United States Patent 12385379
Kind Code B2
Date of Patent August 12, 2025
Inventor(s) Yeung; Tony et al.

Methods for detection and mitigation of well screen out

Abstract

Methods, systems, and controllers for detecting and mitigating well screen outs may include a controller configured to operate a fracturing pump to supply fluid at a discharge rate to a wellhead at a fracturing well site. The controller may also operate a blender positioned to deliver a blend of proppant and fluid to the fracturing pump. The controller may compare a fluid pressure increase rate to a preselected increase rate indicative of a potential well screen out. The controller may incrementally decrease the discharge rate of the fracturing pump and a flow rate of a blender when the fluid pressure increase rate of the wellhead exceeds the preselected increase rate and the fluid pressure is within a preselected percentage of a maximum wellhead pressure until the fluid pressure of the fluid supplied to the wellhead is stabilized.

Inventors: **Yeung; Tony (The Woodlands, TX), Rodriguez-Ramon; Ricardo (The Woodlands, TX), Foster; Joseph (The Woodlands, TX)**

Applicant: **BJ Energy Solutions, LLC** (The Woodlands, TX)

Family ID: **1000008749784**

Assignee: **BJ Energy Solutions, LLC (The Woodlands, TX)**

Appl. No.: **18/583167**

Filed: **February 21, 2024**

Prior Publication Data

Document Identifier	Publication Date
US 20250003321 A1	Jan. 02, 2025

Related U.S. Application Data

continuation parent-doc US 17991007 20221121 US 11939854 child-doc US 18583167
continuation parent-doc US 17355920 20210623 US 11566506 20230131 child-doc US 17991007
continuation parent-doc US 17303841 20210609 US 11208881 20211228 child-doc US 17355920
continuation parent-doc US 17182408 20210223 US 11066915 20210720 child-doc US 17303841
us-provisional-application US 62705050 20200609

Publication Classification

Int. Cl.: **E21B43/267** (20060101); **E21B21/08** (20060101); **E21B43/12** (20060101); **E21B43/26** (20060101); **G08B21/18** (20060101)

U.S. Cl.:

CPC **E21B43/267** (20130101); **E21B21/08** (20130101); **E21B43/12** (20130101); **E21B43/26** (20130101); **E21B43/2607** (20200501); **G08B21/182** (20130101);

Field of Classification Search

CPC: E21B (43/267); E21B (21/08); E21B (43/12); E21B (43/26); E21B (43/2607); G08B (21/182)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
1716049	12/1928	Greve	N/A	N/A
1726633	12/1928	Smith	N/A	N/A
2178662	12/1938	Hanson	N/A	N/A
2427638	12/1946	Vilter et al.	N/A	N/A
2498229	12/1949	Adler	N/A	N/A
2535703	12/1949	Smith et al.	N/A	N/A
2572711	12/1950	Fischer	N/A	N/A
2820341	12/1957	Amann	N/A	N/A
2868004	12/1958	Runde	N/A	N/A
2940377	12/1959	Darnell et al.	N/A	N/A
2947141	12/1959	Russ	N/A	N/A
2956738	12/1959	Af et al.	N/A	N/A
3068796	12/1961	Pfluger et al.	N/A	N/A
3191517	12/1964	Solzman	N/A	N/A
3257031	12/1965	Dietz	N/A	N/A
3274768	12/1965	Klein	N/A	N/A
3332491	12/1966	Flickinger	N/A	N/A
3378074	12/1967	Kiel	N/A	N/A
3382671	12/1967	Ehni, III	N/A	N/A
3401873	12/1967	Privon et al.	N/A	N/A
3463612	12/1968	Whitsel, Jr.	N/A	N/A
3496880	12/1969	Wolff	N/A	N/A
3550696	12/1969	Kenneday	N/A	N/A
3560053	12/1970	Ortloff	N/A	N/A
3586459	12/1970	Zerlauth	N/A	N/A
3632222	12/1971	Cronstedt	N/A	N/A
3656582	12/1971	Alcock	N/A	N/A
3667868	12/1971	Brunner	N/A	N/A
3692434	12/1971	Schnear	N/A	N/A
3739872	12/1972	McNair	N/A	N/A
3757581	12/1972	Mankin et al.	N/A	N/A
3759063	12/1972	Bendall	N/A	N/A
3765173	12/1972	Harris	N/A	N/A
3771916	12/1972	Flanigan et al.	N/A	N/A
3773438	12/1972	Hall et al.	N/A	N/A
3781135	12/1972	Nickell	N/A	N/A
3786835	12/1973	Finger	N/A	N/A
3791682	12/1973	Mitchell	N/A	N/A
3796045	12/1973	Foster-Pegg	N/A	N/A
3814549	12/1973	Cronstedt	N/A	N/A
3820922	12/1973	Sensinger et al.	N/A	N/A
3847511	12/1973	Cole	N/A	N/A
3866108	12/1974	Yannone et al.	N/A	N/A
3875380	12/1974	Rankin	N/A	N/A
3963372	12/1975	McLain et al.	N/A	N/A
4010613	12/1976	McInerney	N/A	N/A
4019477	12/1976	Overton	N/A	N/A
4031407	12/1976	Reed	N/A	N/A
4047569	12/1976	Tagirov et al.	N/A	N/A
4050862	12/1976	Buse	N/A	N/A
4059045	12/1976	McClain	N/A	N/A
4086976	12/1977	Holm et al.	N/A	N/A
4117342	12/1977	Melley, Jr.	N/A	N/A
4173121	12/1978	Yu	N/A	N/A
4204808	12/1979	Reese et al.	N/A	N/A
4209079	12/1979	Marchal et al.	N/A	N/A
4209979	12/1979	Woodhouse et al.	N/A	N/A
4222229	12/1979	Uram	N/A	N/A
4239396	12/1979	Arribau et al.	N/A	N/A
4269569	12/1980	Hoover	N/A	N/A
4311395	12/1981	Douthitt et al.	N/A	N/A

4330237	12/1981	Battah	N/A	N/A
4341508	12/1981	Rambin, Jr.	N/A	N/A
4357027	12/1981	Zeitlow	N/A	N/A
4383478	12/1982	Jones	N/A	N/A
4402504	12/1982	Christian	N/A	N/A
4430047	12/1983	Ilg	N/A	N/A
4442665	12/1983	Fick et al.	N/A	N/A
4457325	12/1983	Green	N/A	N/A
4470771	12/1983	Hall et al.	N/A	N/A
4483684	12/1983	Black	N/A	N/A
4505650	12/1984	Hannett et al.	N/A	N/A
4574880	12/1985	Handke	N/A	N/A
4584654	12/1985	Crane	N/A	N/A
4620330	12/1985	Izzi, Sr.	N/A	N/A
4672813	12/1986	David	N/A	N/A
4754607	12/1987	Mackay	N/A	N/A
4782244	12/1987	Wakimoto	N/A	N/A
4796777	12/1988	Keller	N/A	N/A
4869209	12/1988	Young	N/A	N/A
4913625	12/1989	Gerlowski	N/A	N/A
4983259	12/1990	Duncan et al.	N/A	N/A
4990058	12/1990	Eslinger	N/A	N/A
5032065	12/1990	Yamamuro et al.	N/A	N/A
5135361	12/1991	Dion	N/A	N/A
5167493	12/1991	Kobari	N/A	N/A
5245970	12/1992	Iwaszkiewicz et al.	N/A	N/A
5275041	12/1993	Poulsen	N/A	N/A
5291842	12/1993	Sallstrom et al.	N/A	N/A
5326231	12/1993	Pandeya et al.	N/A	N/A
5362219	12/1993	Paul et al.	N/A	N/A
5482116	12/1995	El-Rabaa et al.	N/A	N/A
5511956	12/1995	Hasegawa et al.	N/A	N/A
5517854	12/1995	Plumb et al.	N/A	N/A
5537813	12/1995	Davis et al.	N/A	N/A
5553514	12/1995	Walkowc	N/A	N/A
5560195	12/1995	Anderson et al.	N/A	N/A
5586444	12/1995	Fung	N/A	N/A
5622245	12/1996	Reik et al.	N/A	N/A
5626103	12/1996	Haws et al.	N/A	N/A
5634777	12/1996	Albertin et al.	N/A	N/A
5651400	12/1996	Corts et al.	N/A	N/A
5678460	12/1996	Walkowc	N/A	N/A
5717172	12/1997	Griffin, Jr. et al.	N/A	N/A
5720598	12/1997	de Chizzelle	N/A	N/A
5761084	12/1997	Edwards	N/A	N/A
5811676	12/1997	Spalding et al.	N/A	N/A
5839888	12/1997	Harrison	N/A	N/A
5846062	12/1997	Yanagisawa et al.	N/A	N/A
5875744	12/1998	Vallejos	N/A	N/A
5983962	12/1998	Gerardot	N/A	N/A
5992944	12/1998	Hara	N/A	N/A
6041856	12/1999	Thrasher et al.	N/A	N/A
6050080	12/1999	Horner	N/A	N/A
6067962	12/1999	Bartley et al.	N/A	N/A
6071188	12/1999	O'Neill et al.	N/A	N/A
6074170	12/1999	Bert et al.	N/A	N/A
6123751	12/1999	Nelson et al.	N/A	N/A
6129335	12/1999	Yokogi	N/A	N/A
6145318	12/1999	Kaplan et al.	N/A	N/A
6186334	12/2000	Dohmann et al.	N/A	N/A
6230481	12/2000	Jahr	N/A	N/A
6279309	12/2000	Lawlor et al.	N/A	N/A
6321860	12/2000	Reddoch	N/A	N/A
6334746	12/2001	Nguyen et al.	N/A	N/A
6367548	12/2001	Purvis et al.	N/A	N/A
6401472	12/2001	Pollrich et al.	N/A	N/A

6530224	12/2002	Conchieri	N/A	N/A
6543395	12/2002	Green	N/A	N/A
6644844	12/2002	Neal et al.	N/A	N/A
6655922	12/2002	Flek	N/A	N/A
6669453	12/2002	Breeden et al.	N/A	N/A
6765304	12/2003	Baten et al.	N/A	N/A
6786051	12/2003	Kristich et al.	N/A	N/A
6832900	12/2003	Leu	N/A	N/A
6851514	12/2004	Han et al.	N/A	N/A
6859740	12/2004	Stephenson et al.	N/A	N/A
6901735	12/2004	Lohn	N/A	N/A
6935424	12/2004	Lehman et al.	N/A	N/A
6962057	12/2004	Kurokawa et al.	N/A	N/A
7007966	12/2005	Campion	N/A	N/A
7047747	12/2005	Tanaka	N/A	N/A
7065953	12/2005	Kopko	N/A	N/A
7143016	12/2005	Discenzo et al.	N/A	N/A
7222015	12/2006	Davis et al.	N/A	N/A
7281519	12/2006	Schroeder et al.	N/A	N/A
7388303	12/2007	Seiver	N/A	N/A
7404294	12/2007	Sundin	N/A	N/A
7442239	12/2007	Armstrong et al.	N/A	N/A
7516793	12/2008	Dykstra	N/A	N/A
7524173	12/2008	Cummins	N/A	N/A
7545130	12/2008	Latham	N/A	N/A
7552903	12/2008	Dunn et al.	N/A	N/A
7563076	12/2008	Brunet et al.	N/A	N/A
7563413	12/2008	Naets et al.	N/A	N/A
7574325	12/2008	Dykstra	N/A	N/A
7581379	12/2008	Yoshida et al.	N/A	N/A
7594424	12/2008	Fazekas	N/A	N/A
7614239	12/2008	Herzog et al.	N/A	N/A
7627416	12/2008	Batenburg et al.	N/A	N/A
7677316	12/2009	Butler et al.	N/A	N/A
7721521	12/2009	Kunkle et al.	N/A	N/A
7730711	12/2009	Kunkle et al.	N/A	N/A
7779961	12/2009	Matte	N/A	N/A
7789452	12/2009	Dempsey et al.	N/A	N/A
7836949	12/2009	Dykstra	N/A	N/A
7841394	12/2009	McNeel et al.	N/A	N/A
7845413	12/2009	Shampine et al.	N/A	N/A
7861679	12/2010	Lemke et al.	N/A	N/A
7886702	12/2010	Jerrell et al.	N/A	N/A
7900724	12/2010	Promersberger et al.	N/A	N/A
7921914	12/2010	Bruins et al.	N/A	N/A
7938151	12/2010	Hockner	N/A	N/A
7955056	12/2010	Pettersson	N/A	N/A
7980357	12/2010	Edwards	N/A	N/A
8056635	12/2010	Shampine et al.	N/A	N/A
8083504	12/2010	Williams et al.	N/A	N/A
8099942	12/2011	Alexander et al.	N/A	N/A
8186334	12/2011	Ooyama	N/A	N/A
8196555	12/2011	Ikeda et al.	N/A	N/A
8202354	12/2011	Iijima	N/A	N/A
8316936	12/2011	Roddy et al.	N/A	N/A
8336631	12/2011	Shampine et al.	N/A	N/A
8388317	12/2012	Sung	N/A	N/A
8414673	12/2012	Raje et al.	N/A	N/A
8469826	12/2012	Brosowske	N/A	N/A
8500215	12/2012	Gastauer et al.	N/A	N/A
8506267	12/2012	Gambier et al.	N/A	N/A
8575873	12/2012	Peterson et al.	N/A	N/A
8616005	12/2012	Cousino, Sr.	N/A	N/A
8621873	12/2013	Robertson et al.	N/A	N/A
8641399	12/2013	Mucibabic et al.	N/A	N/A
8656990	12/2013	Kajaria et al.	N/A	N/A

8672606	12/2013	Glynn et al.	N/A	N/A
8707853	12/2013	Dille et al.	N/A	N/A
8708667	12/2013	Collingborn	N/A	N/A
8714253	12/2013	Sherwood et al.	N/A	N/A
8757918	12/2013	Ramnarain et al.	N/A	N/A
8763583	12/2013	Hofbauer et al.	N/A	N/A
8770329	12/2013	Spitler	N/A	N/A
8784081	12/2013	Blume	N/A	N/A
8789601	12/2013	Broussard et al.	N/A	N/A
8794307	12/2013	Coquilleau et al.	N/A	N/A
8801394	12/2013	Anderson	N/A	N/A
8851186	12/2013	Shampine et al.	N/A	N/A
8851441	12/2013	Acuna et al.	N/A	N/A
8886502	12/2013	Walters et al.	N/A	N/A
8894356	12/2013	Lafontaine et al.	N/A	N/A
8905056	12/2013	Kendrick	N/A	N/A
8951019	12/2014	Hains et al.	N/A	N/A
8973560	12/2014	Krug	N/A	N/A
8997904	12/2014	Cryer et al.	N/A	N/A
9011111	12/2014	Lesko	N/A	N/A
9016383	12/2014	Shampine et al.	N/A	N/A
9032620	12/2014	Frassinelli et al.	N/A	N/A
9057247	12/2014	Kumar et al.	N/A	N/A
9097249	12/2014	Petersen	N/A	N/A
9103193	12/2014	Coli et al.	N/A	N/A
9121257	12/2014	Coli et al.	N/A	N/A
9140110	12/2014	Coli et al.	N/A	N/A
9175810	12/2014	Hains et al.	N/A	N/A
9187982	12/2014	Dehring et al.	N/A	N/A
9206667	12/2014	Khvoshchev et al.	N/A	N/A
9212643	12/2014	Deliyski	N/A	N/A
9217318	12/2014	Dusterhoft et al.	N/A	N/A
9222346	12/2014	Walls	N/A	N/A
9297250	12/2015	Dusterhoft et al.	N/A	N/A
9324049	12/2015	Thomeer et al.	N/A	N/A
9341055	12/2015	Weightman et al.	N/A	N/A
9346662	12/2015	Van Vliet et al.	N/A	N/A
9366114	12/2015	Coli et al.	N/A	N/A
9376786	12/2015	Numasawa	N/A	N/A
9394829	12/2015	Cabeen et al.	N/A	N/A
9395049	12/2015	Vicknair et al.	N/A	N/A
9401670	12/2015	Minato	N/A	N/A
9410406	12/2015	Yuan	N/A	N/A
9410410	12/2015	Broussard et al.	N/A	N/A
9410546	12/2015	Jaeger et al.	N/A	N/A
9429078	12/2015	Crowe et al.	N/A	N/A
9435333	12/2015	McCoy et al.	N/A	N/A
9488169	12/2015	Cochran et al.	N/A	N/A
9493997	12/2015	Liu et al.	N/A	N/A
9512783	12/2015	Veilleux, Jr. et al.	N/A	N/A
9534473	12/2016	Morris et al.	N/A	N/A
9546652	12/2016	Yin	N/A	N/A
9550501	12/2016	Ledbetter et al.	N/A	N/A
9556721	12/2016	Jang et al.	N/A	N/A
9562420	12/2016	Morris et al.	N/A	N/A
9570945	12/2016	Fischer	N/A	N/A
9579980	12/2016	Cryer et al.	N/A	N/A
9587649	12/2016	Oehring	N/A	N/A
9593710	12/2016	Laimboeck et al.	N/A	N/A
9611728	12/2016	Oehring	N/A	N/A
9617808	12/2016	Liu et al.	N/A	N/A
9638101	12/2016	Crowe et al.	N/A	N/A
9638194	12/2016	Wiegman et al.	N/A	N/A
9650871	12/2016	Oehring et al.	N/A	N/A
9656762	12/2016	Kamath et al.	N/A	N/A
9689316	12/2016	Crom	N/A	N/A

