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Value from Innovation

Diosynth biotechnologies

Single-use manufacturing design and implementation: from becoming a reality, to paving the way for future growth

GE Single-use Symposium
Boston, Nov 1, 2016

S. McNaull
Fujifilm Diosynth Biotechnologies

*Your Biologics and Vaccines CDMO **Partner of Choice**.*

One Global Company

3

SITES

Billingham, UK
College Station, TX
RTP, North Carolina

6

LICENSES

For commercial manufacturing.

1,100

EMPLOYEES

World Wide

20+

YEARS

Of Biologics CDMO experience.

280+

MOLECULES

In process development and/or manufacturing.

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With you all along the road
To clinical success

Preclinical	Phase I	Phase II	Phase III	Regulatory Approval	Launch
Gene Expression & Strain / Cell Line Development Process Invention Pre-clinical Manufacture		Process Development & Optimization Analytical & Stability cGMP Manufacture Fill/Finish	Process Characterization Process Validation cGMP Manufacture Stability		Commercial Production Post-approval Activities

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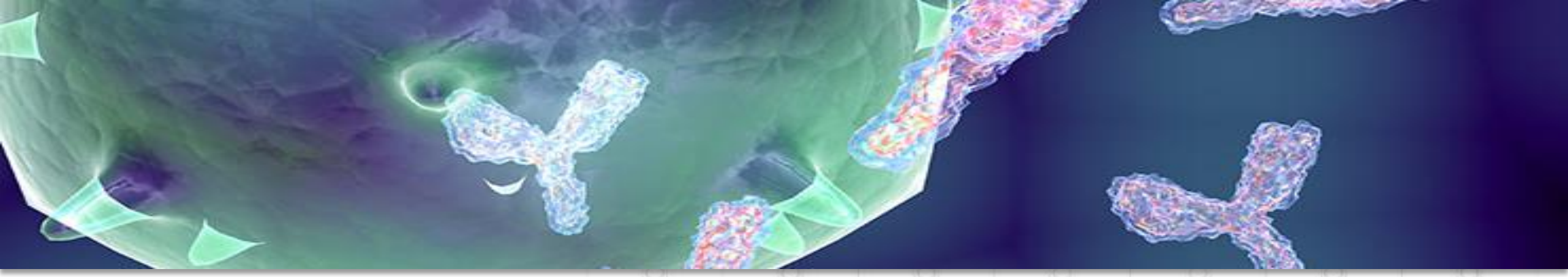

Our Cell Culture Experience

60+

mAb, mAb-like and
Ig-fusion molecules

55

CHO Programs

45

MAb Programs

12

Cell Line Development Programs

29

Programs Completed GMP Manufacturing

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Single-Use Bioprocessing Journey

- The advent of single-use technologies enabled capacity expansions that were previously not realistic
- Our single-use bioprocessing journey started with proof of concept bioreactor evaluations
- Comparability between single-use and stainless steel bioreactors enabled our entry into the GMP manufacturing space
- Knowledge gained as early adopters provides a strong engineering basis that is applied for new equipment design
- Efforts now encompass design of an all single-use manufacturing facility

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Single-use Technology Enabled GMP Expansion

Justification:

- Capacity can be increased quickly within existing facilities
  - Implementation in an existing facility in ~12-14 mo. vs. ~24 mo. for stainless steel
  - Capital investment and payback time is significantly less than stainless steel
- Single-use Efficiency and Operational Flexibility Gains

Implementation:

- Single-use Technology Platform Developed
  - SUB technologies evaluated and operating platform developed
  - Purification mAb platform leveraged with SU implementation
- GMP Manufacturing expansions: Existing suite refurbs and new facilities
  - First 1000L GMP expansion combined two small scale cell culture GMP suites
  - New all single-use facility in the UK: 1,000L and 2,000L USP and all SU downstream
  - 2,000L expansion in the US within existing suites

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Production Bioreactor Selection

- Factors Taken into consideration
  - Process performance; mixing and mass transfer, sparge flexibility and leveraging Fujifilm platforms
  - Speed of implementation and qualification
  - Control system capabilities and automation tie-in
  - Engineering design and workmanship
  - Equipment cost and product support
  - Track Record
  - In-hand process performance for each vendor

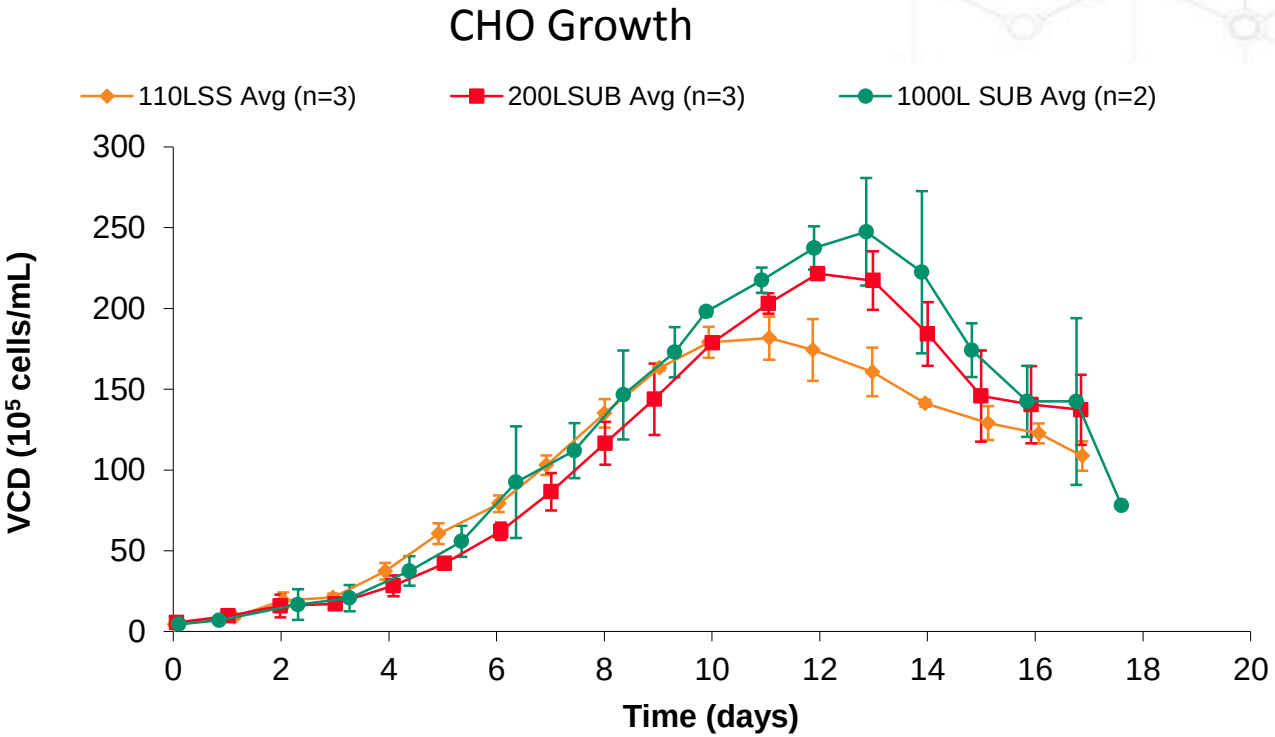
- GE (Xcellerex) was chosen as the PD and Manufacturing model
  - Process performance and flexibility of design
    - 5:1 turndown, good mixing with sparge design flexibility
  - Quality of hardware and ‘software” (bag designs) engineering
  - Speed and ease of implementation in manufacturing were key factors

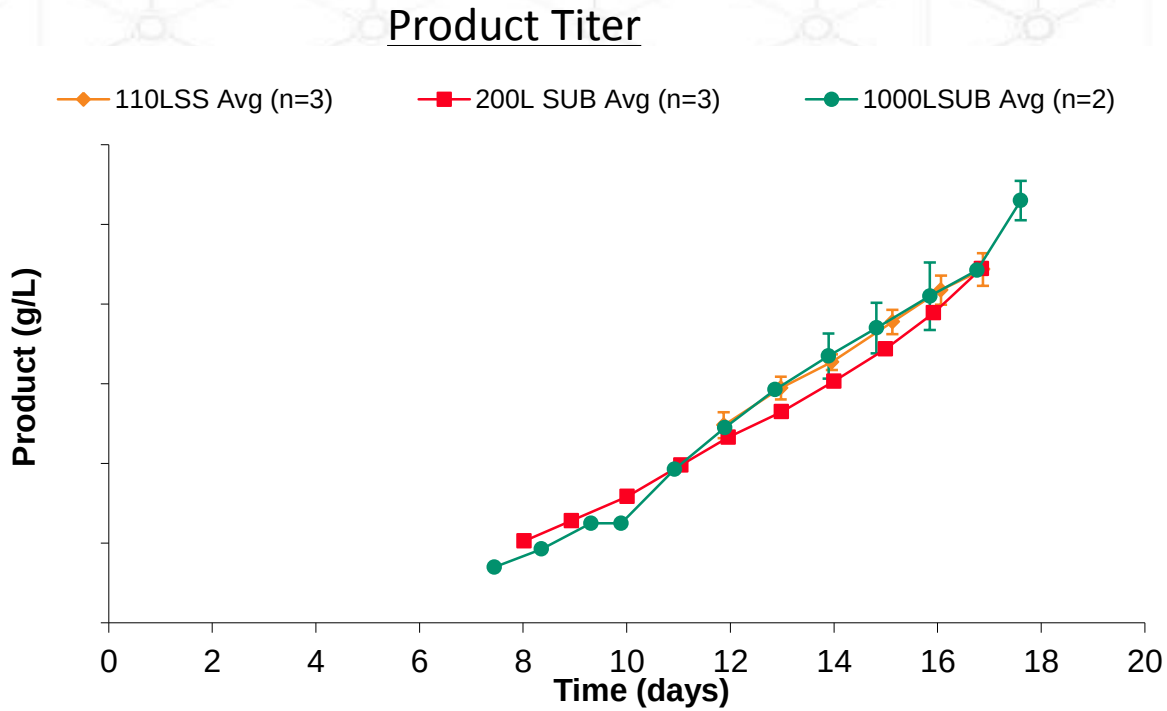
Stainless Steel (SS) vs Single Use Bioreactor (SUB) Comparison:
"The CHO Story"

- XDR-200 CHO mAb runs (n=3) were compared directly to 110 L stainless steel reactors (n=3)
- High cell density process (20-25E06 cells/mL)
- FDB stainless steel bioreactor mass transfer and scale up know-how was used as a basis for sparger customization and gassing strategies
- Mixing speed and gas sparger designs were refined to achieve necessary mixing time, O2 mass transfer and CO2 stripping
- Technical learning from 200 L scale was applied to achieve successful scale-up to 1,000 L scale

Development of Fujifilm single-use platform

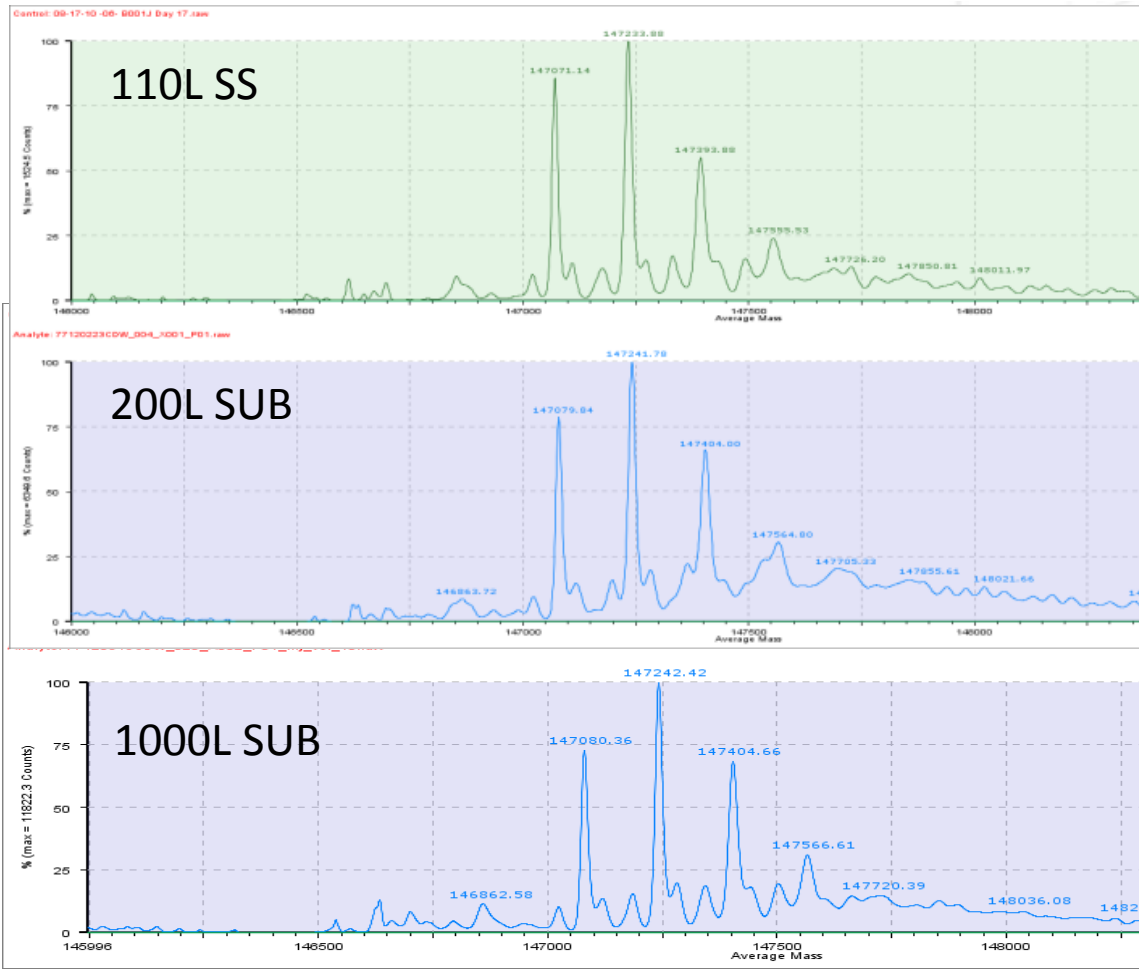
- Fujifilm experience with stainless steel (SS) reactors used as SUB design basis for mixing and mass transfer
- 200L SUB high density CHO runs were used to optimize parameters
- 200L and 1000L SUB growth and productivity were ≥110L SS
- Manufacturing success with over 20 GMP batches produced





