



(51) International Patent Classification:

B01D 45/12 (2006.01) B04C 5/04 (2006.01)

(21) International Application Number:

PCT/IN2019/050607

(22) International Filing Date:

19 August 2019 (19.08.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

201841033298 05 September 2018 (05.09.2018) IN

(71) Applicant: **INDIAN INSTITUTE OF TECHNOLOGY MADRAS (IIT MADRAS)** [IN/IN]; Dean, ICSR, Indian Institute of Technology Madras, IIT P.O., Chennai 600036 (IN).

(72) Inventors: **THIRUVENKATACHARI, Ranga Rajan**; Dept. Civil Engineering, Indian Institute of Technology Madras, Chennai 600036 (IN). **SARAGUR MADANAYAK, Shiva Nagendra**; Dept. Civil Engi-

neering, Indian Institute of Technology Madras, Chennai 600036 (IN). **PEETHAMBARAM, Parthasarathy**; B-41/1 III Stage, Peenya Industrial Estate, Bengaluru 560058 (IN).

(74) Agent: **VENKATARAMAN, Shankar**; Maxval IP Services Pvt. Ltd, Indialand Techpark, Chil Sez, Saravanampatty Po, Coimbatore 641035 (IN).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

(54) Title: SPIRAL BAFFLED CYCLONE SEPARATOR FOR PARTICULATE EMISSION CONTROL

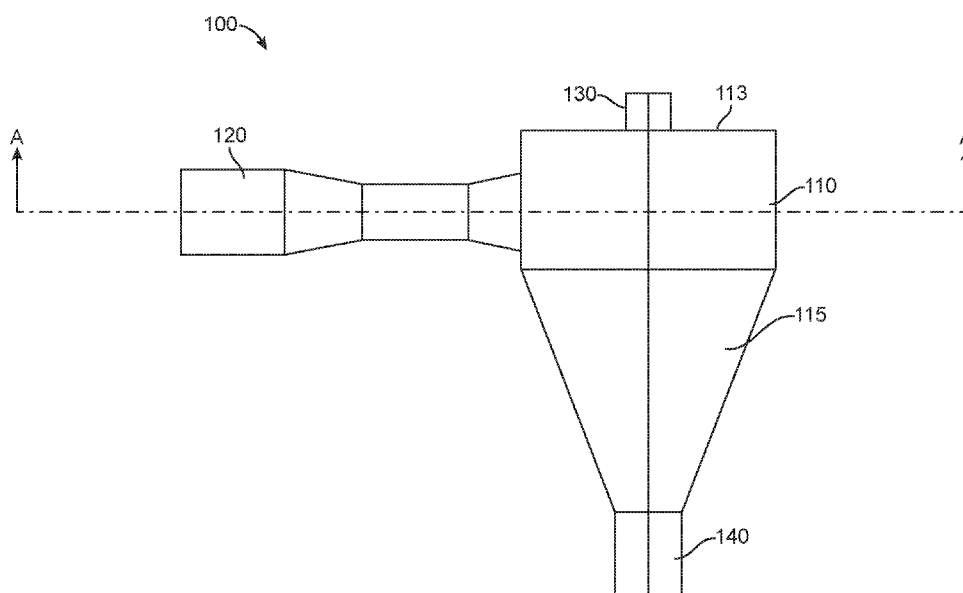


FIG. 1A

(57) Abstract: A spiral baffled cyclone separator with a spiral baffle in the body so as to increase the removal efficiency of micron-sized particulates (< 10 micrometer) is disclosed, for vehicle exhaust systems. Small particles owing to their small mass tend to move towards the center of the cyclone due to the dominant drag force. A spiral baffle traps these smaller particles moving in to the center of the cyclone and thus resulting in efficient particle removal from the exhaust.



GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

**SPIRAL BAFFLED CYCLONE SEPARATOR FOR PARTICULATE EMISSION
CONTROL**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] None.

FIELD OF THE INVENTION

[0002] The present invention generally relates to air pollution control. Specifically, the invention relates to vehicular devices to mitigate particulate air pollution.