9695808	12/2016	Giessbach et al.	N/A	N/A
9739130	12/2016	Young	N/A	N/A
9764266	12/2016	Carter	N/A	N/A
9777748	12/2016	Lu et al.	N/A	N/A
9803467	12/2016	Tang et al.	N/A	N/A
9803793	12/2016	Davi et al.	N/A	N/A
9809308	12/2016	Aguilar et al.	N/A	N/A
9829002	12/2016	Crom	N/A	N/A
9840897	12/2016	Larson	N/A	N/A
9840901	12/2016	Oehring et al.	N/A	N/A
9845730	12/2016	Betti et al.	N/A	N/A
9850422	12/2016	Lestz et al.	N/A	N/A
9856131	12/2017	Moffitt, Jr.	N/A	N/A
9863279	12/2017	Laing et al.	N/A	N/A
9869305	12/2017	Crowe et al.	N/A	N/A
9871406	12/2017	Churnock et al.	N/A	N/A
9879609	12/2017	Crowe et al.	N/A	N/A
RE46725	12/2017	Case et al.	N/A	N/A
9893500	12/2017	Oehring et al.	N/A	N/A
9893660	12/2017	Peterson et al.	N/A	N/A
9897003	12/2017	Motakef et al.	N/A	N/A
9920615	12/2017	Zhang et al.	N/A	N/A
9945365	12/2017	Hernandez et al.	N/A	N/A
9964052	12/2017	Millican et al.	N/A	N/A
9970278	12/2017	Broussard et al.	N/A	N/A
9981840	12/2017	Shock	N/A	N/A
9995102	12/2017	Dille et al.	N/A	N/A
9995218	12/2017	Oehring et al.	N/A	N/A
10008880	12/2017	Vicknair et al.	N/A	N/A
10008912	12/2017	Davey et al.	N/A	N/A
10018096	12/2017	Wallimann et al.	N/A	N/A
10020711	12/2017	Oehring et al.	N/A	N/A
10024123	12/2017	Steffenhagen et al.	N/A	N/A
10029289	12/2017	Wendorski et al.	N/A	N/A
10030579	12/2017	Austin et al.	N/A	N/A
10036238	12/2017	Oehring	N/A	N/A
10040541	12/2017	Wilson et al.	N/A	N/A
10060293	12/2017	Del Bono	N/A	N/A
10060349	12/2017	Morales Álvarez et al.	N/A	N/A
10077933	12/2017	Nelson et al.	N/A	N/A
10082137	12/2017	Graham et al.	N/A	N/A
10094366	12/2017	Marica	N/A	N/A
10100827	12/2017	Devan et al.	N/A	N/A
10107084	12/2017	Coli et al.	N/A	N/A
10107085	12/2017	Coli et al.	N/A	N/A
10114061	12/2017	Frampton et al.	N/A	N/A
10119381	12/2017	Oehring et al.	N/A	N/A
10125750	12/2017	Pfaff et al.	N/A	N/A
10134257	12/2017	Zhang et al.	N/A	N/A
10138098	12/2017	Sørensen et al.	N/A	N/A
10151244	12/2017	Giancotti et al.	N/A	N/A
10161423	12/2017	Rampen et al.	N/A	N/A
10174599	12/2018	Shampine et al.	N/A	N/A
10184397	12/2018	Austin et al.	N/A	N/A
10196258	12/2018	Kalala et al.	N/A	N/A
10221856	12/2018	Hernandez et al.	N/A	N/A
10227854	12/2018	Glass	N/A	N/A
10227855	12/2018	Coli et al.	N/A	N/A
10246984	12/2018	Payne et al.	N/A	N/A
10247182	12/2018	Zhang et al.	N/A	N/A
10253598	12/2018	Crews et al.	N/A	N/A
10254732	12/2018	Oehring et al.	N/A	N/A
10267439	12/2018	Pryce et al.	N/A	N/A
10280724	12/2018	Hinderliter	N/A	N/A
10287943	12/2018	Schiltz	N/A	N/A
10288519	12/2018	De La Cruz	N/A	N/A

10303190	12/2018	Shock	N/A	N/A
10305350	12/2018	Johnson et al.	N/A	N/A
10316832	12/2018	Byrne	N/A	N/A
10317875	12/2018	Pandurangan et al.	N/A	N/A
10329888	12/2018	Urbancic et al.	N/A	N/A
10337402	12/2018	Austin et al.	N/A	N/A
10358035	12/2018	Cryer et al.	N/A	N/A
10371012	12/2018	Davis et al.	N/A	N/A
10374485	12/2018	Morris et al.	N/A	N/A
10378326	12/2018	Morris et al.	N/A	N/A
10393108	12/2018	Chong et al.	N/A	N/A
10407990	12/2018	Oehring et al.	N/A	N/A
10408031	12/2018	Oehring et al.	N/A	N/A
10415348	12/2018	Zhang et al.	N/A	N/A
10415557	12/2018	Crowe et al.	N/A	N/A
10415562	12/2018	Kajita et al.	N/A	N/A
10422207	12/2018	Aidagulov et al.	N/A	N/A
RE47695	12/2018	Case et al.	N/A	N/A
10465689	12/2018	Crom	N/A	N/A
10478753	12/2018	Elms et al.	N/A	N/A
10526882	12/2019	Oehring et al.	N/A	N/A
10563649	12/2019	Zhang et al.	N/A	N/A
10570704	12/2019	Colvin et al.	N/A	N/A
10577908	12/2019	Kisra et al.	N/A	N/A
10577910	12/2019	Stephenson	N/A	N/A
10584645	12/2019	Nakagawa et al.	N/A	N/A
10590867	12/2019	Thomassin et al.	N/A	N/A
10598258	12/2019	Oehring et al.	N/A	N/A
10605060	12/2019	Chuprakov et al.	N/A	N/A
10610842	12/2019	Chong	N/A	N/A
10662749	12/2019	Hill et al.	N/A	N/A
10677961	12/2019	Chen et al.	N/A	N/A
10711787	12/2019	Darley	N/A	N/A
10738580	12/2019	Fischer et al.	N/A	N/A
10753153	12/2019	Fischer et al.	N/A	N/A
10753165	12/2019	Fischer et al.	N/A	N/A
10760416	12/2019	Weng et al.	N/A	N/A
10760556	12/2019	Crom et al.	N/A	N/A
10794165	12/2019	Fischer et al.	N/A	N/A
10794166	12/2019	Reckels et al.	N/A	N/A
10801311	12/2019	Cui et al.	N/A	N/A
10815764	12/2019	Yeung et al.	N/A	N/A
10815978	12/2019	Glass	N/A	N/A
10830032	12/2019	Zhang et al.	N/A	N/A
10830225	12/2019	Repaci	N/A	N/A
10851633	12/2019	Harper	N/A	N/A
10859203	12/2019	Cui et al.	N/A	N/A
10864487	12/2019	Han et al.	N/A	N/A
10865624	12/2019	Cui et al.	N/A	N/A
10865631	12/2019	Zhang et al.	N/A	N/A
10870093	12/2019	Zhong et al.	N/A	N/A
10871045	12/2019	Fischer et al.	N/A	N/A
10892596	12/2020	Enya et al.	N/A	N/A
10895202	12/2020	Yeung et al.	N/A	N/A
10900475	12/2020	Weightman et al.	N/A	N/A
10907459	12/2020	Yeung et al.	N/A	N/A
10914139	12/2020	Shahri et al.	N/A	N/A
10920538	12/2020	Rodriguez Herrera et al.	N/A	N/A
10920552	12/2020	Rodriguez Herrera et al.	N/A	N/A
10927774	12/2020	Cai et al.	N/A	N/A
10927802	12/2020	Oehring et al.	N/A	N/A
10954770	12/2020	Yeung et al.	N/A	N/A
10954855	12/2020	Ji et al.	N/A	N/A
10961614	12/2020	Djavanroodi	N/A	N/A
10961908	12/2020	Yeung et al.	N/A	N/A
10961912	12/2020	Yeung et al.	N/A	N/A

10961914	12/2020	Yeung et al.	N/A	N/A
10961993	12/2020	Ji et al.	N/A	N/A
10961995	12/2020	Mayorca	N/A	N/A
10968837	12/2020	Yeung et al.	N/A	N/A
10982523	12/2020	Hill et al.	N/A	N/A
10989019	12/2020	Cai et al.	N/A	N/A
10989180	12/2020	Yeung et al.	N/A	N/A
10995564	12/2020	Miller et al.	N/A	N/A
11002189	12/2020	Yeung et al.	N/A	N/A
11008950	12/2020	Ethier et al.	N/A	N/A
11015423	12/2020	Yeung et al.	N/A	N/A
11015536	12/2020	Yeung et al.	N/A	N/A
11015594	12/2020	Yeung et al.	N/A	N/A
11022526	12/2020	Yeung et al.	N/A	N/A
11028677	12/2020	Yeung et al.	N/A	N/A
11035213	12/2020	Dusterhoft et al.	N/A	N/A
11035214	12/2020	Cui et al.	N/A	N/A
11047379	12/2020	Li et al.	N/A	N/A
11053853	12/2020	Li et al.	N/A	N/A
11060455	12/2020	Yeung et al.	N/A	N/A
11066915	12/2020	Yeung et al.	N/A	N/A
11068455	12/2020	Shabi et al.	N/A	N/A
11085281	12/2020	Yeung et al.	N/A	N/A
11085282	12/2020	Mazrooee et al.	N/A	N/A
11092152	12/2020	Yeung et al.	N/A	N/A
11098651	12/2020	Yeung et al.	N/A	N/A
11105250	12/2020	Zhang et al.	N/A	N/A
11105266	12/2020	Zhou et al.	N/A	N/A
11109508	12/2020	Yeung et al.	N/A	N/A
11111768	12/2020	Yeung et al.	N/A	N/A
11125066	12/2020	Yeung et al.	N/A	N/A
11125156	12/2020	Zhang et al.	N/A	N/A
11129295	12/2020	Yeung et al.	N/A	N/A
11143000	12/2020	Li et al.	N/A	N/A
11143005	12/2020	Dusterhoft et al.	N/A	N/A
11143006	12/2020	Zhang et al.	N/A	N/A
11149533	12/2020	Yeung et al.	N/A	N/A
11149726	12/2020	Yeung et al.	N/A	N/A
11156159	12/2020	Yeung et al.	N/A	N/A
11168681	12/2020	Boguski et al.	N/A	N/A
11174716	12/2020	Yeung et al.	N/A	N/A
11193360	12/2020	Yeung et al.	N/A	N/A
11193361	12/2020	Yeung et al.	N/A	N/A
11205880	12/2020	Zhou	N/A	N/A
11205881	12/2020	Makino	N/A	N/A
11208879	12/2020	Yeung et al.	N/A	N/A
11208953	12/2020	Yeung et al.	N/A	N/A
11220895	12/2021	Yeung et al.	N/A	N/A
11236739	12/2021	Yeung et al.	N/A	N/A
11242737	12/2021	Zhang et al.	N/A	N/A
11243509	12/2021	Cai et al.	N/A	N/A
11251650	12/2021	Liu et al.	N/A	N/A
11261717	12/2021	Yeung et al.	N/A	N/A
11268346	12/2021	Yeung et al.	N/A	N/A
11280266	12/2021	Yeung et al.	N/A	N/A
11306835	12/2021	Dille et al.	N/A	N/A
RE49083	12/2021	Case et al.	N/A	N/A
11319791	12/2021	Yeung	N/A	E21B 21/08
11339638	12/2021	Yeung et al.	N/A	N/A
11346200	12/2021	Cai et al.	N/A	N/A
11373058	12/2021	Jaaskelainen et al.	N/A	N/A
RE49140	12/2021	Case et al.	N/A	N/A
11377943	12/2021	Kriebel et al.	N/A	N/A
RE49155	12/2021	Case et al.	N/A	N/A
RE49156	12/2021	Case et al.	N/A	N/A
11401927	12/2021	Li et al.	N/A	N/A

11428165	12/2021	Yeung et al.	N/A	N/A
11441483	12/2021	Li et al.	N/A	N/A
11448122	12/2021	Feng et al.	N/A	N/A
11466680	12/2021	Yeung et al.	N/A	N/A
11480040	12/2021	Han et al.	N/A	N/A
11492887	12/2021	Cui et al.	N/A	N/A
11499405	12/2021	Zhang et al.	N/A	N/A
11506039	12/2021	Zhang et al.	N/A	N/A
11512570	12/2021	Yeung et al.	N/A	N/A
11519395	12/2021	Zhang et al.	N/A	N/A
11519405	12/2021	Deng et al.	N/A	N/A
11530602	12/2021	Yeung et al.	N/A	N/A
11549349	12/2022	Wang et al.	N/A	N/A
11555390	12/2022	Cui et al.	N/A	N/A
11555756	12/2022	Yeung et al.	N/A	N/A
11557887	12/2022	Ji et al.	N/A	N/A
11560779	12/2022	Mao et al.	N/A	N/A
11560845	12/2022	Yeung et al.	N/A	N/A
11572775	12/2022	Mao et al.	N/A	N/A
11575249	12/2022	Ji et al.	N/A	N/A
11592020	12/2022	Chang et al.	N/A	N/A
11596047	12/2022	Liu et al.	N/A	N/A
11598263	12/2022	Yeung et al.	N/A	N/A
11603797	12/2022	Zhang et al.	N/A	N/A
11607982	12/2022	Tian et al.	N/A	N/A
11608726	12/2022	Zhang et al.	N/A	N/A
11624326	12/2022	Yeung et al.	N/A	N/A
11629583	12/2022	Yeung et al.	N/A	N/A
11629589	12/2022	Lin et al.	N/A	N/A
11649766	12/2022	Yeung et al.	N/A	N/A
11649819	12/2022	Gillispie	N/A	N/A
11662384	12/2022	Liu et al.	N/A	N/A
11668173	12/2022	Zhang et al.	N/A	N/A
11668289	12/2022	Chang et al.	N/A	N/A
11677238	12/2022	Liu et al.	N/A	N/A
2002/0126922	12/2001	Cheng et al.	N/A	N/A
2002/0197176	12/2001	Kondo	N/A	N/A
2003/0031568	12/2002	Stiefel	N/A	N/A
2003/0061819	12/2002	Kuroki et al.	N/A	N/A
2003/0161212	12/2002	Neal et al.	N/A	N/A
2004/0016245	12/2003	Pierson	N/A	N/A
2004/0074238	12/2003	Wantanabe et al.	N/A	N/A
2004/0076526	12/2003	Fukano et al.	N/A	N/A
2004/0187950	12/2003	Cohen et al.	N/A	N/A
2004/0219040	12/2003	Kugelev et al.	N/A	N/A
2005/0051322	12/2004	Speer	N/A	N/A
2005/0056081	12/2004	Gocho	N/A	N/A
2005/0139286	12/2004	Poulter et al.	N/A	N/A
2005/0196298	12/2004	Manning	N/A	N/A
2005/0226754	12/2004	Orr et al.	N/A	N/A
2005/0274134	12/2004	Ryu et al.	N/A	N/A
2006/0061091	12/2005	Osterloh	N/A	N/A
2006/0062914	12/2005	Garg et al.	N/A	N/A
2006/0155473	12/2005	Soliman et al.	N/A	N/A
2006/0196251	12/2005	Richey	N/A	N/A
2006/0211356	12/2005	Grassman	N/A	N/A
2006/0228225	12/2005	Rogers	N/A	N/A
2006/0260331	12/2005	Andreychuk	N/A	N/A
2006/0272333	12/2005	Sundin	N/A	N/A
2007/0029090	12/2006	Andreychuk et al.	N/A	N/A
2007/0041848	12/2006	Wood et al.	N/A	N/A
2007/0066406	12/2006	Keller et al.	N/A	N/A
2007/0098580	12/2006	Petersen	N/A	N/A
2007/0107981	12/2006	Sicotte	N/A	N/A
2007/0125544	12/2006	Robinson et al.	N/A	N/A
2007/0169543	12/2006	Fazekas	N/A	N/A

2007/0181212	12/2006	Fell	N/A	N/A
2007/0272407	12/2006	Lehman et al.	N/A	N/A
2007/0277982	12/2006	Shampine et al.	N/A	N/A
2007/0295569	12/2006	Manzoor et al.	N/A	N/A
2008/0006089	12/2007	Adnan et al.	N/A	N/A
2008/0041594	12/2007	Boles et al.	N/A	N/A
2008/0098891	12/2007	Feher et al.	N/A	N/A
2008/0161974	12/2007	Alston	N/A	N/A
2008/0212275	12/2007	Waryck et al.	N/A	N/A
2008/0229757	12/2007	Alexander et al.	N/A	N/A
2008/0264625	12/2007	Ochoa	N/A	N/A
2008/0264649	12/2007	Crawford	N/A	N/A
2008/0298982	12/2007	Pabst et al.	N/A	N/A
2009/0053072	12/2008	Borgstadt et al.	N/A	N/A
2009/0064685	12/2008	Busekros et al.	N/A	N/A
2009/0068031	12/2008	Gambier et al.	N/A	N/A
2009/0092510	12/2008	Williams et al.	N/A	N/A
2009/0124191	12/2008	Van Becelaere	N/A	N/A
2009/0178412	12/2008	Spytek	N/A	N/A
2009/0212630	12/2008	Flegel et al.	N/A	N/A
2009/0249794	12/2008	Wilkes et al.	N/A	N/A
2009/0252616	12/2008	Brunet et al.	N/A	N/A
2009/0308602	12/2008	Bruins et al.	N/A	N/A
2010/0019626	12/2009	Stout et al.	N/A	N/A
2010/0071899	12/2009	Coquilleau et al.	N/A	N/A
2010/0218508	12/2009	Brown et al.	N/A	N/A
2010/0224365	12/2009	Abad	N/A	N/A
2010/0300683	12/2009	Looper et al.	N/A	N/A
2010/0310384	12/2009	Stephenson et al.	N/A	N/A
2011/0030963	12/2010	Demong et al.	N/A	N/A
2011/0041681	12/2010	Duerr	N/A	N/A
2011/0052423	12/2010	Gambier et al.	N/A	N/A
2011/0054704	12/2010	Karpman et al.	N/A	N/A
2011/0067857	12/2010	Underhill et al.	N/A	N/A
2011/0085924	12/2010	Shampine et al.	N/A	N/A
2011/0120702	12/2010	Craig	N/A	N/A
2011/0120705	12/2010	Walters et al.	N/A	N/A
2011/0120706	12/2010	Craig	N/A	N/A
2011/0120718	12/2010	Craig	N/A	N/A
2011/0125471	12/2010	Craig et al.	N/A	N/A
2011/0125476	12/2010	Craig	N/A	N/A
2011/0146244	12/2010	Farman et al.	N/A	N/A
2011/0146246	12/2010	Farman et al.	N/A	N/A
2011/0173991	12/2010	Dean et al.	N/A	N/A
2011/0197988	12/2010	Van Vliet et al.	N/A	N/A
2011/0241888	12/2010	Lu et al.	N/A	N/A
2011/0265443	12/2010	Ansari et al.	N/A	N/A
2011/0272158	12/2010	Neal	N/A	N/A
2012/0023973	12/2011	Mayorca	N/A	N/A
2012/0048242	12/2011	Surnilla et al.	N/A	N/A
2012/0085541	12/2011	Love et al.	N/A	N/A
2012/0137699	12/2011	Montagne et al.	N/A	N/A
2012/0179444	12/2011	Ganguly et al.	N/A	N/A
2012/0192542	12/2011	Chillar et al.	N/A	N/A
2012/0199001	12/2011	Chillar et al.	N/A	N/A
2012/0204627	12/2011	Anderl et al.	N/A	N/A
2012/0255734	12/2011	Coli et al.	N/A	N/A
2012/0310509	12/2011	Pardo et al.	N/A	N/A
2012/0324903	12/2011	Dewis et al.	N/A	N/A
2013/0068307	12/2012	Hains et al.	N/A	N/A
2013/0087045	12/2012	Sullivan et al.	N/A	N/A
2013/0087945	12/2012	Kusters et al.	N/A	N/A
2013/0134702	12/2012	Boraas et al.	N/A	N/A
2013/0140031	12/2012	Cohen et al.	N/A	N/A
2013/0189915	12/2012	Hazard	N/A	N/A
2013/0205798	12/2012	Kwok et al.	N/A	N/A

