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(54) **METHODS AND SYSTEMS FOR DESIGNING AND VALIDATING OPERATION OF ABATEMENT SYSTEMS**

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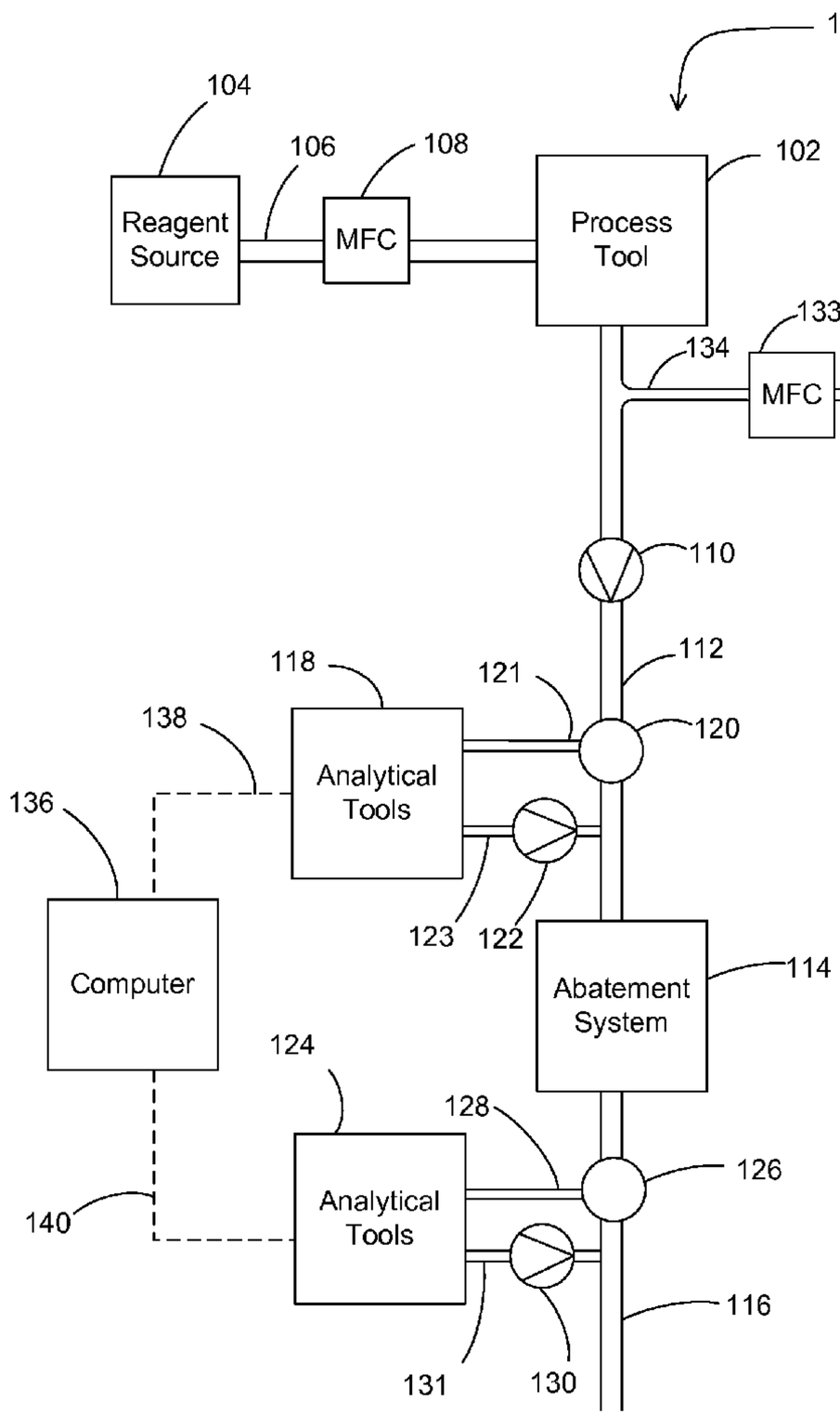
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(57) **ABSTRACT**

A method of developing an integrated abatement system is provided, including the steps: a) determining whether an integrated abatement system meets a destruction removal efficiency standard wherein the determination includes the steps: i) operating an electronic device manufacturing process tool using a best known method, whereby effluent containing a target species is produced; ii) abating the target species to form abated effluent, using an abatement system which is coupled to the process tool; and iii) calculating a destruction removal efficiency for the target species; and b) modifying the abatement system by altering at least one of a design parameter and an operating parameter of the abatement system to improve the destruction removal efficiency. Numerous other aspects are provided.