Development of Fujifilm single-use platform

Product Quality: Glycosylation patterns



Successful SUB Performance

	CHO mAb		BEVS	
	SS	SUB	SS	SUB
Cell growth	✓	✓+	✓	✓
Product titer	✓	✓	✓	✓
Product quality	✓	✓	✓	✓
SUB control	✓	✓+	✓	✓+

- 1000L SUB process transferred from RTP to UK Manufacturing facility with matching results

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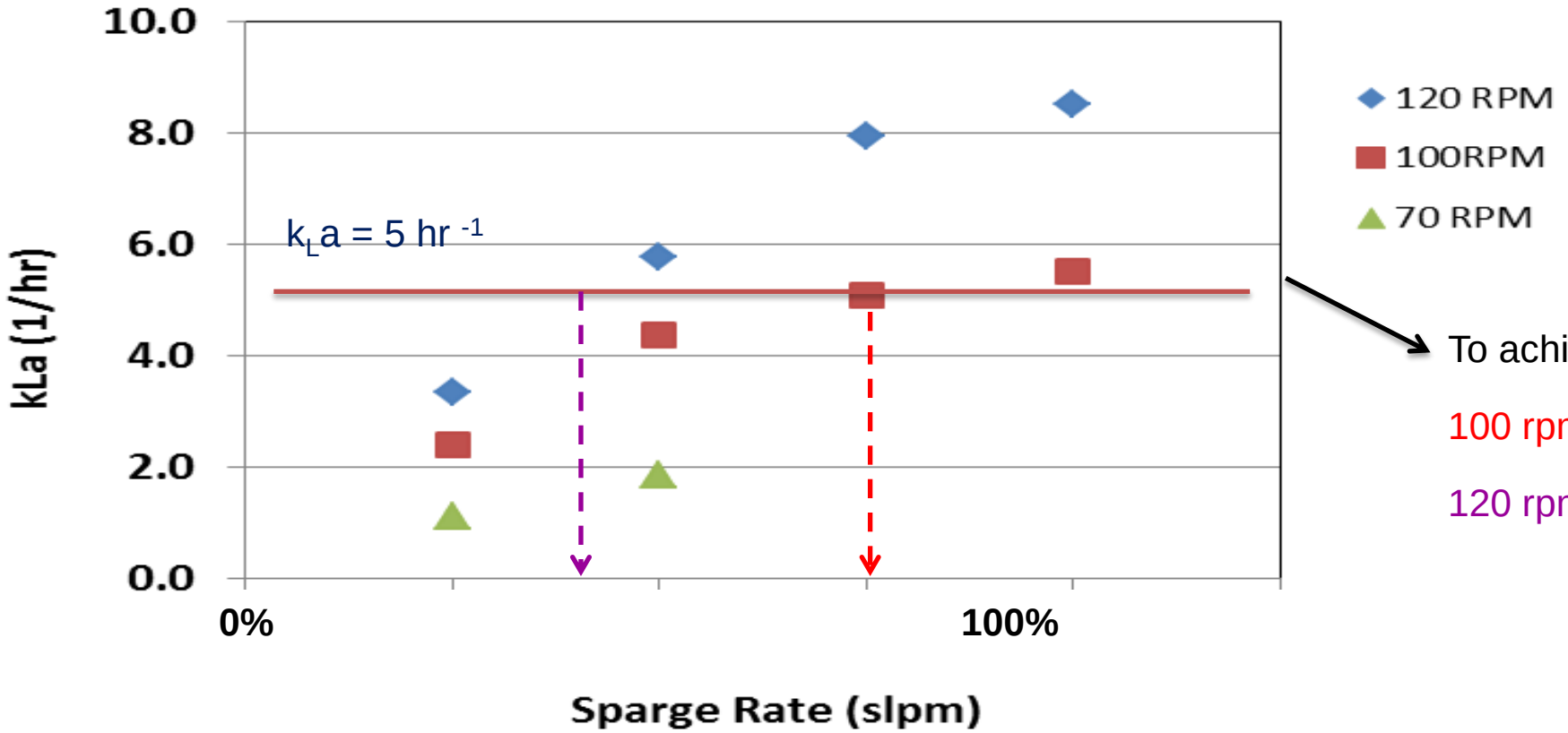
Bioreactor Scale Up by Mass Transfer

- 1) determine (peak) k_La at lab scale
- 2) choose mfg scale agitation rate to achieve peak k_La
- 3) agitation speed will affect sparge on demand (impacts stripping)



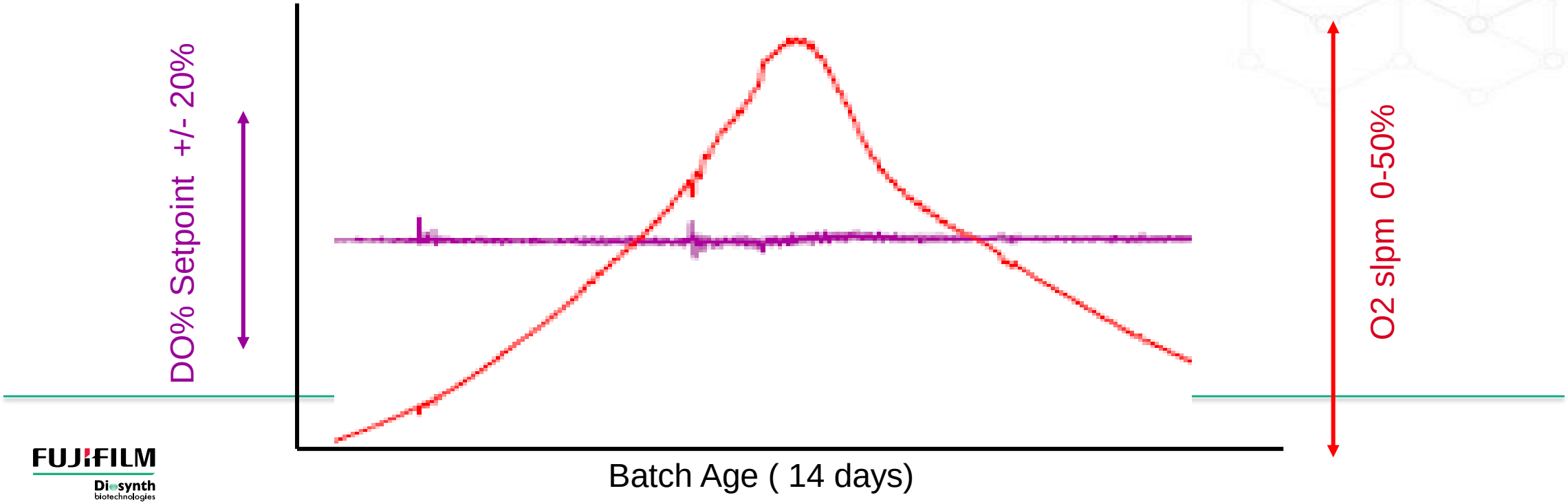
To achieve $k_La = 5\ hr^{-1}$:

100 rpm = 75% sparge rate

120 rpm = 40% sparge rate

1000L SUB Modeling results

- Example below shows the SUB O2 sparge rate and resulting DO control for a 14 day CHO cell culture batch at ~30E06cells/mL
- O2 sparge rate reached 50% of max and provided CO2 levels that were comparable to lab scale (not shown)
- DO% control was within approximately ± 5%



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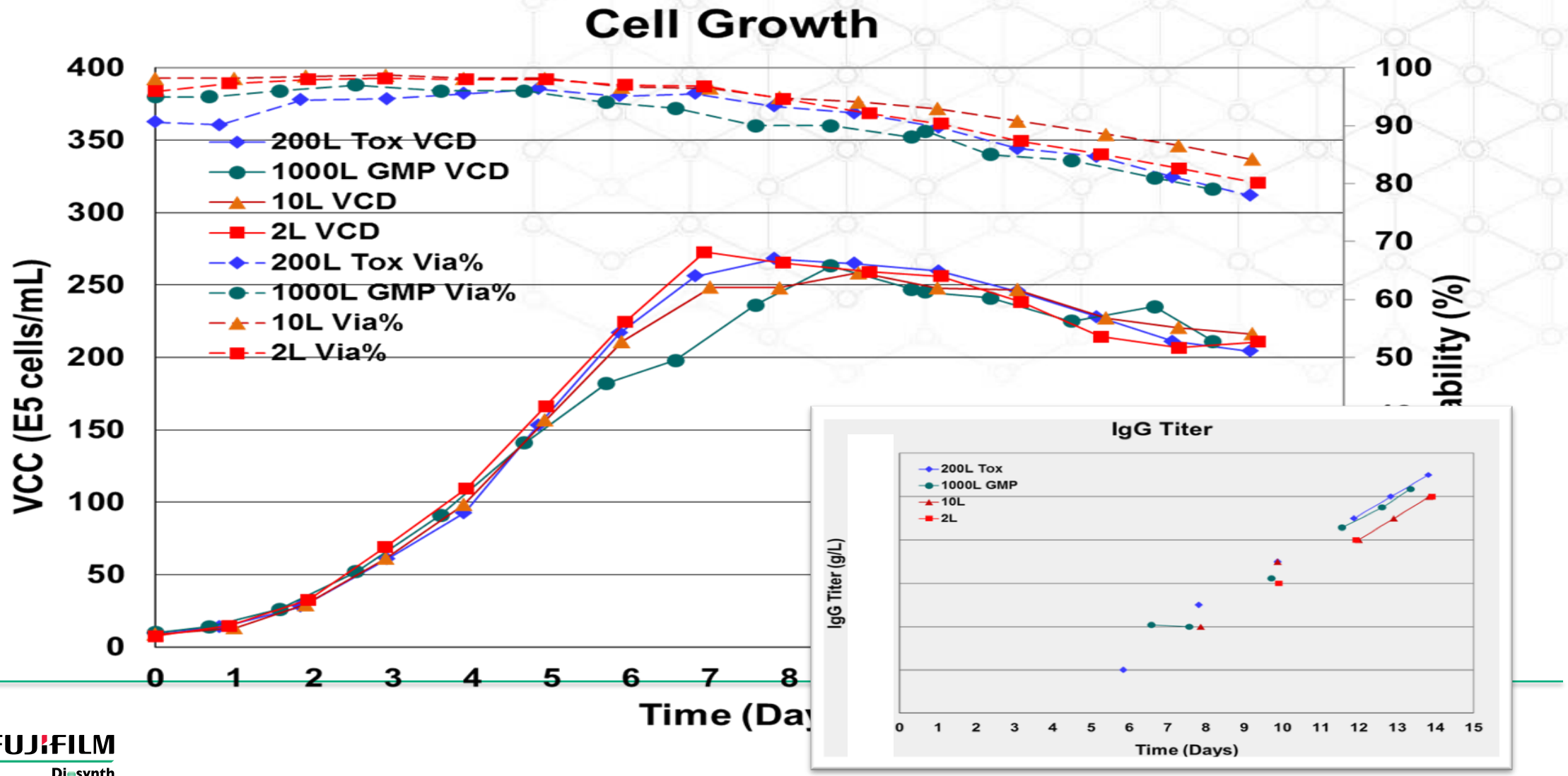
FDB SUB Scale Up Performance



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Upstream Learning from Early Adoption

Design

Well designed connectivity to minimize number of sterile connections

- Design of feed bags with on board filters and tubing to match SUB
- Standard connectors and tubing sizes for welding/sterile connectors
- Use liquid media and many pre-made solutions (feeds, antifoam, etc.). Weigh gains vs. COGs.

Bag design details

- Ensure tubing is long enough for connections to media and other equipment
- Alignment of software (bags and connectors) and hardware (equipment).
  - Example: tubing diameters are appropriate for pump heads to avoid wear, etc.

In-Use Experience

- Bag installation, choice of connections, etc.
- The “Devil is in the details”….

