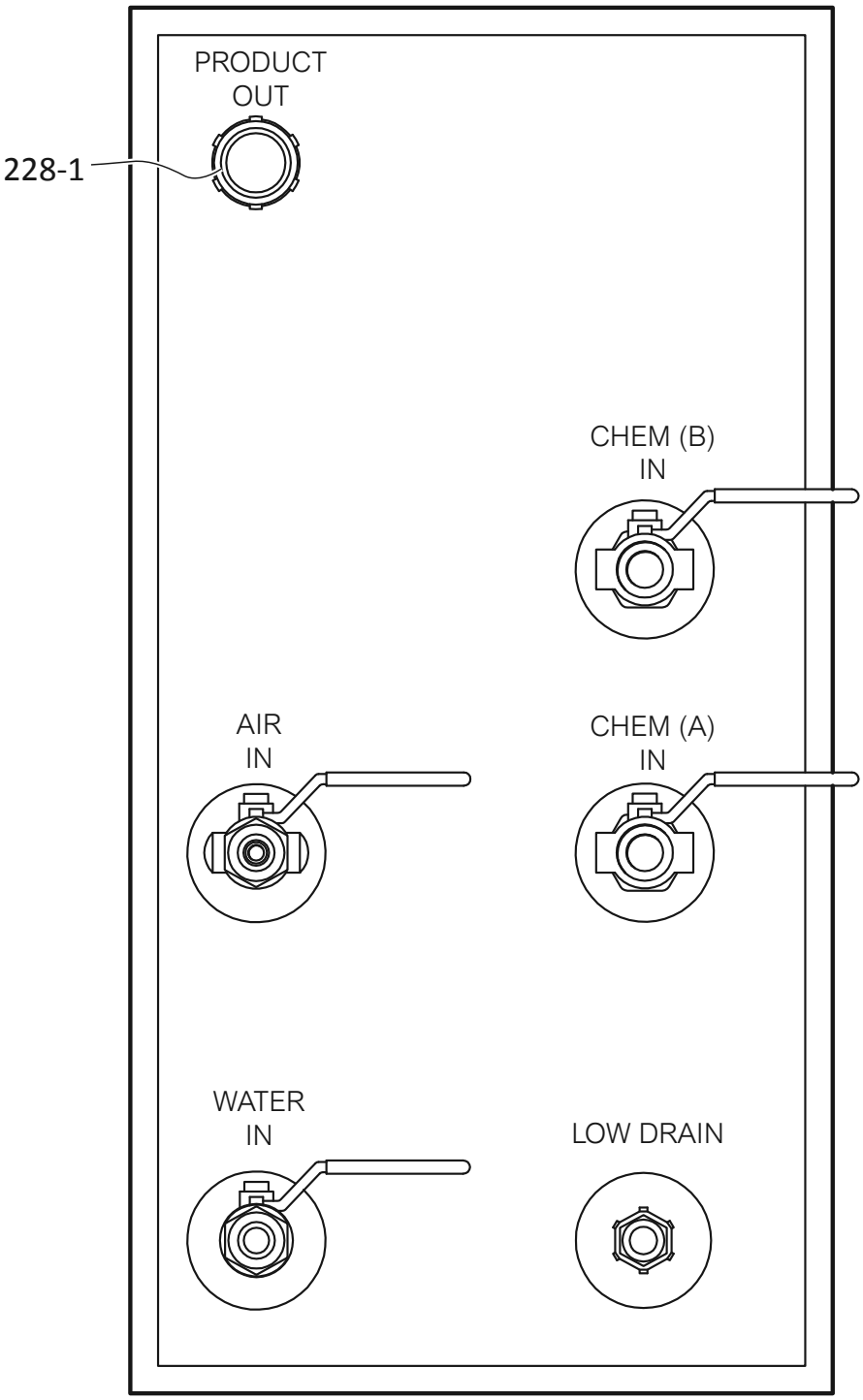


FIG. 12B

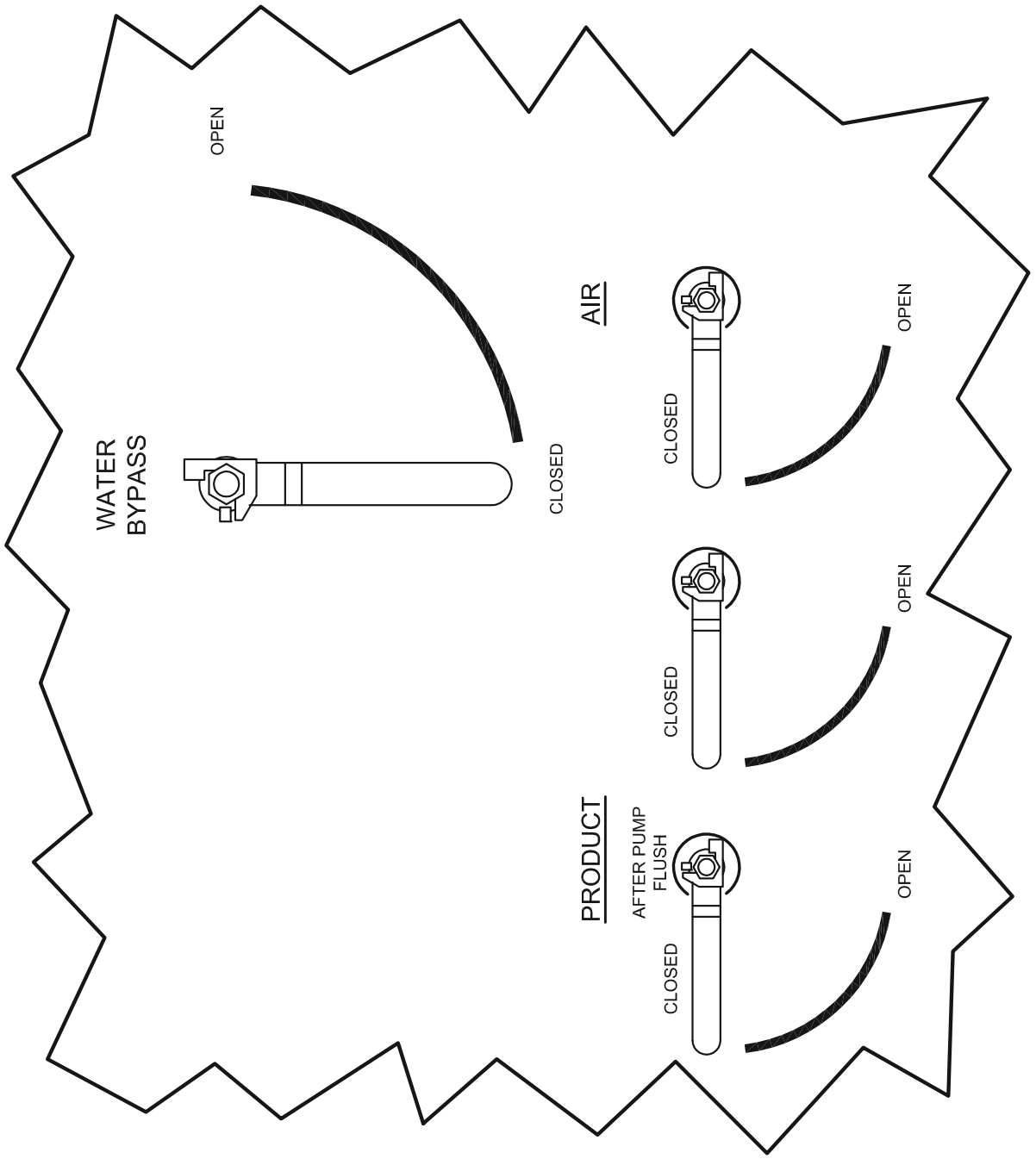

WATER
BYPASS
OPEN
CLOSED
AIR
CLOSED
OPEN
PRODUCT
AFTER PUMP
FLUSH
CLOSED
OPEN
CLOSED
OPEN
CLOSED
OPEN

FIG. 12C

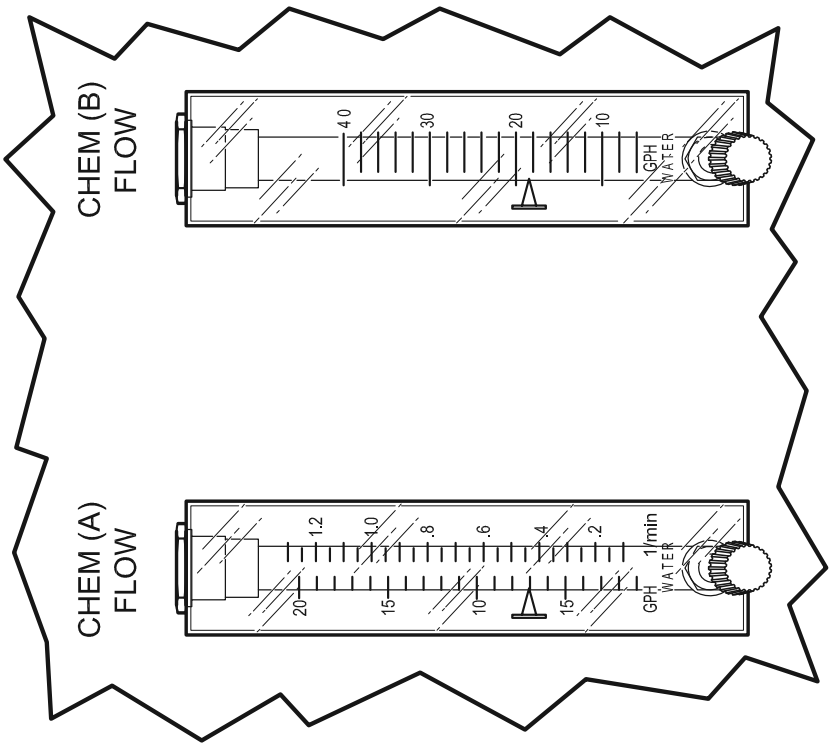


FIG. 13B

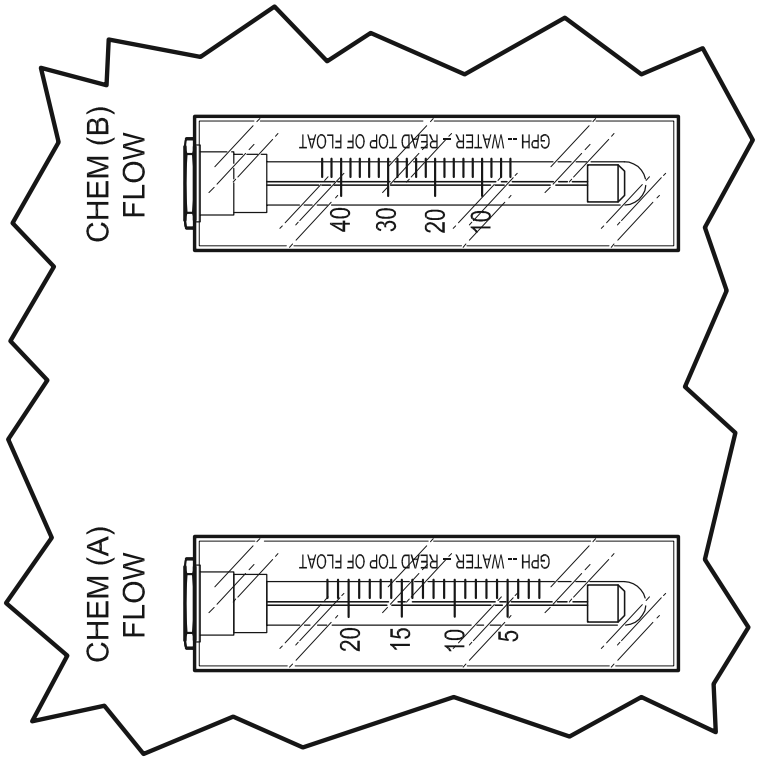


FIG. 13A

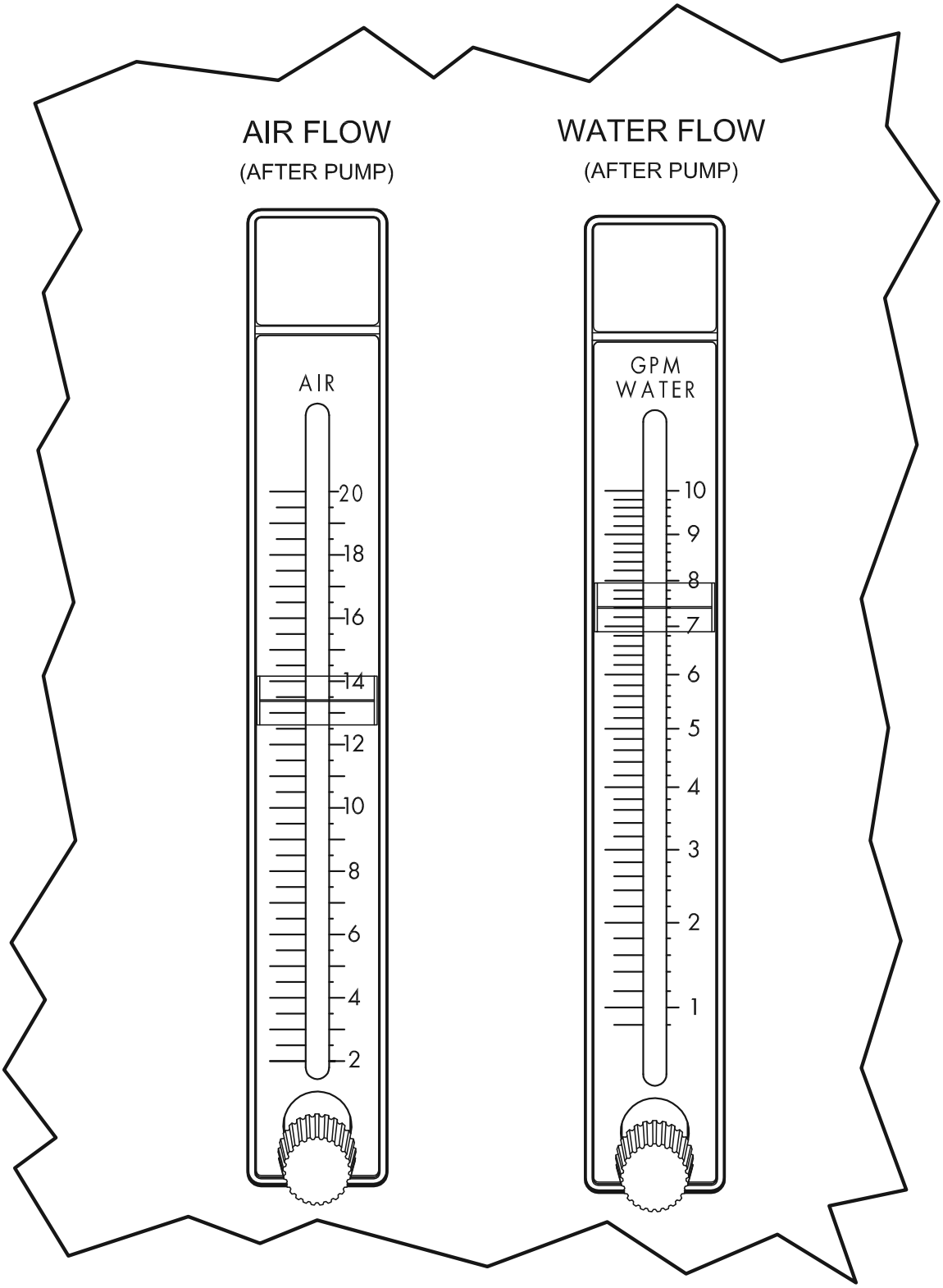

AIR FLOW
(AFTER PUMP)
WATER FLOW
(AFTER PUMP)
AIR
20
18
16
14
12
10
8
6
4
2
GPM
WATER
10
9
8
7
6
5
4
3
2
1

FIG. 13C

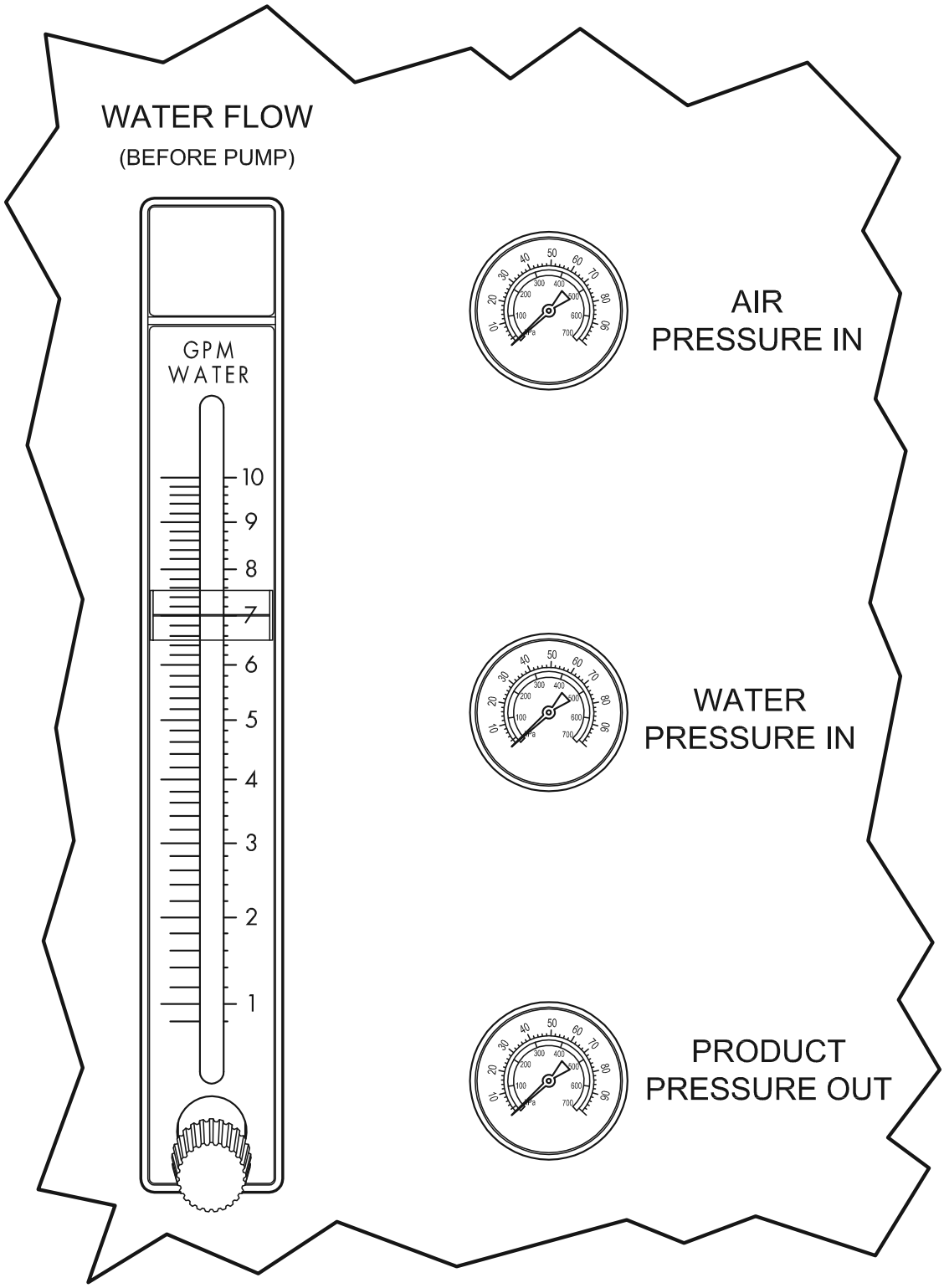

WATER FLOW
(BEFORE PUMP)
GPM
WATER
10
9
8
7
6
5
4
3
2
1
AIR
PRESSURE IN
WATER
PRESSURE IN
PRODUCT
PRESSURE OUT

FIG. 13D

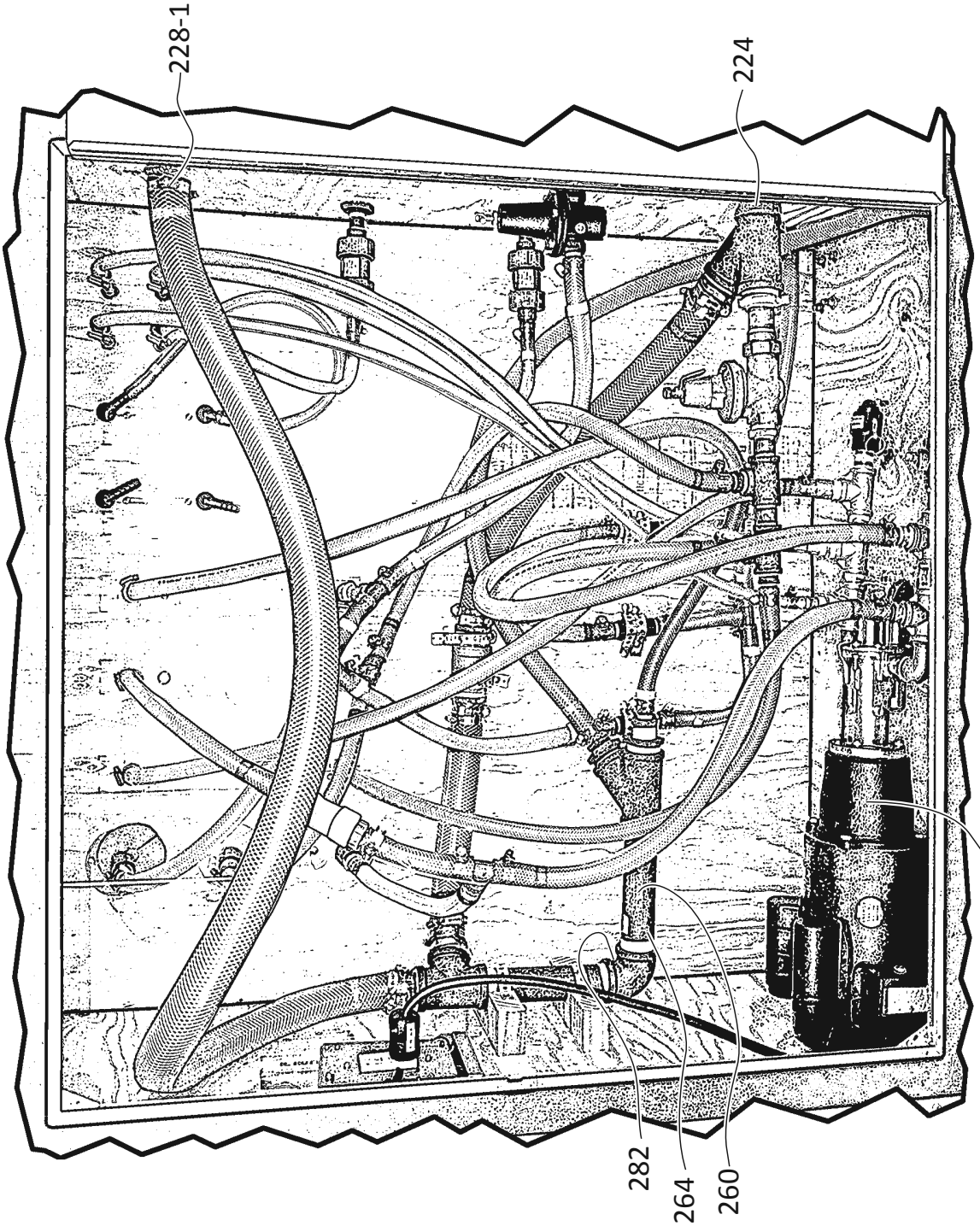


FIG. 14A

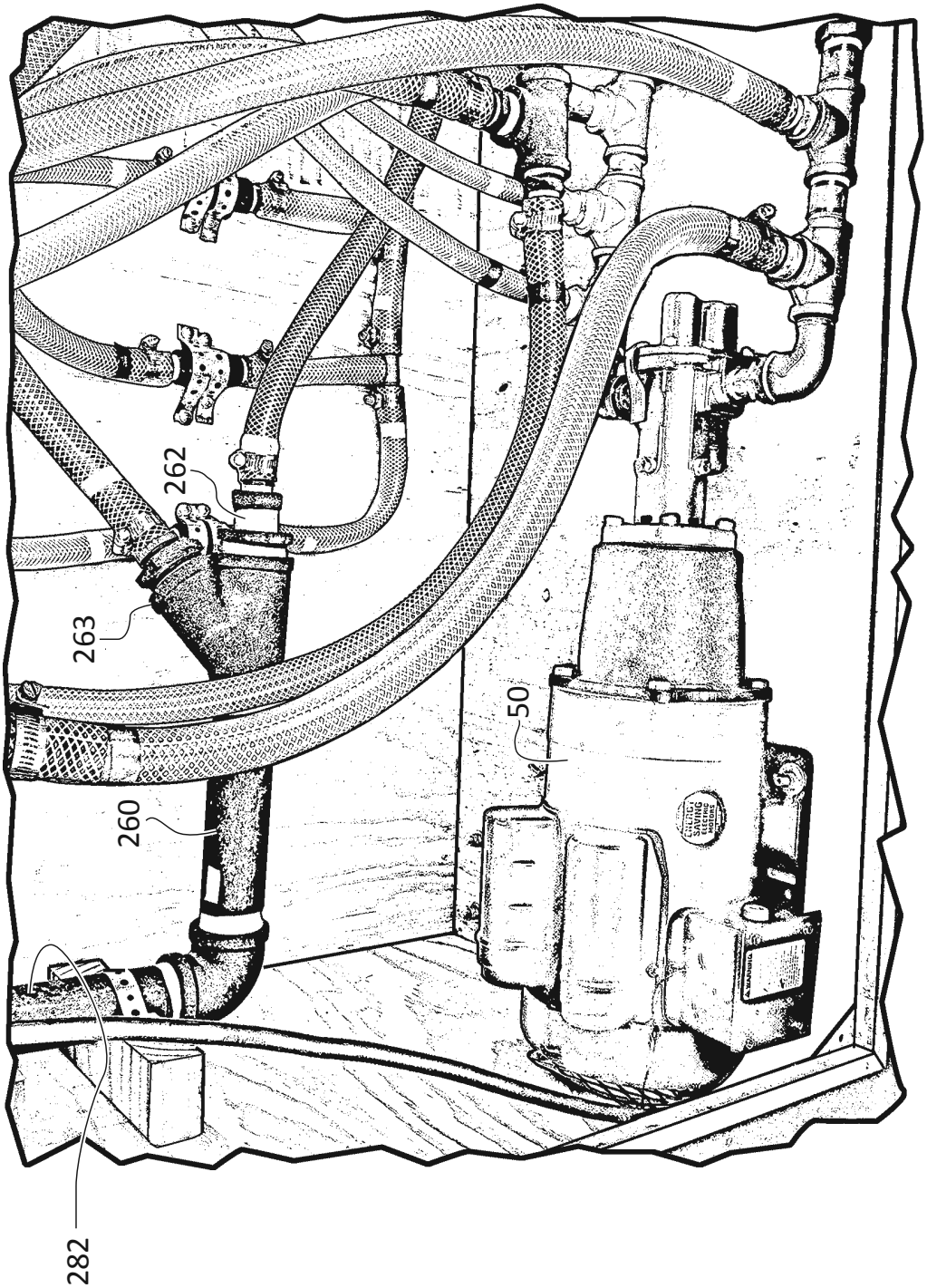


FIG. 14B

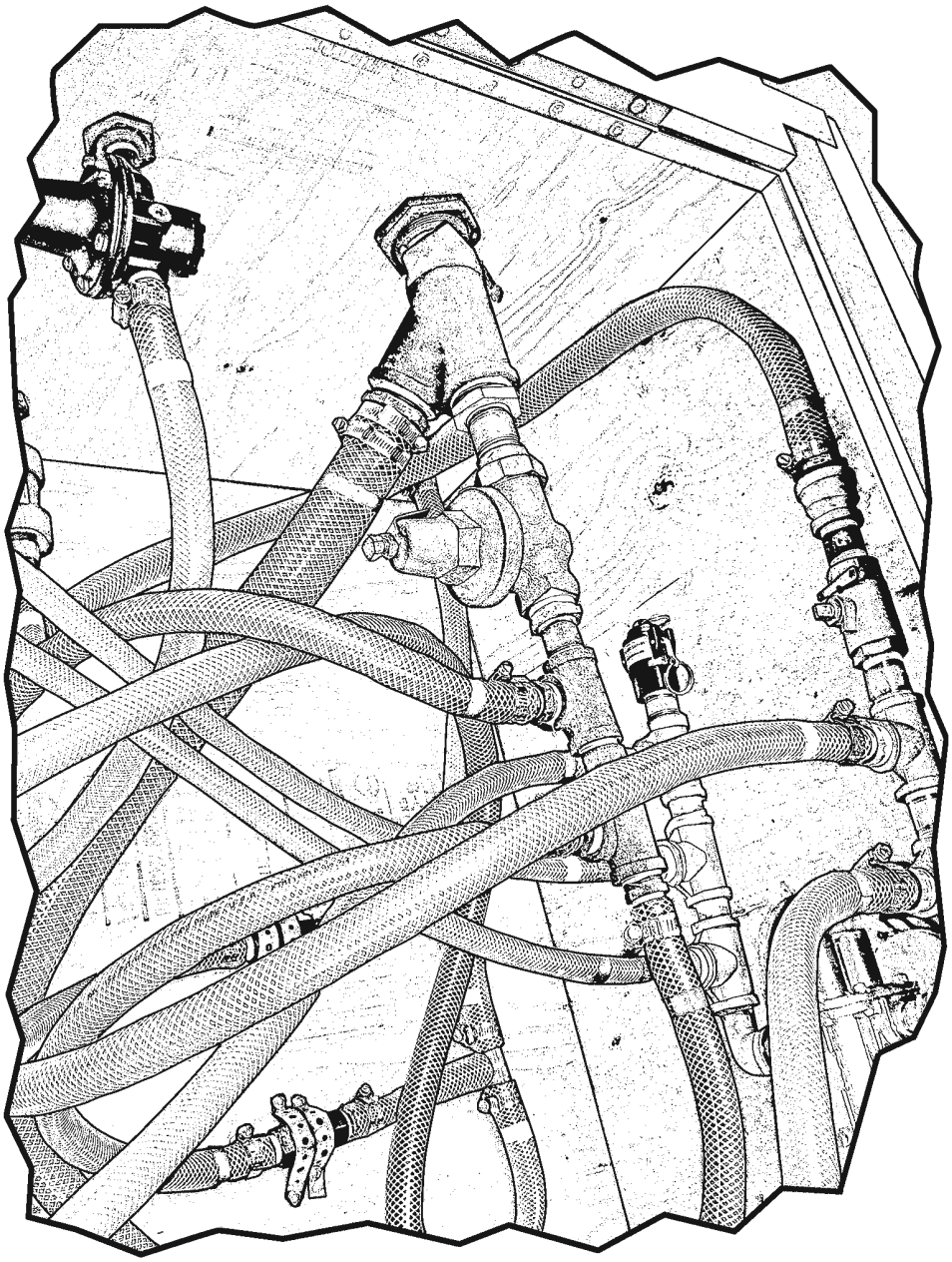


FIG. 14C

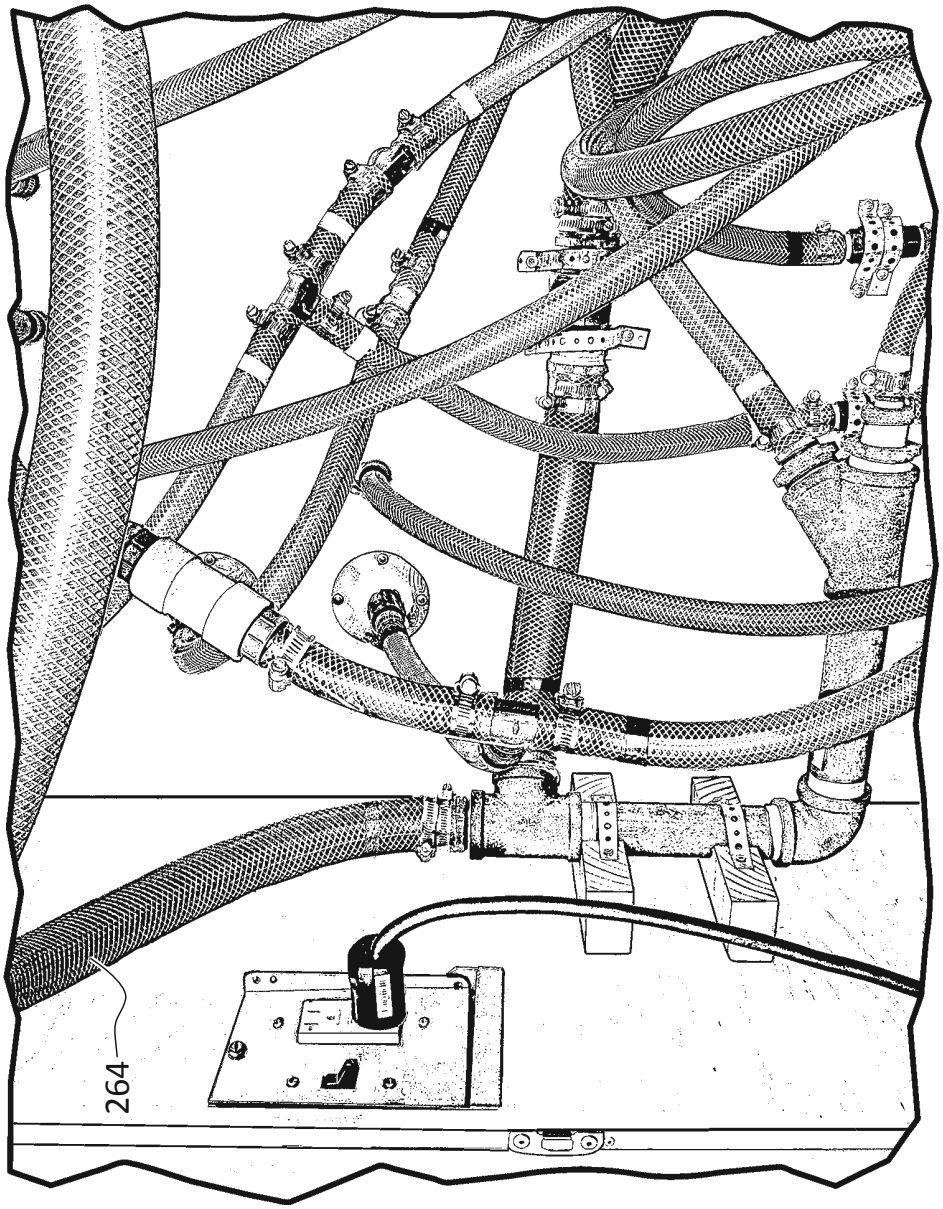


FIG. 14D