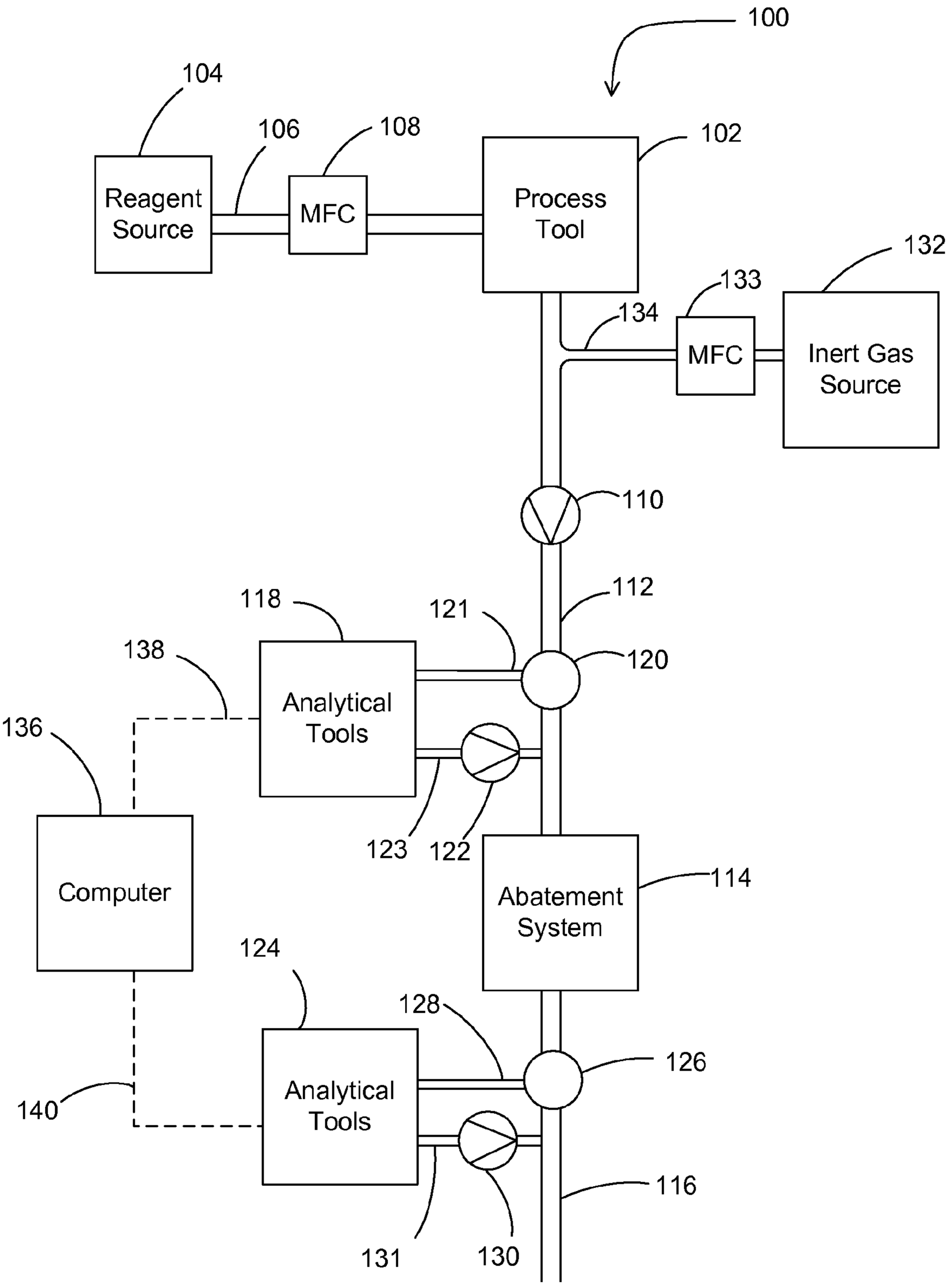
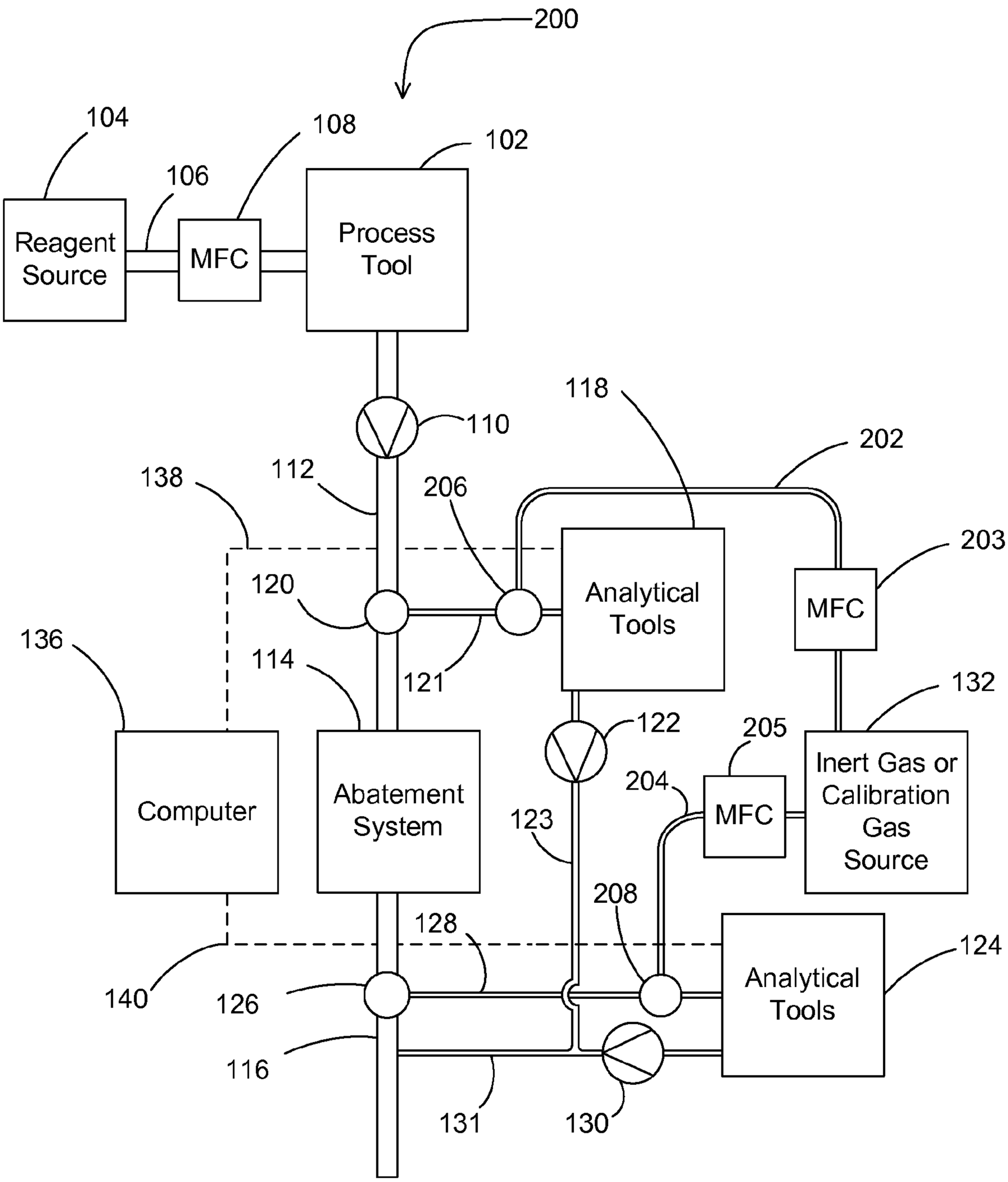

100
104
106
108
102
Reagent Source
MFC
Process Tool
132
133
134
MFC
Inert Gas Source
110
112
118
121
138
120
Analytical Tools
136
123
122
Computer
Abatement System
114
124
128
126
Analytical Tools
116
140
131
130

FIG. 1

$$DRE = \frac{Mass_{In} - Mass_{Out}}{Mass_{In}}$$

FIG. 1A


200
104
108
102
106
Reagent Source
MFC
Process Tool
110
118
202
112
138
206
203
120
Analytical Tools
MFC
136
114
121
132
122
205
Computer
Abatement System
204
MFC
Inert Gas or Calibration Gas Source
123
208
128
124
Analytical Tools
140
126
116
131
130