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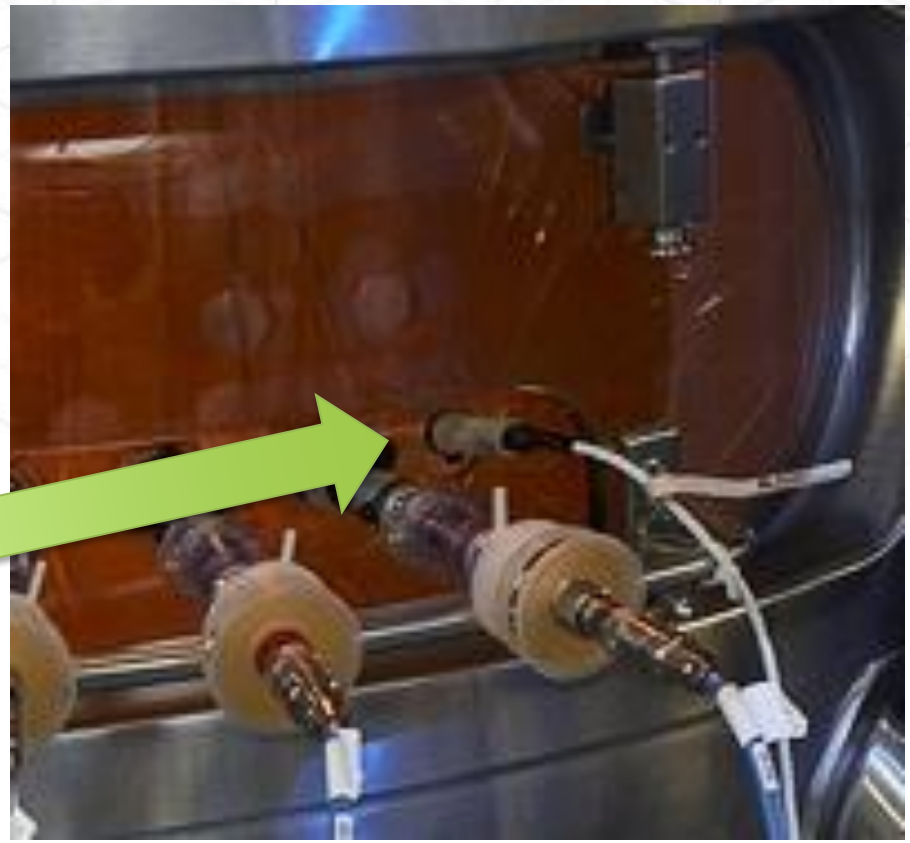
Upstream Learning as Early Adopters

- Example of the Devil in the details…



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Downstream Learning from Early Adoption

Design Limitations

- Skid limitations in terms of sizes, flow rate, mixing, temp control, pressure transfer
- Mab throughout limitations (low chrom skid flow-rates, low TFF membrane capacity, etc.)
- Heating or cooling of large (>1000L) process volumes can be difficult

Instrumentation Limitations

- Sensors (P, T, UV, flow, cond) lack precision and accuracy
- In some cases traditional probes are used (e.q. pH probes)

Installation

- Installation of manifolds can be “cumbersome”
- Cross connectivity issues due to lack of manifold labeling
- Operator standardization of instruments as part of self check
- Standard manifold tubing sizes may require different connectors

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Creating biomanufacturing capacity

A global partnership

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Driven by the industry need for cGMP mammalian cell culture biomanufacturing capacity

Four successful capacity expansion projects on two continents

Creating the UK's first fully single-use biomanufacturing facility

2013

1000 L project

- Single-use WAVE Bioreactor™ systems
- Xcellerex™ XDR cell culture suite
- ÄKTA™ready and ReadyToProcess™ prepacked columns

Billingham, UK

2012

1000 L project

- Xcellerex single-use mixers
- Xcellerex XDR cell culture suite
- ÄKTAready purification system

Research Triangle Park, US

2014

2000 L project

- Xcellerex XDR 2000L bioreactor added

Research Triangle Park, US

2015

2000 L project

- Xcellerex XDR 2000L bioreactor added

Billingham, UK

Ongoing partnership

2017 **2018** **2019**

Fujifilm Single-use mAb Facility Design

- All single-use equipment
- Production Reactors: 3 x 2,000L SUBs with standard seed train
  - Assumed titers ranging from 2 to 8 g/L
  - One batch per week
- Downstream
  - Smaller pre-packed columns with up to 10 cycles to reduce RM costs
  - Use of one set of threee Single-use chromatography skids to run industry standard mAb platform
  - TFF systems must have at least 10m^2 membrane area capacity
  - Goal of small, medium and large downstream bill of materials
- Defined allowable process duration for each unit operation
- Output Goals: operational standardization, reduce consumables/RM costs, facility fit process

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Process Evaluations for Facility Design

1. Process Platform Scaling by mAb Throughput (kg)
   - Media and buffer volumes, resin and filter sizing for 2g/L, 5g/L and 8g/L scenarios
   - Platform scaling and operational strategies
2. Single-Use DSP Equipment Evaluations
   - SU Chromatography and TFF equipment, pre-packed columns-
   - Risk Assessment from FDB experience and next generation vendor offerings
3. Facility Design Implications
   - Finalize placement of unit operations for optimal suite scheduling and process flow
4. Closure Assessment
   - Define closed processing needs, equipment and consumables capabilities for closed processing

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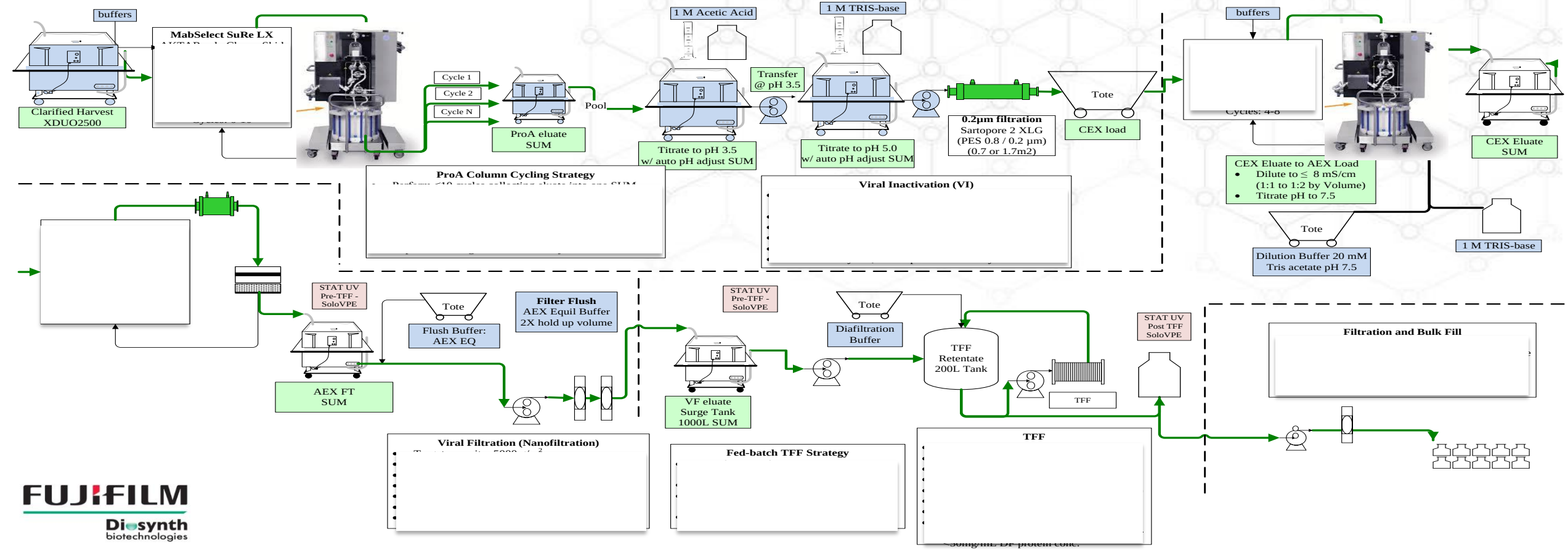
Single-use DSP Process Flow Diagram



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Confidential Draft

Initial (May) Saturn DSP Platform Scaling

- DSP platform scaled by mAb kg throughput (2, 5 and 8 g/L titer scenarios)
- Column size + cycles, platform buffer volumes and filter areas estimated
- RM and consumable costs were estimated using calculator (~$1M/batch @ 5g/L)

Process Scaling			
BRX Titer (g/L)	2 g/L	5 g/L	8 g/L
ProA Resin Binding Capacity	45	45	45
ProA Column Size (L)	10	20	32
ProA Cycles	8	10	10
ProA Skid Flow Rate (LPH)	147	297	477
Net ProA Process Time (hr)	*34*	*31*	*26*
CEX Column Size (L)	10	20	32
CEX Cycles	6	7	7
CEX Skid Flow Rate (LPH)	147	297	477
Net CEX Process Time (hr)	*22*	*21*	*20*
Q Membrane Size (cm2)	9,747	24,368	38,988
Flow Rate (L/min)	8	20	33
Nanofilter Size (m2)	0.5	1.5	2.0
Flow Rate (L/min)	3	9	12
Net Q Membrane + Nanofilter Time (hr)	*5*	*7*	*10*
UF Membrane Area*	5	10	12*
UF Skid Crossflow rate (L/min)	40	40	48
Net UF Process Time (hr)	*5*	*5*	*7*
Total Buffer Volume (L)	*7,406*	*14,478*	*21,433*

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Super Pro Modeling

- Goal was to better quantify process volumes, durations and consumables costs to better define operational aspects…
- Created a simulation to scale the FDB mAb platform over a range of 2g/L to 8g/L
- Inputs: 2000L harvest, flux for filters, resin capacities and yields
- Outputs: Batch duration, size of columns and number of cycles, filter sizes, buffer volumes, SUM sizes

- Stretch Objective: To define small, medium and large purification streams (equipment, column size/cycles, SUMs, BOM)