2013/0233165	12/2012	Matzner et al.	N/A	N/A
2013/0255953	12/2012	Tudor	N/A	N/A
2013/0259707	12/2012	Yin	N/A	N/A
2013/0284455	12/2012	Kajaria et al.	N/A	N/A
2013/0300341	12/2012	Gillette, II	N/A	N/A
2013/0306322	12/2012	Sanborn et al.	N/A	N/A
2014/0000668	12/2013	Lessard	N/A	N/A
2014/0010671	12/2013	Cryer et al.	N/A	N/A
2014/0013768	12/2013	Laing et al.	N/A	N/A
2014/0032082	12/2013	Gehrke et al.	N/A	N/A
2014/0044517	12/2013	Saha et al.	N/A	N/A
2014/0048253	12/2013	Andreychuk	N/A	N/A
2014/0090729	12/2013	Coulter et al.	N/A	N/A
2014/0090742	12/2013	Coskrey et al.	N/A	N/A
2014/0094105	12/2013	Lundh et al.	N/A	N/A
2014/0095114	12/2013	Thomeer et al.	N/A	N/A
2014/0095554	12/2013	Thomeer et al.	N/A	N/A
2014/0123621	12/2013	Driessens et al.	N/A	N/A
2014/0130422	12/2013	Laing et al.	N/A	N/A
2014/0138079	12/2013	Broussard et al.	N/A	N/A
2014/0144641	12/2013	Chandler	N/A	N/A
2014/0147291	12/2013	Burnette	N/A	N/A
2014/0158345	12/2013	Jang et al.	N/A	N/A
2014/0174097	12/2013	Hammer et al.	N/A	N/A
2014/0196459	12/2013	Futa et al.	N/A	N/A
2014/0216736	12/2013	Leugemors et al.	N/A	N/A
2014/0219824	12/2013	Burnette	N/A	N/A
2014/0250845	12/2013	Jackson et al.	N/A	N/A
2014/0251623	12/2013	Lestz et al.	N/A	N/A
2014/0262232	12/2013	Dusterhoft et al.	N/A	N/A
2014/0277772	12/2013	Lopez et al.	N/A	N/A
2014/0290266	12/2013	Veilleux, Jr. et al.	N/A	N/A
2014/0318638	12/2013	Harwood et al.	N/A	N/A
2014/0322050	12/2013	Marette et al.	N/A	N/A
2015/0027730	12/2014	Hall et al.	N/A	N/A
2015/0075778	12/2014	Walters et al.	N/A	N/A
2015/0078924	12/2014	Zhang et al.	N/A	N/A
2015/0096739	12/2014	Ghasripoor et al.	N/A	N/A
2015/0101344	12/2014	Jarrier et al.	N/A	N/A
2015/0114652	12/2014	Lestz et al.	N/A	N/A
2015/0129210	12/2014	Chong et al.	N/A	N/A
2015/0135659	12/2014	Jarrier et al.	N/A	N/A
2015/0159553	12/2014	Kippel et al.	N/A	N/A
2015/0176387	12/2014	Wutherich	N/A	N/A
2015/0192117	12/2014	Bridges	N/A	N/A
2015/0204148	12/2014	Liu et al.	N/A	N/A
2015/0204174	12/2014	Kresse et al.	N/A	N/A
2015/0204322	12/2014	Iund et al.	N/A	N/A
2015/0211512	12/2014	Wiegman et al.	N/A	N/A
2015/0214816	12/2014	Raad	N/A	N/A
2015/0217672	12/2014	Shampine et al.	N/A	N/A
2015/0226140	12/2014	Zhang et al.	N/A	N/A
2015/0252661	12/2014	Glass	N/A	N/A
2015/0275891	12/2014	Chong	N/A	N/A
2015/0337730	12/2014	Kupiszewski et al.	N/A	N/A
2015/0340864	12/2014	Compton	N/A	N/A
2015/0345385	12/2014	Santini	N/A	N/A
2015/0369351	12/2014	Hermann et al.	N/A	N/A
2016/0032703	12/2015	Broussard et al.	N/A	N/A
2016/0032836	12/2015	Hawkinson et al.	N/A	N/A
2016/0076447	12/2015	Merlo et al.	N/A	N/A
2016/0090823	12/2015	Alzahabi et al.	N/A	N/A
2016/0102581	12/2015	Del Bono	N/A	N/A
2016/0105022	12/2015	Oehring et al.	N/A	N/A
2016/0108705	12/2015	Maxwell et al.	N/A	N/A
2016/0108713	12/2015	Dunaeva et al.	N/A	N/A

2016/0123185	12/2015	Le Pache et al.	N/A	N/A
2016/0168979	12/2015	Zhang et al.	N/A	N/A
2016/0177675	12/2015	Morris et al.	N/A	N/A
2016/0177945	12/2015	Byrne et al.	N/A	N/A
2016/0186671	12/2015	Austin et al.	N/A	N/A
2016/0195082	12/2015	Wiegman et al.	N/A	N/A
2016/0215774	12/2015	Oklejas et al.	N/A	N/A
2016/0230525	12/2015	Lestz et al.	N/A	N/A
2016/0244314	12/2015	Van Vliet et al.	N/A	N/A
2016/0248230	12/2015	Tawy et al.	N/A	N/A
2016/0253634	12/2015	Thomeer et al.	N/A	N/A
2016/0258267	12/2015	Payne et al.	N/A	N/A
2016/0265330	12/2015	Mazrooee et al.	N/A	N/A
2016/0265331	12/2015	Weng et al.	N/A	N/A
2016/0273328	12/2015	Oehring	N/A	N/A
2016/0273346	12/2015	Tang et al.	N/A	N/A
2016/0290114	12/2015	Oehring et al.	N/A	N/A
2016/0319650	12/2015	Oehring et al.	N/A	N/A
2016/0326845	12/2015	Djikpesse et al.	N/A	N/A
2016/0348479	12/2015	Oehring et al.	N/A	N/A
2016/0369609	12/2015	Morris et al.	N/A	N/A
2017/0009905	12/2016	Arnold	N/A	N/A
2017/0016433	12/2016	Chong et al.	N/A	N/A
2017/0030177	12/2016	Oehring et al.	N/A	N/A
2017/0038137	12/2016	Turney	N/A	N/A
2017/0045055	12/2016	Hoefel et al.	N/A	N/A
2017/0051598	12/2016	Ouenes	N/A	N/A
2017/0052087	12/2016	Faqihi et al.	N/A	N/A
2017/0074074	12/2016	Joseph et al.	N/A	N/A
2017/0074076	12/2016	Joseph et al.	N/A	N/A
2017/0074089	12/2016	Agarwal et al.	N/A	N/A
2017/0082110	12/2016	Lammers	N/A	N/A
2017/0089189	12/2016	Norris et al.	N/A	N/A
2017/0114613	12/2016	Lecerf et al.	N/A	N/A
2017/0114625	12/2016	Norris et al.	N/A	N/A
2017/0122310	12/2016	Ladrón de Guevara	N/A	N/A
2017/0131174	12/2016	Enev et al.	N/A	N/A
2017/0145918	12/2016	Oehring et al.	N/A	N/A
2017/0177992	12/2016	Klie	N/A	N/A
2017/0191350	12/2016	Johns et al.	N/A	N/A
2017/0218727	12/2016	Oehring et al.	N/A	N/A
2017/0226839	12/2016	Broussard et al.	N/A	N/A
2017/0226842	12/2016	Omont et al.	N/A	N/A
2017/0226998	12/2016	Zhang et al.	N/A	N/A
2017/0227002	12/2016	Mikulski et al.	N/A	N/A
2017/0233103	12/2016	Teicholz et al.	N/A	N/A
2017/0234165	12/2016	Kersey et al.	N/A	N/A
2017/0234308	12/2016	Buckley	N/A	N/A
2017/0241336	12/2016	Jones et al.	N/A	N/A
2017/0241671	12/2016	Ahmad	N/A	N/A
2017/0247995	12/2016	Crews et al.	N/A	N/A
2017/0248034	12/2016	Dzieciol et al.	N/A	N/A
2017/0248208	12/2016	Tamura	N/A	N/A
2017/0248308	12/2016	Makarychev-Mikhailov et al.	N/A	N/A
2017/0254186	12/2016	Aidagulov et al.	N/A	N/A
2017/0275149	12/2016	Schmidt	N/A	N/A
2017/0288400	12/2016	Williams	N/A	N/A
2017/0292409	12/2016	Aguilar et al.	N/A	N/A
2017/0302135	12/2016	Cory	N/A	N/A
2017/0305736	12/2016	Haile et al.	N/A	N/A
2017/0306847	12/2016	Suciu et al.	N/A	N/A
2017/0306936	12/2016	Dole et al.	N/A	N/A
2017/0322086	12/2016	Luharuka et al.	N/A	N/A
2017/0328179	12/2016	Dykstra et al.	N/A	N/A
2017/0333086	12/2016	Jackson	N/A	N/A
2017/0334448	12/2016	Schwunk	N/A	N/A

2017/0335842	12/2016	Robinson et al.	N/A	N/A
2017/0350471	12/2016	Steidl et al.	N/A	N/A
2017/0356470	12/2016	Jaffrey	N/A	N/A
2017/0370199	12/2016	Witkowski et al.	N/A	N/A
2017/0370480	12/2016	Witkowski et al.	N/A	N/A
2018/0016895	12/2017	Weng et al.	N/A	N/A
2018/0034280	12/2017	Pedersen	N/A	N/A
2018/0038216	12/2017	Zhang et al.	N/A	N/A
2018/0038328	12/2017	Louven et al.	N/A	N/A
2018/0041093	12/2017	Miranda	N/A	N/A
2018/0045202	12/2017	Crom	N/A	N/A
2018/0058171	12/2017	Roesner et al.	N/A	N/A
2018/0087499	12/2017	Zhang et al.	N/A	N/A
2018/0087996	12/2017	De La Cruz	N/A	N/A
2018/0149000	12/2017	Roussel et al.	N/A	N/A
2018/0156210	12/2017	Oehring et al.	N/A	N/A
2018/0172294	12/2017	Owen	N/A	N/A
2018/0183219	12/2017	Oehring et al.	N/A	N/A
2018/0186442	12/2017	Maier	N/A	N/A
2018/0187662	12/2017	Hill et al.	N/A	N/A
2018/0209415	12/2017	Zhang et al.	N/A	N/A
2018/0223640	12/2017	Keihany et al.	N/A	N/A
2018/0224044	12/2017	Penney et al.	N/A	N/A
2018/0229998	12/2017	Shock	N/A	N/A
2018/0230780	12/2017	Klenner et al.	N/A	N/A
2018/0252084	12/2017	Nguyen et al.	N/A	N/A
2018/0258746	12/2017	Broussard et al.	N/A	N/A
2018/0266412	12/2017	Stokkevåg et al.	N/A	N/A
2018/0278124	12/2017	Oehring et al.	N/A	N/A
2018/0283102	12/2017	Cook	N/A	N/A
2018/0283618	12/2017	Cook	N/A	N/A
2018/0284817	12/2017	Cook et al.	N/A	N/A
2018/0290877	12/2017	Shock	N/A	N/A
2018/0291781	12/2017	Pedrini	N/A	N/A
2018/0298731	12/2017	Bishop	N/A	N/A
2018/0298735	12/2017	Conrad	N/A	N/A
2018/0307255	12/2017	Bishop	N/A	N/A
2018/0313456	12/2017	Bayyouk et al.	N/A	N/A
2018/0328157	12/2017	Bishop	N/A	N/A
2018/0334893	12/2017	Oehring	N/A	N/A
2018/0363435	12/2017	Coli et al.	N/A	N/A
2018/0363436	12/2017	Coli et al.	N/A	N/A
2018/0363437	12/2017	Coli et al.	N/A	N/A
2018/0363438	12/2017	Coli et al.	N/A	N/A
2019/0003272	12/2018	Morris et al.	N/A	N/A
2019/0003329	12/2018	Morris et al.	N/A	N/A
2019/0010793	12/2018	Hinderliter	N/A	N/A
2019/0011051	12/2018	Yeung	N/A	N/A
2019/0048993	12/2018	Akiyama et al.	N/A	N/A
2019/0055836	12/2018	Felkl et al.	N/A	N/A
2019/0063263	12/2018	Davis et al.	N/A	N/A
2019/0063341	12/2018	Davis	N/A	N/A
2019/0067991	12/2018	Davis et al.	N/A	N/A
2019/0071946	12/2018	Painter et al.	N/A	N/A
2019/0071992	12/2018	Feng	N/A	N/A
2019/0072005	12/2018	Fisher et al.	N/A	N/A
2019/0078471	12/2018	Braglia et al.	N/A	N/A
2019/0088845	12/2018	Sugi et al.	N/A	N/A
2019/0091619	12/2018	Huang	N/A	N/A
2019/0106316	12/2018	Van Vliet et al.	N/A	N/A
2019/0106970	12/2018	Oehring	N/A	N/A
2019/0112908	12/2018	Coli et al.	N/A	N/A
2019/0112910	12/2018	Oehring et al.	N/A	N/A
2019/0119096	12/2018	Haile et al.	N/A	N/A
2019/0120024	12/2018	Oehring et al.	N/A	N/A
2019/0120031	12/2018	Gilje	N/A	N/A

2019/0120134	12/2018	Goleczka et al.	N/A	N/A
2019/0128247	12/2018	Douglas, III	N/A	N/A
2019/0128288	12/2018	Konada et al.	N/A	N/A
2019/0131607	12/2018	Gillette	N/A	N/A
2019/0136677	12/2018	Shampine et al.	N/A	N/A
2019/0136684	12/2018	Felkl et al.	N/A	N/A
2019/0153843	12/2018	Headrick	N/A	N/A
2019/0153938	12/2018	Hammoud	N/A	N/A
2019/0154020	12/2018	Glass	N/A	N/A
2019/0155318	12/2018	Meunier	N/A	N/A
2019/0169962	12/2018	Aqrawi et al.	N/A	N/A
2019/0178234	12/2018	Beisel	N/A	N/A
2019/0178235	12/2018	Coskrey et al.	N/A	N/A
2019/0185312	12/2018	Bush et al.	N/A	N/A
2019/0203572	12/2018	Morris et al.	N/A	N/A
2019/0204021	12/2018	Morris et al.	N/A	N/A
2019/0211661	12/2018	Reckels et al.	N/A	N/A
2019/0211814	12/2018	Weightman et al.	N/A	N/A
2019/0217258	12/2018	Bishop	N/A	N/A
2019/0226317	12/2018	Payne et al.	N/A	N/A
2019/0245348	12/2018	Hinderliter et al.	N/A	N/A
2019/0249652	12/2018	Stephenson et al.	N/A	N/A
2019/0249754	12/2018	Oehring et al.	N/A	N/A
2019/0257297	12/2018	Botting et al.	N/A	N/A
2019/0264667	12/2018	Byrne	N/A	N/A
2019/0277279	12/2018	Byrne et al.	N/A	N/A
2019/0277295	12/2018	Clyburn et al.	N/A	N/A
2019/0309585	12/2018	Miller et al.	N/A	N/A
2019/0316447	12/2018	Oehring et al.	N/A	N/A
2019/0316456	12/2018	Beisel et al.	N/A	N/A
2019/0323337	12/2018	Glass et al.	N/A	N/A
2019/0330923	12/2018	Gable et al.	N/A	N/A
2019/0331117	12/2018	Gable et al.	N/A	N/A
2019/0337392	12/2018	Joshi et al.	N/A	N/A
2019/0338762	12/2018	Curry et al.	N/A	N/A
2019/0345920	12/2018	Surjaatmadja et al.	N/A	N/A
2019/0353103	12/2018	Roberge	N/A	N/A
2019/0356199	12/2018	Morris et al.	N/A	N/A
2019/0376449	12/2018	Carrell	N/A	N/A
2019/0383123	12/2018	Hinderliter	N/A	N/A
2020/0003205	12/2019	Stokkevåg et al.	N/A	N/A
2020/0011165	12/2019	George et al.	N/A	N/A
2020/0040878	12/2019	Morris	N/A	N/A
2020/0049136	12/2019	Stephenson	N/A	N/A
2020/0049153	12/2019	Headrick et al.	N/A	N/A
2020/0071998	12/2019	Oehring et al.	N/A	N/A
2020/0072201	12/2019	Marica	N/A	N/A
2020/0088202	12/2019	Sigmar et al.	N/A	N/A
2020/0095854	12/2019	Hinderliter	N/A	N/A
2020/0109610	12/2019	Husøy et al.	N/A	N/A
2020/0109616	12/2019	Oehring et al.	N/A	N/A
2020/0132058	12/2019	Mollatt	N/A	N/A
2020/0141219	12/2019	Oehring et al.	N/A	N/A
2020/0141326	12/2019	Redford et al.	N/A	N/A
2020/0141907	12/2019	Meck et al.	N/A	N/A
2020/0166026	12/2019	Marica	N/A	N/A
2020/0206704	12/2019	Chong	N/A	N/A
2020/0208733	12/2019	Kim	N/A	N/A
2020/0223648	12/2019	Herman et al.	N/A	N/A
2020/0224645	12/2019	Buckley	N/A	N/A
2020/0225381	12/2019	Walles et al.	N/A	N/A
2020/0232454	12/2019	Chretien et al.	N/A	N/A
2020/0256333	12/2019	Surjaatmadja et al.	N/A	N/A
2020/0263498	12/2019	Fischer et al.	N/A	N/A
2020/0263525	12/2019	Reid et al.	N/A	N/A
2020/0263526	12/2019	Fischer et al.	N/A	N/A