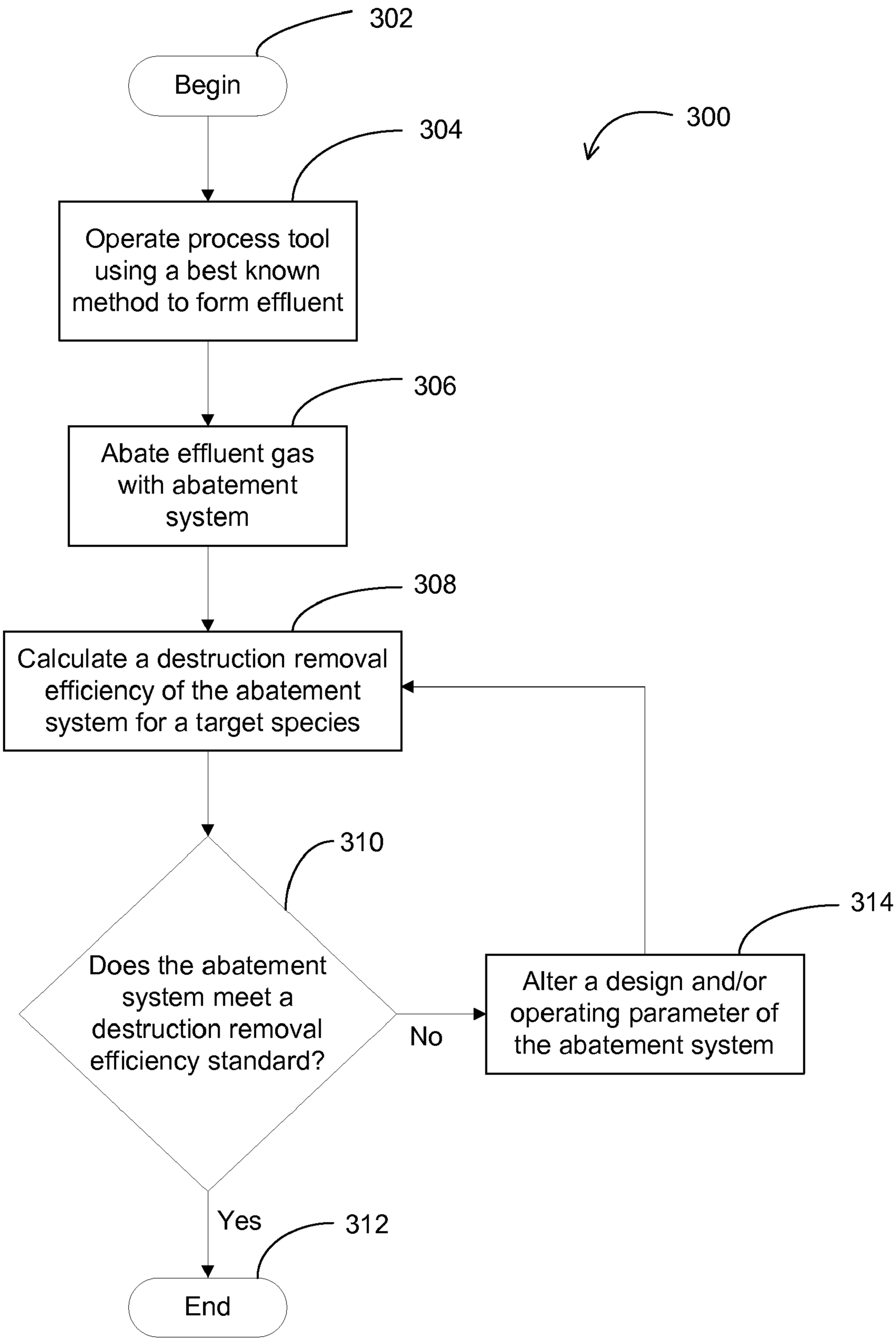

302
Begin
304
300
Operate process tool using a best known method to form effluent
306
Abate effluent gas with abatement system
308
Calculate a destruction removal efficiency of the abatement system for a target species
310
Does the abatement system meet a destruction removal efficiency standard?
No
314
Alter a design and/or operating parameter of the abatement system
Yes
312
End

FIG. 3

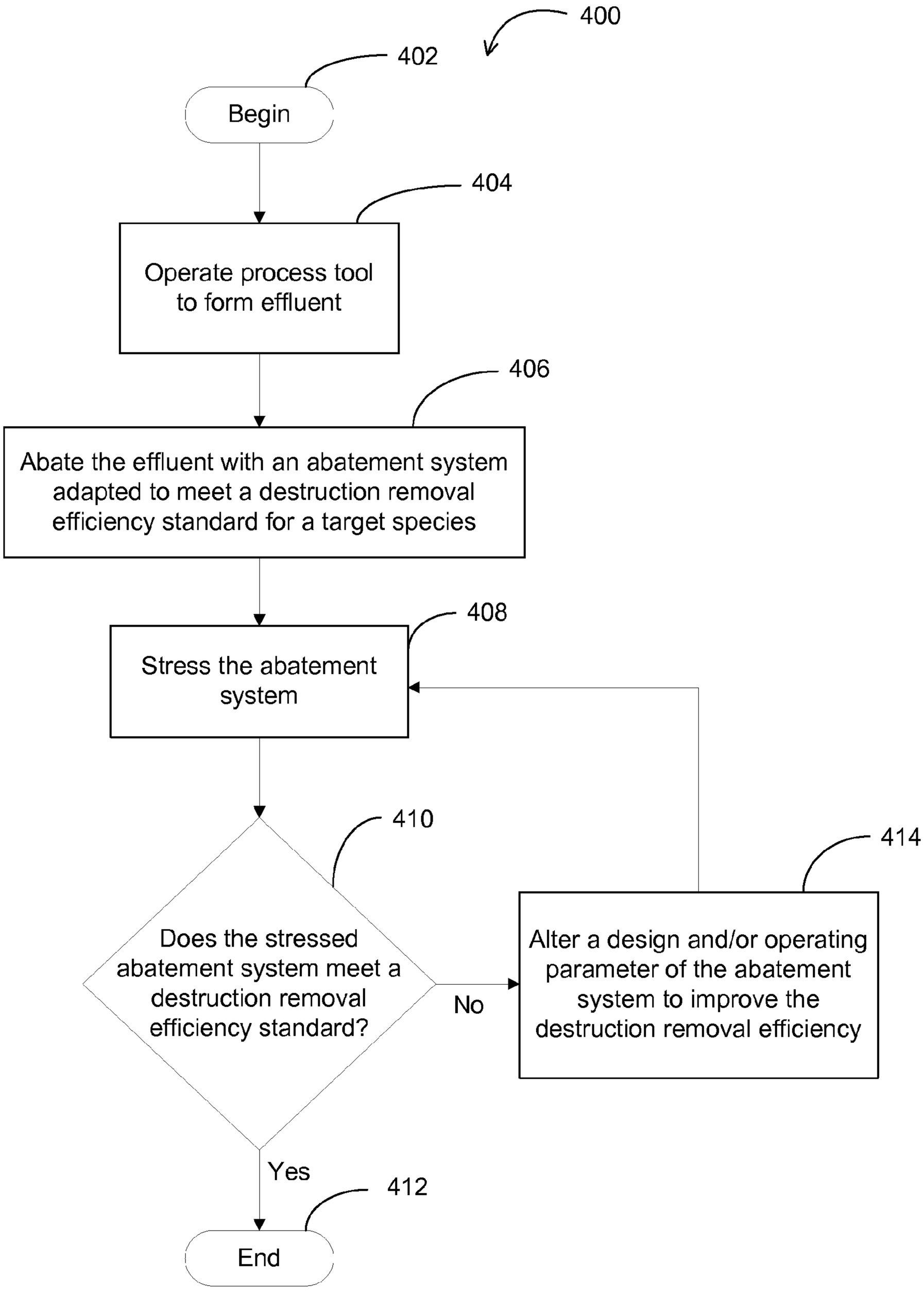

400
402
Begin
404
Operate process tool to form effluent
406
Abate the effluent with an abatement system adapted to meet a destruction removal efficiency standard for a target species
408
Stress the abatement system
410
Does the stressed abatement system meet a destruction removal efficiency standard?
No
414
Alter a design and/or operating parameter of the abatement system to improve the destruction removal efficiency
Yes
412
End