DESCRIPTION OF THE RELATED ART

[0003] Particulate matter (PM) owing to their chemical composition and size are a health and environmental hazard. Particulates less than 2.5 microns in size are also known to be carcinogenic. The emission laws for diesel engines are also becoming more stringent from time to time. Emission standard currently in place for light duty diesel vehicles is Bharat Stage IV which will be revised to Bharat Stage VI by 2020. Thus, very effective control of diesel PM is necessary. To cope up with the new stricter regulations new diesel vehicles can be fitted with advanced catalytic converters, diesel oxidation catalysts or other control devices. The procedure of making an old vehicle on the road to comply with the new standards is also not an easy process. There is therefore a need for pollution control devices for both new and existing vehicles.

[0004] Cyclone separators such as that disclosed in US3953184A are known in the art. Chinese utility model CN202438419U further discloses a cyclone separator with a spiral shaped baffle. However, the dust capture efficiency of existing devices is not known.

SUMMARY OF THE INVENTION

[0005] In various embodiments a spiral baffled cyclone separator for particulate emission control is disclosed herein. The device comprises an inlet (120), an upper cylindrical part (110), and a lower conical part (115). The inlet (120) comprises a venturi portion (122) configured to provide tangential entry of the air stream into the upper cylindrical part. The upper cylindrical part (110) is configured with a spiral baffle (112) placed therewithin, and further comprises an outlet (130) in the middle extending downward from a top surface (113) thereof. The device is configured to receive the air stream tangentially at the cylindrical part, the air stream configured to pass through a spiral passage (119) formed by the baffle (112) and pass through the outlet (130), and trap particles of size less than 10 micrometers. The particles are captured in the lower conical part (115).

[0006] In some embodiments the baffle (112) is coated with a catalyst comprising nickel, palladium or titanium dioxide. In various embodiments, the particle removal efficiency of the device for particles less than 7.5 microns is 54% or better. In some embodiments the device is configured to provide a pressure drop of 5 kPa or lower when fitted to a diesel-fueled vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The invention has other advantages and features which will be more readily apparent from the following detailed description of the invention and the appended claims, when taken in conjunction with the accompanying drawings, in which:

[0008] FIG. 1A shows front view of the cyclone separator.

[0009] FIG. 1B is a horizontal section A-A illustrating internal parts of the cyclone separator including the spiral baffle.

[0010] FIG. 1C shows longitudinal section of the cyclone separator.

[0011] FIG. 2A shows velocity contours through the horizontal section corresponding to A-A.

[0012] FIG. 2B shows velocity contours in vertical section.

[0013] Like numbers indicate like parts throughout the views.

DETAILED DESCRIPTION

[0014] While the invention has been disclosed with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In addition, many modifications may be made to adapt to a particular situation or material to the teachings of the invention without departing from its scope.

[0015] Throughout the specification and claims, the following terms take the meanings explicitly associated herein unless the context clearly dictates otherwise. The meaning of "a", "an", and "the" include plural references. The meaning of "in" includes "in" and "on." Referring to the drawings, like numbers indicate like parts throughout the views. Additionally, a reference to the singular includes a reference to the plural unless otherwise stated or inconsistent with the disclosure herein.

[0016] The invention in its various embodiments relates to a spiral baffled cyclone separator **100** as illustrated in FIG. 1A to 1C. **1** configured to remove particulate matter from vehicle exhaust streams. As illustrated in FIG. 1A, the cyclone separator device for removal of particulate matter from air streams, has an inlet **120**, an upper cylindrical part **110**, and a lower conical part **115**. The inlet **120** is configured to provide tangential entry of the air stream into the upper cylindrical part.

[0017] The upper cylindrical part **110** is configured with a spiral baffle **112** placed therewithin. The spiral baffle is intended in various embodiments to provide a convoluted path to the air stream containing particulates, and to cause impacting of the surface of the baffle by the particulates, causing agglomeration and removal of the particulates. The device further comprises an outlet **130** in the middle extending downward from a top surface **113** thereof.

[0018] A horizontal section corresponding to AA in FIG. 1A is illustrated in FIG. 1B, which further illustrates the device of the invention. The inlet tube **120** is provided with an intake portion **125**, followed by a venturi **127**. In various embodiments, the venturi **127** is configured to provide increase in velocity of the air stream along with particles present therein, while entering the cylindrical part **110**. The accelerated air stream is then configured to pass through a spiral passage **119** formed by the baffle **112** and pass through the outlet **130**. Outlet tube **130** has a downward portion **132** as illustrated in FIG. 1C, configured to ensure a convoluted path for the exiting air stream.

