2024 GAS LIFT WORKSHOP

Erosion Testing of Gas Lift Check Valves for Unconventional Applications

ExxonMobil

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ELC ENERGY · ENDURANCE LIFT SOLUTIONS · Flowco Production Solutions · MAKO LIFT · Weatherford

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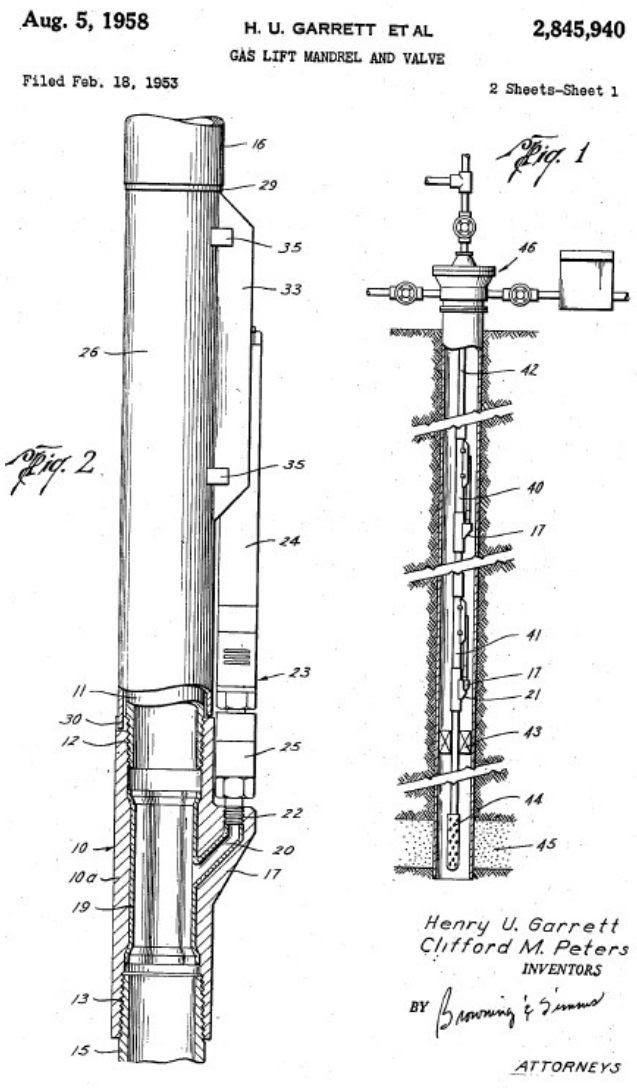
Outline

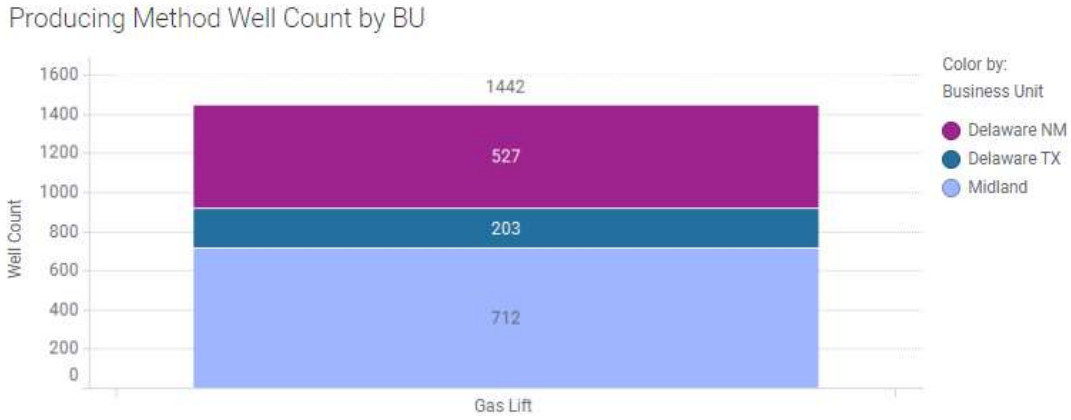
- Background
- API 19G2 Check Testing
- Test Plan
- Flow Loop
- Water Results
- Sand Results
- Summary / Next Steps


Aug. 5, 1958 H. U. GARRETT ET AL 2,845,940
GAS LIFT MANDREL AND VALVE
Filed Feb. 18, 1953 2 Sheets-Sheet 1
Fig. 2
Fig. 1
Henry U. Garrett
Clifford M. Peters
INVENTORS
BY Browning & Simmons
ATTORNEYS

Background

Conventional GLVs

- Over 1400 ExxonMobil Permian wells are on GL
- Majority of installations have conventional mandrels with 1” GLVs (thanks to 5.5” casing)
- A common cause of tubing-annulus communication is failed reverse-flow check valves
- Tubing pulls can be costly, especially if the production packer doesn’t release
- So, just clean up the fluids, right?



