United States Patent	12390586
Kind Code	B2
Date of Patent	August 19, 2025
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Concurrent infusion with common line auto flush

Abstract

An infusion pump system and method provide concurrent infusion with common line auto flush. The infusion pump system has a first reservoir, a second reservoir, a junction, a mixing chamber, a common line having one end in fluid connection with the mixing chamber and having a terminal fluid delivery end, and an infusion pump. The method includes infusing the first fluid at a first rate along a first flow path; determining a common line flush volume value for the common line; switching to a concurrent infusion mode to drive a combination of the first fluid and the second fluid at the first rate along a second flow path including the common line; monitoring a volume of the combination of the first and second fluids driven at the first rate; and driving the combination of the first and second fluids at a combined rate along the second flow path when the monitored volume is equal to or greater than the common line flush volume value.

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Appl. No.: **17/493692**

Filed: **October 04, 2021**

Prior Publication Data

Document Identifier	Publication Date
US 20220176037 A1	Jun. 09, 2022

Related U.S. Application Data

continuation parent-doc US 17114359 20201207 US 11135360 child-doc US 17493692

Publication Classification

Int. Cl.: **A61M5/168** (20060101); **A61M5/14** (20060101); **G06K7/10** (20060101); **G06K19/07** (20060101); **G16H20/17** (20180101); **G16H40/40** (20180101); **G16H40/67** (20180101)

U.S. Cl.:

CPC **A61M5/16827** (20130101); **A61M5/1407** (20130101); **G16H20/17** (20180101); **G16H40/40** (20180101); **G16H40/67** (20180101); A61M2005/1403 (20130101); A61M2205/3334 (20130101); A61M2205/502 (20130101); A61M2205/52 (20130101); G06K7/10297 (20130101); G06K2007/10504 (20130101); G06K19/0723 (20130101)

Field of Classification Search

CPC: A61M (5/14); A61M (5/1407); A61M (5/1409); A61M (5/142); A61M (5/145); A61M (5/168); A61M (5/16804); A61M (5/16827); A61M (5/16877); A61M (5/172); G06F (19/3468)

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5213573	12/1992	Sorich et al.	N/A	N/A
5215450	12/1992	Tamari	N/A	N/A
5216597	12/1992	Beckers	N/A	N/A
5219099	12/1992	Spence et al.	N/A	N/A
5219327	12/1992	Okada	N/A	N/A
5221268	12/1992	Barton et al.	N/A	N/A
5229713	12/1992	Bullock et al.	N/A	N/A
5232476	12/1992	Grant	N/A	N/A
5233571	12/1992	Wirtschafter	N/A	N/A
5237309	12/1992	Frantz et al.	N/A	N/A
5242406	12/1992	Gross et al.	N/A	N/A
5242408	12/1992	Jhuboo et al.	N/A	N/A
5243982	12/1992	Möstl et al.	N/A	N/A
5244463	12/1992	Cordner, Jr. et al.	N/A	N/A
5244568	12/1992	Lindsay et al.	N/A	N/A

5254096	12/1992	Rondelet et al.	N/A	N/A
5256155	12/1992	Yerlikaya et al.	N/A	N/A
5256156	12/1992	Kern et al.	N/A	N/A
5256157	12/1992	Samiotes et al.	N/A	N/A
5257206	12/1992	Hanson	N/A	N/A
5260665	12/1992	Goldberg	N/A	N/A
5267980	12/1992	Dirr et al.	N/A	N/A
5274316	12/1992	Evans et al.	N/A	N/A
5276610	12/1993	Maeda et al.	N/A	N/A
5280728	12/1993	Sato et al.	N/A	N/A
5283510	12/1993	Tamaki et al.	N/A	N/A
5287851	12/1993	Beran et al.	N/A	N/A
5292306	12/1993	Wynkoop et al.	N/A	N/A
5295967	12/1993	Rondelet et al.	N/A	N/A
5298021	12/1993	Sherer	N/A	N/A
5303585	12/1993	Lichte	N/A	N/A
5304126	12/1993	Epstein et al.	N/A	N/A
5304216	12/1993	Wallace	N/A	N/A
5308333	12/1993	Skakoon	N/A	N/A
5317506	12/1993	Coutre et al.	N/A	N/A
5319363	12/1993	Welch et al.	N/A	N/A
5319979	12/1993	Abrahamson	N/A	N/A
5321392	12/1993	Skakoon et al.	N/A	N/A
5325170	12/1993	Bornhop	N/A	N/A
5325728	12/1993	Zimmerman et al.	N/A	N/A
5328460	12/1993	Lord et al.	N/A	N/A
5330634	12/1993	Wong et al.	N/A	N/A
5333497	12/1993	Braend et al.	N/A	N/A
5336051	12/1993	Tamari	N/A	N/A
5338157	12/1993	Blomquist	N/A	N/A
5342298	12/1993	Michaels	N/A	N/A
5343734	12/1993	Maeda et al.	N/A	N/A
5343885	12/1993	Grant	N/A	N/A
5346466	12/1993	Yerlikaya et al.	N/A	N/A
5356378	12/1993	Doan et al.	N/A	N/A
5359271	12/1993	Husher	N/A	N/A
D352778	12/1993	Irvin et al.	N/A	N/A
5364346	12/1993	Schrezenmeir	N/A	N/A
5366346	12/1993	Danby	N/A	N/A
5368562	12/1993	Blomquist et al.	N/A	N/A
5374865	12/1993	Yoshimura et al.	N/A	N/A
5376070	12/1993	Purvis et al.	N/A	N/A
5378231	12/1994	Johnson et al.	N/A	N/A
5382232	12/1994	Hague et al.	N/A	N/A
5383369	12/1994	Khuri-Yakub et al.	N/A	N/A
5389071	12/1994	Kawahara et al.	N/A	N/A
5389078	12/1994	Zalesky et al.	N/A	N/A
5392638	12/1994	Kawahara	N/A	N/A
5394732	12/1994	Johnson et al.	N/A	N/A
5395320	12/1994	Padda et al.	N/A	N/A
5399171	12/1994	Bowman et al.	N/A	N/A
5406954	12/1994	Tomita	N/A	N/A
5408326	12/1994	Priestley	N/A	N/A

5415528	12/1994	Ogden et al.	N/A	N/A
5417119	12/1994	Smoll	N/A	N/A
5417222	12/1994	Dempsey et al.	N/A	N/A
5417395	12/1994	Fowler et al.	N/A	N/A
5418443	12/1994	Kikuchi	N/A	N/A
5421208	12/1994	Packard et al.	N/A	N/A
5423748	12/1994	Uhala	N/A	N/A
5423749	12/1994	Merte et al.	N/A	N/A
5423759	12/1994	Campbell	N/A	N/A
5428284	12/1994	Kaneda et al.	N/A	N/A
5429485	12/1994	Dodge	N/A	N/A
5429601	12/1994	Conley	N/A	N/A
5429602	12/1994	Hauser	N/A	N/A
5431627	12/1994	Pastrone et al.	N/A	N/A
5434508	12/1994	Ishida	N/A	N/A
5437624	12/1994	Langley et al.	N/A	N/A
5444316	12/1994	Ohya et al.	N/A	N/A
5444378	12/1994	Rogers	N/A	N/A
5445621	12/1994	Poli et al.	N/A	N/A
5450758	12/1994	Smoll	N/A	N/A
5451881	12/1994	Finger	N/A	N/A
5455423	12/1994	Mount et al.	N/A	N/A
5455851	12/1994	Chaco et al.	N/A	N/A
5463906	12/1994	Spani et al.	N/A	N/A
5464392	12/1994	Epstein et al.	N/A	N/A
5465082	12/1994	Chaco	N/A	N/A
5469851	12/1994	Lipschutz	N/A	N/A
5473948	12/1994	Moss et al.	N/A	N/A
5480294	12/1995	Di Perna et al.	N/A	N/A
5482438	12/1995	Anderson et al.	N/A	N/A
5485408	12/1995	Blomquist	N/A	N/A
5486286	12/1995	Peterson et al.	N/A	N/A
5489265	12/1995	Montalvo et al.	N/A	N/A
5495566	12/1995	Kwatinetz	N/A	N/A
5496273	12/1995	Pastrone et al.	N/A	N/A
5505696	12/1995	Miki	N/A	N/A
5505828	12/1995	Wong et al.	N/A	N/A
5507288	12/1995	Bocker et al.	N/A	N/A
5507412	12/1995	Ebert et al.	N/A	N/A
5520637	12/1995	Pager et al.	N/A	N/A
5522798	12/1995	Johnson et al.	N/A	N/A
5522799	12/1995	Furukawa	N/A	N/A
5527630	12/1995	Nagata	N/A	N/A
5533389	12/1995	Kamen et al.	N/A	N/A
5537853	12/1995	Finburgh et al.	N/A	N/A
5542040	12/1995	Chang et al.	N/A	N/A
5545140	12/1995	Conero et al.	N/A	N/A
5547470	12/1995	Johnson et al.	N/A	N/A
5551850	12/1995	Williamson et al.	N/A	N/A
5554013	12/1995	Owens et al.	N/A	N/A
5554115	12/1995	Thomas et al.	N/A	N/A
5558638	12/1995	Evers et al.	N/A	N/A
5562615	12/1995	Nassif	N/A	N/A

5563486	12/1995	Yamamoto et al.	N/A	N/A
5572105	12/1995	Nojima et al.	N/A	N/A
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5583280	12/1995	Mo et al.	N/A	N/A
5584667	12/1995	Davis	N/A	N/A
5584806	12/1995	Amano	N/A	N/A
5586868	12/1995	Lawless et al.	N/A	N/A
5590653	12/1996	Aida et al.	N/A	N/A
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5600073	12/1996	Hill	N/A	N/A
5601420	12/1996	Warner et al.	N/A	N/A
5609575	12/1996	Larson et al.	N/A	N/A
5609576	12/1996	Voss	N/A	N/A
5611784	12/1996	Barresi et al.	N/A	N/A
5616124	12/1996	Hague et al.	N/A	N/A
5620312	12/1996	Hyman et al.	N/A	N/A
5620608	12/1996	Rosa et al.	N/A	N/A
5626140	12/1996	Feldman et al.	N/A	N/A
5626151	12/1996	Linden	N/A	N/A
5626563	12/1996	Dodge et al.	N/A	N/A
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5628309	12/1996	Brown	N/A	N/A
5628731	12/1996	Dodge et al.	N/A	N/A
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5634896	12/1996	Bryant et al.	N/A	N/A
5637095	12/1996	Nason et al.	N/A	N/A
5640075	12/1996	Brasseur et al.	N/A	N/A
5640150	12/1996	Atwater	N/A	N/A
5643212	12/1996	Coutre et al.	N/A	N/A
5648710	12/1996	Ikeda	N/A	N/A
5649536	12/1996	Ogura et al.	N/A	N/A
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5657000	12/1996	Ellingboe	N/A	N/A
5658133	12/1996	Anderson et al.	N/A	N/A
5658250	12/1996	Blomquist et al.	N/A	N/A
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5661245	12/1996	Svoboda et al.	N/A	N/A
D384052	12/1996	Kodosky	N/A	N/A
5662612	12/1996	Niehoff	N/A	N/A
5665065	12/1996	Colman et al.	N/A	N/A
5669877	12/1996	Blomquist	N/A	N/A
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5681285	12/1996	Ford et al.	N/A	N/A
5681286	12/1996	Niehoff	N/A	N/A
5685844	12/1996	Marttila	N/A	N/A
5685866	12/1996	Lopez	N/A	N/A
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5689229	12/1996	Chaco et al.	N/A	N/A
5691613	12/1996	Gutwillinger	N/A	N/A
5695464	12/1996	Viallet	N/A	N/A
5695473	12/1996	Olsen	N/A	N/A
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5714691	12/1997	Hill	N/A	N/A
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5722417	12/1997	Rudolph	N/A	N/A
5728074	12/1997	Castellano et al.	N/A	N/A
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5733257	12/1997	Stemby	N/A	N/A
5733259	12/1997	Valcke et al.	N/A	N/A
5734464	12/1997	Gibbs	N/A	N/A
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5743856	12/1997	Oka et al.	N/A	N/A
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5744929	12/1997	Miyazaki	N/A	N/A
5745378	12/1997	Barker et al.	N/A	N/A
5752813	12/1997	Tyner et al.	N/A	N/A
5752918	12/1997	Fowler et al.	N/A	N/A
5752919	12/1997	Schrimpf	N/A	N/A
5755691	12/1997	Hilborne	N/A	N/A
5758643	12/1997	Wong et al.	N/A	N/A
5761072	12/1997	Bardsley, Jr. et al.	N/A	N/A
5764034	12/1997	Bowman et al.	N/A	N/A
5766155	12/1997	Hyman et al.	N/A	N/A
5772635	12/1997	Dastur et al.	N/A	N/A
5778256	12/1997	Darbee	N/A	N/A
5781442	12/1997	Engleson et al.	N/A	N/A
5782805	12/1997	Meinzer et al.	N/A	N/A
5788669	12/1997	Peterson	N/A	N/A
5788674	12/1997	McWilliams	N/A	N/A
5789923	12/1997	Shimoyama et al.	N/A	N/A
5792069	12/1997	Greenwald et al.	N/A	N/A
5793211	12/1997	Shimoyama et al.	N/A	N/A
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5798934	12/1997	Saigo et al.	N/A	N/A
5800387	12/1997	Duffy et al.	N/A	N/A
5803712	12/1997	Davis et al.	N/A	N/A
5803917	12/1997	Butterfield	N/A	N/A
5805455	12/1997	Lipps	N/A	N/A
5807322	12/1997	Lindsey et al.	N/A	N/A
5810770	12/1997	Chin et al.	N/A	N/A
5813972	12/1997	Nazarian et al.	N/A	N/A
5814004	12/1997	Tamari	N/A	N/A
5814015	12/1997	Gargano et al.	N/A	N/A
5816779	12/1997	Lawless et al.	N/A	N/A
5822715	12/1997	Worthington et al.	N/A	N/A
5827179	12/1997	Lichter et al.	N/A	N/A
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5871465	12/1998	Vasko	N/A	N/A
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6358225	12/2001	Butterfield	N/A	N/A
6358387	12/2001	Kopf-Sill et al.	N/A	N/A
6362591	12/2001	Moberg	N/A	N/A
6385505	12/2001	Lipps	N/A	N/A
6386050	12/2001	Yin et al.	N/A	N/A
6394958	12/2001	Bratteli et al.	N/A	N/A
6396583	12/2001	Clare	N/A	N/A
D459362	12/2001	Platz	N/A	N/A
6398760	12/2001	Danby	N/A	N/A
6405076	12/2001	Taylor et al.	N/A	N/A
6408679	12/2001	Kline-Schoder et al.	N/A	N/A
6409699	12/2001	Ash	N/A	N/A
6413238	12/2001	Maget	N/A	N/A
6416291	12/2001	Butterfield et al.	N/A	N/A
6418334	12/2001	Unger et al.	N/A	N/A
6418535	12/2001	Kulakowski et al.	N/A	N/A
6445053	12/2001	Cho	N/A	N/A
6456245	12/2001	Crawford	N/A	N/A
6457346	12/2001	Kline-Schoder et al.	N/A	N/A
6463785	12/2001	Kline-Schoder et al.	N/A	N/A
6467331	12/2001	Kline-Schoder et al.	N/A	N/A
6468242	12/2001	Wilson et al.	N/A	N/A
6475178	12/2001	Krajewski	N/A	N/A
6481980	12/2001	Vandlik	N/A	N/A
6482158	12/2001	Mault	N/A	N/A

