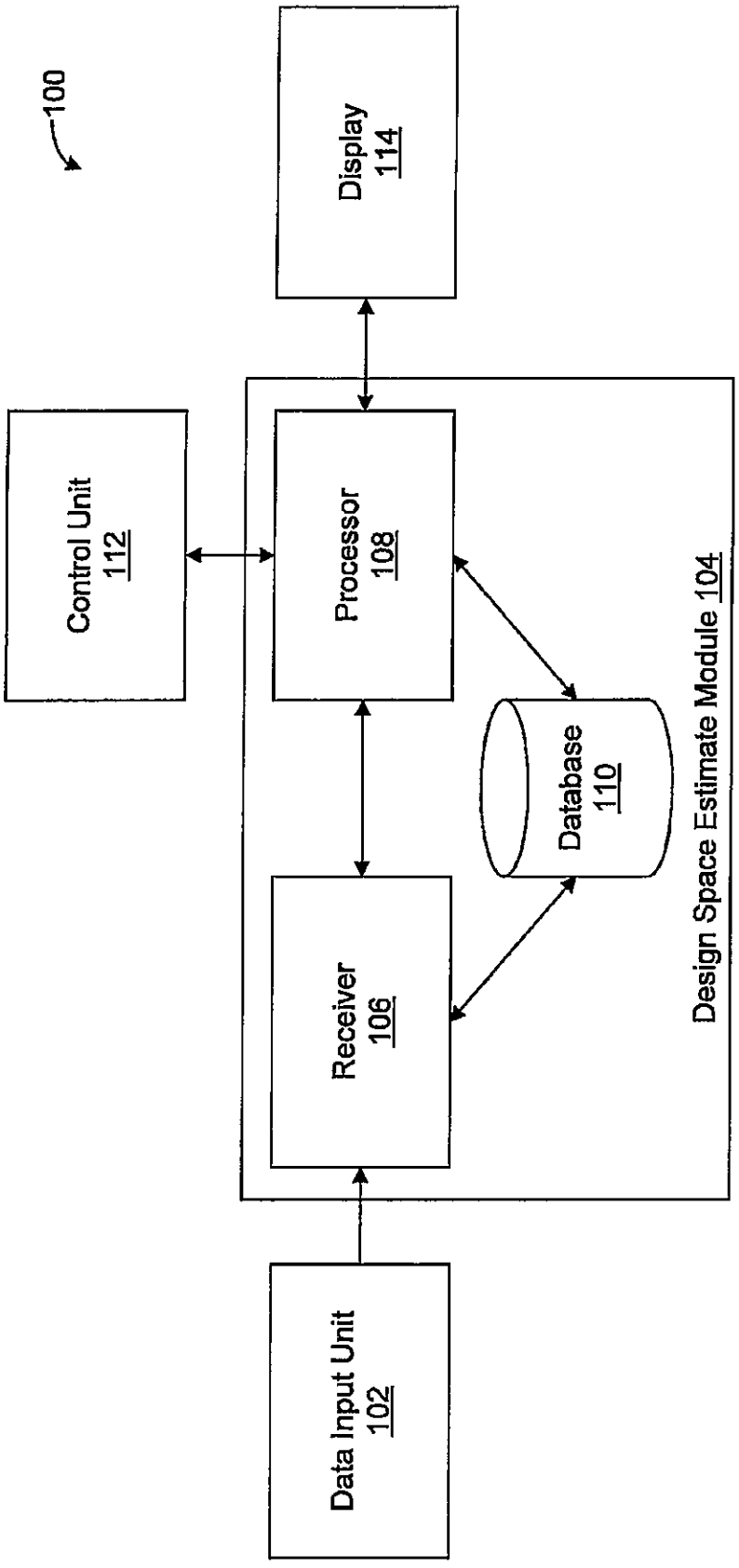
100
Display
114
Control Unit
112
Processor
108
Database
110
Receiver
106
Design Space Estimate Module 104
Data Input Unit
102

FIG. 1

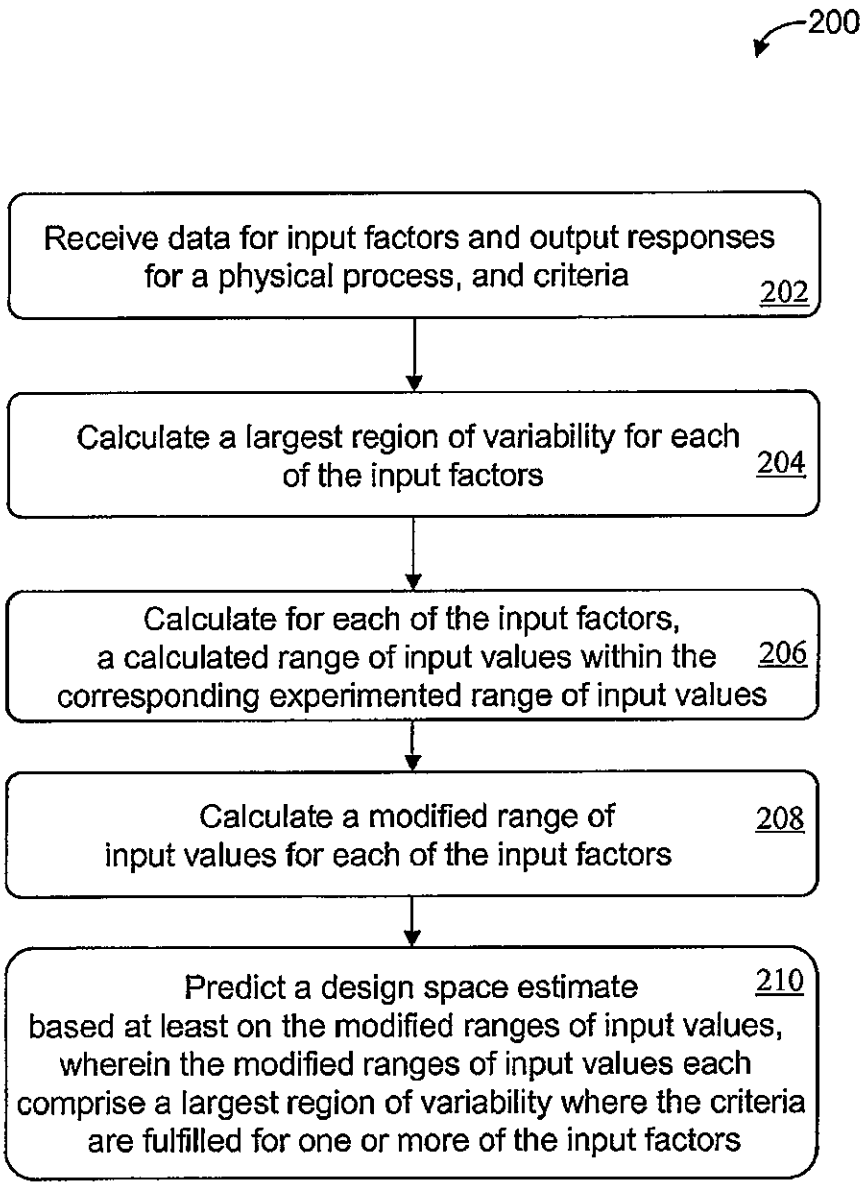
200
Receive data for input factors and output responses for a physical process, and criteria
202
Calculate a largest region of variability for each of the input factors
204
Calculate for each of the input factors, a calculated range of input values within the corresponding experimented range of input values
206
Calculate a modified range of input values for each of the input factors
208
Predict a design space estimate based at least on the modified ranges of input values, wherein the modified ranges of input values each comprise a largest region of variability where the criteria are fulfilled for one or more of the input factors
210