Background

Fracturing

- Unconventional wells are hydraulically fractured with > 2500 lb proppant / lateral ft
- That's > 13 million lb / mile, enough to fill 2 US football fields 1ft high…most laterals are > 2 miles!
- Some sand will remain in the well and more will be produced—is removing it all a feasible goal?
- No matter how clean your unloading fluids are, 100-mesh sand can and will find the GLVs
- Annular- / tubular-flow GL swaps do not help
- So, the GLV checks must be able to resist solids

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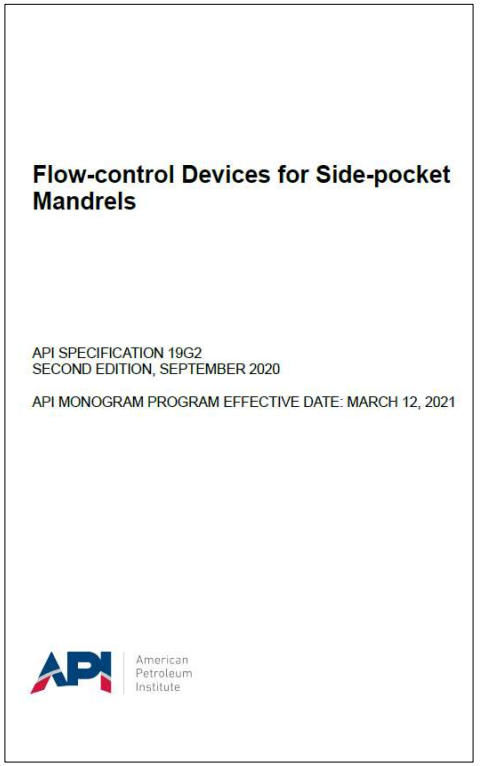
API SPEC 19G2 Check Testing

19G2 = Flow-Control Devices for Side-Pocket Mandrels

- API Specification for GLVs used in SPMs (1st ed., Jun 2010)
- SPMs initially developed when GL went offshore in the 1960s+
- Various Validation (V), Functional (F), and Quality (Q) grades
- Commonly specified for offshore GL (EM East Canada and Indonesia, recently)

Annex K.3 = Reverse-Flow Check Erosion Test

- Liquid tests for retrievable GLV checks (gas testing also required in Annex H)
- V2/V1 Test: 1 bbl/min for 400 bbl of **fresh water**
- Passing Criteria
  - "No pressure drop over a 1 min hold-period"
  - "~~No damage to the back-check valve~~, and the dart should move freely from open to closed position and from closed to open position without human intervention"



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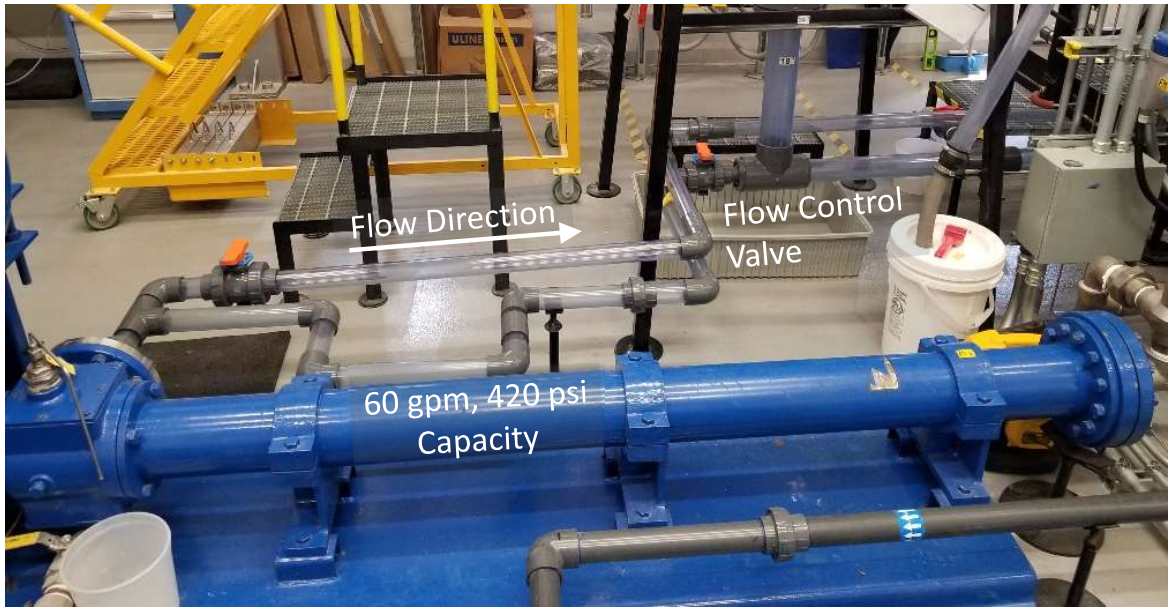
Water? How About Some Sand for Fun…