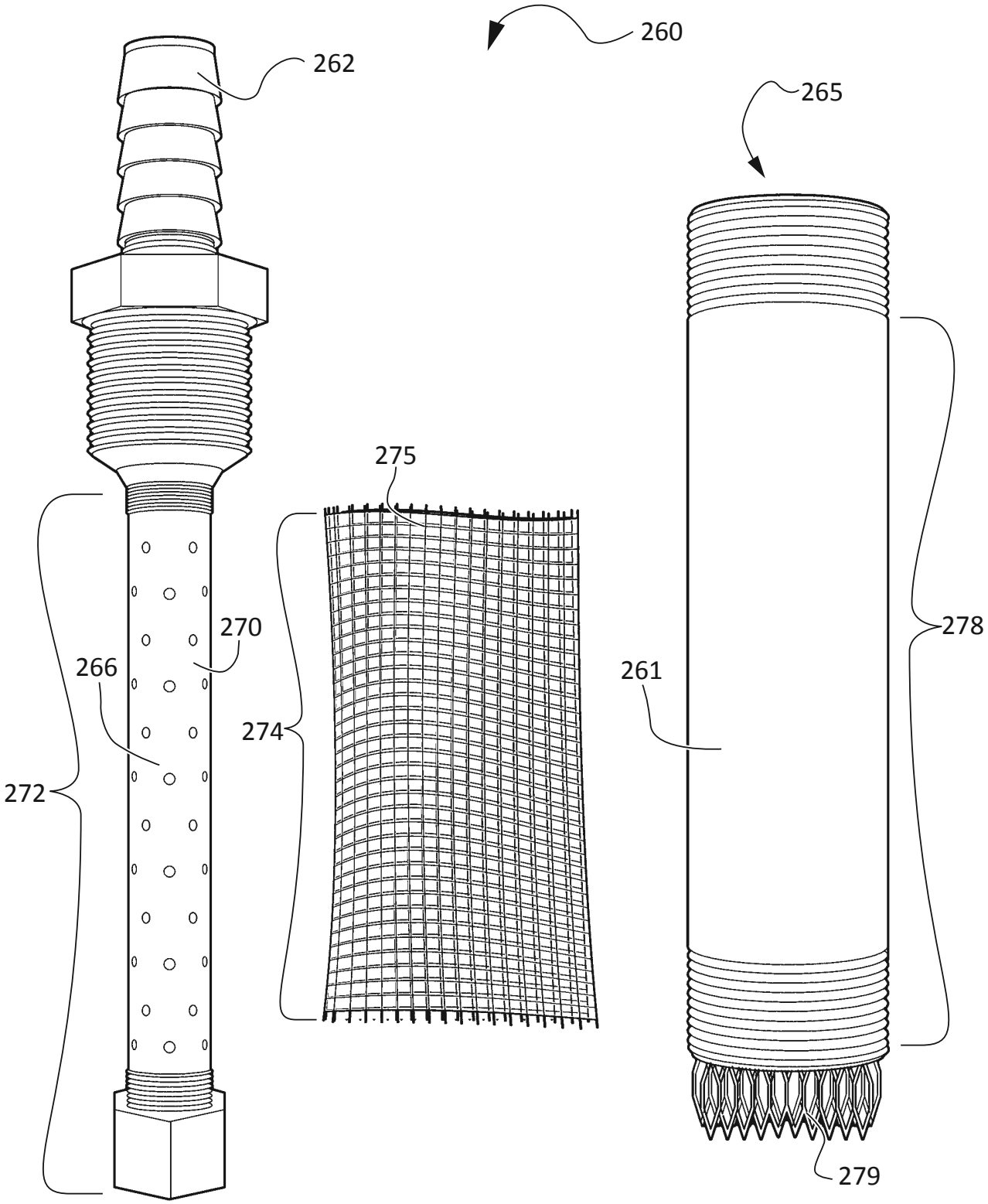


FIG. 15A

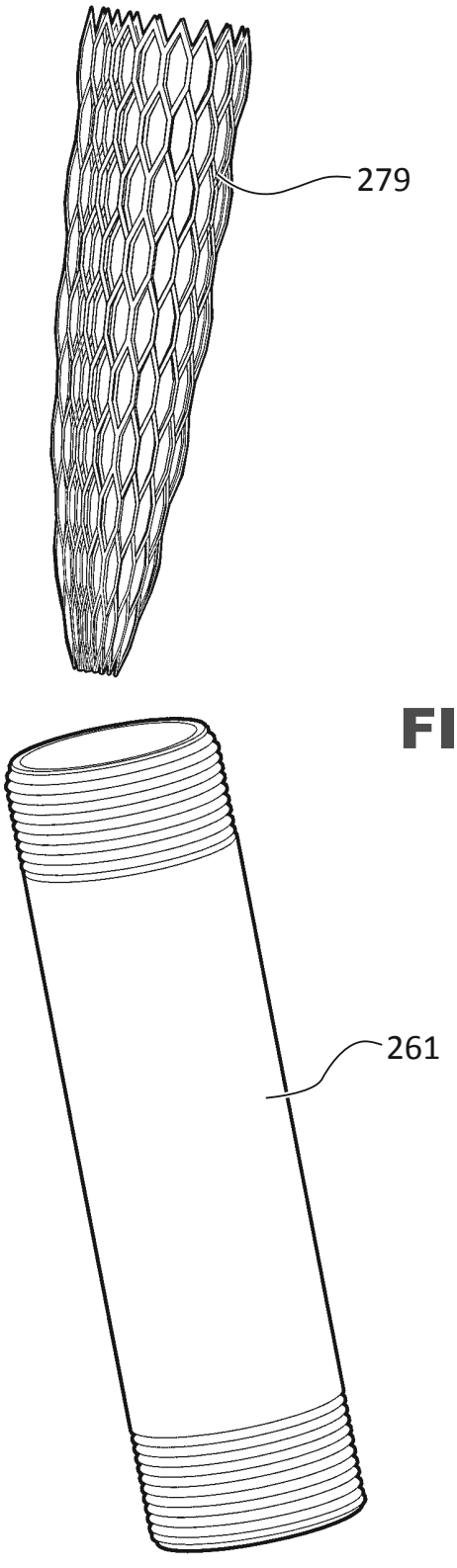


FIG. 15B

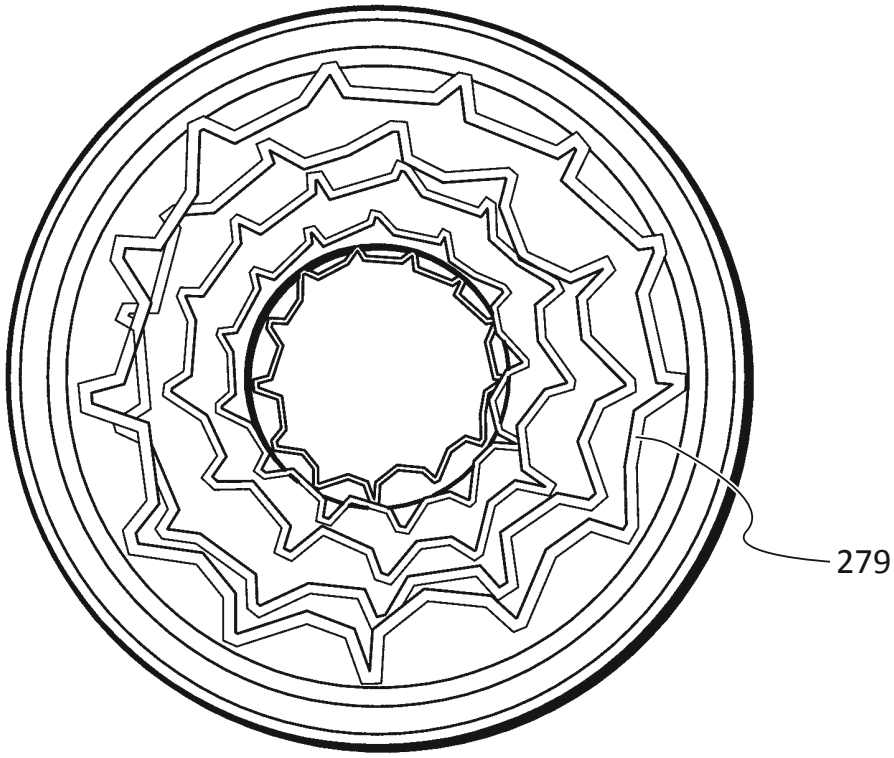


FIG. 15C

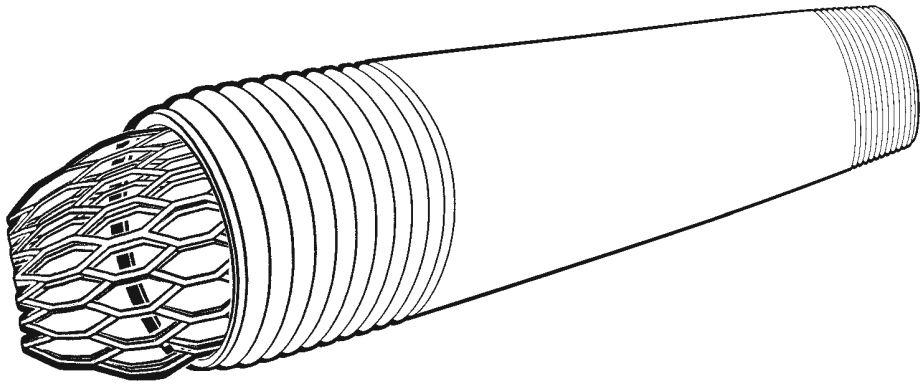


FIG. 15D

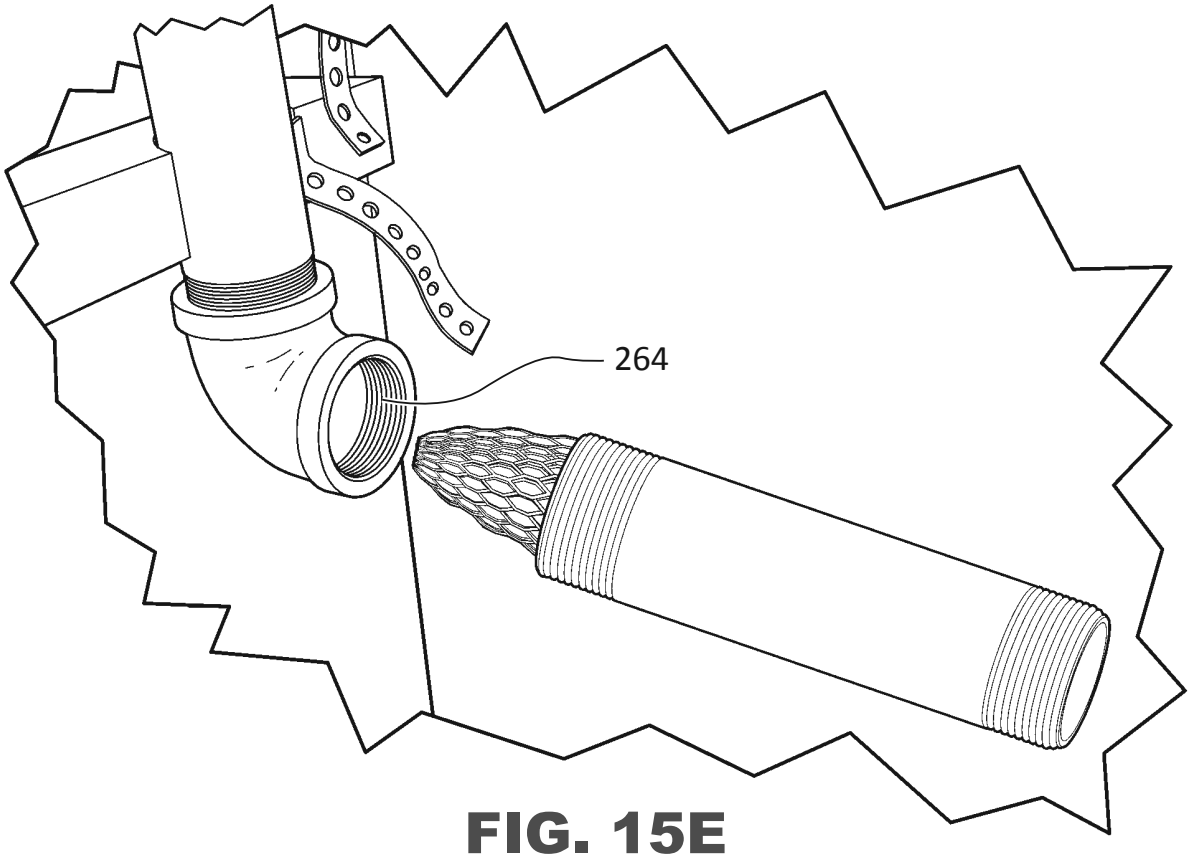


FIG. 15E

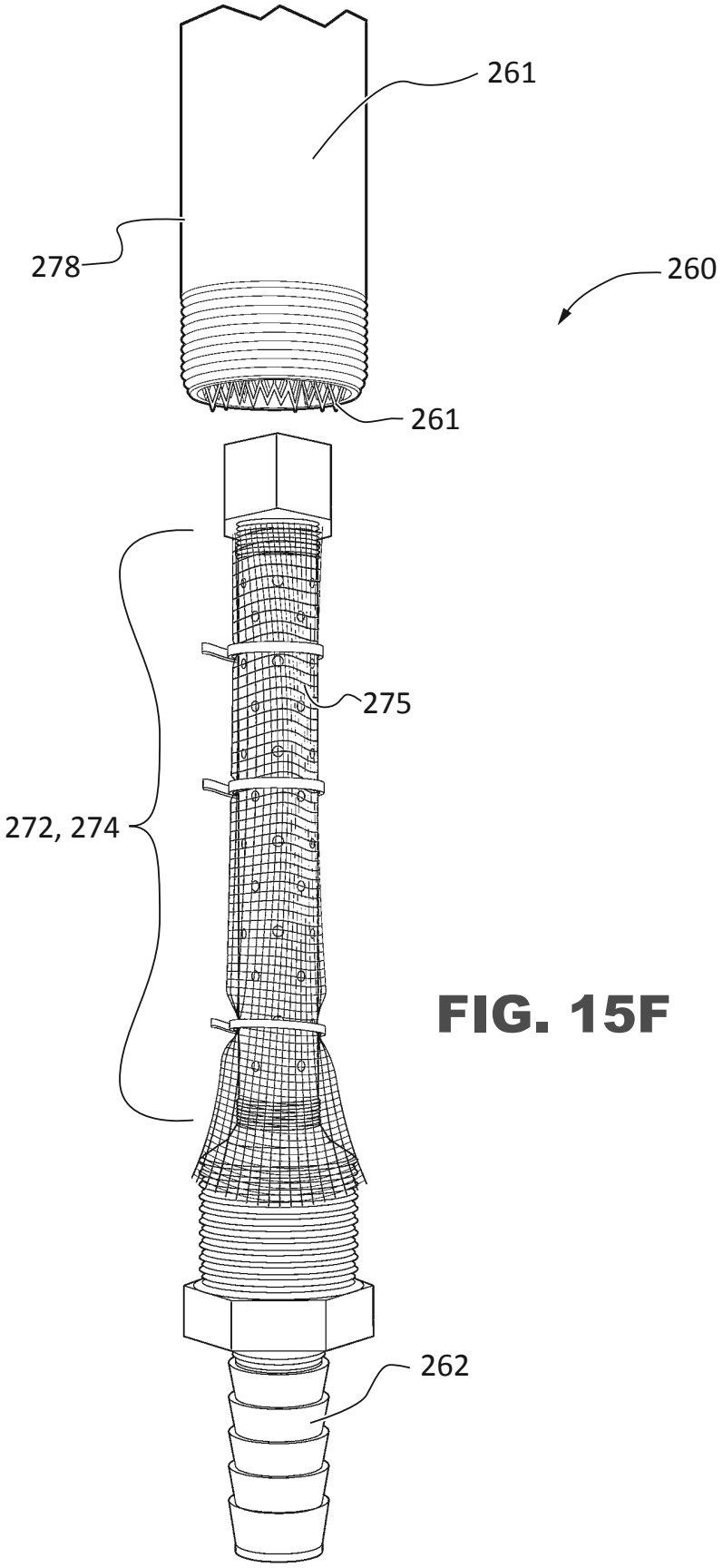


FIG. 15F

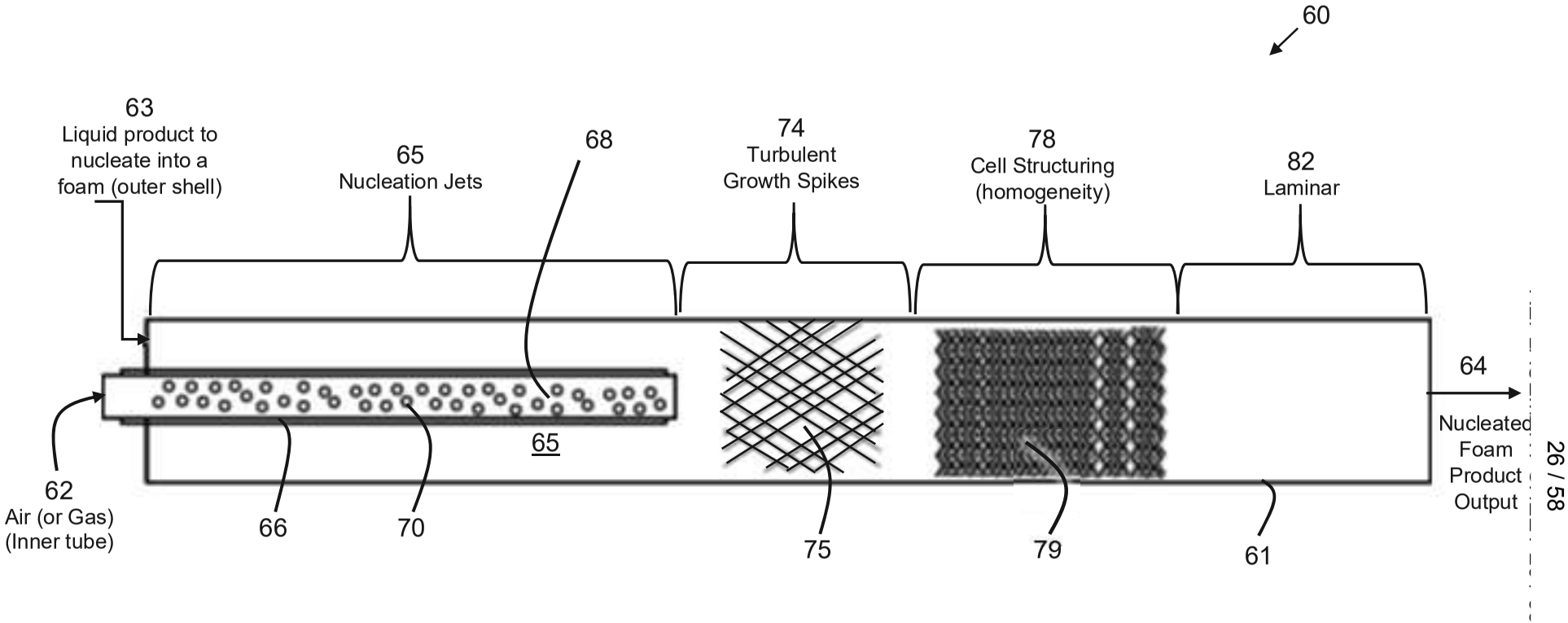

60
63
Liquid product to nucleate into a foam (outer shell)
65
Nucleation Jets
68
74
Turbulent Growth Spikes
78
Cell Structuring (homogeneity)
82
Laminar
64
Nucleated Foam Product Output
65
62
Air (or Gas) (Inner tube)
66
70
75
79
61

FIG. 16A

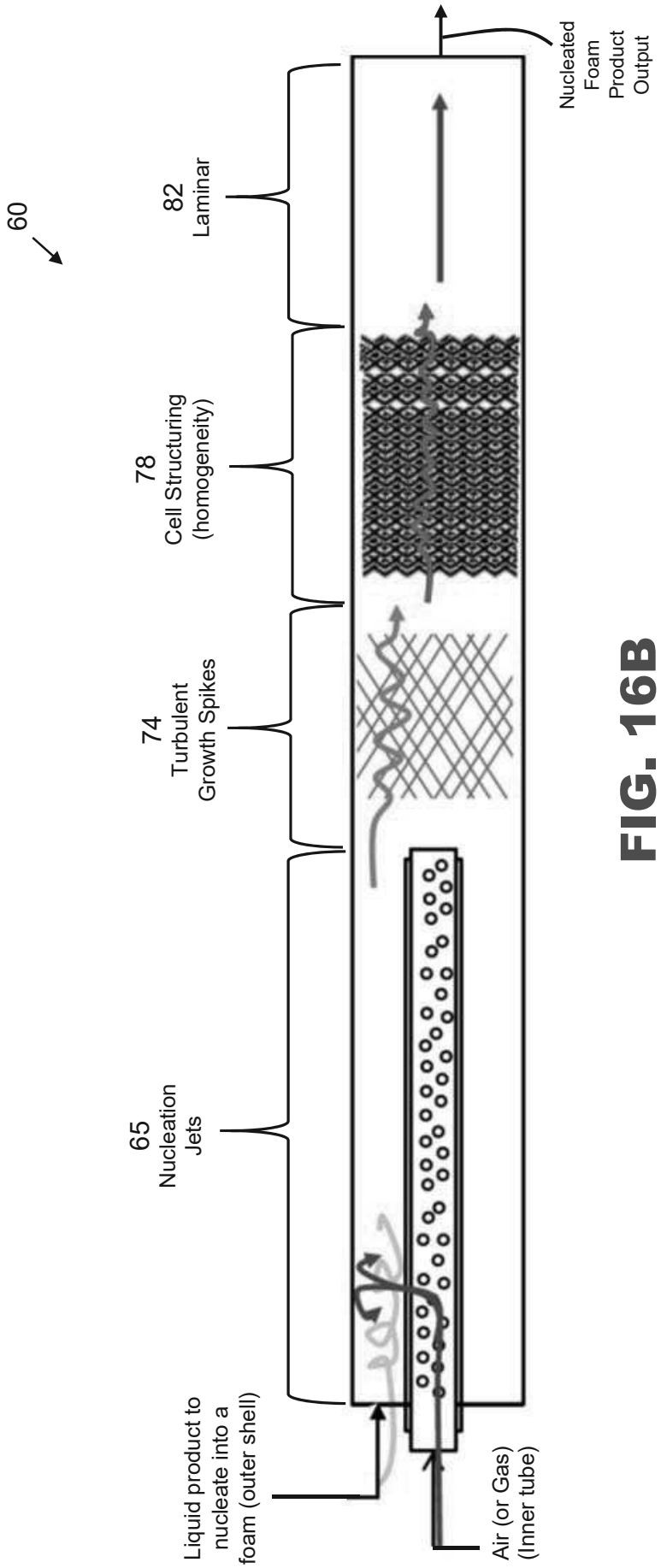

60
82
Laminar
78
Cell Structuring
(homogeneity)
74
Turbulent
Growth Spikes
65
Nucleation
Jets
Nucleated
Foam
Product
Output
Liquid product to
nucleate into a
foam (outer shell)
Air (or Gas)
(Inner tube)