6482185	12/2001	Hartmann	N/A	N/A
6485263	12/2001	Bryant et al.	N/A	N/A
6485418	12/2001	Yasushi et al.	N/A	N/A
6485465	12/2001	Moberg et al.	N/A	N/A
6487916	12/2001	Gomm et al.	N/A	N/A
6489896	12/2001	Platt	N/A	N/A
6494694	12/2001	Lawless et al.	N/A	N/A
6494831	12/2001	Koritzinsky	N/A	N/A
6497680	12/2001	Holst et al.	N/A	N/A
6503221	12/2002	Briggs	N/A	N/A
6512944	12/2002	Kovtun et al.	N/A	N/A
6516667	12/2002	Broad et al.	N/A	N/A
6517482	12/2002	Eiden et al.	N/A	N/A
6519569	12/2002	White et al.	N/A	N/A
6529751	12/2002	Van Driel et al.	N/A	N/A
6531708	12/2002	Malmstrom	N/A	N/A
6539315	12/2002	Adams et al.	N/A	N/A
D473238	12/2002	Cockerill	N/A	N/A
6540672	12/2002	Simonsen et al.	N/A	N/A
6544212	12/2002	Galley et al.	N/A	N/A
6544228	12/2002	Heitmeier	N/A	N/A
6558125	12/2002	Futterknecht	N/A	N/A
6558351	12/2002	Steil et al.	N/A	N/A
6562012	12/2002	Brown et al.	N/A	N/A
6564825	12/2002	Lowery et al.	N/A	N/A
6565509	12/2002	Say et al.	N/A	N/A
6568416	12/2002	Tucker et al.	N/A	N/A
6572542	12/2002	Houben et al.	N/A	N/A
6572545	12/2002	Knobbe et al.	N/A	N/A
6572576	12/2002	Brugger et al.	N/A	N/A
6578422	12/2002	Lam et al.	N/A	N/A
6578435	12/2002	Gould et al.	N/A	N/A
6581117	12/2002	Klein et al.	N/A	N/A
RE38189	12/2002	Walker et al.	N/A	N/A
6585675	12/2002	O'Mahony et al.	N/A	N/A
6589229	12/2002	Connelly et al.	N/A	N/A
6589792	12/2002	Malachowski	N/A	N/A
6599281	12/2002	Struys et al.	N/A	N/A
6599282	12/2002	Burko	N/A	N/A
6602191	12/2002	Quy	N/A	N/A
6605072	12/2002	Struys et al.	N/A	N/A
6606047	12/2002	Börjesson et al.	N/A	N/A
6609047	12/2002	Lipps	N/A	N/A
6615674	12/2002	Ohnishi	N/A	N/A
6616633	12/2002	Butterfield et al.	N/A	N/A
6617564	12/2002	Ockerse et al.	N/A	N/A
6618916	12/2002	Eberle et al.	N/A	N/A
6622542	12/2002	Derek	N/A	N/A
6622561	12/2002	Lam et al.	N/A	N/A
D481121	12/2002	Evans	N/A	N/A
6629449	12/2002	Kline-Schoder et al.	N/A	N/A
6634233	12/2002	He	N/A	N/A
6640246	12/2002	Gardy, Jr. et al.	N/A	N/A

6641533	12/2002	Causey, III et al.	N/A	N/A
6641541	12/2002	Lovett et al.	N/A	N/A
6648861	12/2002	Platt et al.	N/A	N/A
6652455	12/2002	Kocher	N/A	N/A
6653937	12/2002	Nelson et al.	N/A	N/A
6659980	12/2002	Moberg et al.	N/A	N/A
D485356	12/2003	Evans	N/A	N/A
6685668	12/2003	Cho et al.	N/A	N/A
6685678	12/2003	Evans et al.	N/A	N/A
6689069	12/2003	Bratteli et al.	N/A	N/A
6689091	12/2003	Bui et al.	N/A	N/A
6692241	12/2003	Watanabe et al.	N/A	N/A
D487574	12/2003	Glaser	N/A	N/A
6716004	12/2003	Vandlik	N/A	N/A
6719535	12/2003	Rakestraw et al.	N/A	N/A
6721582	12/2003	Trepagnier et al.	N/A	N/A
6722211	12/2003	Ciobanu et al.	N/A	N/A
6725200	12/2003	Rost	N/A	N/A
6725721	12/2003	Venczel	N/A	N/A
6731989	12/2003	Engleson et al.	N/A	N/A
6732595	12/2003	Lynnworth	N/A	N/A
6738052	12/2003	Manke et al.	N/A	N/A
6740072	12/2003	Starkweather et al.	N/A	N/A
6741212	12/2003	Kralovec et al.	N/A	N/A
6748808	12/2003	Lam et al.	N/A	N/A
6749403	12/2003	Bryant et al.	N/A	N/A
6752787	12/2003	Causey, III et al.	N/A	N/A
6753842	12/2003	Williams et al.	N/A	N/A
6759007	12/2003	Westberg	N/A	N/A
6760643	12/2003	Lipps	N/A	N/A
6768920	12/2003	Lange	N/A	N/A
6773412	12/2003	O'Mahony	N/A	N/A
6780156	12/2003	Haueter et al.	N/A	N/A
6783328	12/2003	Lucke et al.	N/A	N/A
6785573	12/2003	Kovtun et al.	N/A	N/A
6786885	12/2003	Hochman et al.	N/A	N/A
6789426	12/2003	Yaralioglu et al.	N/A	N/A
6790198	12/2003	White et al.	N/A	N/A
6793625	12/2003	Cavallaro et al.	N/A	N/A
6801227	12/2003	Bocionek et al.	N/A	N/A
6805671	12/2003	Stergiopoulos et al.	N/A	N/A
6807965	12/2003	Hickle	N/A	N/A
6809653	12/2003	Mann et al.	N/A	N/A
6813964	12/2003	Clark et al.	N/A	N/A
6814547	12/2003	Childers	N/A	N/A
6824528	12/2003	Faries	N/A	N/A
6830558	12/2003	Flaherty et al.	N/A	N/A
6840113	12/2004	Fukumura et al.	N/A	N/A
6846161	12/2004	Kline	N/A	N/A
6852094	12/2004	Beck	N/A	N/A
6852104	12/2004	Blomquist	N/A	N/A
6854338	12/2004	Khuri-Yakub et al.	N/A	N/A
6857318	12/2004	Silber et al.	N/A	N/A

6869425	12/2004	Briggs et al.	N/A	N/A
6873268	12/2004	Lebel et al.	N/A	N/A
6883376	12/2004	He	N/A	N/A
6885881	12/2004	Leonhardt	N/A	N/A
6887216	12/2004	Hochman et al.	N/A	N/A
6898301	12/2004	Iwanaga	N/A	N/A
6907361	12/2004	Molenaar	N/A	N/A
6907792	12/2004	Ohnishi	N/A	N/A
6915170	12/2004	Engleson et al.	N/A	N/A
6920795	12/2004	Bischoff et al.	N/A	N/A
6923763	12/2004	Kovatchev et al.	N/A	N/A
6928338	12/2004	Buchser et al.	N/A	N/A
6929619	12/2004	Fago et al.	N/A	N/A
6929751	12/2004	Bowman	N/A	N/A
6932114	12/2004	Sparks	N/A	N/A
6932796	12/2004	Sage et al.	N/A	N/A
6935192	12/2004	Sobek et al.	N/A	N/A
6936029	12/2004	Mann et al.	N/A	N/A
6941005	12/2004	Lary et al.	N/A	N/A
6942636	12/2004	Holst et al.	N/A	N/A
6945954	12/2004	Hochman et al.	N/A	N/A
6958705	12/2004	Lebel et al.	N/A	N/A
6964204	12/2004	Clark et al.	N/A	N/A
6973374	12/2004	Ader	N/A	N/A
6974437	12/2004	Lebel et al.	N/A	N/A
6975922	12/2004	Duncan et al.	N/A	N/A
6978779	12/2004	Haveri et al.	N/A	N/A
6979326	12/2004	Mann et al.	N/A	N/A
6981960	12/2005	Cho et al.	N/A	N/A
6984218	12/2005	Nayak et al.	N/A	N/A
6985768	12/2005	Hemming et al.	N/A	N/A
6985870	12/2005	Martucci et al.	N/A	N/A
6986347	12/2005	Hickle	N/A	N/A
6986753	12/2005	Bui	N/A	N/A
6997905	12/2005	Gillespie, Jr. et al.	N/A	N/A
6997920	12/2005	Mann et al.	N/A	N/A
7006005	12/2005	Nazarian et al.	N/A	N/A
7017623	12/2005	Tribble et al.	N/A	N/A
7021148	12/2005	Kuhn	N/A	N/A
7025743	12/2005	Mann et al.	N/A	N/A
7029455	12/2005	Flaherty	N/A	N/A
7029456	12/2005	Ware et al.	N/A	N/A
7059184	12/2005	Kanouda et al.	N/A	N/A
7060059	12/2005	Keith et al.	N/A	N/A
7069793	12/2005	Ishikawa et al.	N/A	N/A
7072725	12/2005	Bristol et al.	N/A	N/A
7074209	12/2005	Evans et al.	N/A	N/A
7080557	12/2005	Adnan	N/A	N/A
7082843	12/2005	Clark et al.	N/A	N/A
7087444	12/2005	Wong et al.	N/A	N/A
7092796	12/2005	Vanderveen	N/A	N/A
7092797	12/2005	Gaines et al.	N/A	N/A
7093502	12/2005	Kupnik et al.	N/A	N/A

7096729	12/2005	Repko et al.	N/A	N/A
7103419	12/2005	Engleson et al.	N/A	N/A
7104763	12/2005	Bouton et al.	N/A	N/A
7104769	12/2005	Davis	N/A	N/A
7108680	12/2005	Rohr et al.	N/A	N/A
7109878	12/2005	Mann et al.	N/A	N/A
7115113	12/2005	Evans et al.	N/A	N/A
7117041	12/2005	Engleson et al.	N/A	N/A
7137964	12/2005	Flaherty	N/A	N/A
7141037	12/2005	Butterfield et al.	N/A	N/A
7152490	12/2005	Freund, Jr. et al.	N/A	N/A
7154397	12/2005	Zerhusen et al.	N/A	N/A
7161488	12/2006	Frasch	N/A	N/A
7162290	12/2006	Levin	N/A	N/A
7162927	12/2006	Selvan et al.	N/A	N/A
7171277	12/2006	Engleson et al.	N/A	N/A
7171992	12/2006	DiGianfilippo et al.	N/A	N/A
7174789	12/2006	Orr et al.	N/A	N/A
7185288	12/2006	McKeever	N/A	N/A
7197943	12/2006	Lee et al.	N/A	N/A
7201734	12/2006	Hickle	N/A	N/A
7204823	12/2006	Estes et al.	N/A	N/A
7206715	12/2006	Vanderveen et al.	N/A	N/A
7213009	12/2006	Pestotnik	N/A	N/A
7220240	12/2006	Struys et al.	N/A	N/A
7229430	12/2006	Hickle et al.	N/A	N/A
7230529	12/2006	Ketcherside	N/A	N/A
7232430	12/2006	Carlisle	N/A	N/A
7238164	12/2006	Childers et al.	N/A	N/A
7247154	12/2006	Hickle	N/A	N/A
7253779	12/2006	Greer et al.	N/A	N/A
7254425	12/2006	Lowery et al.	N/A	N/A
7258534	12/2006	Fathallah et al.	N/A	N/A
7267664	12/2006	Rizzo	N/A	N/A
7267665	12/2006	Steil et al.	N/A	N/A
7272529	12/2006	Hogan et al.	N/A	N/A
7278983	12/2006	Ireland et al.	N/A	N/A
7291123	12/2006	Baraldi et al.	N/A	N/A
7293461	12/2006	Gimdt	N/A	N/A
7294109	12/2006	Lovett et al.	N/A	N/A
7296482	12/2006	Schaffer et al.	N/A	N/A
7300418	12/2006	Zaleski	N/A	N/A
7305883	12/2006	Khuri-Yakub et al.	N/A	N/A
7327273	12/2007	Hung et al.	N/A	N/A
D563986	12/2007	Lettau	N/A	N/A
7338470	12/2007	Katz	N/A	N/A
7343224	12/2007	DiGianfilippo et al.	N/A	N/A
7347836	12/2007	Peterson et al.	N/A	N/A
7347854	12/2007	Shelton et al.	N/A	N/A
7354420	12/2007	Steil et al.	N/A	N/A
7356382	12/2007	Vanderveen	N/A	N/A
7360999	12/2007	Nelson et al.	N/A	N/A
7364562	12/2007	Braig et al.	N/A	N/A

