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⑤4 Virsraksts: METODE UN SISTĒMA MAINĪGA APSTEIDZOŠA PARAMETRA UN PIEREGULĒJAMA
ATPALIEKOŠA PARAMETRA ATTIECĪBAS REGULĒŠANAI ATPALIKŠANAS -
⑤7 Kopsavilkums: APSTEIGŠANAS TIPĀ REGULĒŠANAS PROCESĀ

Piedāvātajā metodē un sistēmā, lai regulētu gaisa/gāzes attiecību sadedzināšanai krasnī, izmantojot atpalikšanas - apsteigšanas tipa regulēšanu, apsteidzošie un atpaliekošie parametri tiek kontrolēti, lai ģenerētu apsteidzes un atpalikšanas signālus, kas reprezentē šo parametru vērtības. Tie tiek salīdzināti, lai ģenerētu kļūdas signālu, kas reprezentē apsteidzošo un atpaliekošo parametru attiecības novirzi no iepriekš izvēlētās attiecības. Pēc tam atpaliekošais parametrs tiek pieregulēts, lai samazinātu novirzi, atbildot uz to, ka novirze pārsniegusi iepriekš izvēlēto novirzi.

IZGUDROJUMA FORMULA

1. Metode mainīga apstaidzoša parametra un pierēgulējama atpaliekoša parametra attiecības regulēšanai atpalikšanas – apsteigšanas tipa regulēšanas procesā, kur metode satur:
 - minētā apstaidzošā parametra kontrolēšanu un apstaidzes signāla ģenerēšanu, kas reprezentē minētā apstaidzošā parametra vērtību;
 - minētā atpaliekošā parametra kontrolēšanu un atpalikšanas signāla ģenerēšanu, kas reprezentē minētā atpaliekošā parametra vērtību;
 - minēto apstaidzes un atpalikšanas signālu salīdzināšanu un kļūdas signāla ģenerēšanu, kas reprezentē minēto apstaidzes un atpalikšanas signālu attiecības novirzi no iepriekš izvēlētas attiecības; un
 - minētā atpalikšanas parametra pierēgulēšanu, lai samazinātu minēto novirzi, atbildot uz to, ka minētā novirze pārsniedz iepriekš izvēlēto novirzi.
2. Metode atbilstoši 1. punktam, kas satur minētā kļūdas signāla salīdzināšanu ar iepriekš izvēlētu sliekšņa vērtību un minētā atpaliekošā parametra pierēgulēšanu, atbildot uz to, ka kļūdas signāls pārsniedz minēto iepriekš izvēlēto sliekšņa vērtību.
3. Metode atbilstoši 1. vai 2. punktam, kas satur minētā kļūdas signāla salīdzināšanu ar kļūdas diapazonu, ko nosaka pirmā, augšējā, iepriekš izvēlēta sliekšņa vērtība un otra, apakšējā, iepriekš izvēlēta sliekšņa vērtība, un minētā atpaliekošā parametra pierēgulēšanu, atbildot uz to, ka minētais kļūdas signāls ir izgājis ārpus minētā kļūdas diapazona.
4. Metode atbilstoši 3. punktam, kas satur:
 - minētā atpaliekošā parametra pierēgulēšanu, lai samazinātu minēto attiecību, atbildot uz to, ka minētais kļūdas signāls ir virs minētā kļūdas diapazona; un
 - minētā atpaliekošā parametra pierēgulēšanu, lai palielinātu minēto attiecību, atbildot uz to, ka minētais kļūdas signāls ir zem minētā kļūdas diapazona.
5. Metode atbilstoši 4. punktam, kur:
 - minētā pirmā, augšējā, iepriekš izvēlēta sliekšņa vērtība ir pozitīva vērtība un minētā otra, apakšējā, iepriekš izvēlēta sliekšņa vērtība ir negatīva vērtība;
 - pozitīvs kļūdas signāls indicē minētās attiecības palielināšanos no minētās

iepriekš izvēlētās attiecības un negatīvs kļūdas signāls indicē minētās attiecības samazināšanos no minētās iepriekš izvēlētās attiecības;

un metode satur:

- minētā atpaliekošā parametra pieregulēšanu, lai samazinātu minēto attiecību, atbildot uz to, ka minētais kļūdas signāls ir pozitīvs un pārsniedz pirmo, augšējo, iepriekš izvēlēto sliekšņa vērtību; un
- minētā atpaliekošā parametra pieregulēšanu, lai palielinātu minēto attiecību, atbildot uz to, ka minētais kļūdas signāls ir negatīvs un pārsniedz minēto otro, apakšējo, iepriekš izvēlēto sliekšņa vērtību.

6. Metode atbilstoši no 2. līdz 5. punktam, kur tā vai katra minētā sliekšņa vērtība ir fiksēta vērtība.
7. Metode atbilstoši no 2. līdz 5. punktam, kur tā vai katra minētā sliekšņa vērtība ir minētā atpaliekošā parametra vērtības funkcija.
8. Metode atbilstoši 7. punktam, kur solis, kurā notiek minētā kļūdas signāla salīdzināšana ar to vai katru sliekšņa vērtību, satur minētā sliekšņa vērtības pieregulēšanu atkarībā no minētā atpaliekošā parametra vērtības un minētā kļūdas signāla salīdzināšanu ar minēto pieregulēto sliekšņa vērtību.
9. Metode atbilstoši 8. punktam, kas satur:
 - references tabulas izveidošanu sliekšņa vērtību daudzuma ierakstīšanai; un
 - minētās sliekšņa vērtības pieregulēšanas soli, kas satur vienas no minētajām sliekšņa vērtībām izvēli atkarībā no minētā atpaliekošā parametra vērtības.
10. Metode atbilstoši 7. punktam, kur:
 - tā vai katra sliekšņa vērtība satur daudzus sliekšņa līmeņus; un
 - solis, kurā notiek minētā kļūdas signāla salīdzināšana ar to vai katru sliekšņa vērtību, satur sliekšņa līmeņa izvēlēšanos katrai sliekšņa vērtībai atkarībā no minētā atpaliekošā parametra vērtības un minētā kļūdas signāla salīdzināšanu ar minēto izvēlēto sliekšņa vērtību.
11. Metode atbilstoši 10. punktam, kas satur:
 - references tabulas izveidošanu minētā sliekšņa līmeņu daudzuma ierakstīšanai; un
 - minētās sliekšņa vērtības pieregulēšanas soli, kas satur viena no minētajiem sliekšņa līmeņiem izvēlēšanos atkarībā no minētā atpaliekošā parametra vērtības.

12. Metode atbilstoši jebkuram no 1. līdz 11. punktam, kur:

- minētie apstaidzošie un atpaliekošie parametri ir minētā rūpnieciskā procesa apstaidzošo un atpaliekošo gāzu plūsmu ātrumi;
un minētā metode satur:
- atpaliekošu ventiļu līdzekļu ierīkošanu minētās atpaliekošās gāzes plūsmas regulēšanai;
- minēto atpaliekošo ventiļu līdzekļu stāvokļa kontrolēšanu minēto ventiļu līdzekļu atvēršanas vai aizvēršanas laikā;
- minētās atpaliekošās gāzes plūsmas ātruma kontrolēšanu minēto ventiļu līdzekļu atvēršanas vai aizvēršanas laikā;
- minēto ventiļu līdzekļu stāvokļa izmaiņu salīdzināšanu ar minētās atpaliekošās gāzes plūsmas ātruma izmaiņām; un
- minētās sliekšņa vērtības pielāgošanu, atbildot uz to, ka minētā salīdzināšana indicē izmaiņas minēto ventiļu līdzekļu raksturlielos.

13. Metode atbilstoši 12. punktam, kas pievienots 9. vai 11. punktam, kur minētās sliekšņa vērtības pielāgošanas solis satur sliekšņa vērtību pielāgošanu vai līmeņu pielāgošanu minētajā references tabulā.

14. Metode atbilstoši jebkuram no 1. līdz 13. punktam, kur:

- minētais apstaidzošais parametrs ir sadedzināmās gāzes plūsmas ātrums;
- minētais atpaliekošais parametrs ir gaisa plūsmas ātrums;
- minētais process ir sadedzināšanas process.

15. Regulēšanas sistēma (34), lai veiktu atpalikšanas – apsteigšanas tipa regulēšanu procesam, kuram ir mainīgs apstaidzošs parametrs un pielāgojams atpaliekošs parametrs, kur sistēma satur:

- apsteigšanas kontroles līdzekļus (26) minētā apstaidzošā parametra kontrolēšanai un apstaidzes signāla ģenerēšanai, kas reprezentē minētā apstaidzošā parametra vērtību;
- atpalikšanas kontroles līdzekļus (32) minētā atpaliekošā parametra kontrolēšanai un atpalikšanas signāla ģenerēšanai, kas reprezentē minētā atpaliekošā parametra vērtību;
- komparatora līdzekļus (102) minēto apstaidzes un atpalikšanas signālu salīdzināšanai un kļūdas signāla ģenerēšanai, kas reprezentē minēto apstaidzes un atpalikšanas signālu attiecības novirzi no iepriekš izvēlētās attiecības; un

- pierēgulēšanas lēdzekļus (116, 118) minētā atpalēkošā parametra pierēgulēšanai, lai samazinātu minēto novirzi, atbildot uz to, ka minētā novirze pārsniedz iepriekš izvēlēto novirzi.

16. Regulēšanas sistēma atbilstoši 15. punktam, kas papildus satur:

- sliekšņa vērtēbas lēdzekļus (108, 110) iepriekš izvēlamas sliekšņa vērtēbas iestādēšanai;
- komparatora lēdzekļus (104, 106) minētā klēdas signāla salēdzināšanai ar minēto iepriekš izvēlamo sliekšņa vērtēbu;
- un kur minētie pierēgulēšanas lēdzekļi (116, 118) ir darbināmi, lai pierēgulētu minēto atpalēkošo parametru, atbildot uz to, ka minētais klēdas signāls pārsniedz minēto iepriekš izvēlamo sliekšņa vērtēbu.

17. Regulēšanas sistēma atbilstoši 16. punktam, kur:

- minētie sliekšņa vērtēbas lēdzekļi satur pirmos, augšējos sliekšņa vērtēbas lēdzekļus (108) pirmās, augšējās, iepriekš izvēlētās sliekšņa vērtēbas iestādēšanai un otros, apakšējos sliekšņa vērtēbas lēdzekļus (110) otrās, apakšējās, iepriekš izvēlētās sliekšņa vērtēbas iestādēšanai, tādējādi definējot klēdas diapazonu;
- minētie komparatora lēdzekļi (104, 106) ir darbināmi, lai salēdzinātu minēto klēdas signālu ar minēto augšējo un apakšējo iepriekš izvēlamo sliekšņa vērtēbu; un
- kur minētie pierēgulēšanas lēdzekļi (116, 118) ir darbināmi, lai pierēgulētu minēto atpalēkošo parametru, atbildot uz to, ka minētais klēdas signāls atrodas ārpus minētā klēdas diapazona.