Scaling by Titer: SuperPro Model Outputs

Total Cost	Titer (g/L)	Resin Cost	SUM Cost	Filter Cost	Buffer Cost	Jumper/Other Costs	Upstream Costs	Batch Time	Protein A Volume	Number of ProA cycles	ProA cycling + VI time	CEX Column Volume	Number of CEX cycles	CEX cycling time
$ 585,438.96	2	$ 252,319.00	$ 17,596.20	$ 44,592.79	$ 13,773.67	$ 145,157.30	$ 112,000.00	97:25:06	10 L	8	49:00:30	10 L	6	20:19:34
$ 586,518.85	2.05	$ 252,319.00	$ 17,596.20	$ 45,390.19	$ 14,056.16	$ 145,157.30	$ 112,000.00	101:01:57	10 L	9	52:30:20	10 L	6	20:27:29
$ 586,521.58	2.1	$ 252,319.00	$ 17,596.20	$ 45,390.19	$ 14,058.89	$ 145,157.30	$ 112,000.00	101:02:05	10 L	9	52:30:20	10 L	6	20:27:32
$ 586,524.32	2.15	$ 252,319.00	$ 17,596.20	$ 45,390.19	$ 14,061.63	$ 145,157.30	$ 112,000.00	101:02:14	10 L	9	52:30:21	10 L	6	20:27:34
$ 586,527.05	2.2	$ 252,319.00	$ 17,596.20	$ 45,390.19	$ 14,064.36	$ 145,157.30	$ 112,000.00	101:02:22	10 L	9	52:30:22	10 L	6	20:27:36
$ 590,498.11	2.25	$ 252,319.00	$ 17,596.20	$ 47,625.52	$ 15,800.09	$ 145,157.30	$ 112,000.00	105:05:27	10 L	9	52:30:22	10 L	7	23:41:38
$ 591,578.00	2.3	$ 252,319.00	$ 17,596.20	$ 48,422.92	$ 16,082.58	$ 145,157.30	$ 112,000.00	108:44:17	10 L	10	56:01:12	10 L	7	23:48:34
$ 591,580.73	2.35	$ 252,319.00	$ 17,596.20	$ 48,422.92	$ 16,085.31	$ 145,157.30	$ 112,000.00	108:44:26	10 L	10	56:01:12	10 L	7	23:48:36
$ 591,583.46	2.4	$ 252,319.00	$ 17,596.20	$ 48,422.92	$ 16,088.04	$ 145,157.30	$ 112,000.00	108:44:34	10 L	10	56:01:13	10 L	7	23:48:38
$ 591,586.19	2.45	$ 252,319.00	$ 17,596.20	$ 48,422.92	$ 16,090.77	$ 145,157.30	$ 112,000.00	108:44:43	10 L	10	56:01:13	10 L	7	23:48:40
$ 591,588.93	2.5	$ 252,319.00	$ 17,596.20	$ 48,422.92	$ 16,093.51	$ 145,157.30	$ 112,000.00	108:44:51	10 L	10	56:01:14	10 L	7	23:48:43
$ 591,591.66	2.55	$ 252,319.00	$ 17,596.20	$ 48,422.92	$ 16,096.24	$ 145,157.30	$ 112,000.00	108:45:00	10 L	10	56:01:15	10 L	7	23:48:45
$ 597,662.85	2.6	$ 252,319.00	$ 17,596.20	$ 52,440.06	$ 18,150.29	$ 145,157.30	$ 112,000.00	116:26:47	10 L	11	59:32:04	10 L	8	27:08:40
$ 597,665.58	2.65	$ 252,319.00	$ 17,596.20	$ 52,440.06	$ 18,153.02	$ 145,157.30	$ 112,000.00	116:26:55	10 L	11	59:32:05	10 L	8	27:08:42
$ 597,668.31	2.7	$ 252,319.00	$ 17,596.20	$ 52,440.06	$ 18,155.75	$ 145,157.30	$ 112,000.00	116:27:04	10 L	11	59:32:05	10 L	8	27:08:45
$ 597,671.05	2.75	$ 252,319.00	$ 17,596.20	$ 52,440.06	$ 18,158.49	$ 145,157.30	$ 112,000.00	116:27:12	10 L	11	59:32:06	10 L	8	27:08:47
$ 597,673.78	2.8	$ 252,319.00	$ 17,596.20	$ 52,440.06	$ 18,161.22	$ 145,157.30	$ 112,000.00	116:27:21	10 L	11	59:32:07	10 L	8	27:08:49
$ 598,753.67	2.85	$ 252,319.00	$ 17,596.20	$ 53,237.46	$ 18,443.71	$ 145,157.30	$ 112,000.00	120:04:11	10 L	12	63:02:56	10 L	8	27:15:45
$ 598,756.40	2.9	$ 252,319.00	$ 17,596.20	$ 53,237.46	$ 18,446.44	$ 145,157.30	$ 112,000.00	120:04:19	10 L	12	63:02:57	10 L	8	27:15:47
$ 602,727.46	2.95	$ 252,319.00	$ 17,596.20	$ 55,472.79	$ 20,182.17	$ 145,157.30	$ 112,000.00	124:08:24	10 L	12	63:02:57	10 L	9	30:30:49
$ 813,685.60	3	$ 458,426.00	$ 24,603.00	$ 53,970.37	$ 19,528.93	$ 145,157.30	$ 112,000.00	75:21:45	20 L	6	31:49:37	20 L	4	13:38:24
$ 821,786.97	3.05	$ 458,426.00	$ 24,603.00	$ 58,523.82	$ 23,076.85	$ 145,157.30	$ 112,000.00	80:15:59	20 L	6	31:49:38	20 L	5	16:52:25
$ 821,789.70	3.1	$ 458,426.00	$ 24,603.00	$ 58,523.82	$ 23,079.58	$ 145,157.30	$ 112,000.00	80:16:06	20 L	6	31:49:39	20 L	5	16:52:26
$ 823,959.53	3.15	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,654.61	$ 145,157.30	$ 112,000.00	83:56:49	20 L	7	35:23:22	20 L	5	16:59:20
$ 823,962.26	3.2	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,657.34	$ 145,157.30	$ 112,000.00	83:56:56	20 L	7	35:23:22	20 L	5	16:59:21
$ 823,965.00	3.25	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,660.08	$ 145,157.30	$ 112,000.00	83:57:04	20 L	7	35:23:23	20 L	5	16:59:22
$ 823,967.73	3.3	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,662.81	$ 145,157.30	$ 112,000.00	83:57:11	20 L	7	35:23:24	20 L	5	16:59:24
$ 823,970.46	3.35	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,665.54	$ 145,157.30	$ 112,000.00	83:57:18	20 L	7	35:23:24	20 L	5	16:59:25
$ 823,973.19	3.4	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,668.27	$ 145,157.30	$ 112,000.00	83:57:26	20 L	7	35:23:25	20 L	5	16:59:26
$ 823,975.93	3.45	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,671.01	$ 145,157.30	$ 112,000.00	83:57:33	20 L	7	35:23:26	20 L	5	16:59:27
$ 823,978.66	3.5	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,673.74	$ 145,157.30	$ 112,000.00	83:57:40	20 L	7	35:23:26	20 L	5	16:59:28
$ 823,981.39	3.55	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,676.47	$ 145,157.30	$ 112,000.00	83:57:48	20 L	7	35:23:27	20 L	5	16:59:29
$ 823,984.12	3.6	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,679.20	$ 145,157.30	$ 112,000.00	83:57:55	20 L	7	35:23:27	20 L	5	16:59:30
$ 823,986.86	3.65	$ 458,426.00	$ 24,603.00	$ 60,118.62	$ 23,681.94	$ 145,157.30	$ 112,000.00	83:58:02	20 L	7	35:23:28	20 L	5	16:59:31
$ 826,156.69	3.7	$ 458,426.00	$ 24,603.00	$ 61,713.42	$ 24,256.97	$ 145,157.30	$ 112,000.00	87:36:45	20 L	8	38:55:11	20 L	5	17:06:25
$ 826,159.42	3.75	$ 458,426.00	$ 24,603.00	$ 61,713.42	$ 24,259.70	$ 145,157.30	$ 112,000.00	87:36:53	20 L	8	38:55:12	20 L	5	17:06:26
$ 834,260.79	3.8	$ 458,426.00	$ 24,603.00	$ 66,266.87	$ 27,807.62	$ 145,157.30	$ 112,000.00	92:31:06	20 L	8	38:55:12	20 L	6	20:19:28
$ 835,286.50	3.85	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,848.92	$ 145,157.30	$ 112,000.00	92:32:14	20 L	8	38:55:13	20 L	6	20:19:29
$ 835,289.23	3.9	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,851.65	$ 145,157.30	$ 112,000.00	92:32:21	20 L	8	38:55:14	20 L	6	20:19:30
$ 835,291.96	3.95	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,854.38	$ 145,157.30	$ 112,000.00	92:32:29	20 L	8	38:55:14	20 L	6	20:19:31
$ 835,294.70	4	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,857.12	$ 145,157.30	$ 112,000.00	92:32:36	20 L	8	38:55:15	20 L	6	20:19:32
$ 835,297.43	4.05	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,859.85	$ 145,157.30	$ 112,000.00	92:32:44	20 L	8	38:55:16	20 L	6	20:19:33
$ 835,300.16	4.1	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,862.58	$ 145,157.30	$ 112,000.00	92:32:51	20 L	8	38:55:16	20 L	6	20:19:34
$ 835,302.89	4.15	$ 458,426.00	$ 24,603.00	$ 67,251.28	$ 27,865.31	$ 145,157.30	$ 112,000.00	92:32:58	20 L	8	38:55:17	20 L	6	20:19:35
$ 837,472.72	4.2	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,440.34	$ 145,157.30	$ 112,000.00	96:13:41	20 L	9	42:29:00	20 L	6	20:27:29
$ 837,475.46	4.25	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,443.08	$ 145,157.30	$ 112,000.00	96:13:48	20 L	9	42:29:01	20 L	6	20:27:31
$ 837,478.19	4.3	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,445.81	$ 145,157.30	$ 112,000.00	96:13:56	20 L	9	42:29:01	20 L	6	20:27:32
$ 837,480.92	4.35	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,448.54	$ 145,157.30	$ 112,000.00	96:14:03	20 L	9	42:29:02	20 L	6	20:27:33
$ 837,483.65	4.4	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,451.27	$ 145,157.30	$ 112,000.00	96:14:11	20 L	9	42:29:03	20 L	6	20:27:34
$ 837,486.39	4.45	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,454.01	$ 145,157.30	$ 112,000.00	96:14:18	20 L	9	42:29:03	20 L	6	20:27:35
$ 837,489.12	4.5	$ 458,426.00	$ 24,603.00	$ 68,846.08	$ 28,456.74	$ 145,157.30	$ 112,000.00	96:14:25	20 L	9	42:29:04	20 L	6	20:27:36
$ 845,590.49	4.55	$ 458,426.00	$ 24,603.00	$ 73,399.53	$ 32,004.66	$ 145,157.30	$ 112,000.00	101:08:39	20 L	9	42:29:04	20 L	7	23:41:37
$ 845,593.22	4.6	$ 458,426.00	$ 24,603.00	$ 73,399.53	$ 32,007.39	$ 145,157.30	$ 112,000.00	101:08:46	20 L	9	42:29:05	20 L	7	23:41:38
$ 845,595.96	4.65	$ 458,426.00	$ 24,603.00	$ 73,399.53	$ 32,010.13	$ 145,157.30	$ 112,000.00	101:08:53	20 L	9	42:29:06	20 L	7	23:41:39
$ 847,765.79	4.7	$ 458,426.00	$ 24,603.00	$ 74,994.33	$ 32,585.16	$ 145,157.30	$ 112,000.00	104:47:36	20 L	10	46:00:49	20 L	7	23:48:34
$ 847,768.52	4.75	$ 458,426.00	$ 24,603.00	$ 74,994.33	$ 32,587.89	$ 145,157.30	$ 112,000.00	104:47:44	20 L	10	46:00:49	20 L	7	23:48:35
$ 847,771.25	4.8	$ 458,426.00	$ 24,603.00	$ 74,994.33	$ 32,590.62	$ 145,157.30	$ 112,000.00	104:47:51	20 L	10	46:00:50	20 L	7	23:48:36
$ 847,773.99	4.85	$ 458,426.00	$ 24,603.00	$ 74,994.33	$ 32,593.36	$ 145,157.30	$ 112,000.00	104:47:58	20 L	10	46:00:51	20 L	7	23:48:37
$ 847,776.72	4.9	$ 458,426.00	$ 24,603.00	$ 74,994.33	$ 32,596.09	$ 145,157.30	$ 112,000.00	104:48:06	20 L	10	46:00:51	20 L	7	23:48:38
$ 847,779.45	4.95	$ 458,426.00	$ 24,603.00	$ 74,994.33	$ 32,598.82	$ 145,157.30	$ 112,000.00	104:48:13	20 L	10	46:00:52	20 L	7	23:48:39
$ 1,274,793.38	5	$ 875,581.00	$ 24,603.00	$ 80,480.26	$ 36,971.82	$ 145,157.30	$ 112,000.00	85:26:56	32 L	7	32:02:05	32 L	5	16:59:21
$ 1,274,796.12	5.05	$ 875,581.00	$ 24,603.00	$ 80,480.26	$ 36,974.56	$ 145,157.30	$ 112,000.00	85:27:02	32 L	7	32:02:06	32 L	5	16:59:22
$ 1,274,798.85	5.1	$ 875,581.00	$ 24,603.00	$ 80,480.26	$ 36,977.29	$ 145,157.30	$ 112,000.00	85:27:09	32 L	7	32:02:06	32 L	5	16:59:22
$ 1,275,824.56	5.15	$ 875,581.00	$ 24,603.00	$ 81,464.67	$ 37,018.59	$ 145,157.30	$ 112,000.00	85:28:17	32 L	7	32:02:07	32 L	5	16:59:23
$ 1,275,827.29	5.2	$ 875,581.00	$ 24,603.00	$ 81,464.67	$ 37,021.32	$ 145,157.30	$ 112,000.00	85:28:24	32 L	7	32:02:08	32 L	5	16:59:24
$ 1,275,830.02	5.25	$ 875,581.00	$ 24,603.00	$ 81,464.67	$ 37,024.05	$ 145,157.30	$ 112,000.00	85:28:31	32 L	7	32:02:08	32 L	5	16:59:24
$ 1,275,832.76	5.3	$ 875,581.00	$ 24,603.00	$ 81,464.67	$ 37,026.79	$ 145,157.30	$ 112,000.00	85:28:38	32 L	7	32:02:09	32 L	5	16:59:25
$ 1,275,835.49	5.35	$ 875,581.00	$ 24,603.00	$ 81,464.67	$ 37,029.52	$ 145,157.30	$ 112,000.00	85:28:45	32 L	7	32:02:09	32 L	5	16:59:26
$ 1,275,997.70	5.4	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,032.25	$ 145,157.30	$ 112,000.00	85:28:52	32 L	7	32:02:10	32 L	5	16:59:27
$ 1,276,000.43	5.45	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,034.98	$ 145,157.30	$ 112,000.00	85:28:59	32 L	7	32:02:11	32 L	5	16:59:27
$ 1,276,003.17	5.5	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,037.72	$ 145,157.30	$ 112,000.00	85:29:06	32 L	7	32:02:11	32 L	5	16:59:28
$ 1,276,005.90	5.55	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,040.45	$ 145,157.30	$ 112,000.00	85:29:13	32 L	7	32:02:12	32 L	5	16:59:29
$ 1,276,008.63	5.6	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,043.18	$ 145,157.30	$ 112,000.00	85:29:20	32 L	7	32:02:13	32 L	5	16:59:29
$ 1,276,011.37	5.65	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,045.92	$ 145,157.30	$ 112,000.00	85:29:27	32 L	7	32:02:13	32 L	5	16:59:30
$ 1,276,014.10	5.7	$ 875,581.00	$ 24,603.00	$ 81,624.15	$ 37,048.65	$ 145,157.30	$ 112,000.00	85:29:33	32 L	7	32:02:14	32 L	5	16:59:31
$ 1,279,308.24	5.75	$ 875,581.00	$ 24,603.00	$ 84,016.35	$ 37,950.59	$ 145,157.30	$ 112,000.00	89:11:23	32 L	8	35:38:04	32 L	5	17:06:24
$ 1,279,310.97	5.8	$ 875,581.00	$ 24,603.00	$ 84,016.35	$ 37,953.32	$ 145,157.30	$ 112,000.00	89:11:30	32 L	8	35:38:05	32 L	5	17:06:25
$ 1,279,313.70	5.85	$ 875,581.00	$ 24,603.00	$ 84,016.35	$ 37,956.05	$ 145,157.30	$ 112,000.00	89:11:37	32 L	8	35:38:05	32 L	5	17:06:26
$ 1,292,006.64	5.9	$ 875,581.00	$ 24,603.00	$ 91,136.29	$ 43,529.05	$ 145,157.30	$ 112,000.00	95:02:01	32 L	8	35:38:06	32 L	6	20:19:27
$ 1,292,009.37	5.95	$ 875,581.00	$ 24,603.00	$ 91,136.29	$ 43,531.78	$ 145,157.30	$ 112,000.00	95:02:08	32 L	8	35:38:07	32 L	6	20:19:27
$ 1,292,012.10	6	$ 875,581.00	$ 24,603.00	$ 91,136.29	$ 43,534.51	$ 145,157.30	$ 112,000.00	95:02:15	32 L	8	35:38:07	32 L	6	20:19:28
$ 1,292,014.84	6.05	$ 875,581.00	$ 24,603.00	$ 91,136.29	$ 43,537.25	$ 145,157.30	$ 112,000.00	95:02:22	32 L	8	35:38:08	32 L	6	20:19:29
$ 1,292,017.57	6.1	$ 875,581.00	$ 24,603.00	$ 91,136.29	$ 43,539.98	$ 145,157.30	$ 112,000.00	95:02:29	32 L	8	35:38:09	32 L	6	20:19:29
$ 1,292,179.78	6.15	$ 875,581.00	$ 24,603.00	$ 91,295.77	$ 43,542.71	$ 145,157.30	$ 112,000.00	95:02:36	32 L	8	35:38:09	32 L	6	20:19:30
$ 1,292,265.31	6.2	$ 875,581.00	$ 24,603.00	$ 91,378.56	$ 43,545.45	$ 145,157.30	$ 112,000.00	95:02:43	32 L	8	35:38:10	32 L	6	20:19:31
$ 1,292,268.04	6.25	$ 875,581.00	$ 24,603.00	$ 91,378.56	$ 43,548.18	$ 145,157.30	$ 112,000.00	95:02:50	32 L	8	35:38:10	32 L	6	20:19:32
$ 1,292,270.77	6.3	$ 875,581.00	$ 24,603.00	$ 91,378.56	$ 43,550.91	$ 145,157.30	$ 112,000.00	95:02:57	32 L	8	35:38:11	32 L	6	20:19:32
$ 1,292,273.50	6.35	$ 875,581.00	$ 24,603.00	$ 91,378.56	$ 43,553.64	$ 145,157.30	$ 112,000.00	95:03:03	32 L	8	35:38:12	32 L	6	20:19:33
$ 1,293,216.42	6.4	$ 875,581.00	$ 24,603.00	$ 92,280.18	$ 43,594.94	$ 145,157.30	$ 112,000.00	95:04:11	32 L	8	35:38:12	32 L	6	20:19:34
$ 1,293,219.16	6.45	$ 875,581.00	$ 24,603.00	$ 92,280.18	$ 43,597.68	$ 145,157.30	$ 112,000.00	95:04:18	32 L	8	35:38:13	32 L	6	20:19:34
$ 1,293,221.89	6.5	$ 875,581.00	$ 24,603.00	$ 92,280.18	$ 43,600.41	$ 145,157.30	$ 112,000.00	95:04:25	32 L	8	35:38:14	32 L	6	20:19:35
$ 1,293,224.62	6.55	$ 875,581.00	$ 24,603.00	$ 92,280.18	$ 43,603.14	$ 145,157.30	$ 112,000.00	95:04:32	32 L	8	35:38:14	32 L	6	20:19:36
$ 1,296,601.55	6.6	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,505.08	$ 145,157.30	$ 112,000.00	98:46:21	32 L	9	39:13:04	32 L	6	20:27:29
$ 1,296,604.28	6.65	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,507.81	$ 145,157.30	$ 112,000.00	98:46:28	32 L	9	39:13:05	32 L	6	20:27:30
$ 1,296,607.01	6.7	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,510.54	$ 145,157.30	$ 112,000.00	98:46:35	32 L	9	39:13:06	32 L	6	20:27:31
$ 1,296,609.75	6.75	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,513.28	$ 145,157.30	$ 112,000.00	98:46:42	32 L	9	39:13:06	32 L	6	20:27:32
$ 1,296,612.48	6.8	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,516.01	$ 145,157.30	$ 112,000.00	98:46:49	32 L	9	39:13:07	32 L	6	20:27:32
$ 1,296,615.21	6.85	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,518.74	$ 145,157.30	$ 112,000.00	98:46:56	32 L	9	39:13:08	32 L	6	20:27:33
$ 1,296,617.95	6.9	$ 875,581.00	$ 24,603.00	$ 94,755.17	$ 44,521.48	$ 145,157.30	$ 112,000.00	98:47:03	32 L	9	39:13:08	32 L	6	20:27:34
$ 1,296,780.16	6.95	$ 875,581.00	$ 24,603.00	$ 94,914.65	$ 44,524.21	$ 145,157.30	$ 112,000.00	98:47:10	32 L	9	39:13:09	32 L	6	20:27:34
$ 1,296,782.89	7	$ 875,581.00	$ 24,603.00	$ 94,914.65	$ 44,526.94	$ 145,157.30	$ 112,000.00	98:47:17	32 L	9	39:13:09	32 L	6	20:27:35
$ 1,296,785.63	7.05	$ 875,581.00	$ 24,603.00	$ 94,914.65	$ 44,529.68	$ 145,157.30	$ 112,000.00	98:47:24	32 L	9	39:13:10	32 L	6	20:27:36
$ 1,309,478.56	7.1	$ 875,581.00	$ 24,603.00	$ 102,034.59	$ 50,102.67	$ 145,157.30	$ 112,000.00	104:39:48	32 L	9	39:13:11	32 L	7	23:41:37
$ 1,309,481.30	7.15	$ 875,581.00	$ 24,603.00	$ 102,034.59	$ 50,105.41	$ 145,157.30	$ 112,000.00	104:39:55	32 L	9	39:13:11	32 L	7	23:41:37
$ 1,309,484.03	7.2	$ 875,581.00	$ 24,603.00	$ 102,034.59	$ 50,108.14	$ 145,157.30	$ 112,000.00	104:40:02	32 L	9	39:13:12	32 L	7	23:41:38
$ 1,309,486.76	7.25	$ 875,581.00	$ 24,603.00	$ 102,034.59	$ 50,110.87	$ 145,157.30	$ 112,000.00	104:40:09	32 L	9	39:13:13	32 L	7	23:41:39
$ 1,309,489.50	7.3	$ 875,581.00	$ 24,603.00	$ 102,034.59	$ 50,113.61	$ 145,157.30	$ 112,000.00	104:40:16	32 L	9	39:13:13	32 L	7	23:41:39
$ 1,309,492.23	7.35	$ 875,581.00	$ 24,603.00	$ 102,034.59	$ 50,116.34	$ 145,157.30	$ 112,000.00	104:40:23	32 L	9	39:13:14	32 L	7	23:41:40
$ 1,312,786.37	7.4	$ 875,581.00	$ 24,603.00	$ 104,426.79	$ 51,018.28	$ 145,157.30	$ 112,000.00	108:21:12	32 L	10	42:47:04	32 L	7	23:48:34
$ 1,312,789.10	7.45	$ 875,581.00	$ 24,603.00	$ 104,426.79	$ 51,021.01	$ 145,157.30	$ 112,000.00	108:21:19	32 L	10	42:47:05	32 L	7	23:48:34
$ 1,312,791.83	7.5	$ 875,581.00	$ 24,603.00	$ 104,426.79	$ 51,023.74	$ 145,157.30	$ 112,000.00	108:21:26	32 L	10	42:47:05	32 L	7	23:48:35
$ 1,312,794.57	7.55	$ 875,581.00	$ 24,603.00	$ 104,426.79	$ 51,026.48	$ 145,157.30	$ 112,000.00	108:21:33	32 L	10	42:47:06	32 L	7	23:48:36
$ 1,312,797.30	7.6	$ 875,581.00	$ 24,603.00	$ 104,426.79	$ 51,029.21	$ 145,157.30	$ 112,000.00	108:21:40	32 L	10	42:47:07	32 L	7	23:48:37
$ 1,312,800.03	7.65	$ 875,581.00	$ 24,603.00	$ 104,426.79	$ 51,031.94	$ 145,157.30	$ 112,000.00	108:21:47	32 L	10	42:47:07	32 L	7	23:48:37
$ 1,313,985.22	7.7	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,073.24	$ 145,157.30	$ 112,000.00	108:23:55	32 L	10	42:47:08	32 L	7	23:48:38
$ 1,313,987.96	7.75	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,075.98	$ 145,157.30	$ 112,000.00	108:24:02	32 L	10	42:47:09	32 L	7	23:48:39
$ 1,313,990.69	7.8	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,078.71	$ 145,157.30	$ 112,000.00	108:24:09	32 L	10	42:47:09	32 L	7	23:48:39
$ 1,313,993.42	7.85	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,081.44	$ 145,157.30	$ 112,000.00	108:24:16	32 L	10	42:47:10	32 L	7	23:48:40
$ 1,313,996.16	7.9	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,084.18	$ 145,157.30	$ 112,000.00	108:24:23	32 L	10	42:47:10	32 L	7	23:48:41
$ 1,313,998.89	7.95	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,086.91	$ 145,157.30	$ 112,000.00	108:24:29	32 L	10	42:47:11	32 L	7	23:48:42
$ 1,314,001.62	8	$ 875,581.00	$ 24,603.00	$ 105,570.68	$ 51,089.64	$ 145,157.30	$ 112,000.00	108:24:36	32 L	10	42:47:12	32 L	7	23:48:42