FIG. 16B

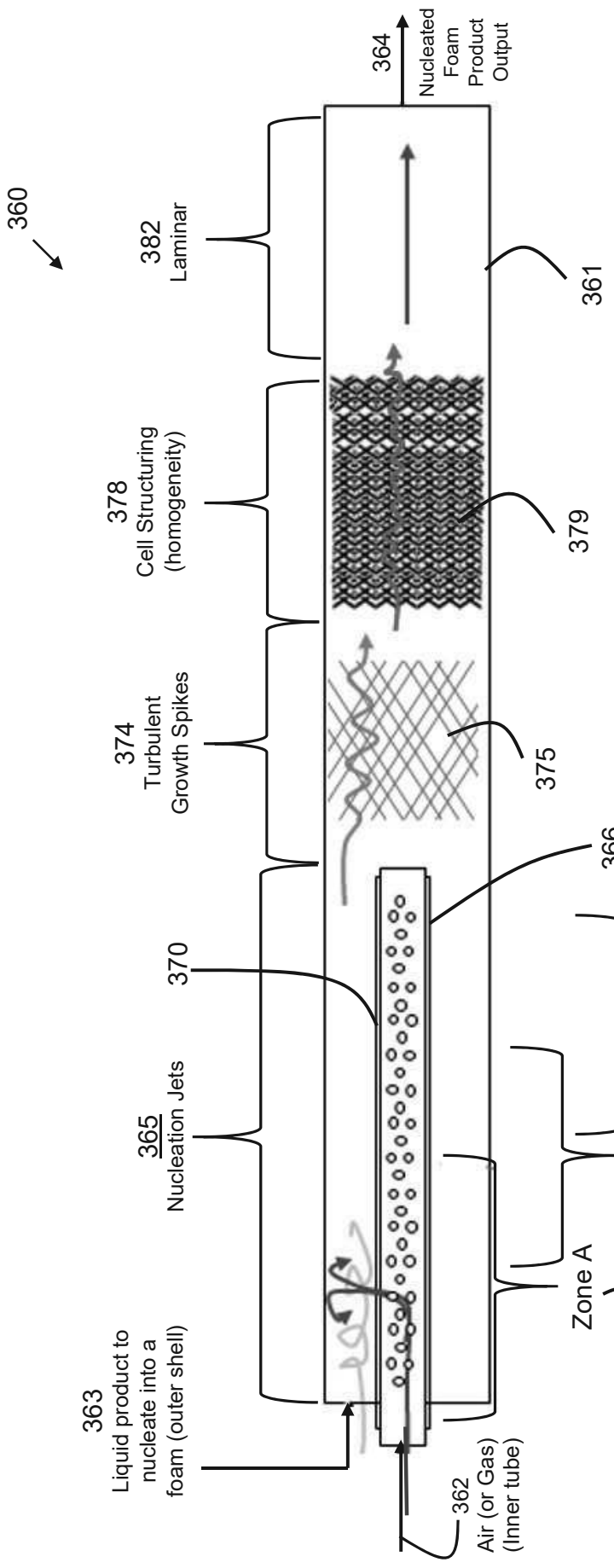

360
363
Liquid product to nucleate into a foam (outer shell)
362
Air (or Gas) (Inner tube)
365
Nucleation Jets
370
374
Turbulent Growth Spikes
375
378
Cell Structuring (homogeneity)
379
382
Laminar
361
364
Nucleated Foam Product Output
366
Zone A
372A
Zone B
327B
Zone C
372C

FIG. 16C

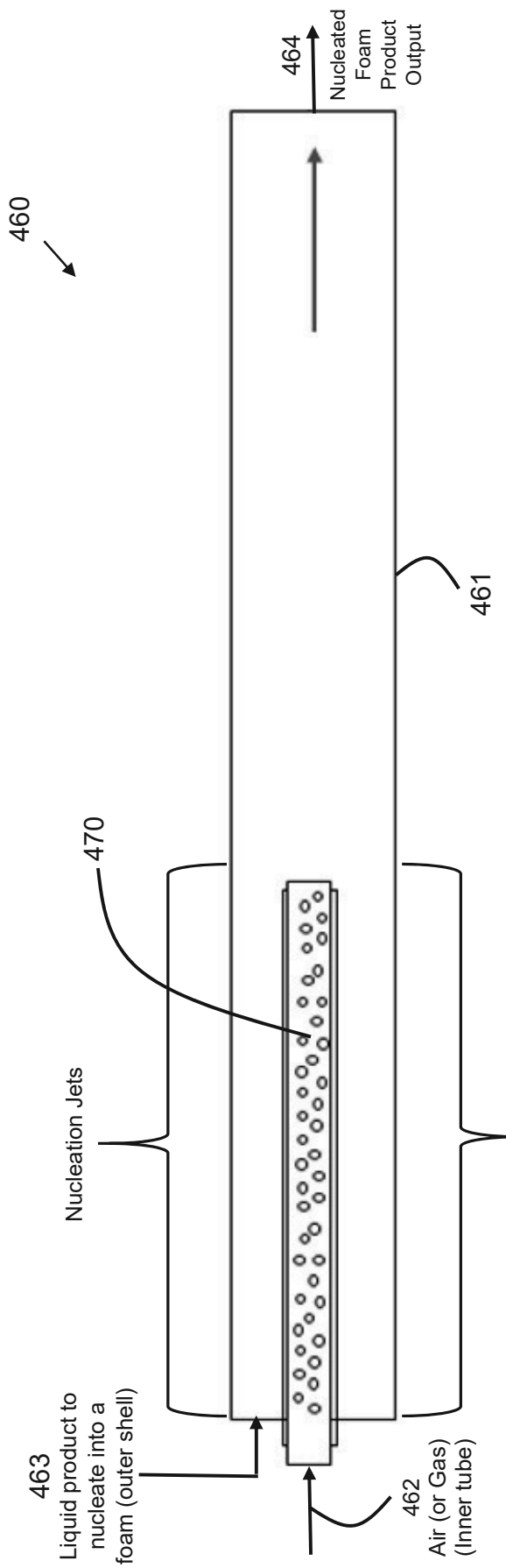

460
464
Nucleated Foam Product Output
461
470
Nucleation Jets
472
463
Liquid product to nucleate into a foam (outer shell)
462
Air (or Gas) (Inner tube)

FIG. 16D

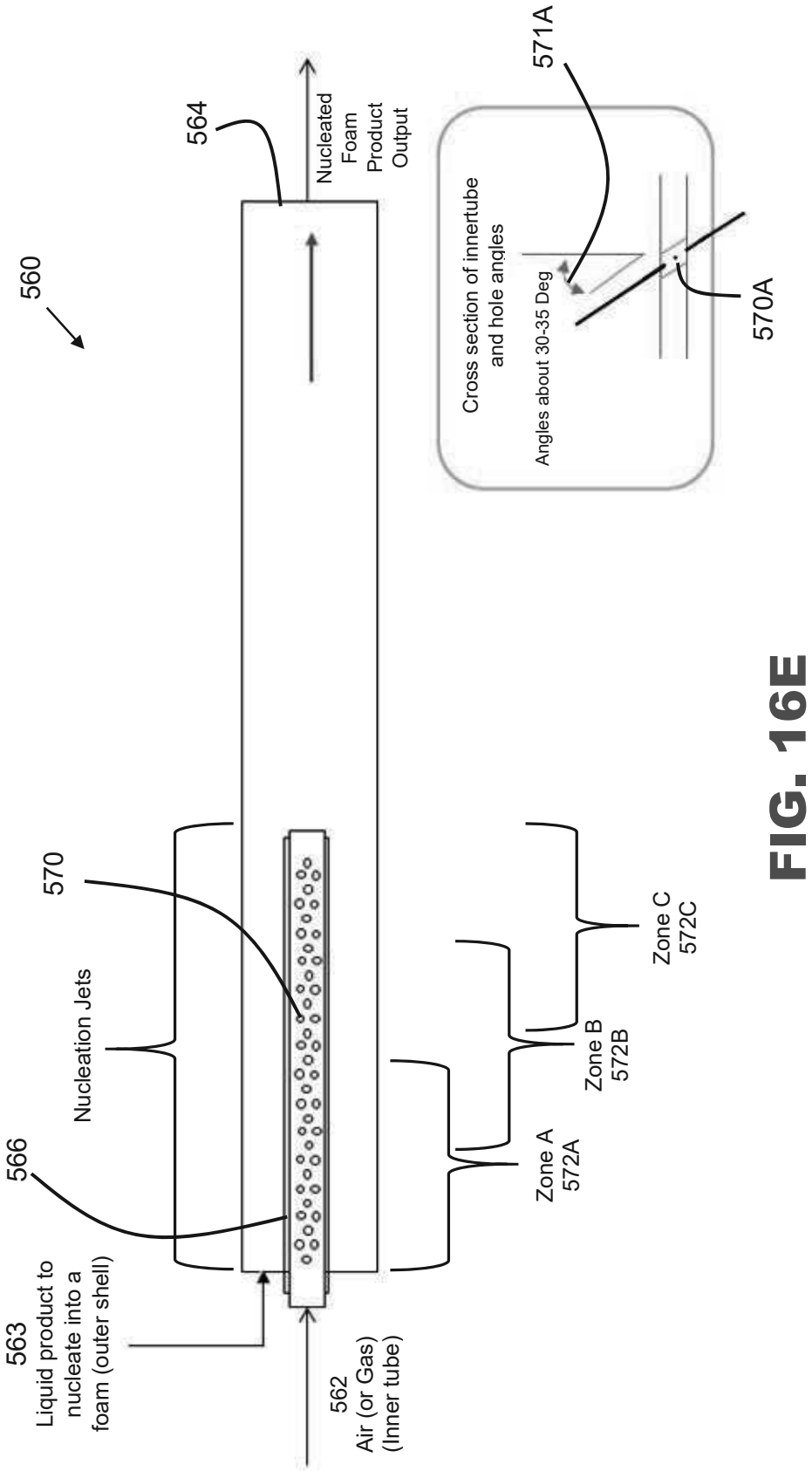

560
564
Nucleated Foam Product Output
571A
Cross section of innertube and hole angles
Angles about 30-35 Deg
570A
570
Nucleation Jets
566
563
Liquid product to nucleate into a foam (outer shell)
562
Air (or Gas) (Inner tube)
Zone A 572A
Zone B 572B
Zone C 572C