FIG. 2

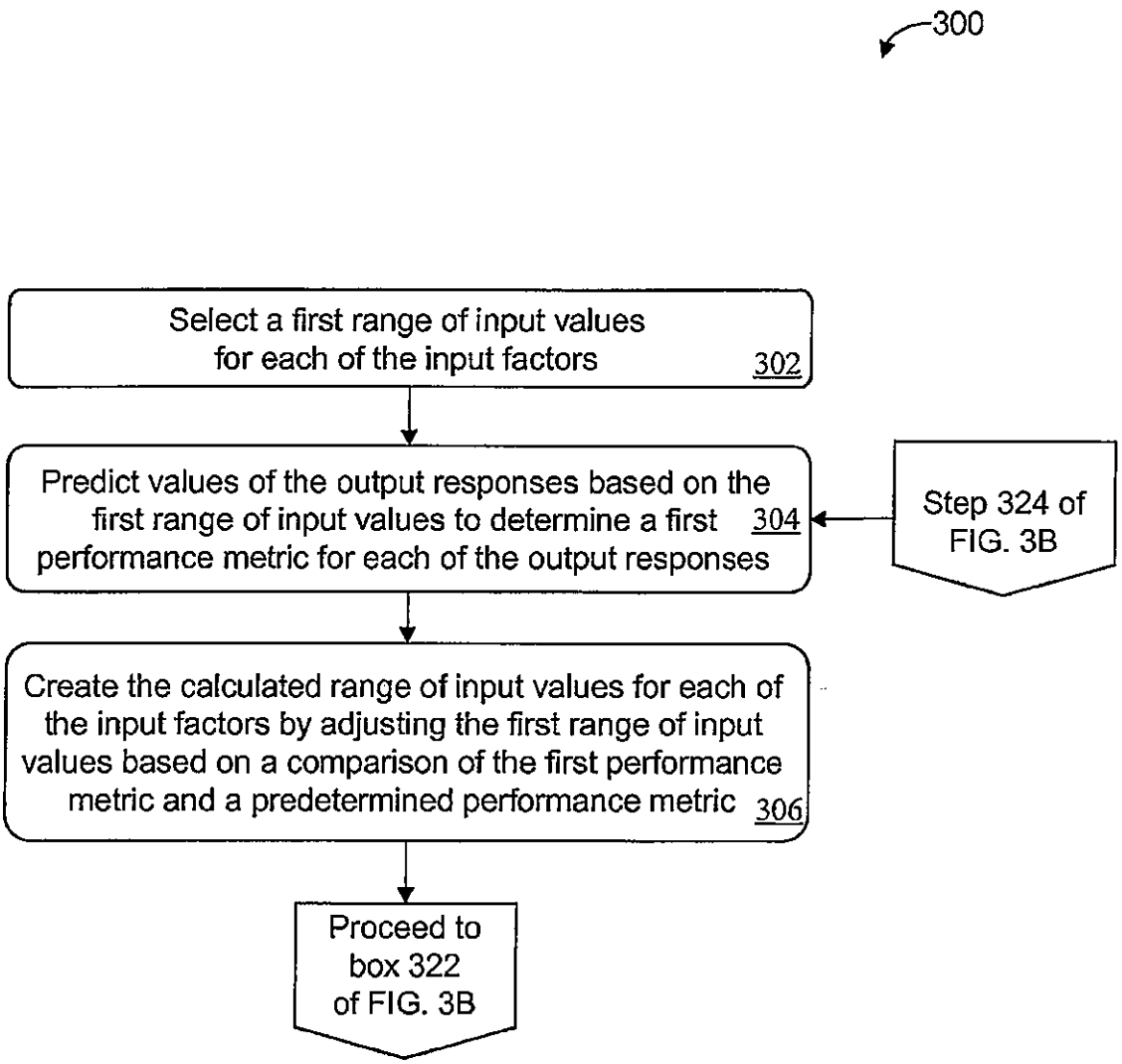
300
Select a first range of input values for each of the input factors 302
Predict values of the output responses based on the first range of input values to determine a first performance metric for each of the output responses 304
Step 324 of FIG. 3B
Create the calculated range of input values for each of the input factors by adjusting the first range of input values based on a comparison of the first performance metric and a predetermined performance metric 306
Proceed to box 322 of FIG. 3B