7367942	12/2007	Grage et al.	N/A	N/A
7369948	12/2007	Ferenczi et al.	N/A	N/A
7384410	12/2007	Eggers et al.	N/A	N/A
7397166	12/2007	Morgan et al.	N/A	N/A
7398183	12/2007	Holland et al.	N/A	N/A
7399277	12/2007	Saidara et al.	N/A	N/A
7402153	12/2007	Steil et al.	N/A	N/A
7402154	12/2007	Mendez	N/A	N/A
7407489	12/2007	Mendez	N/A	N/A
7414534	12/2007	Kroll et al.	N/A	N/A
7415895	12/2007	Kurisaki et al.	N/A	N/A
7426443	12/2007	Simon	N/A	N/A
7430675	12/2007	Lee et al.	N/A	N/A
7447566	12/2007	Knauper et al.	N/A	N/A
7447643	12/2007	Olson	N/A	N/A
7452190	12/2007	Bouton et al.	N/A	N/A
7454314	12/2007	Holland et al.	N/A	N/A
7471994	12/2007	Ford et al.	N/A	N/A
7477997	12/2008	Kaplit	N/A	N/A
7482818	12/2008	Greenwald et al.	N/A	N/A
7483756	12/2008	Engleson et al.	N/A	N/A
7490021	12/2008	Holland et al.	N/A	N/A
7491187	12/2008	Van Den Berghe et al.	N/A	N/A
7503903	12/2008	Carlisle et al.	N/A	N/A
7517332	12/2008	Tonelli et al.	N/A	N/A
7523401	12/2008	Aldridge	N/A	N/A
D593125	12/2008	Danton	N/A	N/A
7545075	12/2008	Huang et al.	N/A	N/A
D596195	12/2008	Wall	N/A	N/A
7556616	12/2008	Fathallah et al.	N/A	N/A
7561986	12/2008	Vanderveen et al.	N/A	N/A
7571024	12/2008	Duncan et al.	N/A	N/A
7605730	12/2008	Tomioka et al.	N/A	N/A
7614310	12/2008	Konzelmann	N/A	N/A
7645258	12/2009	White et al.	N/A	N/A
7654127	12/2009	Krulevitch et al.	N/A	N/A
7657443	12/2009	Crass	N/A	N/A
7668731	12/2009	Martucci et al.	N/A	N/A
7678048	12/2009	Urbano et al.	N/A	N/A
7693697	12/2009	Westenskow et al.	N/A	N/A
7699806	12/2009	Ware et al.	N/A	N/A
7705727	12/2009	Pestotnik	N/A	N/A
D617807	12/2009	Christie	N/A	N/A
D621845	12/2009	Anzures	N/A	N/A
7766873	12/2009	Moberg et al.	N/A	N/A
7775126	12/2009	Eckhardt	N/A	N/A
7775127	12/2009	Wade	N/A	N/A
7785284	12/2009	Baralsi et al.	N/A	N/A
7785313	12/2009	Mastrototaro	N/A	N/A
7786909	12/2009	Udupa et al.	N/A	N/A
7806886	12/2009	Kanderian, Jr. et al.	N/A	N/A
7826981	12/2009	Goode, Jr. et al.	N/A	N/A
7847276	12/2009	Carlisle	N/A	N/A

7860583	12/2009	Condurso et al.	N/A	N/A
7871394	12/2010	Halbert et al.	N/A	N/A
7876443	12/2010	Bernacki	N/A	N/A
7895053	12/2010	Holland et al.	N/A	N/A
7895882	12/2010	Carlisle	N/A	N/A
7896834	12/2010	Smisson, III	N/A	N/A
7896842	12/2010	Palmroos et al.	N/A	N/A
7905710	12/2010	Wang et al.	N/A	N/A
7933780	12/2010	de la Huerga	N/A	N/A
7938817	12/2010	Gelfand et al.	N/A	N/A
7945452	12/2010	Fathallah et al.	N/A	N/A
D642195	12/2010	Marks	N/A	N/A
7976508	12/2010	Hoag	N/A	N/A
7981073	12/2010	Mollstam	N/A	N/A
7981082	12/2010	Wang et al.	N/A	N/A
7998134	12/2010	Fangrow	N/A	N/A
8002736	12/2010	Patrick et al.	N/A	N/A
8034020	12/2010	Dewey	N/A	N/A
8038593	12/2010	Friedman et al.	N/A	N/A
8065161	12/2010	Howard et al.	N/A	N/A
8067760	12/2010	Carlisle	N/A	N/A
8075514	12/2010	Butterfield et al.	N/A	N/A
8075546	12/2010	Carlisle et al.	N/A	N/A
8078983	12/2010	Davis et al.	N/A	N/A
8121857	12/2011	Galasso et al.	N/A	N/A
8149131	12/2011	Blomquist	N/A	N/A
D659709	12/2011	Eby	N/A	N/A
8175668	12/2011	Nabutovsky et al.	N/A	N/A
8177739	12/2011	Cartledge et al.	N/A	N/A
8180440	12/2011	McCombie et al.	N/A	N/A
8185322	12/2011	Schroeder et al.	N/A	N/A
8197444	12/2011	Bazargan et al.	N/A	N/A
8219413	12/2011	Martinez et al.	N/A	N/A
8221395	12/2011	Shelton et al.	N/A	N/A
8226597	12/2011	Jacobson et al.	N/A	N/A
8231578	12/2011	Fathallah et al.	N/A	N/A
8234128	12/2011	Martucci et al.	N/A	N/A
D667452	12/2011	Wujcik	N/A	N/A
D667840	12/2011	Anzures	N/A	N/A
8271106	12/2011	Wehba et al.	N/A	N/A
8287514	12/2011	Miller et al.	N/A	N/A
8291337	12/2011	Gannin et al.	N/A	N/A
8313308	12/2011	Lawless et al.	N/A	N/A
8317698	12/2011	Lowery	N/A	N/A
8317750	12/2011	Ware et al.	N/A	N/A
8317752	12/2011	Cozmi et al.	N/A	N/A
8318094	12/2011	Bayandorian et al.	N/A	N/A
8340792	12/2011	Condurso et al.	N/A	N/A
8347731	12/2012	Genosar	N/A	N/A
8359338	12/2012	Butterfield et al.	N/A	N/A
8361021	12/2012	Wang et al.	N/A	N/A
8378837	12/2012	Wang et al.	N/A	N/A
8388598	12/2012	Steinkogler	N/A	N/A

8398616	12/2012	Budiman	N/A	N/A
8403908	12/2012	Jacobson et al.	N/A	N/A
D679727	12/2012	Abratowski	N/A	N/A
8409164	12/2012	Fangrow	N/A	N/A
8449524	12/2012	Braig et al.	N/A	N/A
8469942	12/2012	Kow et al.	N/A	N/A
8477307	12/2012	Yufa et al.	N/A	N/A
8494879	12/2012	Davis et al.	N/A	N/A
8504179	12/2012	Blomquist	N/A	N/A
8506552	12/2012	Rebours	N/A	N/A
8517990	12/2012	Teel et al.	N/A	N/A
8518021	12/2012	Stewart et al.	N/A	N/A
8522832	12/2012	Lopez et al.	N/A	N/A
8523797	12/2012	Lowery et al.	N/A	N/A
8539812	12/2012	Stringham et al.	N/A	N/A
8543416	12/2012	Palmroos et al.	N/A	N/A
8577692	12/2012	Silkaitis et al.	N/A	N/A
8622990	12/2013	Estes et al.	N/A	N/A
8630722	12/2013	Condurso et al.	N/A	N/A
8665214	12/2013	Forutanpour et al.	N/A	N/A
8666769	12/2013	Butler et al.	N/A	N/A
8700421	12/2013	Feng et al.	N/A	N/A
8706233	12/2013	Su et al.	N/A	N/A
D705260	12/2013	Gerssen	N/A	N/A
8721584	12/2013	Braithwaite et al.	N/A	N/A
8728020	12/2013	Caleffi et al.	N/A	N/A
D706294	12/2013	Jewitt	N/A	N/A
8758306	12/2013	Lopez et al.	N/A	N/A
8761906	12/2013	Condurso et al.	N/A	N/A
D709091	12/2013	Kwon	N/A	N/A
8768719	12/2013	Wehba et al.	N/A	N/A
8771251	12/2013	Ruchti et al.	N/A	N/A
8792981	12/2013	Yudovsky et al.	N/A	N/A
D711916	12/2013	Matas	N/A	N/A
D712926	12/2013	Meegan	N/A	N/A
D713417	12/2013	Daniel	N/A	N/A
D713418	12/2013	Yang	N/A	N/A
D713420	12/2013	Dallmeyer	N/A	N/A
8821432	12/2013	Unverdorben	N/A	N/A
8823382	12/2013	Rondoni et al.	N/A	N/A
8857269	12/2013	Johnson et al.	N/A	N/A
8858185	12/2013	Johnson et al.	N/A	N/A
8905965	12/2013	Mandro et al.	N/A	N/A
D721385	12/2014	Barling	N/A	N/A
8948734	12/2014	Vaglio	N/A	N/A
8964185	12/2014	Luo et al.	N/A	N/A
9005150	12/2014	Ware et al.	N/A	N/A
9026370	12/2014	Rubalcaba et al.	N/A	N/A
9084855	12/2014	Ware et al.	N/A	N/A
9114217	12/2014	Sur et al.	N/A	N/A
9134735	12/2014	Lowery et al.	N/A	N/A
9134736	12/2014	Lowery et al.	N/A	N/A
9138526	12/2014	Ware et al.	N/A	N/A

D742413	12/2014	Torres	N/A	N/A
D742414	12/2014	Brunner	N/A	N/A
D742415	12/2014	Cahill	N/A	N/A
D743414	12/2014	Uno	N/A	N/A
9190010	12/2014	Vik et al.	N/A	N/A
D747339	12/2015	Cohen	N/A	N/A
9240002	12/2015	Hume et al.	N/A	N/A
D750099	12/2015	Kadosh	N/A	N/A
9272089	12/2015	Jacobson et al.	N/A	N/A
9316216	12/2015	Cook et al.	N/A	N/A
D757099	12/2015	Seo	N/A	N/A
9333291	12/2015	Jacobson et al.	N/A	N/A
D758379	12/2015	Kadosh	N/A	N/A
D759036	12/2015	Evanes	N/A	N/A
D760238	12/2015	Suarez	N/A	N/A
D760248	12/2015	Smith	N/A	N/A
D760295	12/2015	Smith	N/A	N/A
D760788	12/2015	Cho	N/A	N/A
D761820	12/2015	Lee	N/A	N/A
D762238	12/2015	Day	N/A	N/A
9381296	12/2015	Arrizza et al.	N/A	N/A
9393362	12/2015	Cozmi et al.	N/A	N/A
D764538	12/2015	Lee	N/A	N/A
9468718	12/2015	Hung et al.	N/A	N/A
9498583	12/2015	Sur et al.	N/A	N/A
D773519	12/2015	Hurley	N/A	N/A
D777205	12/2016	Orr	N/A	N/A
9545475	12/2016	Borges et al.	N/A	N/A
9545476	12/2016	Qi et al.	N/A	N/A
D779537	12/2016	Wingate-Whyte	N/A	N/A
D781874	12/2016	Dunn	N/A	N/A
D782535	12/2016	Menz	N/A	N/A
9707341	12/2016	Dumas, III et al.	N/A	N/A
9764087	12/2016	Peterfreund et al.	N/A	N/A
9773330	12/2016	Douglas	N/A	N/A
D803881	12/2016	Hurley	N/A	N/A
D806109	12/2016	Day	N/A	N/A
9852265	12/2016	Treacy et al.	N/A	N/A
D809006	12/2017	Mehta	N/A	N/A
9883987	12/2017	Lopez et al.	N/A	N/A
9943269	12/2017	Muhsin et al.	N/A	N/A
9995611	12/2017	Ruchti et al.	N/A	N/A
10002496	12/2017	Humphrey	N/A	N/A
10022498	12/2017	Ruchti et al.	N/A	N/A
10046112	12/2017	Oruklu et al.	N/A	N/A
D827665	12/2017	Segars	N/A	N/A
10089055	12/2017	Fryman	N/A	N/A
10099009	12/2017	Anderson et al.	N/A	N/A
10166328	12/2018	Oruklu et al.	N/A	N/A
10241626	12/2018	Miyazawa	N/A	N/A
10297350	12/2018	Duke et al.	N/A	N/A
10342917	12/2018	Shubinsky et al.	N/A	N/A
10430761	12/2018	Hume et al.	N/A	N/A

D865777	12/2018	Kovács	N/A	N/A
10463788	12/2018	Day	N/A	N/A
10549248	12/2019	Brown et al.	N/A	N/A
10578474	12/2019	Ruchti et al.	N/A	N/A
10596316	12/2019	Dumas, III et al.	N/A	N/A
10635784	12/2019	Rubalcaba, Jr. et al.	N/A	N/A
10656894	12/2019	Fryman	N/A	N/A
10682102	12/2019	Declerck	N/A	N/A
10709885	12/2019	Janders et al.	N/A	N/A
D898055	12/2019	Connolly	N/A	N/A
10850024	12/2019	Day et al.	N/A	N/A
10874793	12/2019	Oruklu et al.	N/A	N/A
11004035	12/2020	Hume et al.	N/A	N/A
11007119	12/2020	Lopez et al.	N/A	N/A
D922432	12/2020	Kataoka et al.	N/A	N/A
D923050	12/2020	Kataoka et al.	N/A	N/A
11029911	12/2020	Fryman	N/A	N/A
D926201	12/2020	Bryant et al.	N/A	N/A
D926224	12/2020	Hummel	N/A	N/A
D928813	12/2020	Nurutdinov et al.	N/A	N/A
D928840	12/2020	Amit et al.	N/A	N/A
11090431	12/2020	Dumas, III et al.	N/A	N/A
D931884	12/2020	Bryant et al.	N/A	N/A
D931892	12/2020	Nurutdinov	N/A	N/A
D934282	12/2020	Clymer	N/A	N/A
11135360	12/2020	Jacobson et al.	N/A	N/A
11219715	12/2021	Gray et al.	N/A	N/A
11246985	12/2021	Gylland et al.	N/A	N/A
D946608	12/2021	Higuchi	N/A	N/A
11278671	12/2021	Cavendish, Jr. et al.	N/A	N/A
11298456	12/2021	Shubinsky et al.	N/A	N/A
11324888	12/2021	Shubinsky et al.	N/A	N/A
11344668	12/2021	Sileika et al.	N/A	N/A
11344673	12/2021	Lindo et al.	N/A	N/A
11376361	12/2021	Ruchti et al.	N/A	N/A
11378430	12/2021	Ruchti et al.	N/A	N/A
11395875	12/2021	Rubalcaba, Jr. et al.	N/A	N/A
11433177	12/2021	Oruklu et al.	N/A	N/A
11439570	12/2021	Lopez et al.	N/A	N/A
11596737	12/2022	Dumas, III et al.	N/A	N/A
11599854	12/2022	Hume et al.	N/A	N/A
11623042	12/2022	Day	N/A	N/A
11868161	12/2023	Fryman	N/A	N/A
11883361	12/2023	Janssen	N/A	N/A
D1017633	12/2023	Chung	N/A	N/A
D1018593	12/2023	Chiah	N/A	N/A
11933650	12/2023	Ruchti et al.	N/A	N/A
D1021917	12/2023	Ceniceroz	N/A	N/A
D1023027	12/2023	Slettnes	N/A	N/A
D1024096	12/2023	Zhong	N/A	N/A
11972395	12/2023	Hume et al.	N/A	N/A
D1027974	12/2023	Correy	N/A	N/A
12048831	12/2023	Oruklu et al.	N/A	N/A

12059551	12/2023	Dumas, III et al.	N/A	N/A
12076531	12/2023	Shubinsky et al.	N/A	N/A
12083310	12/2023	Shubinsky et al.	N/A	N/A
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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) The present application is a continuation of U.S. Ser. No. 17/114,359, filed Dec. 7, 2020, now U.S. Pat. No. 11,135,360, which is incorporated by reference herein. The present application is also related to U.S. application Ser. No. 16/301,379, filed

Nov. 13, 2018, which is the national stage of International Application No. PCT/US2017/032017, filed May 10, 2017, which claims the benefit of priority from U.S. Provisional No. 62/336,191, filed May 13, 2016, all of which are incorporated by reference in their entireties.