2020/0263527	12/2019	Fischer et al.	N/A	N/A
2020/0263528	12/2019	Fischer et al.	N/A	N/A
2020/0267888	12/2019	Putz	N/A	N/A
2020/0291731	12/2019	Haiderer et al.	N/A	N/A
2020/0295574	12/2019	Batsch-Smith	N/A	N/A
2020/0300050	12/2019	Oehring et al.	N/A	N/A
2020/0309027	12/2019	Rytkönen	N/A	N/A
2020/0309113	12/2019	Hunter et al.	N/A	N/A
2020/0325752	12/2019	Clark et al.	N/A	N/A
2020/0325760	12/2019	Markham	N/A	N/A
2020/0325761	12/2019	Williams	N/A	N/A
2020/0325791	12/2019	Himmelmann	N/A	N/A
2020/0325893	12/2019	Kraige et al.	N/A	N/A
2020/0332784	12/2019	Zhang et al.	N/A	N/A
2020/0332788	12/2019	Cui et al.	N/A	N/A
2020/0340313	12/2019	Fischer et al.	N/A	N/A
2020/0340322	12/2019	Sizemore et al.	N/A	N/A
2020/0340340	12/2019	Oehring et al.	N/A	N/A
2020/0340344	12/2019	Reckels et al.	N/A	N/A
2020/0340404	12/2019	Stockstill et al.	N/A	N/A
2020/0347725	12/2019	Morris et al.	N/A	N/A
2020/0354928	12/2019	Wehler et al.	N/A	N/A
2020/0355055	12/2019	Dusterhoft et al.	N/A	N/A
2020/0362760	12/2019	Morenko et al.	N/A	N/A
2020/0362764	12/2019	Saintignan et al.	N/A	N/A
2020/0370394	12/2019	Cai et al.	N/A	N/A
2020/0370408	12/2019	Cai et al.	N/A	N/A
2020/0370429	12/2019	Cai et al.	N/A	N/A
2020/0371490	12/2019	Cai et al.	N/A	N/A
2020/0386169	12/2019	Hinderliter et al.	N/A	N/A
2020/0386222	12/2019	Pham et al.	N/A	N/A
2020/0388140	12/2019	Gomez et al.	N/A	N/A
2020/0392826	12/2019	Cui et al.	N/A	N/A
2020/0392827	12/2019	George et al.	N/A	N/A
2020/0393088	12/2019	Sizemore et al.	N/A	N/A
2020/0398238	12/2019	Zhong et al.	N/A	N/A
2020/0400000	12/2019	Ghasripoor et al.	N/A	N/A
2020/0400005	12/2019	Han et al.	N/A	N/A
2020/0407625	12/2019	Stephenson	N/A	N/A
2020/0408071	12/2019	Li et al.	N/A	N/A
2020/0408144	12/2019	Feng et al.	N/A	N/A
2020/0408147	12/2019	Zhang et al.	N/A	N/A
2020/0408149	12/2019	Li et al.	N/A	N/A
2021/0010361	12/2020	Kriebel et al.	N/A	N/A
2021/0010362	12/2020	Kriebel et al.	N/A	N/A
2021/0025324	12/2020	Morris et al.	N/A	N/A
2021/0025383	12/2020	Bodishbaugh et al.	N/A	N/A
2021/0032961	12/2020	Hinderliter et al.	N/A	N/A
2021/0054727	12/2020	Floyd	N/A	N/A
2021/0071503	12/2020	Ogg et al.	N/A	N/A
2021/0071574	12/2020	Feng et al.	N/A	N/A
2021/0071579	12/2020	Li et al.	N/A	N/A
2021/0071654	12/2020	Brunson, Jr.	N/A	N/A
2021/0071752	12/2020	Cui et al.	N/A	N/A
2021/0079758	12/2020	Yeung et al.	N/A	N/A
2021/0079851	12/2020	Yeung et al.	N/A	N/A
2021/0086851	12/2020	Zhang et al.	N/A	N/A
2021/0087883	12/2020	Zhang et al.	N/A	N/A
2021/0087916	12/2020	Zhang et al.	N/A	N/A
2021/0087925	12/2020	Heidari et al.	N/A	N/A
2021/0087943	12/2020	Cui et al.	N/A	N/A
2021/0088042	12/2020	Zhang et al.	N/A	N/A
2021/0123425	12/2020	Cui et al.	N/A	N/A
2021/0123434	12/2020	Cui et al.	N/A	N/A
2021/0123435	12/2020	Cui et al.	N/A	N/A
2021/0131409	12/2020	Cui et al.	N/A	N/A

2021/0140416	12/2020	Buckley	N/A	N/A
2021/0148208	12/2020	Thomas et al.	N/A	N/A
2021/0156240	12/2020	Cicci et al.	N/A	N/A
2021/0156241	12/2020	Cook	N/A	N/A
2021/0172282	12/2020	Wang et al.	N/A	N/A
2021/0180517	12/2020	Zhou et al.	N/A	N/A
2021/0190045	12/2020	Zhang et al.	N/A	N/A
2021/0199110	12/2020	Albert et al.	N/A	N/A
2021/0222690	12/2020	Beisel	N/A	N/A
2021/0239112	12/2020	Buckley	N/A	N/A
2021/0246774	12/2020	Cui et al.	N/A	N/A
2021/0270261	12/2020	Zhang et al.	N/A	N/A
2021/0270264	12/2020	Byrne et al.	N/A	N/A
2021/0285311	12/2020	Ji et al.	N/A	N/A
2021/0285432	12/2020	Ji et al.	N/A	N/A
2021/0301807	12/2020	Cui et al.	N/A	N/A
2021/0301815	12/2020	Chretien et al.	N/A	N/A
2021/0306720	12/2020	Sandoval et al.	N/A	N/A
2021/0308638	12/2020	Zhong et al.	N/A	N/A
2021/0324718	12/2020	Anders	N/A	N/A
2021/0348475	12/2020	Yeung et al.	N/A	N/A
2021/0348476	12/2020	Yeung et al.	N/A	N/A
2021/0348477	12/2020	Yeung et al.	N/A	N/A
2021/0355927	12/2020	Jian et al.	N/A	N/A
2021/0372394	12/2020	Bagulayan et al.	N/A	N/A
2021/0372395	12/2020	Li et al.	N/A	N/A
2021/0376413	12/2020	Asfha	N/A	N/A
2021/0388760	12/2020	Feng et al.	N/A	N/A
2022/0082007	12/2021	Zhang et al.	N/A	N/A
2022/0090476	12/2021	Zhang et al.	N/A	N/A
2022/0090477	12/2021	Zhang et al.	N/A	N/A
2022/0090478	12/2021	Zhang et al.	N/A	N/A
2022/0112892	12/2021	Cui et al.	N/A	N/A
2022/0120262	12/2021	Ji et al.	N/A	N/A
2022/0145740	12/2021	Yuan et al.	N/A	N/A
2022/0154775	12/2021	Liu et al.	N/A	N/A
2022/0155373	12/2021	Liu et al.	N/A	N/A
2022/0162931	12/2021	Zhong et al.	N/A	N/A
2022/0162991	12/2021	Zhang et al.	N/A	N/A
2022/0181859	12/2021	Ji et al.	N/A	N/A
2022/0186724	12/2021	Chang et al.	N/A	N/A
2022/0213777	12/2021	Cui et al.	N/A	N/A
2022/0220836	12/2021	Zhang et al.	N/A	N/A
2022/0224087	12/2021	Ji et al.	N/A	N/A
2022/0228468	12/2021	Cui et al.	N/A	N/A
2022/0228469	12/2021	Zhang et al.	N/A	N/A
2022/0235639	12/2021	Zhang et al.	N/A	N/A
2022/0235640	12/2021	Mao et al.	N/A	N/A
2022/0235641	12/2021	Zhang et al.	N/A	N/A
2022/0235642	12/2021	Zhang et al.	N/A	N/A
2022/0235802	12/2021	Jiang et al.	N/A	N/A
2022/0242297	12/2021	Tian et al.	N/A	N/A
2022/0243613	12/2021	Ji et al.	N/A	N/A
2022/0243724	12/2021	Li et al.	N/A	N/A
2022/0250000	12/2021	Zhang et al.	N/A	N/A
2022/0255319	12/2021	Liu et al.	N/A	N/A
2022/0258659	12/2021	Cui et al.	N/A	N/A
2022/0259947	12/2021	Li et al.	N/A	N/A
2022/0259964	12/2021	Zhang et al.	N/A	N/A
2022/0268201	12/2021	Feng et al.	N/A	N/A
2022/0282606	12/2021	Zhong et al.	N/A	N/A
2022/0282726	12/2021	Zhang et al.	N/A	N/A
2022/0290549	12/2021	Zhang et al.	N/A	N/A
2022/0294194	12/2021	Cao et al.	N/A	N/A
2022/0298906	12/2021	Zhong et al.	N/A	N/A
2022/0307359	12/2021	Liu et al.	N/A	N/A

2022/0307424	12/2021	Wang et al.	N/A	N/A
2022/0314248	12/2021	Ge et al.	N/A	N/A
2022/0315347	12/2021	Liu et al.	N/A	N/A
2022/0316306	12/2021	Liu et al.	N/A	N/A
2022/0316362	12/2021	Zhang et al.	N/A	N/A
2022/0316461	12/2021	Wang et al.	N/A	N/A
2022/0325608	12/2021	Zhang et al.	N/A	N/A
2022/0330411	12/2021	Liu et al.	N/A	N/A
2022/0333471	12/2021	Zhong et al.	N/A	N/A
2022/0339646	12/2021	Yu et al.	N/A	N/A
2022/0341358	12/2021	Ji et al.	N/A	N/A
2022/0341362	12/2021	Feng et al.	N/A	N/A
2022/0341415	12/2021	Deng et al.	N/A	N/A
2022/0345007	12/2021	Liu et al.	N/A	N/A
2022/0349345	12/2021	Zhang et al.	N/A	N/A
2022/0353980	12/2021	Liu et al.	N/A	N/A
2022/0361309	12/2021	Liu et al.	N/A	N/A
2022/0364452	12/2021	Wang et al.	N/A	N/A
2022/0364453	12/2021	Chang et al.	N/A	N/A
2022/0372865	12/2021	Lin et al.	N/A	N/A
2022/0376280	12/2021	Shao et al.	N/A	N/A
2022/0381126	12/2021	Cui et al.	N/A	N/A
2022/0389799	12/2021	Mao et al.	N/A	N/A
2022/0389803	12/2021	Zhang et al.	N/A	N/A
2022/0389804	12/2021	Cui et al.	N/A	N/A
2022/0389865	12/2021	Feng et al.	N/A	N/A
2022/0389867	12/2021	Li et al.	N/A	N/A
2022/0412196	12/2021	Cui et al.	N/A	N/A
2022/0412199	12/2021	Mao et al.	N/A	N/A
2022/0412200	12/2021	Zhang et al.	N/A	N/A
2022/0412258	12/2021	Li et al.	N/A	N/A
2022/0412379	12/2021	Wang et al.	N/A	N/A
2023/0001524	12/2022	Jiang et al.	N/A	N/A
2023/0003238	12/2022	Du et al.	N/A	N/A
2023/0015132	12/2022	Feng et al.	N/A	N/A
2023/0015529	12/2022	Zhang et al.	N/A	N/A
2023/0015581	12/2022	Ji et al.	N/A	N/A
2023/0017968	12/2022	Deng et al.	N/A	N/A
2023/0029574	12/2022	Zhang et al.	N/A	N/A
2023/0029671	12/2022	Han et al.	N/A	N/A
2023/0036118	12/2022	Xing et al.	N/A	N/A
2023/0040970	12/2022	Liu et al.	N/A	N/A
2023/0042379	12/2022	Zhang et al.	N/A	N/A
2023/0047033	12/2022	Fu et al.	N/A	N/A
2023/0048551	12/2022	Feng et al.	N/A	N/A
2023/0049462	12/2022	Zhang et al.	N/A	N/A
2023/0064964	12/2022	Wang et al.	N/A	N/A
2023/0074794	12/2022	Liu et al.	N/A	N/A
2023/0085124	12/2022	Zhong et al.	N/A	N/A
2023/0092506	12/2022	Zhong et al.	N/A	N/A
2023/0092705	12/2022	Liu et al.	N/A	N/A
2023/0106683	12/2022	Zhang et al.	N/A	N/A
2023/0107300	12/2022	Huang et al.	N/A	N/A
2023/0107791	12/2022	Zhang et al.	N/A	N/A
2023/0109018	12/2022	Du et al.	N/A	N/A
2023/0116458	12/2022	Liu et al.	N/A	N/A
2023/0117362	12/2022	Zhang et al.	N/A	N/A
2023/0119725	12/2022	Wang et al.	N/A	N/A
2023/0119876	12/2022	Mao et al.	N/A	N/A
2023/0119896	12/2022	Zhang et al.	N/A	N/A
2023/0120810	12/2022	Fu et al.	N/A	N/A
2023/0121251	12/2022	Cui et al.	N/A	N/A
2023/0124444	12/2022	Chang et al.	N/A	N/A
2023/0138582	12/2022	Li et al.	N/A	N/A
2023/0144116	12/2022	Li et al.	N/A	N/A
2023/0145963	12/2022	Zhang et al.	N/A	N/A

2023/0151722	12/2022	Cui et al.	N/A	N/A
2023/0151723	12/2022	Ji et al.	N/A	N/A
2023/0152793	12/2022	Wang et al.	N/A	N/A
2023/0160289	12/2022	Cui et al.	N/A	N/A
2023/0160510	12/2022	Bao et al.	N/A	N/A
2023/0163580	12/2022	Ji et al.	N/A	N/A
2023/0167776	12/2022	Cui et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	**Application Date**	**Country**	**CPC**
9609498	12/1998	AU	N/A
737970	12/2000	AU	N/A
2043184	12/1993	CA	N/A
2829762	12/2011	CA	N/A
2737321	12/2012	CA	N/A
2876687	12/2013	CA	N/A
2693567	12/2013	CA	N/A
2964597	12/2016	CA	N/A
3138533	12/2019	CA	N/A
2919175	12/2020	CA	N/A
2622404	12/2003	CN	N/A
2779054	12/2005	CN	N/A
2890325	12/2006	CN	N/A
200964929	12/2006	CN	N/A
101323151	12/2007	CN	N/A
201190660	12/2008	CN	N/A
201190892	12/2008	CN	N/A
201190893	12/2008	CN	N/A
101414171	12/2008	CN	N/A
201215073	12/2008	CN	N/A
201236650	12/2008	CN	N/A
201275542	12/2008	CN	N/A
201275801	12/2008	CN	N/A
201333385	12/2008	CN	N/A
201443300	12/2009	CN	N/A
201496415	12/2009	CN	N/A
201501365	12/2009	CN	N/A
201507271	12/2009	CN	N/A
201560210	12/2009	CN	N/A
201581862	12/2009	CN	N/A
201610728	12/2009	CN	N/A
201610751	12/2009	CN	N/A
201618530	12/2009	CN	N/A
201661255	12/2009	CN	N/A
101949382	12/2010	CN	N/A
201756927	12/2010	CN	N/A
102128011	12/2010	CN	N/A
102140898	12/2010	CN	N/A
102155172	12/2010	CN	N/A
102182904	12/2010	CN	N/A
202000930	12/2010	CN	N/A
202055781	12/2010	CN	N/A
202082265	12/2010	CN	N/A
202100216	12/2011	CN	N/A
202100217	12/2011	CN	N/A
202100815	12/2011	CN	N/A
202124340	12/2011	CN	N/A
202140051	12/2011	CN	N/A
202140080	12/2011	CN	N/A
202144789	12/2011	CN	N/A
202144943	12/2011	CN	N/A
202149354	12/2011	CN	N/A
102383748	12/2011	CN	N/A
202156297	12/2011	CN	N/A
202158355	12/2011	CN	N/A
202163504	12/2011	CN	N/A

202165236	12/2011	CN	N/A
202180866	12/2011	CN	N/A
202181875	12/2011	CN	N/A
202187744	12/2011	CN	N/A
202191854	12/2011	CN	N/A
202250008	12/2011	CN	N/A
101885307	12/2011	CN	N/A
102562020	12/2011	CN	N/A
202326156	12/2011	CN	N/A
202370773	12/2011	CN	N/A
202417397	12/2011	CN	N/A
202417461	12/2011	CN	N/A
102729335	12/2011	CN	N/A
202463955	12/2011	CN	N/A
202463957	12/2011	CN	N/A
202467739	12/2011	CN	N/A
202467801	12/2011	CN	N/A
202531016	12/2011	CN	N/A
202544794	12/2011	CN	N/A
102825039	12/2011	CN	N/A
202578592	12/2011	CN	N/A
202579164	12/2011	CN	N/A
202594808	12/2011	CN	N/A
202594928	12/2011	CN	N/A
202596615	12/2011	CN	N/A
202596616	12/2011	CN	N/A
102889191	12/2012	CN	N/A
202641535	12/2012	CN	N/A
202645475	12/2012	CN	N/A
202666716	12/2012	CN	N/A
202669645	12/2012	CN	N/A
202669944	12/2012	CN	N/A
202671336	12/2012	CN	N/A
202673269	12/2012	CN	N/A
202751982	12/2012	CN	N/A
102963629	12/2012	CN	N/A
202767964	12/2012	CN	N/A
202789791	12/2012	CN	N/A
202789792	12/2012	CN	N/A
202810717	12/2012	CN	N/A
202827276	12/2012	CN	N/A
202833093	12/2012	CN	N/A
202833370	12/2012	CN	N/A
202895467	12/2012	CN	N/A
202926404	12/2012	CN	N/A
202935216	12/2012	CN	N/A
202935798	12/2012	CN	N/A
202935816	12/2012	CN	N/A
202970631	12/2012	CN	N/A
103223315	12/2012	CN	N/A
203050598	12/2012	CN	N/A
103233714	12/2012	CN	N/A
103233715	12/2012	CN	N/A
103245523	12/2012	CN	N/A
103247220	12/2012	CN	N/A
103253839	12/2012	CN	N/A
103277290	12/2012	CN	N/A
103321782	12/2012	CN	N/A
203170270	12/2012	CN	N/A
203172509	12/2012	CN	N/A
203175778	12/2012	CN	N/A
203175787	12/2012	CN	N/A
102849880	12/2012	CN	N/A
203241231	12/2012	CN	N/A
203244941	12/2012	CN	N/A
203244942	12/2012	CN	N/A

203303798	12/2012	CN	N/A
103420532	12/2012	CN	N/A
203321792	12/2012	CN	N/A
203412658	12/2013	CN	N/A
203420697	12/2013	CN	N/A
203480755	12/2013	CN	N/A
103711437	12/2013	CN	N/A
203531815	12/2013	CN	N/A
203531871	12/2013	CN	N/A
203531883	12/2013	CN	N/A
203556164	12/2013	CN	N/A
203558809	12/2013	CN	N/A
203559861	12/2013	CN	N/A
203559893	12/2013	CN	N/A
203560189	12/2013	CN	N/A
102704870	12/2013	CN	N/A
203611843	12/2013	CN	N/A
203612531	12/2013	CN	N/A
203612843	12/2013	CN	N/A
203614062	12/2013	CN	N/A
203614388	12/2013	CN	N/A
203621045	12/2013	CN	N/A
203621046	12/2013	CN	N/A
203621051	12/2013	CN	N/A
203640993	12/2013	CN	N/A
203655221	12/2013	CN	N/A
103899280	12/2013	CN	N/A
103923670	12/2013	CN	N/A
203685052	12/2013	CN	N/A
203716936	12/2013	CN	N/A
103990410	12/2013	CN	N/A
103993869	12/2013	CN	N/A
203754009	12/2013	CN	N/A
203754025	12/2013	CN	N/A
203754341	12/2013	CN	N/A
203756614	12/2013	CN	N/A
203770264	12/2013	CN	N/A
203784519	12/2013	CN	N/A
203784520	12/2013	CN	N/A
104057864	12/2013	CN	N/A
203819819	12/2013	CN	N/A
203823431	12/2013	CN	N/A
203835337	12/2013	CN	N/A
104074500	12/2013	CN	N/A
203876633	12/2013	CN	N/A
203876636	12/2013	CN	N/A
203877364	12/2013	CN	N/A
203877365	12/2013	CN	N/A
203877375	12/2013	CN	N/A
203877424	12/2013	CN	N/A
203879476	12/2013	CN	N/A
203879479	12/2013	CN	N/A
203890292	12/2013	CN	N/A
203899476	12/2013	CN	N/A
203906206	12/2013	CN	N/A
104150728	12/2013	CN	N/A
104176522	12/2013	CN	N/A
104196464	12/2013	CN	N/A
104234651	12/2013	CN	N/A
203971841	12/2013	CN	N/A
203975450	12/2013	CN	N/A
204020788	12/2013	CN	N/A
204021980	12/2013	CN	N/A
204024625	12/2013	CN	N/A
204051401	12/2013	CN	N/A
204060661	12/2013	CN	N/A