FIG. 3A

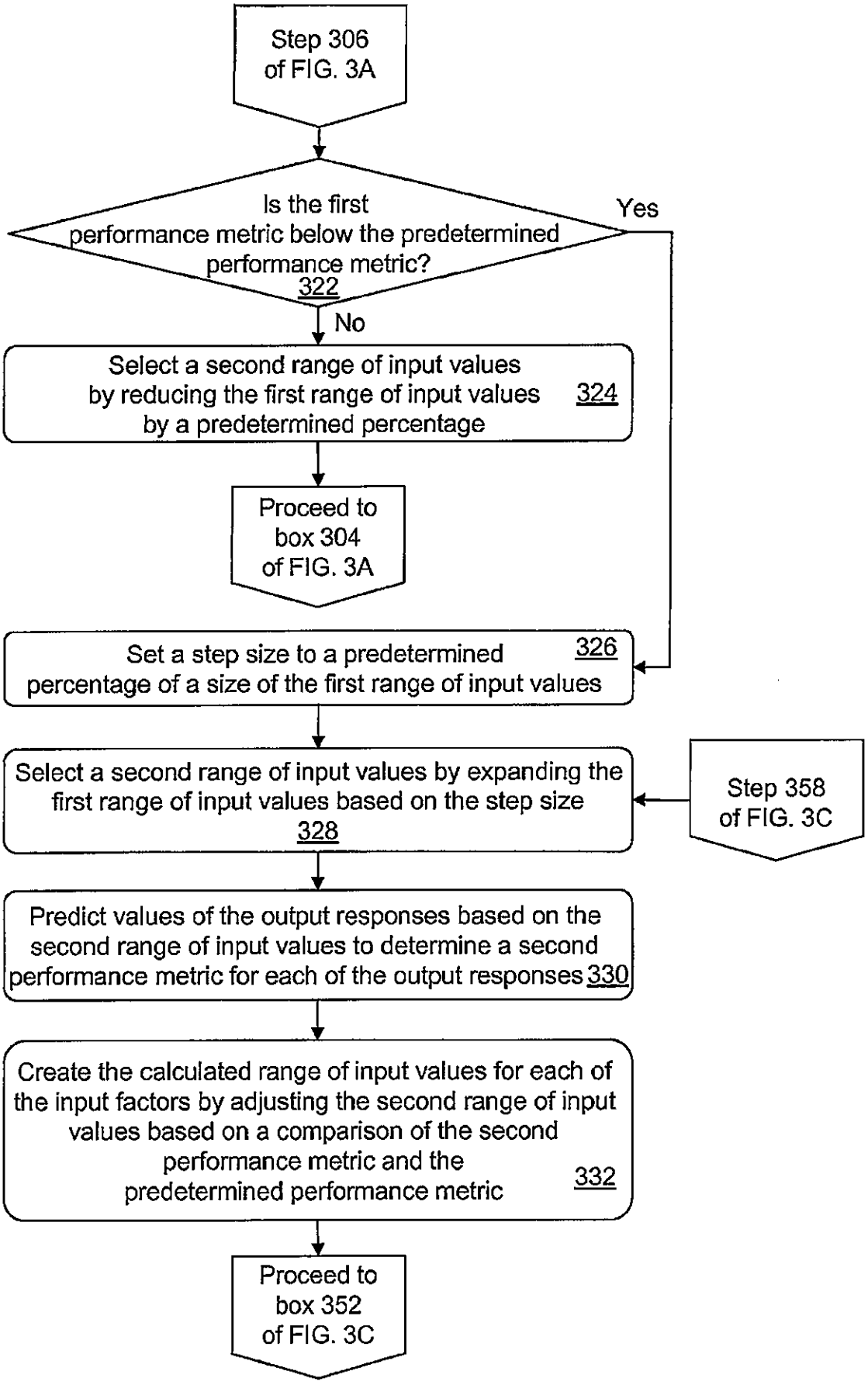
Step 306 of FIG. 3A
Is the first performance metric below the predetermined performance metric? 322
Yes
No
Select a second range of input values by reducing the first range of input values by a predetermined percentage 324
Proceed to box 304 of FIG. 3A
Set a step size to a predetermined percentage of a size of the first range of input values 326
Select a second range of input values by expanding the first range of input values based on the step size 328
Step 358 of FIG. 3C
Predict values of the output responses based on the second range of input values to determine a second performance metric for each of the output responses 330
Create the calculated range of input values for each of the input factors by adjusting the second range of input values based on a comparison of the second performance metric and the predetermined performance metric 332
Proceed to box 352 of FIG. 3C

FIG. 3B

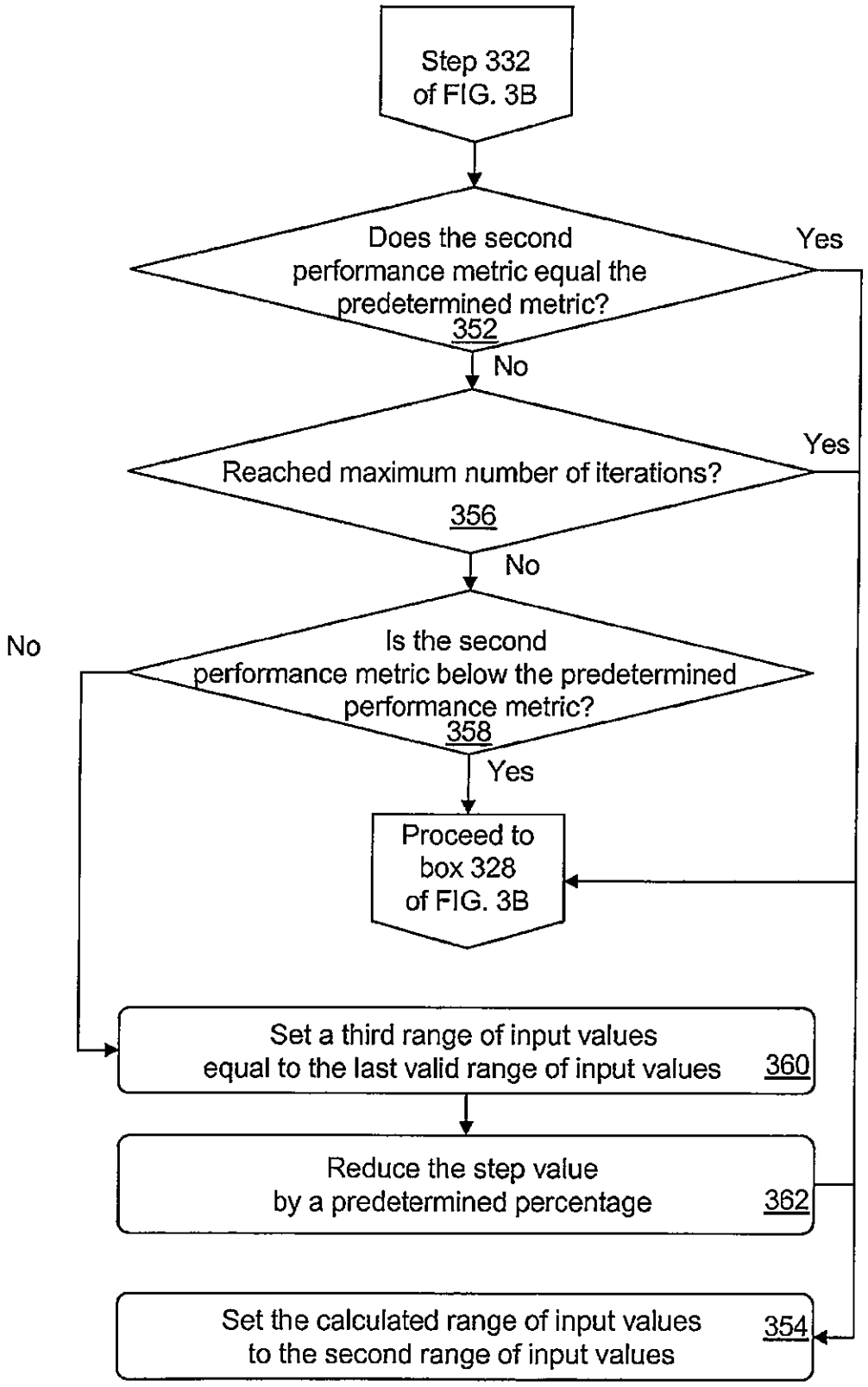
Step 332
of FIG. 3B
Does the second performance metric equal the predetermined metric?
352
Yes
No
Reached maximum number of iterations?
356
Yes
No
Is the second performance metric below the predetermined performance metric?
358
No
Yes
Proceed to box 328 of FIG. 3B
Set a third range of input values equal to the last valid range of input values
360
Reduce the step value by a predetermined percentage
362
Set the calculated range of input values to the second range of input values
354