18. Regulēšanas sistēma atbilstoši 17. punktam, kur:

- minētie pierēgulēšanas lēdzekļi (116, 118) ir darbināmi, pierēgulējot minēto atpalēkošo parametru, lai samazinātu minēto attēcēbu, atbildot uz to, ka minētais klēdas signāls ir virs minētā klēdas diapazona, un pierēgulējot minēto atpalēkošo parametru, lai palielinātu minēto attēcēbu, atbildot uz to, ka minētais klēdas signāls ir zem minētā klēdas diapazona.

19. Regulēšanas sistēma atbilstoši 18. punktam, kur

- minētā pirmā, augšējā, iepriekš izvēlētā sliekšņa vērtēba ir pozitēva vērtēba un minētā otrā, apakšējā, iepriekš izvēlētā sliekšņa vērtēba ir negatēva vērtēba;
- pozitēvs klēdas signāls indicē minētās attēcēbas palielināšanos pret minēto iepriekš izvēlēto attēcēbu, un negatēvs klēdas signāls indicē minētās attēcēbas

samazināšanos pret minēto iepriekš izvēlēto attiecību; un

- kur minētie pieregulēšanas līdzekļi (116, 118) ir darbināmi, lai samazinātu minēto attiecību, atbildot uz to, ka kļūdas signāls ir pozitīvs un pārsniedz minēto pirmo, augšējo, iepriekš izvēlēto sliekšņa vērtību, un lai palielinātu minēto attiecību, atbildot uz to, ka kļūdas signāls ir negatīvs un pārsniedz minēto otro, apakšējo, iepriekš izvēlēto sliekšņa vērtību.

20. Regulēšanas sistēma atbilstoši jebkuram no 16. līdz 19. punktam, kur tā vai katra minētā sliekšņa vērtība ir fiksēta vērtība.
21. Regulēšanas sistēma atbilstoši jebkuram no 16. līdz 19. punktam, kur tā vai katra minētā sliekšņa vērtība ir minētā atpaliekošā parametra vērtības funkcija.
22. Regulēšanas sistēma atbilstoši 21. punktam, kas papildus satur pieregulēšanas līdzekļus (222) minētās sliekšņa vērtības pieregulēšanai atkarībā no minētā atpaliekošā parametra vērtības un kur minētie komparatora līdzekļi (104, 106) ir darbināmi, lai salīdzinātu minēto kļūdas signālu ar minēto ieregulēto sliekšņa vērtību.
23. Regulēšanas sistēma atbilstoši 22. punktam, kur:
 - minētie sliekšņa vērtības līdzekļi satur references tabulu (208, 210) sliekšņa vērtību daudzuma ierakstīšanai; un
 - kur minētie sliekšņu vērtību pieregulēšanas līdzekļi (222) ir darbināmi, lai pieregulētu minēto sliekšņa vērtību, izvēloties vienu no minētajām sliekšņa vērtībām atkarībā no minētā atpaliekošā parametra vērtības.
24. Regulēšanas sistēma atbilstoši 21. punktam, kas papildus satur:
 - pieregulēšanas līdzekļus (222) minētās sliekšņa vērtības pieregulēšanai atkarībā no minētā atpaliekošā parametra vērtības;
 - un kur:
 - tā vai katra sliekšņa vērtība satur daudzus sliekšņa līmeņus;
 - minētie sliekšņa vērtības pieregulēšanas līdzekļi (222) ir darbināmi, lai pieregulētu minēto sliekšņa vērtību, izvēloties vienu no minētajiem sliekšņa līmeņiem atkarībā no minētā atpaliekošā parametra vērtības; un
 - minētie komparatora līdzekļi (104, 106) ir darbināmi, lai salīdzinātu minēto kļūdas signālu ar minēto izvēlēto sliekšņa līmeni.

25. Regulēšanas sistēma atbilstoši 24. punktam, kur:

- minētie sliekšņa vērtības līdzekļi satur references tabulu (208, 210) daudzu sliekšņa vērtību ierakstīšanai; un
- minētie sliekšņa vērtības pierēgulēšanas līdzekļi (222) ir darbināmi, lai pierēgulētu minēto sliekšņa vērtību, izvēloties vienu no minētajām sliekšņa vērtībām atkarībā no minētā atpaliekošā parametra vērtības.

26. Regulēšanas sistēma atbilstoši jebkuram no 15. līdz 25. punktam, kur:

- minētie apsteidzošie un atpaliekošie parametri ir minētā rūpnieciskā procesa apsteidzošo un atpaliekošo gāzu plūsmu ātrumi;
- un minētā regulēšanas sistēma satur:

- atpaliekošos ventiļu līdzekļus (28) minētās atpaliekošās gāzes plūsmas regulēšanai;
- stāvokļa kontroles līdzekļus (322) minēto atpaliekošo ventiļa līdzekļu (28) stāvokļa kontrolēšanai minēto atpaliekošo ventiļu līdzekļu atvēšanas vai aizvēšanas laikā un to reprezentējoša stāvokļa signāla ģenerēšanai;

kur:

- minētie atpalikšanas kontroles līdzekļi (32) ir darbināmi, lai kontrolētu minētās atpaliekošās gāzes plūsmas ātrumu minēto atpaliekošo ventiļu līdzekļu (28) atvēšanas vai aizvēšanas laikā un ģenerētu to reprezentējošu plūsmas ātruma signālu;

un minētā regulēšanas sistēma papildus satur:

- uzglabāšanas līdzekļus (302), lai uzglabātu minēto stāvokļa un plūsmas ātruma signālu paraugu vērtības, kas reprezentē minēto atpaliekošo ventiļu līdzekļu iepriekš izvēlētos raksturlielumus;
- otru komparatora līdzekļu (302) minēto atpaliekošo ventiļu līdzekļu (28) ventiļa stāvokļa un atpaliekošās gāzes plūsmas ātruma salīdzināšanai minēto atpaliekošo ventiļu līdzekļu kustības laikā ar uzglabātajām vērtībām;
- un otru pierēgulēšanas līdzekļu (302) minētās sliekšņa vērtības pierēgulēšanai, atbildot uz minēto salīdzinājumu, kas uzrāda izmaiņu minēto atpaliekošo ventiļu līdzekļu (28) raksturlielumos.

27. Regulēšanas sistēma atbilstoši jebkuram no 15. līdz 25. punktam, kur:

- minētie apsteidzošie un atpaliekošie parametri ir minētā rūpnieciskā procesa apsteidzošo un atpaliekošo gāzu plūsmu ātrumi;

un minētā regulēšanas sistēma satur:

- atpaliekošos ventiļu līdzekļus (28) minētās atpaliekošās gāzes plūsmas regulēšanai;
- stāvokļa kontroles līdzekļus (322) minēto atpaliekošo ventiļu līdzekļu stāvokļa kontrolēšanai minēto atpaliekošo ventiļu līdzekļu atvēršanas vai aizvēršanas laikā un to reprezentējoša stāvokļa signāla ģenerēšanai;

kur:

- minētie atpalikšanas kontroles līdzekļi (32) ir darbināmi, lai kontrolētu minētās atpaliekošās gāzes plūsmas ātrumu minēto atpaliekošo ventiļu līdzekļu (28) atvēršanas vai aizvēršanas laikā un ģenerētu to reprezentējošu plūsmas ātruma signālu;

un minētā regulēšanas sistēma papildus satur:

- uzglabāšanas līdzekļus (302), lai uzglabātu minēto stāvokļa un plūsmas ātruma signālu paraugu vērtības, kas reprezentē minēto atpaliekošo ventiļu līdzekļu iepriekš izvēlētos raksturlielumus;
- otru komparatora līdzekļus (302), lai salīdzinātu atpaliekošās gāzes plūsmas ātrumu minēto ventiļa līdzekļu kustības laikā ar uzglabāto vērtību, kas atbilst kontrolētajam minēto atpaliekošo ventiļa līdzekļu stāvoklim; un
- otru pieregulēšanas līdzekļus (302) minētās sliekšņa vērtības pieregulēšanai atbildot uz minēto salīdzinājumu, kas uzrāda izmaiņu minēto atpaliekošo ventiļu līdzekļu raksturlielos.

28. Regulēšanas sistēma atbilstoši jebkuram no 15. līdz 27. punktam, kur:

- minētais apstaidzošais parametrs ir sadedzināmās gāzes plūsmas ātrums;
- minētais atpaliekošais parametrs ir gaisa plūsmas ātrums;
- un minētais process ir sadedzināšanas process.