BACKGROUND

Field

(1) The present invention relates to medical devices and infusion pump systems.

(2) Infusion pumps are medical devices that deliver fluids, including nutrients and medications such as antibiotics, chemotherapy drugs, and pain relievers, in controlled amounts. Many types of pumps, including large volume, patient-controlled analgesia (PCA), elastomeric, syringe, enteral, and insulin pumps, are used worldwide in healthcare facilities, such as hospitals, and in the home. Clinicians and patients rely on pumps for safe and accurate administration of fluids and medications.

(3) It is often desirable to provide more than one therapeutic fluid to the patient from the same infusion pump. Two fluid reservoirs with different therapeutic fluids are connected to the infusion pump and then delivered through a common line having a terminal fluid delivery end. The terminal fluid delivery end is attached to the patient. The first therapeutic fluid and second therapeutic fluid may be administered concurrently or one at a time by controlling the fluid flow path to draw fluid from both reservoirs or from only one reservoir.

(4) When switching from single to concurrent fluid delivery, the therapeutic fluid remaining in the common line may lead to complexity in controlling delivery volumes or flow rates when switching between fluid sources. For example, the remaining therapeutic fluid must be cleared from the common line before the next therapeutic fluid begins administration (entering the patient's body), which delays the next therapeutic fluid from reaching the patient. In addition, when the therapeutic fluids are administered concurrently, the first therapeutic fluid remaining in the common line will be administered at the combined rate of the first therapeutic fluid infusion rate plus the second therapeutic fluid infusion rate, e.g., the remaining first therapeutic fluid will be administered at the combined rate determined from the rates specified for the first and second therapeutic fluids. This can result in the patient receiving more or less than the optimum therapy with respect to the first therapeutic fluid. Furthermore, the remaining therapeutic fluid may not be correctly accounted for, potentially creating delays in the values indicated at the infusion pump, versus therapeutic fluid received by the patient. Finally, a single medication delivered at a combined rate may actually result in the single medication being infused at a rate that can exceed an upper soft or hard limit specified for such medication until the medication in the common line is displaced by an intended second fluid (in the case of a piggyback infusion) or a mixture of first and second fluids (in the case of a concurrent delivery). While the pump data will be correct in terms of infusion rates over given times, the actual fluid delivery to the terminal fluid delivery end at the patient may not be correctly captured in pump and system data.

(5) In addition, while some infusion therapies specify a particular volume of fluid to infuse to a patient, in some therapies it is preferred to deliver 100% of the volume of fluid contained within a particular fluid reservoir, such that the fluid is delivered until the reservoir is emptied. However, with many infusion pump systems, due to variable fluid volume contained in the reservoir and typical pump delivery accuracy tolerances and system dependencies, it is only possible to achieve 100% fluid delivery by over-programming the pump, or by entering pump programming parameters that do not accurately reflect the volume and duration of fluid actually administered to the patient.

(6) It would be desirable to have infusion pump systems and methods with common line auto flush that would overcome the above disadvantages.

SUMMARY

(7) In one embodiment, a control system is provided to control operation of an infusion pump of an infusion pump system. The infusion pump system includes a first reservoir configured to hold a first fluid, a second reservoir configured to hold a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, a common line in fluid communication with the junction and having a terminal fluid delivery end, and the infusion pump, wherein the infusion pump is operable to drive fluid through the common line toward the terminal fluid delivery end. The control system includes: one or more hardware processors; and a memory storing executable instructions that when executed by

the one or more hardware processors, configure the infusion pump to: receive instructions to deliver the first fluid at a first rate, subsequently concurrently deliver a mixture of the first fluid and the second fluid, and concurrently deliver the first fluid at the first rate and the second fluid at a second rate; infuse the first fluid at the first rate along a first flow path, the first flow path including the common line; determine a common line volume corresponding to a volume of the common line; draw the first fluid from the first reservoir the second fluid from the second reservoir to deliver the mixture of the first fluid and the second fluid; infuse the mixture of the first fluid and the second fluid at a flushing rate along a second flow path, the second flow path including the common line; determine that an infused volume of the mixture of the first fluid and the second fluid equals or exceeds the common line volume; and change the infusion rate of the mixture of the first fluid and the second fluid from the flushing rate to a combined rate, wherein the combined rate is the sum of the first rate and the second rate, and continue to infuse the mixture of the first fluid and the second fluid along the second flow path at the combined rate.

(8) The control system may also include a mixing chamber in fluid communication with the first reservoir, the second reservoir, and the common line. The executable instructions may further configure the infusion pump to determine the flushing rate based upon whether the first fluid is a medicinal fluid, determine the flushing rate as the first rate when the first fluid is a medicinal fluid, or determine the flushing rate as the first rate increased by a flushing rate factor when the first fluid is not a medicinal fluid.

(9) The instructions may further configure the infusion pump to receive the common line volume from a user input, retrieve the common line volume from the memory, or retrieve the common line volume over a network. The common line volume may be predetermined. The instructions may further configure the infusion pump to determine the common volume based on the first fluid. The first rate may be different than the second rate.

(10) The instructions may further configure the infusion pump to receive the instructions for the delivery from an input via a user interface. The executable instructions further configure the infusion pump to: determine that an infusion of the second fluid has completed; draw the first fluid from the first reservoir without drawing the second fluid from the second reservoir; infuse the first fluid at the combined rate; determine that a volume of the first fluid infused at the combined rate equals or exceeds the common line volume; and change the infusion rate of the first fluid from the combined rate to the first rate.

(11) The executable instructions may configure the infusion pump to determine that an infusion of the second fluid has completed by comparing a volume of fluid infused to a programmed volume to infuse, determine that an infusion of the second fluid has completed by receiving an instruction to stop infusing the second fluid, or determine that an infusion of the second fluid has completed by determining that the second reservoir has been depleted of second fluid.

(12) The executable instructions may further configure the infusion pump to: determine that an infusion of the first fluid has completed; draw the second fluid from the second reservoir without drawing the first fluid from the first reservoir; infuse the second fluid at the combined rate; determine that a volume of the second fluid infused at the combined rate equals or exceeds the common line volume; and change the infusion rate of the second fluid from the combined rate to the second rate.

(13) The executable instructions may configure the infusion pump to determine that an infusion of the first fluid has completed by comparing a volume of fluid infused to a programmed volume to infuse, determine that an infusion of the first fluid has completed by receiving an instruction to stop infusing the first fluid, or determine that an infusion of the first fluid has completed by determining that the first reservoir has been depleted of first fluid.

(14) In another embodiment, a method for controlling operation of an infusion pump of an infusion pump system is provided. The infusion pump system includes a first reservoir configured to hold a first fluid, a second reservoir configured to hold a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, a common line in fluid communication with the junction and having a terminal fluid delivery end, and the infusion pump, wherein the infusion pump is operable to drive fluid through the common line toward the terminal fluid delivery end. The method includes: drawing the first fluid from the first reservoir and the second fluid from the second reservoir to form a mixture of the first fluid and the second fluid; infusing the mixture of the first fluid and the second fluid at a combined rate, wherein the combined rate is a sum of a first infusion rate associated with the first

fluid and a second infusion rate associated with the second fluid; determining a common line volume corresponding to a volume of the common line; determining that the second reservoir is depleted; drawing the first fluid from the first reservoir without drawing the second fluid from the second reservoir; driving the first fluid at the combined rate along a flow path including the common line; determining that a driven volume of the first fluid equals or exceeds the common line volume; and changing the infusion rate of the first fluid from the combined rate to the first rate, and continuing to infuse the first fluid along the flow path at the first rate.

(15) The infusion pump may also include a mixing chamber in fluid communication with the first reservoir, the second reservoir, and the common line. Determining the common line volume may include receiving the common line volume from a user input, retrieving the common line volume from a memory, or retrieving the common line volume over a network. The common line volume may be predetermined.

(16) Determining the common line volume may include determining the common line volume based on the first fluid. The first rate may be different than the second rate. Driving the first fluid at the combined rate may include driving the first fluid at a rate that exceeds a drug library rate limit associated with the first fluid. Determining that the second reservoir is depleted may include receiving a sensor signal that air is present in the junction or in a line coupling the junction to the second reservoir.

(17) The method may further include pumping the first fluid from the first reservoir towards the second reservoir in response to receiving the sensor signal that air is present in the junction or in the line coupling the junction to the second reservoir.

(18) In yet another embodiment, a control system for controlling operation of an infusion pump of an infusion pump system is provided. The infusion pump system includes a first reservoir configured to hold a first fluid, a second reservoir configured to hold a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, a common line in fluid communication with the junction and having a terminal fluid delivery end, and the infusion pump, wherein the infusion pump is operable to drive fluid through the common line toward the terminal fluid delivery end. The control system includes: one or more hardware processors; and a memory storing executable instructions that when executed by the one or more hardware processors, configure the infusion pump to: draw the first fluid from the first reservoir and the second fluid from the second reservoir to form a mixture of the first fluid and the second fluid; infuse the mixture of the first fluid and the second fluid at a combined rate, wherein the combined rate is a sum of a first infusion rate associated with the first fluid and a second infusion rate associated with the second fluid; determine a common line volume corresponding to a volume of the common line; draw the first fluid from the first reservoir without drawing the second fluid from the second reservoir; drive the first fluid at the combined rate along a flow path including the common line; determine that a driven volume of the first fluid equals or exceeds the common line volume; and change the infusion rate of the first fluid from the combined rate to the first rate, and continue to infuse the first fluid along the flow path at the first rate.

(19) The infusion pump may also include a mixing chamber in fluid communication with the first reservoir, the second reservoir, and the common line.

(20) The executable instructions may also configure the infusion pump to determine the common line volume by receiving the common line volume from a user input, determine the common line volume by retrieving the common line volume from a memory, or determine the common line volume by retrieving the common line volume over a network. The common line volume may be predetermined.

(21) The executable instructions may also configure the infusion pump to determine the common line volume by determining the common line volume based on the first fluid. The first rate may be different than the second rate.

(22) The executable instructions may configure the infusion pump to drive the first fluid at the combined rate by driving the first fluid at a rate that exceeds a drug library rate limit associated with the first fluid. The executable instructions may configure the infusion pump to determine that the second reservoir is depleted by receiving a sensor signal that air is present in the junction or in a line coupling the junction to the second reservoir. The executable instructions may further configure the infusion pump to pump the first fluid from the first reservoir towards the second reservoir in response to receiving the sensor signal that air is present in the junction or in the line coupling the junction to the second reservoir.

(23) In yet another embodiment, a method for controlling operation of an infusion pump of an infusion pump system is provided. The infusion pump system includes a first reservoir configured to hold a first fluid, a second reservoir configured to hold a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, a common line in fluid communication with the junction and having a terminal fluid delivery end, and the infusion pump, wherein the infusion pump is operable to drive fluid through the common line toward the terminal fluid delivery end. The method includes: receiving instructions to deliver the first fluid at a first rate, subsequently concurrently deliver a mixture of the first fluid and the second fluid, and concurrently deliver the first fluid at the first rate and the second fluid at a second rate; infusing the first fluid at the first rate along a first flow path, the first flow path including the common line; determining a common line volume corresponding to a volume of the common line; drawing the first fluid from the first reservoir the second fluid from the second reservoir to deliver the mixture of the first fluid and the second fluid; infusing the mixture of the first fluid and the second fluid at a flushing rate along a second flow path, the second flow path including the common line; determining that an infused volume of the mixture of the first fluid and the second fluid equals or exceeds the common line volume; and changing the infusion rate of the mixture of the first fluid and the second fluid from the flushing rate to a combined rate, wherein the combined rate is the sum of the first rate and the second rate, and continue to infuse the mixture of the first fluid and the second fluid along the second flow path at the combined rate.

(24) The infusion pump system may also include a mixing chamber in fluid communication with the first reservoir, the second reservoir, and the common line. The method may also include determining the flushing rate based upon whether the first fluid is a medicinal fluid, determining the flushing rate as the first rate when the first fluid is a medicinal fluid, or determining the flushing rate as the first rate increased by a flushing rate factor when the first fluid is not a medicinal fluid.

(25) The method may also include receiving the common line volume from a user input, retrieving the common line volume from the memory, or retrieving the common line volume over a network. The common line volume may be predetermined.

(26) The method may also include determining the common volume based on the first fluid. The first rate may be different than the second rate. Infusing the mixture of the first fluid and the second fluid at the flushing rate may include one or more of delivering the first fluid at a first fluid flush rate that exceeds a drug library rate limit associated with the first fluid or delivering the second fluid at a second fluid flush rate that exceeds a drug library rate limit associated with the second fluid.