Titer (g/L)	VI Filter Size (m2)	Absorber Membrane Volume (m3)	NF size (m2)	UFDF size (m2)	Bulk fill filter size (m2)	SUM A Volume	Associated Volume (L)	SUM B Volume	Associated Volume (L)	SUM C Volume	Associated Volume (L)	SUM D1 Volume	Associated Volume (L)
2	0.4	0.36	0.51	10	1.65	2500	2000	500	122.0046616	500	139.9709734	1000	486.194048
2.05	0.45	0.36	0.51	10	1.65	2500	2000	500	136.9310189	500	157.0928069	1000	486.3451897
2.1	0.45	0.36	0.51	10	1.65	2500	2000	500	137.0120855	500	157.1864533	1000	486.4963322
2.15	0.45	0.36	0.51	10	1.65	2500	2000	500	137.0931524	500	157.2801001	1000	486.6474753
2.2	0.45	0.36	0.51	10	1.65	2500	2000	500	137.1742198	500	157.3737473	1000	486.7986192
2.25	0.45	0.36	0.51	10	1.92	2500	2000	500	137.2552875	500	157.467395	1000	566.9745916
2.3	0.5	0.36	0.51	10	1.92	2500	2000	500	152.1816467	500	174.5892307	1000	567.1257369
2.35	0.5	0.36	0.51	10	1.92	2500	2000	500	152.2627152	500	174.6828793	1000	567.2768829
2.4	0.5	0.36	0.51	10	1.92	2500	2000	500	152.3437841	500	174.7765284	1000	567.4280296
2.45	0.5	0.36	0.51	10	1.92	2500	2000	500	152.4248534	500	174.8701778	1000	567.579177
2.5	0.5	0.36	0.51	10	1.92	2500	2000	500	152.505923	500	174.9638278	1000	567.7303252
2.55	0.5	0.36	0.51	10	1.92	2500	2000	500	152.5869931	500	175.0574781	1000	567.8814741
2.6	0.55	0.54	0.51	10	2.2	2500	2000	500	167.5133546	500	192.1793165	1000	648.0574515
2.65	0.55	0.54	0.51	10	2.2	2500	2000	500	167.5944254	500	192.2729677	1000	648.2086018
2.7	0.55	0.54	0.51	10	2.2	2500	2000	500	167.6754966	500	192.3666194	1000	648.3597528
2.75	0.55	0.54	0.51	10	2.20	2500	2000	500	167.7565682	500	192.4602716	1000	648.5109046
2.8	0.55	0.54	0.51	10	2.20	2500	2000	500	167.8376402	500	192.5539242	1000	648.662057
2.85	0.6	0.54	0.51	10	2.20	2500	2000	500	182.7640036	500	209.6757647	1000	648.8132102
2.9	0.6	0.54	0.51	10	2.20	2500	2000	500	182.8450763	500	209.7694182	1000	648.9643641
2.95	0.6	0.54	0.51	10	2.47	2500	2000	500	182.9261494	500	209.8630721	1000	729.1403466
3	0.62	0.54	0.51	10	2.25	2500	2000	500	187.0775958	500	214.6256192	2500	663.8944723
3.05	0.62	0.54	0.51	10	2.80	2500	2000	500	187.1586696	500	214.719274	2500	827.7522336
3.1	0.62	0.54	0.51	10	2.80	2500	2000	500	187.2397439	500	214.8129293	2500	827.9033904
3.15	0.72	0.54	0.51	10	2.80	2500	2000	500	217.6897962	500	249.7411088	2500	828.0545478
3.2	0.72	0.54	0.51	10	2.80	2500	2000	500	217.7708712	500	249.834765	2500	828.205706
3.25	0.72	0.54	0.51	10	2.80	2500	2000	500	217.8519467	500	249.9284215	2500	828.3568649
3.3	0.72	0.54	0.51	10	2.80	2500	2000	500	217.9330225	500	250.0220786	2500	828.5080245
3.35	0.72	0.54	0.51	10	2.80	2500	2000	500	218.0140987	500	250.115736	2500	828.6591849
3.4	0.72	0.54	0.51	10	2.8	2500	2000	500	218.0951752	500	250.209394	2500	828.8103459
3.45	0.72	0.54	0.51	10	2.8	2500	2000	500	218.1762522	500	250.3030523	2500	828.9615077
3.5	0.72	0.54	0.51	10	2.8	2500	2000	500	218.2573295	500	250.3967111	2500	829.1126702
3.55	0.72	0.54	0.51	10	2.8	2500	2000	500	218.3384073	500	250.4903704	2500	829.2638334
3.6	0.72	0.54	0.51	10	2.8	2500	2000	500	218.4194854	500	250.5840301	2500	829.4149973
3.65	0.72	0.54	0.51	10	2.8	2500	2000	500	218.5005639	500	250.6776902	2500	829.5661619
3.7	0.82	0.54	0.51	10	2.8	2500	2000	500	248.9506204	500	285.6058746	2500	829.7173273
3.75	0.82	0.54	0.51	10	2.8	2500	2000	500	249.0316997	500	285.6995356	2500	829.8684933
3.8	0.82	0.54	0.51	10	3.35	2500	2000	500	249.1127793	500	285.7931971	2500	993.7262654
3.85	0.82	0.72	0.51	10	3.36	2500	2000	500	249.1938593	500	285.886859	2500	993.8774329
3.9	0.82	0.72	0.51	10	3.36	2500	2000	500	249.2749398	500	285.9805214	2500	994.0286011
3.95	0.82	0.72	0.51	10	3.36	2500	2000	500	249.3560206	500	286.0741842	2500	994.1797701
4	0.82	0.72	0.51	10	3.36	2500	2000	500	249.4371018	500	286.1678474	2500	994.3309397
4.05	0.82	0.72	0.51	10	3.36	2500	2000	500	249.5181833	500	286.2615111	2500	994.4821101
4.1	0.82	0.72	0.51	10	3.36	2500	2000	500	249.5992653	500	286.3551752	2500	994.6332812
4.15	0.82	0.72	0.51	10	3.36	2500	2000	500	249.6803476	500	286.4488398	2500	994.784453
4.2	0.92	0.72	0.51	10	3.36	2500	2000	500	280.130408	500	321.3770287	2500	994.9356255
4.25	0.92	0.72	0.51	10	3.36	2500	2000	500	280.2114911	500	321.4706941	2500	995.0867987
4.3	0.92	0.72	0.51	10	3.36	2500	2000	500	280.2925746	500	321.56436	2500	995.2379727
4.35	0.92	0.72	0.51	10	3.36	2500	2000	500	280.3736585	500	321.6580264	2500	995.3891473
4.4	0.92	0.72	0.51	10	3.36	2500	2000	500	280.4547427	500	321.7516932	2500	995.5403227
4.45	0.92	0.72	0.51	10	3.36	2500	2000	500	280.5358274	500	321.8453604	2500	995.6914988
4.5	0.92	0.72	0.51	10	3.36	2500	2000	500	280.6169124	500	321.9390281	2500	995.8426756
4.55	0.92	0.72	0.51	10	3.91	2500	2000	500	280.6979978	500	322.0326962	2500	1159.700458
4.6	0.92	0.72	0.51	10	3.91	2500	2000	500	280.7790836	500	322.1263648	2500	1159.851637
4.65	0.92	0.72	0.51	10	3.91	2500	2000	500	280.8601698	500	322.2200338	2500	1160.002816
4.7	1.02	0.72	0.51	10	3.91	2500	2000	500	311.310234	500	357.1482271	2500	1160.153995
4.75	1.02	0.72	0.51	10	3.91	2500	2000	500	311.391321	500	357.241897	2500	1160.305176
4.8	1.02	0.72	0.51	10	3.91	2500	2000	500	311.4724083	500	357.3355674	2500	1160.456357
4.85	1.02	0.72	0.51	10	3.91	2500	2000	500	311.553496	500	357.4292382	2500	1160.607539
4.9	1.02	0.72	0.51	10	3.91	2500	2000	500	311.6345841	500	357.5229094	2500	1160.758721
4.95	1.02	0.72	0.51	10	3.91	2500	2000	500	334.7580881	500	357.6165811	2500	1160.909905
5	1.12	0.72	0.51	10	4.38	2500	2000	500	342.1207327	500	392.4931528	2500	1301.207742
5.05	1.12	0.72	0.51	10	4.38	2500	2000	500	342.201822	500	392.5868253	2500	1301.358927
5.1	1.12	0.72	0.51	10	4.38	2500	2000	500	342.2829116	500	392.6804983	2500	1301.510112
5.15	1.12	0.9	0.51	10	4.39	2500	2000	500	342.3640016	500	392.7741718	2500	1301.661299
5.2	1.12	0.9	0.51	10	4.39	2500	2000	500	342.4450921	500	392.8678457	2500	1301.812485
5.25	1.12	0.9	0.51	10	4.39	2500	2000	500	342.5261829	500	392.96152	2500	1301.963673
5.3	1.12	0.9	0.51	10	4.39	2500	2000	500	342.607274	500	393.0551948	2500	1302.114861
5.35	1.12	0.9	0.51	10	4.39	2500	2000	500	342.6883656	500	393.1488701	2500	1302.26605
5.4	1.13	0.9	0.51	10	4.39	2500	2000	500	342.7694576	500	393.2425457	2500	1302.41724
5.45	1.13	0.9	0.51	10	4.39	2500	2000	500	342.8505499	500	393.3362218	2500	1302.56843
5.5	1.13	0.9	0.51	10	4.39	2500	2000	500	342.9316426	500	393.4298984	2500	1302.719622
5.55	1.13	0.9	0.51	10	4.39	2500	2000	500	343.0127357	500	393.5235754	2500	1302.870813
5.6	1.13	0.9	0.51	10	4.39	2500	2000	500	343.0938292	500	393.6172529	2500	1303.022006
5.65	1.13	0.9	0.51	10	4.39	2500	2000	500	343.1749231	500	393.7109308	2500	1303.173199
5.7	1.13	0.9	0.51	10	4.39	2500	2000	500	343.2560173	500	393.8046091	2500	1303.324393
5.75	1.28	0.9	0.51	10	4.39	2500	2000	500	391.0533616	500	448.6308791	2500	1303.475588
5.8	1.28	0.9	0.51	10	4.39	2500	2000	500	391.1344567	500	448.7245583	2500	1303.626783
5.85	1.28	0.9	0.51	10	4.39	2500	2000	500	391.2155521	500	448.818238	2500	1303.77798
5.9	1.28	0.9	0.51	10	5.25	2500	2000	500	391.2966479	500	448.9119181	2500	1561.147755
5.95	1.28	0.9	0.51	10	5.25	2500	2000	500	391.377744	500	449.0055986	2500	1561.298952
6	1.28	0.9	0.51	10	5.25	2500	2000	500	391.4588406	500	449.0992796	2500	1561.450151
6.05	1.28	0.9	0.51	10	5.25	2500	2000	500	391.5399376	500	449.1929611	2500	1561.60135
6.1	1.28	0.9	0.51	10	5.25	2500	2000	500	391.6210349	500	449.286643	2500	1561.752549
6.15	1.29	0.9	0.51	10	5.25	2500	2000	500	391.7021326	500	449.3803253	2500	1561.90375
6.2	1.29	0.9	0.51	10	5.26	2500	2000	500	391.7832307	500	449.4740081	2500	1562.054951
6.25	1.29	0.9	0.51	10	5.26	2500	2000	500	391.8643292	500	449.5676913	2500	1562.206153
6.3	1.29	0.9	0.51	10	5.26	2500	2000	500	391.9454281	500	449.661375	2500	1562.357356
6.35	1.29	0.9	0.51	10	5.26	2500	2000	500	392.0265273	500	449.7550591	2500	1562.508559
6.4	1.29	1.08	0.51	10	5.26	2500	2000	500	392.107627	500	449.8487437	2500	1562.659763
6.45	1.29	1.08	0.51	10	5.26	2500	2000	500	392.188727	500	449.9424287	2500	1562.810968
6.5	1.29	1.08	0.51	10	5.26	2500	2000	500	392.2698274	500	450.0361141	2500	1562.962173
6.55	1.29	1.08	0.51	10	5.26	2500	2000	500	392.3509282	500	450.1298	2500	1563.113379
6.6	1.44	1.08	0.51	10	5.27	2500	2000	500	440.148279	500	504.9560775	2500	1563.264586
6.65	1.44	1.08	0.51	10	5.27	2500	2000	500	440.2293806	500	505.0497643	2500	1563.415794
6.7	1.44	1.08	0.51	10	5.27	2500	2000	500	440.3104825	500	505.1434515	2500	1563.567002
6.75	1.44	1.08	0.51	10	5.27	2500	2000	500	440.3915849	500	505.2371392	2500	1563.718211
6.8	1.44	1.08	0.51	10	5.27	2500	2000	500	440.4726876	500	505.3308273	2500	1563.869421
6.85	1.44	1.08	0.51	10	5.27	2500	2000	500	440.5537907	500	505.4245158	2500	1564.020632
6.9	1.44	1.08	0.51	10	5.27	2500	2000	500	440.6348942	500	505.5182048	2500	1564.171843
6.95	1.45	1.08	0.51	10	5.27	2500	2000	500	440.7159981	500	505.6118943	2500	1564.323055
7	1.45	1.08	0.51	10	5.27	2500	2000	500	440.7971023	500	505.7055842	2500	1564.474268
7.05	1.45	1.08	0.51	10	5.27	2500	2000	500	440.8782069	500	505.7992745	2500	1564.625481
7.1	1.45	1.08	0.51	10	6.13	2500	2000	500	440.959312	500	505.8929653	2500	1821.995273
7.15	1.45	1.08	0.51	10	6.13	2500	2000	500	441.0404174	500	505.9866565	2500	1822.146488
7.2	1.45	1.08	0.51	10	6.13	2500	2000	500	441.1215232	500	506.0803482	2500	1822.297704
7.25	1.45	1.08	0.51	10	6.13	2500	2000	500	441.2026294	500	506.1740403	2500	1822.44892
7.3	1.45	1.08	0.51	10	6.13	2500	2000	500	441.2837359	500	506.2677328	2500	1822.600137
7.35	1.45	1.08	0.51	10	6.13	2500	2000	500	441.3648429	500	506.3614258	2500	1822.751354
7.4	1.6	1.08	0.51	10	6.13	2500	2000	500	489.1621998	500	561.1877104	2500	1822.902573
7.45	1.6	1.08	0.51	10	6.13	2500	2000	500	489.2433076	500	561.2814043	2500	1823.053792
7.5	1.6	1.08	0.51	10	6.13	2500	2000	500	489.3244157	500	561.3750986	2500	1823.205012
7.55	1.6	1.08	0.51	10	6.13	2500	2000	500	489.4055241	500	561.4687934	2500	1823.356232
7.6	1.6	1.08	0.51	10	6.13	2500	2000	500	489.486633	500	561.5624886	2500	1823.507454
7.65	1.6	1.08	0.51	10	6.13	2500	2000	500	489.5677423	500	561.6561843	2500	1823.658676
7.7	1.61	1.26	0.51	10	6.14	2500	2000	500	489.6488519	500	561.7498804	2500	1823.809898
7.75	1.61	1.26	0.51	10	6.14	2500	2000	500	489.7299619	500	561.843577	2500	1823.961122
7.8	1.61	1.26	0.51	10	6.14	2500	2000	500	489.8110723	500	561.937274	2500	1824.112346
7.85	1.61	1.26	0.51	10	6.14	2500	2000	500	489.8921831	500	562.0309714	2500	1824.263571
7.9	1.61	1.26	0.51	10	6.14	2500	2000	500	489.9732943	500	562.1246693	2500	1824.414796
7.95	1.61	1.26	0.51	10	6.14	2500	2000	500	490.0544059	500	562.2183676	2500	1824.566022
8	1.61	1.26	0.51	10	6.14	2500	2000	500	490.1355178	500	562.3120664	2500	1824.717249