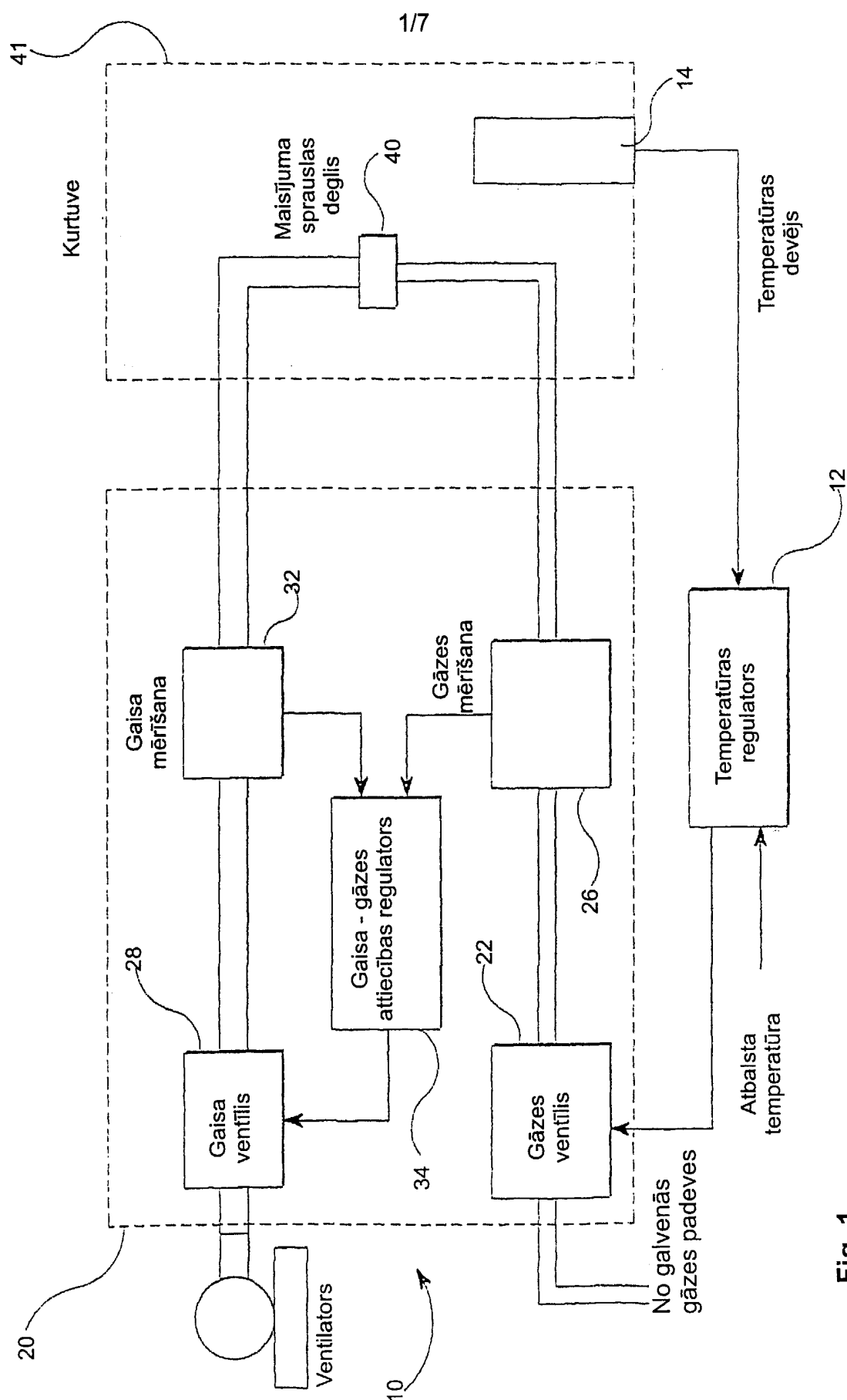


Fig. 1

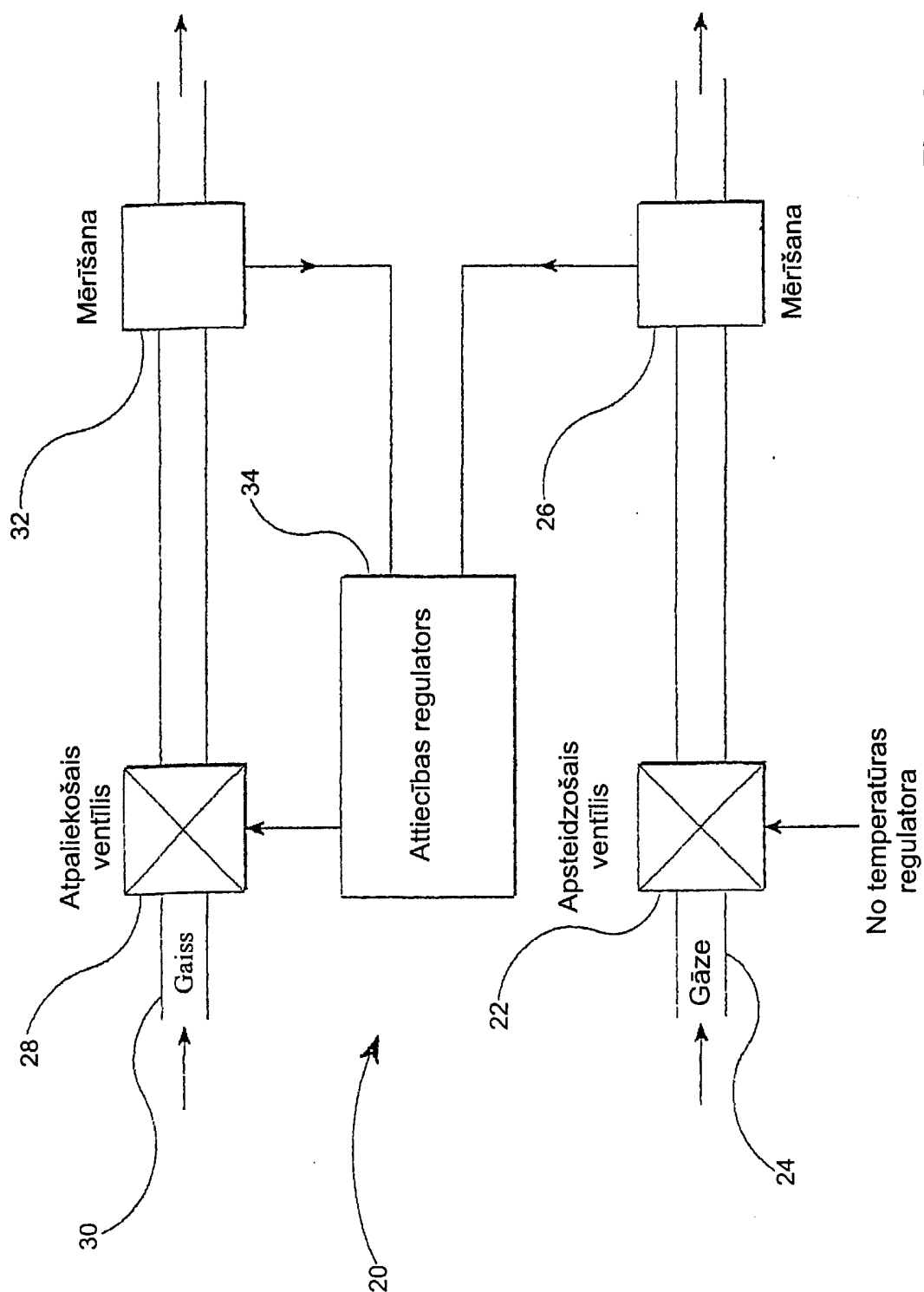


Fig. 2

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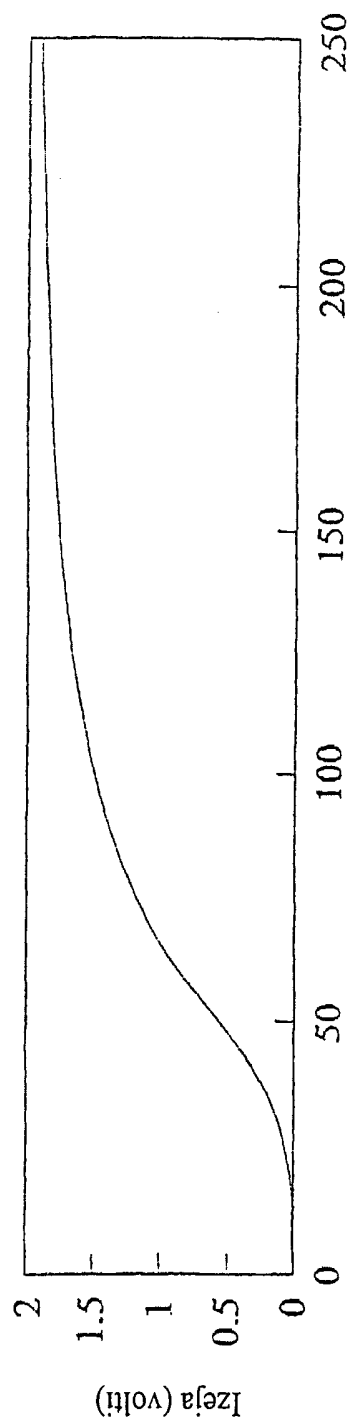


Fig. 6

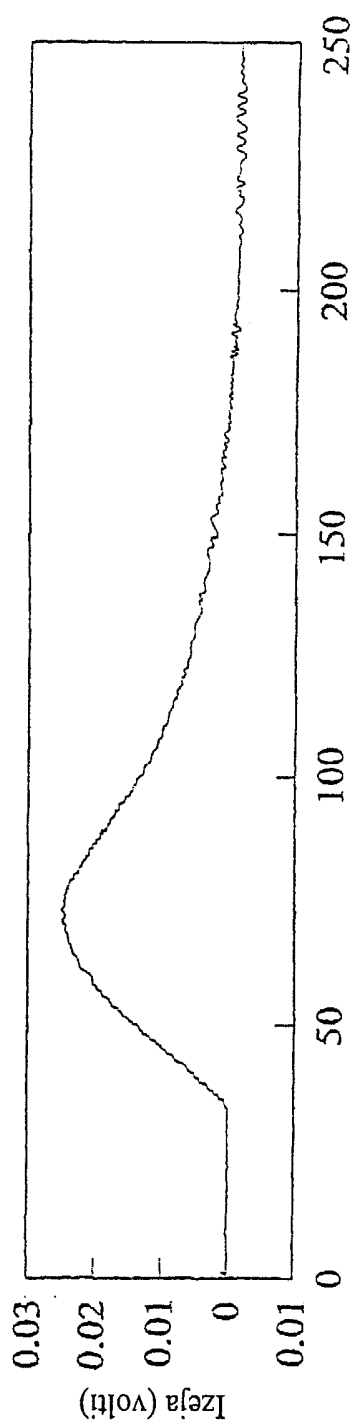


Fig. 7

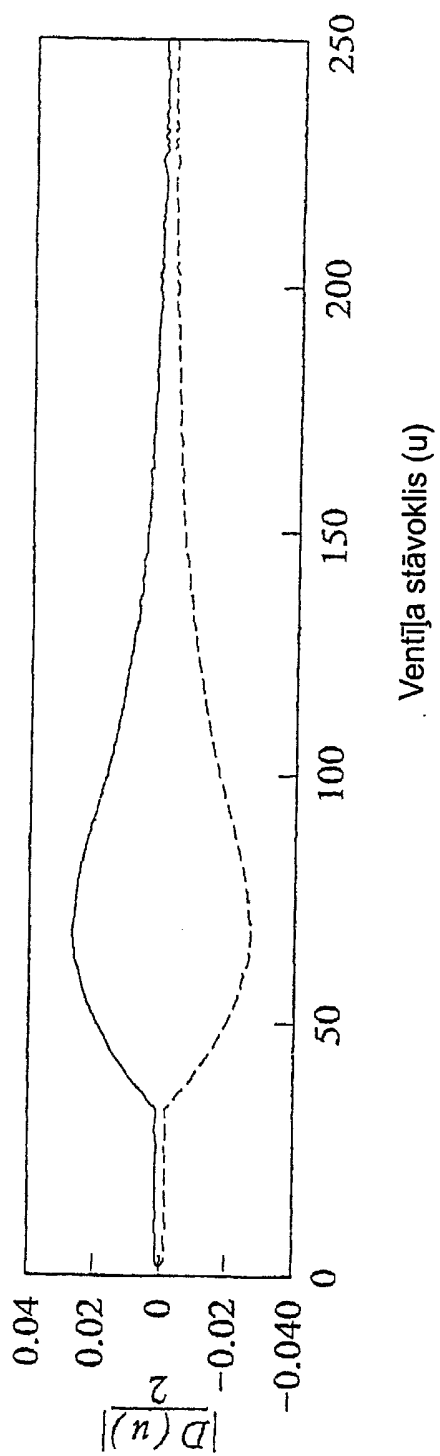


Fig. 8

Method of And System For Controlling The Ratio of A Variable Lead Parameter And
An Adjustable Lag Parameter For A Lag-lead Process

The present invention relates to a method of and system for controlling the ratio of a variable lead parameter and an adjustable lag parameter for a lag-lead process and particularly, but
5 not exclusively, to apparatus for controlling the air/gas ratio in a gas combustion plant.