FIG. 16E

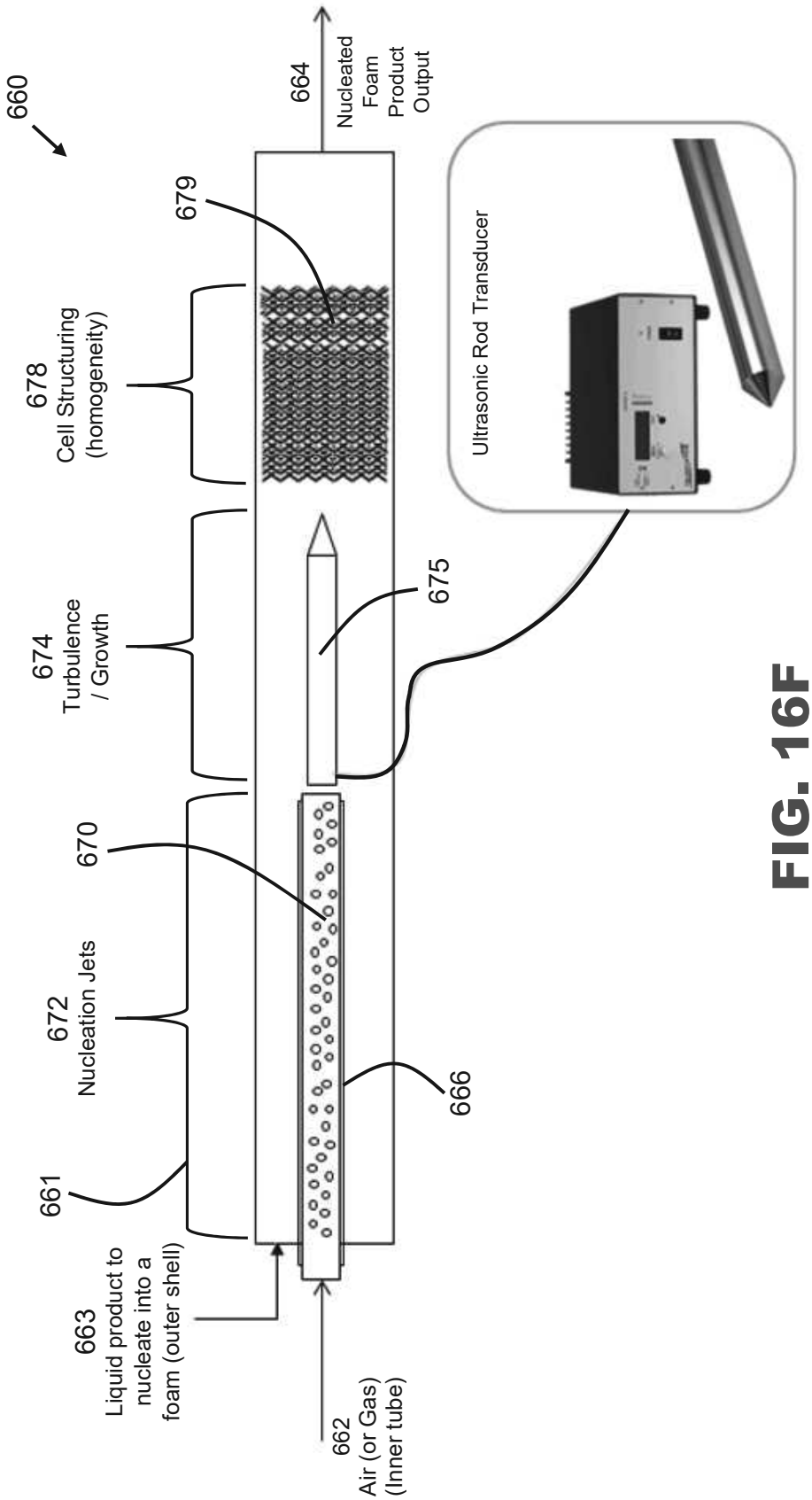

660
664
Nucleated Foam Product Output
679
678
Cell Structuring (homogeneity)
674
Turbulence / Growth
675
Ultrasonic Rod Transducer
670
672
Nucleation Jets
666
661
663
Liquid product to nucleate into a foam (outer shell)
662
Air (or Gas) (Inner tube)

FIG. 16F

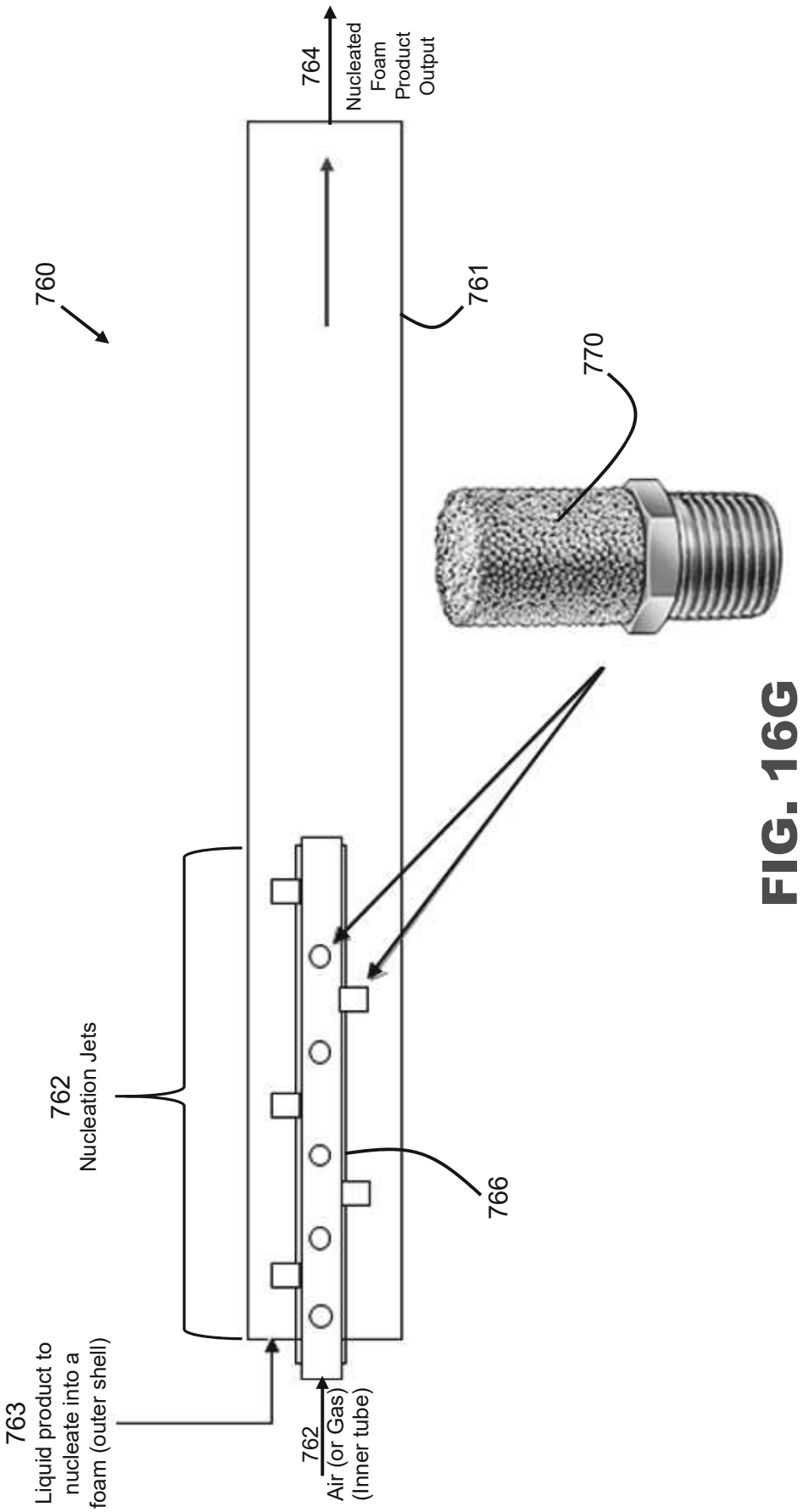

760
764
Nucleated Foam Product Output
761
770
762
Nucleation Jets
766
763
Liquid product to nucleate into a foam (outer shell)
762
Air (or Gas) (Inner tube)

FIG. 16G

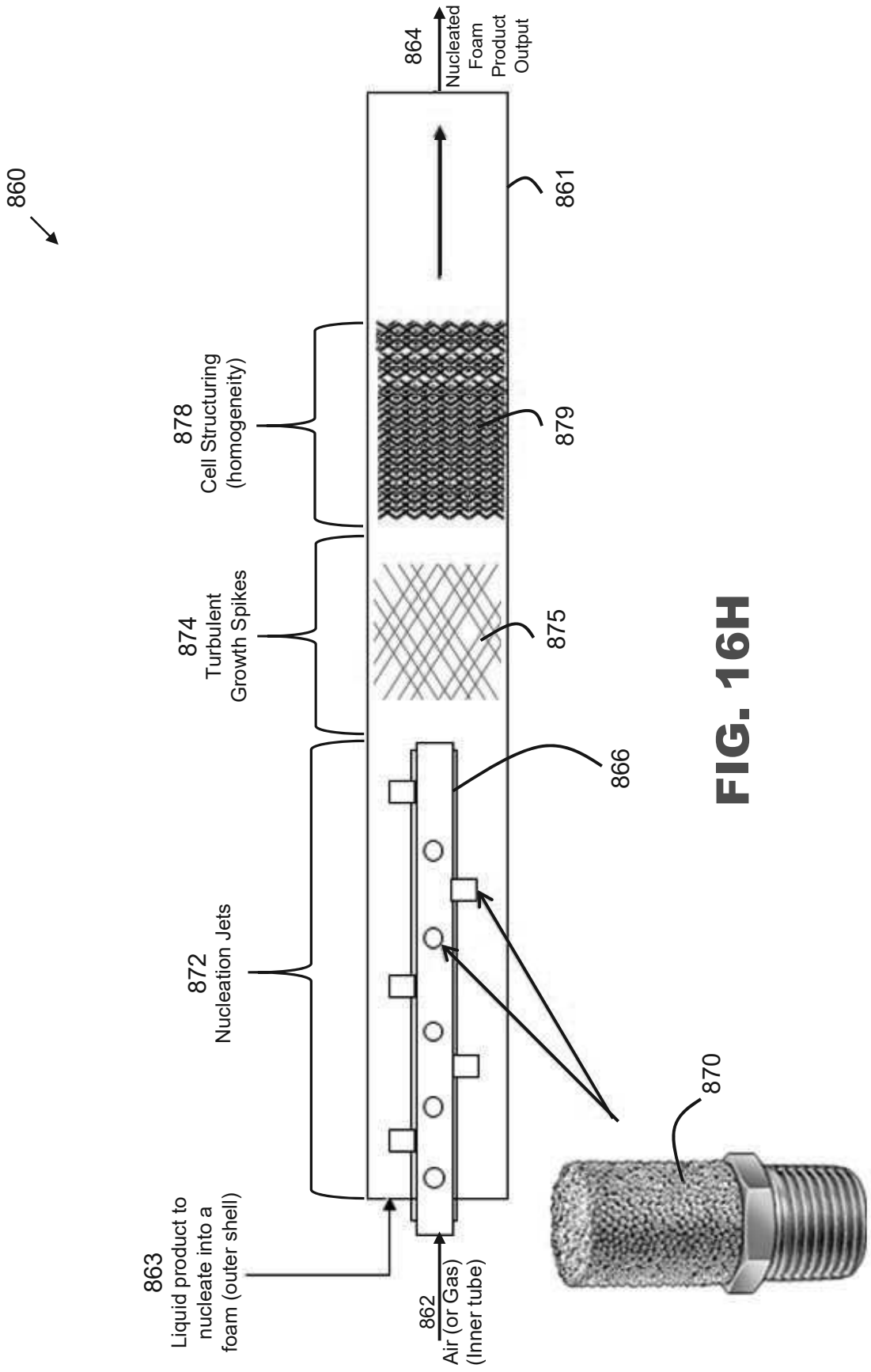

860
863
Liquid product to nucleate into a foam (outer shell)
862
Air (or Gas) (Inner tube)
872
Nucleation Jets
874
Turbulent Growth Spikes
878
Cell Structuring (homogeneity)
866
875
879
861
864
Nucleated Foam Product Output
870

FIG. 16H

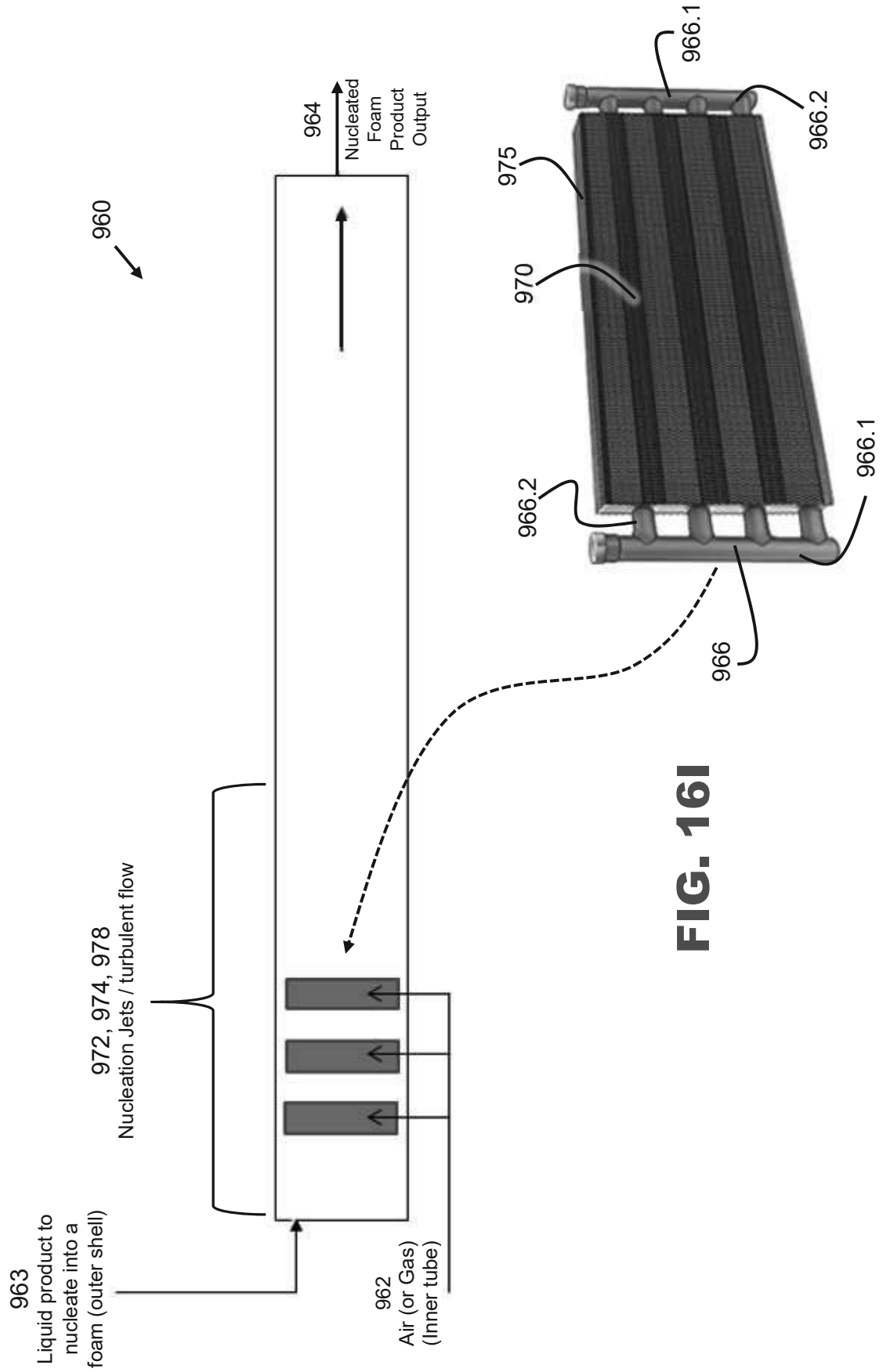

960
963
Liquid product to nucleate into a foam (outer shell)
962
Air (or Gas) (Inner tube)
972, 974, 978
Nucleation Jets / turbulent flow
964
Nucleated Foam Product Output
966
966.1
966.2
970
975

FIG. 16I

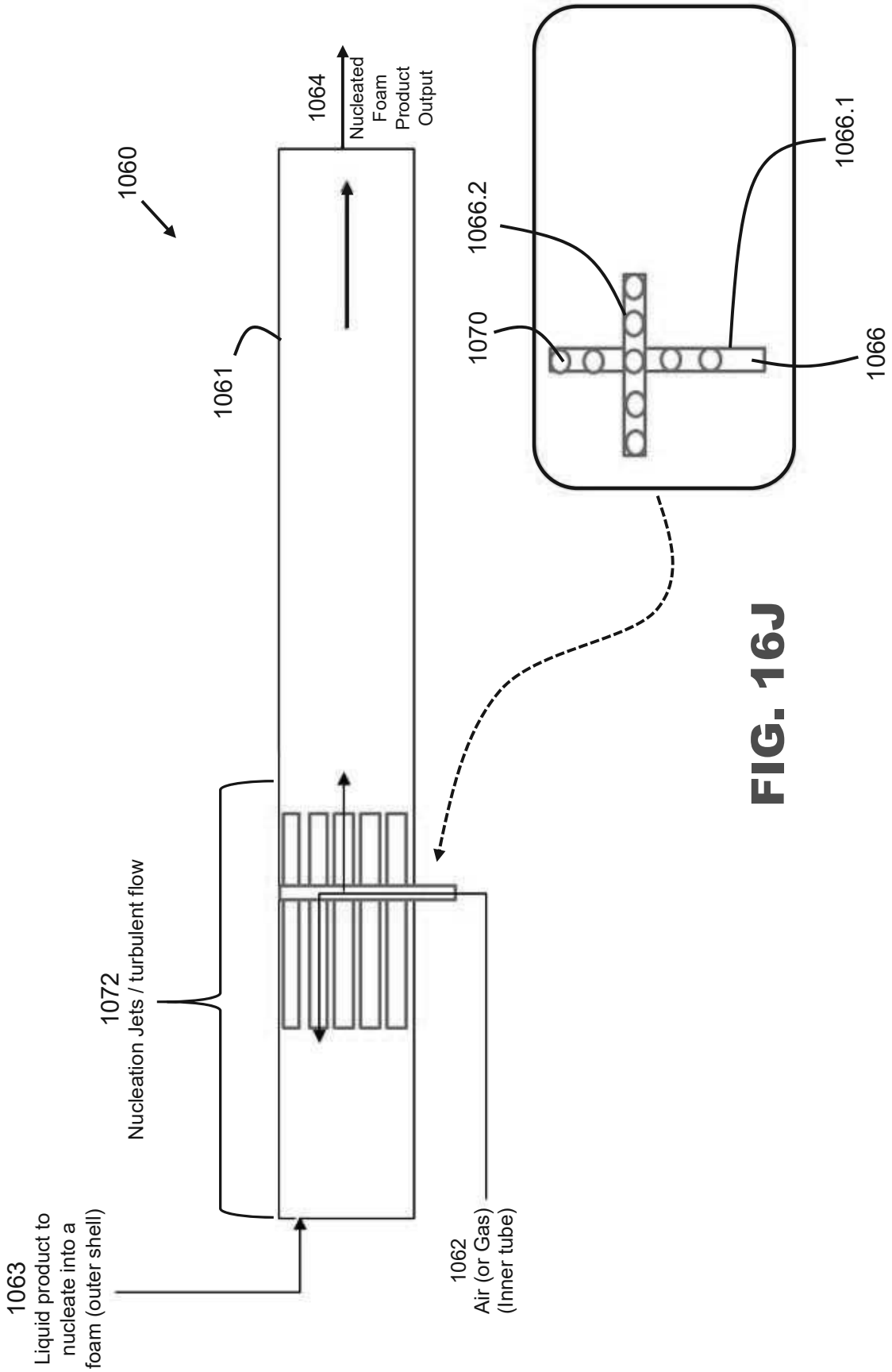

1060
1064
Nucleated Foam Product Output
1061
1066.2
1066.1
1070
1066
1072
Nucleation Jets / turbulent flow
1063
Liquid product to nucleate into a foam (outer shell)
1062
Air (or Gas) (Inner tube)

FIG. 16J

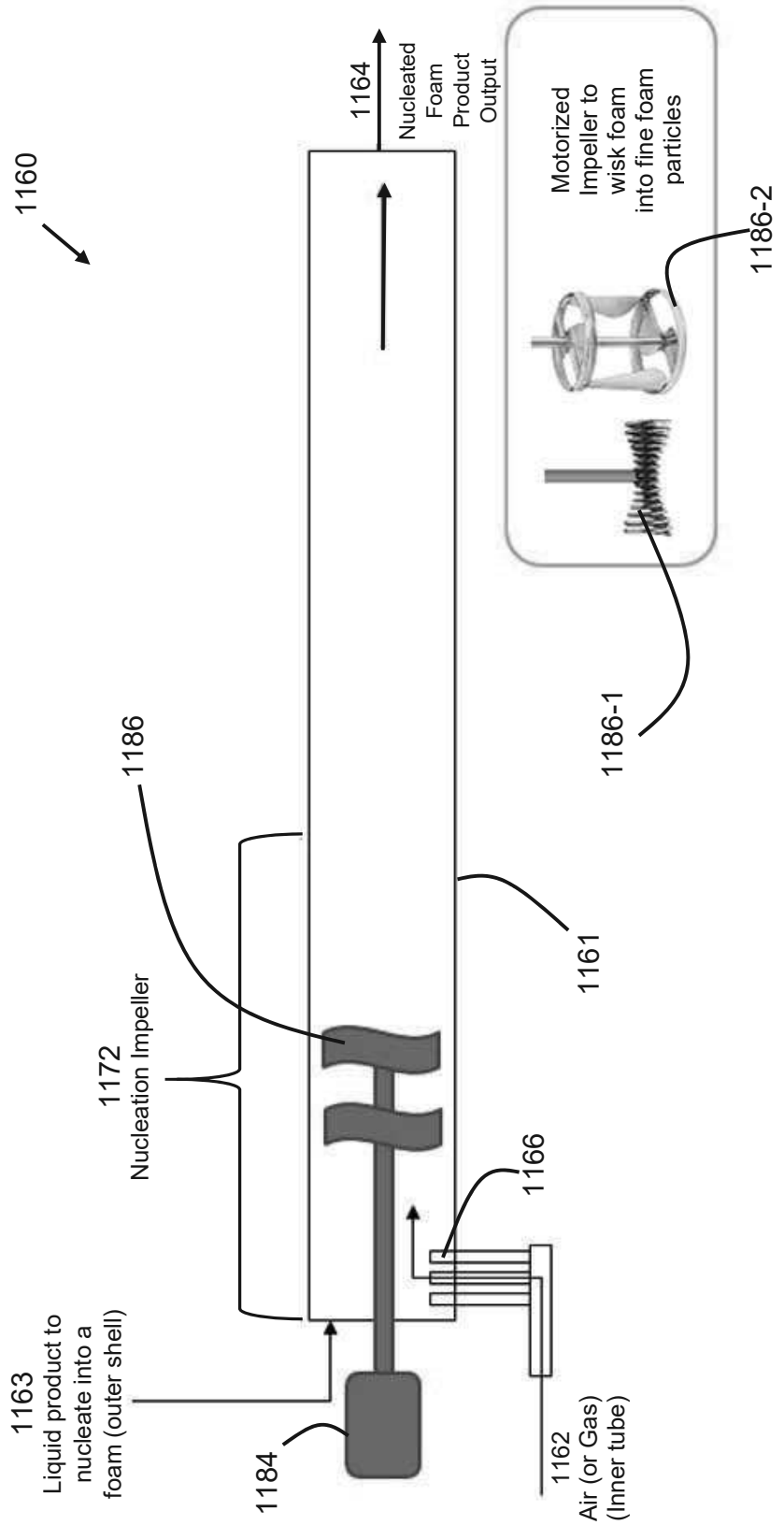

1160
1164
Nucleated Foam Product Output
Motorized Impeller to wisk foam into fine foam particles
1186-2
1186-1
1186
1172
Nucleation Impeller
1161
1166
1163
Liquid product to nucleate into a foam (outer shell)
1184
1162
Air (or Gas) (Inner tube)