[0019] In some embodiments the venturi inlet **127** is configured to provide a natural mechanism for dilution by sucking in the atmospheric air. This dilution improves the nuclearization of particles thereby increasing the particle sizes and promoting entrapment. The venturi **127** may further provide equalisation of flow by smoothing the intermittent pressure surges in vehicle exhaust.

[0020] In various embodiments the device **100** is configured to trap particles of size less than 10 micrometers from the air stream. In various embodiments the particles present in the air stream are configured to fall and be captured in the lower conical part **115**. In some embodiments, the lower conical part may be provided with a removable cap **140** for cleaning the device.

[0021] In some embodiments the baffle **112** of the device **100** may be provided with one or more coatings to enhance entrapment of the particles from the air stream. In some embodiments the coatings may include a metal catalyst. In some embodiments the metal catalyst may contain nickel, palladium or titanium dioxide as active agent. In some embodiments the coating may increase the roughness of the surface thereby improving particle capture. In some embodiments the surface may be roughened to capture or adsorb any toxic gases in the exhaust stream.

[0022] In operation, the device **100** may provide particle removal efficiency of 54% or better for particles less than 7.5 microns. In some embodiments the device **100** is configured to provide a pressure drop of 5 kPa or lower when fitted to a diesel-fueled vehicle.

[0023] The invention is further explained in the following examples, which however, are not to be construed to limit the scope of the invention which is as delineated in the claims.

EXAMPLES

[0024] EXAMPLE 1: Fabrication of Cyclone Separator

[0025] A modified cyclone separator was fabricated. Conventional cyclone separators cannot remove particles less than 10 microns efficiently. Thus, a spiral baffle was used inside the body of the cyclone separator. The idea behind the baffle is that the small particles having a smaller radius of rotation inside the cyclone will strike the inner side of the baffle and thus their momentum will be removed. The material used was mild steel. Table. 1 shows the dimensions of the cyclone separator.

Table 1: Dimensions of Cyclone Separator Fabricated and Tested

PART	DIMENSION (mm)
Body Length	170
Cone Length	400
Body Diameter	310
Outlet diameter	54
Outlet length	115
Venturi Inlet Diameter	105
Venturi Neck Diameter	67

Baffle Maximum Dia	280
Baffle Minimum Dia	113
Baffle Thickness	3
Baffle Height	195

[0026] EXAMPLE 2: Test Results

[0027] Pressure Drop: Pressure measurements were carried out to determine pressure drop across the cyclone device for diesel vehicle exhaust emissions. The pressure at the inlet of the cyclone was 105470 Pa while at the outlet it was 101330 Pa. Thus, the pressure drop is 4.14 kPa. The pressure drop is well within the range of the maximum recommended exhaust back pressure of 10 kPa allowed for vehicles 500 kW and above.

[0028] Particle Removal Efficiency: The cascade impactor was used to analyse the particle size distribution of diesel exhaust particulates and it was found that the mean size of PM was 1.6 ± 0.1 microns. Particle removal efficiency was measured by measuring the initial weight and final weight of the filters at each particle size and % removal is provided in Table 2. The average particle removal efficiency for <7.5 microns was estimated as 54%.

[0029] Simulation Results: Simulation results of velocity distribution within the fabricated device in horizontal section AA is shown in FIG. 2A and longitudinal section is shown in FIG. 2B. The figures show dark portions where the flow velocity is relatively higher, such as the venturi portion **127** and outlet **130**.

Table 2: Experimental Particle Removal Efficiency Measured for Cyclone Separator

Particle Size	% Removal
9	74
7.4	82

5.25	52
2.7	31
1.6	49
0.54	47

We claim:

1. A cyclone separator device for removal of particulate matter from air streams, comprising:

an inlet (120), an upper cylindrical part (110), and a lower conical part (115);

the inlet (120) comprising a venturi portion (122) configured to provide tangential entry of the air stream into the upper cylindrical part;

the upper cylindrical part (110) configured with a spiral baffle (112) placed therewithin, and further comprising an outlet (130) in the middle extending downward from a top surface (113) thereof, wherein the device is configured to receive the air stream tangentially at the cylindrical part, the air stream configured to pass through a spiral passage (119) formed by the baffle (112) and pass through the outlet (130), and wherein the device is configured to trap particles of size less than 10 micrometers and the particles are captured in the lower conical part (115).