It is known that the air/gas ratio (AGR) in a gas combustion plant should be maintained substantially constant to achieve optimum combustion efficiency of the plant. Air/gas ratio controllers are used in the plant to maintain the air/gas ratio when the gas flow rate is increased or decreased. To achieve this, the air/gas ratio controller monitors the gas flow rate
10 and adjusts the air flow rate accordingly, usually by adjusting a valve in an air supply line.

A problem with existing air/gas ratio control is the difficulty in adjusting the air flow rate to match accurately the gas flow rate. The present invention aims to provide an improved method and system for air/gas ratio control.

Accordingly, the present invention provides a method of controlling the ratio of a variable
15 lead parameter and an adjustable lag parameter for a lag-lead process, the method comprising: monitoring said lead parameter and providing a lead signal representative of the value of said lead parameter; monitoring said lag parameter and providing a lag signal representative of the value of said lag parameter; comparing said lead and lag signals and providing an error signal representative of the deviation of the ratio of said lead and lag
20 parameters from a preselected ratio; and adjusting said lag parameter to reduce said deviation in response to said deviation exceeding a preselected deviation.

In a preferred form of the invention said error signal is compared with a preselected threshold value and said lag parameter is adjusted in response to said error signal exceeding said preselected threshold value. Advantageously, the error signal is compared with an error

range defined by a first, upper preselected threshold value and a second, lower preselected threshold value and said lag parameter is adjusted in response to said error signal falling outside said error range.

5 The present invention also provides a control system for providing lag-lead control of a process having a variable lead parameter and an adjustable lag parameter, the system comprising: lead monitoring means for monitoring said lead parameter and providing a lead signal representative of the value of said lead parameter; lag monitoring means for monitoring said lag parameter and providing a lag signal representative of the value of said lag parameter; comparator means for comparing said lead and lag signals and providing an
10 error signal representative of the deviation of the ratio of said lead and lag parameters from a preselected ratio; and adjusting means for adjusting said lag parameter to reduce said deviation in response to said deviation exceeding a preselected deviation.

Advantageously, the system further comprises threshold value means for providing a preselectable threshold value and comparator means for comparing said error signal with said
15 preselectable threshold value. The adjusting means is operable to adjust said lag parameter in response to said error signal exceeding said preselectable threshold value.

Preferably, said threshold value means comprises a first, upper threshold value means for providing a first, upper preselected threshold value and a second, lower threshold value means for providing a second, lower preselectable threshold value, thereby to define an error
20 range; said comparator means is operable to compare said error signal with said upper and lower preselectable threshold values; and said adjusting means is operable to adjust said lag parameter in response to said error signal falling outside said error range.

The present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

25 Figure 1 is a schematic block diagram showing a typical gas combustion plant;

Figure 2 is a schematic block diagram of an air/gas ratio controller used in the plant of Figure 1;

Figure 3 is a schematic block diagram of a control system having a preferred form of air/gas ratio controller according to one aspect of the present invention;

- 5 Figure 4 is a schematic block diagram of a preferred form of air/gas ratio controller according to another aspect of the present invention;

Figure 5 is a schematic block diagram of a modification to the controller of fig. 4;

Figure 6 is a graph showing the change in valve position with applied control voltage;

Figure 7 is a graph showing the derivative of the valve characteristic of Figure.6; and

- 10 Figure 8 is a graph showing the relationship between the valve derivative and total deadband value.

A typical gas combustion plant 10 is shown in Figure 1. The plant 10 consists of three main parts, a temperature controller 12, an air/gas ratio control system 20 and a burner 40 within, for example, a kiln or furnace 41.

- 15 The temperature controller 12 is able to control the temperature of the furnace 41, either by following a predetermined temperature profile or by allowing a user to define the desired temperature profile. To increase the temperature of the furnace, for example, the controller 12 adjusts the valve in the gas supply line to increase the flow rate of the gas supplied to the burner and the air/gas ratio control system 20 adjusts the air flow rate to attempt to maintain
20 the ratio between the flow rates of the air and the gas supplied to the burner substantially constant. A typical configuration for an air/gas ratio control system is shown in Figure 2.

The system 20 includes a gas valve 22 connected to the gas supply line 24 for varying the gas flow rate along the line. A gas flow measurement sensor 26 is positioned downstream of the gas valve 22 for monitoring the gas flow rate along the line. Similarly, an air valve 28 is positioned at a point in the air supply line 30 for varying the air flow rate along the line and
5 an air flow measurement sensor 32 is positioned downstream of the air valve 28 for monitoring the air flow rate along the air line.

The gas valve 22 is connected to receive an input signal from the temperature controller 12 to adjust the flow rate of the gas. The air valve 28 is connected to receive an input from an air/gas ratio controller 34 to adjust the flow rate of the air in dependence on the gas flow rate.

10 The air/gas ratio controller 34 receives an input from both of the gas and air measurement sensors 26, 32 and compares the flow rates of the gas and the air and adjusts the air valve to maintain the required air/gas ratio.

It can be seen that if the combustion process is to function with the maximum possible efficiency, the air/gas ratio controller 34 must control the air valve to follow changes in the
15 gas valve as closely as possible.

Such a system is commonly known as a lag-lead system. In a lag-lead system when a lead parameter (the gas flow rate) varies, a lag parameter (in this case the air flow rate) is adjusted to maintain the ratio of the parameters substantially constant.

The flow rate of the air and the gas are monitored by the measurement sensors of the air/gas ratio control system 20. These preferably sample the flow rate at a predetermined sampling rate. The lead parameter (here the gas flow rate) and the lag parameter (here the air flow rate) are sampled at regular time intervals. The lead parameter is sampled usually at a faster rate than the lag parameter and can be sampled as fast as once every 20ms. The sample rate of the lag parameter would be adjusted to suit the lead parameter sample rate and in this
20 instance would be typically once every 120ms. A typical sample range for the lag parameter would be between 100ms and 500ms. In a natural gas combustion system the air/gas ratio
25

is typically required to be maintained in the order of 10:1, known as the stoichiometric/gas ratio. Changes in the temperature reference signal result in the gas valve being adjusted by the temperature controller 12. This changes the gas flow rate and thus the air/gas ratio from the desired value. This change in the gas flow rate is monitored by the controller 34 which
5 acts to adjust the air valve 28 to return the air/gas ratio to the desired value.

If a change in the air/gas ratio is detected (i.e. the air/gas ratio moves away from the desired value) by the air/gas ratio controller during a particular sampling of the air and gas flow the controller will move the air valve in the required direction (either towards its fully open or
10 fully closed position) until the next sample is taken.

However, if the error in the air/gas ratio is smaller than the change in the air/gas ratio effected by the air valve movement over one sample interval (the period between one sample time and the next) the valve will overshoot the desired position and the desired air flow rate will not be achieved. At the next sampling, the controller 34 will detect a reverse error and will move
15 the valve in the opposite direction i.e. it will move the valve towards its closed position if the previous error caused the valve to be moved towards its open position, and vice versa. Again, the valve will be moved too far in the reverse direction during the sample interval and will stop at or close to its initial position i.e. the position from which it was first moved in response to the originally monitored error in the air/gas ratio. This opening and closing of
20 the valve, known as hunting, will repeat for as long as the error in the air/gas ratio remains substantially the same as or smaller than the change effected by movement of the air valve over one sampling interval. The air valve and consequently the air flow rate will thus oscillate about the level required to achieve the desired air/gas ratio. These oscillations are known as limit cycles.

25 It can be seen that if the error in the air/gas ratio exceeds a particular threshold level (being defined by the change in the air/gas ratio effected by the air valve movement over one sample interval) then no limit cycling will occur. However, if the error lies below the threshold level then limit cycling will occur. For valves with linear characteristics i.e. which exhibit a linear

response, the threshold level is constant throughout the valve's operating range. However, many electromagnetically operated valves exhibit a non-linear response where the air flow rate through the valve varies non-linearly in relation to the applied control signal. Thus, the change in the air flow through the valve during movement of the valve towards its fully open or fully closed position over a single sample interval will be different depending on the position of the valve within its operating range (Figure 6). Consequently, the threshold level defining the area value below which limit cycling occurs will vary over the operating range of the valve.

Since the motor driving the valve acts as an integrator, the change in flow over one sampling interval can be found by differentiating the valve characteristic (Figure 7). The differential curve of the valve characteristic shows how much the valve moves (and thus by how much the air flow rate will alter) during one sample interval, depending on the initial position of the valve in the valve operating range. Since errors in the air/gas ratio can have negative as well as positive values, it is necessary to establish both positive and negative derivative curves centred around a zero value in order to establish the threshold level. As shown in Figure 8, this effectively produces an "error envelope" within which limit cycling occurs (Figure 8). Thus limit cycling will occur where:

$$|\epsilon_{(Ts, u)}| < |\delta(u)| \quad \dots\dots\dots(1)$$

where:

$\delta(u)$ is the derivative of the valve characteristic at any given valve position (u) and $2*\delta(u)$ represents the deadband value;

T_s is the sample time; and

u is the valve position.

Conversely, limit cycling will not occur where:

$$|\epsilon_{(T_s, u)}| \geq |\delta(u)| \quad \dots\dots\dots(2)$$

In order to reduce or substantially eliminate limit cycling in the air/gas ratio controller, it is therefore desirable to ensure that the air valve is not adjusted when the error lies within the error envelope of the valve. In other words when equation 1 applies. In a preferred form of the invention, this is achieved by implementing a so-called "deadband" as described below.

Fig. 3 is a schematic block diagram of part of a control system 90 having a preferred form of air/gas ratio controller 100. The controller 100 has a first comparator 102 which is connected to receive two input signals, the first from the gas flow sensor 26 being connected to a non-inverting input of the comparator 102 and the second from the air flow sensor 32 connected to an inverting input. An output of the first comparator 102 is connected firstly to a non-inverting input of a second comparator 104 and secondly to an inverting input of a third comparator 106.

Positive and negative fixed threshold value circuits 108, 110; the purpose of which is described below, are connected to non-inverting and inverting inputs of the second and third comparators 104, 106 respectively. An output of each of the second and third comparators 104, 106 is connected to a respective operational amplifier 112, 114. An output of each operational amplifier is connected to a respective relay 116, 118 which actuate movement of the air valve 28.

During operation of the combustion plant 10, the flow rates of the gas and the air supplied to the burner 40 are measured by the flow sensors 26, 32 each of which generates a signal S_g , S_a corresponding to the respective flow rate and sends the signal to the air/gas ratio controller 100.

The gas flow signal S_g and the air flow signal S_a are fed to the first comparator 102, the gas flow signal S_g to the non-inverting input and the air flow signal S_a to the inverting input. The

comparator 102 compares the two signals and generates an error signal ϵ as a function of the comparison.