FIG. 3C

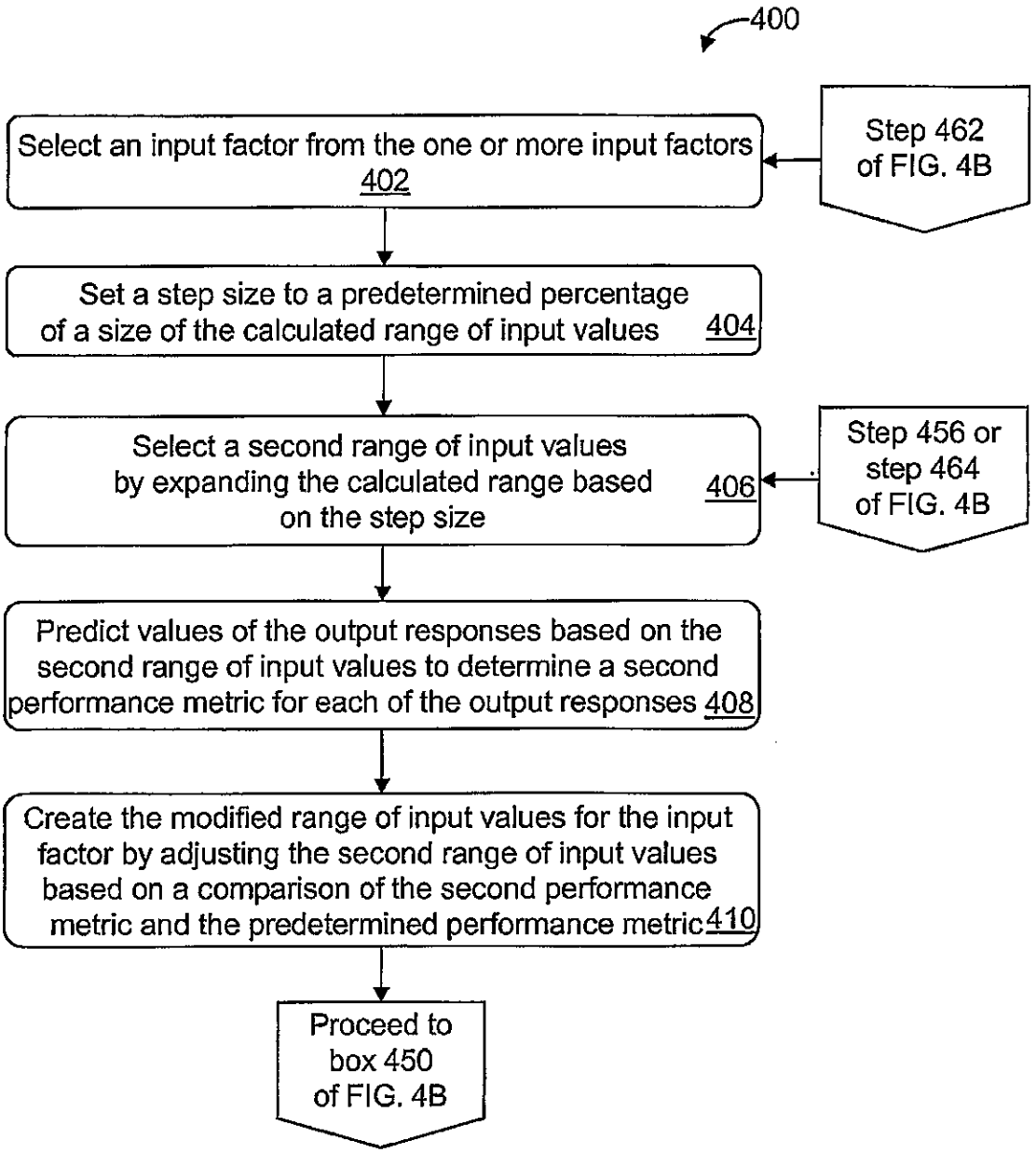
400
Select an input factor from the one or more input factors 402
Step 462 of FIG. 4B
Set a step size to a predetermined percentage of a size of the calculated range of input values 404
Select a second range of input values by expanding the calculated range based on the step size 406
Step 456 or step 464 of FIG. 4B
Predict values of the output responses based on the second range of input values to determine a second performance metric for each of the output responses 408
Create the modified range of input values for the input factor by adjusting the second range of input values based on a comparison of the second performance metric and the predetermined performance metric 410
Proceed to box 450 of FIG. 4B