FIG. 4

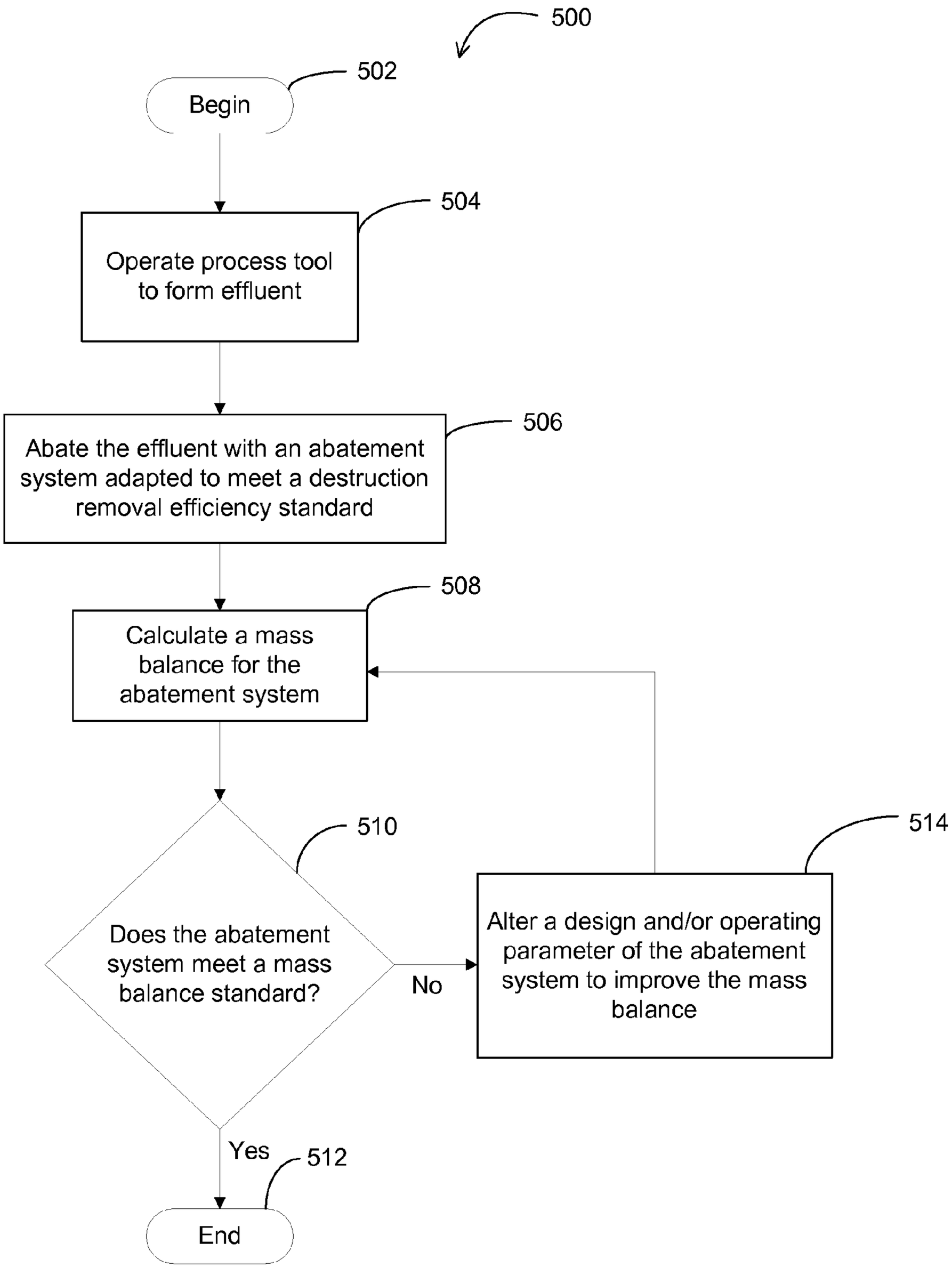

500
502
Begin
504
Operate process tool to form effluent
506
Abate the effluent with an abatement system adapted to meet a destruction removal efficiency standard
508
Calculate a mass balance for the abatement system
510
Does the abatement system meet a mass balance standard?
No
514
Alter a design and/or operating parameter of the abatement system to improve the mass balance
Yes
512
End

FIG. 5

METHODS AND SYSTEMS FOR DESIGNING AND VALIDATING OPERATION OF ABATEMENT SYSTEMS

[0001] The present application claims priority to U.S. Provisional Patent Application Ser. No. 60/944,485, filed Jun. 15, 2007 and entitled "METHODS AND SYSTEMS FOR VALIDATING OPERATION OF ABATEMENT SYSTEMS" (Attorney Docket No. 12073/L2), which is hereby incorporated herein by reference in its entirety for all purposes.

RELATED APPLICATIONS

[0002] Co-owned U.S. patent application Ser. No. 11/685,993, filed Mar. 14, 2007 and entitled "METHODS AND APPARATUS FOR IMPROVING OPERATION OF AN ELECTRONIC DEVICE MANUFACTURING SYSTEM" (Attorney Docket No. 9137), is hereby incorporated by reference herein in its entirety and for all purposes.

FIELD OF THE INVENTION

[0003] The present invention relates generally to the manufacture of electronic devices and is more particularly directed to the design of integrated abatement systems used to abate undesirable species contained in the exhaust of electronic device manufacturing process tools.

BACKGROUND OF THE INVENTION

[0004] The manufacture of electronic devices typically results in the creation of byproduct effluent gases. These effluent gases may contain undesirable species which may be harmful and/or hazardous. The governments of the United States and of many other countries may closely regulate the amount of undesirable species which may be emitted to the environment. Some regulations may specify a maximum concentration of an undesirable species in the effluent from a fabrication plant and other regulations may specify a maximum mass of an undesirable species which may be emitted from a fabrication plant over a specified period of time.

[0005] The operator of an electronic device manufacturing fabrication plant may have an understanding of the amount and concentration of undesirable species which are created by process tools operated in the fabrication plant and may purchase abatement systems to reduce the amount and/or the concentration of the undesirable species which are created by the process tools. The operator, understanding the effluent which is produced by the process tools and the regulations which govern the chemical species which may be emitted from the fabrication plant, may calculate a percentage of the undesirable species in a process tool effluent which must be abated by an abatement system. This percentage may be referred to as a destruction removal efficiency, which will be discussed in more detail below. The operator may specify this destruction removal efficiency to an abatement system manufacturer, who may design the system to this standard.