5 The error signal ϵ represents the difference between the actual air flow measured by the sensor 32 and the desired air flow to produce a stoichiometric air/gas ratio with the current gas flow rate. Since the sensor 32 would normally produce an air signal S_a which is a magnitude of 10 greater than the gas signal S_g produced by the gas sensor 26 for a stoichiometric ratio (i.e. an air flow rate which is a magnitude of 10 greater than the gas flow rate) the value of the air signal S_a is adjusted to the same level as the gas signal S_g for a stoichiometric ratio. This can be effected by a simple voltage divider in the air flow sensor
10 32.

The error signal ϵ is fed to the non-inverting input of the second comparator 104 and to the inverting input of the third comparator 106, each of which compares the error signal ϵ value with fixed positive and negative threshold values generated by the positive and negative threshold value circuits 108, 110 respectively.

15 If the error signal value is greater than or equal to the positive threshold value, then the comparator 104 applies an actuation signal through the first operational amplifier 112 to the first relay 116 which energises the air valve 28 to move in a first direction, towards its fully closed position. Similarly, if the error signal value is less than or equal to the negative threshold value, the comparator 106 applies an actuation signal through the second
20 operational amplifier 114 to the second relay 116 which energises the air valve 28 to move in the opposite direction towards its fully open position.

If, however, the error signal value is less than the positive threshold value and greater than the negative threshold value, the second and third comparators are unaffected and the air valve is not adjusted.

25 The threshold value circuits 108, 110 set an error signal range within which the controller 100

takes no corrective action. Thus, if the gas flow rate is changed in order to increase or decrease the temperature of the burner 40 this will result in an air/gas ratio which moves away from the desired value. This will result in an error signal being generated by the comparator 102, the error signal representing the difference between the actual air/gas ratio and the desired air/gas ratio. It will therefore be appreciated that if the change in the air flow rate which is required to return the air/gas ratio to the desired level is less than the change represented by the error signal range set by the threshold value circuits 108, 110 then the error signal ϵ will fall within this range and the air valve 28 will remain unactuated. The error is in effect deemed to be zero and the air valve is not adjusted. The threshold range set by the threshold circuits 108, 110 is termed a "deadband". In practice, this reduces the occurrence of limit cycling in the air flow and allows the desired air/gas ratio to be maintained more closely.

The value of the deadband affects the performance of the air/gas ratio controller 100 which in turn affects the efficiency of the combustion plant. Selection of the correct value for the deadband is therefore important. By making the deadband value high, limit cycle oscillations are reduced, but the accuracy of control of the air valve to provide the desired air/gas ratio is reduced. Conversely, a low threshold value gives good accuracy but increases the occurrence of limit cycling. It is preferable, therefore to make the deadband as small as possible, without causing limit cycling.

It is apparent from the above description that if the deadband value represents a change in air flow rate which is slightly larger than the movement of the air valve (change in air flow rate) in a single sample interval, then adjustment of the valve can be made without limit cycling occurring. A constant deadband value can therefore be used for valves with linear characteristics. However, for non-linear valves having an error envelope such as that shown in Figure 8, the use of a constant deadband value is ineffective since limit cycling may occur in some parts of the operating range of the valve even though a deadband is used.

A solution is to vary the value of the deadband according to the valve characteristic over the

valve's operating range. It is found that the optimum deadband value for a given valve position is equal to twice the value of the differential of the valve characteristic at that position. Since the deadband is centred around a zero value the upper and lower threshold levels of the deadband (set by the positive and negative threshold circuits 108, 110) correspond to the positive and negative derivative curves of the valve. Thus, the deadband is chosen to map exactly the error envelope of the valve. Thus, the controller will adjust the air valve in the instance where:

$$|\epsilon_{(Ts, u)}| \geq \frac{|D(u)|}{2}$$

where $D(u) = \delta(u)$ and represents the deadband value defined by the error envelope at a given valve position (u) which is the region within which limit cycling does not occur even in the absence of a deadband since the value of an error within which region is greater than or equal to the change in flow caused by adjustment of the valve during one sample interval. Conversely, the controller will not adjust the air valve in the instance where:

$$|\epsilon_{(Ts, u)}| < \frac{|D(u)|}{2}$$

In this case, the error lies within the deadband which is the region in which limit cycling would occur if the air valve were adjusted and the deadband were not present.

A solution is to vary the value of the deadband in dependence on the valve characteristic over the operating range of the valve.

Figure 4 shows a second embodiment of air/gas ratio controller 200 as part of a control system 190. In figures, 3, 4 and 5 like reference numerals indicate like parts. As can be seen, the controller 200 is similar in form to the controller 100 of Figure 3 but with the fixed threshold value circuits replaced by variable threshold value circuits 208, 210 each of which

comprises a look-up table. The variable threshold value circuits 208, 210 are connected to receive a signal from an air valve position sensor 222 via an operational amplifier 220. The valve position sensor 222 can be of the form which simply monitors the voltage applied to the valve to drive the valve between its open and closed positions.

- 5 Before the control system is put into operation the characteristic of the air valve is measured and the differential curve shown in Figure 7 determined for the valve in order to provide the error envelope shown in Figure 8. A number of different threshold values or levels are then taken from the envelope of Figure 8, a positive and a negative value for selected valve positions. The positive values are stored in the look-up table of the threshold value circuit
10 208 and the negative values are stored in the look-up table of the threshold value circuit 210.

During operation, as the valve position changes, the threshold value in the look-up table which is compared with the error signal is selected according to the position signal from the air valve position sensor.

- The value generated by each variable threshold value circuit 208, 210 is thus a function of
15 the position of the air valve 28 and thus of the air flow rate. As the position of the air valve varies, the change in the air flow rate which occurs during each sample interval also varies. The air valve characteristics are effectively stored in the look-up table in each threshold circuit 208, 210. The look-up table therefore gives the characteristic at a given valve position and thus determines the deadband value for that position. The deadband is thus varied
20 according to the instantaneous position of the air valve 28.

As in the previous embodiment, if the error signal ϵ calculated by comparator 202, lies within the range defined by the instantaneous positive and negative threshold values generated by the threshold circuits 208, 210, then the error is deemed to be zero and no corrective action is made to air valve 28.

If, however, the error value lies on or outside the error envelope, the air valve 28 is adjusted as described previously.

Since the deadband value is always greater than the change in air flow effected by movement of the air valve during one sample interval, the occurrence of limit cycling is minimised. In addition, the accuracy of the air/gas ratio controller 200 is increased. This results in a significant improvement in combustion efficiency of the gas combustion plant since the air/gas ratio is maintained at an optimum.

It will be apparent that various modifications and improvements can be made to the present invention.

The present invention may be modified such that the movement of the air valve 28 is continuously monitored to determine whether the characteristics of the valve have changed owing to wear, for example. If the valve characteristics have changed, this information can be fed to the variable threshold value circuits to modify the deadband value for each position of the valve. An example of such a modification to the present invention is shown in fig. 5 in which like reference numerals indicate like parts.

In Figure 5 one of the relays, in this case relay 116 which actuates the valve towards its fully closed position, is connected to an input of a multiplexer 300. An output of the air flow sensor 32 and the valve position sensor 222 are also connected to the multiplexer 300.

The output from the multiplexer 300 is connected to a parameter estimator 302 whose output in turn is connected to the variable threshold value circuits 208, 210.

The parameter estimator 302 may be a microprocessor running, for example, MATLAB.

Before the control system is put into operation the characteristic of the air valve is measured and the response curve shown in Figure 6 is stored in a store in the parameter estimator 302.

This can be effected by moving the valve from one of a fully open and closed position to the other and monitoring the signals from the valve position sensor 222 and the air flow rate sensor 32 which are then stored in the parameter estimator 302 as continuously variable values or discrete values.

- 5 When relay 116 is actuated to move the air flow valve 28 towards its fully closed position the parameter estimator 302 is also enabled. During closing of the valve 28 the parameter estimator 302 processes the outputs from the air flow rate and position sensors 32, 222 and compares the monitored flow rate with the previously stored flow rate. If there is a deviation between the monitored flow rate with the previously stored flow rate this would suggest, for
 10 example, wear in the valve mechanism. The parameter estimator 302 then adjusts the threshold values in the look up tables in the threshold value circuits 208, 210 which relate to the monitored valve position to take account of changes in the valve characteristics which have occurred. It will be appreciated that equally the movement of the valve towards its fully open position may be used to update the look up tables to take account of wear, in which case
 15 the estimator 302 would be enabled with relay 118.

Whilst the above description is made with reference to a lag-lead control system wherein the lead parameter is the gas flow rate and the lag parameter is the air flow rate, it will be appreciated that the invention is equally applicable to systems wherein the lead parameter is the air flow rate and the lag parameter is the gas flow rate, or any other lag-lead system.

- 20 It Will also be appreciated that whilst the preferred form of the invention has been described with reference to an air/gas combustion plant or furnace, the invention is equally applicable to lag-lead control systems for controlling the ratio of two fluids where the fluids may be in gas or liquid form.

(57) Abstract: In a method of and system for controlling the air/gas ratio in a lag-lead combustion plant the lead and lag parameters are monitored to provide lead and lag signals representative of the values of the parameters. These are compared to provide an error signal representative of the deviation of the ratio of the lead and lag parameters from a preselected ratio. The lag parameter is then adjusted to reduce the deviation in response to the deviation exceeding a preselected deviation.

Claims

1 A method of controlling the ratio of a variable lead parameter and an adjustable lag parameter for a lag-lead process, the method comprising:

5 monitoring said lead parameter and providing a lead signal representative of the value of said lead parameter;

monitoring said lag parameter and providing a lag signal representative of the value of said lag parameter;

comparing said lead and lag signals and providing an error signal representative of the deviation of the ratio of said lead and lag parameters from a preselected ratio;

10 and adjusting said lag parameter to reduce said deviation in response to said deviation exceeding a preselected deviation.

2 A method as claimed in claim 1 comprising comparing said error signal with a preselected threshold value and adjusting said lag parameter in response to said error signal exceeding said preselected threshold value.

15 3 A method as claimed in claim 1 or 2 comprising comparing said error signal with an error range defined by a first, upper preselected threshold value and a second, lower preselected threshold value and adjusting said lag parameter in response to said error signal falling outside said error range.

4 A method as claimed in claim 3 comprising:

20 adjusting said lag parameter to reduce said ratio in response to said error signal being above said error range;

and adjusting said lag parameter to increase said ratio in response to said error signal being below said error range.

5 A method as claimed in claim 4 wherein:

5 said first, upper preselected threshold value is a positive value and said second, lower preselected threshold value is a negative value;

a positive error signal indicates an increase in said ratio from said preselected ratio and a negative error signal indicates a decrease in said ratio from said preselected ratio;

and the method comprises:

10 adjusting said lag parameter to reduce said ratio in response to said error signal being positive and exceeding said first, upper preselected threshold value;

and adjusting said lag parameter to increase said ratio in response to said error signal being negative and exceeding said second, lower preselected threshold value.