FIG. 4A

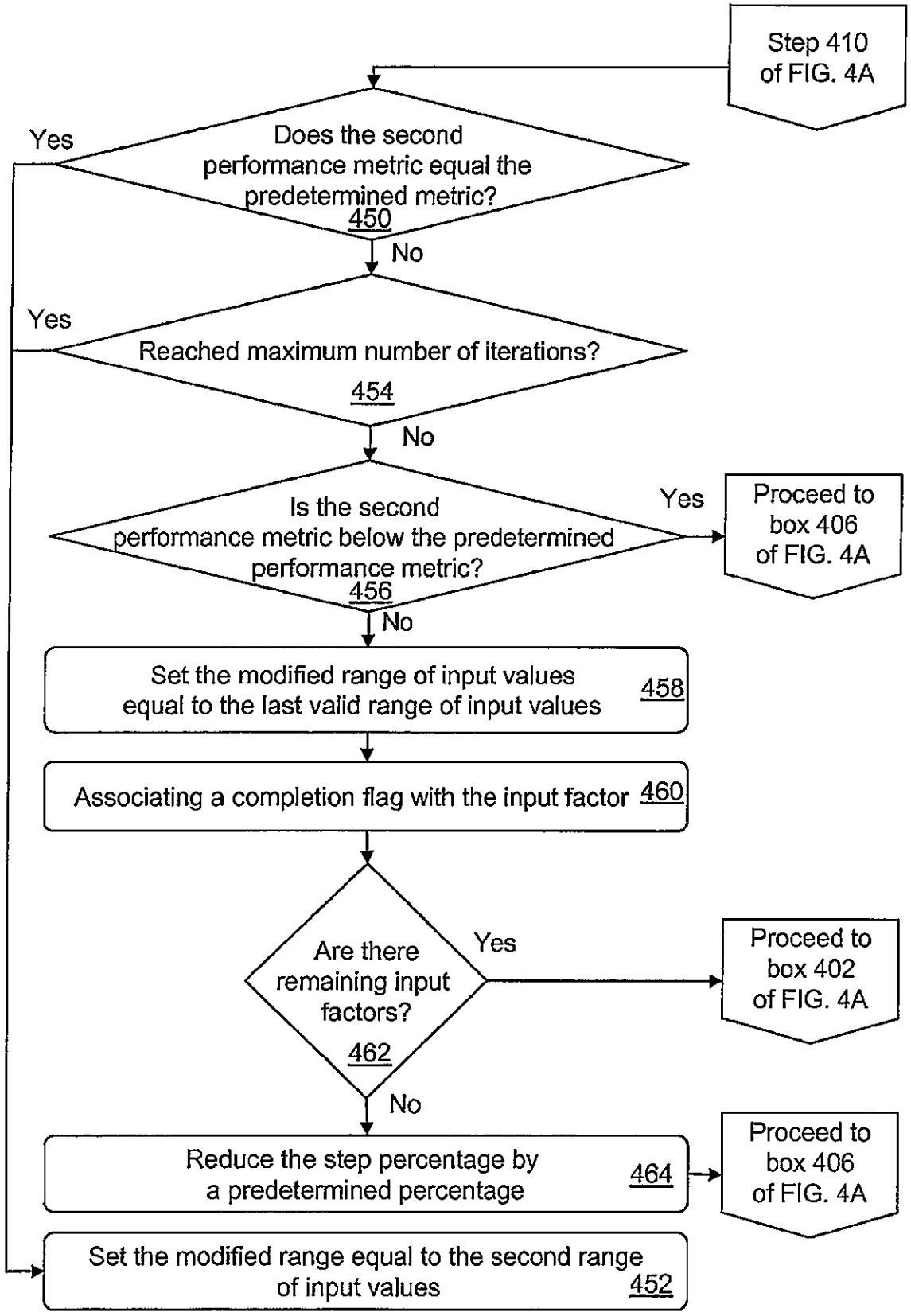
Step 410 of FIG. 4A
Does the second performance metric equal the predetermined metric? 450
Yes
No
Reached maximum number of iterations? 454
Yes
No
Is the second performance metric below the predetermined performance metric? 456
Yes
Proceed to box 406 of FIG. 4A
No
Set the modified range of input values equal to the last valid range of input values 458
Associating a completion flag with the input factor 460
Are there remaining input factors? 462
Yes
Proceed to box 402 of FIG. 4A
No
Reduce the step percentage by a predetermined percentage 464
Proceed to box 406 of FIG. 4A
Set the modified range equal to the second range of input values 452