104260672	12/2014	CN	N/A
104314512	12/2014	CN	N/A
204077478	12/2014	CN	N/A
204077526	12/2014	CN	N/A
204078307	12/2014	CN	N/A
204083051	12/2014	CN	N/A
204113168	12/2014	CN	N/A
104340682	12/2014	CN	N/A
104358536	12/2014	CN	N/A
104369687	12/2014	CN	N/A
104402178	12/2014	CN	N/A
104402185	12/2014	CN	N/A
104402186	12/2014	CN	N/A
204209819	12/2014	CN	N/A
204224560	12/2014	CN	N/A
204225813	12/2014	CN	N/A
204225839	12/2014	CN	N/A
104533392	12/2014	CN	N/A
104563938	12/2014	CN	N/A
104563994	12/2014	CN	N/A
104563995	12/2014	CN	N/A
104563998	12/2014	CN	N/A
104564033	12/2014	CN	N/A
204257122	12/2014	CN	N/A
204283610	12/2014	CN	N/A
204283782	12/2014	CN	N/A
204297682	12/2014	CN	N/A
204299810	12/2014	CN	N/A
104594857	12/2014	CN	N/A
104595493	12/2014	CN	N/A
104612647	12/2014	CN	N/A
104612928	12/2014	CN	N/A
104632126	12/2014	CN	N/A
204325094	12/2014	CN	N/A
204325098	12/2014	CN	N/A
204326983	12/2014	CN	N/A
204326985	12/2014	CN	N/A
204344040	12/2014	CN	N/A
204344095	12/2014	CN	N/A
104727797	12/2014	CN	N/A
204402414	12/2014	CN	N/A
204402423	12/2014	CN	N/A
204402450	12/2014	CN	N/A
104803568	12/2014	CN	N/A
204436360	12/2014	CN	N/A
204457524	12/2014	CN	N/A
204472485	12/2014	CN	N/A
204473625	12/2014	CN	N/A
204477303	12/2014	CN	N/A
204493095	12/2014	CN	N/A
204493309	12/2014	CN	N/A
104820372	12/2014	CN	N/A
104832093	12/2014	CN	N/A
104863523	12/2014	CN	N/A
204552723	12/2014	CN	N/A
204553866	12/2014	CN	N/A
204571831	12/2014	CN	N/A
204703814	12/2014	CN	N/A
204703833	12/2014	CN	N/A
204703834	12/2014	CN	N/A
105092401	12/2014	CN	N/A
103790927	12/2014	CN	N/A
105207097	12/2014	CN	N/A
204831952	12/2014	CN	N/A
204899777	12/2014	CN	N/A
102602323	12/2015	CN	N/A

105240064	12/2015	CN	N/A
204944834	12/2015	CN	N/A
205042127	12/2015	CN	N/A
205172478	12/2015	CN	N/A
105536299	12/2015	CN	N/A
105545207	12/2015	CN	N/A
205260249	12/2015	CN	N/A
205297518	12/2015	CN	N/A
205298447	12/2015	CN	N/A
205391821	12/2015	CN	N/A
205400701	12/2015	CN	N/A
205477370	12/2015	CN	N/A
205479153	12/2015	CN	N/A
205503058	12/2015	CN	N/A
205503068	12/2015	CN	N/A
205503089	12/2015	CN	N/A
105958098	12/2015	CN	N/A
205599180	12/2015	CN	N/A
106121577	12/2015	CN	N/A
205709587	12/2015	CN	N/A
106246120	12/2015	CN	N/A
205805471	12/2015	CN	N/A
106321045	12/2016	CN	N/A
205858306	12/2016	CN	N/A
106438310	12/2016	CN	N/A
205937833	12/2016	CN	N/A
206129196	12/2016	CN	N/A
106715165	12/2016	CN	N/A
106761561	12/2016	CN	N/A
206237147	12/2016	CN	N/A
206287832	12/2016	CN	N/A
206346711	12/2016	CN	N/A
107120822	12/2016	CN	N/A
107143298	12/2016	CN	N/A
107159046	12/2016	CN	N/A
107188018	12/2016	CN	N/A
206496016	12/2016	CN	N/A
107234358	12/2016	CN	N/A
107261975	12/2016	CN	N/A
206581929	12/2016	CN	N/A
107476769	12/2016	CN	N/A
107520526	12/2016	CN	N/A
206754664	12/2016	CN	N/A
107605427	12/2017	CN	N/A
107654196	12/2017	CN	N/A
107656499	12/2017	CN	N/A
107728657	12/2017	CN	N/A
206985503	12/2017	CN	N/A
207017968	12/2017	CN	N/A
107859053	12/2017	CN	N/A
207057867	12/2017	CN	N/A
207085817	12/2017	CN	N/A
107883091	12/2017	CN	N/A
107902427	12/2017	CN	N/A
107939290	12/2017	CN	N/A
107956708	12/2017	CN	N/A
207169595	12/2017	CN	N/A
207194873	12/2017	CN	N/A
207245674	12/2017	CN	N/A
108034466	12/2017	CN	N/A
108036071	12/2017	CN	N/A
108087050	12/2017	CN	N/A
207380566	12/2017	CN	N/A
108103483	12/2017	CN	N/A
108179046	12/2017	CN	N/A
108254276	12/2017	CN	N/A

108311535	12/2017	CN	N/A
207583576	12/2017	CN	N/A
207634064	12/2017	CN	N/A
207648054	12/2017	CN	N/A
207650621	12/2017	CN	N/A
108371894	12/2017	CN	N/A
207777153	12/2017	CN	N/A
108547601	12/2017	CN	N/A
108547766	12/2017	CN	N/A
108555826	12/2017	CN	N/A
108561098	12/2017	CN	N/A
108561750	12/2017	CN	N/A
108590617	12/2017	CN	N/A
207813495	12/2017	CN	N/A
207814698	12/2017	CN	N/A
207862275	12/2017	CN	N/A
108687954	12/2017	CN	N/A
207935270	12/2017	CN	N/A
207961582	12/2017	CN	N/A
207964530	12/2017	CN	N/A
108789848	12/2017	CN	N/A
108799473	12/2017	CN	N/A
108868675	12/2017	CN	N/A
208086829	12/2017	CN	N/A
208089263	12/2017	CN	N/A
208169068	12/2017	CN	N/A
108979569	12/2017	CN	N/A
109027662	12/2017	CN	N/A
109058092	12/2017	CN	N/A
208179454	12/2017	CN	N/A
208179502	12/2017	CN	N/A
208253147	12/2017	CN	N/A
208260574	12/2017	CN	N/A
109114418	12/2018	CN	N/A
109141990	12/2018	CN	N/A
208313120	12/2018	CN	N/A
208330319	12/2018	CN	N/A
208342730	12/2018	CN	N/A
208430982	12/2018	CN	N/A
208430986	12/2018	CN	N/A
109404274	12/2018	CN	N/A
109429610	12/2018	CN	N/A
109491318	12/2018	CN	N/A
109515177	12/2018	CN	N/A
109526523	12/2018	CN	N/A
109534737	12/2018	CN	N/A
208564504	12/2018	CN	N/A
208564516	12/2018	CN	N/A
208564525	12/2018	CN	N/A
208564918	12/2018	CN	N/A
208576026	12/2018	CN	N/A
208576042	12/2018	CN	N/A
208650818	12/2018	CN	N/A
208669244	12/2018	CN	N/A
109555484	12/2018	CN	N/A
109682881	12/2018	CN	N/A
208730959	12/2018	CN	N/A
208735264	12/2018	CN	N/A
208746733	12/2018	CN	N/A
208749529	12/2018	CN	N/A
208750405	12/2018	CN	N/A
208764658	12/2018	CN	N/A
109736740	12/2018	CN	N/A
109751007	12/2018	CN	N/A
208868428	12/2018	CN	N/A
208870761	12/2018	CN	N/A

109869294	12/2018	CN	N/A
109882144	12/2018	CN	N/A
109882372	12/2018	CN	N/A
209012047	12/2018	CN	N/A
209100025	12/2018	CN	N/A
110080707	12/2018	CN	N/A
110118127	12/2018	CN	N/A
110124574	12/2018	CN	N/A
110145277	12/2018	CN	N/A
110145399	12/2018	CN	N/A
110152552	12/2018	CN	N/A
110155193	12/2018	CN	N/A
110159225	12/2018	CN	N/A
110159432	12/2018	CN	N/A
110159433	12/2018	CN	N/A
110208100	12/2018	CN	N/A
110252191	12/2018	CN	N/A
110284854	12/2018	CN	N/A
110284972	12/2018	CN	N/A
209387358	12/2018	CN	N/A
110374745	12/2018	CN	N/A
209534736	12/2018	CN	N/A
110425105	12/2018	CN	N/A
110439779	12/2018	CN	N/A
110454285	12/2018	CN	N/A
110454352	12/2018	CN	N/A
110467298	12/2018	CN	N/A
110469312	12/2018	CN	N/A
110469314	12/2018	CN	N/A
110469405	12/2018	CN	N/A
110469654	12/2018	CN	N/A
110485982	12/2018	CN	N/A
110485983	12/2018	CN	N/A
110485984	12/2018	CN	N/A
110486249	12/2018	CN	N/A
110500255	12/2018	CN	N/A
110510771	12/2018	CN	N/A
110513097	12/2018	CN	N/A
209650738	12/2018	CN	N/A
209653968	12/2018	CN	N/A
209654004	12/2018	CN	N/A
209654022	12/2018	CN	N/A
209654128	12/2018	CN	N/A
209656622	12/2018	CN	N/A
107849130	12/2018	CN	N/A
110566173	12/2018	CN	N/A
110608030	12/2018	CN	N/A
110617187	12/2018	CN	N/A
110617188	12/2018	CN	N/A
110617318	12/2018	CN	N/A
209740823	12/2018	CN	N/A
209780827	12/2018	CN	N/A
209798631	12/2018	CN	N/A
209799942	12/2018	CN	N/A
209800178	12/2018	CN	N/A
209855723	12/2018	CN	N/A
209855742	12/2018	CN	N/A
209875063	12/2018	CN	N/A
110656919	12/2019	CN	N/A
110787667	12/2019	CN	N/A
110821464	12/2019	CN	N/A
110833665	12/2019	CN	N/A
110848028	12/2019	CN	N/A
210049880	12/2019	CN	N/A
210049882	12/2019	CN	N/A
210097596	12/2019	CN	N/A

210105817	12/2019	CN	N/A
210105818	12/2019	CN	N/A
210105993	12/2019	CN	N/A
110873093	12/2019	CN	N/A
210139911	12/2019	CN	N/A
110947681	12/2019	CN	N/A
111058810	12/2019	CN	N/A
111075391	12/2019	CN	N/A
210289931	12/2019	CN	N/A
210289932	12/2019	CN	N/A
210289933	12/2019	CN	N/A
210303516	12/2019	CN	N/A
111089003	12/2019	CN	N/A
111151186	12/2019	CN	N/A
111167769	12/2019	CN	N/A
111169833	12/2019	CN	N/A
111173476	12/2019	CN	N/A
111185460	12/2019	CN	N/A
111185461	12/2019	CN	N/A
111188763	12/2019	CN	N/A
111206901	12/2019	CN	N/A
111206992	12/2019	CN	N/A
111206994	12/2019	CN	N/A
210449044	12/2019	CN	N/A
210460875	12/2019	CN	N/A
210522432	12/2019	CN	N/A
210598943	12/2019	CN	N/A
210598945	12/2019	CN	N/A
210598946	12/2019	CN	N/A
210599194	12/2019	CN	N/A
210599303	12/2019	CN	N/A
210600110	12/2019	CN	N/A
111219326	12/2019	CN	N/A
111350595	12/2019	CN	N/A
210660319	12/2019	CN	N/A
210714569	12/2019	CN	N/A
210769168	12/2019	CN	N/A
210769169	12/2019	CN	N/A
210769170	12/2019	CN	N/A
210770133	12/2019	CN	N/A
210825844	12/2019	CN	N/A
210888904	12/2019	CN	N/A
210888905	12/2019	CN	N/A
210889242	12/2019	CN	N/A
111397474	12/2019	CN	N/A
111412064	12/2019	CN	N/A
111441923	12/2019	CN	N/A
111441925	12/2019	CN	N/A
111503517	12/2019	CN	N/A
111515898	12/2019	CN	N/A
111594059	12/2019	CN	N/A
111594062	12/2019	CN	N/A
111594144	12/2019	CN	N/A
211201919	12/2019	CN	N/A
211201920	12/2019	CN	N/A
211202218	12/2019	CN	N/A
111608965	12/2019	CN	N/A
111664087	12/2019	CN	N/A
111677476	12/2019	CN	N/A
111677647	12/2019	CN	N/A
111692064	12/2019	CN	N/A
111692065	12/2019	CN	N/A
211384571	12/2019	CN	N/A
211397553	12/2019	CN	N/A
211397677	12/2019	CN	N/A
211412945	12/2019	CN	N/A

211500955	12/2019	CN	N/A
211524765	12/2019	CN	N/A
4004854	12/1990	DE	N/A
4241614	12/1993	DE	N/A
102009022859	12/2009	DE	N/A
102012018825	12/2013	DE	N/A
102013111655	12/2013	DE	N/A
102015103872	12/2014	DE	N/A
102013114335	12/2019	DE	N/A
0835983	12/1997	EP	N/A
1378683	12/2003	EP	N/A
2143916	12/2009	EP	N/A
2613023	12/2012	EP	N/A
3095989	12/2015	EP	N/A
3211766	12/2016	EP	N/A
3049642	12/2017	EP	N/A
3354866	12/2017	EP	N/A
3075946	12/2018	EP	N/A
2795774	12/2000	FR	N/A
474072	12/1936	GB	N/A
1438172	12/1975	GB	N/A
S57135212	12/1981	JP	N/A
20020026398	12/2001	KR	N/A
13562	12/1999	RU	N/A
9320328	12/1992	WO	N/A
2006025886	12/2005	WO	N/A
2009023042	12/2008	WO	N/A
2011119668	12/2010	WO	N/A
2011133821	12/2010	WO	N/A
2012139380	12/2011	WO	N/A
2013158822	12/2012	WO	N/A
WO-2013163786	12/2012	WO	N/A
2013185399	12/2012	WO	N/A
2015073005	12/2014	WO	N/A
2015158020	12/2014	WO	N/A
2016014476	12/2015	WO	N/A
2016033983	12/2015	WO	N/A
2016078181	12/2015	WO	N/A
2016086138	12/2015	WO	N/A
2016101374	12/2015	WO	N/A
2016112590	12/2015	WO	N/A
2016186790	12/2015	WO	N/A
2017146279	12/2016	WO	N/A
2017123656	12/2016	WO	N/A
2017213848	12/2016	WO	N/A
2018031031	12/2017	WO	N/A
2018031029	12/2017	WO	N/A
2018038710	12/2017	WO	N/A
2018044293	12/2017	WO	N/A
2018044307	12/2017	WO	N/A
2018071738	12/2017	WO	N/A
2018075034	12/2017	WO	N/A
2018084871	12/2017	WO	N/A
2018101912	12/2017	WO	N/A
2018106210	12/2017	WO	N/A
2018106225	12/2017	WO	N/A
2018106252	12/2017	WO	N/A
2018125176	12/2017	WO	N/A
2018132106	12/2017	WO	N/A
2018101909	12/2017	WO	N/A
2018152051	12/2017	WO	N/A
2018156131	12/2017	WO	N/A
2018160171	12/2017	WO	N/A
2018187346	12/2017	WO	N/A
2019045691	12/2018	WO	N/A
2019046680	12/2018	WO	N/A

2019060922	12/2018	WO	N/A
2019117862	12/2018	WO	N/A
2019126742	12/2018	WO	N/A
2019147601	12/2018	WO	N/A
2019169366	12/2018	WO	N/A
2019195651	12/2018	WO	N/A
2019200510	12/2018	WO	N/A
2019210417	12/2018	WO	N/A
2020018068	12/2019	WO	N/A
2020046866	12/2019	WO	N/A
2020076569	12/2019	WO	N/A
2020097060	12/2019	WO	N/A
2020104088	12/2019	WO	N/A
2020072076	12/2019	WO	N/A
2020131085	12/2019	WO	N/A
2020211083	12/2019	WO	N/A
2020211086	12/2019	WO	N/A
2021038604	12/2020	WO	N/A
2021041783	12/2020	WO	N/A

OTHER PUBLICATIONS

Green Field Energy Services Natural Gas Driven Turbine Frac Pumps HHP Summit Presentation, Yumpu (Sep. 2012), https://www.yumpu.com/en/document/read/49685291/turbine-frac-pump-assembly-hhp (“Green Field”). cited by applicant

Halliburton, Vessel-based Modular Solution (VMS), 2015. cited by applicant

HCI Jet Frac, Screenshots from YouTube, Dec. 11, 2010. https://www.youtube.com/watch?v=6HjXkdbFaFQ. cited by applicant

Hydraulic Fracturing: Gas turbine proves successful in shale gasfield operations, Vericor (2017), https://www.vericor.com/wp-content/uploads/2020/02/7.-Fracing-4500hp-Pump-China-En.pdf (“Vericor Case Study”). cited by applicant

Ibragimov, ?.S., Use of gas turbine engines in oil field pumping units; Chem Petrol Eng; (1994) 30: 530. https://doi.org/10.1007/BF01154919. (Translated from Khimicheskaya i Neftyanoe Mashinostroenie, No. 11, pp. 24-26, Nov. 1994.). cited by applicant

IHS Markit Standards Store, https://global.ihs.com/doc_ detail.cfm?document_name=API%20STD%20674&item_s_key=00010672#doc-detail-history-anchor, accessed Dec. 30, 2021; and https://global.ihs.com/doc_detail.cfm?&input_doc _number=671&input_doc_title=&document_name=API%20STD%20671&item_s_key=00010669&item_key_date=890331&origin=DSSC accessed Dec. 30, 2021. cited by applicant

II-VI Marlow Industries, Thermoelectric Technologies in Oil, Gas, and Mining Industries, blog.marlow.com (Jul. 24, 2019). cited by applicant

Integrated Flow, Skid-mounted Modular Process Systems, Jul. 15, 2017, https://ifsolutions.com/why-modular/. cited by applicant

ISM, What is Cracking Pressure, 2019. cited by applicant

J. Porteiro et al., Feasibility of a new domestic CHP trigeneration with heat pump: II. Availability analysis. Design and development, Applied Thermal Engineering 24 (2004) 1421-1429. cited by applicant

JBG Enterprises, Inc., WS-Series Blowout Prevention Safety Coupling—Quick Release Couplings, Sep. 11, 2015, http://www.jgbhose.com/products/WS-Series-Blowout-Prevention-Safety-Coupling.asp. cited by applicant

Jereh Apollo 4500 Turbine Frac Pumper Finishes Successful Field Operation in China, Jereh Group (Feb. 13, 2015), as available on Apr. 20, 2015, https://web.archive.org/web/20150420220625/https://www. prnewswire.com/news-releases/jereh-apollo-4500-turbine-frac-pumper-finishes-successful-field-operation-in-china-300035829.html. cited by applicant