Titer (g/L)	SUM D2 Volume	Associated Volume (L)	SUM E Volume	Associated Volume (L)	, Powder, USP/EP/J	Acid, Glacial,	Chloride, Granular	NF,EP, JP, BP	Injection, USP/EP/J	Phosphate Dibasic	Alcohol, 190(Etha	Phosphate,	Histidine, USP, BP,	Histidine Monohyd	Hydroxide, 50%	amine (Tris	Acetate, Trihydrat	Media	Polycarbonate	Polysorbate 80	Protein
2	1000	494.2475811	1000	489.8012585	25.51922	3.9326	22.41037	47.95083	6157.724	3.241135	5.860603	1.677302	2.101246	6.945829	6.75206	2.650807	23.29268	0	0	0.033136	0
2.05	1000	494.3987227	1000	489.9524002	25.52696	4.286977	23.78399	47.96537	6361.334	3.635212	5.860603	1.885805	2.101883	6.947934	6.75206	2.823496	23.31298	0	0	0.033147	0
2.1	1000	494.549865	1000	490.1035427	25.53469	4.287356	23.78399	47.97991	6362.107	3.635212	5.860603	1.885805	2.10252	6.95004	6.75206	2.824866	23.31298	0	0	0.033157	0
2.15	1000	494.701008	1000	490.2546858	25.54243	4.287735	23.78399	47.99444	6362.88	3.635212	5.860603	1.885805	2.103158	6.952146	6.75206	2.826235	23.31298	0	0	0.033168	0
2.2	1000	494.8521518	1000	490.4058296	25.55017	4.288114	23.78399	48.00898	6363.653	3.635212	5.860603	1.885805	2.103795	6.954252	6.75206	2.827604	23.31298	0	0	0.033178	0
2.25	1000	575.0288096	1000	570.5818021	29.6543	4.438652	25.56201	55.72068	7019.89	3.635212	5.860603	1.885805	2.441728	8.071315	6.75206	3.027093	27.14721	0	0	0.038552	0
2.3	1000	575.1799547	1000	570.7329474	29.66203	4.793029	26.93562	55.73522	7223.5	4.029289	5.860603	2.094309	2.442365	8.073421	6.75206	3.199782	27.16751	0	0	0.038562	0
2.35	1000	575.3311006	1000	570.8840934	29.66977	4.793408	26.93562	55.74975	7224.273	4.029289	5.860603	2.094309	2.443002	8.075527	6.75206	3.201151	27.16751	0	0	0.038573	0
2.4	1000	575.4822472	1000	571.0352401	29.67751	4.793787	26.93562	55.76429	7225.046	4.029289	5.860603	2.094309	2.443639	8.077633	6.75206	3.20252	27.16751	0	0	0.038583	0
2.45	1000	575.6333945	1000	571.1863875	29.68524	4.794167	26.93562	55.77883	7225.82	4.029289	5.860603	2.094309	2.444276	8.079739	6.75206	3.20389	27.16751	0	0	0.038594	0
2.5	1000	575.7845425	1000	571.3375357	29.69298	4.794546	26.93562	55.79337	7226.593	4.029289	5.860603	2.094309	2.444913	8.081845	6.75206	3.205259	27.16751	0	0	0.038604	0
2.55	1000	575.9356913	1000	571.4886846	29.70072	4.794925	26.93562	55.80791	7227.366	4.029289	5.860603	2.094309	2.44555	8.08395	6.75206	3.206628	27.16751	0	0	0.038614	0
2.6	1000	657.915975	1000	653.4682673	33.89717	5.29946	30.08726	63.69308	8099.969	4.423366	5.860603	2.302812	2.791085	9.226143	6.825264	3.588806	31.02204	0	0	0.044109	0
2.65	1000	658.0671251	1000	653.6194176	33.90491	5.299839	30.08726	63.70762	8100.742	4.423366	5.860603	2.302812	2.791722	9.228249	6.825264	3.590176	31.02204	0	0	0.044119	0
2.7	1000	658.218276	1000	653.7705686	33.91265	5.300219	30.08726	63.72216	8101.515	4.423366	5.860603	2.302812	2.792359	9.230355	6.825264	3.591545	31.02204	0	0	0.04413	0
2.75	1000	658.3694276	1000	653.9217203	33.92039	5.300598	30.08726	63.7367	8102.288	4.423366	5.860603	2.302812	2.792996	9.232461	6.825264	3.592914	31.02204	0	0	0.04414	0
2.8	1000	658.52058	1000	654.0728728	33.92812	5.300977	30.08726	63.75124	8103.062	4.423366	5.860603	2.302812	2.793634	9.234567	6.825264	3.594284	31.02204	0	0	0.044151	0
2.85	1000	658.671733	1000	654.2240259	33.93586	5.655354	31.46087	63.76577	8306.672	4.817444	5.860603	2.511315	2.794271	9.236673	6.825264	3.766973	31.04235	0	0	0.044161	0
2.9	1000	658.8228868	1000	654.3751798	33.9436	5.655734	31.46087	63.78031	8307.445	4.817444	5.860603	2.511315	2.794908	9.238779	6.825264	3.768342	31.04235	0	0	0.044172	0
2.95	1000	738.9995546	1000	734.5511623	38.04773	5.806271	33.23889	71.49201	8963.682	4.817444	5.860603	2.511315	3.132841	10.35584	6.825264	3.967831	34.87658	0	0	0.049545	0
3	2500	673.75312	2500	669.305288	34.70786	5.973933	32.95027	65.21636	8906.279	5.018057	11.98902	2.578184	2.857837	9.446794	12.03168	3.854269	31.87936	0	0	0.045173	0
3.05	2500	837.6122835	2500	833.1630493	43.09558	6.28149	36.58756	80.97696	10247.93	5.018057	11.98902	2.578184	3.548479	11.72977	12.03168	4.26093	39.72304	0	0	0.056155	0
3.1	2500	837.7634402	2500	833.3142061	43.10331	6.281869	36.58756	80.9915	10248.71	5.018057	11.98902	2.578184	3.549117	11.73187	12.03168	4.262299	39.72304	0	0	0.056165	0
3.15	2500	837.9145975	2500	833.4653636	43.11105	7.006421	39.39756	81.00604	10664.42	5.82422	11.98902	3.004719	3.549754	11.73398	12.03168	4.614137	39.76457	0	0	0.056176	0
3.2	2500	838.0657556	2500	833.6165217	43.11879	7.0068	39.39756	81.02057	10665.19	5.82422	11.98902	3.004719	3.550391	11.73608	12.03168	4.615507	39.76457	0	0	0.056186	0
3.25	2500	838.2169143	2500	833.7676806	43.12653	7.00718	39.39756	81.03511	10665.97	5.82422	11.98902	3.004719	3.551028	11.73819	12.03168	4.616876	39.76457	0	0	0.056196	0
3.3	2500	838.3680738	2500	833.9188403	43.13426	7.007559	39.39756	81.04965	10666.74	5.82422	11.98902	3.004719	3.551665	11.7403	12.03168	4.618246	39.76457	0	0	0.056207	0
3.35	2500	838.519234	2500	834.0700006	43.142	7.007938	39.39756	81.06419	10667.51	5.82422	11.98902	3.004719	3.552302	11.7424	12.03168	4.619615	39.76457	0	0	0.056217	0
3.4	2500	838.670395	2500	834.2211616	43.14974	7.008318	39.39756	81.07873	10668.29	5.82422	11.98902	3.004719	3.552939	11.74451	12.03168	4.620985	39.76457	0	0	0.056228	0
3.45	2500	838.8215566	2500	834.3723234	43.15748	7.008697	39.39756	81.09327	10669.06	5.82422	11.98902	3.004719	3.553576	11.74661	12.03168	4.622354	39.76457	0	0	0.056238	0
3.5	2500	838.972719	2500	834.5234859	43.16521	7.009076	39.39756	81.10781	10669.83	5.82422	11.98902	3.004719	3.554213	11.74872	12.03168	4.623724	39.76457	0	0	0.056249	0
3.55	2500	839.1238821	2500	834.6746491	43.17295	7.009455	39.39756	81.12235	10670.61	5.82422	11.98902	3.004719	3.554851	11.75083	12.03168	4.625093	39.76457	0	0	0.056259	0
3.6	2500	839.2750459	2500	834.825813	43.18069	7.009835	39.39756	81.13689	10671.38	5.82422	11.98902	3.004719	3.555488	11.75293	12.03168	4.626463	39.76457	0	0	0.05627	0
3.65	2500	839.4262104	2500	834.9769777	43.18843	7.010214	39.39756	81.15143	10672.15	5.82422	11.98902	3.004719	3.556125	11.75504	12.03168	4.627832	39.76457	0	0	0.05628	0
3.7	2500	839.5773756	2500	835.128143	43.19617	7.734766	42.20756	81.16597	11087.87	6.630382	11.98902	3.431253	3.556762	11.75715	12.03168	4.97967	39.8061	0	0	0.056291	0
3.75	2500	839.7285415	2500	835.2793091	43.2039	7.735145	42.20756	81.18051	11088.64	6.630382	11.98902	3.431253	3.557399	11.75925	12.03168	4.98104	39.8061	0	0	0.056301	0
3.8	2500	1003.587716	2500	999.1370812	51.59162	8.042702	45.84485	96.94111	12430.3	6.630382	11.98902	3.431253	4.248042	14.04222	12.03168	5.3877	47.64978	0	0	0.067283	0
3.85	2500	1005.542504	2500	1001.091854	51.69169	8.043082	45.84485	97.12913	12444.6	6.630382	11.98902	3.431253	4.256281	14.06946	12.10488	5.40044	47.64978	0	0	0.067414	0
3.9	2500	1005.693672	2500	1001.243022	51.69943	8.043461	45.84485	97.14367	12445.37	6.630382	11.98902	3.431253	4.256918	14.07157	12.10488	5.401809	47.64978	0	0	0.067425	0
3.95	2500	1005.844841	2500	1001.394191	51.70716	8.04384	45.84485	97.15821	12446.15	6.630382	11.98902	3.431253	4.257556	14.07367	12.10488	5.403179	47.64978	0	0	0.067435	0
4	2500	1005.99601	2500	1001.545361	51.7149	8.04422	45.84485	97.17275	12446.92	6.630382	11.98902	3.431253	4.258193	14.07578	12.10488	5.404548	47.64978	0	0	0.067446	0
4.05	2500	1006.147181	2500	1001.696531	51.72264	8.044599	45.84485	97.18729	12447.69	6.630382	11.98902	3.431253	4.25883	14.07788	12.10488	5.405918	47.64978	0	0	0.067456	0
4.1	2500	1006.298352	2500	1001.847702	51.73038	8.044978	45.84485	97.20183	12448.47	6.630382	11.98902	3.431253	4.259467	14.07999	12.10488	5.407288	47.64978	0	0	0.067466	0
4.15	2500	1006.449523	2500	1001.998874	51.73812	8.045358	45.84485	97.21637	12449.24	6.630382	11.98902	3.431253	4.260104	14.0821	12.10488	5.408657	47.64978	0	0	0.067477	0
4.2	2500	1006.600696	2500	1002.150046	51.74585	8.76991	48.65485	97.23091	12864.96	7.436545	11.98902	3.857788	4.260741	14.0842	12.10488	5.760495	47.69131	0	0	0.067487	0
4.25	2500	1006.751869	2500	1002.30122	51.75359	8.770289	48.65485	97.24545	12865.73	7.436545	11.98902	3.857788	4.261379	14.08631	12.10488	5.761865	47.69131	0	0	0.067498	0
4.3	2500	1006.903043	2500	1002.452394	51.76133	8.770668	48.65485	97.25999	12866.5	7.436545	11.98902	3.857788	4.262016	14.08841	12.10488	5.763234	47.69131	0	0	0.067508	0
4.35	2500	1007.054217	2500	1002.603568	51.76907	8.771047	48.65485	97.27453	12867.28	7.436545	11.98902	3.857788	4.262653	14.09052	12.10488	5.764604	47.69131	0	0	0.067519	0
4.4	2500	1007.205392	2500	1002.754744	51.77681	8.771427	48.65485	97.28907	12868.05	7.436545	11.98902	3.857788	4.26329	14.09263	12.10488	5.765974	47.69131	0	0	0.067529	0
4.45	2500	1007.356568	2500	1002.90592	51.78455	8.771806	48.65485	97.30361	12868.82	7.436545	11.98902	3.857788	4.263927	14.09473	12.10488	5.767343	47.69131	0	0	0.06754	0
4.5	2500	1007.507745	2500	1003.057097	51.79229	8.772185	48.65485	97.31815	12869.6	7.436545	11.98902	3.857788	4.264564	14.09684	12.10488	5.768713	47.69131	0	0	0.06755	0
4.55	2500	1171.36693	2500	1166.914879	60.18001	9.079743	52.29214	113.0788	14211.25	7.436545	11.98902	3.857788	4.955207	16.37981	12.10488	6.175374	55.53498	0	0	0.078532	0
4.6	2500	1171.518108	2500	1167.066058	60.18775	9.080122	52.29214	113.0933	14212.02	7.436545	11.98902	3.857788	4.955845	16.38192	12.10488	6.176743	55.53498	0	0	0.078542	0
4.65	2500	1171.669287	2500	1167.217237	60.19548	9.080501	52.29214	113.1078	14212.8	7.436545	11.98902	3.857788	4.956482	16.38402	12.10488	6.178113	55.53498	0	0	0.078553	0
4.7	2500	1171.820467	2500	1167.368416	60.20322	9.805053	55.10214	113.1224	14628.51	8.242708	11.98902	4.284323	4.957119	16.38613	12.10488	6.529951	55.57652	0	0	0.078563	0
4.75	2500	1171.971647	2500	1167.519597	60.21096	9.805433	55.10214	113.1369	14629.29	8.242708	11.98902	4.284323	4.957756	16.38824	12.10488	6.531321	55.57652	0	0	0.078574	0
4.8	2500	1172.122828	2500	1167.670778	60.2187	9.805812	55.10214	113.1515	14630.06	8.242708	11.98902	4.284323	4.958393	16.39034	12.10488	6.532691	55.57652	0	0	0.078584	0
4.85	2500	1172.27401	2500	1167.82196	60.22644	9.806191	55.10214	113.166	14630.83	8.242708	11.98902	4.284323	4.959031	16.39245	12.10488	6.53406	55.57652	0	0	0.078595	0
4.9	2500	1172.425192	2500	1167.973142	60.23418	9.806571	55.10214	113.1805	14631.61	8.242708	11.98902	4.284323	4.959668	16.39456	12.10488	6.53543	55.57652	0	0	0.078605	0