FIG. 4B

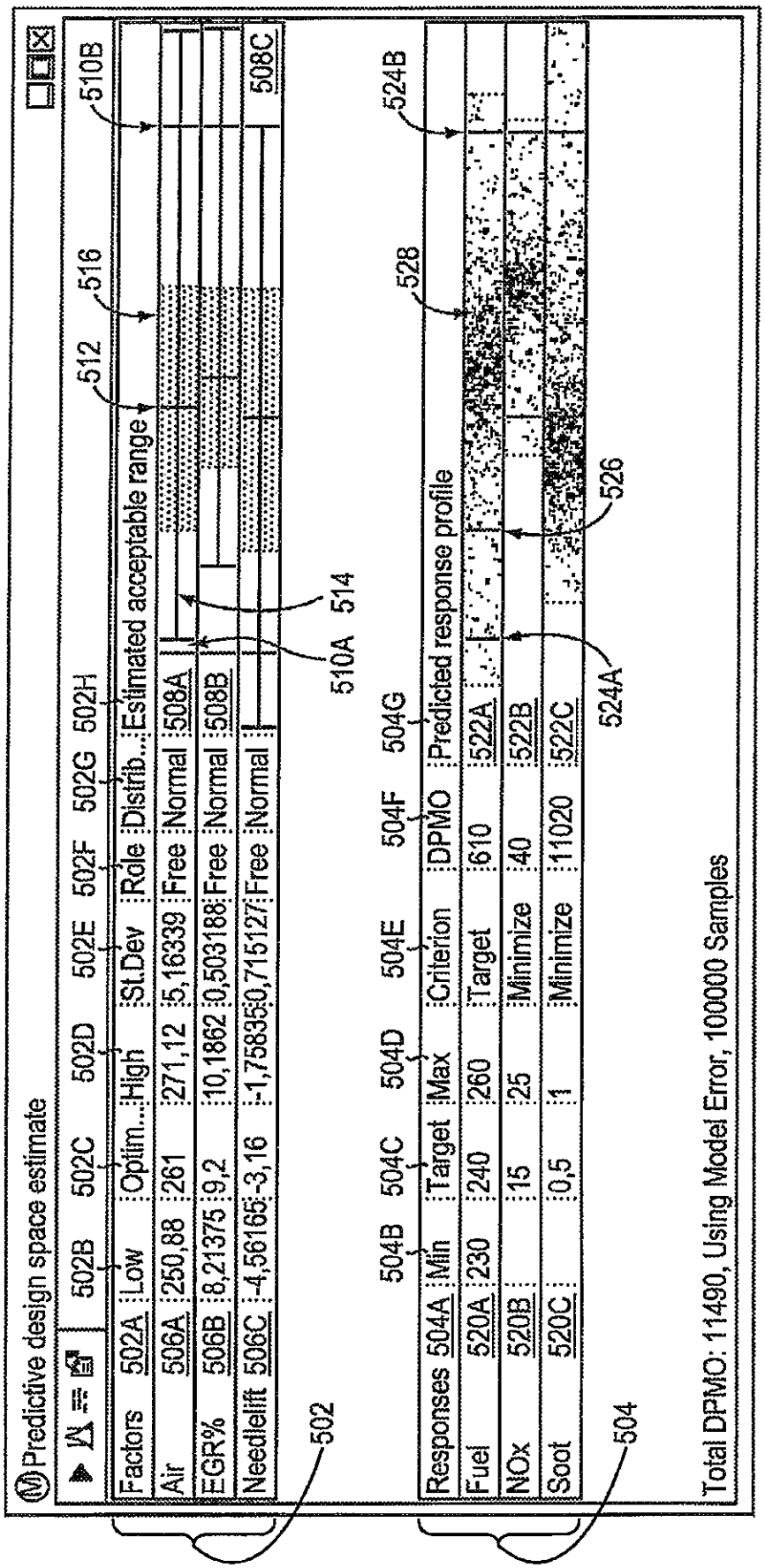
500
Predictive design space estimate
502B 502C 502D 502E 502F 502G 502H
510B
512
516
Factors 502A Low Optim... High St.Dev Role Distrib... Estimated acceptable range
Air 506A 250,88 261 271,12 5,16339 Free Normal 508A
EGR% 506B 8,21375 9,2 10,1862 0,503188 Free Normal 508B
Needlelift 506C -4,56166 -3,16 -1,75835 0,715127 Free Normal 508C
502
510A 514
504B 504C 504D 504E 504F 504G
528
524B
Responses 504A Min Target Max Criterion DPMO Predicted response profile
Fuel 520A 230 240 260 Target 610 522A
NOx 520B 15 25 Minimize 40 522B
Soot 520C 0,5 1 Minimize 11020 522C
526
524A
504
Total DPMO: 11490, Using Model Error, 100000 Samples

FIG. 5A

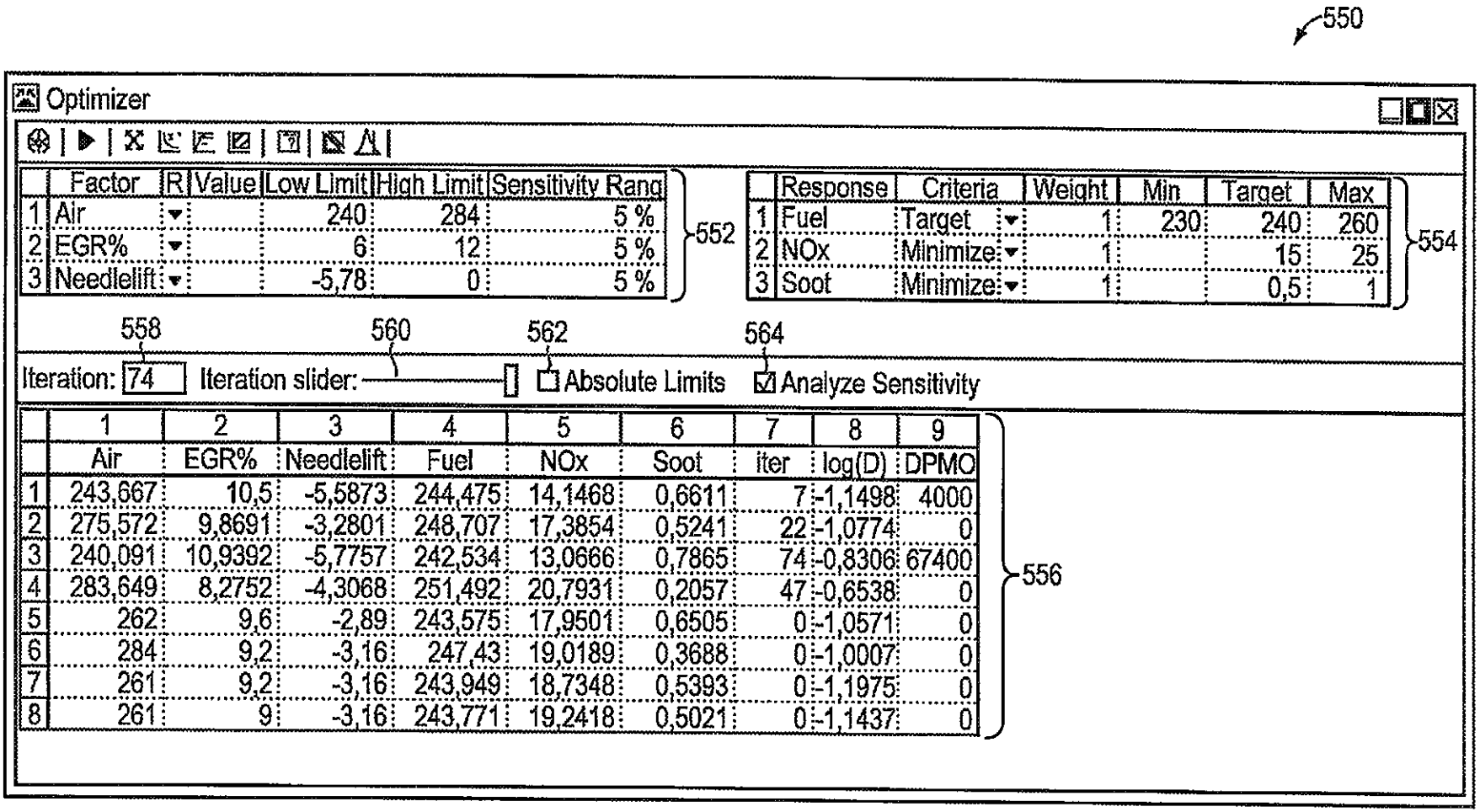
550
Optimizer
Factor | R | Value | Low Limit | High Limit | Sensitivity Rang
1 Air | 240 | 284 | 5 %
2 EGR% | 6 | 12 | 5 %
3 Needlelift | -5,78 | 0 | 5 %
552
Response | Criteria | Weight | Min | Target | Max
1 Fuel | Target | 1 | 230 | 240 | 260
2 NOx | Minimize | 1 | | 15 | 25
3 Soot | Minimize | 1 | | 0,5 | 1
554
558
560
562
564
Iteration: 74
Iteration slider:
Absolute Limits
Analyze Sensitivity
1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
Air | EGR% | Needlelift | Fuel | NOx | Soot | iter | log(D) | DPMO
1 243,667 | 10,5 | -5,5873 | 244,475 | 14,1468 | 0,6611 | 7 | -1,1498 | 4000
2 275,572 | 9,8691 | -3,2801 | 248,707 | 17,3854 | 0,5241 | 22 | -1,0774 | 0
3 240,091 | 10,9392 | -5,7757 | 242,534 | 13,0666 | 0,7865 | 74 | -0,8306 | 67400
4 283,649 | 8,2752 | -4,3068 | 251,492 | 20,7931 | 0,2057 | 47 | -0,6538 | 0
5 262 | 9,6 | -2,89 | 243,575 | 17,9501 | 0,6505 | 0 | -1,0571 | 0
6 284 | 9,2 | -3,16 | 247,43 | 19,0189 | 0,3688 | 0 | -1,0007 | 0
7 261 | 9,2 | -3,16 | 243,949 | 18,7348 | 0,5393 | 0 | -1,1975 | 0
8 261 | 9 | -3,16 | 243,771 | 19,2418 | 0,5021 | 0 | -1,1437 | 0
556