FIG. 16K

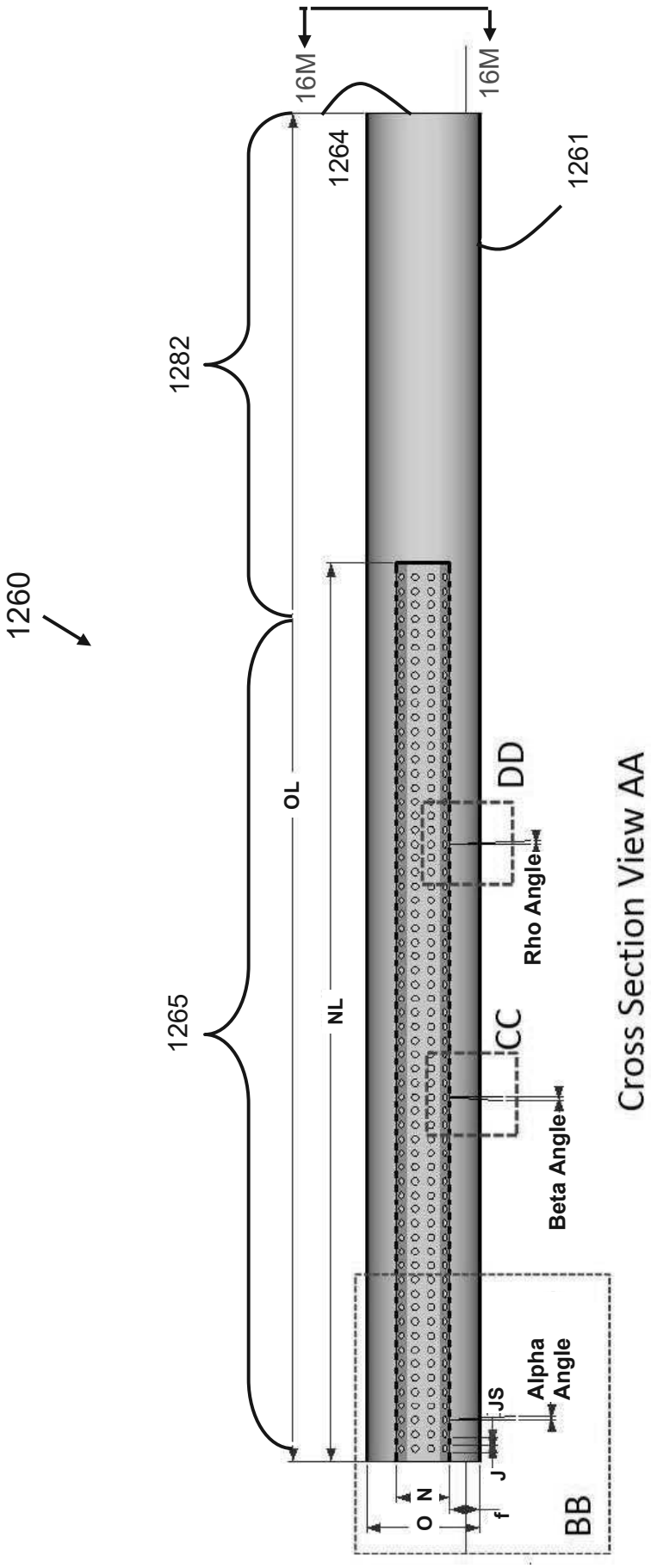

1260
16M
16M
1264
1261
1282
1265
OL
NL
DD
Rho Angle
CC
Beta Angle
Alpha Angle
JS
J
N
O
f
BB
Cross Section View AA

FIG. 16L

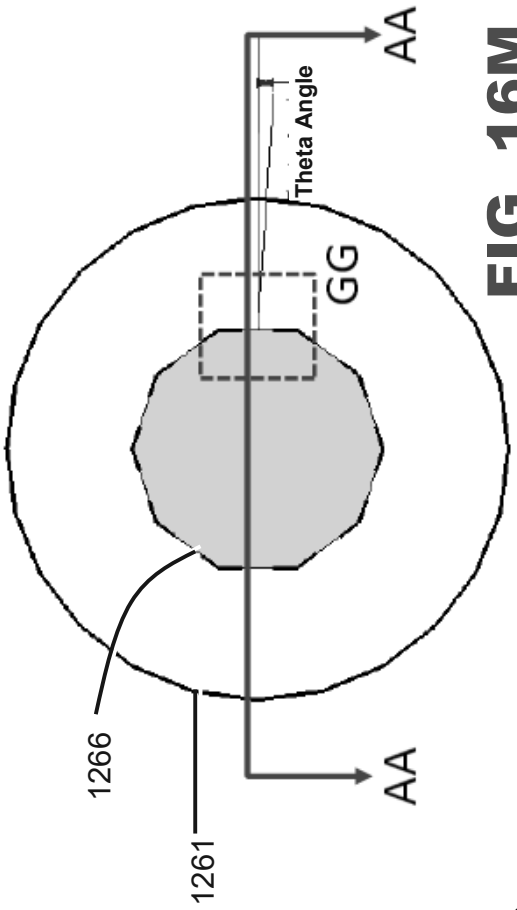


FIG. 16M

OL – Outer Shell Length
NL – Inner Shell Length
O – Outer Shell Diameter
N – Inner Shell Diameter
f – centered or off –centered dimension
J – Nucleation Jet Orifice Diameter
JS – Nucleation Jet Orifice Spacing
Alpha Angle – Nucleation Jet Orifice Angle x-axis
Beta Angle – Nucleation Jet Orifice Angle x-axis
Theta Angle – Nucleation Jet Orifice Angle Z-axis
Rho – Nucleation Jet Orifice Angle – y-axis