4.95	2500	1172.576375	2500	1168.124326	60.24192	9.80695	55.10214	113.1951	14632.38	8.242708	11.98902	4.284323	4.960305	16.39666	12.10488	6.5368	55.57652	0	0	0.078616	0
5	2500	1312.875413	2500	1308.422163	67.42363	11.00899	61.90211	126.6896	16666.8	9.151112	18.83735	4.721065	5.551645	18.35138	17.9229	7.235082	62.47876	0	0	0.088018	0
5.05	2500	1313.026598	2500	1308.573348	67.43137	11.00937	61.90211	126.7041	16667.58	9.151112	18.83735	4.721065	5.552283	18.35349	17.9229	7.236452	62.47876	0	0	0.088029	0
5.1	2500	1313.177783	2500	1308.724533	67.43911	11.00975	61.90211	126.7187	16668.35	9.151112	18.83735	4.721065	5.55292	18.3556	17.9229	7.237821	62.47876	0	0	0.088039	0
5.15	2500	1315.13259	2500	1310.679325	67.53917	11.01013	61.90211	126.9067	16682.65	9.151112	18.83735	4.721065	5.561159	18.38283	17.99611	7.250561	62.47876	0	0	0.088171	0
5.2	2500	1315.283777	2500	1310.830512	67.54691	11.01051	61.90211	126.9212	16683.43	9.151112	18.83735	4.721065	5.561796	18.38494	17.99611	7.25193	62.47876	0	0	0.088181	0
5.25	2500	1315.434964	2500	1310.981699	67.55465	11.01089	61.90211	126.9358	16684.2	9.151112	18.83735	4.721065	5.562434	18.38704	17.99611	7.2533	62.47876	0	0	0.088192	0
5.3	2500	1315.586152	2500	1311.132887	67.56239	11.01127	61.90211	126.9503	16684.97	9.151112	18.83735	4.721065	5.563071	18.38915	17.99611	7.25467	62.47876	0	0	0.088202	0
5.35	2500	1315.737341	2500	1311.284076	67.57013	11.01165	61.90211	126.9648	16685.75	9.151112	18.83735	4.721065	5.563708	18.39126	17.99611	7.25604	62.47876	0	0	0.088212	0
5.4	2500	1315.888531	2500	1311.435266	67.57786	11.01203	61.90211	126.9794	16686.52	9.151112	18.83735	4.721065	5.564345	18.39336	17.99611	7.257409	62.47876	0	0	0.088223	0
5.45	2500	1316.039721	2500	1311.586457	67.5856	11.01241	61.90211	126.9939	16687.29	9.151112	18.83735	4.721065	5.564982	18.39547	17.99611	7.258779	62.47876	0	0	0.088233	0
5.5	2500	1316.190912	2500	1311.737648	67.59334	11.01279	61.90211	127.0085	16688.07	9.151112	18.83735	4.721065	5.56562	18.39758	17.99611	7.260149	62.47876	0	0	0.088244	0
5.55	2500	1316.342104	2500	1311.88884	67.60108	11.01317	61.90211	127.023	16688.84	9.151112	18.83735	4.721065	5.566257	18.39968	17.99611	7.261519	62.47876	0	0	0.088254	0
5.6	2500	1316.493296	2500	1312.040032	67.60882	11.01355	61.90211	127.0376	16689.61	9.151112	18.83735	4.721065	5.566894	18.40179	17.99611	7.262888	62.47876	0	0	0.088265	0
5.65	2500	1316.64449	2500	1312.191226	67.61656	11.01393	61.90211	127.0521	16690.39	9.151112	18.83735	4.721065	5.567532	18.4039	17.99611	7.264258	62.47876	0	0	0.088275	0
5.7	2500	1316.795683	2500	1312.34242	67.6243	11.01431	61.90211	127.0666	16691.16	9.151112	18.83735	4.721065	5.568169	18.406	17.99611	7.265628	62.47876	0	0	0.088286	0
5.75	2500	1316.946878	2500	1312.493614	67.63204	12.15252	66.31723	127.0812	17343.9	10.41777	18.83735	5.391243	5.568806	18.40811	17.99611	7.81766	62.54402	0	0	0.088296	0
5.8	2500	1317.098073	2500	1312.64481	67.63978	12.1529	66.31723	127.0957	17344.67	10.41777	18.83735	5.391243	5.569443	18.41022	17.99611	7.81903	62.54402	0	0	0.088307	0
5.85	2500	1317.249269	2500	1312.796006	67.64752	12.15328	66.31723	127.1103	17345.45	10.41777	18.83735	5.391243	5.570081	18.41232	17.99611	7.820399	62.54402	0	0	0.088317	0
5.9	2500	1574.621248	2500	1570.165781	80.82203	12.6363	72.0322	151.8653	19453.03	10.41777	18.83735	5.391243	6.654867	21.99816	17.99611	8.45857	74.86813	0	0	0.105566	0
5.95	2500	1574.772445	2500	1570.316979	80.82977	12.63668	72.0322	151.8798	19453.81	10.41777	18.83735	5.391243	6.655504	22.00027	17.99611	8.45994	74.86813	0	0	0.105576	0
6	2500	1574.923643	2500	1570.468177	80.83751	12.63706	72.0322	151.8944	19454.58	10.41777	18.83735	5.391243	6.656141	22.00238	17.99611	8.461309	74.86813	0	0	0.105587	0
6.05	2500	1575.074842	2500	1570.619376	80.84525	12.63744	72.0322	151.9089	19455.35	10.41777	18.83735	5.391243	6.656778	22.00448	17.99611	8.462679	74.86813	0	0	0.105597	0
6.1	2500	1575.226042	2500	1570.770576	80.85299	12.63782	72.0322	151.9235	19456.13	10.41777	18.83735	5.391243	6.657416	22.00659	17.99611	8.464049	74.86813	0	0	0.105608	0
6.15	2500	1575.377242	2500	1570.921776	80.86073	12.6382	72.0322	151.938	19456.9	10.41777	18.83735	5.391243	6.658053	22.0087	17.99611	8.465419	74.86813	0	0	0.105618	0
6.2	2500	1575.528443	2500	1571.072977	80.86847	12.63857	72.0322	151.9525	19457.67	10.41777	18.83735	5.391243	6.65869	22.0108	17.99611	8.466789	74.86813	0	0	0.105629	0
6.25	2500	1575.679645	2500	1571.224179	80.87621	12.63895	72.0322	151.9671	19458.45	10.41777	18.83735	5.391243	6.659328	22.01291	17.99611	8.468159	74.86813	0	0	0.105639	0
6.3	2500	1575.830848	2500	1571.375382	80.88395	12.63933	72.0322	151.9816	19459.22	10.41777	18.83735	5.391243	6.659965	22.01502	17.99611	8.469528	74.86813	0	0	0.10565	0
6.35	2500	1575.982051	2500	1571.526585	80.89169	12.63971	72.0322	151.9962	19459.99	10.41777	18.83735	5.391243	6.660602	22.01712	17.99611	8.470898	74.86813	0	0	0.10566	0
6.4	2500	1577.936876	2500	1573.481394	80.99175	12.64009	72.0322	152.1842	19474.3	10.41777	18.83735	5.391243	6.668841	22.04436	18.06931	8.483638	74.86813	0	0	0.105791	0
6.45	2500	1578.08808	2500	1573.632599	80.99949	12.64047	72.0322	152.1987	19475.07	10.41777	18.83735	5.391243	6.669479	22.04647	18.06931	8.485008	74.86813	0	0	0.105802	0
6.5	2500	1578.239286	2500	1573.783805	81.00723	12.64085	72.0322	152.2133	19475.84	10.41777	18.83735	5.391243	6.670116	22.04857	18.06931	8.486378	74.86813	0	0	0.105812	0
6.55	2500	1578.390492	2500	1573.935011	81.01497	12.64123	72.0322	152.2278	19476.62	10.41777	18.83735	5.391243	6.670753	22.05068	18.06931	8.487748	74.86813	0	0	0.105823	0
6.6	2500	1578.541699	2500	1574.086218	81.02271	13.77944	76.44733	152.2424	20129.36	11.68442	18.83735	6.061421	6.671391	22.05279	18.06931	9.039779	74.93339	0	0	0.105833	0
6.65	2500	1578.692906	2500	1574.237425	81.03045	13.77982	76.44733	152.2569	20130.13	11.68442	18.83735	6.061421	6.672028	22.05489	18.06931	9.041149	74.93339	0	0	0.105844	0
6.7	2500	1578.844114	2500	1574.388634	81.03819	13.7802	76.44733	152.2715	20130.9	11.68442	18.83735	6.061421	6.672665	22.057	18.06931	9.042519	74.93339	0	0	0.105854	0
6.75	2500	1578.995323	2500	1574.539843	81.04593	13.78058	76.44733	152.286	20131.68	11.68442	18.83735	6.061421	6.673303	22.05911	18.06931	9.043889	74.93339	0	0	0.105865	0
6.8	2500	1579.146533	2500	1574.691053	81.05367	13.78096	76.44733	152.3005	20132.45	11.68442	18.83735	6.061421	6.67394	22.06121	18.06931	9.045259	74.93339	0	0	0.105875	0
6.85	2500	1579.297743	2500	1574.842263	81.06141	13.78134	76.44733	152.3151	20133.22	11.68442	18.83735	6.061421	6.674577	22.06332	18.06931	9.046629	74.93339	0	0	0.105885	0
6.9	2500	1579.448954	2500	1574.993474	81.06915	13.78172	76.44733	152.3296	20134	11.68442	18.83735	6.061421	6.675215	22.06543	18.06931	9.047999	74.93339	0	0	0.105896	0
6.95	2500	1579.600166	2500	1575.144686	81.07689	13.7821	76.44733	152.3442	20134.77	11.68442	18.83735	6.061421	6.675852	22.06753	18.06931	9.049369	74.93339	0	0	0.105906	0
7	2500	1579.751379	2500	1575.295899	81.08463	13.78248	76.44733	152.3587	20135.55	11.68442	18.83735	6.061421	6.676489	22.06964	18.06931	9.050739	74.93339	0	0	0.105917	0
7.05	2500	1579.902592	2500	1575.447112	81.09237	13.78286	76.44733	152.3733	20136.32	11.68442	18.83735	6.061421	6.677127	22.07175	18.06931	9.052109	74.93339	0	0	0.105927	0
7.1	2500	1837.274587	2500	1832.816905	94.26688	14.26588	82.1623	177.1283	22243.91	11.68442	18.83735	6.061421	7.761913	25.65759	18.06931	9.690279	87.2575	0	0	0.123176	0
7.15	2500	1837.425802	2500	1832.968119	94.27462	14.26626	82.1623	177.1428	22244.68	11.68442	18.83735	6.061421	7.76255	25.6597	18.06931	9.691649	87.2575	0	0	0.123187	0
7.2	2500	1837.577017	2500	1833.119335	94.28236	14.26664	82.1623	177.1574	22245.45	11.68442	18.83735	6.061421	7.763187	25.6618	18.06931	9.693019	87.2575	0	0	0.123197	0
7.25	2500	1837.728234	2500	1833.270551	94.29011	14.26702	82.1623	177.1719	22246.23	11.68442	18.83735	6.061421	7.763825	25.66391	18.06931	9.694389	87.2575	0	0	0.123207	0
7.3	2500	1837.87945	2500	1833.421768	94.29785	14.2674	82.1623	177.1865	22247	11.68442	18.83735	6.061421	7.764462	25.66602	18.06931	9.695759	87.2575	0	0	0.123218	0
7.35	2500	1838.030668	2500	1833.572986	94.30559	14.26778	82.1623	177.201	22247.77	11.68442	18.83735	6.061421	7.7651	25.66812	18.06931	9.697129	87.2575	0	0	0.123228	0
7.4	2500	1838.181886	2500	1833.724204	94.31333	15.40599	86.57742	177.2156	22900.51	12.95108	18.83735	6.7316	7.765737	25.67023	18.06931	10.24916	87.32276	0	0	0.123239	0
7.45	2500	1838.333105	2500	1833.875423	94.32107	15.40637	86.57742	177.2301	22901.29	12.95108	18.83735	6.7316	7.766374	25.67234	18.06931	10.25053	87.32276	0	0	0.123249	0
7.5	2500	1838.484325	2500	1834.026643	94.32881	15.40675	86.57742	177.2446	22902.06	12.95108	18.83735	6.7316	7.767012	25.67444	18.06931	10.2519	87.32276	0	0	0.12326	0
7.55	2500	1838.635545	2500	1834.177864	94.33655	15.40713	86.57742	177.2592	22902.83	12.95108	18.83735	6.7316	7.767649	25.67655	18.06931	10.25327	87.32276	0	0	0.12327	0
7.6	2500	1838.786767	2500	1834.329085	94.34429	15.40751	86.57742	177.2737	22903.61	12.95108	18.83735	6.7316	7.768286	25.67866	18.06931	10.25464	87.32276	0	0	0.123281	0
7.65	2500	1838.937988	2500	1834.480307	94.35203	15.40789	86.57742	177.2883	22904.38	12.95108	18.83735	6.7316	7.768924	25.68076	18.06931	10.25601	87.32276	0	0	0.123291	0
7.7	2500	1840.892832	2500	1836.435135	94.4521	15.40826	86.57742	177.4763	22918.68	12.95108	18.83735	6.7316	7.777163	25.708	18.14251	10.26875	87.32276	0	0	0.123422	0
7.75	2500	1841.044055	2500	1836.586358	94.45984	15.40864	86.57742	177.4908	22919.46	12.95108	18.83735	6.7316	7.777801	25.71011	18.14251	10.27012	87.32276	0	0	0.123433	0
7.8	2500	1841.195279	2500	1836.737582	94.46758	15.40902	86.57742	177.5054	22920.23	12.95108	18.83735	6.7316	7.778438	25.71221	18.14251	10.27149	87.32276	0	0	0.123443	0
7.85	2500	1841.346504	2500	1836.888807	94.47532	15.4094	86.57742	177.5199	22921	12.95108	18.83735	6.7316	7.779075	25.71432	18.14251	10.27286	87.32276	0	0	0.123454	0
7.9	2500	1841.497729	2500	1837.040033	94.48306	15.40978	86.57742	177.5345	22921.78	12.95108	18.83735	6.7316	7.779713	25.71643	18.14251	10.27423	87.32276	0	0	0.123464	0
7.95	2500	1841.648955	2500	1837.191259	94.4908	15.41016	86.57742	177.549	22922.55	12.95108	18.83735	6.7316	7.78035	25.71853	18.14251	10.2756	87.32276	0	0	0.123475	0
8	2500	1841.800182	2500	1837.342486	94.49854	15.41054	86.57742	177.5636	22923.32	12.95108	18.83735	6.7316	7.780987	25.72064	18.14251	10.27697	87.32276	0	0	0.123485	0

