



(51) International Patent Classification:

B01D 1/14 (2006.01) **C02F 1/04** (2006.01)
B01D 19/00 (2006.01)

(21) International Application Number:

PCT/US2014/041226

(22) International Filing Date:

6 June 2014 (06.06.2014)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

13/916,038 12 June 2013 (12.06.2013) US

(71) Applicants: **MASSACHUSETTS INSTITUTE OF TECHNOLOGY** [US/US]; 77 Massachusetts Avenue, Cambridge, Massachusetts 02139 (US). **KING FAHD UNIVERSITY OF PETROLEUM & MINERALS** [SA/SA]; University Boulevard, 31261 Dhahran (SA).

(72) Inventors: **GOVINDAN, Prakash**; Gradiant Corporation, 78-H Olympia Avenue, Woburn, Massachusetts 01801 (US). **ELSHARQAWY, Mostafa**; House #5283, KFUPM

Compound, 31261 Dhahran (SA). **LAM, Steven**; Gradiant Corporation, 78-H Olympia Avenue, Woburn, Massachusetts 01801 (US). **ST. JOHN, Maximus**; Gradiant Corporation, 78-H Olympia Avenue, Woburn, Massachusetts 01801 (US). **LIENHARD, John**; Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139 (US).

(74) Agent: **SAYRE, Robert**; Modern Times Legal, 1 Broadway, 14th Floor, Cambridge, Massachusetts 02142 (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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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.

[Continued on next page]

(54) Title: MULTI-STAGE BUBBLE COLUMN HUMIDIFIER

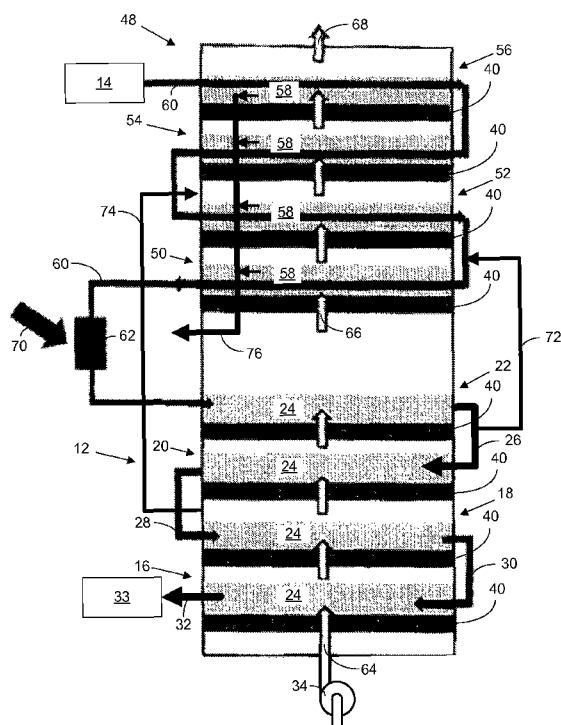


FIG. 4

(57) Abstract: A feed liquid flows into a second-stage humidifier chamber to form a second-stage humidifier bath. A first remnant of the feed liquid from the second-stage humidifier chamber then flows into a first-stage humidifier chamber to form a first-stage humidifier bath having a temperature lower than that of the second-stage bath. A second remnant of the feed liquid is then removed from the first-stage humidifier. Meanwhile, a carrier gas is injected into and bubbled through the first-stage humidifier bath, collecting a vaporizable component in vapor form from the first remnant of the feed liquid to partially humidify the carrier gas. The partially humidified carrier gas is then bubbled through the second-stage humidifier bath, where the carrier gas collects more of the vaporized component from the feed liquid to further humidify the carrier gas before removal from the second-stage humidifier chamber.



(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, 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)*)