(27) The method may also include: determining that an infusion of the second fluid has completed; drawing the first fluid from the first reservoir without drawing the second fluid from the second reservoir; infusing the first fluid at the combined rate; determining that a volume of the first fluid infused at the combined rate equals or exceeds the common line volume; and changing the infusion rate of the first fluid from the combined rate to the first rate.

(28) The method may also include determining that an infusion of the second fluid has completed by comparing a volume of fluid infused to a programmed volume to infuse, determining that an infusion of the second fluid has completed by receiving an instruction to stop infusing the second fluid, or determining that an infusion of the second fluid has completed by determining that the second reservoir has been depleted of second fluid. Infusing the first fluid at the combined rate may include infusing the first fluid at a rate that exceeds a drug library rate limit associated with the first fluid.

(29) The method may also include: determining that an infusion of the first fluid has completed; drawing the second fluid from the second reservoir without drawing the first fluid from the first reservoir; infusing the second fluid at the combined rate; determining that a volume of the second fluid infused at the combined rate equals or exceeds the common line volume; and changing the infusion rate of the second fluid from the combined rate to the second rate.

(30) The method may also include determining that an infusion of the first fluid has completed by comparing a volume of fluid infused to a programmed volume to infuse, determining that an infusion of the first fluid has completed by receiving an instruction to stop infusing the first fluid, or determining that an infusion of the first fluid has completed by determining that the first reservoir has been depleted of first fluid. Infusing the second fluid at the combined rate may include infusing the second fluid at a rate that exceeds a drug library rate limit associated with the second fluid.

(31) The foregoing and other features and advantages of the invention will become further apparent from the following detailed description of the presently preferred embodiments, read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the invention rather than limiting. The scope of the invention is defined by the appended claims and equivalents thereof.

(32) In certain embodiments, a control system can control operation of an infusion pump system. The infusion pump system can include a first reservoir that can hold a first fluid, a second reservoir configured to hold a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, a common line in fluid communication with the junction and having a terminal fluid delivery end, and an infusion pump operable to drive fluid through the common line toward the terminal fluid delivery end. The control system can control whether fluids from the reservoirs are drawn individually or concurrently (e.g., simultaneously or in an alternating manner). For example, the control system can include a flow control mechanism to manipulate a flow path at the junction to draw fluid from the first reservoir alone, the second reservoir alone, or both first and second reservoirs in an alternating manner.

(33) The first reservoir may be referred to as the primary source and the second reservoir may be referred to as the secondary source. During a primary infusion, fluid is infused from the first, or primary reservoir, into the junction, and through the common line to the terminal end (and into the patient) at a first infusion rate. During a secondary infusion, fluid is infused from the second, or secondary reservoir, into the junction, and through the common line to the terminal end (and into the patient) at a second infusion rate. During a concurrent infusion (sometimes referred to as concurrent delivery), first and second fluids are infused simultaneously to a patient at respective first and second infusion rates. A first volume of the first fluid is drawn from the first reservoir, and a second volume of the second fluid is drawn from the second reservoir. The first and second volumes are proportionate to the first and second infusion rates. Once the first and second fluids have been drawn, the pump drives (e.g., pumps or pushes out) the fluid combination through the common line to the terminal and (and into the patient) at a combined rate.

(34) The combined rate can be equal to one of the first or second infusion rates, or it can be determined from the first and second infusion rates. For example, the combined rate can be determined as the sum as the first and second infusion rates. In some cases, a maximum rate may be established, and if the sum of the programmed first and second rates exceeds the maximum rate, then the combined rate may be set to the maximum rate. Other methods of determining a combined rate using the first and second rates are possible, as well. In addition, if the combined rate equals or exceeds a predetermined maximum combined rate, the first and second rates may be reduced proportionally such that their sum is less than or equals the maximum combined rate. In other embodiments, if the combined rate equals or exceeds a predetermined maximum combined rate, only the first rate is reduced until the sum of the first and second rates is less than or equals the maximum combined rate. For example, only the first rate may be reduced based upon a determination of fluid types of the first and second fluids. If the first fluid is a non-medication and the second fluid is a medication, then in some embodiments, the only the first rate is reduced (or the first rate is reduced by an amount or proportion that is greater than an amount or proportion that the second rate is reduced), such that the sum of the first and second rates is less than or equal to the maximum combined rate. In such embodiments, the user would be presented with a suggested first and second rate for approval or confirmation via a user interface before changing and/or initiating an infusion according to such adjusted first and/or second rates.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIGS. **1**A and **1**B are block diagrams of infusion pump systems with concurrent fluid delivery and common line auto flush in accordance with the present invention.

(2) FIG. **2** is a block diagram of an infusion pump with concurrent fluid delivery and common line auto flush in accordance with the present invention.

(3) FIG. **3** is a schematic diagram of an infusion pump with concurrent fluid delivery and common line auto flush in accordance with the present invention.
(4) FIGS. **4**A and **4**B are graphs of fluid volume delivered at the terminal fluid delivery end of the common line versus time for a method of use for an infusion pump with concurrent fluid delivery and common line auto flush in accordance with the present invention.
(5) FIG. **5**A is a flowchart of a method of concurrent fluid delivery and common line auto flush in accordance with the present invention that may be performed by the infusion pumps of FIGS. **1-3**.
(6) FIG. **5**B is a flowchart of a method of providing a secondary infusion until the secondary reservoir is depleted in accordance with the present invention that may be performed by the infusion pumps of FIGS. **1-3**.
(7) FIG. **5**C is a flowchart of a method of providing sequential infusions, where a primary infusion is provided until the primary reservoir is depleted in accordance with the present invention that may be performed by the infusion pumps of FIGS. **1-3**.
(8) FIG. **6** is a flowchart of a method of determining fluid drive start times to cause infusions to reach a patient at desired infusion start times in accordance with the present invention that may be performed by the infusion pumps of FIGS. **1-3**.
(9) FIGS. **7**A-**7**E are schematic diagrams of use for an infusion pump system with concurrent fluid delivery and common line auto flush in accordance with the present invention.
(10) Like elements share like reference numbers throughout the various figures.

DETAILED DESCRIPTION

(11) Systems and methods that improve an infusion pump system with concurrent delivery and common line auto flush are described herein. An infusion pump can operate in a primary delivery mode and deliver a first fluid from a first reservoir at a first rate, and then switch to a concurrent delivery mode, such as by delivering a combination of the first fluid from the first reservoir and a second fluid from a second reservoir at a combined delivery rate. The pump may switch from a concurrent delivery mode to a primary delivery mode (or to a secondary delivery mode where a second fluid is delivered from a second reservoir at a second rate), as well.
(12) As discussed above, first fluid will remain in the common line at the time the delivery mode is switched from primary delivery mode to concurrent delivery mode. Therefore, if the first and second fluids are delivered at the combined delivery rate as soon as the concurrent delivery mode begins, the first fluid remaining in the common line will be delivered into the patient at the incorrect (i.e., the combined) rate. Furthermore, delivering fluids at rates other than the desired rates may result in inaccurate therapy, which can be dangerous to the patient. The systems and methods described herein improve delivery and accurately account for the fluid remaining in the volume of the common line. Fluid as used herein can be any fluid suitable to be administered to a patient by infusion, including saline fluid, fluid including a drug or other therapeutic agent, or the like.
(13) FIGS. **1**A & **1**B are block diagrams for embodiments of infusion pump systems with concurrent delivery and a common line. The infusion pump system illustrated in FIG. **1**A includes a junction in fluid communication with the first reservoir and the second reservoir. An optional mixing chamber is located at the junction, or between the junction and the common line. The junction and/or mixing chamber is located internal to the infusion pump. In the embodiment of the infusion pump system illustrated in FIG. **1**B a junction in fluid communication with the first reservoir and the second reservoir is located external to the infusion pump. An optional mixing chamber is located at the junction, or between the junction and the common line. The location of the junction, in part, determines the length and internal volume of the common line between the junction and the terminal fluid delivery end. The internal cross-sectional shape, which is usually substantially circular, and the diameter and length of the common line determine its internal volume. Other shapes can be used without detracting from the scope of the disclosure.
(14) The infusion pump system **100** of FIG. **1**A includes a junction **180** internal to the infusion pump **130** and an optional mixing chamber (not shown) at the junction or between the junction **180** and a common line **140**. The infusion pump system **100** includes a first reservoir **110** that contains a first fluid **112**; a second reservoir **120** that contains a second fluid **122**; a junction **180** in fluid communication with the first reservoir **110** and the second reservoir **120**; an optional mixing chamber (not shown); a common line **140** in fluid communication with the mixing chamber and/or the junction **180** at one end **140**A and

having a terminal fluid delivery end **140**B for connection to the patient **102**, and an infusion pump **130** operable to drive fluid through the common line **140**.

(15) Primary Infusion Mode

(16) The infusion pump **130** is operable to operate in a primary infusion mode during which the infusion pump infuses the first fluid **112** at a first rate along a first flow path **150** that includes the first reservoir **110**, the junction **180**, the optional mixing chamber, and the common line **140**. The infusion pump **130** is further operable to determine a common line flush volume value corresponding to the internal volume of the common line **140**. The infusion pump **130** may determine the common line flush volume by receiving the value from an operator, receiving it over a network (e.g., from a drug library or other database), retrieving it from a memory of the infusion pump, or any other method described herein.

(17) Primary to Concurrent Infusion Mode with Auto Flush

(18) The infusion pump **130** is further configured to change to a concurrent infusion mode by drawing a second fluid **122** from a second reservoir **120** along a second flow path **160** into the junction **180** and/or mixing chamber and mixing it with the first fluid **112**, drawn from the first reservoir **110** via the first flow path **150**. The second flow path **160** includes the second reservoir **120**, the junction **180**, and the optional mixing chamber. The infusion pump is configured to initially infuse the mixture at the first rate until the volume of the first fluid is flushed out of the common line **140**. The infusion pump **130** is configured to monitor volume of the mixture of first and second fluids **112**, **122** driven at the first rate and subsequently pump the mixture of first and second fluids **112**, **122** at the programmed combined rate when the monitored volume of the mixture is equal to or greater than the common line flush volume value. In this case, the delivery rates of fluid **1** and fluid **2** would be reduced (scaled down) from programmed rates during displacement of the common line volume, and the pump system may allow an override of one or both lower rate limits, or other associated limits, defined respectively for each of fluid **1** and fluid **2**, during this phase of delivery.

(19) Alternatively, for example in a scenario where the first fluid is a not a medication (e.g., saline) and it is desired to initiate delivery of the second fluid (that is a medication) rapidly, the infusion pump could be configured to initially infuse the mixture at a more rapid rate to quickly displace the relatively inert common line volume. In this case, the initial combined rate could be increased (scaled up) to the programmed first rate plus the programmed second rate until the monitored volume of the mixture is equal to the common line flush volume. In this case, the delivery rates of fluid **1** and/or fluid **2** may be increased above upper rate limits defined for those respective fluids and the pump system may allow override of those limits during this phase of delivery. Further, the resulting scaled combined rate will be applied to the common line fluid **1**, whose upper rate limit may limit or define allowable increased combined rates during the common line displacement phase. In this case, drug library defined limits would be considered and applied by the pump system at the point of infusion to the patient as well as per pump programming activity.

(20) Concurrent to Primary Infusion Mode with Auto Flush

(21) The infusion pump **130** is further configured to change from concurrent delivery to a primary infusion mode by refraining from drawing the second fluid **122** from the second reservoir **120**, and by infusing only the first fluid **112** from the first reservoir **110** along the first flow path **150**. When the infusion pump switches to primary infusion mode, the infusion pump is configured to initially drive the first fluid **112** at the combined rate until the volume of the mixture of first and second fluids **112**, **122** is flushed out of the common line **140**. The infusion pump **130** is configured to monitor volume of the first fluid **112** driven at the combined rate and subsequently pump the first fluid **112** at the first rate when the monitored first fluid volume is equal to or greater than the common line flush volume value. In one example, the infusion pump **130** can be a fluid displacement pump employing a cassette, such as the Plum 360™ infusion pump available from ICU Medical, Inc. of San Clemente, CA Those skilled in the art will appreciate that the infusion pump **130** can be any type of pump operable to drive fluid from two reservoirs through a common line **140**. In this case, driving of the first fluid at the combined rate during common line displacement may require that the pump system allows override of drug library-defined upper rate limits for the first fluid.

(22) Concurrent to Secondary Infusion Mode with Auto Flush

(23) In another embodiment, the infusion pump **130** is further configured to change from a concurrent

delivery to a secondary infusion mode by refraining from drawing the first fluid **112** from the first reservoir **110**, and by infusing only the second fluid **122** from the second reservoir **120** along the second flow path **160**. For example, if the first fluid **112** infusion is completed or is stopped, the infusion pump **130** may automatically switch to a secondary infusion mode. In such case, the infusion pump **130** will stop drawing first fluid **112** from the first reservoir **110**, and it will continue to pump at the combined rate until the common line is cleared of the fluid mixture. In this case, the pump system may need to allow an override of upper rate limits for the second fluid while it is pumped at the combined rate during common line displacement. The infusion pump **130** is configured to monitor volume of the second fluid **122** driven at the combined rate and subsequently pump the second fluid **122** at the second rate when the monitored second fluid volume is equal to or greater than the common line flush volume value.

(24) In one embodiment, the infusion pump **130** can be operably connected to a medication management unit (MMU) **170** or a server over a hospital network and/or the Internet, to receive a drug library (or other database), which may specify an appropriate common line flush volume value. For example, the drug library (or other database) may include information regarding the volume of various tubing assemblies, each tubing assembly including a common line. The infusion pump (or server) may be configured to determine a tubing assembly identifier associated with a tubing assembly that is attached to the infusion pump and the patient **102**. The infusion pump may determine the tubing assembly identifier by receiving it from a server over the hospital network and/or the Internet, by receiving it via manual data entry by an operator, and/or by reading the tubing assembly identifier from the tubing assembly (or by other methods). For example, a tag, such as an RFID tag, an NFC tag or other wireless tag, may include the tubing assembly identifier. A tag reader incorporated into or in communication (directly or indirectly) with the infusion pump, may read the tag to determine the tubing assembly identifier. The common line flush volume value may be determined using the tubing assembly identifier and the drug library (or database).