2. The device of claim 1, wherein the baffle (112) is coated with a catalyst comprising nickel, palladium or titanium dioxide.

3. The device of claim 1, wherein the particle removal efficiency for particles less than 7.5 microns is 54% or better.

4. The device of claim 1, wherein the device is configured to provide a pressure drop of 5 kPa or lower when fitted to a diesel-fueled vehicle.

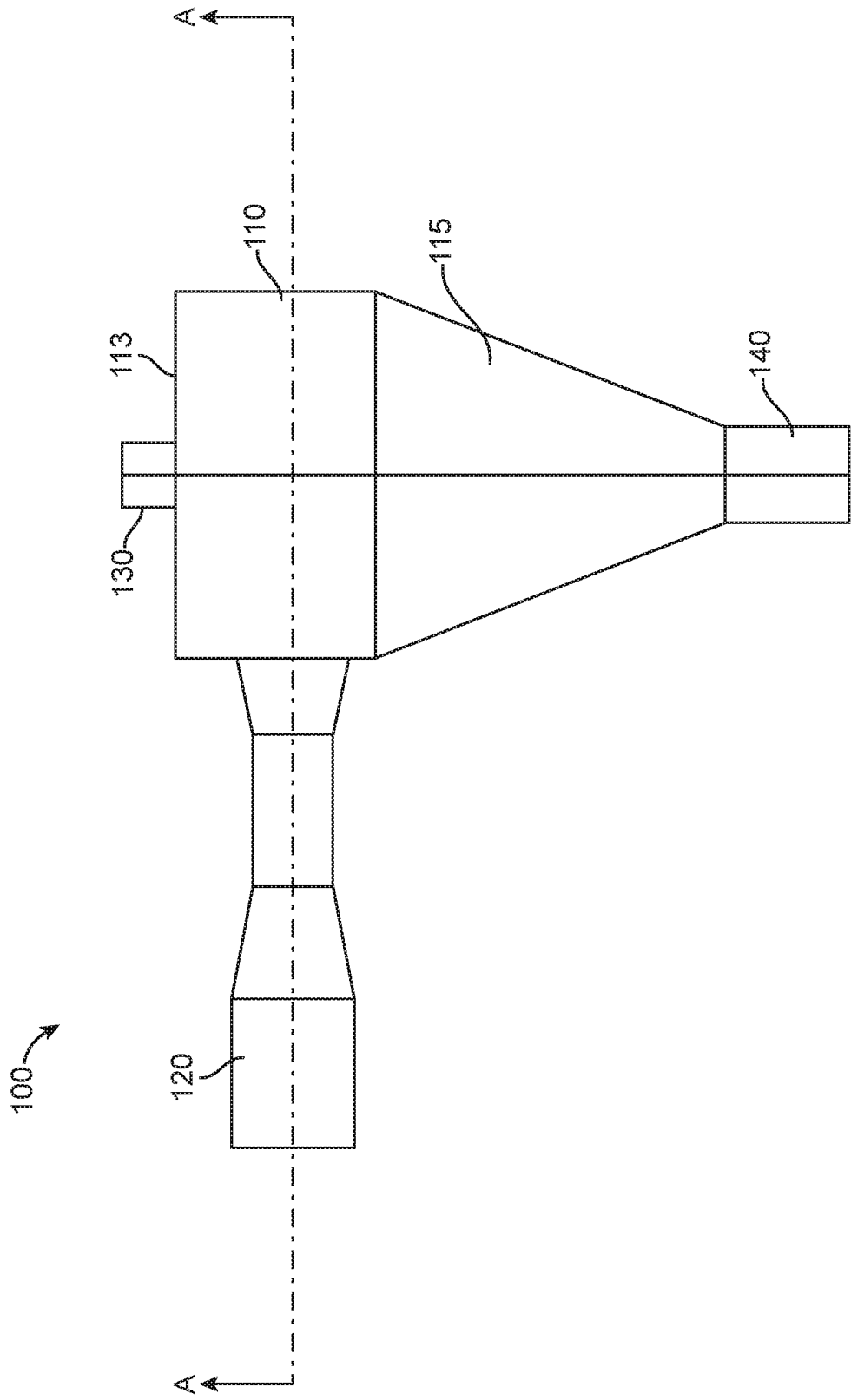


FIG. 1A

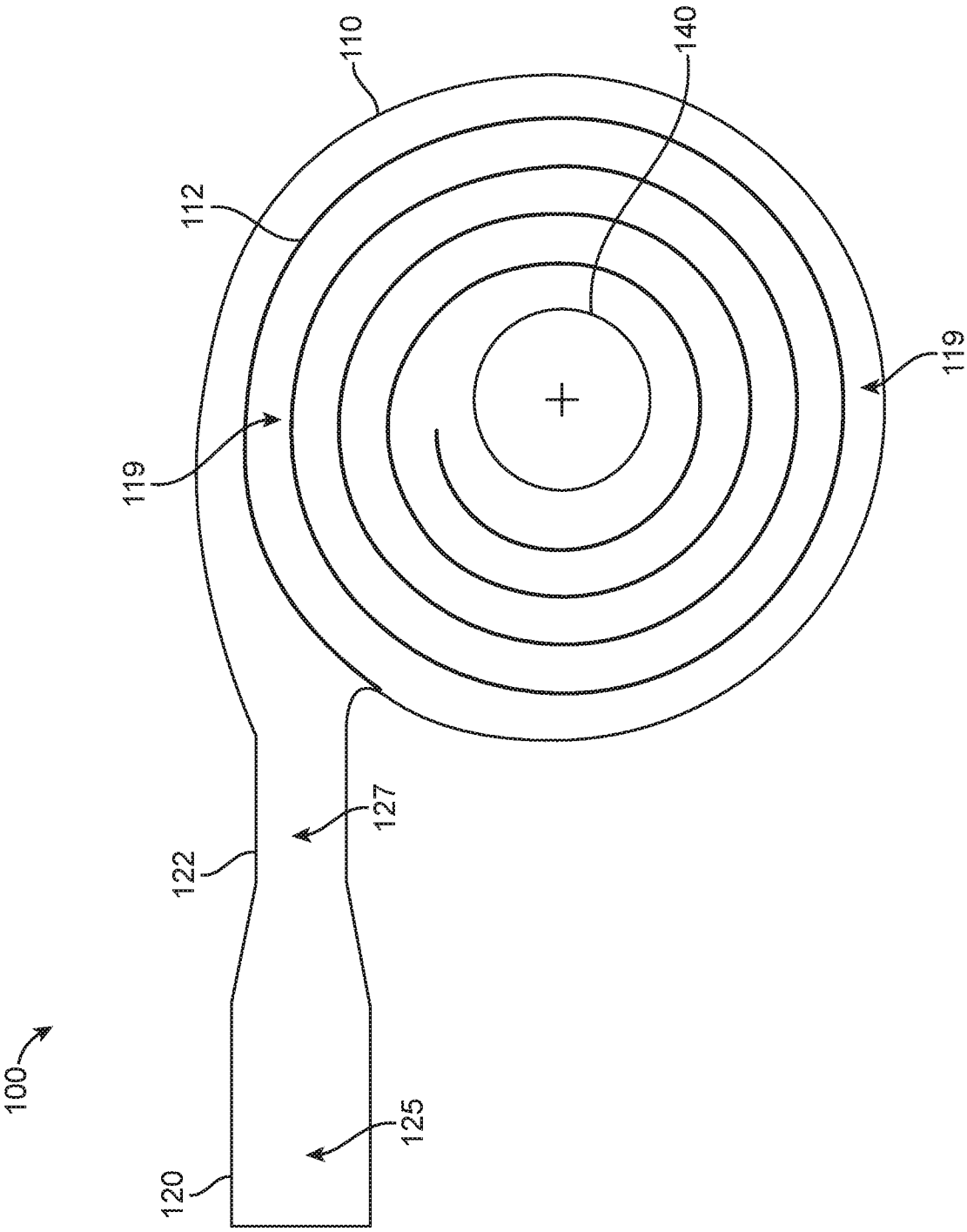
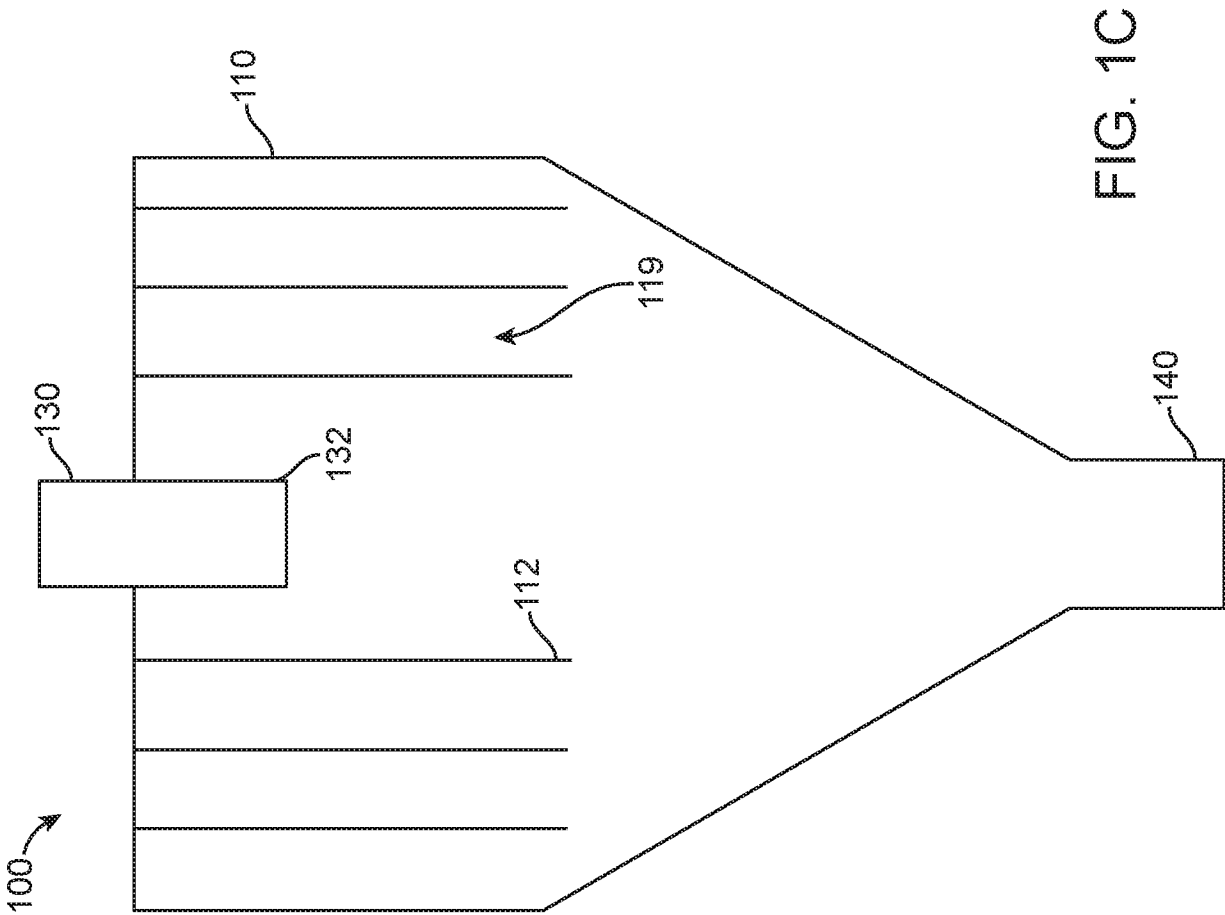