Jereh Apollo Turbine Fracturing Pumper Featured on China Central Television, Jereh Group (Mar. 9, 2018), https://www.jereh.com/en/news/press-release/news-detail-7267.htm. cited by applicant

Jereh Debut's Super power Turbine Fracturing Pump, Leading the Industrial Revolution, Jereh Oilfield Services Group (Mar. 19, 2014), https://www.prnewswire.com/news-releases/jereh-debuts-super-power-turbine-fracturing-pump-leading-the-industrial-revolution-250992111.html. cited by applicant

Jereh Group, Jereh Fracturing Equipment. YouTube (Jun. 8, 2015), https://www.youtube.com/watch?v=m0vMiq84P4Q. cited by applicant

Jereh Group, Jereh Fracturing Unit, Fracturing Spread, YouTube (Mar. 30, 2015), https://www.youtube.com/watch?v=PlkDbU5dE0o. cited by applicant

Jereh Unveiled New Electric Fracturing Solution at OTC 2019, Jereh Group (May 7, 2019), as available on May 28, 2019, https://web.archive.org/web/20190528183906/https://www.prnewswire .com/news-releases/jereh-unveiled-new-electric-fracturing-solution-at-otc-2019-300845028.html. cited by applicant

Jp Yadav et al., Power Enhancement of Gas Turbine Plant by Intake Air Fog Cooling, Jun. 2015. cited by applicant

Karassik, Igor, Joseph Messina, Paul Cooper, and Charles Heald. Pump Handbook. 4th ed. New York: McGraw-Hill Education, 2008. cited by applicant

Karen Boman, Turbine Technology Powers Green Field Multi-Fuel Frack Pump, Rigzone (Mar. 7, 2015), as available on Mar. 14, 2015, https://web.archive.org/web/20150314203227/https://www.rigzone.com/news/oil-gas/a/124883/Turbine_Technology_Powers_Green_Field_MultiFuel_Frack_Pump. cited by applicant

Kas'yanov et al., Application of gas-turbine engines in pumping units complexes of hydraulic fracturing of oil and gas reservoirs; Exposition Oil & Gas; (Oct. 2012) (published in Russian). cited by applicant

Lekontsev, Yu M., et al. “Two-side sealer operation.” Journal of Mining Science 49.5 (2013): 757-762. cited by applicant

Leslie Turj, Green Field asset sale called ‘largest disposition industry has seen,’ The INDsider Media (Mar. 19, 2014), http://theind.com/

article-16497-green-field-asset-sale-called-%E2%80%98largest-disposition-industry-has-seen%60.html. cited by applicant
M. Ahmadzadehtalatapeh et al. Performance enhancement of gas turbine units by retrofitting with inlet air cooling technologies (IACTs): a hour-by-hour simulation study, Journal of the Brazilian Society of Mechanical Sciences and Engineering, Mar. 2020. cited by applicant
Marine Turbine Technologies, 1 MW Power Generation Package, http://marineturbine.com/power-generation, 2017. cited by applicant
Marine Turbine. Turbine Powered Frac Units. Franklin, Louisiana: Marine Turbine Technologies, 2020. cited by applicant
Mee Industries: Inlet Air Fogging Systems for Oil, Gas and Petrochemical Processing, Verdict Media Limited Copyright 2020. cited by applicant
Mobile Fuel Delivery, atlasoil.com. Mar. 6, 2019. https://www.atlasoil.com/nationwide-fueling/onsite-and-mobile-fueling. cited by applicant
Neal, J.C. (Gulf Oil Corp. Odessa Texas), Gas Turbine Driven Centrifugal Pumps for High Pressure Water Injection; American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.; SPE-1888 (1967). cited by applicant
Overview of Industry Guidance/Best Practices on Hydraulic Fracturing (HF), American Petroleum Institute, © 2012. cited by applicant
PbNG, Natural Gas Fuel for Drilling and Hydraulic Fracturing, Diesel Displacement / Dual Fuel & Bi-Fuel, May 2014. cited by applicant
Pettigrew, Dana, et al., High Pressure Multi-Stage Centrifugal Pump for 10,000 psi Frac Pump—HPHPS Frac Pump, Copyright 2013, Society of Petroleum Engineers, SPE 166191. cited by applicant
Plos One, Dynamic Behavior of Reciprocating Plunger Pump Discharge Valve Based on Fluid Structure Interaction and Experimental Analysis. Oct. 21, 2015. cited by applicant
Porter, John A. (Solar Division International Harvester Co.), Modern Industrial Gas Turbines for the Oil Field; American Petroleum Institute; Drilling and Production Practice; API-67-243 (Jan. 1, 1967). cited by applicant
PowerShelter Kit II, nooutage.com, Sep. 6, 2019. cited by applicant
Procedures for Standards Development, American Petroleum Institute, Third Edition (2006). cited by applicant
Publications, American Petroleum Institute, WaybackMachine Capture, https://web.archive.org/web/20110427043936 / http://www.api.org:80/Publications/, captured Apr. 27, 2011. cited by applicant
Pump Control With Variable Frequency Drives, Kevin Tory, Pumps & Systems: Advances in Motors and Drives, Reprint from Jun. 2008. cited by applicant
Researchgate, Answer by Byron Woolridge, found at https://www.researchgate.net/post/How_can_we_improve_the_efficiency_of_the_gas_turbine_cycles, Jan. 1, 2013. cited by applicant
Review of HHP Summit 2012, Gladstein, Neandross & Associates https://www.gladstein.org/gna-conferences/high-horsepower-summit-2012/. cited by applicant
Rigmaster Machinery Ltd., Model: 2000 RMP-6-PLEX, brochure, downloaded at https://www.rigmastermachinery.com/_files/ugd/431e62_eaecd77091e54af8b13d08396072da67.pdf. cited by applicant
Rotating Right. Quintuplex Power Pump Model Q700. Edmonton, Alberta, Canada: Weatherford International Ltd. https://www.rotatingright.com/pdf/weatherford/RR%2026-Weatherford%20Model%20Q700.pdf, 2021. cited by applicant
Shandong Saigao Group Corporation. Q4 (5W115) Quintuplex Plunger Pump. Jinan City, Shandong Province, China; Saigao. Oct. 20, 2014. https://www.saigaogroup.com/product/q400-5w115-quintuplex-plunger-pump.html. cited by applicant
Special-Purpose Couplings for Petroleum, Chemical, and Gas Industry Services, API Standard 671 (4th Edition) (2010). cited by applicant
SPM® QEM 5000 E-Frac Pump Specification Sheet, Weir Group (2019) (“Weir 5000”). cited by applicant
Standards, American Petroleum Institute, WaybackMachine Capture, https://web.archive.org/web/20110207195046/http:/www.api.org/Standards/, captured Feb. 7, 2011; and https://web.archive.org/web/20110204112554/http://global.ihs.com/?RID=API1, captured Feb. 4, 2011. cited by applicant
Swagelok, The right valve for controlling flow direction? Check, 2016. cited by applicant
Technology.org, Check valves how do they work and what are the main type, 2018. cited by applicant
The Application of Flexible Couplings for Turbomachinery, Jon R.Mancuso et al., Proceedings of the Eighteenthturbomachinery Symposium (1989). cited by applicant
The Leader in Frac Fueling, suncoastresources.com. Jun. 29, 2015. https://web.archive.org/web/20150629220609/https://www.suncoastresources.com/oilfield/fueling-services/. cited by applicant
The Weir Group, Inc. Weir SPM Pump Product Catalog. Ft. Worth, TX: S.P.M. Flow Control, Inc. Oct. 30, 2017. https://manage.global.weir/assets/files/product%20brochures/SPM_2P140706_Pump_Product_Catalogue_View.pdf. cited by applicant
Tom Hausfeld, GE Power & Water, and Eldon Schelske, Evolution Well Services, TM2500+ Power for Hydraulic Fracturing. cited by applicant
Transcript of Jereh Group, Jereh Fracturing Equipment, YouTube (Jun. 8, 2015), https://www.youtube.com/watch?v=m0vMiq84P4Q. cited by applicant
Transcript of Jereh Group, Jereh Fracturing Unit, Fracturing Spread, YouTube (Mar. 30, 2015). cited by applicant
US 11,555,493, 1/2023, Chang et al. (withdrawn) cited by applicant
Wallace, E.M., Associated Shale Gas: From Flares to Rig Power, Copyright 2015, Society of Petroleum Engineers, SPE-173491-MS. cited by applicant
Walzel, Brian, Hart Energy, Oil, Gas Industry Discovers Innovative Solutions to Environmental Concerns, Dec. 10, 2018. cited by applicant
Weir Oil & Gas Introduces Industry's First Continuous Duty 5000-Horsepower Pump, Weir Group (Jul. 25, 2019), https://www.global.weir/newsroom/news-articles/weir-oil-and-gas-introduces-industrys-first-continuous-duty-5000-horsepower-pump/. cited by applicant
Weir SPM. Weir SPM General Catalog: Well Service Pumps, Flow Control Products, Manifold Trailers, Safety Products, Post Sale Services. Ft. Worth, TX: Weir Oil & Gas. May 28, 2016. https://www.pumpfundamentals.com/pumpdatabase2/weir-spm-general.pdf. cited by applicant
Wikipedia, Westinghouse Combustion Turbine Systems Division, https://en.wikipedia.org/wiki/Westinghouse_Combustion_Turbine_Systems_Division, circa 1960. cited by applicant
Wikipedia, Union Pacific GTELs, https://en.wikipedia.org/wiki/Union_Pacific_GTELs, circa 1950. cited by applicant
Williams, C.W. (Gulf Oil Corp. Odessa Texas), The Use of Gas-turbine Engines in an Automated High-Pressure Water-Injection Stations; American Petroleum Institute; API-63-144 (Jan. 1, 1963). cited by applicant

Wolf, J?rgen J., and Marko A. Perkavec. “Safety Aspects and Environmental Considerations for a 10 MW Cogeneration Heavy Duty Gas Turbine Burning Coke Oven Gas with 60% Hydrogen Content.” ASME 1992 International Gas Turbine and Aeroengine Congress and Exposition. American Society of Mechanical Engineers Digital Collection, 1992. cited by applicant
WorldCat Library Collections Database Records for API Standard 671 and API Standard 674, https://www.worldcat.org/title/positive-displacement-pumps-reciprocating/oclc/ 858692269&referer=brief_results, accessed Dec. 30, 2021; and https://www.worldcat.org/title/special-purpose-couplings-for-petroleum-chemical-and-gas-industry-services/bclc/871254217&referer=brief_results, accessed Dec. 22, 2021. cited by applicant
ZSi-Foster, Energy | Solar | Fracking | Oil and Gas, Aug. 2020, https://www.zsi-foster.com/energy-solar-fracking-oil-and-gas.html. cited by applicant
“Turbine Frac Units,” WMD Squared (2012), https://wmdsquared.com/work/gfes-turbine-frac-units/. cited by applicant
“Honghua developing new-generation shale-drilling rig, plans testing of frac pump”; Katherine Scott; Drilling Contractor; May 23, 2013; accessed at https://www.drillingcontractororg/honghua-developing-new-generation-shale-drilling-rig-plans-testing-of-frac-pump-23278. cited by applicant
2011 Publications and Services, American Petroleum Institute (2011). cited by applicant
2012 High Horsepower Summit Agenda, Natural Gas for High Horsepower Applications (Sep. 5, 2012). cited by applicant
35% Economy Increase, Dual-fuel System Highlighting Jereh Apollo Frac Pumper, Jereh Group (Apr. 13, 2015), https://www.jereh.com/en/news/press-release/news-detail-7345.htm. cited by applicant
About API, American Petroleum Institute, https://www.api.org /about, accessed Dec. 30, 2021. cited by applicant
About API, American Petroleum Institute, WaybackMachine Capture, https://web.archive.org/web/20110422104346 / http://api.org/aboutapi/, captured Apr. 22, 2011. cited by applicant
Advances in Popular Torque-Link Solution Offer OEMs Greater Benefit, Jun. 21, 2018. cited by applicant
AFD Petroleum Ltd., Automated Hot Zone, Frac Refueling System, Dec. 2018. cited by applicant
AFGlobal Corporation, Durastim Hydraulic Fracturing Pump, A Revolutionary Design for Continuous Duty Hydraulic Fracturing, 2018. cited by applicant
American Petroleum Institute. API 616: Gas Turbines for the Petroleum, Chemical, and Gas Industry Services. 5th ed. Washington, DC: API Publishing Services, 2011. cited by applicant
American Petroleum Institute. API 674: Positive Displacement Pumps—Reciprocating. 3rd ed. Washington, DC: API Publishing Services, 2010. cited by applicant
Ankit Tiwari, Design of a Cooling System for a Hydraulic Fracturing Equipment, The Pennsylvania State University, The Graduate School College of Engineering, 2015. cited by applicant
API Member Companies, American Petroleum Institute, WaybackMachine Capture, https://web.archive.org/web/20130424080625/http://api.org/globalitems/globalheaderpages/membership/api-member-companies, accessed Jan. 4, 2021. cited by applicant
API's Global Industry Services, American Petroleum Institute, © Aug. 2020. cited by applicant
Arop, Julius Bankong. Geomechanical review of hydraulic fracturing technology. Thesis (M. Eng.). Cambridge, MA: Massachusetts Institute of Technology, Dept. of Civil and Environmental Engineering. Oct. 29, 2013. https://dspace.mit.edu/handle/1721.1/82176. cited by applicant
B.M. Mahlalela, et al., .Electric Power Generation Potential Based on Waste Heat and Geothermal Resources in South Africa, pangea.Stanford.edu (Feb. 11, 2019). cited by applicant
Blago Minovski, Coupled Simulations of Cooling and Engine Systems for Unsteady Analysis of the Benefits of Thermal Engine Encapsulation, Department of Applied Mechanics, Chalmers University of Technology G{umlaut over ( )} oteborg, Sweden 2015. cited by applicant
Business Week: Fiber-optic cables help fracking, cablinginstall.com. Jul. 12, 2013. https://www.cablinginstall.com/cable/article/16474208/businessweek-fiberoptic-cables-help-fracking. cited by applicant
Cameron, A Schlumberger Company, Frac Manifold Systems, 2016. cited by applicant
CanDyne Pump Services, Inc. Weatherford Q700 Pump. Calgary, Alberta, Canada: CanDyne Pump Services. Aug. 15, 2015. http://candyne.com/wp-content/uploads/2014/10//181905-94921.q700-quintuplex-pump.pdf. cited by applicant
Capstone Turbine Corporation, Capstone Receives Three Megawatt Order from Large Independent Oil & Gas Company in Eagle Ford Shale Play, Dec. 7, 2010. cited by applicant
Chaichan, Miqdam Tariq. “The impact of equivalence ratio on performance and emissions of a hydrogen-diesel dual fuel engine with cooled exhaust gas recirculation.” International Journal of Scientific & Engineering Research 6.6 (2015): 938-941. cited by applicant
Chun, M. K., H. K. Song, and R. Lallemand. “Heavy duty gas turbines in petrochemical plants: Samsung's Daesan plant (Korea) beats fuel flexibility records with over 95% hydrogen in process gas.” Proceedings of PowerGen Asia Conference, Singapore. 1999. cited by applicant
CNG Delivery, Fracturing with natural gas, dual-fuel drilling with CNG, Aug. 22, 2019. cited by applicant
Cooper et al., Jet Frac Porta-Skid—A New Concept in Oil Field Service Pump Equipments[sic]; Halliburton Services; SPE-2706 (1969). cited by applicant
De Gevigney et al., “Analysis of No. load dependent power losses in a planetary gear train by using thermal network method”, International Gear Conference 2014: Aug. 26-28, 2014, Lyon, pp. 615-624. cited by applicant
Department of Energy, United States of America, The Water-Energy Nexus: Challenges and Opportunities purenergypolicy.org (Jun. 2014). cited by applicant
Dowell B908 “Turbo-Jet” Operator's Manual. cited by applicant
Dziubak, Tadeusz, “Experimental Studies of Dust Suction Irregularity from Multi-Cyclone Dust Collector of Two-Stage Air Filter”, Energies 2021, 14, 3577, 28 pages. cited by applicant
Ecob, David J., et al. “Design and Development of a Landfill Gas Combustion System for the Typhoon Gas Turbine.” ASME 1996 International Gas Turbine and Aeroengine Congress and Exhibition. American Society of Mechanical Engineers Digital Collection, 1996. cited by applicant

Elle Seybold, et al., Evolution of Dual Fuel Pressure Pumping for Fracturing: Methods, Economics, Field Trial Results and Improvements i Availability of Fuel, Copyright 2013, Society of Petroleum Engineers, SPE 166443. cited by applicant
Emmanuel Akita et al., Mewbourne College of Earth & Energy, Society of Petroleum Engineers; Drilling Systems Automation Technical Section (DSATS); 2019. cited by applicant
EMPengineering.com, HEMP Resistant Electrical Generators / Hardened Structures HEMP/GMD Shielded Generators, Virginia, Nov. 3, 2012. cited by applicant
Europump and Hydrualic Institute, Variable Speed Pumping: A Guide to Successful Applications, Elsevier Ltd, 2004. cited by applicant
Eygun, Christiane, et al., URTeC: 2687987, Mitigating Shale Gas Developments Carbon Footprint: Evaluating and Implementing Solutions in Argentina, Copyright 2017, Unconventional Resources Technology Conference. cited by applicant
Ferdinand P. Beer et al., Mechanics of Materials (6th ed. 2012). cited by applicant
Filipovi?, Ivan, Preliminary Selection of Basic Parameters of Different Torsional Vibration Dampers Intended for use in Medium-Speed Diesel Engines, Transactions of Famena XXXVI-3 (2012). cited by applicant
Final written decision of PGR2021-00102 dated Feb. 6, 2023. cited by applicant
Final written decision of PGR2021-00103 dated Feb. 6, 2023. cited by applicant
FMC Technologies, Operation and Maintenance Manual, L06 Through L16 Triplex Pumps Doc No. OMM50000903 Rev: E p. 1 of 66. Aug 27, 2009. cited by applicant
Frac Shack, Bi-Fuel FracFueller brochure, 2011. cited by applicant
Frac Tank Hose (FRAC), 4starhose.com. Accessed: Nov. 10, 2019. http://www.4starhose.com/product/frac_tank_hose_frac.aspx. cited by applicant
Fracking companies switch to electric motors to power pumps, iadd-intl.org. Jun. 27, 2019. https://www.iadd-intl.org/articles/fracking-companies-switch-to-electric-motors-to-power-pumps/. cited by applicant
Fracture Design and Stimulation, Mike Eberhard, P.E., Wellconstruction & Operations Technical Workshop Insupport of the EPA Hydraulic Fracturing Study, Mar. 10-11, 2011. cited by applicant
FTS International's Dual Fuel Hydraulic Fracturing Equipment Increases Operational Efficiencies, Provides Cost Benefits, Jan. 3, 2018. cited by applicant
Gardner Denver Hydraulic Fracturing Pumps GD 3000 https://www.gardnerdenver.com/en-us/pumps/triplex-fracking-pump-gd-3000. cited by applicant
General Purpose vs. Special Purpose Couplings, Jon Mancuso, Proceedings of the Twenty-Third Turbomachinerysymposium (1994). cited by applicant
Ginter, Timothy, and Thomas Bouvay. “Uprate options for the MS7001 heavy duty gas turbine.” GE paper GER-3808C, GE Energy 12 (2006). cited by applicant
Green Field Energy Services Deploys Third New Hydraulic Fracturing System, Green Field Energy Services, Inc. (Jul. 11, 2012), https://www.prnewswire.com/news-releases/green-field-energy-services-deploys-third-new-hydraulic-fracturing-spread-162113425. cited by applicant

---

Primary Examiner: Sayre; James G

Attorney, Agent or Firm: Norton Rose Fulbright US LLP

Background/Summary

PRIORITY CLAIM (1) This is a continuation of U.S. Non-Provisional application Ser. No. 17/991,007, filed Nov. 21, 2022, titled “METHODS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT,” now U.S. Pat. No. 11,939,854 issued Mar. 26, 2024, which is a continuation of U.S. Non-Provisional application Ser. No. 17/355,920, filed Jun. 23, 2021, titled “METHODS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT,” now U.S. Pat. No. 11,566,506 issued Jan. 31, 2023, which is continuation of U.S. Non-Provisional application Ser. No. 17/303,841, filed Jun. 9, 2021, titled “METHODS AND SYSTEMS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT,” now U.S. Pat. No. 11,208,881, issued Dec. 28, 2021, which is a continuation of U.S. Non-Provisional application Ser. No. 17/182,408, filed Feb. 23, 2021, titled “METHODS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT,” now U.S. Pat. No. 11,066,915, issued Jul. 20, 2021, which claims priority to and the benefit of U.S. Provisional Application No. 62/705,050, filed Jun. 9, 2020, titled “METHODS AND SYSTEMS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT,” the disclosures of which are incorporated herein by reference in their entireties.