(25) In one embodiment, the infusion pump **130** can be further operable to increment a displayed value of first fluid volume by the monitored volume when the mixture of first and second fluids **112**, **122** are driven at the first rate. The infusion pump **130** can be further operable to increment a displayed value of first and second fluid volumes when the first fluid **112** is driven at the combined rate. In one embodiment, the infusion pump **130** is operable to monitor the volume of infused first fluid **112** and switch to a concurrent infusion mode when the volume of the infused first fluid is equal to a Volume To Be Infused (VTBI) for the first fluid or when the volume of the infused first fluid is equal to the VTBI for the first fluid minus the volume of the common line. In one embodiment, the infusion pump **130** is operable to monitor the volume of infused second fluid **112** during a concurrent infusion mode and switch to a primary infusion mode when the volume of the infused second fluid is equal to a Volume To Be Infused (VTBI) for the second fluid or when the volume of the infused second fluid is equal to the VTBI for the second fluid minus the volume of the common line.

(26) The infusion pump **130** can be operable to receive the common line flush volume value for the common line **140** automatically from the drug library stored in a memory locally in the infusion pump system **100** or remotely on a server. In one example, the drug library associates the common flush volume value with a particular therapeutic agent. In some cases, the drug library may include an indication (e.g., a flag, value, etc.) that a particular fluid is a rate dependent medicinal fluid whose action is rate dependent. The infusion pump **130** may be configured to infuse such fluids (whether alone or concurrently with a second fluid) at the infusion rate specified for such fluids. In another example, the drug library associates the common flush volume value with a particular clinical care area (CCA), such as general care, an intensive care unit (ICU), a neonatal ICU, or the like. In yet another example, the drug library associates the common flush volume value with a particular consumable infusion set, which provides the common line volume. The drug library can include upper and lower dosing limits with hard and soft limits for a number of therapeutic agents. In another embodiment, the infusion pump **130** can be operable to receive the common line flush volume value for the common line **140** from a caregiver via an input on a user interface of the infusion pump.

(27) The common line **140** as illustrated includes the line between the junction **180** and the terminal fluid delivery end **140**B that is generally connectable to the patient **102** and includes any fluid path common to the first flow path **150** and the second flow path **160**. Thus, the common line **140** can include flow paths

within the infusion pump **130** (including the associated consumable infusion set, when applicable) common to the first flow path **150** and the second flow path **160**, and is not limited to tubing external to the infusion pump **130**. The common line **140** is any portion of the infusion pump system **100** through which the first fluid **112** or a combination of the first fluid **112** and the second fluid **122** can alternately flow when switched. In one embodiment, the common line flush volume value is an internal volume of the common line **140**. The common line flush volume value can include an associated consumable infusion set volume, extension sets, filters, stopcocks, manifolds, patient access devices, catheters, and the like. In another embodiment, the common line flush volume value is an internal volume of the common line **140** plus an adjustment volume. The adjustment volume can be any volume desired as a safety factor to assure that the common line **140** is free of the first fluid **112** before the second fluid **122** is infused at the second rate.

(28) The infusion pump system **100′** of FIG. **1**B has a junction **180′** external to the infusion pump **130′** and an optional mixing chamber (not shown) at the junction **180′** or between the junction **180′** and a common line **140′**. The infusion pump system **100′** includes a first reservoir **110′** containing a first fluid **112′**; a second reservoir **120′** containing a second fluid **122′**; a junction **180′** in fluid communication with the first reservoir **110′** and the second reservoir **120′**; an optional mixing chamber (not shown); a common line **140′** in fluid communication with the mixing chamber and/or the junction **180′** at one end **140***a′* of the common line **140′** and a terminal fluid delivery end **140**B′ that is generally connectable to the patient **102′**, and an infusion pump **130′** operable to drive fluid through the common line **140′**. The infusion pump **130′** is operable to: infuse the first fluid **112′** at a first rate along a first flow path **150′** including the first reservoir **110′**, the junction **180′**, the optional mixing chamber, and the common line **140′**; determine a common line flush volume value for the common line **140′**. The infusion pump **130′** may determine the common line flush volume by receiving the value from an operator, receiving it over a network (e.g., from a drug library or other database), retrieving it from a memory of the infusion pump, or any other method described herein.

(29) The infusion pump **130′** is further configured to change to a concurrent infusion mode by drawing a second fluid from a second reservoir **120′** along a second flow path **160′** into the optional mixing chamber and mixing it with the first fluid, drawn from the first reservoir **110′** via the first flow path **150′**. The second flow path **160′** includes the second reservoir **120′**, the junction **180′**, and the optional mixing chamber. The infusion pump is configured to initially infuse the mixture at the first rate until the volume of the first fluid is flushed out of the common line **140′**. The infusion pump **130′** is configured to monitor volume of the mixture of first and second fluids **112′**, **122′** driven at the first rate and subsequently pump the mixture of first and second fluids **112′**, **122′** at a combined rate when the monitored volume is equal to or greater than the common line flush volume value.

(30) The infusion pump **130′** is further configured to change to a primary infusion mode by refraining from drawing the second fluid **122′** from the second reservoir **120′**, and by infusing only the first fluid **112′** from the first reservoir **110′** along the first flow path **150′**. When the infusion pump **130′** switches to primary infusion mode, the infusion pump **130′** is configured to initially infuse the first fluid **112′** at the combined rate until the volume of the mixture of first and second fluids **112′**, **122′** is flushed out of the common line **140′**. The infusion pump **130′** is configured to monitor volume of the first fluid **112′** driven at the combined rate and subsequently pump the first fluid **112′** at the first rate when the monitored volume is equal to or greater than a common line flush volume value. The infusion pump **130′** is further configured to determine the common line flush volume value according to any of the methods described herein.

(31) In one embodiment, the junction **180′** can include a two-way valve to manually or automatically switch the infusion pump system **100′** between the first flow path **150′** and the second flow path **160′**. In one example, the infusion pump **130′** can be a peristaltic pump. Those skilled in the art will appreciate that the infusion pump **130′** can be any type of pump operable to drive fluid through the common line **140′**.

(32) FIG. **2** is a block diagram of an embodiment of an infusion pump with concurrent fluid delivery and common line auto flush. The infusion pump **230** is operably connected to a common line **240** in fluid communication with a junction **280** and/or mixing chamber at one end **240**A and having a terminal fluid delivery end **240**B (not shown), the junction **280** being in fluid communication with a first reservoir (not

shown) containing a first fluid and a second reservoir (not shown) containing a second fluid. In this example, a first reservoir line **211** provides fluid communication between the first reservoir and the junction **280** and a second reservoir line **221** provides fluid communication between the second reservoir and the junction **280**.

(33) The infusion pump **230** includes a memory **233** operable to store programming code; a flow controller **235** operably connected to the memory **233**; and a fluid driver **232** operably connected to receive a control signal **231** from the flow controller **235**, the fluid driver **232** being operable to drive fluid through the common line **240**. The flow controller **235** is operable to execute the programming code and provide the control signal **231** to the fluid driver **232** in response to the programming code. The fluid driver **232** is responsive to the control signal **231** to infuse the first fluid at a first rate along a first flow path **211** including the first reservoir, the junction **280**, and the common line **240**; receive a common line flush volume value associated with the common line **240**; switch from infusing only the first fluid via the first flow path **250** to infusing a combination of the first fluid from the first reservoir and a second fluid from the second reservoir; drive the fluid combination at the first rate; monitor volume of the fluid combination driven at the first rate; and drive the fluid combination at a combined rate when the monitored volume is equal to or greater than the common line flush volume value. The fluid driver **232** is also responsive to the control signal **231** to infuse the fluid combination at the combined rate; switch to infusing only the first fluid via the first flow path **250**; drive the first fluid at the combined rate; monitor the volume of the first fluid driven at the combined rate; and drive the first fluid at the first rate when the monitored volume is equal to or greater than the common line flush volume value. The combined rate may be retrieved from the memory **233** or determined from a first infusion rate associated with the first fluid and a second infusion rate associated with the second fluid. For example, the combined rate may be determined as the sum of the first and second infusion rates.

(34) In an embodiment, the flow controller **235** monitors the volume based on a time elapsed and a rate of delivery. The flow controller **235** can also monitor volume based on measurements, such as number of turns of a motor or signals from a sensor.

(35) The flow controller **235** can include a hardware processor, microprocessor, or the like responsive to the programming code to generate the control signal **231**. The fluid driver **232** can include a metered pump, such as a cartridge pump, peristaltic pump, or the like, operable to drive fluid at a desired rate in response to the control signal **231**. In one embodiment, the fluid driver **232** can be further responsive to the control signal **231** to increment a displayed first fluid volume by the monitored volume when the fluid combination is driven at the first rate or when the monitored volume is equal to or greater than an internal volume of the common line **240**. The fluid driver **232** can be further responsive to the control signal **231** to increment displayed first and second fluid volumes as the first fluid is driven at the combination rate or when the monitored volume is equal to or greater than the internal volume of the common line **240**. The first fluid displayed volume and/or the second fluid displayed volume can be displayed on a user interface **236**.

(36) The memory **233** can also be operable to store data and other information, such as a drug library **234** (or other database) including the common flush volume value, which can optionally be associated with a particular therapeutic agent, a particular clinical care area, and/or a particular consumable infusion set. Different therapeutic agents may have different fluid properties and thus it may be advantageous in some embodiments to associate particular common flush volume value with particular therapeutic agents. In one embodiment, the infusion pump **230** can receive the common line flush volume value for the common line **240** automatically from the drug library **234**. In another embodiment, the infusion pump **230** can receive the common line flush volume value manually via direct entry of the value on a user interface **236**. The manual entry can be accomplished using a manufacturer provided volume value based upon the length and internal diameter of the common line **240** or a list number or other identifier that is used to access an associated volume value from a lookup table in the pump memory **233**, drug library, stored in a network location, at a server, or MMU. The possibility for manual typographical errors can be reduced by use of a barcode, radio frequency (RFID), optical, touch memory reader, near field communicator, or the like to input or scan a machine readable identifier on the infusion set, common line, or its package to obtain the volume value, the list number or other identifier associated with the volume value.

(37) The infusion pump **230** can include human and/or machine interfaces as desired for a particular application. A user interface **236** operably connected to the flow controller **235** can provide input from and/or output to a caregiver or other user to the infusion pump **230**. Exemplary user interfaces can include display screens, soft keys or fixed keys, touchscreen displays, and the like. An I/O interface **237** operably connected to the flow controller **235** can provide input from and/or output to hardware associated with the infusion pump **230**. Exemplary I/O interfaces can include a wired and/or wireless interface to an electronic network, medication management unit (MMU), medication management system (MMS), or the like.
(38) The common line flush volume value can be selected as desired for a particular application. The common line **240** includes the line between the junction **280** and the terminal fluid delivery end **240**B, and includes any fluid path common to the first flow path **250** and the second flow path **260** and so can include any portion of the infusion pump **230** (including the associated consumable infusion set) through which the first fluid or the second fluid can alternately flow or flow in a combined manner. In one embodiment, the common line flush volume value is equal to the internal volume of the common line **240**, so that the second fluid is infused at the second rate along the second flow path as soon as the first fluid has been cleared from the common line **240**. In another embodiment, the common line flush volume value is equal to the internal volume of the common line **240** plus an adjustment volume (to take into account the added/subtracted volume of other connectors or components), so that the second fluid is infused at the second rate along the second flow path after the first fluid has been cleared from the common line **240** plus the adjustment volume of the second fluid has been delivered at the first rate. In another embodiment, the common line flush volume value is equal to the internal volume of the common line modified by a percentage, which could provide a desired overage or underage. The adjustment volume can be used as a safety factor to assure that the common line **240** is free of the first fluid before the second fluid is infused at the second rate.
(39) FIG. **3** is a schematic diagram of an infusion pump with common line auto flush in accordance with the present invention. In this example, the infusion pump **330** includes a display **340**, soft keys **350**, and fixed keys **360** as a user interface. The display **340** provides operational and/or programming information to the user. The soft keys **350** perform different functions depending on the command displayed on an adjacent command portion **342** of the display **340**. The fixed keys **360** are labeled with an input or function which functions the same, regardless of whatever is displayed on the display **340**. In this example, the infusion pump **330** also includes a pump mechanism **370** operable to communicate with the first reservoir line and the second reservoir line and to move the first fluid or the second fluid to the terminal fluid delivery end of the common line.
(40) FIGS. **4**A & **4**B are graphs of fluid volume delivered at the terminal end of the common line or patient versus time for a method of use for an infusion pump with common line auto flush in accordance with the present invention.
(41) Referring to FIG. **4**A, graph **510** is the fluid volume delivered at the terminal fluid delivery end of the common line for a first fluid versus time and graph **520** is the fluid volume delivered at the terminal fluid delivery end of the common line for a mixture of the first fluid and a second fluid versus time. From T**1** to T**2**, the first fluid is infused at a first rate along a first flow path including the first reservoir and the second fluid is not infused. From T**2** to T**3**, the first fluid is infused at a flushing rate greater than the first rate as a mixture of first and second fluids are drawn from first and second reservoirs, respectively, into the junction and/or mixing chamber and driven out at the flushing rate. For example, if the first fluid is a non-medicinal fluid (e.g., a saline solution, etc.), it may be desirable to flush the first fluid from the common line at an increased rate in order to infuse the second fluid into the patient as soon as possible. The flushing rate can be equal to the combined first rate plus second rate (as shown) or it can be determined by increasing the combined rate (e.g., the first rate plus the second rate by a flushing factor (e.g., 10%, 20%, 50%, 100%, etc.). The second fluid cannot be infused (e.g., it will not enter the patient) until the internal volume of the common line is cleared of the first fluid. From T**3** to T**4**, the internal volume of the common line has been cleared of the first fluid and beginning at T**3** the mixture of the first and second fluids are infused into the patient at a combined rate. From T**4** to T**5**, auto flush is performed: the mixture of the first fluid and the second fluid is infused into the patient at the combined rate as only the first fluid is drawn into the junction and/or mixing chamber and driven out at

the combined rate until the internal volume of the common line is cleared of the first and second fluid mixture. The first fluid cannot be infused by itself (e.g., it cannot enter the patient without the second fluid) until the internal volume is cleared of the first and second fluid mixture. After T**5**, the first fluid is infused at the first rate along the first flow path including the first reservoir after the internal volume of the common line has been cleared of the first and second fluid mixture. In this example, no additional second fluid is infused after T**5**, although in other embodiments, additional concurrent infusions (of first and second fluid mixtures) and/or secondary infusions (of just the second fluid) may be programmed to occur, as well.