6 A method as claimed in any of claims 2 to 5 wherein the or each said threshold value is a fixed value.

15 7 A method as claimed in any of claims 2 to 5 wherein the or each said threshold value is a function of the value of said lag parameter.

8 A method as claimed in claim 7 wherein the step of comparing said error signal with the or each threshold value comprises adjusting said threshold value in dependence on the value of said lag parameter and comparing said error signal with said adjusted threshold
9 level.

9 A method as claimed in claim 8 comprising:

providing a look up table for storing a plurality of threshold values;

and the step of adjusting said threshold value comprising selecting one of said threshold values in dependence on the value of said lag parameter.

5 10 A method as claimed in claim 7 wherein:

the or each threshold value comprises a plurality of threshold levels;

and the step of comparing said error signal with the or each threshold value comprises selecting a threshold level for said threshold value in dependence on the value of said lag parameter and comparing said error signal with said selected threshold level.

10 11 A method as claimed in claim 10 comprising:

providing a look up table for storing said plurality of threshold levels;

and the step of adjusting said threshold value comprising selecting one of said threshold levels in dependence on the value of said lag parameter.

12 A method as claimed in any of claims 1 to 11 wherein:

15 said lead and lag parameters are lead and lag fluid flow rates for said industrial process;

and said method comprises:

providing lag valve means for controlling flow of said lag fluid;

monitoring the position of said lag valve means during opening or closing of said valve means;

monitoring the flow rate of said lag fluid during opening or closing of said valve means;

5 comparing the change in position of said valve means with the change in said flow rate of said lag fluid;

and adjusting said threshold value in response to said comparison indicating a change in the characteristic of said valve means.

13 A method as claimed in claim 12 when appendant to claim 9 or 11 wherein the step of adjusting said threshold value comprises adjusting the threshold values or levels in said
10 look up table.

14 A method as claimed in any of claims 1 to 13 wherein:

said lead parameter is the flow rate of a combustion gas;

said lag parameter is the flow rate of air;

and said process is a combustion process.

15 15 A control system (34) for providing lag-lead control of a process having a variable lead parameter and an adjustable lag parameter, the system comprising:

lead monitoring means (26) for monitoring said lead parameter and providing a lead signal representative of the value of said lead parameter;

lag monitoring means (32) for monitoring said lag parameter and providing a lag signal

representative of the value of said lag parameter;

comparator means (102) for comparing said lead and lag signals and providing an error signal representative of the deviation of the ratio of said lead and lag parameters from a preselected ratio;

- 5 and adjusting means (116, 118) for adjusting said lag parameter to reduce said deviation in response to said deviation exceeding a preselected deviation.

16 A control system as claimed in claim 15 further comprising:

threshold value means (108, 110) for providing a preselectable threshold value;

comparator means (104, 106) for comparing said error signal with said preselectable
10 threshold value;

and wherein said adjusting means (116, 118) is operable to adjust said lag parameter in response to said error signal exceeding said preselectable threshold value.

17 A control system as claimed in claim 16 wherein:

said threshold value means comprises a first, upper threshold value means (108) for
15 providing a first, upper preselected threshold value and a second, lower threshold value means (110) for providing a second, lower preselectable threshold value, thereby to define an error range;

said comparator means (104, 106) is operable to compare said error signal with said upper and lower preselectable threshold values;

20 and said adjusting means (116, 118) is operable to adjust said lag parameter in response to

said error signal falling outside said error range.

18 A control system as claimed in claim 17 wherein:

said adjusting means (116, 118) is operable to adjust said lag parameter to reduce said ratio in response to said error signal being above said error range and to adjust said lag parameter
5 to increase said ratio in response to said error signal being below said error range.

19 A control system as claimed in claim 18 wherein:

said first, upper preselected threshold value is a positive value and said second, lower preselected threshold value is a negative value;

a positive error signal indicates an increase in said ratio from said preselected ratio and a
10 negative error signal indicates a decrease in said ratio from said preselected ratio;

and said adjusting means (116, 118) is operable reduce said ratio in response to said error signal being positive and exceeding said first, upper preselected threshold value and to increase said ratio in response to said error signal being negative and exceeding said second, lower preselected threshold value.

15 20 A control system as claimed in any of claims 16 to 19 wherein the or each said threshold value is a fixed value.

21 A control system as claimed in any of claims 16 to 19 wherein the or each said threshold value is a function of the value of said lag parameter.

22 A control system as claimed in claim 21 further comprising adjusting means (222)
20 for adjusting said threshold value in dependence on the value of said lag parameter and wherein said comparator means (104, 106) is operable to compare said error signal with said

adjusted threshold value.

23 A control system as claimed in claim 22 wherein:

said threshold value means comprises a look up table (208, 210) for storing a plurality of threshold values;

5 and said threshold value adjusting means (222) is operable to adjust said threshold value by selecting one of said threshold values in dependence on the value of said lag parameter.

24 A control system as claimed in claim 21 further comprising:

adjusting means (222) for adjusting said threshold value in dependence on the value of said lag parameter;

10 and wherein:

the or each threshold value comprises a plurality of threshold levels;

said threshold value adjusting means (222) is operable to adjust said threshold value by selecting one of said threshold levels in dependence on the value of said lag parameter;

and said comparator means (104, 106) is operable to compare said error signal with said
15 selected threshold level.

25 A control system as claimed in claim 24 wherein:

said threshold value means comprises a look up table (208, 210) for storing a plurality of threshold values;

and said threshold value adjusting means (222) is operable to adjust said threshold value by selecting one of said threshold values in dependence on the value of said lag parameter.

26 A control system as claimed in any of claims 15 to 25 wherein:

said lead and lag parameters are lead and lag fluid flow rates for said process;

5 and said control system comprises:

lag valve means (28) for controlling the flow of said lag fluid;

position monitoring means (322) for monitoring the position of said lag valve means (28) during opening or closing of said lag valve means and providing a position signal representative thereof;

10 wherein:

said lag monitoring means (32) is operable to monitor the flow rate of said lag fluid during opening or closing of said lag valve means (28) and provide a flow rate signal representative thereof;

and said control system further comprises:

5 storage means (302) for storing sampled values of said position and flow rate signals representing a preselected characteristic of said lag valve means;

second comparator means (302) for comparing the valve position of said lag valve means (28) and lag fluid flow rate during movement of said lag valve means with the stored values;

and second adjusting means (302) for adjusting said threshold value in response to said

comparison indicating a change in the characteristic of said lag valve means (28).

27 A control system as claimed in any of claims 15 to 25 wherein:

said lead and lag parameters are lead and lag fluid flow rates for said process;

and said control system comprises:

5 lag valve means (28) for controlling the flow of said lag fluid;

position monitoring means (322) for monitoring the position of said lag valve means during opening or closing of said lag valve means and providing a position signal representative thereof;

wherein:

10 said lag monitoring means (32) is operable to monitor the flow rate of said lag fluid during opening or closing of said valve means (28) and provide a flow rate signal representative thereof;

and said control system further comprises:

storage means (302) for storing sampled values of said position and flow rate signals
15 representing a preselected characteristic of said lag valve means;

second comparator means (302) for comparing the lag fluid flow rate during movement of said valve means with stored value corresponding to the monitored position of said lag valve means;

and second adjusting means (302) for adjusting said threshold value in response to said

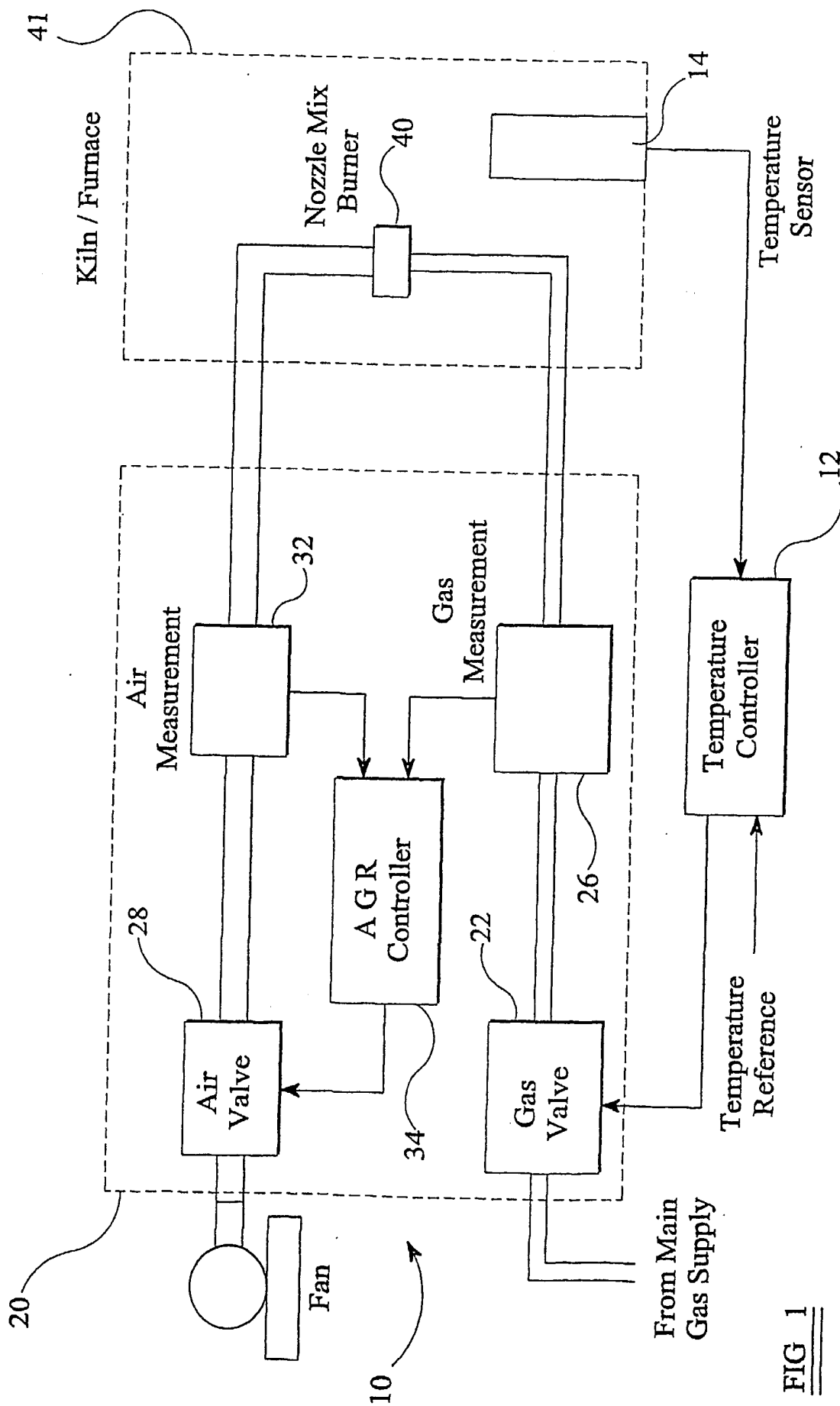
comparison indicating a change in the characteristic of said valve means.