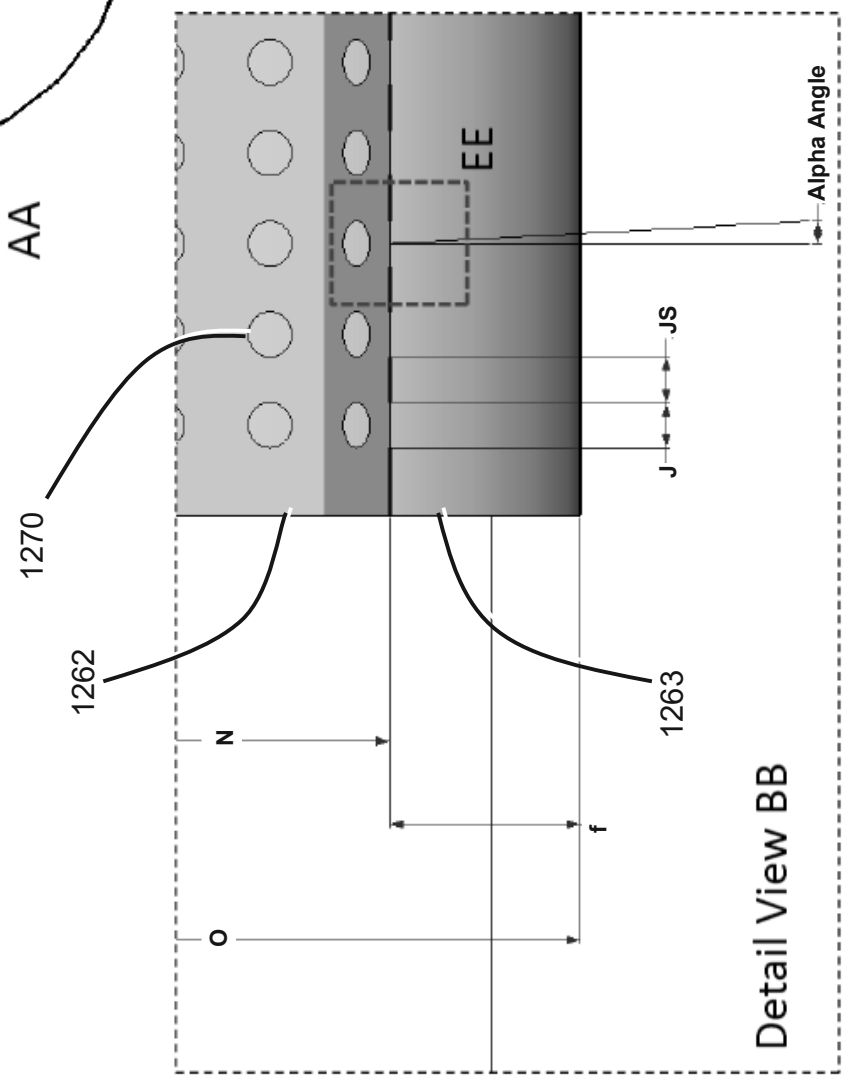


FIG. 16N

Varying degrees by zone

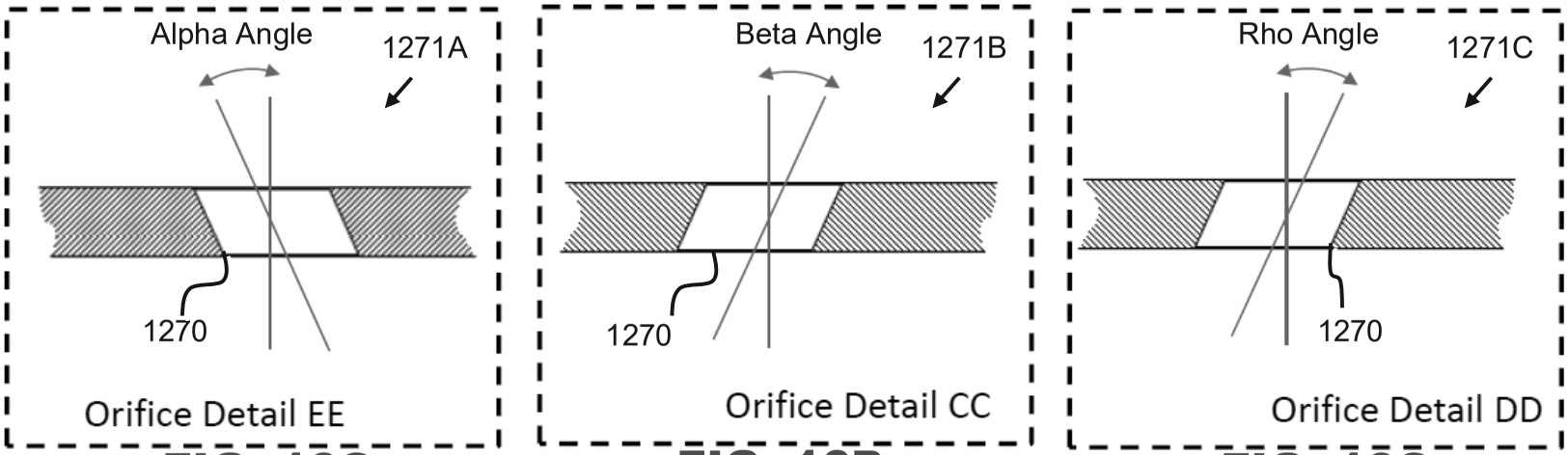


FIG. 16O FIG. 16P FIG. 16Q

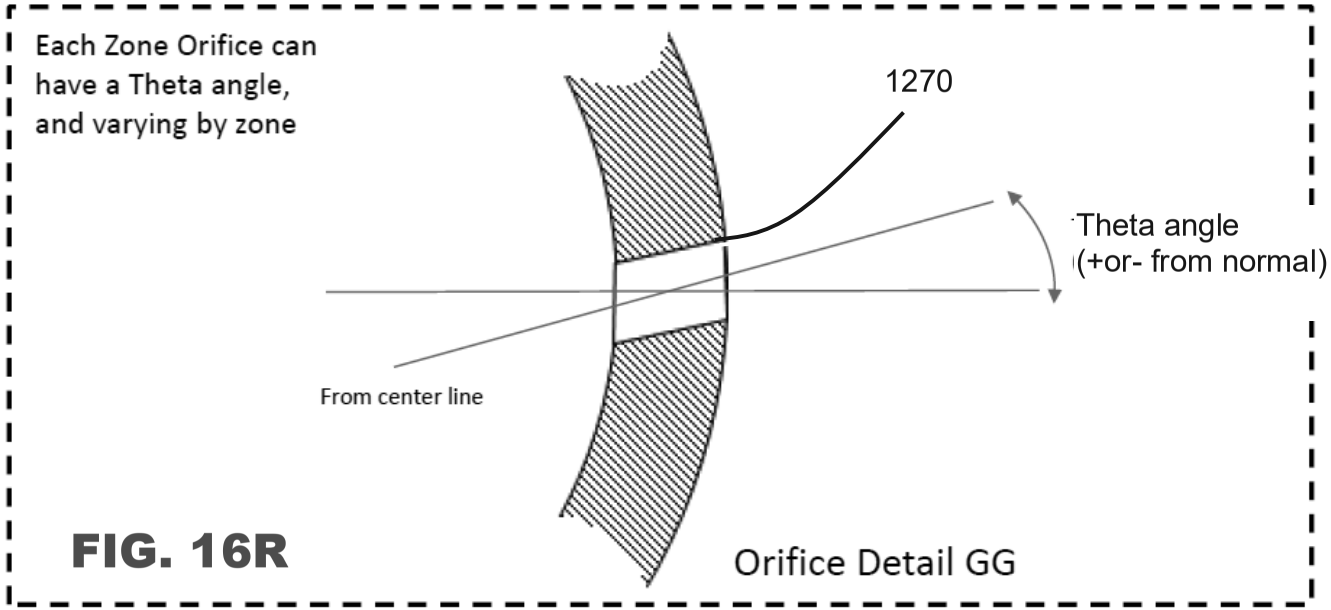


FIG. 16R

Other extras

Vehicle positions Foam for ingestion

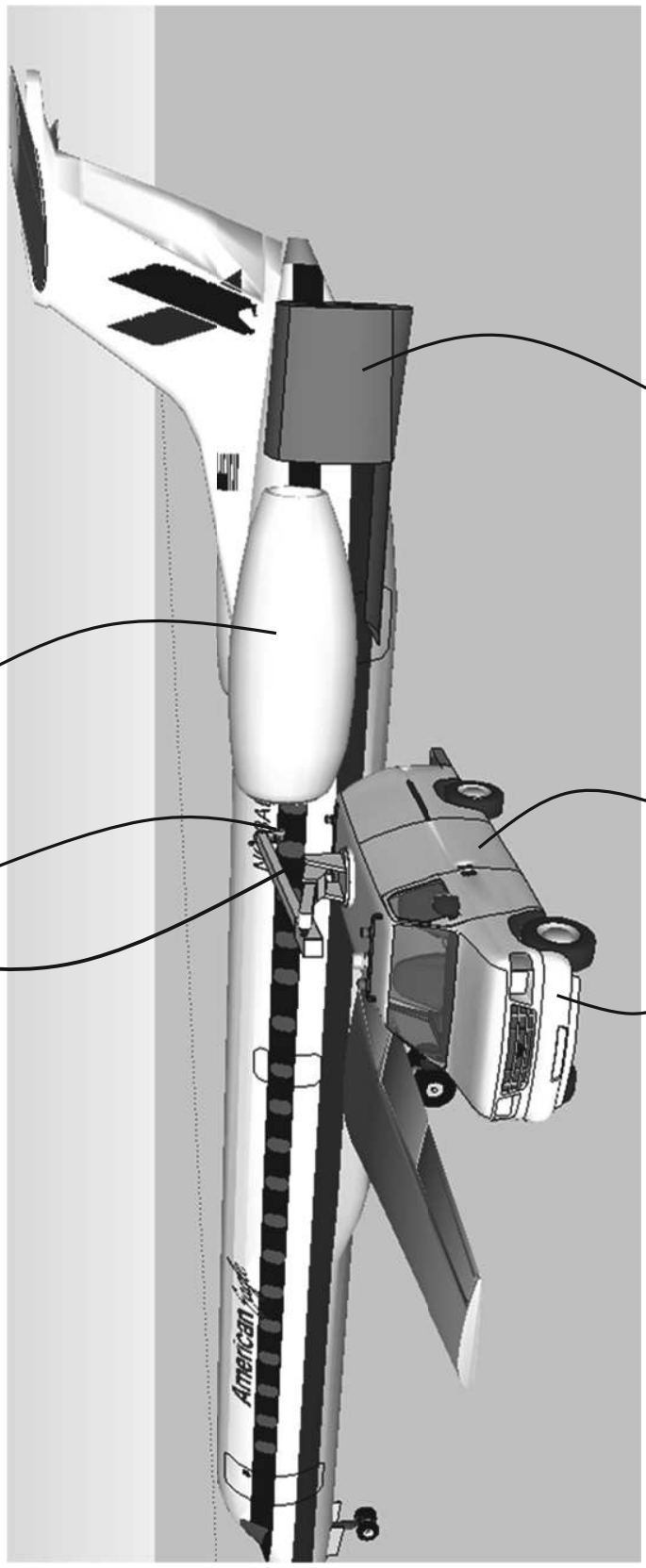


FIG. 17A

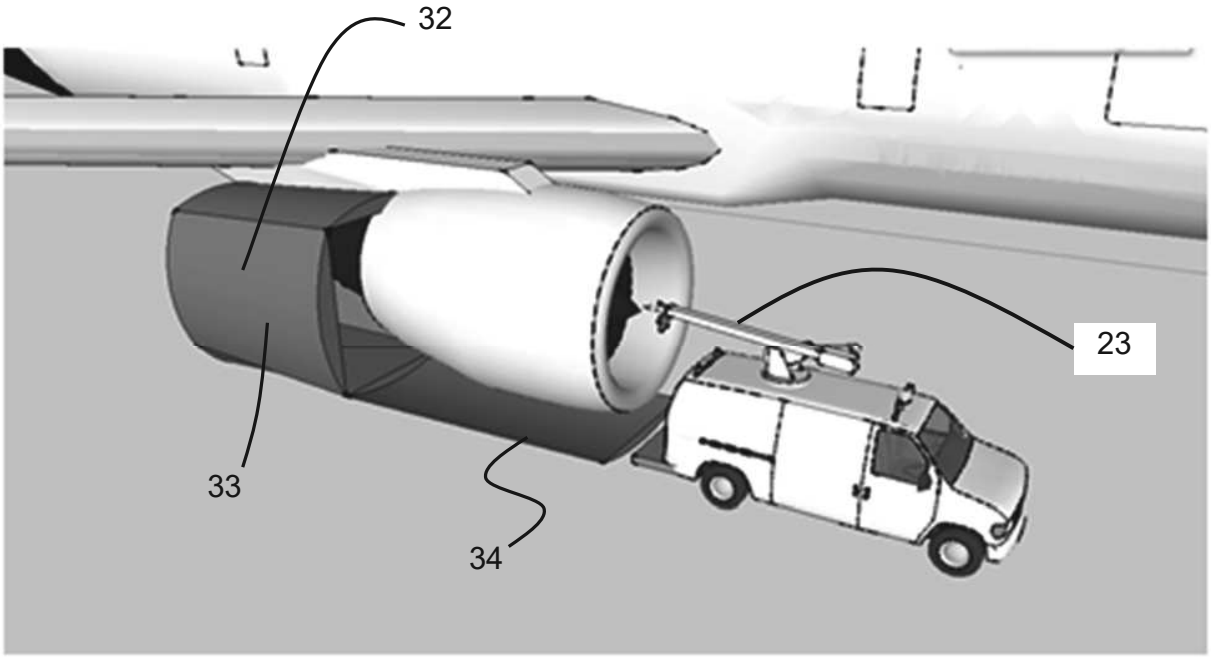


FIG. 17B

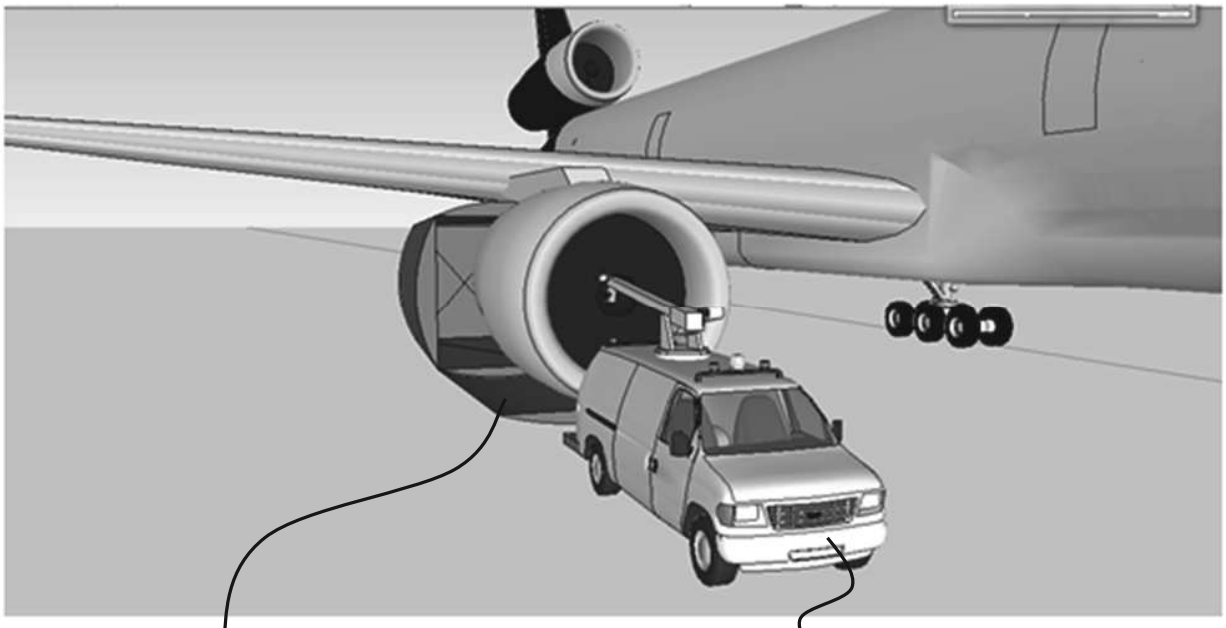


FIG. 17C

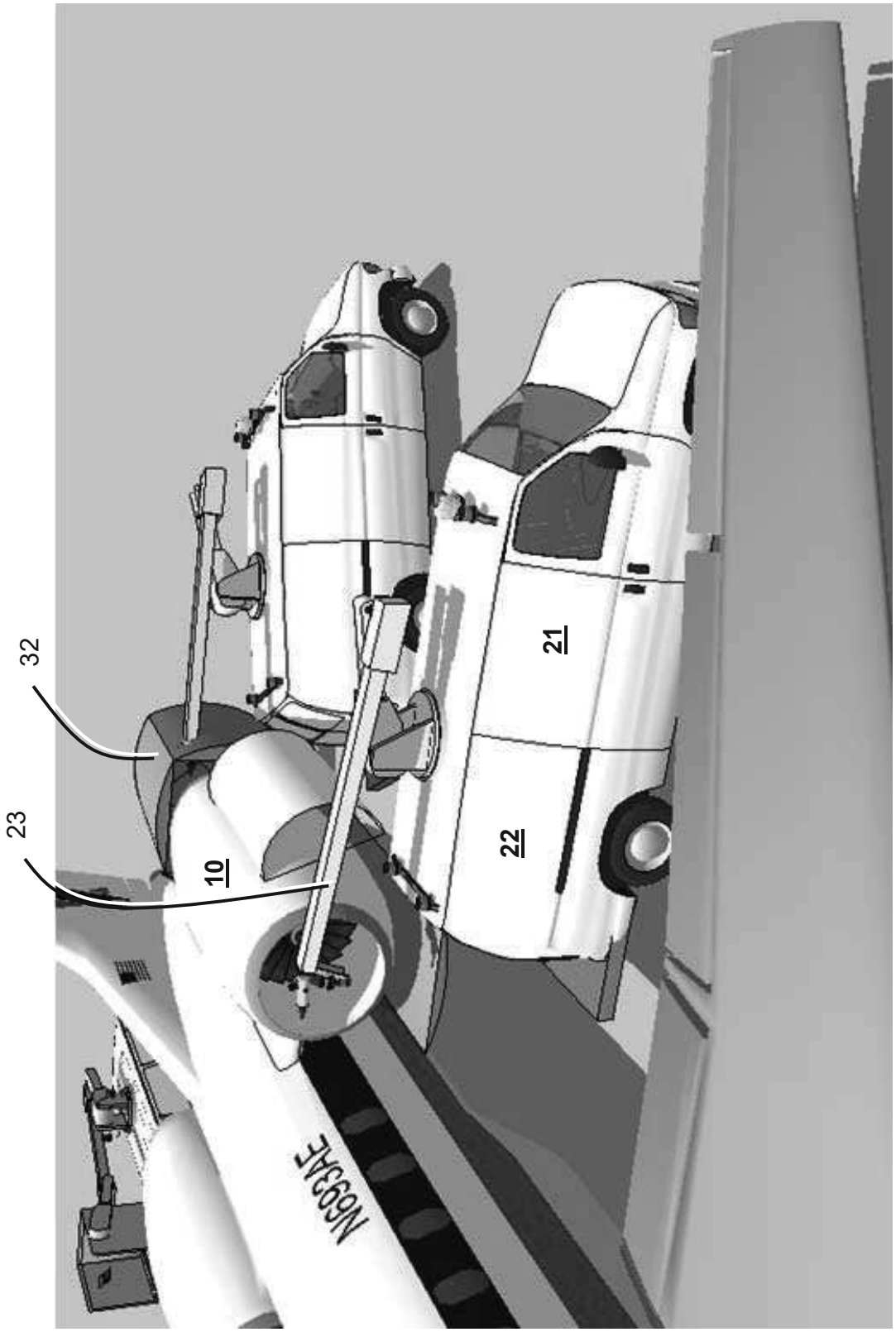


FIG. 17D

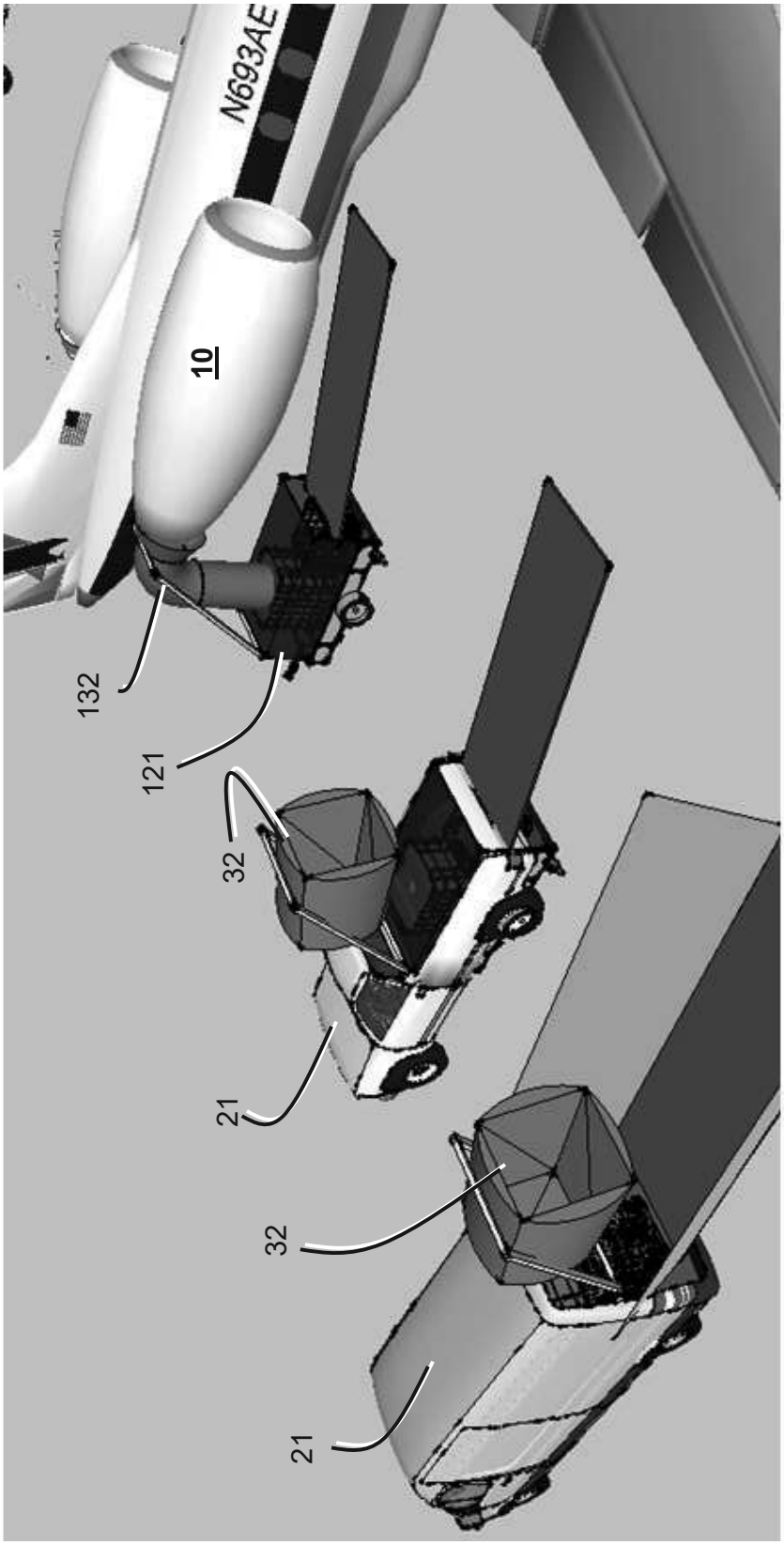


FIG. 17E

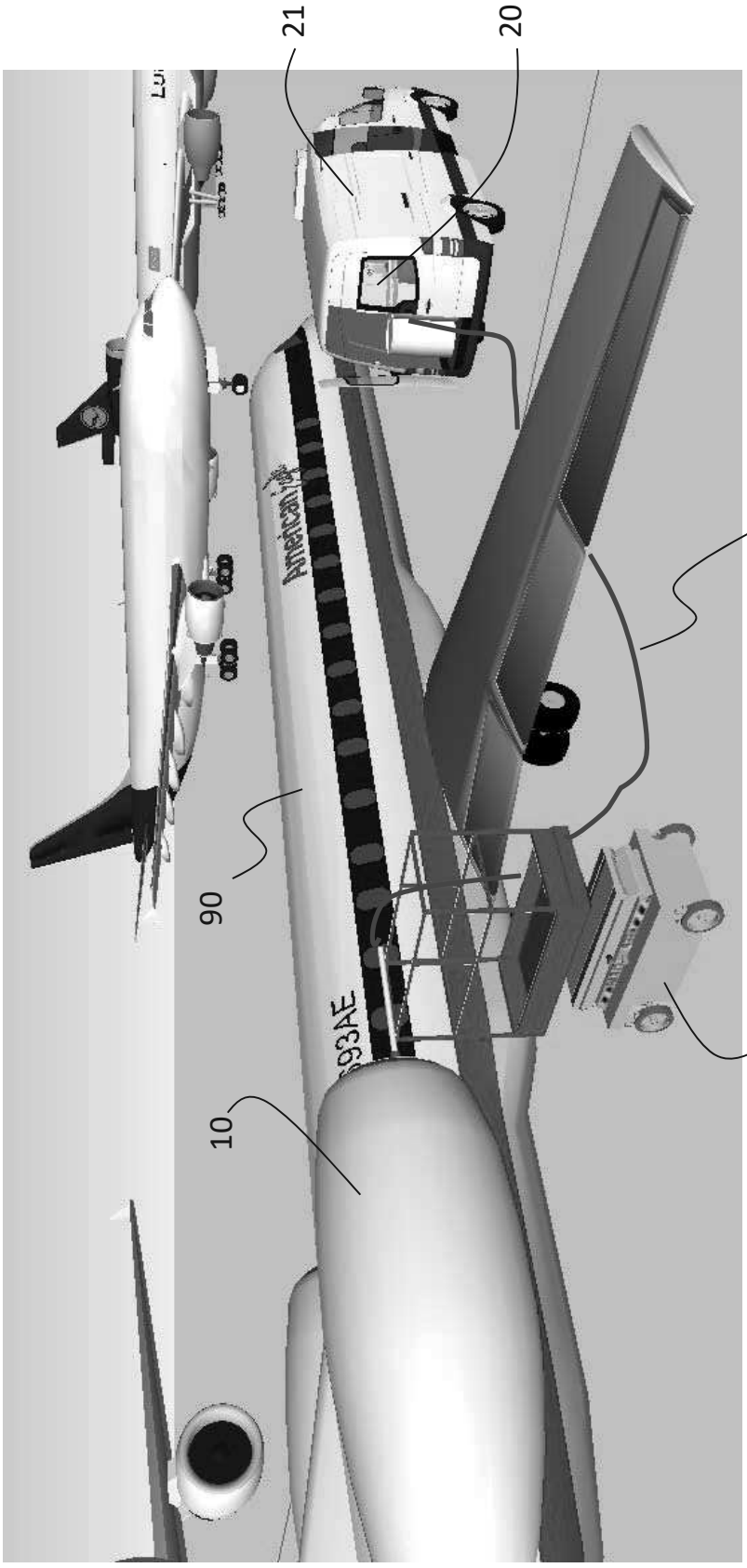


FIG. 18A

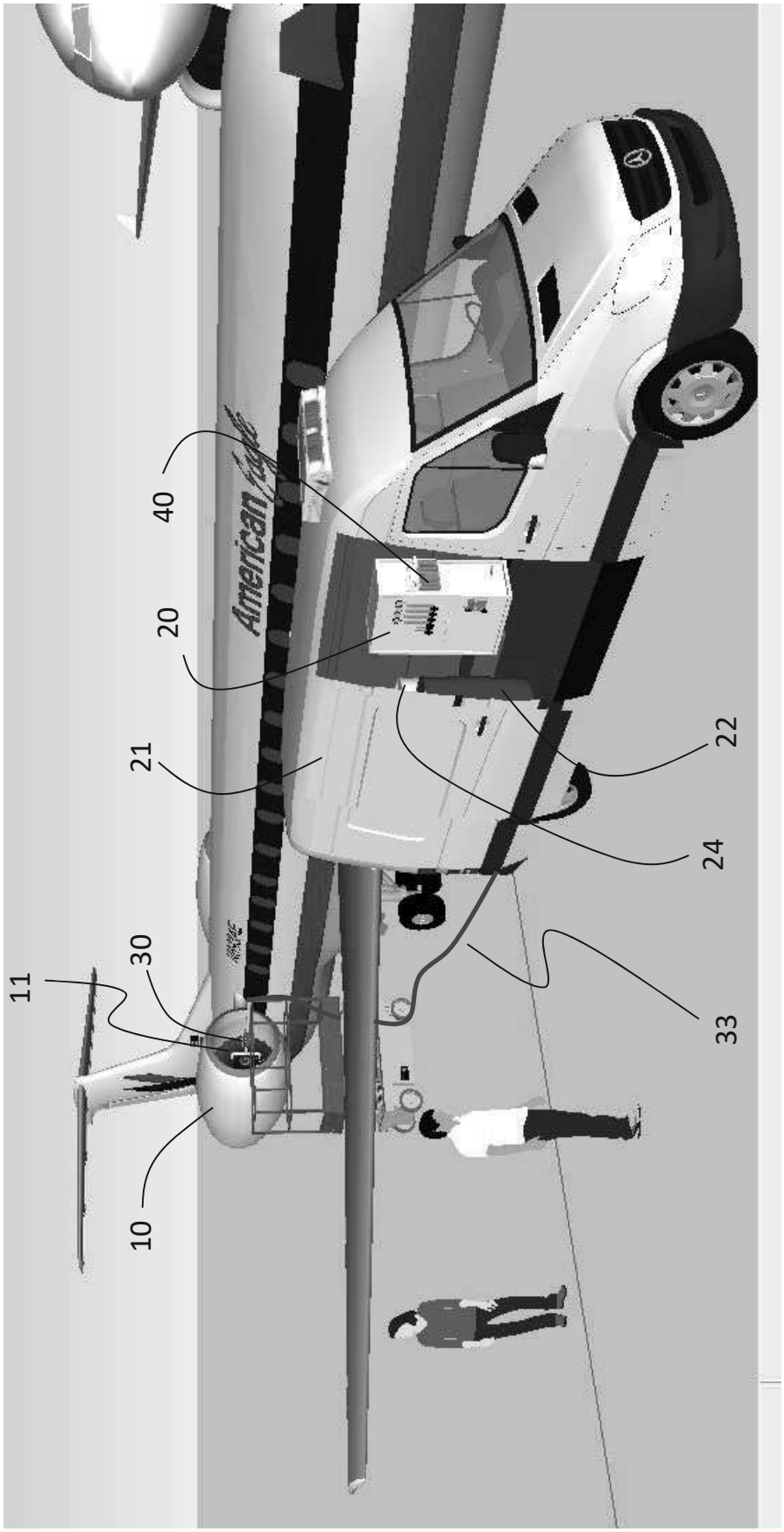


FIG. 18B

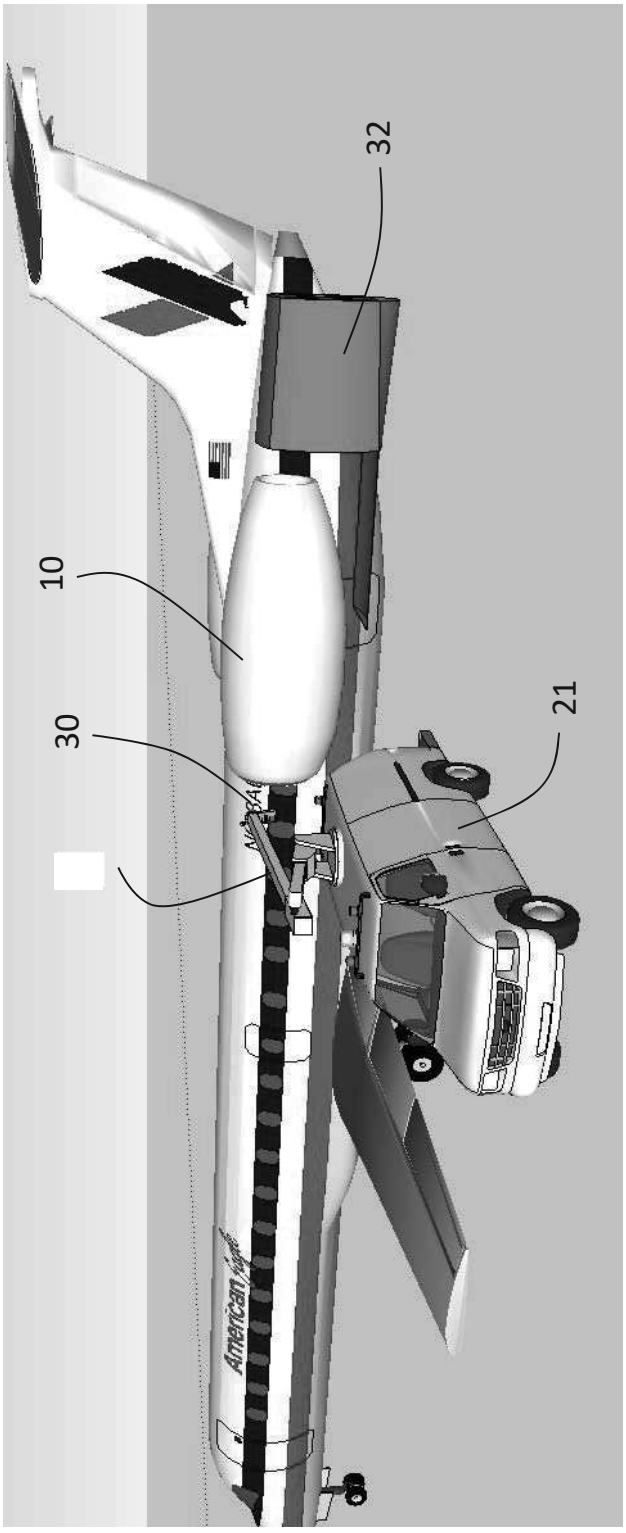


FIG. 19

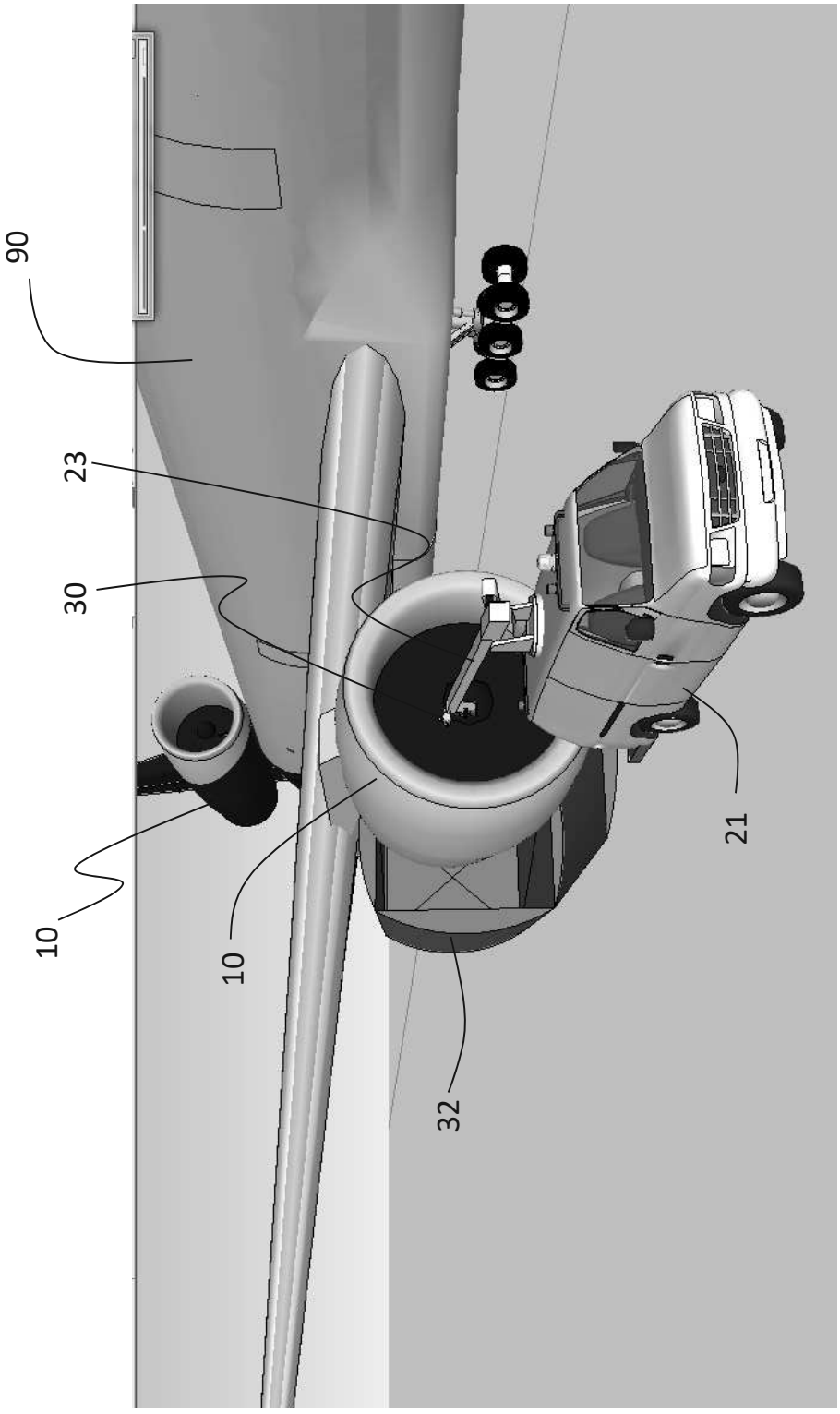


FIG. 20

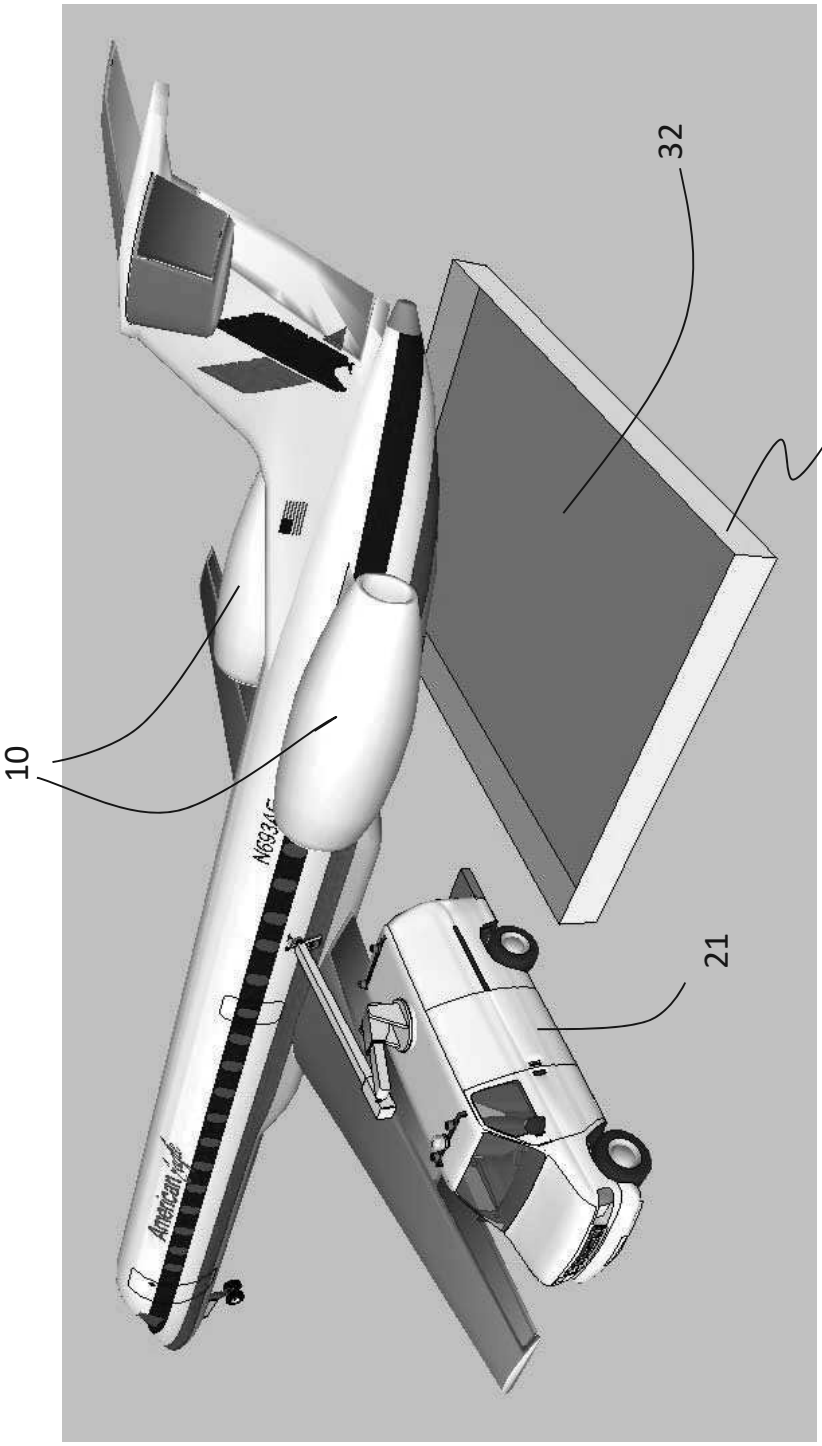