[0006] It is desirable for manufacturers of abatement systems to be able to design abatement systems to provide the desired destruction removal inefficiencies.

SUMMARY OF THE INVENTION

[0007] In one aspect, the present invention provides a method of developing an integrated abatement system including the steps: a) determining whether an integrated abatement system meets a destruction removal efficiency standard wherein the determination includes the steps: i) operating an electronic device manufacturing process tool using a best known method, whereby effluent containing a target species is produced; ii) abating the target species to form abated effluent, using an abatement system which is coupled to the process tool; and iii) calculating a destruction removal efficiency of the target species; and b) modifying the abatement system by altering at least one of a design parameter and an operating parameter of the abatement system to improve the destruction removal efficiency.

[0008] In a second aspect, the present invention provides a method of developing an integrated abatement system including the steps: operating an electronic device manufacturing process tool, whereby effluent is produced; abating the effluent using an abatement system which is adapted to abate the effluent from the process tool and to meet destruction removal efficiency standards for the process tool when the process tool is operated using a best known method; stressing the abatement system, wherein stressing the abatement system includes introducing a precursor species into the process tool in an amount greater than an amount prescribed by the best known method; calculating a destruction removal efficiency of the stressed abatement system for a target species; and modifying the abatement system, by altering at least one of a design parameter and an operating parameter of the abatement system, to improve the destruction removal efficiency of the abatement system for the target species.

[0009] In a third aspect, the present invention provides a method of developing an integrated abatement system including the steps: operating an electronic device manufacturing process tool using a best known method, whereby effluent is produced; abating the effluent to form abated effluent, using an abatement system which is adapted to abate effluent from the process tool and to meet a destruction removal efficiency standard; measuring a mass flow rate of a target atom entering the abatement system; measuring a mass flow rate of the target atom exiting the abatement system; calculating a mass balance; modifying the abatement system by altering at least one of a design parameter and an operating parameter of the abatement system to improve the mass balance.

[0010] Numerous other aspects are provided in accordance with these and other aspects of the invention. Other features and aspects of the present invention will become more fully apparent from the following detailed description, the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a schematic view of an apparatus for performing methods of the present invention.

[0012] FIG. **1**A is an equation which may be used to calculate a destruction removal efficiency of an abatement system.

[0013] FIG. **2** is a second schematic view of an apparatus for performing methods of the present invention.

[0014] FIG. **3** is a flow chart depicting a method of the present invention.

[0015] FIG. **4** is a flow chart depicting a second method of the present invention.

[0016] FIG. **5** is a flow chart depicting a third method of the present invention.

DETAILED DESCRIPTION

[0017] Electronic device manufacturing systems typically employ process chambers for performing manufacturing steps in the production of an electronic device. The process chambers may perform many different types of operations, including deposition, crystal growth, epitaxial crystal growth, etching, cleaning, etc., and may produce undesirable effluents. As described above, these undesirable effluents may include harmful and/or hazardous materials. A harmful and/or hazardous material for which a destruction removal efficiency is calculated may be referred to herein as a target species. This undesirable effluent may need to be abated to avoid harm to persons and/or the environment.

[0018] The abatement of undesirable effluent in the exhaust of semiconductor process tools is a key challenge. Today, there may be more than 300 precursor species used in various processes and more than 2000 compounds in the exhaust of semiconductor process tools that may need to be abated. In addition, as new fabrication processes are developed, new precursor species and new compounds in the exhaust of semiconductor process tools may be encountered. Such innovation may require the development of new and/or improved abatement processes. In addition, it may be anticipated that the acceptable levels for release of undesirable species to the environment will decrease, requiring more effective abatement of effluent. The increasing stringency of these personal and environmental protection requirements may also necessitate the development of new and/or improved abatement processes.

[0019] Another challenge faced by the electronic device manufacturing industry is that some abatement processes may cause some of the chemical species in the process tool effluent to deposit within an abatement tool. Such deposition may result in the inefficient abatement of effluent, and/or the creation of a dangerous condition. In some cases, the deposition of matter in an abatement tool may become so severe that the abatement tool and the process tool which it supports must be shut down. Shutting down a process tool may cause an expensive piece of capital equipment (which may create a large profit when operating) to lay idle.

[0020] In addition to being able to abate effluent from a process tool which is operating within specifications, an abatement system may need to be able to abate a transient increase in an undesirable species. Such transient increases in an undesirable species may occur, for example, when a mass flow controller which is adapted to introduce a precursor compound into a process tool at a measured rate, fails in an open position.

[0021] Methods and apparatus for designing abatement systems which are effective to abate effluent from electronic device manufacturing processes, and which are able to prevent or reduce the deposition of materials within abatement tools, are desirable.

[0022] The present invention provides methods and apparatus for developing and validating new and/or improved abatement systems and processes. In one embodiment, for example, a process tool may exist or be designed to perform a step in an electronic device manufacturing process. The manufacturer of the process tool typically may create a process recipe which will provide optimal results in the process step. This may be referred to as a best-known method. The same, or a different, manufacturer may design an abatement system which is effective to abate undesirable species which may exist in the process tool effluent when the process tool is operated using best-known methods.

[0023] Using the methods and apparatus of the present invention, the manufacturer/designer of the abatement system may analyze the exhaust from a process tool to determine the nature and amount of undesirable species existing in the effluent. Having knowledge of the nature and amount of undesirable species which exist in the effluent, the manufacturer/designer may draw on its own knowledge, and/or publicly available knowledge of abatement technology, to design a first approximation of an effective abatement system. This design may include selecting abatement tools which the manufacturer knows or believes to be effective with the undesirable species contained in the effluent. The manufacturer may then analyze the exhaust from the abatement system and determine whether the exhaust meets environmental standards and is releasable to the atmosphere, or whether the exhaust does not meet environmental standards and the abatement system instead needs to be improved. If the abatement system needs to be improved, the manufacturer may modify the abatement system by selecting different and/or additional abatement tools or by changing the design and/or operating parameters of the abatement tools which make up the abatement system. The process of analyzing the efficiency of the abatement system followed by modifying the abatement system and then re-analyzing the efficiency of the altered system, may be repeated until such time as the abated effluent meets acceptable standards.

[0024] The manufacturer/designer, having designed an abatement system which is effective to abate the effluent from the process tool which is operated using a best-known method, may also wish to design the abatement system to effectively abate the effluent from the process tool when the process tool is operated outside of the best-known method. According to another embodiment of the present invention, the abatement system may be stressed by increasing the amount of a precursor material which is provided to the process tool. The increase of the precursor material may result in more of an undesirable species appearing in the effluent from the process tool. The manufacturer may then abate this effluent and analyze the composition of the abated effluent and determine whether the abatement system continues to meet environmental standards or whether additional modifications to the design of the abatement system need to be made. If additional modifications need to be made, the manufacturer may follow the process described above, e.g., selecting a different and/or additional abatement tool or by changing the design and/or operating parameters of one or more abatement tools which make up the abatement system.