28 A control system as claimed in any of claims 15 to 27 wherein:

said lead parameter is the flow rate of a combustion gas;

said lag parameter is the flow rate of air;

5 and said process is a combustion process.



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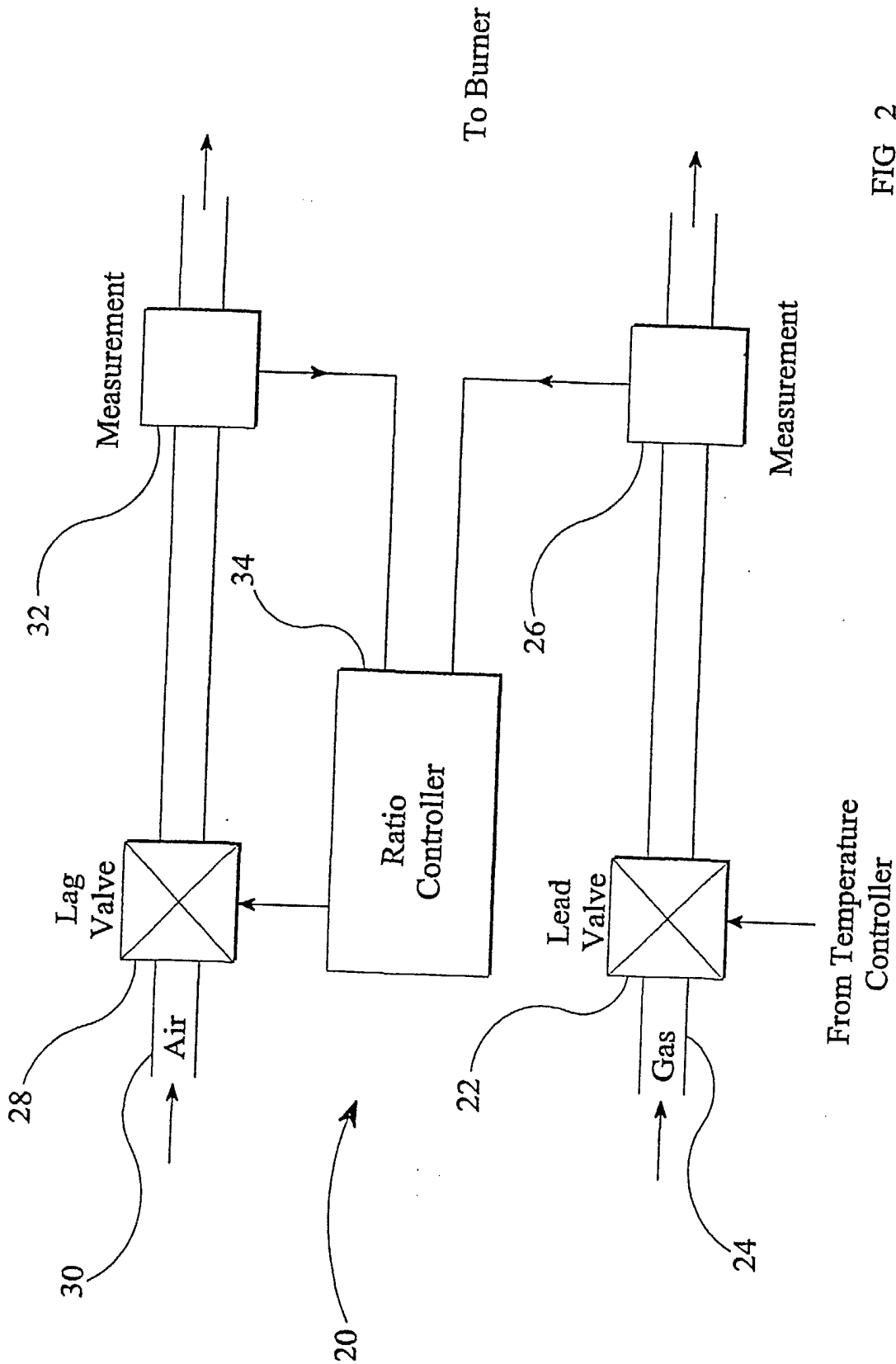
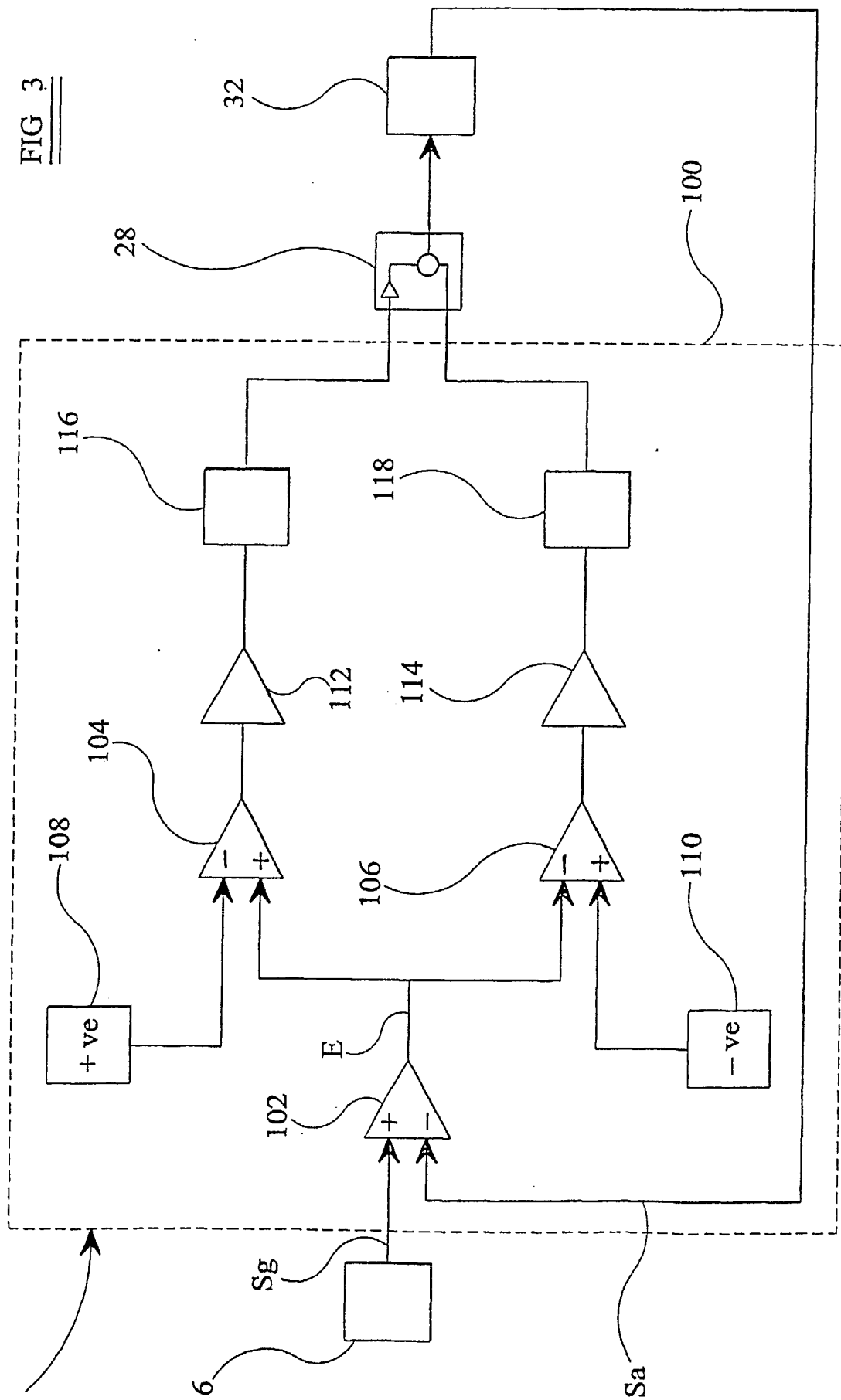
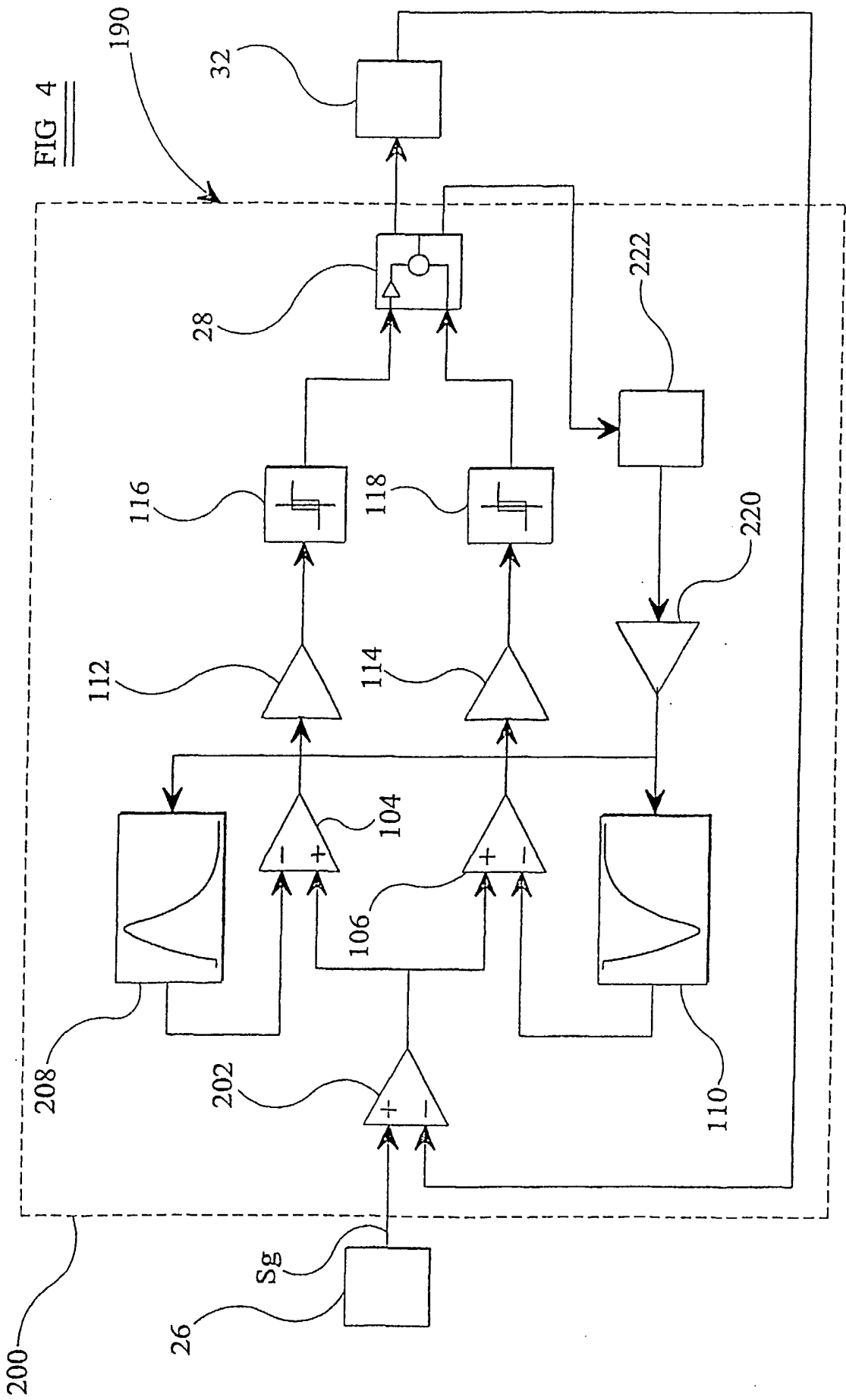