(42) Those skilled in the art will appreciate that the transition between the two infusion modes can be selected as desired for a particular application. In the example of FIG. **4**A, a common line auto flush is performed from T**4** to T**5**, but not from T**2** to T**3**. As long as the common line flush volume value is known, the common line auto flush maintaining the first rate between T**2** and T**3** can be performed as desired.

(43) Referring to FIG. **4**B, graph **530** is the fluid volume delivered at the terminal fluid delivery end of the common line for a first fluid versus time and graph **540** is the fluid volume delivered at the terminal fluid delivery end of the common line for a mixture of the first fluid and a second fluid versus time. From T**1** to T**2**, the first fluid is infused at the first rate along a first flow path including the first reservoir and the second fluid is not infused. From T**2** to T**3**, auto flush occurs and the first fluid is infused at the first rate as a mixture of first and second fluids are drawn from first and second reservoirs, respectively, into a junction and/or mixing chamber, and driven out at a combined rate (as discussed above). The first fluid is infused, driven or displaced until the internal volume of the common line has been cleared of the first fluid. After T**3**, the mixture of the first and second fluids is infused, driven or displaced at the combined rate (as discussed above) after the internal volume of the common line has been cleared of the first fluid. In one embodiment, the common line is cleared of the first fluid when the monitored volume of the mixture of the first and second fluids driven at the first rate between T**2** and T**3** is equal to or greater than the common line flush volume value. In this example, no additional second fluid is infused after T**3**, although in other embodiments, additional concurrent infusions (of first and second fluid mixtures) and/or secondary infusions (of just the second fluid) may be programmed to occur, as well.

(44) Concurrent Delivery with Common Line Auto Flush

(45) FIG. **5**A is a flowchart of an embodiment of a method for concurrent infusion with common line auto flush. The method **550** can be performed with any infusion pump system described herein. In one embodiment, the infusion pump system includes a first reservoir containing a first fluid, a second reservoir containing a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, an optional mixing chamber at or in fluid communication with the junction, and a common line in fluid communication with the junction and/or mixing chamber at one end and having a terminal fluid delivery end, and an infusion pump operable to drive fluid through the common line. The method **550** can be performed by any of the systems discussed herein. In an embodiment, some or all aspects of the method **550** are stored as programmed instructions to be executed by an infusion pump flow controller (e.g., flow controller **235**). The method **550** can be used with an infusion pump system and infusion pump as described in FIGS. **1**A, **1**B, & **2** above. A drug library may include an indication (e.g., flag, value, etc.) to enable or disable concurrent infusion with auto flush, as described with respect to FIG. **5**A. In this example, the infusion pump infuses a first fluid on a first flow path at a first rate and switches to a concurrent infusion mode during which it infuses a mixture of the first fluid and a second fluid, maintaining the first rate long enough to clear the remaining first fluid from the common line before changing to a combined rate for infusing the mixture of the first and second fluids.

(46) Referring to FIG. **5**A, at block **552**, the flow controller **235** determines a common line flush volume value. As discussed above, the common line flush value can be received based on a user input via any of the user interfaces discussed above. In an embodiment, the flow controller **235** can automatically retrieve the common line flush volume value from the memory **233** or over a network (e.g., from a drug library or other database), or by wirelessly reading information from a tag associated with the common line and using the information to retrieve the common line flush volume from the memory or over the network. The common line flush volume may be predetermined for particular fluids. The common line flush volume may also depend on the VTBI or rate of the infusion.

(47) At block **554**, a first infusion mode to infuse the first fluid at a first infusion rate begins. The first fluid is infused or driven at a first infusion rate along a first flow path that includes the first reservoir, the junction, the optional mixing chamber, and the common line. The infusion of the first fluid can be controlled by the flow controller **235** based on a control signal to activate the pump or other mechanical system. In some embodiments, the infusion of the first fluid can also be based on a user input or user control of the pump or the mechanical system. During the first infusion mode, the infusion pump drives the first fluid from the first reservoir at the first infusion rate. At block **556**, the flow controller **235** can determine to switch from the first infusion mode to a concurrent infusion mode. During an auto flush period, at block **556**, the infusion pump drives a mixture or combination of the first fluid and the second fluid toward the common line at the first rate. By driving the combination of the first and second fluids at the first rate, the first fluid remaining in the common line is flushed and delivered to the patient at the same rate as therapeutically required. In some embodiments, during the auto flush period, the infusion pump drives the combination of the first fluid and the second fluid at a combined rate, instead of the first rate. For example, it may be advantageous to use a combined rate to more quickly flush the common line, particularly when the fluid being flushed from the common line is a non-medicinal fluid, such as saline, or other non-medicinal fluid. The combined rate can be determined using any of the methods described herein. For example, the combined rate may be determined as the sum as the first and second rates. The flow controller **235** can use control signals to control the driving of the mixture of the first fluid and the second fluid and to control the rate of delivery. It also may be desirable to flush the common line of a non-medicinal first fluid such as saline, at a rate even higher than the combined rate to expedite delivery of the second medication. In scenarios where drug library-defined limits are assigned for one or both of the two fluid delivery rates, the pump system may allow overrides of the upper rate limit for one or both of the fluids during the common line flush. For example, the pump system could effectively apply these delivery limits upon delivery to the patient, versus upon delivery from the pump. In another embodiment, the method **550** of FIG. **5**A may be modified at block **556** such that the infusion pump drives a fluid combination at a rate that is a ratio of a first programmed first fluid rate and a programmed second fluid rate.

(48) At block **558**, the flow controller **235** can monitor volume of the mixture of first and second fluids driven at the first rate. The flow controller **235** can determine when the monitored volume is equal to the common line flush volume value. When it is determined that the monitored volume equals or exceeds the common line flush volume, the method **550** proceeds to block **560**, where the flow controller **235** continues driving the mixture of the first and second fluids, but at the combined rate. In some embodiments, the flow controller **235** can measure an amount of time before changing the rate of the mixture fluid delivery to the combined rate. In one embodiment, the flow controller **235** can further include incrementing a first fluid displayed volume and a second fluid displayed volume by a proportion of the monitored volume when the monitored volume is equal to or greater than an internal volume of the common line. The proportion of monitored volume to be incremented for each of the first and second fluids can be equal to the proportion of first and second flow rates associated with the first and second fluids, respectively. For example, if the first flow rate is 10 ml/hr and the second flow rate is 5 ml/hr, the proportions of the monitored value incremented on the first and second volume displays will have a 2:1 ratio. If the monitored volume is 3 ml, then the display of the first fluid value will be increased by 2 ml and the display of the second fluid value will be increased by 1 ml. The flow controller **235** can thus accurately track the rate, time, and an amount of each fluid delivered to the patient. In some embodiments, the flow controller **235** executes only some of the steps described above with respect to FIG. **5**A. Furthermore, the flow controller **235** can change the order of the steps, include additional steps, or modify some of the steps discussed above.

(49) The common line flush volume value can be selected as desired for a particular application. In one embodiment, the common line flush volume value is an internal volume of the common line. In another embodiment, the common line flush volume value is an internal volume of the common line plus or minus an adjustment volume. The adjustment volume can be any volume desired as a safety factor to assure that the common line is free of the first fluid before the second fluid is infused at the second rate.

(50) In one embodiment, the method **550** further includes incrementing a first fluid displayed volume by the monitored volume when driving a mixture of the first and second fluids at the first rate. The first

fluid displayed volume is incremented by the monitored volume when the monitored volume is equal to or greater than an internal volume of the common line.
(51) In some embodiments, the method **550** ends after the concurrent infusion at the combined rate ends. However, in other embodiments, the method **550** continues concurrent delivery of the first and second fluids until one of the fluids is depleted or until the desired volume of one of the fluids has been delivered. In such case, for example, when the second fluid reservoir is depleted, the infusion continues according to the method **580** discussed below with respect to FIG. **5**B. If instead, the concurrent infusion continues until the desired volume of one of the fluids has been delivered, then the infusion may continue according to a slightly modified method **580**, as discussed below with respect to FIG. **5**B.
(52) Concurrent Delivery to Infusion Completion with Common Line Auto Flush
(53) FIG. **5**B illustrates a method **580** of safely performing a concurrent infusion of first and second fluids until the volume of the second fluid reservoir is depleted (e.g., totally depleted or emptied of the second fluid), such that no second fluid or substantially no second fluid remains in the second reservoir. The method **580** can be performed by a flow controller (e.g., flow controller **235**) alone and/or in conjunction with the method **550** of FIG. **5**A. For example, method **580** may be performed beginning at block **586** and following block **560** of method **550** of FIG. **5**A. A drug library may include an indication (e.g., flag, value, etc.) to enable or disable infusion until depletion functionality, as described with respect to FIG. **5**B.
(54) At block **582**, the method **580** determines a common line flush volume of a common line. Any of the methods described herein may be used to determine the common line flush volume. At block **584**, a concurrent infusion occurs, where a fluid combination is driven by an infusion pump at a combined rate. The fluid combination includes a mixture of a first fluid drawn into a junction and/or mixing chamber from a first reservoir and a second fluid drawn into the junction and/or mixing chamber from a second reservoir. As discussed herein, a first infusion rate may be associated with the infusion of the first fluid and a second infusion rate may be associated with the infusion of the second fluid. The ratio of the volumes of first and second fluids drawn into the mixing chamber is equal to the ratio of the ratio of first and second infusion rates. The fluid combination is driven from the junction and/or mixing chamber to the common line at a combined rate, which may be determined according to any of the methods described herein. For example, the combined rate may be determined as the sum of the first and second infusion rates.
(55) At block **586**, the method **580** determines whether the second reservoir has been depleted. For example, a sensor can detect whether there is air or air bubbles in the line between the junction and the second reservoir. If the method **580** does not determine that the second reservoir is depleted, the method **580** returns to block **584**. If the method **580** determines that the second reservoir has been depleted, the method **580** proceeds to block **588**. The method **580** may also optionally cause the infusion pump to at least partially back-prime the line between the junction and the second reservoir. For example, the infusion pump may pump some fluid from the first reservoir to force fluid into the line between the junction and the second reservoir in order to remove air from the line (or at least the portion of the line near the junction).
(56) In a modified version of method **580**, at block **586** the method **580** instead determines whether a desired or programmed volume of the second fluid has been delivered. For example, if the infusion pump was programmed to delivery only 100 ml of the second fluid during concurrent delivery mode, the method **580** would determine whether 100 ml of the second fluid had been delivered. In another embodiment, the method **580**, determines whether a desired volume of second fluid has been delivered by receiving a command to stop an infusion of the second fluid. When a user provides an input to stop the infusion, the method **580** determines that the desired volume of second fluid has been delivered. If so, the method **580** continues to block **588**. If not, the method **580** returns to block **584**.
(57) At block **588**, the method **580** stops drawing fluid from the second reservoir, and instead only draws fluid from the first reservoir. The method **580** drives the first fluid to the common line at the combined rate in order to auto flush or clear the volume of the common line of the fluid combination remaining in the common line. In the case when there is a drug-library defined limit on the first fluid, the pump system may need to allow an override of this limit in order to support pumping of the first fluid at the combined rate. In other words, drug library-defined delivery limits for the first fluid would apply at the

patient, versus at the pump.
(58) At block **590**, the method **580** monitors the volume of first fluid driven at the combined rate and determine when the monitored volume equals or exceeds the common line flush volume. If the monitored volume is not equal to the common line flush volume, the method **580** returns to block **588**. If the monitored volume is equal to or exceeds the common line flush volume, the method **580** proceeds to block **592**.
(59) At block **592**, the method **580** continues to draw the first fluid from the first reservoir, but at the first rate. In some embodiments, the method **580** can measure an amount of time before changing the rate of the first fluid delivery to the first rate. In one embodiment, the method **580** can further include incrementing a first fluid displayed volume and a second fluid displayed volume by a proportion of the monitored volume when the monitored volume is equal to or greater than an internal volume of the common line. The proportion of monitored volume to be incremented for each of the first and second fluids can be equal to the proportion of first and second flow rates associated with the first and second fluids, respectively. For example, if the first flow rate is 10 ml/hr and the second flow rate is 5 ml/hr, the proportions of the monitored value incremented on the first and second volume displays will have a 2:1 ratio. If the monitored volume is 3 ml, then the display of the first fluid value will be increased by 2 ml and the display of the second fluid value will be increased by 1 ml. The method **580** can thus accurately track the rate, time, and an amount of each fluid delivered to the patient. In some embodiments, the method **580** executes only some of the steps described above with respect to FIG. **5**B. Furthermore, the method **580** can change the order of the steps, include additional steps, or modify some of the steps discussed above
(60) Sequential Delivery to Reservoir Depletion with Common Line Auto Flush
(61) FIG. **5**C illustrates a method **581** of safely performing a sequential infusion (sometimes referred to as a piggyback infusion) of a first fluid at a first infusion rate until the infusion of the first fluid at the first rate is stopped and the infusion switches to an infusion of a second fluid at a second infusion rate. The method **581** can be performed by a flow controller (e.g., flow controller **235**) alone and/or in conjunction with the method **550** of FIG. **5**A or the method **580** of FIG. **5**B. A drug library may include an indication (e.g., flag, value, etc.) to enable or disable infusion until reservoir depletion functionality, as described with respect to FIG. **5**B.
(62) At block **583**, the method **581** determines a common line flush volume of a common line. Any of the methods described herein may be used to determine the common line flush volume. At block **585**, a primary infusion occurs, where a first fluid is driven by an infusion pump at a first infusion rate. The first fluid is drawn into a junction and/or mixing chamber from a first reservoir. The first infusion rate may be associated with the infusion of the first fluid and a second infusion rate may be associated with an infusion of the second fluid. The first fluid is driven from the junction and/or mixing chamber to the common line at the first infusion rate.
(63) At block **587**, the method **581** determines whether to pause the first infusion and initiate a "piggyback" infusion, or infusion of a second fluid at a second rate. If the method **581** determines that the second fluid program should be initiated, the method **581** proceeds to block **589**. If not, the method **581** returns to block **585**.
(64) At block **589**, the method **581** stops drawing fluid from the first reservoir (pauses the primary infusion), and instead only draws fluid from the second reservoir. The method **581** drives the second fluid to the common line at the first infusion rate in order to auto flush or clear the volume of the common line of the first fluid remaining in the common line. If the drug library includes limits on the delivery of fluid **2**, these limits may need to be allowed to be overridden during the common line flush period defined by block **589**. For example, if fluid **1** was programmed at a rate below the lower limit allowed for fluid **2**, or if fluid **1** was programmed at a rate above the upper limit allowed for fluid **2**, an override of such a limit would be allowed during the common line flush.
(65) At block **591**, the method **581** monitors the volume of second fluid driven at the first infusion rate and determines when the monitored volume equals or exceeds the common line flush volume. If the monitored volume is not equal to the common line flush volume, the method **581** returns to block **589**. If the monitored volume is equal to or exceeds the common line flush volume, the method **581** proceeds to block **593**.