[0025] In yet another embodiment of the present invention, the manufacturer may determine whether any materials are becoming deposited inside of the abatement system when the abatement system is adapted and operated to effectively abate undesirable species in the effluent from a process tool which is operated using best-known methods. The manufacturer may accomplish this by measuring the mass of materials entering the abatement system and the mass of materials exiting the abatement system. If the manufacturer determines that materials are becoming deposited inside of the abatement system, the manufacturer may alter the abatement system by selecting different abatement tools, different configurations of abatement tools, and/or different abatement tool operating

parameters to prevent the materials from becoming deposited inside of the abatement system.

[0026] FIG. **1** is a schematic drawing of an electronic device manufacturing system **100** which includes an integrated abatement system. As used herein, an "integrated abatement system" refers to an abatement system which is adapted to effectively abate the effluent from a particular process tool to which it is connected. System **100** may include a process tool **102** which may be adapted to perform one or more process steps in the manufacture of an electronic device. The process tool **102** may be any tool which is used in an electronic device manufacturing fabrication plant which produces effluent as a byproduct. Such process tools may perform deposition, crystal growth, etching, stripping, lithography, etc. Process tool **102** may receive a reagent or precursor material from a reagent source **104** through a conduit **106**. Typical reagents or precursor materials may include any reagents which are used in the manufacture of electronic devices. The mass flow rate of the reagent from reagent source **104** to the process tool **102** may be governed by a mass flow controller **108**. Any suitable mass flow controller **108** may be used. Although only one reagent source **104** is shown, it is to be understood that more than one reagent may be provided by more than one reagent source **104** through more than one mass flow controller **108**.

[0027] The process tool **102** may produce an effluent as a byproduct of the manufacturing step which the process tool **102** is performing. A vacuum pump **110** may draw effluent from the process tool **102** through a conduit **112** from which the effluent may enter an abatement system **114**. Abatement system **114**, which may include one or more abatement tools, such as wet scrubbers, burners, plasma units, filters, oxidizing units, thermal units, dry scrubbers, adsorbing units, absorbing units, catalyst units, and acid gas scrubbers, etc., may be adapted to abate the undesirable species in the process tool effluent and pass the abated effluent through conduit **116** to the atmosphere, a house exhaust system (not shown), or to further abatement systems (not shown).

[0028] System **100** may also include analytical tools **118** which may be adapted to determine the concentrations of chemical species in the effluent flowing through conduit **112**. Analytical tools **118** may include one or more of a Fourier transform infrared spectrometer ("FTIR") and a quadrupole mass spectrometer ("QMS"). Any other appropriate analytical tools such as, for example, a fluorine chemiluminescence sensor ("FCS"), an electrolytic cell, etc., may be used as well. The use of FTIR and QMS to measure the composition of an effluent gas flow is described in SEMATECH 1300I, which is hereby incorporated by reference. The use of multiple analytical tools may increase the accuracy of the measurements of species concentrations. Analytical tools **118** may receive a sample of the effluent flowing through conduit **112** through valve **120** and conduit **121**. It should be noted that the effluent flowing through conduit **112** is effluent which has not been abated by abatement system **114**. Analytical tools **118** may return effluent to conduit **112** through pump **122** and conduit **123**. Although a valve **120** is shown at the connection of conduits **112**, **121**, it should be understood that any suitable connector may be used. In addition, although a simple connection is shown between conduit **123** and conduit **112**, it is to be understood that any suitable connector, including a valve, may be used at this connection point.

[0029] In addition to analytical tools **118**, system **100** may include analytical tools **124**. Like analytical tools **118**, analytical tools **124** may be adapted to determine the concentration of chemical species in the effluent flowing through conduit **116**. It should be noted that the effluent flowing through conduit **116** is effluent which has been abated in abatement system **114**. Analytical tools **124** may include the same or different instruments as analytical tools **118**. In some embodiments analytical tools **124** and analytical tools **118** may include the same instruments. Analytical tools **124** may receive abated effluent from conduit **116** through valve **126** and conduit **128**. Analytical tools **124** may return abated effluent to conduit **116** through pump **130** and conduit **131**. Although FIG. **1** depicts the use of valves **120**, **126** to divert effluent from conduits **112**, **116** to analytical tools **118**, **124**, it is to be understood that valves **120**, **126** may be replaced any suitable couplings.

[0030] System **100** may include inert gas source **132**, which may be adapted to supply an inert gas through mass flow controller **133** and conduit **134** into conduit **112**. Useful inert gases may include krypton, helium, or argon, etc. Krypton works well because it is easy to detect and does not occur in room air to any significant extent. The inert gas from inert gas **132** may be used for several purposes, depending upon the configuration and location of inert gas source **132**. For example, inert gas may be used to calibrate instruments, to dilute an effluent to be tested, and as a tool useful and calculating destruction removal efficiency. These uses will be discussed in further detail below.

[0031] Finally, system **100** may include computer or controller **136** which may receive data from analytical tools **118**, **124** through signal lines **138**, **140**. Signal lines may be any suitable form of communication medium, including wireless communication. Computer **136** may be used to perform calculations such as destruction removal efficiency and mass balance.

[0032] In operation, process tool **102** may receive one or more reagents from reagent supplies **104**. Process tool **102** may use the reagents in an electronic device manufacturing process performed on a substrate. As a byproduct of the process conducted by the process tool **102**, an effluent gas which contains one or more undesirable species may be produced by the process tool **102**. The effluent gas containing the undesirable species may then be abated in abatement system **114**.

[0033] System **100** may also perform measurements and calculations to calculate a destruction removal efficiency of the abatement system. Thus, the effluent which passes through conduit **112** may also be analyzed by the instruments contained in analytical tools **118**. Some of the effluent flowing through conduit **112** may be diverted by valve **120** into analytical tools **118**, where the effluent may be analyzed. After being analyzed, the effluent may pass through pump **122** and conduit **123** back into conduit **112**. Analytical tools **118** may send information, including the results of analyses performed on the effluent, through signal line **138** to computer **136**.

[0034] As described above, the effluent exiting from abatement system **114** may be passed to a house exhaust system, the atmosphere, or to further abatement treatment through conduit **116**. Some of the effluent passing through conduit **116** may be diverted through valve **126** and conduit **128** into analytical tools **124** where the effluent may be analyzed. Analytical tools **124** may then send data, including the results of the analyses performed on the effluent, through signal line **140** to computer **136**.

[0035] Inert gas source **132** may supply a flow of inert gas through conduit **136** into conduit **112**. In the configuration of FIG. **1**, the inert gas may be used by system **100** to calculate mass flow rates of target species.