FIG 2

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FIG 3



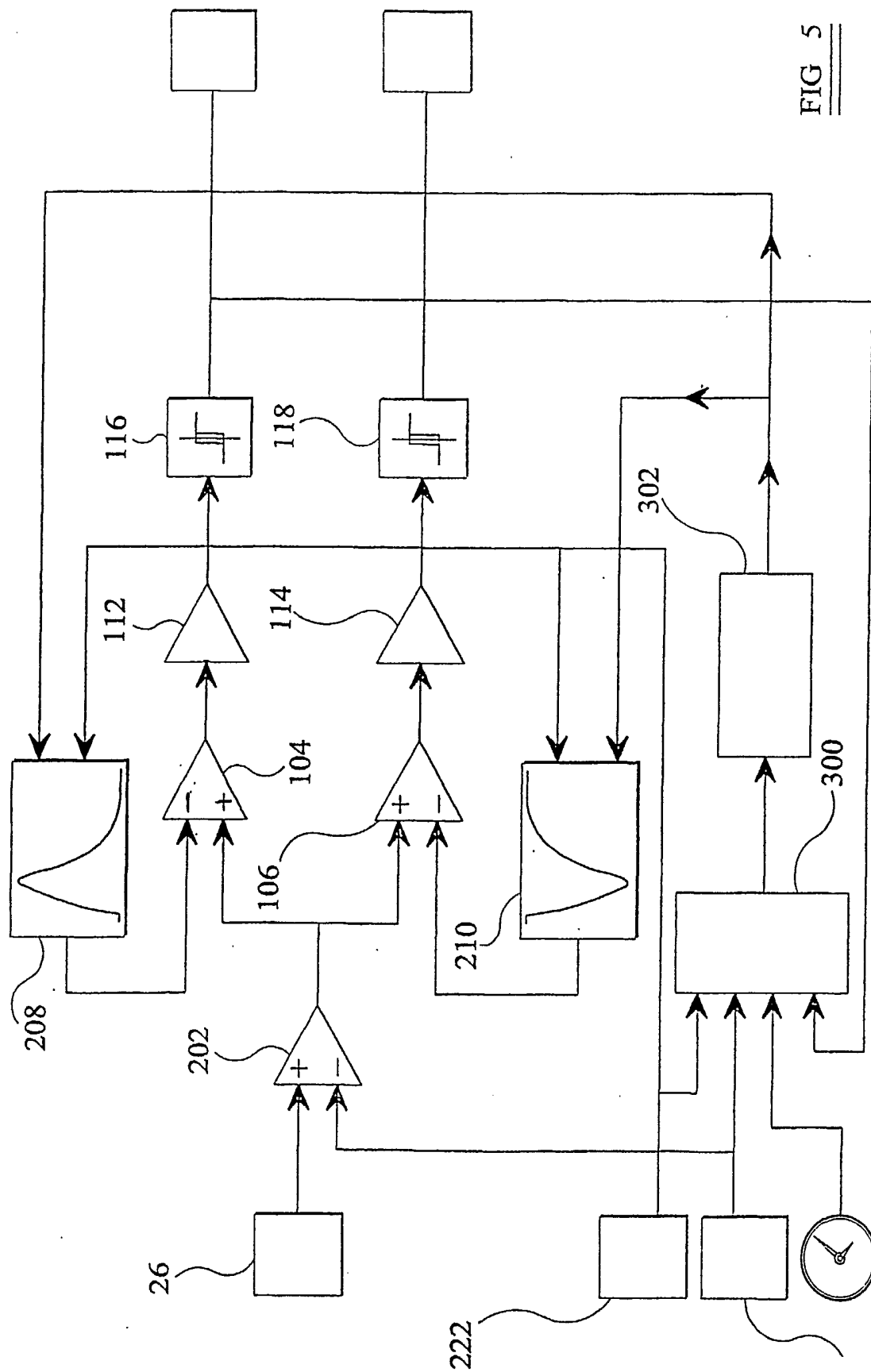
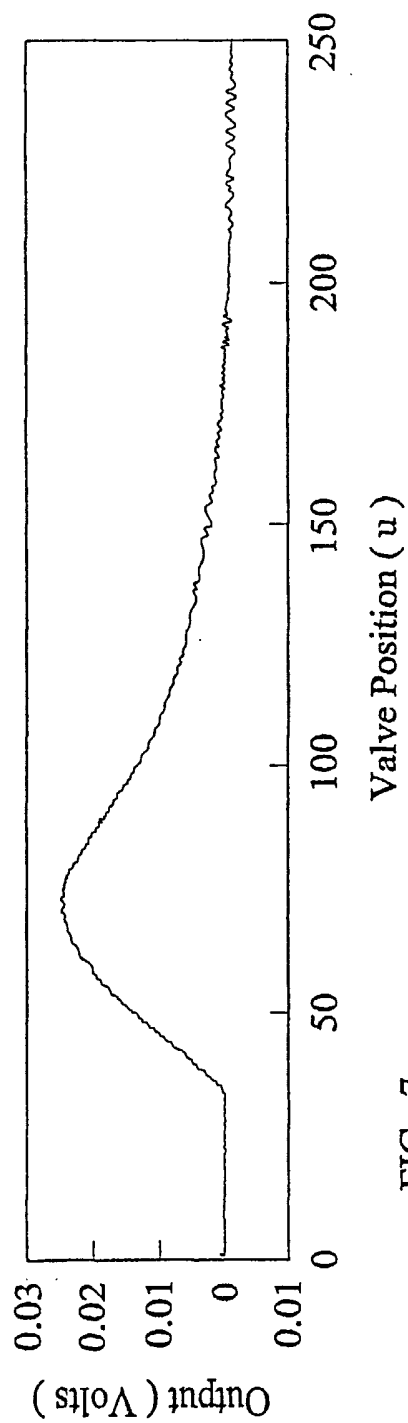
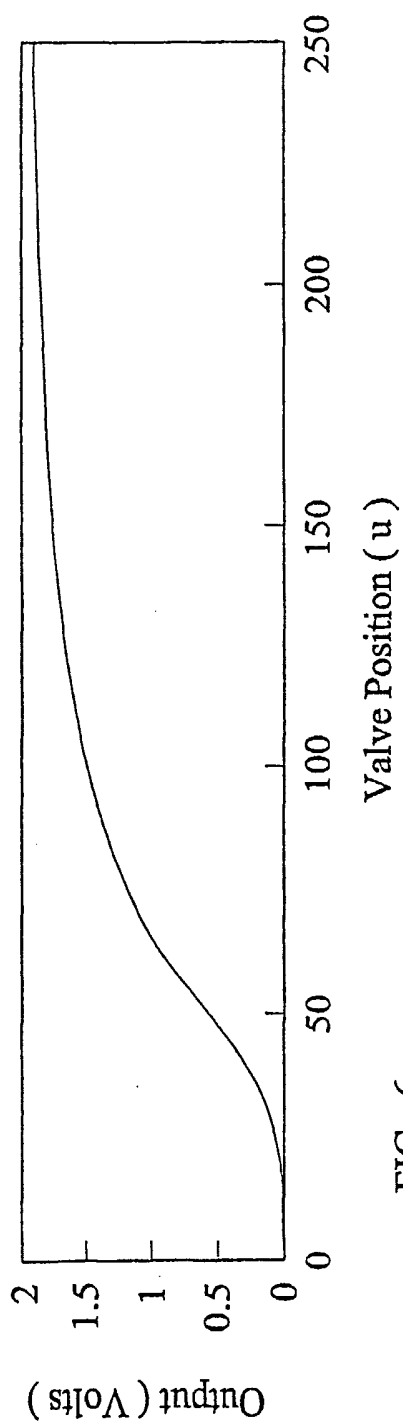
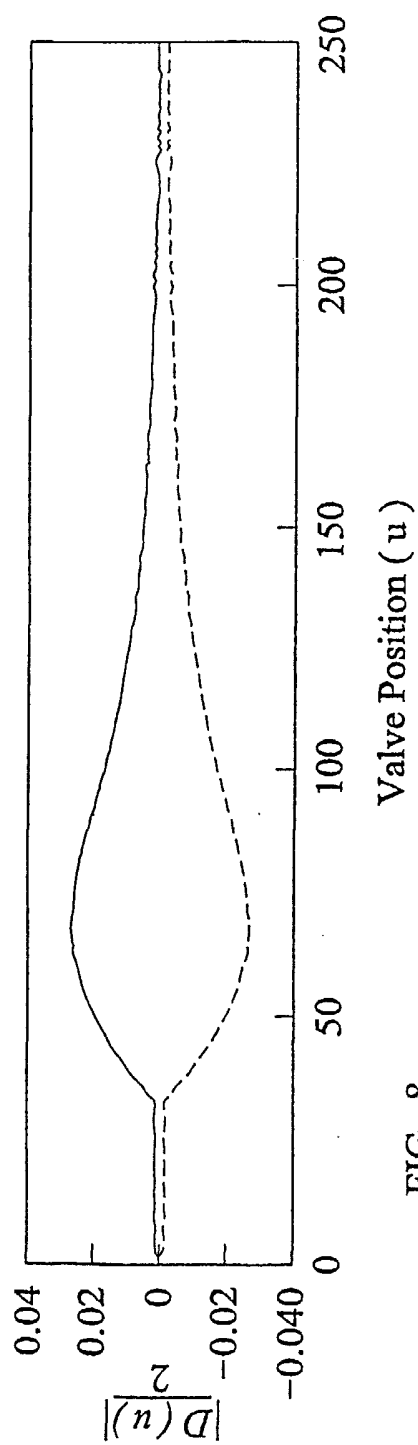


FIG 5

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FIG 8