SuperPro Results

- 2000L
  - –2.5CV ProA Elution
  - –Raw materials (RM) $ per gram is for one run

	Protein Titer	Process Time	Protein A Size	ProA Cycles	CEX Size	CEX Cycles	kg of Buffer	SUM A	SUM B	SUM C	SUM D1	SUM D2	SUM E
Small	2.0-3.0	98h - 125h	10L	8-12	10L	7-9	6,322-9,203	2500L	500L	500L	1000L	1000L	1000L
Medium	3.0-5.0	76h - 106h	20L	6-10	20L	5-8	9,143-15,023	2500L	500L	1000L	2500L	2500L	2500L
Large	5.0-8.0	86h - 110h	32L	7-10	32L	5-8	17,113-23,534	2500L	1000L	1000L	2500L	2500L	2500L

FDB Modeling Outputs: Process Volume

- SuperPro model provides process volumes for given mAb throughput
- Process volumes drive mixer sizes and PFD defines options needed (cooling, pH control etc)

Titer (g/L)	SUM A	SUM B	SUM C	SUM D	SUM E	SUM F	DS Fill Tank
2	2500	200	200	1000	1000	1000	200L
2.5	2500	200	200	1000	1000	1000	200L
3	2500	500	500	1000*	1000*	1000	200L
3.5	2500	500	500	1000*	1000*	1000	200L
4	2500	500	500	1000*	1000*	1000	200L
4.5	2500	500	500	1000*	1000*	1000	200L
5	2500	1000	1000	2500	2500	1000	200L
6	2500	1000	1000	2500	2500	1000	200L
7	2500	1000	1000	2500	2500	1000	200L
8	2500	1000	1000	2500	2500	1000	200L

SUM A – Harvest Collection
SUM B – 1st SUM in Viral Inactivation
SUM C – 2nd SUM in Viral Inactivation
Note: Use 500L tote(s) to collect VI filtrate/CEX load

SUM D – CEX Eluate/AEX Load
SUM E – AEX Eluate
SUM F – TFF load surge tank

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Raw Materials Cost per Gram

- Preliminary data plot removed

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Process Design Results

- Created a simulation of the mAb platform over a range of 2g/L to 8g/L
- This model facilitated equipment definition and allowed operational strategies and process schedules to be defined
- This model is used to quickly fit processes coming from internal Process Development, or transferred in from sponsors
- We are achieving our dream of standard small, medium and large downstream BOMs

FUJIFILM Diosynth biotechnologies

Creating biomanufacturing capacity

A global partnership

FUJIFILM Diosynth biotechnologies

Driven by the industry need for cGMP mammalian cell culture biomanufacturing capacity

Four successful capacity expansion projects on two continents

Creating the UK's first fully single-use biomanufacturing facility

2013

1000 L project

- Single-use WAVE Bioreactor™ systems
- Xcellerex™ XDR cell culture suite
- ÄKTA™ready and ReadyToProcess™ prepacked columns

Billingham, UK

2012

1000 L project

- Xcellerex single-use mixers
- Xcellerex XDR cell culture suite
- ÄKTAready purification system

Research Triangle Park, US

2014

2000 L project

- Xcellerex XDR 2000L bioreactor added

Research Triangle Park, US

2015

2000 L project

- Xcellerex XDR 2000L bioreactor added

Billingham, UK

Ongoing partnership

2017 **2018** **2019**

Your Biologics and Vaccines Partner of Choice