



(51) International Patent Classification:

G21C 13/02 (2006.01) *G21C 15/04* (2006.01)
G21C 15/22 (2006.01) *G21C 3/40* (2006.01)
G21C 15/02 (2006.01)

(21) International Application Number:

PCT/US2019/038253

(22) International Filing Date:

20 June 2019 (20.06.2019)

(25) Filing Language:

English

(26) Publication Language:

English

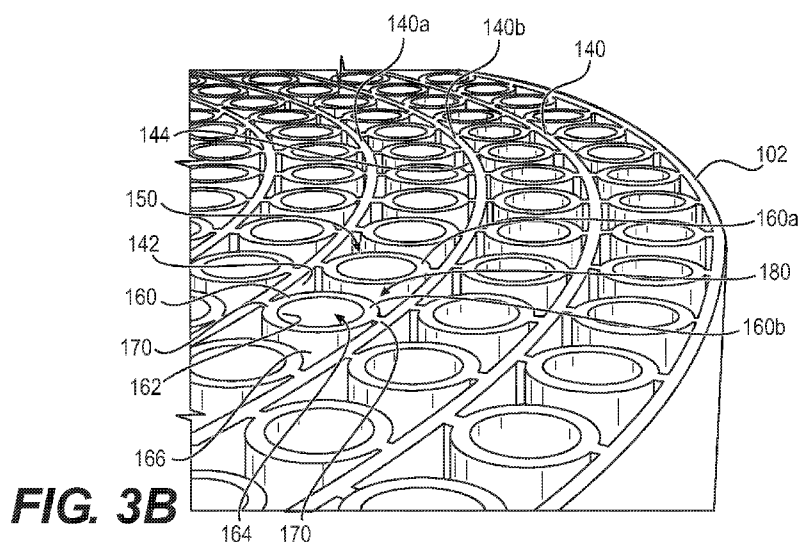
(30) Priority Data:

62/688,255	21 June 2018 (21.06.2018)	US
16/446,663	20 June 2019 (20.06.2019)	US

(71) Applicant: **BWXT NUCLEAR ENERGY, INC.**
[US/US]; 109 Ramsey Place, Lynchburg, Virginia 24501 (US).

(72) Inventors: **RUSSELL, II, William E.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **BERGMAN, Joshua J.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **CIRTAİN, Jonathan W.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **GRAMLICH, Craig D.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **INMAN, James B.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **LEVASSEUR, Matthew P.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **MILLER, Joseph K.**; c/o BWXT: 11525 N. Communi-

(54) Title: UNIVERSAL INVERTED REACTOR AND METHOD FOR DESIGN AND MANUFACTURE OF UNIVERSAL INVERTED REACTOR



(57) Abstract: Fission reactor has a shell encompassing a reactor space within which are a central longitudinal channel, a plurality of axially extending rings with adjacent rings defining an annular cylindrical space in which a first plurality of primary axial tubes are circumferential located. Circumferentially adjacent primary axial tubes are separated by one of the plurality of secondary channels and a plurality of webbings connects at least a portion of the plurality of primary axial tubes to adjacent structure. A fissionable nuclear fuel composition is located in at least some of the plurality of secondary channels and a primary coolant passes thorough at least some of the primary axial tubes. Additive and/or subtractive manufacturing techniques produce an integral and unitary structure for the fuel loaded reactor space. During manufacturing and as-built, the reactor design can be analyzed using a computational platform that integrates and analyzes data from in-situ monitoring during manufacturing.



ty House Rd., Suite 600, Charlotte, North Carolina 28277 (US). **ZIEGLER, Ryan Z.**; c/o BWXT: 11525 N. Community House Rd., Suite 600, Charlotte, North Carolina 28277 (US).

(74) **Agent: KILLIAN, Jeffrey G.** et al.; Morgan, Lewis & Bockius LLP, 1111 Pennsylvania Ave., NW, Washington, District of Columbia 20004 (US).

(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, 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).

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) **Date of publication of the international search report:**
02 April 2020 (02.04.2020)

(15) **Information about Correction:**
see Notice of 27 February 2020 (27.02.2020)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 19/38253

A. CLASSIFICATION OF SUBJECT MATTER

IPC - G21C 13/02, G21C 15/22, G21C 15/02, G21C 15/04, G21C 3/40 (2020.01)

CPC - G21C 13/02, G21C 15/22, G21C 15/02, G21C 15/04, G21C 3/40, G21C 3/04, G21C 3/06, G21C 3/16, G21C 3/322, G21D 7/04, Y02E 30/38

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0334595 A1 (THORIUM POWER, INC.) 13 November 2014 (13.11.2014), Fig 3, 7A; para [0075]-[0077], [0080]	1-3, 7
A	US 2015/0228363 A1 (TRANSATOMIC POWER CORPORATION) 13 August 2015 (13.08.2015), Fig 1, 7, 24; para [0340]	1-3, 7
A	US 5,408,510 A (BALL et al.) 18 April 1995 (18.04.1995), Fig 1, 2; col 3, ln 15-19, 46-49; col 3, ln 15-19	1-3, 7

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"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

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search

16 January 2020

Date of mailing of the international search report

30 JAN 2020

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Lee Young

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 19/38253

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-6, 8-19
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-3, 7 are directed to a fission reactor.

Group II: Claims 20-22 is directed to a method of manufacturing a fission reactor.

-- see extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-3, 7

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 19/38253

Continuation of Box No. III -- Observations where unity of invention is lacking

The inventions listed in the above-mentioned groups do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special technical features

Group I includes the technical feature of a first plurality of a shell, an axial cylinder, and primary axial tubes located circumferential within the annular cylindrical space, not found in the other group.

Group II includes the technical feature of applying predictive and causal analytics to prepare a model of the fission reactor and fabricating the fission reactor on a layer-by-layer basis using additive manufacturing techniques, not found in the other group.

Common Technical Features:

There are no common technical features shared by Groups I-II that would otherwise unify the groups.

Groups I-II, therefore, lack unity under PCT Rule 13.

Note: Claims 4-6 and 8-19 are determined to be unsearchable because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a) and are, therefore, not included in any claim group.