TECHNICAL FIELD
(1) The application generally relates to mobile power units and, more specifically, drive equipment and methods for usage, installation on, and controls for mobile fracturing transportation platforms.
BACKGROUND
(2) Hydrocarbon exploration and energy industries employ various systems and operations to accomplish activities including drilling, formation evaluation, stimulation and production. Measurements such as temperature, pressure, and flow measurements are typically performed to monitor and assess such operations. During such operations, problems or situations may arise that may have a detrimental effect on the operation, equipment, and/or safety of operators. For example, during a stimulation or fracturing operation, screen out conditions may occur, which may cause rapid pressure increases that may compromise the operation and/or damage equipment.
SUMMARY
(3) Embodiment of systems, methods, and controllers that control the operation to detect and mitigate screen outs such that screen

outs are avoided, for example, may save time, may increase awareness of conditions within the well, and may increase safety at a wellsite hydraulic fracturing pumper system. For example, Applicant has recognized that a controller detecting and mitigating screen outs may avoid packing of a well and avoid the need for additional operations to stimulate a well, e.g., wire line operations. In addition, a controller that avoids rapid pressure increases associated with screen outs may reduce stress on fracturing equipment including power end assemblies, shocking of prime movers and gearing systems associated therewith, and piping of the well. Further, the methods and systems detailed herein may prevent energy release in the form of release pressure through a pressure relief valve, e.g., a wellhead or manifold pressure relief valve. Avoiding pressure release from a pressure valve may also increase the safety of the wellhead, for example, by not over pressuring a wellhead.

(4) Applicant also has recognized that a controller that detects and mitigates screen outs may also increase awareness of conditions within the well by detecting a rate of pressure increase more accurately and at a more frequent rate than with manual control. In some embodiments, the controller may prewarn by one or more tiers of pressure increase rates such that an operator may manually adjust proppant concentration or take other measures to avoid screen outs before the controller intervenes as would be appreciated by those skilled in the art. The controller may also control the blender and the fracturing pump with a single command such that an operator is not required to sequence both elements in a safe manner to avoid damage to equipment, e.g., via cavitation, and to avoid screen out.

(5) In accordance with an embodiment of the present disclosure, a method of detecting and mitigating well screen out at a fracturing well site during hydrocarbon production may include operating a fracturing pump to supply fluid at a discharge rate to a wellhead at a fracturing well site. The method also may include operating a blender positioned to deliver a blend of proppant and fluid to the fracturing pump. A fluid pressure of the fluid supplied to the wellhead may be measured and a fluid pressure increase rate of the fluid may be determined from the fluid pressure. The fluid pressure increase rate may be compared to a preselected increase rate indicative of a potential well screen out. When the fluid pressure increase rate exceeds the preselected increase rate and the fluid pressure is within a preselected percentage of a maximum wellhead pressure of the well head, the discharge rate of the fracturing pumps may be incrementally decreased until the fluid pressure increase rate is stabilized. Stabilizing the fluid pressure increase rate may include the fluid pressure increase rate being equal to or less than zero.

(6) In accordance with another embodiment of the present disclosure, a wellsite hydraulic fracturing pumper system may include one or more fracturing pumps, a blender, a pressure transducer, and a controller. The one or more fracturing pumps may be configured to provide fluid to a wellhead when positioned a hydrocarbon well site. The blender may be configured to provide fluid and proppant to the one or more fracturing pumps. The pressure transducer may be positioned adjacent an output of the one or more fracturing pumps or at the wellhead. The pressure transducer may be configured to measure a fluid pressure of the fluid provided to the wellhead. The controller may control the one or more fracturing pumps and the blender. The controller may be positioned in signal communication with the pressure transducer such that the controller receives the fluid pressure of the fluid provided to the wellhead. The controller may include memory, a processor to process data, and a screen out detection and mitigation protocol program stored in the memory and responsive to the process and in which the protocol of the controller may incrementally decrease a discharge rate of the one or more fracturing pumps and a flow rate of the blender in response to a fluid pressure increase rate of the fluid suppled to the wellhead being greater than a preselected increase rate and the fluid pressure of the fluid provided to the wellhead being greater than a preselected percentage of a maximum wellhead pressure until the fluid pressure is stabilized.

(7) In yet another embodiment of the present disclosure, a controller for a hydraulic fracturing pumper system may include a pressure input, a first control output, and a second control output. The pressure input may be in signal communication with a pressure transducer that measures a fluid pressure of a fluid being provided to a wellhead. The first control output may be in signal communication with a fracturing pump such that the controller provides pump control signals to the fracturing pump to control a discharge rate of the fracturing pump. The second control output may be in signal communication with a blender such that the controller provides blender control signals to the blender to control a flow rate of the blender and delivery of a proppant from the blender. The controller may be configured to calculate a fluid pressure increase rate of the fluid pressure, compare the fluid pressure increase rate of the fluid pressure to a preselected increase rate, and incrementally decrease a discharge rate of the fracturing pump and a flow rate of the blender when the fluid pressure increase rate is greater than the preselected increase rate and the fluid pressure is within a preselected percentage of a maximum wellhead pressure of the wellhead until the fluid pressure of the fluid is supplied to the wellhead is stabilized.

(8) Those skilled in the art will appreciate the benefits of various additional embodiments reading the following detailed description of the embodiments with reference to the below-listed drawing figures. It is within the scope of the present disclosure that the above-discussed embodiments and aspects be provided both individually and in various combinations.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The accompanying drawings, which are included to provide a further understanding of the embodiments of the present disclosure, are incorporated in and constitute a part of this specification, and together with the detailed description, serve to explain the principles of the embodiments discussed herein. The present disclosure may be more readily described with reference to the accompanying drawings.

(2) FIG. **1** is a schematic view of a wellsite hydraulic fracturing pumper system according to an embodiment of the disclosure.

(3) FIG. **2** is a schematic view of a control system of the wellsite hydraulic fracturing pumper system of FIG. **1**.

(4) FIG. **3** is a flowchart of a method of detecting and mitigating a well screen out of a well according to an embodiment of the present disclosure.

(5) Corresponding parts are designated by corresponding reference numbers throughout the drawings.

DETAILED DESCRIPTION

(6) The present disclosure will now be described more fully hereinafter with reference to example embodiments thereof with reference to the drawings in which like reference numerals designate identical or corresponding elements in each of the several views. These example embodiments are described so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Features from one embodiment or aspect may be combined with features from any other embodiment or aspect in any appropriate combination. For example, any individual or collective features of method aspects or embodiments may be applied to apparatus, product, or component aspects or embodiments and vice versa. The disclosure may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. As used in the specification and the appended claims, the singular forms “a,” “an,” “the,” and the like include plural referents unless the context clearly dictates otherwise. In addition, while reference may be made herein to quantitative measures, values, geometric relationships or the like, unless otherwise stated, any one or more if not all of these may be absolute or approximate to account for acceptable variations that may occur, such as those due to manufacturing or engineering tolerances or the like.
(7) Embodiments of the present disclosure are directed to methods and systems for detecting and mitigating well screen outs during the operations of wellsite hydraulic fracturing pumping systems during the production of hydrocarbons. The methods and systems detailed herein may be executed on a controller that provides alerts or alarms to an operator of a potential well screen out and may intervene to prevent the fluid pressure provided to the well from exceeding a maximum well pressure.
(8) FIG. **1** illustrates an exemplary wellsite hydraulic fracturing pumper system **1000** that is provided in accordance with an embodiment of the present disclosure. The wellsite hydraulic fracturing pumper system **1000** includes a plurality of mobile power units **100** arranged around a wellhead **10** to supply the wellhead **10** with high-pressure fracturing fluids and recover oil and/or gas from the wellhead **10** as will be understood by those skilled in the art. As shown, some of the mobile power units **100**, e.g., mobile power units **100***a*, drive a hydraulic fracturing pump **200** that discharges high pressure fluid to a manifold **20** such that the high pressure fluid is provided to the wellhead **10**. Additionally, some of the mobile power units **100**, e.g., mobile power units **100***b*, drive an electrical generator **300** that provides electrical power to the wellsite hydraulic fracturing pumper system **1000**.
(9) The wellsite hydraulic fracturing pumper system **1000** also includes a blender unit **410**, a hydration unit **420**, or a chemical additive unit **430** which may be referred to generally as backside equipment **400**. Specifically, the blender unit **410** provides a flow of fluid to the fracturing pumps **200** which is pressurized by and discharged from the fracturing pumps **200** into the manifold **20**. The blender unit **410** may include one or more screw conveyors **412** that provides proppant to a mixer **416** of the blender unit **410**. The blender unit **410** also includes a discharge pump **418** that draws fluid from the mixer **416** such that a flow of fluid is provided from the blender unit **410** to the fracturing pumps **200**. The fluid from the mixer **416** may include proppant provided by the screw conveyors **412** and/or chemicals for the fluid of the fracturing pumps **200**. When blender unit **410** provides proppant to the fracturing pumps **200**, the proppant is in a slurry which may be considered a fluid as will be understood by those skilled in the art.
(10) The wellsite hydraulic fracturing pumper system **1000** includes a supervisory control unit that monitors and controls operation of the mobile power units **100***a* driving the fracturing pumps **200**, the mobile power units **100***b* driving electrical generators **300**, and the units **410**, **420**, **430** and may be referred to generally as controller **30**. The controller **30** may be a mobile control unit in the form of a trailer or a van, as appreciated by those skilled in the art. As used herein, the term “fracturing pump” may be used to refer to one or more of the hydraulic fracturing pumps **200** of the hydraulic fracturing pumper system **1000**. In some embodiments, all of the hydraulic fracturing pumps **200** are controlled by the controller **30** such that to an operator of the controller **30**, the hydraulic fracturing pumps **200** are controlled as a single pump or pumping system.
(11) The controller **30** is in signal communication with the blender unit **410** to control the delivery of the proppant to the mixer **416** and a flow rate of fluid from the discharge pump **418** to the fracturing pumps **200**. The controller **30** is also in signal communication with the fracturing pumps **200** to control a discharge rate of fluid from the fracturing pumps **200** into the manifold **20**. In addition, the controller **30** is in signal communication with one or more sensors of the wellsite hydraulic fracturing pumper system **1000** to receive measurements or data with respect to the fracturing operation. For example, the controller **30** receives a measurement of pressure of the fluid being delivered to the wellhead **10** from a wellhead pressure transducer **13**, a manifold pressure transducer **23**, or a pump output pressure transducer **213**. The wellhead pressure transducer **13** is disposed at the wellhead **10** to measure a pressure of the fluid at the wellhead **10**. The manifold pressure transducer **23** is shown at an end of the manifold **20**. However, as understood by those skilled in the art, the pressure within the manifold **20** is substantially the same throughout the entire manifold **20** such that the manifold pressure transducer **23** may be disposed anywhere within the manifold **20** to provide a pressure of the fluid being delivered to the wellhead **10**. The pump output pressure transducer **213** is disposed adjacent an output of one of the fracturing pumps **200** which is in fluid communication with the manifold **20** and thus, the fluid at the output of the fracturing pumps **200** is at substantially the same pressure as the fluid in the manifold **20** and the fluid being provided to the wellhead **10**. Each of the fracturing pumps **200** may include a pump output pressure transducer **213** and the controller **30** may calculate the fluid pressure provided to the wellhead **10** as an average of the fluid pressure measured by each of the pump output pressure transducers **213**.
(12) The controller **30** is also in signal communication with sensors disposed about the blender unit **410**. For example, the blender unit **410** may include a blender screw encoder/pickup **411** that provides a rotation rate of the screw conveyors **412** of the blender unit **410** which provide proppant to the mixer **416** such that proppant is provided to the fracturing pumps **200**. When the screw conveyors **412** are not active or rotating, proppant is not being added to the mixer **416** such that no proppant is being provided to the fracturing pumps **200**. The blender unit **410** may include a blender flow meter **413** that measures a flow of fluid from the blender unit **410** to the fracturing pumps **200**.
(13) As used herein, “signal communication” refers to electric communication such as hard wiring two components together or wireless communication, as understood by those skilled in the art. For example, wireless communication may be Wi-Fi®, Bluetooth®, ZigBee, or forms of near field communications. In addition, signal communication may include one or more intermediate controllers or relays disposed between elements that are in signal communication with one another. For example, a pump output pressure transducer **213** may be in direct electrical communication with a pump controller (not explicitly shown) and the pump controller may be in direct electrical communication or wireless communication with a master controller (not explicitly

shown) of the mobile power unit **100** which is in electrical or wireless communication with the controller **30**.
(14) FIG. **2** illustrates a schematic of a control system for the wellsite hydraulic fracturing pumper system **1000** referred to generally as a control system **1010**. The control system **1010** includes the controller **30** that is in signal communication with the wellhead pressure transducer **13**, a manifold pressure transducer **23**, and a pump output transducer **213**. The controller **30** includes memory **32** and a processor **34**. The memory **32** may be loaded or preloaded with programs, e.g., detection and mitigation protocol programs as detailed below, that are executed on the processor **34**. The pump output transducer **213** may be in direct signal or electrical communication with a pump controller **215** which may be in direct signal or electrical communication with a mobile power unit controller **105** with the mobile power unit controller **105** in direct signal or electrical communication with the controller **30** such that the pump output transducer **213** is in signal communication with the controller **30**. In some embodiments, the pump output transducer is in direct signal communication with the controller **30**. The pump controller **215** is configured to control the fracturing pump **200** in response to commands signals provided by the controller **30** or the mobile power unit controller **30**. The pump controller **215** may include a pump profiler that records events experienced by the fracturing pump **200**. The recorded events may be used to schedule maintenance of the fracturing pump **200**.
(15) The control system **1010** may include a blender controller **419**, a blender flow meter **413**, and a blender screw encoder/pickup **411**. The blender flow meter **413** and the blender screw encoder/pickup **411** may be in direct signal or electrical communication with the blender controller **419** which may be in direct signal or electrical communication with the controller **30** such that the blender flow meter **413** and the blender screw encoder/pickup **411** are in signal communication with the controller **30**.
(16) FIG. **3** illustrates a method of detecting and mitigating well screen out for a hydraulic fracturing operation is described in accordance with embodiments of the present disclosure and is referred to generally as method **500**. The method **500** is detailed with reference to the wellsite hydraulic fracturing pumper system **1000** and the control system **1010** of FIGS. **1** and **2**. Unless otherwise specified, the actions of the method **500** may be completed within the controller **30**. Specifically, the method **500** may be included in one or more programs or protocols loaded into the memory **32** of the controller **30** and executed on the processor **34**. The well screen out protocol is activated (Step **501**) either automatically when the controller **30** is started or may be manually activated by an operator. When well screen out protocol is activated, a maximum wellhead pressure is provided to the controller **30** (Step **510**). The maximum wellhead pressure may be input by an operator into a human interface of the controller **30** or may be a preselected pressure programmed into the controller **30**. When the maximum wellhead pressure is provided by an operator, the controller may verify that the inputted maximum wellhead pressure is within a preselected range. If the inputted maximum wellhead pressure is outside of the preselected range, the controller **30** may display an alarm or reject the inputted maximum wellhead pressure and request another value be inputted by the operator and verify the new inputted maximum wellhead pressure until the inputted maximum wellhead pressure is within the preselected range. The preselected range may be in a range of up to 15,000 per square inch (psi), for example, as will be understood by those skilled in the art.
(17) With the maximum wellhead pressure, the controller **30** verifies that the wellsite hydraulic fracturing pumper system **1000** is in a pumping mode in which at least one of the fracturing pumps **200** is active and that the blender unit **410** is adding proppant to the fluid provided to the fracturing pumps **200** (Step **520**). The controller **30** may verify the blender unit **410** is adding proppant from verifying that one or more of the screw conveyors **412** is rotating via the blender screw encoder/pickups **411**. If either the wellsite hydraulic fracturing pumper system **1000** is not in a pumping mode or that the blender unit **410** is not adding proppant to the fluid being supplied to the fracturing pumps **200** the method **500** is terminated or deactivated. The method **500** may be reactivated manually or when the fracturing pumps **200** and the blender unit **410** are activated to provide fluid including proppant to the wellhead **10**.
(18) Continuing to refer to FIG. **3**, when the fracturing pumps **200** and the blender unit **410** are activated to provide fluid including proppant to the wellhead **10**, the controller **30** monitors a fluid pressure of fluid being provided to the wellhead **10** to detect a potential screen out within the well (Step **530**). The fluid pressure of the fluid provided to the wellhead **10** may be monitored from the wellhead pressure transducer **13**, the manifold pressure transducer **23**, the pump output pressure transducers **213**, or combinations thereof. To detect for a potential screen out within the well, the controller **30** monitors a rate of increase of the fluid pressure of fluid being provided to the wellhead **10** which is referred to as fluid pressure increase rate. The fluid pressure increase rate may be calculated by comparing the fluid pressure at a first time P(t.sub.1) and fluid pressure at a second time P(t.sub.2) such that the fluid pressure increase rate is calculated as:
(19) $\text{FluidPressureIncreaseRate} = \frac{\Delta P}{\Delta t} = \frac{P(t_2) - P(t_1)}{t_2 - t_1}$.
The fluid pressure may be sampled at a rate in a range of 1 Hertz (Hz) to 300 Hz and the fluid pressure increase rate may be smoothed by taking an average of 2 samples to 100 samples to prevent a single spike of a sample or an erroneous sample from triggering the detection of a potential screen out.
(20) The calculated fluid pressure increase rate is compared to a preselected increase rate to determine if there is a potential for screen out within the well (Step **540**). The preselected increase rate may be an increase rate that is entered by an operator or may be preprogrammed into the controller **30**. The preselected increase rate may be based on historical data of well screen out from other wells, for example, or specific to the well being monitored, as will be understood by those skilled in the art. When the fluid pressure increase rate is below the preselected increase rate, the controller **30** continues to monitor the fluid pressure increase rate while proppant is being added to the fluid provided to the fracturing pumps **200**.
(21) When the fluid pressure increase rate meets or exceeds the preselected increase rate, a tier of the fluid pressure increase rate may be determined (Step **542**). For example, when the fluid pressure increase rate is in a first range of 600 psi/s to 800 psi/s such that the fluid pressure increase rate is a Tier 1 Potential Screen Out and the potential for screen out may be minor. When the fluid pressure increase rate is a Tier 1 Potential Screen Out, the controller **30** provides an alert or message to an operator that the fluid pressure increase rate is high or there is a potential for screen out (Step **544**). The message or alert may be a warning light, a message on a screen, an audible alert, or combinations thereof. In response to the alert or message, an operator may take no action, reduce or stop the addition of proppant to the fluid provided to the fracturing pumps **200**, or reduce a discharge rate of the fracturing pumps **200**.
(22) Continuing with the example, when the fluid pressure increase rate is in a second range of 800 psi/s to 1200 psi/s such that the

fluid pressure increase rate is a Tier 2 Potential Screen Out and the potential for screen out is high. When the fluid pressure increase rate is a Tier 2 Potential Screen Out, the controller **30** provides an alarm or message to an operator that the fluid pressure increase rate is high or potential screen out is high (Step **546**). The message or alarm may be a warning light, a message on a screen, an audible alert, or combinations thereof and is escalated from the message or alert provided for a Tier 1 Potential Screen Out. In response to the alarm or message, an operator may take no action, reduce or stop the addition of proppant to the fluid provided to the fracturing pumps **200**, or reduce a discharge rate of the fracturing pumps **200**.