[0036] Mass flows may be important to calculate in cases where the total mass of a target species which can be released to the atmosphere is regulated, as opposed to only the concentration of the target species in the effluent being regulated. Measuring mass flow rates may be important to the calculation of destructive removal efficiency, because in some abatement systems, a large quantity of non-effluent gasses may be introduced into the abatement system. These non-effluent gases may include fuel, oxidants, and/or inert gases, such as nitrogen, for example. Other non-effluent gases may also be used. The introduction of these non-effluent gases into the abatement unit may have the effect of reducing the concentration of the target species in the abated effluent, and giving a false impression of a high destruction removal efficiency.

[0037] In one embodiment, an inert gas may be used to calculate a mass flow rate of a target species as follows: the inert gas may be flowed at a known mass flow rate established by mass flow controller **133** into conduit **112**, at a location upstream from a location, e.g., valve **120**, where the mass flow rate of a target species may be measured; the concentration of the inert gas in the conduit **112** which carries the inert gas and the target species may be measured by analytical tools **118**; the concentration of the target species in the conduit which carries the inert gas and the target species may be measured by analytical tools **118**; the total mass flow rate of the effluent in the conduit **112** may be calculated by dividing the mass flow rate of the inert gas by the concentration of the inert gas in the conduit **112**; and the mass flow rate of the target species may be calculated by multiplying the total flow rate of the effluent by the concentration of the target species in the conduit **112**.

[0038] Thus, the inert gas injection may make possible an accurate destruction removal efficiency calculation based upon mass flow rates of a target species, as discussed in more detail below.

[0039] FIG. **1**A is an equation which may be used to calculate a destruction removal efficiency of an abatement system. Thus, in system **100**, analytical tools **118** may measure the $mass_{In}$ of a target species and report this measurement to computer **136**, and analytical tools **124** may measure the $mass_{out}$ of the selected species and report this measurement to computer **136**. Computer **136** may then use the equation of FIG. **1**A to calculate the destruction removal efficiency of the abatement system with respect to the selected species using the equation $(mass_{in}\text{-}mass_{out})/mass_{in}$.

[0040] FIG. **2** is a schematic drawing of a second electronic device manufacturing system **200** of the present invention. System **200** is similar to system **100** with the exception that inert gas source **132** is connected to the system through conduits **202**, **204** and mass flow controllers **203**, **205**, instead of through conduit **134** and mass flow controller **133**, as in FIG. **1**. Conduits **202**, **204** connect to conduits **121**, **128** through connectors **206**, **208**. Connectors **206**, **208** may be three-way valves or any other suitable connectors. Analytical tools **118**, **124** return effluent to conduit **116** through conduits **123**, **131**. Although conduit **123** is shown connected to conduit **131**, conduit **123** may alternatively be connected to conduit **116** directly. In addition, although the connection of conduit **131** to conduit **116** is depicted as a simple connector, the connector may alternatively be a valve.

[0041] In operation, system **200** may operate similarly to system **100**, with the exception of the inert gas. In this embodiment, inert gas source **132** may supply inert gas directly into the conduits **121**, **128** which conduits may feed effluent gases to analytical instruments **118**, **124** respectively.

[0042] In one embodiment of the present invention inert gas may be used to calibrate the analytical instruments **118**, **124**. By flowing a known mass of inert gas into the analytical instruments **118**, **124**, the instruments may be calibrated. In another embodiment of the present invention, inert gas may be used to dilute the effluent gas in conduits **121**, **128**, so that a target species concentration may be reduced by a known dilution factor to a concentration which falls within a range within which the instruments of analytical tools **118**, **124** are more sensitive. By knowing how much inert gas was introduced into the effluent gas to dilute the target species, the actual concentration of the target species may be calculated. This may be useful, because the instruments may be used to detect species which are present in the effluent gas in wide ranges of composition, and it may be impractical to modify the sensitivity ranges of the instruments during operation of the system **200**.

[0043] It should be noted that the systems **100** and **200** may be combined such that the inert gas or calibration gas source may located in both depicted locations so that all three uses for the inert gas/calibration gas may be employed in one system.

[0044] FIG. **3** is a flowchart depicting a method for designing an integrated abatement system **300** of the present invention. The method begins in step **302**. In step **304**, an electronic device manufacturing process tool is operated using a best-known method. In step **306**, the effluent gas from the process tool is abated with an abatement system. One of ordinary skill in the abatement art will be able to design an initial abatement system to use in step **306** based on knowledge of the process being performed in the process chamber and familiarity with available abatement components. Thus, the abatement system used in step **306** to abate the effluent may be more or less appropriate for abating the effluent. In step **308**, a destruction removal efficiency of the abatement system for a target species is calculated for the initial abatement system, as described above with respect to FIG. **1**A. In step **310**, the destruction removal efficiency of the abatement system for the target species is compared to a destruction removal efficiency standard. The standard may be selected in accordance with the requirements of a customer for whom the system is being designed. If the destruction removal efficiency of the abatement system for the target species meets or exceeds the destruction removal efficiency standard, the method **300** may end in step **312**. If, instead, the destruction removal efficiency of the abatement system for the target species fails to meet the destruction removal efficiency standard, the abatement system is modified in step **314** by altering a design and/or an operating parameter of the abatement system and/or abatement tools which make up the abatement system.

[0045] The selection of a design parameter may include a selection of an abatement tool type, a size of an abatement tool, a flow capacity of an abatement tool, a configuration of an abatement tool, a configuration of the abatement system (for example, the order of abatement tools in the abatement system), etc. and the selection of an operational parameter may include selecting how an abatement tool, which is already incorporated into the abatement system, is operated. For example, operational parameters may include fuel flow

rate, water flow rate, oxidant flow rate, region flow rate, plasma flow rate, electrical power, inert gas flow rate, etc. Other operational parameters may also be altered.

[0046] After modifying the abatement system, step **308** is repeated and a destruction removal efficiency of the modified abatement system for the target species is calculated. Steps **308**, **314**, and **310**, may be repeated until the abatement system meets the destruction removal efficiency standard for the target species, at which point the method **300** may end in step **312**.

[0047] During step **314**, wherein the abatement system is modified, the process tool may continue to be operated or may be shut down. If the process tool is continued to be operated while the abatement system is modified, then the effluent gas may be diverted to a secondary abatement system or shunted directly into the house abatement system. If the process tool is shut down during modification of the abatement system, then, before returning to step **308**, steps **304** and **306** must be started again.