FIG. 5B

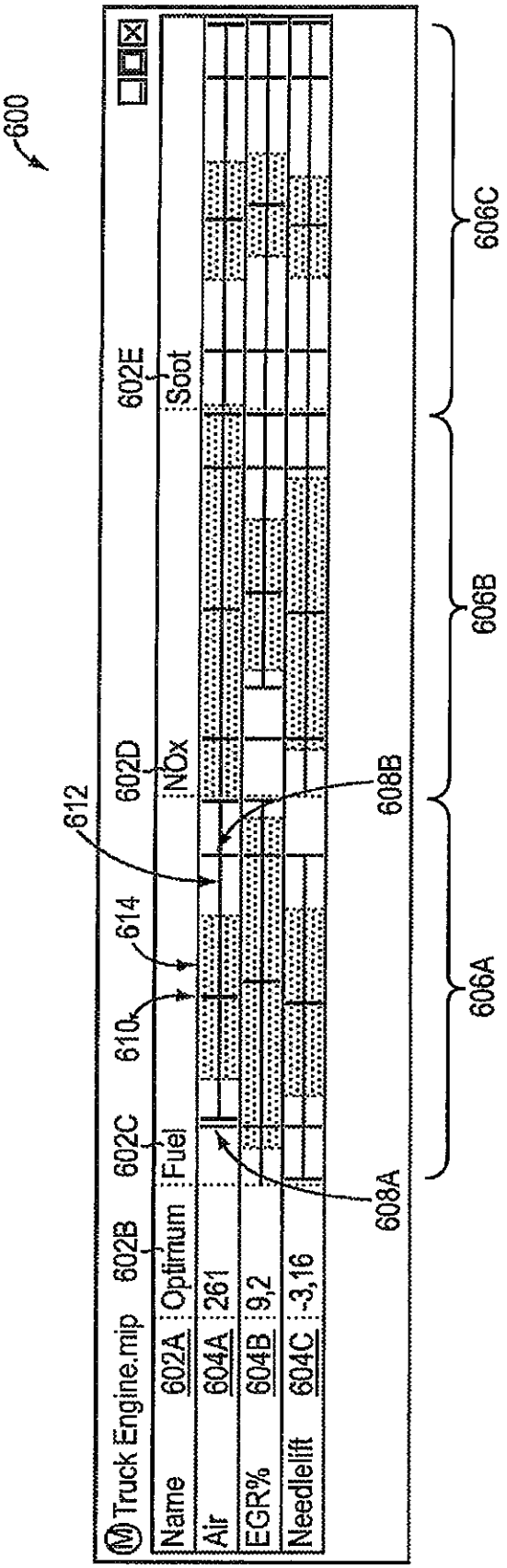
600
Truck Engine.mip
602B
602C
610
602D
602E
Name
Optimum
Fuel
NOx
Soot
Air
261
EGR%
9,2
Needlelift
-3,16
612
614
608A
608B
606A
606B
606C