FIG. 1B



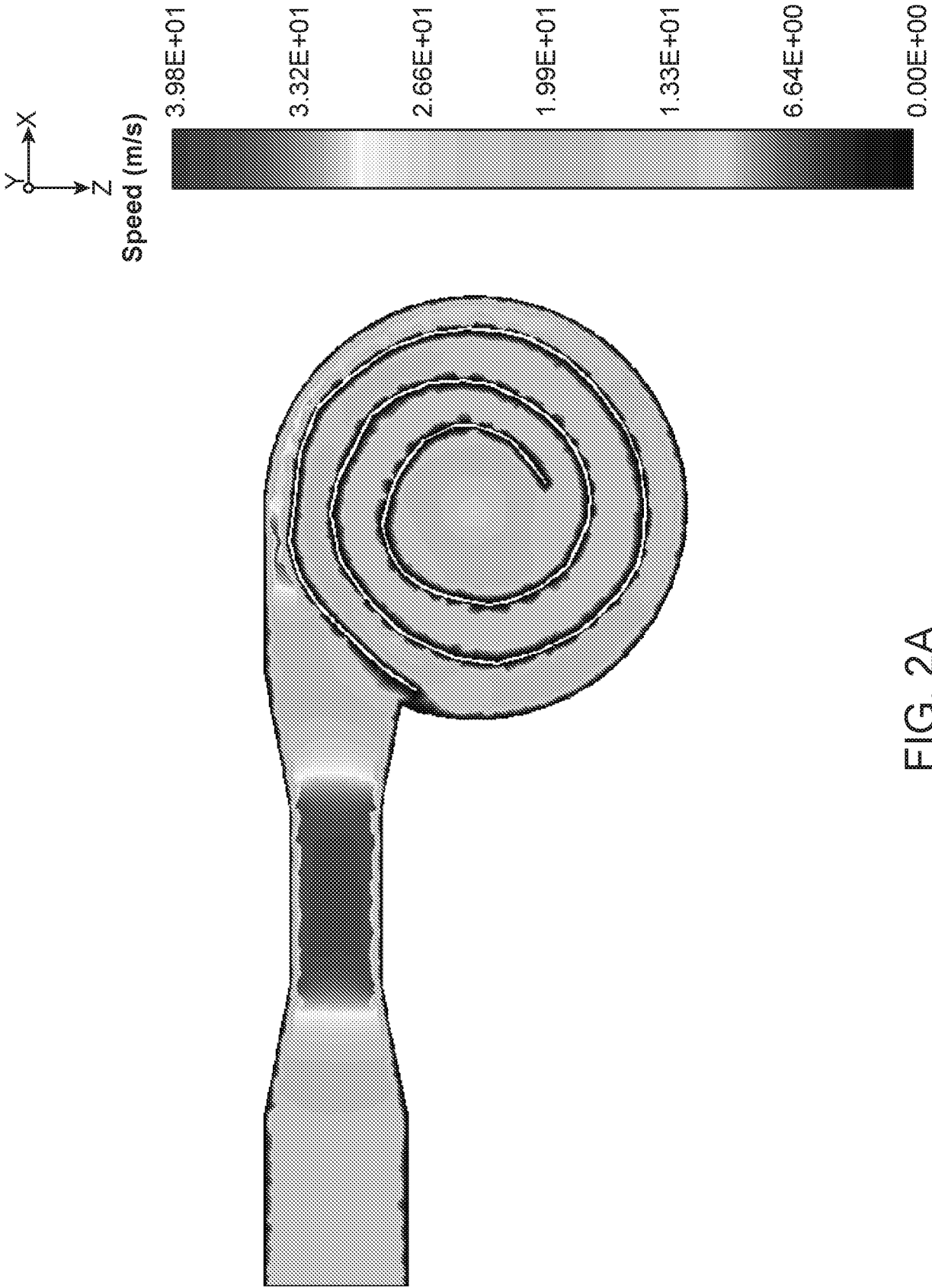


FIG. 2A

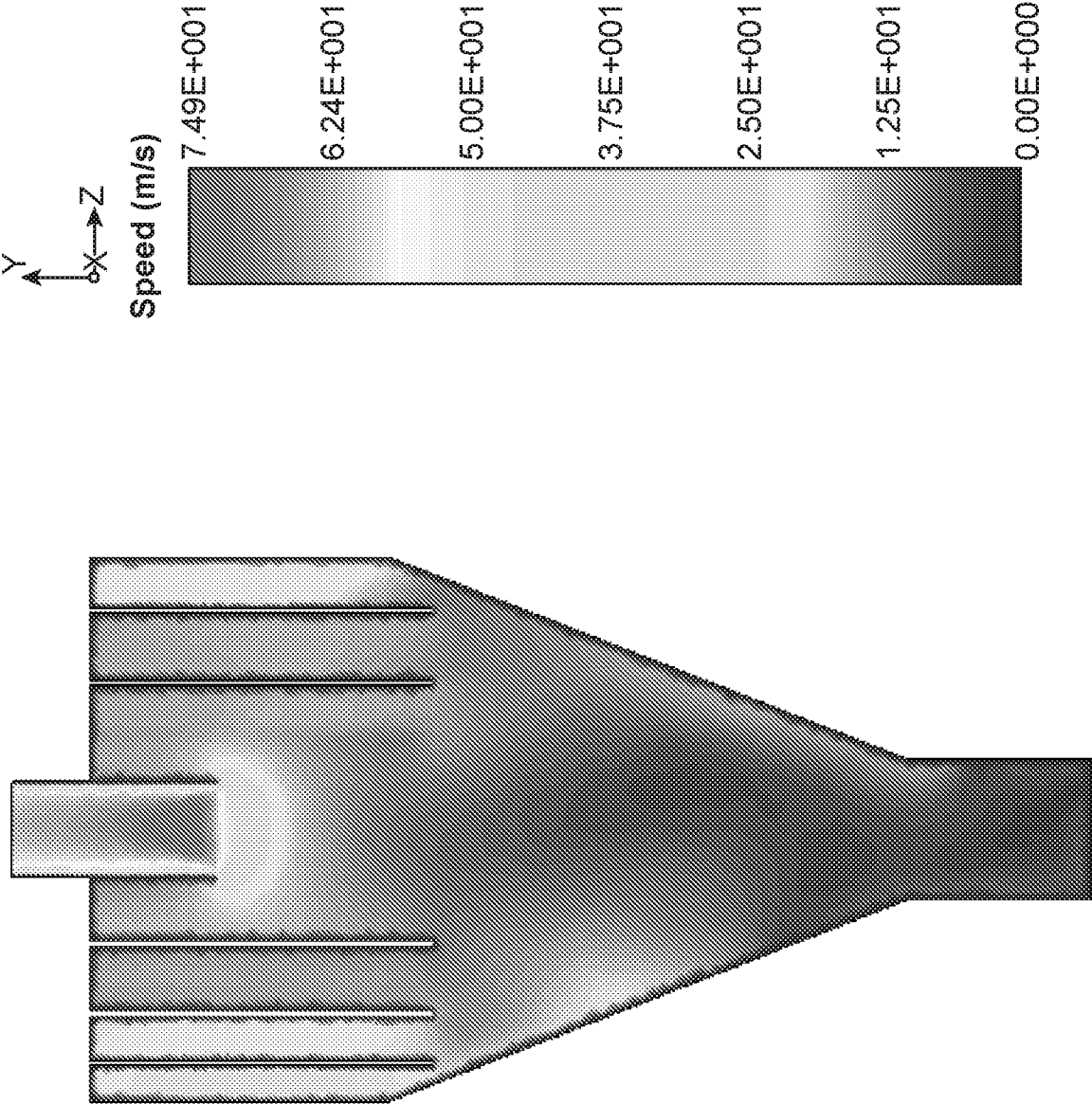


FIG. 2B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2019/050607

A. CLASSIFICATION OF SUBJECT MATTER
B01D45/12, B04C5/04 Version=2019.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01D, B04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

TotalPatent One, IPO Internal Database
Keyword used- cyclone separator, spiral baffle, venturi

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 202438419 U (XINMING CUI) 19.09.2012 (19 September, 2012) Abstract, Para [0005, 0014-0021] As per English translation on Espacenet, Figure 1-3	1-4
Y	CN 101967407 A (UNIV CHANGZHOU) 09.02.2011 (09 February, 2011) Abstract, Para [0013, 0023, 0025] As per English translation on Espacenet, Figure 1	1-4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D" document cited by the applicant in the international application	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 22-11-2019	Date of mailing of the international search report 22-11-2019
---	--

Name and mailing address of the ISA/ Indian Patent Office Plot No.32, Sector 14, Dwarka, New Delhi-110075 Facsimile No.	Authorized officer Anand Kumar Soni Telephone No. +91-1125300200
--	--