FIG. 21

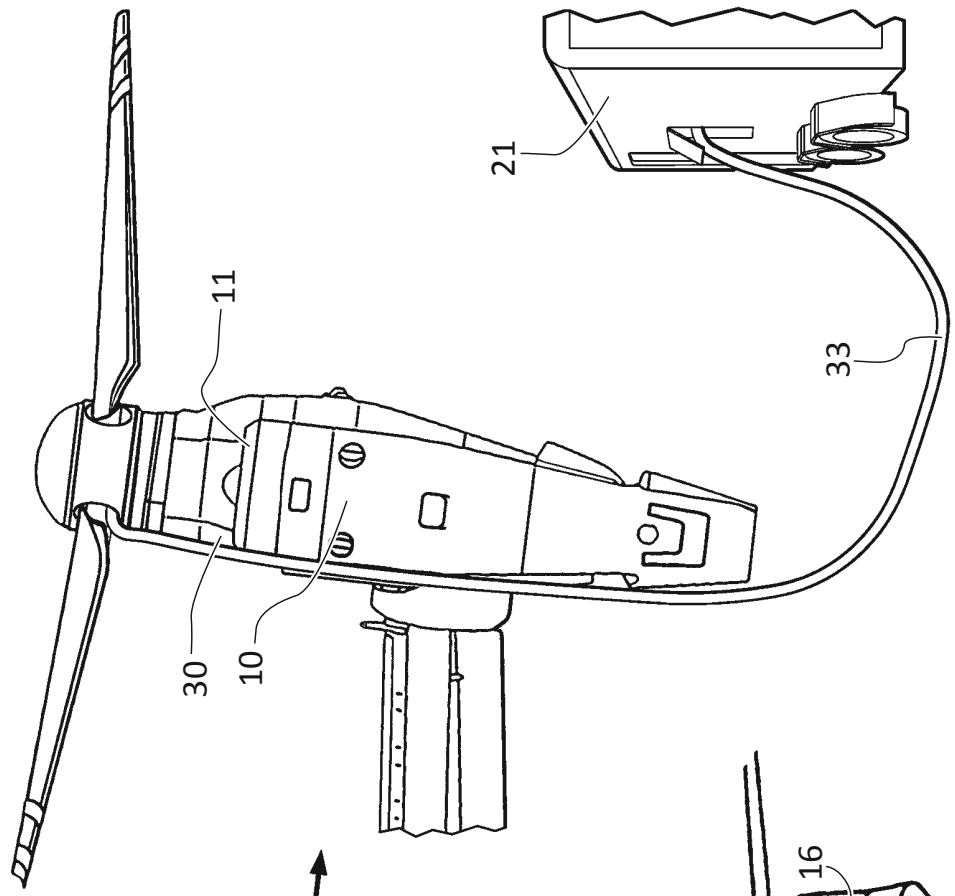


FIG. 22A

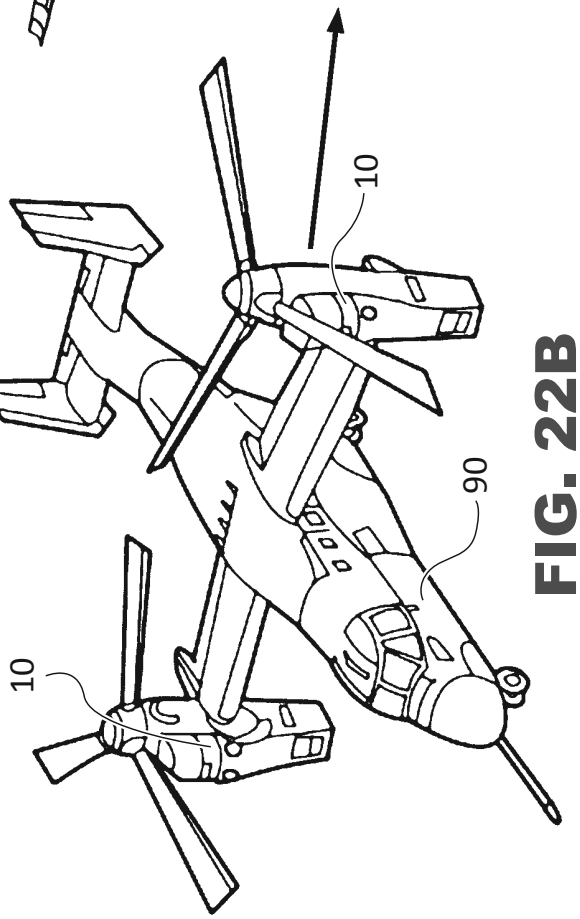


FIG. 22B

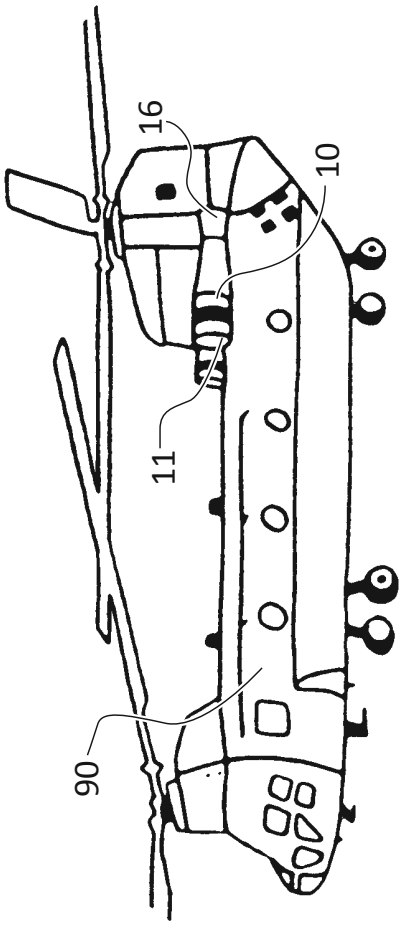


FIG. 22C

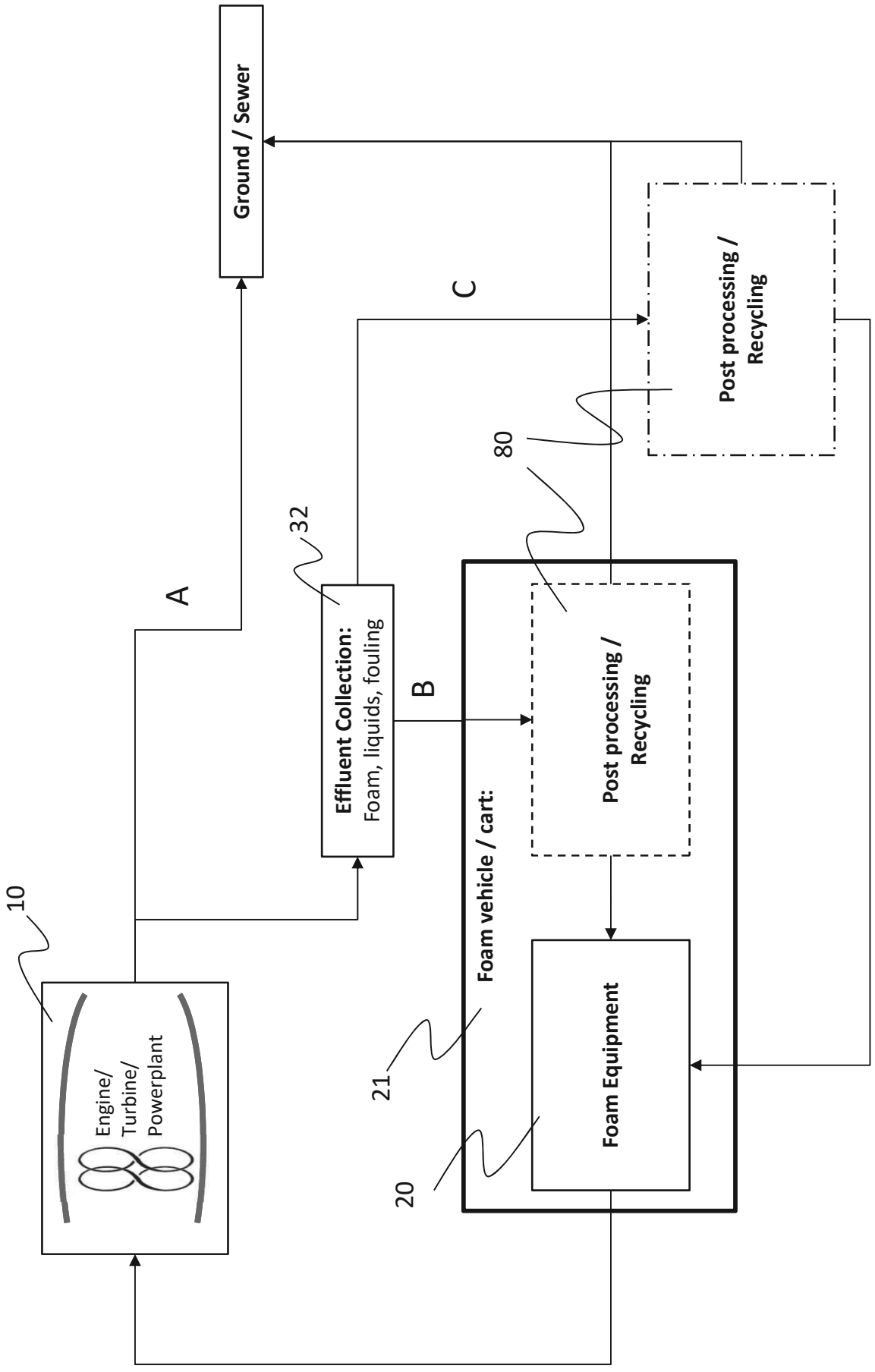

Ground / Sewer
C
Post processing / Recycling
80
32
A
Effluent Collection:
Foam, liquids, fouling
B
Post processing / Recycling
Foam vehicle / cart:
10
Engine/ Turbine/ Powerplant
21
20
Foam Equipment

FIG. 23

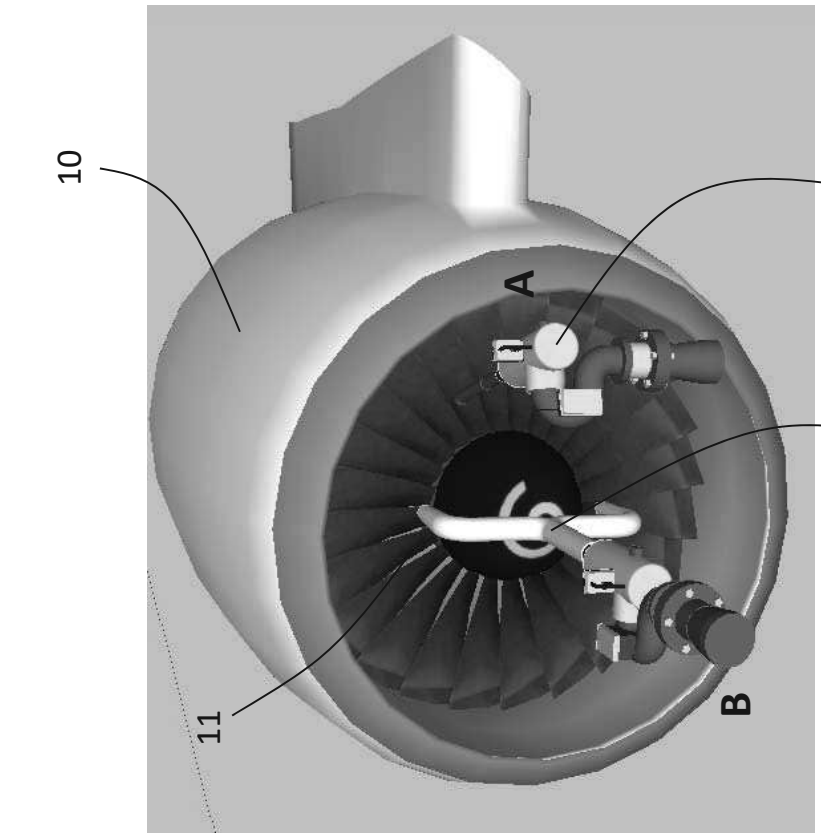


FIG. 24B

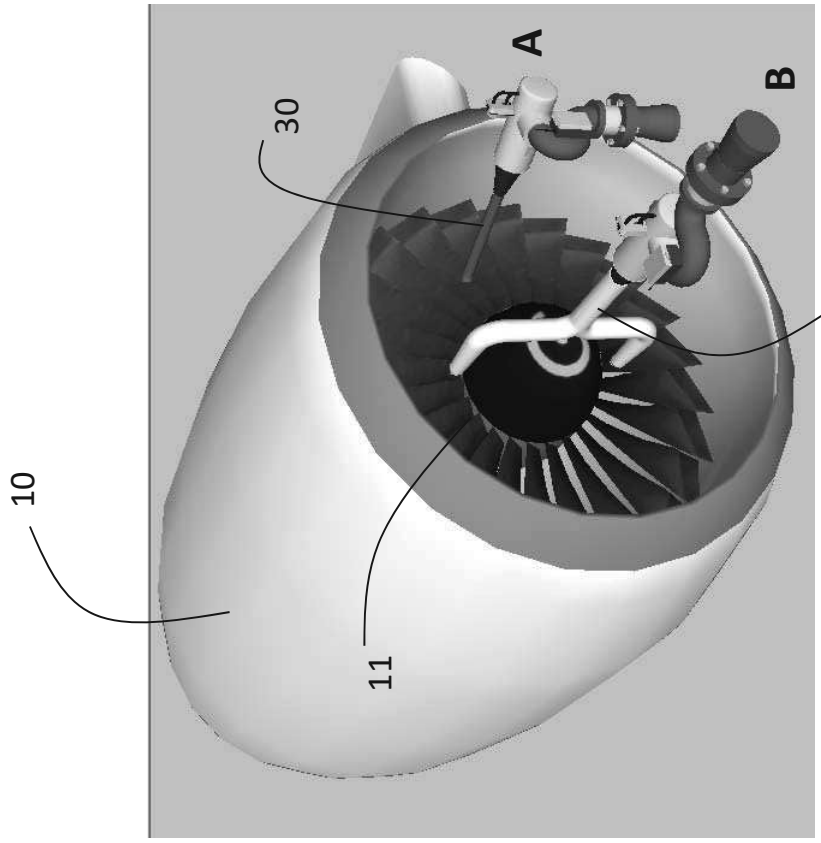


FIG. 24A

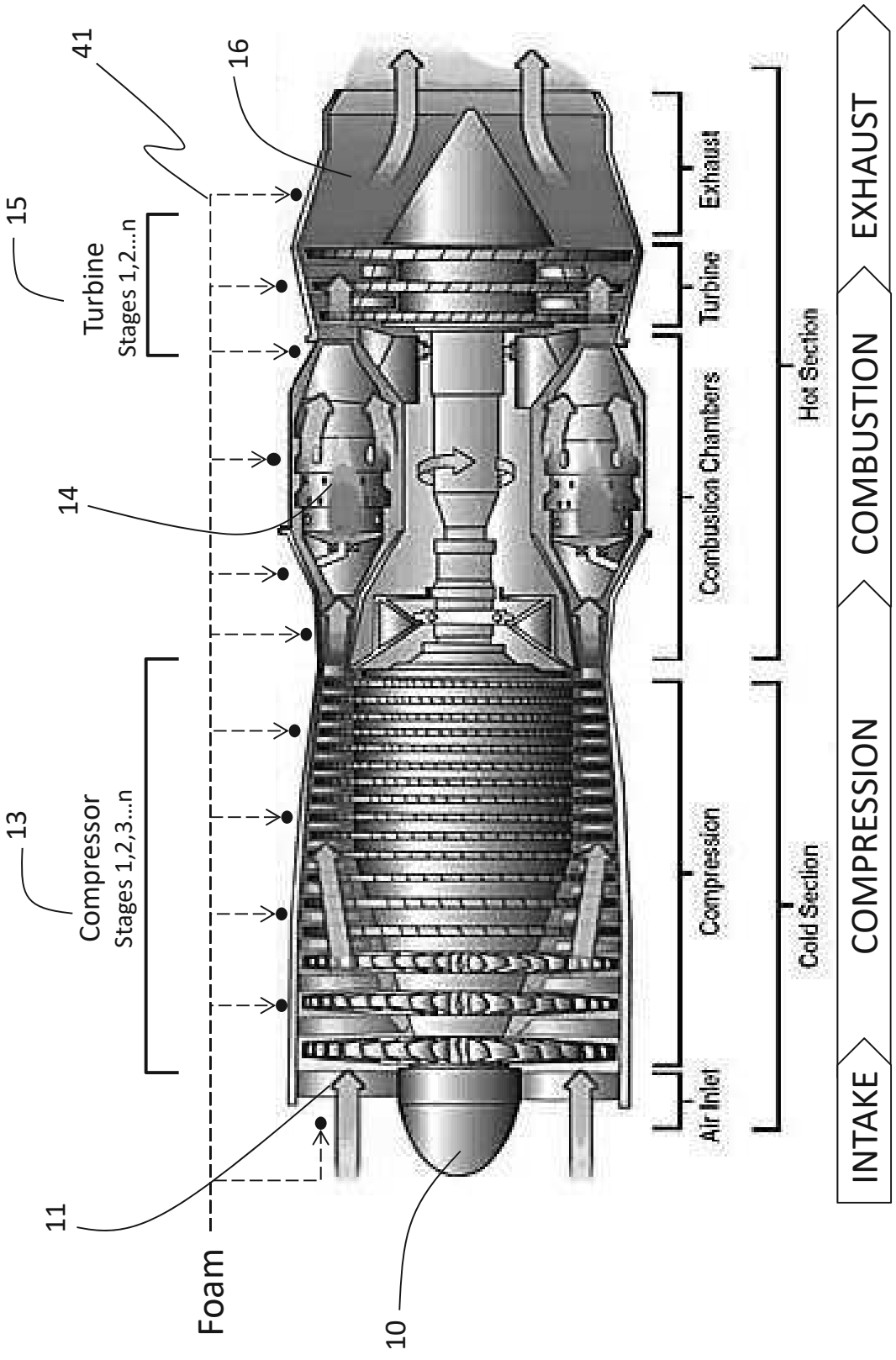

41
16
15
Turbine
Stages 1,2...n
14
13
Compressor
Stages 1,2,3...n
11
Foam
10
Air Inlet
Compression
Combustion Chambers
Turbine
Exhaust
Cold Section
Hot Section
INTAKE
COMPRESSION
COMBUSTION
EXHAUST