FIG. 5C

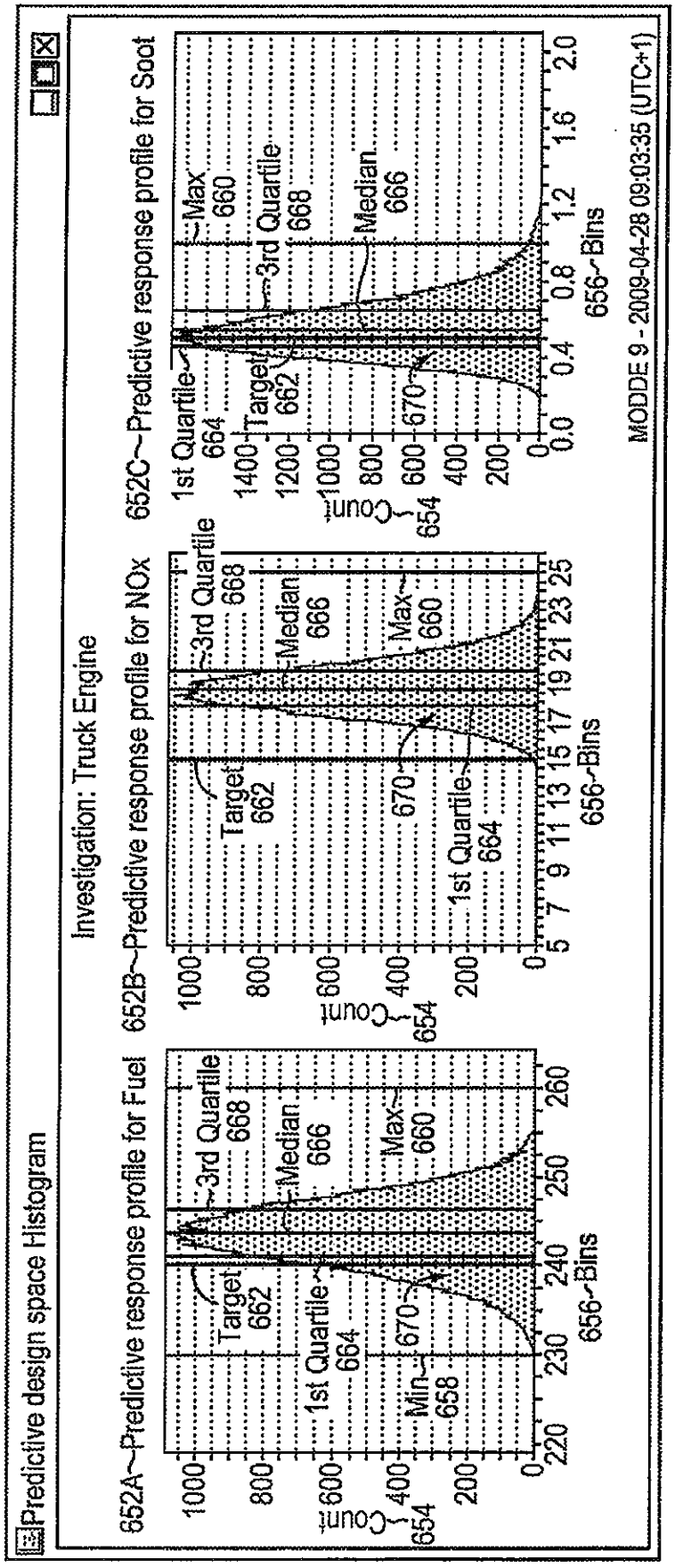
650
Predictive design space Histogram
Investigation: Truck Engine
652A~Predictive response profile for Fuel
652B~Predictive response profile for NOx
652C~Predictive response profile for Soot
Count
656~Bins
Min
1st Quartile
Target
Median
3rd Quartile
Max
654
MODDE 9 - 2009-04-28 09:03:35 (UTC+1)

FIG. 5D

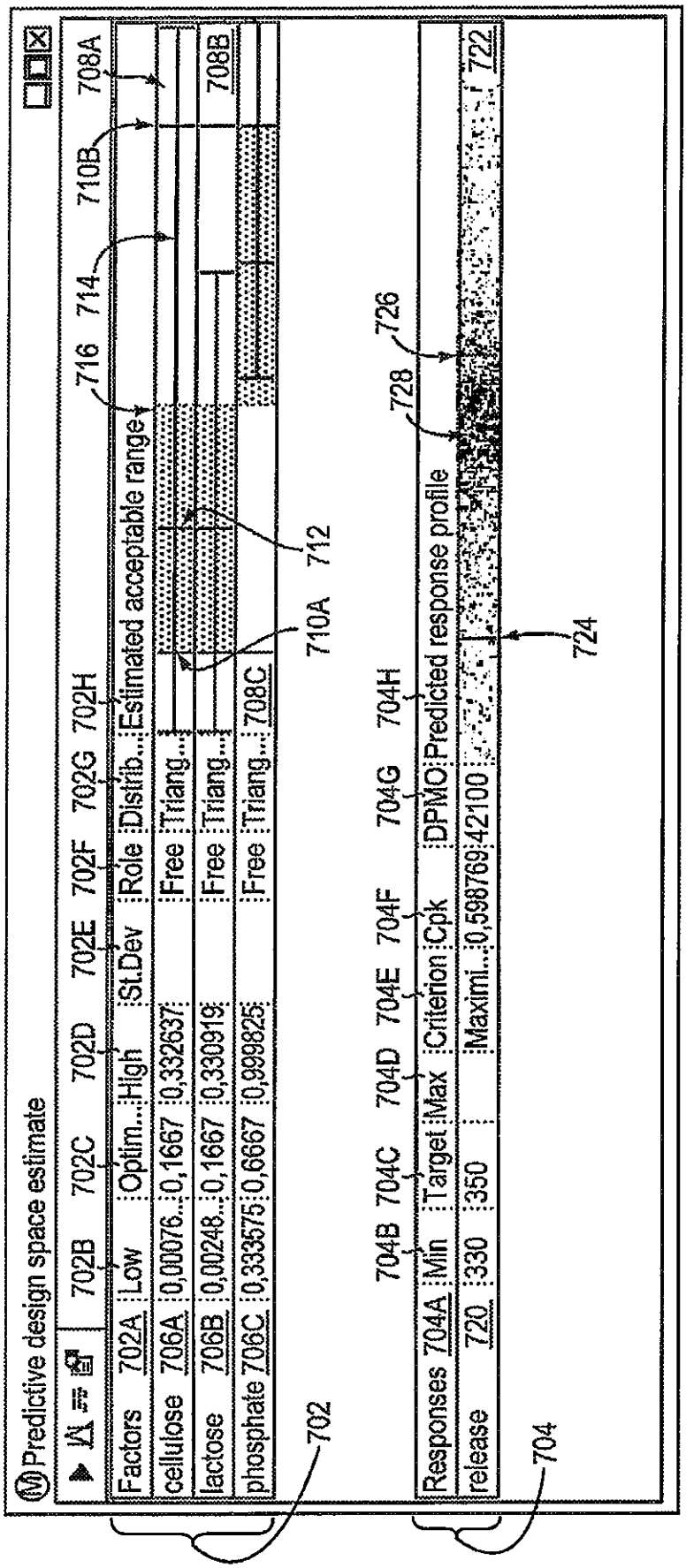
650
Predictive design space estimate
702B
702C
702D
702E
702F
702G
702H
Factors
Low
Optim...
High
St.Dev
Role
Distrib...
Estimated acceptable range
cellulose
0,00076...
0,1667
0,332637
Free
Triang...
lactose
0,00248...
0,1667
0,330919
Free
Triang...
phosphate
0,333575
0,6667
0,999825
Free
Triang...
708A
708B
708C
710A
710B
712
714
716
702
704B
704C
704D
704E
704F
704G
704H
Responses
Min
Target
Max
Criterion
Cpk
DPMO
Predicted response profile
release
330
350
Maximi...
0,598769
42100
720
722
724
726
728
704

FIG. 5E