(66) At block **593**, the method **581** continues to draw the second fluid from the second reservoir, but at the second infusion rate. In some embodiments, the method **581** can measure an amount of time before changing the rate of the first fluid delivery to the second infusion rate. In one embodiment, the method **581** can further include incrementing a first fluid displayed volume by the monitored volume when the monitored volume is equal to or greater than an internal volume of the common line. The method **581** can thus accurately track the rate, time, and an amount of each fluid delivered to the patient. In some embodiments, the method **581** executes only some of the steps described above with respect to FIG. **5**B. Furthermore, the method **581** can change the order of the steps, include additional steps, or modify some of the steps discussed above. In some embodiments, it may be preferable to infuse the second fluid at a rate that exceeds the first infusion rate until the common line (filled with non-medicinal fluid) is cleared, in order to more quickly introduce the second (medicinal) fluid to the patient. If a drug library defined limit for fluid **2** is present, the pump system may permit an override of this limit to allow pumping of fluid **2** at this increased rate. Similarly, there may be limits on fluid **1** delivery rates that should be considered by the pump system, imposing a limit on fluid **2** pumping rates intended to displace common line volume. At block **595**, the method **581** determines whether the piggyback infusion is complete. For example, the method **581** may determine that the second reservoir is depleted of fluid, that a desired volume of fluid has been infused, that a desired infusion duration period has been reached, etc. In one embodiment, a sensor determines that air is detected within the fluid line. If the piggyback infusion is not complete, the method **581** returns to block **593**. If the piggyback infusion is complete, the method **581** proceeds to block **597**. At block **591**, the primary infusion, e.g., the infusion of the first fluid, is resumed, though at the second infusion rate until the driven first fluid volume is equal to or greater than the common line volume. In the case where the first fluid has a drug library defined limit(s), the pump system may need to support an override of such a lower or upper limit to support pumping at the rate programmed for the second fluid. Method **581** then continues to drive the first fluid, but now at the first infusion rate.

(67) The method **581** may also optionally cause the infusion pump to at least partially back-prime the line between the junction and the second reservoir after air is recognized at the depletion of the second fluid reservoir. For example, the infusion pump may pump some fluid from the first reservoir to force fluid into the line between the junction and the second reservoir in order to remove air from the line (or at least the portion of the line near the junction).

(68) Intermittent Concurrent Delivery

(69) FIG. **6** illustrates a method **600** of scheduling intermittent concurrent deliveries. Method **600** can be performed by an infusion pump, a flow controller (e.g., flow controller **235**), and/or alone or in conjunction with the method **550** of FIG. **5**A and/or method **580** of FIG. **5**B. Method **600** may be performed when it is desired to deliver a secondary infusion (e.g., deliver a second fluid via a concurrent infusion with a first fluid) multiple times per day at specific start times. Method **600** enables an infusion pump to determine a time to start an auto flush procedure to assure that the second fluid is infused into the patient (e.g., enters the patient) at the desired, specific start times.

(70) For example, if a common line volume will take 10 minutes to flush at the primary (first) infusion rate, then the concurrent infusion will initiate an auto flush process (infusing a mixture of first and second fluids at the first infusion rate to flush the first fluid out of the common line tubing) 10 minutes before the desired secondary infusion start time (e.g., 10 minutes before the second fluid is to enter the patient).

(71) At block **602**, the method **600** determines a common line flush volume. However, the method may skip block **602** if the common line flush volume has already been determined. At block **604**, the method **600** determines one or more second fluid infusion start times. For example, the method **600** may receive or download schedule information corresponding to desired start times to infuse a second fluid into a patient. The schedule information may define specific times during the day (e.g., 8 am, noon, 4 pm, 8 pm, etc.), it may define a number of infusions per day (e.g., 2, 3, 4, 6 infusions per day, etc.), or it may define an interval between second fluid infusions (e.g., one bag of second fluid every 4 hours, etc.). The schedule information may be used to determine one or more second fluid infusion start times.

(72) At block **606**, the method **600** determines a flush time period based on the first fluid infusion rate (or first fluid flush rate if a faster flush rate is desired for the particular, e.g., non-medicinal, first fluid)

and the common line flush volume. For example, the flush time period may be determined by dividing the common line flush volume by the first fluid infusion rate (or first fluid flush rate). The flush time period represents the amount of time it will take to flush remaining fluid from the common line between the junction (or mixing chamber) and the common line distal end when fluid is driven at the first (or first fluid flush) rate.

(73) At block **608**, the method **600** determines second fluid drive start times, which correspond to the actual times that the infusion pump will begin to draw first fluid from a first reservoir and second fluid from a second reservoir, and drive the mixture of first and second fluids to the common line at the first (or first fluid flush) rate. In one embodiment, the method **600** may determine the second fluid drive start times by subtracting the flush time period from each of the second fluid infusion start times. For example, if the flush time period is determined to be 20 minutes and the second fluid infusion start times are 8:00 am, 2:00 pm, and 8:00 pm, then the second fluid drive start times may be determined as 7:40 am, 1:40 pm, and 7:40 pm. By initiating an auto flush concurrent infusion at the second fluid drive start times, a mixture of the second fluid and the first fluid will reach the patient and will be infused into the patient (e.g., enter the patient's body) at the second fluid infusion start times. At block **610**, the method causes the infusion pump to initiate such auto flush concurrent infusions at the second fluid drive start times.

(74) FIGS. **7**A-**7**E are schematic diagrams of use for an infusion pump system with concurrent infusion and common line auto flush in accordance with the present invention. FIGS. **7**A-**7**E illustrate switching from infusing a first fluid to infusing a mixture or combination of first and second fluids, then switching back to infusing the first fluid, while accounting for the previously infused fluid in the common line. In this example, the infusion pump is infusing a first fluid on a first flow path at a first rate and switches to infusing a mixture or combination of first and second fluids on a second flow path, maintaining the first rate long enough to clear the remaining first fluid from the common line before changing to a combined rate for infusing the mixture or combination of first and second fluids. The infusion pump then switches to infusing a first fluid on the first flow path, maintaining the combined rate long enough to clear the remaining mixture or combination of first and second fluids from the common line before changing to a first rate for infusing the first fluid.

(75) Referring to FIG. **7**A, the first fluid **712** is delivered to the terminal end **740**B of a common line **740** at a first rate along a first flow path **750** including the first reservoir **710**, the junction **780**, an optional mixing chamber (not shown), and the common line **740**. The first fluid **712** is indicated by upward from left to right diagonal lines. Referring to FIG. **7**B, the infusion has changed to a concurrent mode. During the concurrent mode, first fluid **712** is drawn from the first reservoir **710** and second fluid **722** is drawn from the second reservoir **720** along a second flow path **760**. The second fluid **722** is indicated by downward from left to right diagonal lines. The mixture of first and second fluids **712**, **722** is driven by the infusion pump into the common line **740**. During this auto flush mode of concurrent delivery, the common line **740** contains first common line fluid **741** remaining from the initial infusion of the first fluid **712** and indicated by the upward diagonal lines, and second common line fluid **742** (the mixture of the first and second fluids **712**, **722**) indicated by the hashed lines. The flow rate remains at the first rate because the remaining first common line fluid **741** is being delivered to the terminal fluid delivery end **740**B or to the patient when connected. Referring to FIG. **7**C, none of the first fluid remains in the common line **740**, so the second common line fluid **743** (the mixture of the first and second fluids **712**, **722**) is driven at the combined rate.

(76) The infusion pump system can subsequently switch back to infusing only the first fluid (for example, after a predetermined time period, after a predetermined volume of combined first and second fluids are infused, after a predetermined volume of the second fluid is infused, or after the infusion pump determines that the second reservoir has been depleted of the second fluid, etc.). Referring to FIG. **7**D, the infusion mode has changed from concurrent delivery to primary delivery (infusing only first fluid **712** from the first reservoir **710**). Initially, the common line **740** still contains a mixture of the first and second fluids **712**, **722** (represented by the hashed lines) as second common line fluid **744** remaining from the previous infusion, and first common line fluid **745** (the first fluid **712** alone) indicated by the upward diagonal lines. The flow rate remains at the combined rate because the remaining second common line fluid **744** is being delivered. Referring to FIG. **7**E, none of the mixture of first and second

fluids remains in the common line **740**, so the first common line fluid **746** is driven at the first rate along the first flow path **750**.

(77) While the embodiments of the invention disclosed herein are presently considered to be preferred, various changes, rearrangement of steps, and modifications can be made without departing from the scope of the invention. The scope of the invention is indicated in the appended claims, and all changes that come within the meaning and range of equivalents are intended to be embraced therein.

Claims

1. A method for controlling operation of an infusion pump of an infusion pump system, the infusion pump system comprising a first reservoir configured to hold a first fluid, a second reservoir configured to hold a second fluid, a junction in fluid communication with the first reservoir and the second reservoir, a common line in fluid communication with the junction and having a terminal fluid delivery end, and the infusion pump, wherein the infusion pump is operable to drive fluid through the common line toward the terminal fluid delivery end, the method comprising: receiving instructions to deliver the first fluid at a first rate, subsequently concurrently deliver a mixture of the first fluid and the second fluid, and concurrently deliver the first fluid at the first rate and the second fluid at a second rate; infusing the first fluid at the first rate along a first flow path, the first flow path including the common line; determining a common line volume corresponding to a volume of the common line; drawing the first fluid from the first reservoir and the second fluid from the second reservoir to deliver the mixture of the first fluid and the second fluid into a first end of the common line; infusing the mixture of the first fluid and the second fluid at a flushing rate into the first end of the common line, wherein infusing the mixture of the first fluid and the second fluid at the flushing rate into the first end of the common line causes displacement of a volume of the first fluid remaining in the common line and infusion of the first fluid out of a terminal end of the common line at the flushing rate; determining that an infused volume of the mixture of the first fluid and the second fluid equals or exceeds the common line volume; and changing infusion of the mixture of the first fluid and the second fluid from the flushing rate to a combined rate in response to determining that the infused volume of the mixture of the first fluid and the second fluid equal or exceeds the common line volume, wherein the combined rate is a sum of the first rate and the second rate, and continue to infuse the mixture of the first fluid and the second fluid at the combined rate.

2. The method of claim 1, wherein the infusion pump system further comprises a mixing chamber in fluid communication with the first reservoir, the second reservoir, and the common line.

3. The method of claim 1, further comprising determining the flushing rate based upon whether the first fluid is a medicinal fluid.

4. The method of claim 3, further comprising determining the flushing rate as the first rate when the first fluid is a medicinal fluid.

5. The method of claim 3, further comprising determining the flushing rate as the first rate increased by a flushing rate factor when the first fluid is not a medicinal fluid.

6. The method of claim 1, further comprising receiving the common line volume from a user input.

7. The method of claim 1, further comprising retrieving the common line volume from a memory.

8. The method of claim 1, further comprising retrieving the common line volume over a network.

9. The method of claim 1, wherein the common line volume is predetermined.

10. The method of claim 1, further comprising determining the common line volume based on the first fluid.

11. The method of claim 1, wherein the first rate is different than the second rate.

12. The method of claim 1, wherein receiving the instructions further comprises receiving the instructions from an input via a user interface.

13. The method of claim 1, wherein infusing the mixture of the first fluid and the second fluid at the flushing rate comprises one or more of delivering the first fluid at a flush rate outside of drug library defined rate limits associated with the first fluid or delivering the second fluid at a second fluid flush rate outside of drug library defined rate limits associated with the second fluid.

14. The method of claim 1, further comprising: determining that an infusion of the second fluid has

completed; drawing the first fluid from the first reservoir without drawing the second fluid from the second reservoir; infusing the first fluid at the combined rate; determining that a volume of the first fluid infused at the combined rate equals or exceeds the common line volume; and changing infusion of the first fluid from the combined rate to the first rate.

15. The method of claim 14, further comprising determining that an infusion of the second fluid has completed by comparing a volume of fluid infused to a programmed volume to infuse.

16. The method of claim 14, further comprising determining that an infusion of the second fluid has completed by receiving an instruction to stop infusing the second fluid.

17. The method of claim 14, further comprising determining that an infusion of the second fluid has completed by determining that the second reservoir has been depleted of second fluid.

18. The method of claim 14, wherein infusing the first fluid at the combined rate comprises infusing the first fluid at a rate that exceeds a drug library rate limit associated with the first fluid.

19. The method of claim 1, further comprising: determining that an infusion of the first fluid has completed; drawing the second fluid from the second reservoir without drawing the first fluid from the first reservoir; infusing the second fluid at the combined rate; determining that a volume of the second fluid infused at the combined rate equals or exceeds the common line volume; and changing infusion of the second fluid from the combined rate to the second rate.

20. The method of claim 19, further comprising determining that an infusion of the first fluid has completed by comparing a volume of fluid infused to a programmed volume to infuse.

21. The method of claim 19, further comprising determining that an infusion of the first fluid has completed by receiving an instruction to stop infusing the first fluid.

22. The method of claim 19, further comprising determining that an infusion of the first fluid has completed by determining that the first reservoir has been depleted of first fluid.

23. The method of claim 19, wherein infusing the second fluid at the combined rate comprises infusing the second fluid at a rate that exceeds a drug library rate limit associated with the second fluid.