FIG. 25A

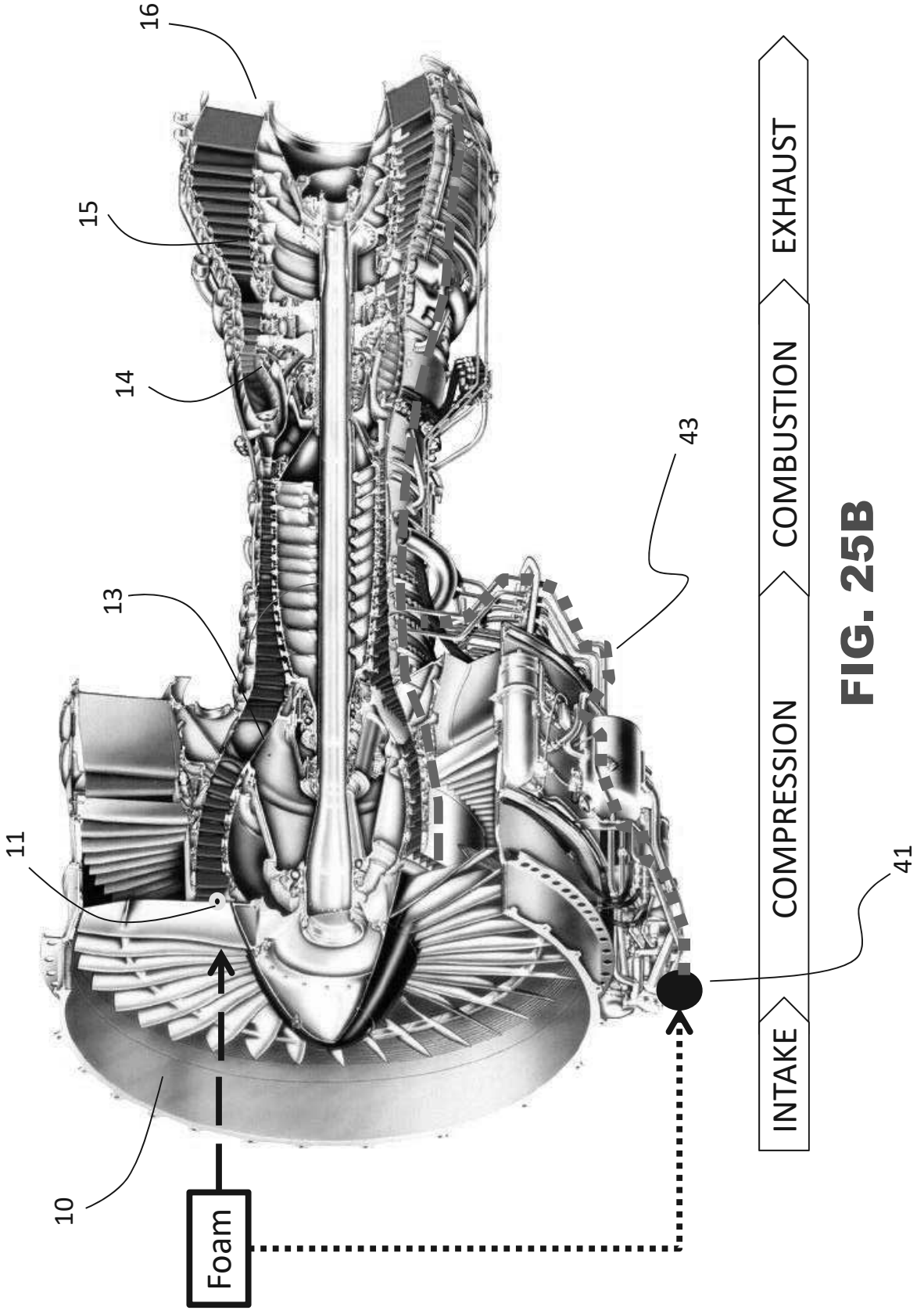

16
15
14
13
11
10
43
41
Foam
INTAKE
COMPRESSION
COMBUSTION
EXHAUST

FIG. 25B

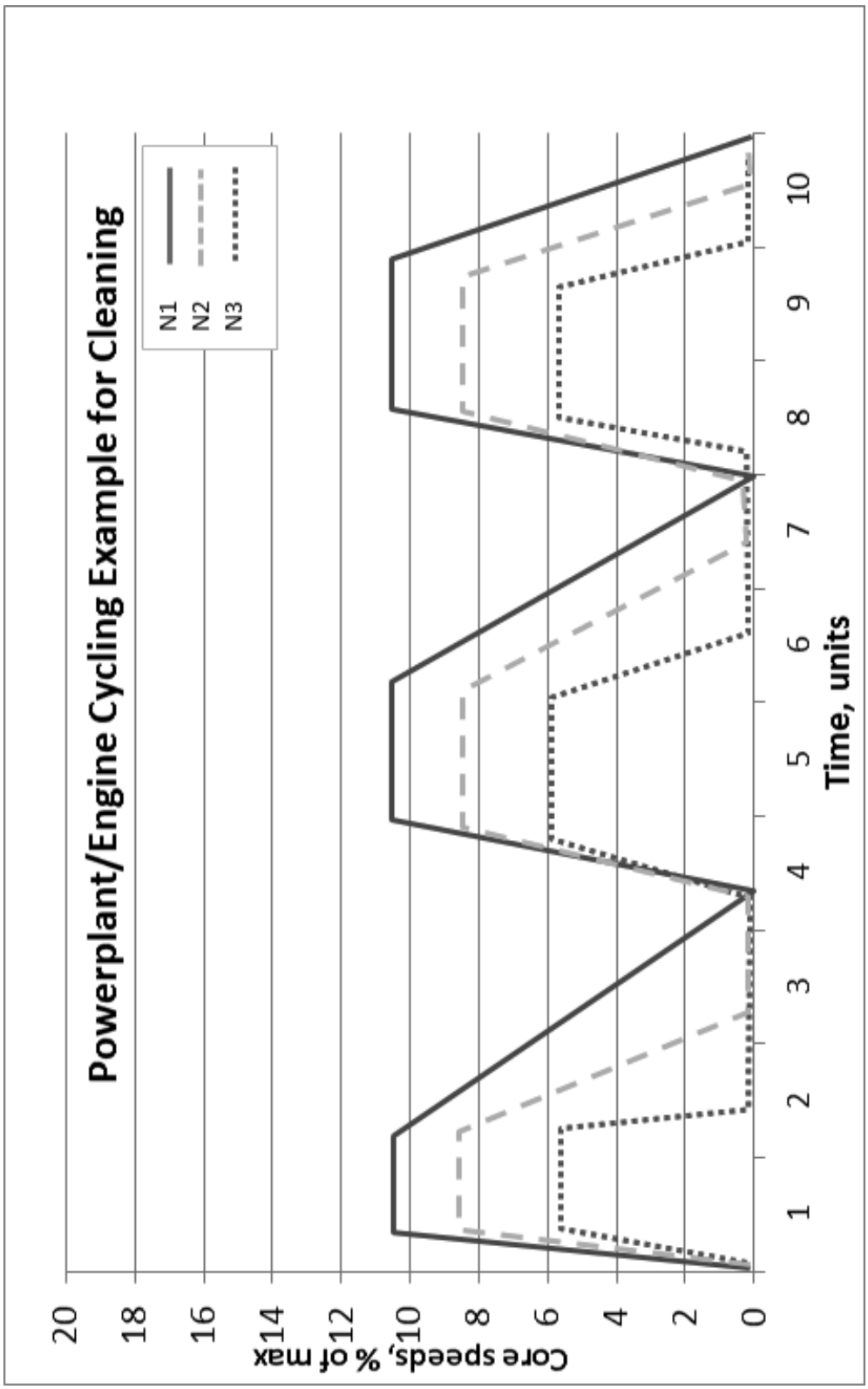

Powerplant/Engine Cycling Example for Cleaning
N1
N2
N3
Core speeds, % of max
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
Time, units

FIG. 26

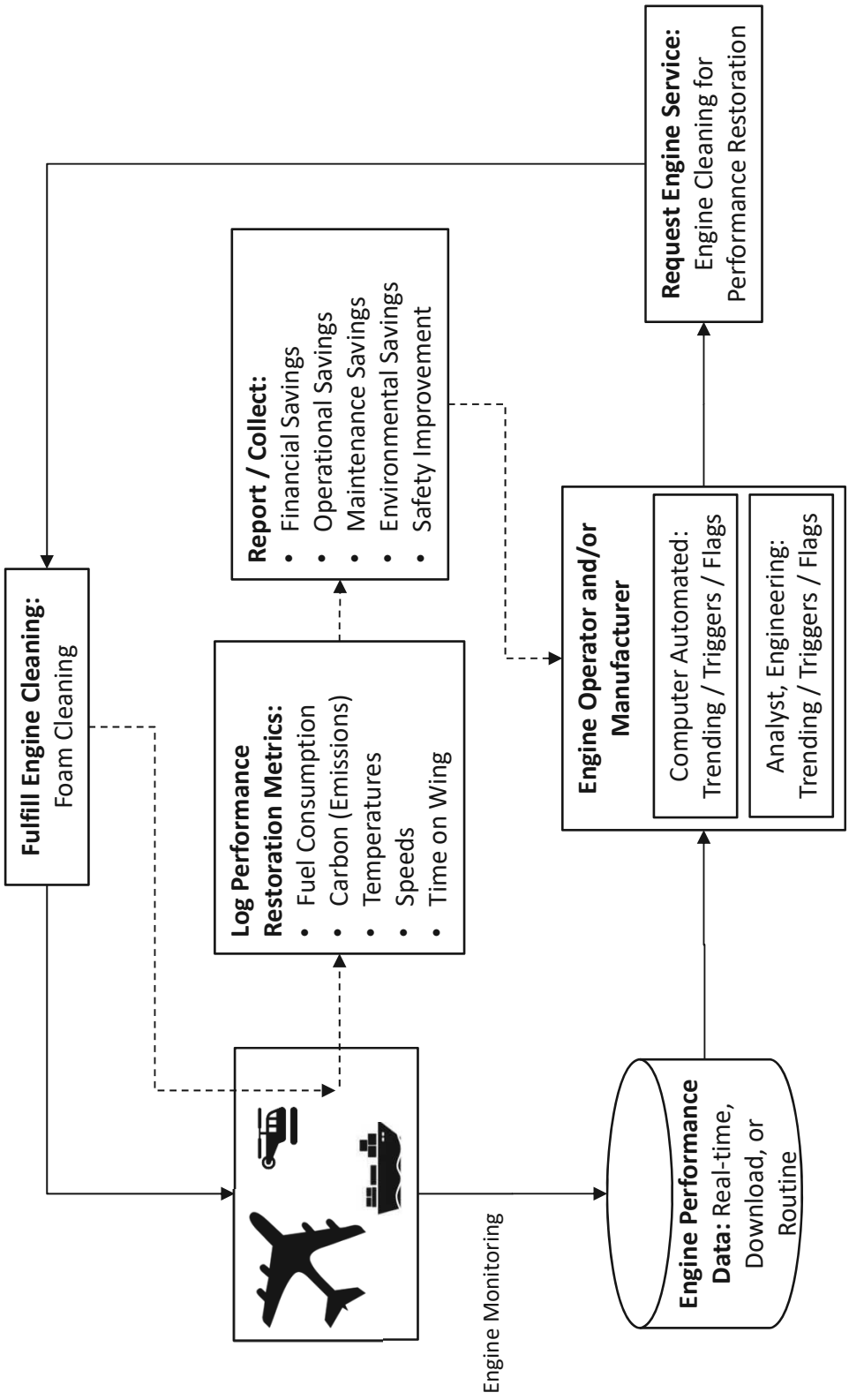

Request Engine Service: Engine Cleaning for Performance Restoration
Report / Collect:
• Financial Savings
• Operational Savings
• Maintenance Savings
• Environmental Savings
• Safety Improvement
Fulfill Engine Cleaning: Foam Cleaning
Log Performance Restoration Metrics:
• Fuel Consumption
• Carbon (Emissions)
• Temperatures
• Speeds
• Time on Wing
Engine Operator and/or Manufacturer
Computer Automated: Trending / Triggers / Flags
Analyst, Engineering: Trending / Triggers / Flags
Engine Performance Data: Real-time, Download, or Routine
Engine Monitoring

FIG. 27

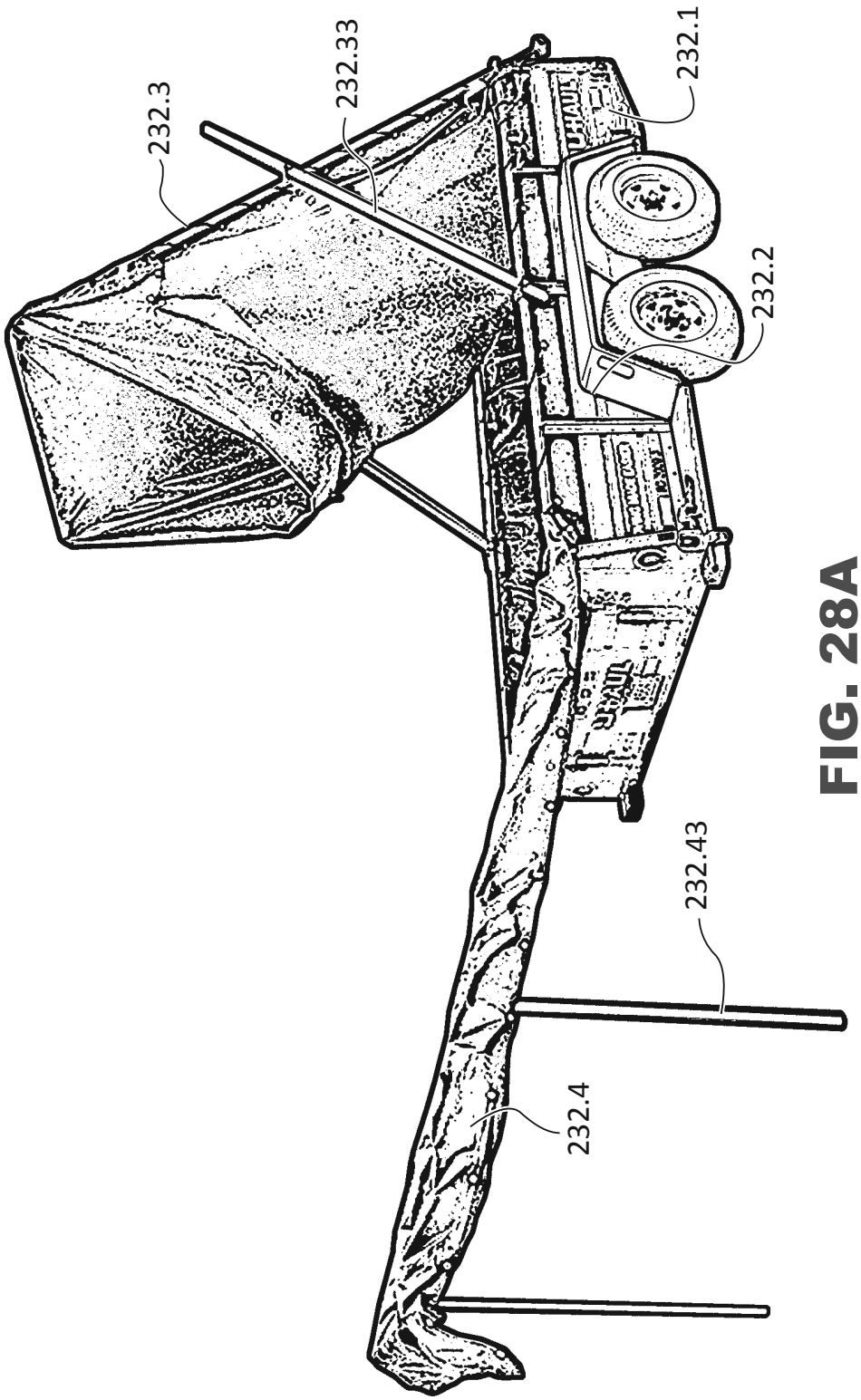


FIG. 28A

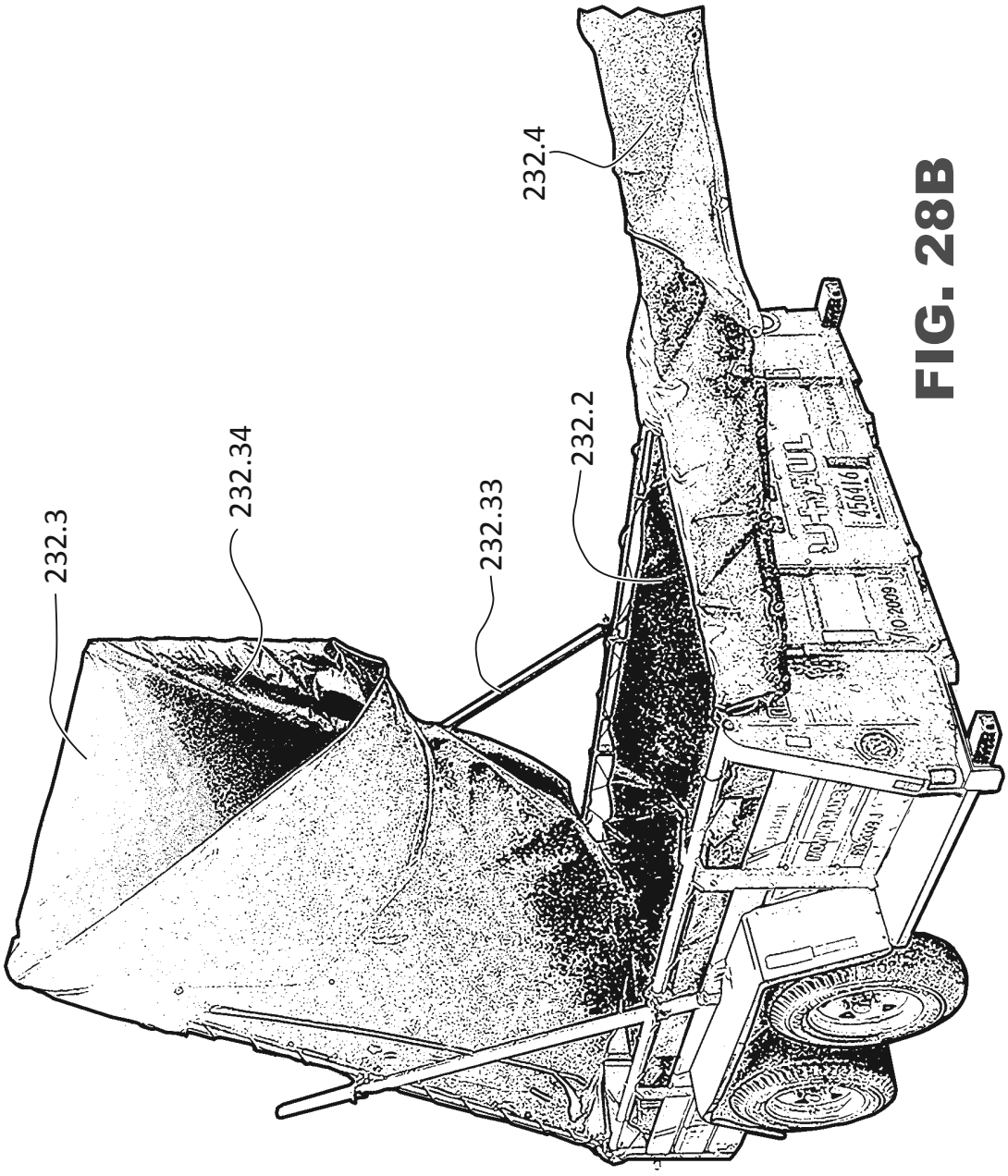


FIG. 28B

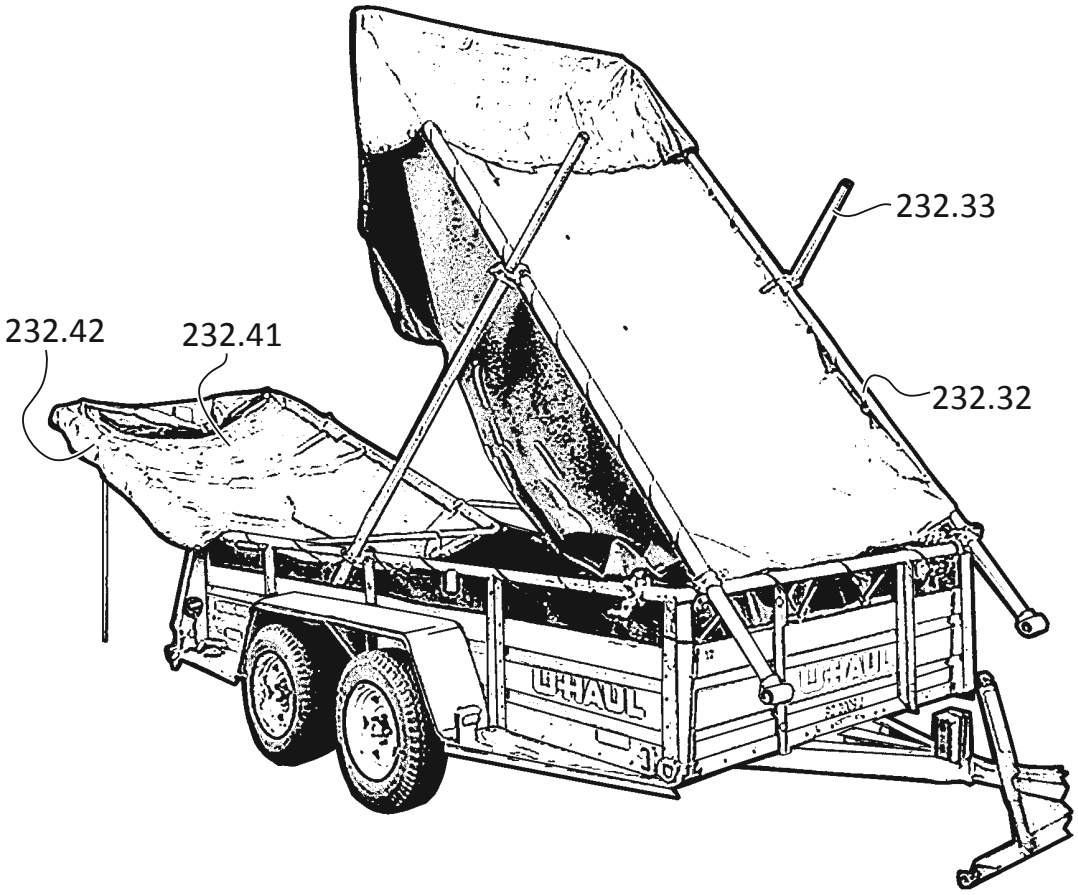


FIG. 28C