[0048] FIG. **4** is a flowchart depicting a second method for designing an integrated abatement system **400** of the present invention. Method **400** begins in step **402**. In step **404**, an electronic device manufacturing process tool is operated, whereby an effluent is formed. The effluent is abated in step **406** using an abatement system which is adapted to meet a destruction removal efficiency standard for a target species which is exhausted from a process tool with which the abatement system is integrated. At this point in the method, the effluent from the process tool is successfully abated to meet the destruction removal efficiency standard. This may result in a steady state operation. In step **408**, the abatement system is stressed by deviating from a best-known method for operating the process tool. This may be accomplished by, for example, increasing the mass flow of a precursor material above the mass flow prescribed by the best-known method. One reason for stressing the abatement system in this fashion may be to ensure or certify that an abatement system will continue to effectively abate the effluent from a process tool in the event that a precursor mass flow controller fails in the full open position. In step **410**, the destruction removal efficiency of the stressed abatement system is measured and compared to a destruction removal efficiency standard for the integrated abatement system. If the stressed abatement system continues to meet the destruction removal efficiency standard for the target species, the process may end in step **412**. However, if the stressed abatement system fails to meet the destruction removal efficiency standard for the target species, the method may pass to step for **414** wherein the abatement system is modified by altering a design and/or an operating parameter of the abatement system to improve the destruction removal efficiency for the target species. The method may then pass to step **408**, where the abatement system is continued to be stressed, and then to step **410**, where the destruction removal efficiency of the abatement system is re-measured. Steps **414**, **408** and **410** may be repeated until the stressed abatement system meets the destruction removal efficiency standard for the target species. The method may then pass to step **412** where the method **400** ends.

[0049] FIG. **5** is a flowchart depicting another method **500** of designing an abatement system of the present invention. The method begins in step **502**. In step **504**, a process tool is operated using a best-known method whereby effluent is formed. In step **506**, the effluent is abated with an abatement system which may be adapted to meet a destruction removal efficiency standard for a target species. The method passes to step **508** where a mass balance is calculated for the abatement system. As described above, the mass balance may be calculated for a target atomic species by measuring the $mass_{in}$ of the target atomic species in conduit **112**, measuring the $mass_{out}$ of the target species in conduit **116**, and then subtracting $mass_{out}$ from $mass_{in}$ and dividing the result by $mass_{in}$.

[0050] If the mass balance for the abatement system meets a mass balance standard, the method may end in step **512**. However, if the abatement system does not meet the mass balance standard, the abatement system is modified by altering a design and/or an operating parameter of the abatement system and/or an abatement tool to improve the mass balance. Steps **514**, **508** and **510** may be repeated until the abatement system does meet the mass balance standard, at which time the method may pass to step **512** where the method **500** ends.

[0051] The foregoing description discloses only exemplary embodiments of the invention. Modifications of the above disclosed apparatus and methods which fall within the scope of the invention will be readily apparent to those of ordinary skill in the art. For example, instruments which may measure the concentration of target species in the waste water from an abatement system may be used to add this measure to the calculations of destruction removal efficiency and mass balance.

The invention claimed is:

1. A method of developing an integrated abatement system comprising the steps:

a) determining whether an integrated abatement system meets a destruction removal efficiency standard wherein the determination comprises the steps:

i) operating an electronic device manufacturing process tool using a best known method, whereby effluent containing a target species is produced;

ii) abating the target species to form abated effluent, using an abatement system which is coupled to the process tool; and

iii) calculating a destruction removal efficiency for the target species; and

b) modifying the abatement system by altering at least one of a design parameter and an operating parameter of the abatement system to improve the destruction removal efficiency.

2. The method of claim **1** further comprising:

c) repeating steps a) and b) at least once.

3. The method of claim **1** wherein the abatement system is modified by altering a design parameter.

4. The method of claim **3** wherein altering the design parameter comprises selecting an abatement tool for inclusion in the abatement system.

5. The method of claim **4** wherein the abatement tool is selected from the group consisting of wet scrubbers, burners, plasma units, filters, oxidizing units, thermal units; dry scrubbers, adsorbing units, absorbing units, catalyst units, and acid gas scrubbers.

6. The method of claim **3** wherein altering the design parameter comprises selecting a configuration for the abatement system.

7. The method of claim **6** wherein selecting the configuration for the abatement system the comprises selecting at least one of a size, a capacity, a physical configuration, and an order of one or more abatement tools.

8. The method of claim **1** wherein the step of calculating a destruction removal efficiency of the target species comprises measuring a mass flow rate of the target species produced by the process tool.

9. The method of claim **8** wherein the step of calculating a destruction removal efficiency of the target species further comprises measuring a mass flow rate of the target species in the abated effluent.

10. The method of claim **9** wherein the measurement of the mass flow rate of the target species comprises:

injecting an inert gas at a known mass flow rate into a conduit which contains the effluent, at a location upstream from a location where the mass flow rate of the target species will be measured;

measuring the concentration of the inert gas in the conduit which carries the inert gas and the target species;

measuring the concentration of the target species in the conduit which carries the inert gas and the target species;

calculating the total mass flow rate of the effluent in the conduit by dividing the mass flow rate of the inert gas by the concentration of the inert gas in the conduit; and

multiplying the total flow rate of the effluent by the concentration of the target species.

11. A method of developing an integrated abatement system comprising the steps:

operating an electronic device manufacturing process tool, whereby effluent is produced by the process tool;

abating the effluent, using an abatement system which is adapted to abate effluent from the process tool and to meet a destruction removal efficiency standard for the process tool when the process tool is operated using a best known method;

stressing the abatement system, wherein stressing the abatement system comprises introducing a precursor species into the process tool in an amount greater than an amount prescribed by the best known method;

calculating a destruction removal efficiency of the stressed abatement system for a target species; and

modifying the abatement system, by altering at least one of a design parameter and an operating parameter of the abatement system, to improve the destruction removal efficiency of the abatement system for the target species.

12. The method of claim **11** further comprising

continuing to stress the abatement system;

abating the effluent using the modified abatement system;

calculating a destruction removal efficiency of the modified abatement system; and

further modifying the abatement system, by altering at least one of a design parameter and an operating parameter.

13. The method of claim **11** wherein stressing the abatement system further comprises stabilizing a mass flow controller connected to the process tool.

14. The method of claim **11** wherein stressing the abatement system further comprises calibrating a mass flow controller connected to the process tool.

15. The method of claim **11** wherein stressing the abatement system further comprises simulating the failure a mass flow controller connected to the process tool, wherein the mass flow controller fails at a maximum flow.

16. A method of developing an integrated abatement system comprising the steps:

operating an electronic device manufacturing process tool using a best known method, whereby effluent is produced by the process tool;

abating the effluent to form abated effluent, using an abatement system which is adapted to abate effluent from the process tool and to meet a destruction removal efficiency standard;

measuring a mass flow rate of material entering the abatement system;

measuring a mass flow rate of material exiting the abatement system;

calculating a mass balance;

modifying the abatement system by altering at least one of a design parameter and an operating parameter of the abatement system to improve the mass balance.

17. The method of claim **16** further comprising:

calculating a mass balance for the modified abatement system, and

further modifying the abatement system by altering at least one of a design parameter and an operating parameter of the abatement system to improve the mass balance.

18. The method of claim **16** where the material is an atom.

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