(23) When the fluid pressure increase rate is above the second range, e.g., 1200 psi/s, the potential for screen out is extremely high such that the fluid pressure increase rate is a Tier 3 Potential Screen Out and a screen out is likely. When the fluid pressure increase rate is a Tier 3 Potential Screen Out, a screen out is likely and the controller **30** enters an intervention or mitigation mode to prevent screen out and prevent or reduce damage to the well and the wellsite hydraulic fracturing pumper system **1000** by the mitigation process **550**. When the controller **30** begins the mitigation process **550**, the controller **30** provides an alert or message to an operator that the mitigation process **550** is running. The message or alert may be a warning light, a message on a screen, an audible alert, or combinations thereof and is escalated from the message or alert provided for a Tier 2 Potential Screen Out.

(24) In the mitigation mode, the controller **30** compares the fluid pressure to the maximum wellhead pressure (Step **552**). When the fluid pressure is greater than a first preselected percentage of the maximum wellhead pressure, e.g., 90%, the controller **30** verifies that the blender screw conveyors **412** are not providing proppant to the blender unit **410**, e.g., that the blender screw conveyors **412** are not rotating. If the blender screw conveyors **412** are providing proppant to the blender unit **410**, the controller **30** stops the blender screw conveyors **412** to stop delivery of proppant (Step **554**). When the delivery of proppant is stopped or verified to be stopped, the controller **30** begins to incrementally decrease a discharge rate of the fracturing pumps **200** as defined by process **560**.

(25) The process **560** may include multiple iterations of decreases in a discharge rate of the fracturing pumps **200** by a preselected increment (Step **562**) and determining the fluid pressure increase rate (Step **564**). The process **560** continues to iterate through Steps **562** and **564** until the fluid pressure increase rate is no longer increasing or stabilized, e.g., less than or equal to zero. The preselected increment may be in a range of 0.5 barrels per minute (BPM) to 10 BPM, e.g., 2 BPM. In some embodiments, the preselected increment is less than 5 BPM. The process **560** may include decreasing the discharge rate of the fracturing pumps **200** by the preselected increment (Step **562**) and delaying the determining the fluid pressure increase rate (Step **564**) for a period of time or a number of cycles of the fracturing pump **200**, e.g., 1 second or 25 cycles or revolutions of the fracturing pump **200**. The delay in determining the fluid pressure increase rate may allow for the fluid pressure to react to the decreased discharge rate before the fluid pressure increase rate is determined. During each iteration of the process **560**, the controller **30** may sequence the flow rate of the blender unit **410** and the discharge rate of the fracturing pump **200**. Specifically, the controller **30** may first send a control signal to the fracturing pump **200** to decrease a discharge rate of the fracturing pump **200** by the increment and then send a control signal to the blender unit **410**, e.g., the discharge pump **418** of the blender unit **410**, to decrease a flow rate of fluid to the fracturing pump **200**. By sequencing the blender unit **410** and the fracturing pumps **200** cavitation at the fracturing pumps **200** may be avoided. In addition, by the controller **30** sequencing the blender unit **410** and the fracturing pumps **200**, the need for an operator to manually sequence the blender unit **410** and the fracturing pumps **200** to maintain a safe operation state is removed.

(26) When the fluid pressure increase rate is stabilized such that the fluid pressure is not increasing or is decreasing (e.g., equal to or less than zero), the controller **30** terminates the mitigation process **550** and maintains the discharge rate of the fracturing pumps **200** (Step **570**). When the mitigation process **550** is completed, an operator may begin providing proppant to in the fluid provided to the fracturing pumps **200** by activating the blender screw conveyors **412** (Step **580**) and/or may manually change the discharge rate of the fracturing pumps **200** (Step **582**). When the operator takes control at Steps **580**, **582**, the operator may reactivate an automatic or scheduled program of the operation the controller **30** returns to monitoring the fluid pressure increase rate of Step **530**.

(27) Returning back to the entry into the mitigation process **550**, when the fluid pressure increase rate is a Tier 3 Potential Screen Out and the fluid pressure is below or less than the first preselected percentage of the maximum fluid pressure, e.g., 90%, the controller **30** maintains the discharge rate of the fracturing pumps **200** and the delivery of the proppant (Step **556**). When the discharge rate of the fracturing pumps **200** and the delivery of the proppant is maintained, an operator may provide input to the controller **30** to manually change the discharge rate of the fracturing pumps **200** or reactivate an automatic or scheduled program to the operation of the controller **30** (Step **582**). If an operator does not intervene, the controller **30** continues to monitor fluid pressure.

(28) If the operator does not intervene and the fluid pressure reaches a second preselected percentage of the maximum fluid pressure, e.g., 94%, the controller **30** intervenes by preparing for and running the process **560**. Specifically, the controller **30** prepares for the process **560** by stopping the blender screw conveyors **412** to stop delivery of proppant (Step **554**). When the delivery of proppant is stopped, the controller **30** begins the process **560** to incrementally decrease a discharge rate of the fracturing pumps **200** as detailed above until by cycling through Step **562** and Step **564** until the fluid pressure increase rate is no longer increasing or stabilized, e.g., less than or equal to zero. When the fluid pressure increase rate is stabilized, the discharge rate of the fracturing pumps **200** is maintained (Step **570**) such that the mitigation process **550** is complete or terminated. When the mitigation process **550** is completed, an operator may begin providing proppant to in the fluid provided to the fracturing pumps **200** by activating the blender screw conveyors **412** (Step **580**) and/or may manually change the discharge rate of the fracturing pumps **200** (Step **582**). When the operator takes control at Steps **580**, **582**, the operator may reactivate an automatic or scheduled program of the operation the controller **30** returns to monitoring the fluid pressure increase rate of Step **530**.

(29) The mitigation process **550** enables the controller **30** to automatically stop delivery of proppant to the fluid provided to the fracturing pumps **200** and to decrease the discharge rate of the fracturing pumps **200** until the fluid pressure increase rate is stabilized without input from an operator. During the mitigation process **550**, including the process **560**, an operator may be prevented or locked out from certain commands of the controller **30**. For example, in some embodiments, during the mitigation process **550**, an operator may be locked out of all commands to the controller **30** except at step **556** until the mitigation process **550** such that the fluid pressure increase rate has been stabilized. In certain embodiments, an operator may be locked out of increasing the discharge rate of the fracturing pumps **200** or initiating or increasing delivery of proppant during the mitigation process **550**.

(30) By reducing well screen out, the need for operations to reopen fractures or a well (e.g., wire line operations) may be reduced

or eliminated such that time, and thus costs, to stimulate a well may be reduced. In addition, the method **500** of detecting and mitigating well screen out with a controller **30** may reduce rapid pressure increases associated with well screen outs such that stress on fracturing equipment may be reduced. The fracturing equipment may include, but not be limited to, fracturing pumps, power end assemblies of power units (e.g., gas turbine engines), gearboxes, transmissions, and piping or iron of the well site. Further, by intervening before the fluid supplied to the wellhead reaches the maximum fluid pressure, reliance on pressure relief valves, such as a wellhead pressure relief valve, may be reduced. Reducing reliance on pressure relief valves may conserve energy by not releasing pressure within the system and reduce stress on the fracturing equipment by maintaining a more consistent fluid pressure within the maximum wellhead pressure.
(31) The method **500** being executed by the controller **30** allows for continuous monitoring of the fluid pressure and the fluid pressure increase rate at higher rate (e.g., 1 Hz to 300 Hz) when compared to relying on manual control and monitoring. In addition, by including multiple tiers of warnings (e.g., Tier 1 and Tier 2) the controller **30** alerts an operator to intervene before the fluid pressure approaches the maximum wellhead pressure and may automatically intervene if the fluid pressure increase rate reaches Tier 3 and the fluid pressure approaches the maximum wellhead pressure.
(32) This is a continuation of U.S. Non-Provisional application Ser. No. 17/991,007, filed Nov. 21, 2022, titled "METHODS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT," now U.S. Pat. No. 11,939,854 issued Mar. 26, 2024, which is a continuation of U.S. Non-Provisional application Ser. No. 17/355,920, filed Jun. 23, 2021, titled "METHODS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT," now U.S. Pat. No. 11,566,506 issued Jan. 31, 2023, which is continuation of U.S. Non-Provisional application Ser. No. 17/303,841, filed Jun. 9, 2021, titled "METHODS AND SYSTEMS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT," now U.S. Pat. No. 11,208,881, issued Dec. 28, 2021, which is a continuation of U.S. Non-Provisional application Ser. No. 17/182,408, filed Feb. 23, 2021, titled "METHODS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT," now U.S. Pat. No. 11,066,915, issued Jul. 20, 2021, which claims priority to and the benefit of U.S. Provisional Application No. 62/705,050, filed Jun. 9, 2020, titled "METHODS AND SYSTEMS FOR DETECTION AND MITIGATION OF WELL SCREEN OUT," the disclosures of which are incorporated herein by reference in their entireties.
(33) The foregoing description of the disclosure illustrates and describes various exemplary embodiments. Various additions, modifications, changes, etc., may be made to the exemplary embodiments without departing from the spirit and scope of the disclosure. It is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense. Additionally, the disclosure shows and describes only selected embodiments of the disclosure, but the disclosure is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the inventive concept as expressed herein, commensurate with the above teachings, and/or within the skill or knowledge of the relevant art. Furthermore, certain features and characteristics of each embodiment may be selectively interchanged and applied to other illustrated and non-illustrated embodiments of the disclosure.

Claims

1. A wellsite hydraulic fracturing pumper system, the system comprising: one or more fracturing pumps configured to pump fluid to a wellhead when positioned at a hydrocarbon well site; one or more pressure transducers positioned at a location of one or more of: (a) adjacent an output of the one or more fracturing pumps, and (b) at the wellhead, the one or more pressure transducers each configured to measure a fluid pressure of the fluid provided to the wellhead; and a controller to control the one or more fracturing pumps and positioned in signal communication with the one or more pressure transducers such that the controller receives the fluid pressure of the fluid provided to the wellhead, the controller (a) including memory, a processor to process data, and a screen out detection and mitigation protocol program stored in the memory and (b) being responsive to a process in which the protocol of the controller incrementally decreases a discharge rate of the one or more fracturing pumps, in response to: (i) a fluid pressure increase rate of the fluid supplied to the wellhead being greater than a preselected increase rate, and (ii) the fluid pressure of the fluid provided to the wellhead being greater than a preselected percentage of a maximum wellhead pressure, until the fluid pressure is stabilized.
2. The wellsite hydraulic fracturing pumper system according to claim 1, wherein the screen out detection and mitigation protocol includes an alarm to provide an alert indicative of when the fluid pressure increase rate is greater than the preselected increase rate before the pressure of the fluid provided to the wellhead is within the preselected percentage of the maximum wellhead pressure.
3. The wellsite hydraulic fracturing pumper system according to claim 2, wherein the one or more pressure transducers also are positioned at a location adjacent the output of the one or more fracturing pumps.
4. The wellsite hydraulic fracturing pumper system according to claim 3, further comprising one or more blenders configured to provide fluid and proppant to the one or more fracturing pumps, wherein each of the one or more blenders includes a blender conveyor configured to rotate such that proppant is provided to the one or more fracturing pumps in response to rotation of the blender conveyor.
5. The wellsite hydraulic fracturing pumper system according to claim 4, the controller further being responsive to a process in which the protocol of the controller incrementally decreases a flow rate of the one or more blenders, wherein incrementally decreasing the discharge rate of the one or more fracturing pumps and the flow rate of the one or more blenders by the controller includes stopping delivery of proppant at the one or more blenders prior to decreasing the discharge rate of the fracturing pump when the one or more blenders are delivering proppant.
6. The wellsite hydraulic fracturing pumper system according to claim 5, wherein incrementally decreasing the discharge rate of the one or more fracturing pumps and the flow rate of the one or more blenders by the controller includes decreasing the discharge rate of the one or more fracturing pumps prior to decreasing the flow rate of the one or more blenders.
7. A wellsite hydraulic fracturing pumper system, the system comprising: one or more fracturing pumps configured to pump fluid to a wellhead when positioned at a hydrocarbon well site; one or more pressure transducers positioned at a location of one or more of: (a) adjacent an output of the one or more fracturing pumps, (b) at the wellhead, the one or more pressure transducers each configured to measure a fluid pressure of the fluid provided to the wellhead, and (c) adjacent the output of the one or more

fracturing pumps; and a controller to control the one or more fracturing pumps and positioned in signal communication with the one or more pressure transducers such that the controller receives the fluid pressure of the fluid provided to the wellhead, the controller configured to incrementally decrease a discharge rate of the one or more fracturing pumps in response to: (i) a fluid pressure increase rate of the fluid supplied to the wellhead being greater than a preselected increase rate, and (ii) the fluid pressure of the fluid provided to the wellhead being greater than a preselected percentage of a maximum wellhead pressure, until the fluid pressure is stabilized.

8. The wellsite hydraulic fracturing pumper system according to claim 7, wherein the one or more pressure transducers also are positioned at a location adjacent the output of the one or more fracturing pumps.

9. The wellsite hydraulic fracturing pumper system according to claim 7, further comprising one or more blenders configured to provide fluid and proppant to the one or more fracturing pumps.

10. The wellsite hydraulic fracturing pumper system according to claim 9, the controller further being responsive to a process in which the protocol of the controller incrementally decreases a flow rate of the one or more blenders, wherein incrementally decreasing the discharge rate of the one or more fracturing pumps and the flow rate of the one or more blenders by the controller includes stopping delivery of proppant at the one or more blenders prior to decreasing the discharge rate of the fracturing pump when the one or more blenders are delivering proppant.

11. The wellsite hydraulic fracturing pumper system according to claim 10, wherein incrementally decreasing the discharge rate of the one or more fracturing pumps and the flow rate of the one or more blenders by the controller includes decreasing the discharge rate of the one or more fracturing pumps prior to decreasing the flow rate of the one or more blenders.

12. The wellsite hydraulic fracturing pumper system according to claim 7, wherein the controller is configured to incrementally decrease the discharge rate of the one or more fracturing pumps by one or more increments, each increment in the range of 0.5 barrels per minute to 10 barrels per minute.

13. A wellsite hydraulic fracturing pumper system, the system comprising: one or more mobile fracturing pump units to pump fluid to a wellhead when positioned at a hydrocarbon well site, each of the fracturing pump units comprising a gas turbine engine configured to drive a fracturing pump; one or more pressure transducers configured to be positioned at a location of one or more of: (a) adjacent an output of the one or more fracturing pumps, or (b) at the wellhead, and to measure a fluid pressure of the fluid when provided to the wellhead; and a controller to control the one or more fracturing pumps and configured to be positioned in signal communication with the one or more pressure transducers such that the controller receives measurement of the fluid pressure of the fluid when provided to the wellhead and controllingly stabilizes the fluid pressure when the fluid pressure supplied to the wellhead increases greater than a preselected increase rate and being greater than a preselected percentage of a maximum wellhead pressure, the controller configured to incrementally decrease a discharge rate of the one or more fracturing pumps, in response to a fluid pressure measurement obtained by the one or more pressure transducers.

14. The wellsite hydraulic fracturing pumper system according to claim 13, wherein the controller comprises a memory, a processor to process data, and a screen out detection and mitigation protocol program stored in the memory, the controller being responsive to a process in which the protocol of the controller incrementally decreases a discharge rate of the one or more fracturing pumps, in response to: (i) a fluid pressure increase rate of the fluid supplied to the wellhead being greater than a preselected increase rate, and (ii) the fluid pressure of the fluid provided to the wellhead being greater than a preselected percentage of a maximum wellhead pressure.

15. The wellsite hydraulic fracturing pumper system according to claim 14, wherein the screen out detection and mitigation protocol includes an alarm to provide an alert indicative of when the fluid pressure increase rate is greater than the preselected increase rate before the pressure of the fluid provided to the wellhead is within the preselected percentage of the maximum wellhead pressure.

16. The wellsite hydraulic fracturing pumper system according to claim 15, wherein the controller is configured to incrementally decrease the discharge rate of the one or more fracturing pumps by one or more increments, each increment in the range of 0.5 barrels per minute to 10 barrels per minute.

17. The wellsite hydraulic fracturing pumper system according to claim 16, wherein the controller is configured to delay determination of a fluid pressure increase rate after incrementally decreasing the discharge rate of the one or more fracturing pumps by the one or more increments.

18. The wellsite hydraulic fracturing pumper system according to claim 13, wherein the one or more pressure transducers also are positioned at a location adjacent the output of the one or more fracturing pumps.

19. The wellsite hydraulic fracturing pumper system according to claim 13, wherein the controller is configured to incrementally decrease the discharge rate of the one or more fracturing pumps by one or more increments, each increment in the range of 0.5 barrels per minute to 10 barrels per minute.