- Goal is 1% (by weight) sand erosion testing at 1 bbl/min for 400 bbl
- Attempted 0.5 bbl/min for “easier” test, but found that sand dropped out of solution
- Minimum injection rate for suspension is 0.6 bbl/min
- 70/100 mesh sand replaced every few runs to ensure angularity

Test Plan

1. Chattering
- Test with air at low dp to determine whether the check chatters
- Informational test – haven't noticed chatter, yet

2. Water "Erosion"
- 400 bbl water at 1 bbl/min
- Reverse-flow seal tests every 100 bbl, if it passes all 4, then

3. Sand Erosion, Low Rate
- 400 bbl water with 1% sand at 0.6 bbl/min
- Seal tests every 100 bbl, if it passes all 4, then

4. Sand Erosion, High Rate
- 400 bbl water with 1% sand at 1 bbl/min
- Seal tests every 100 bbl, if it passes all 4, then it's done!

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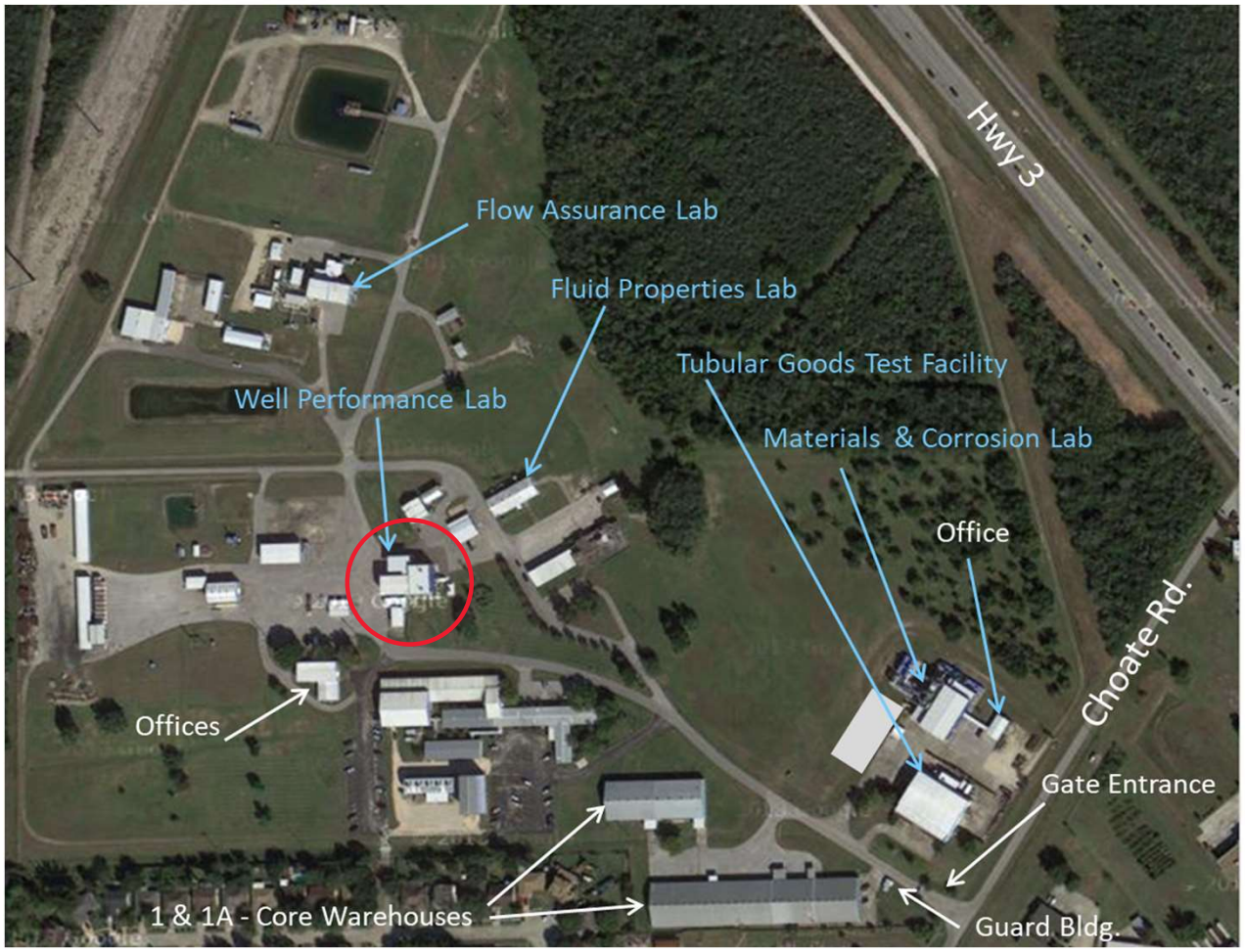
EMTEC Friendswood Testing Facility



NASA
15 min.

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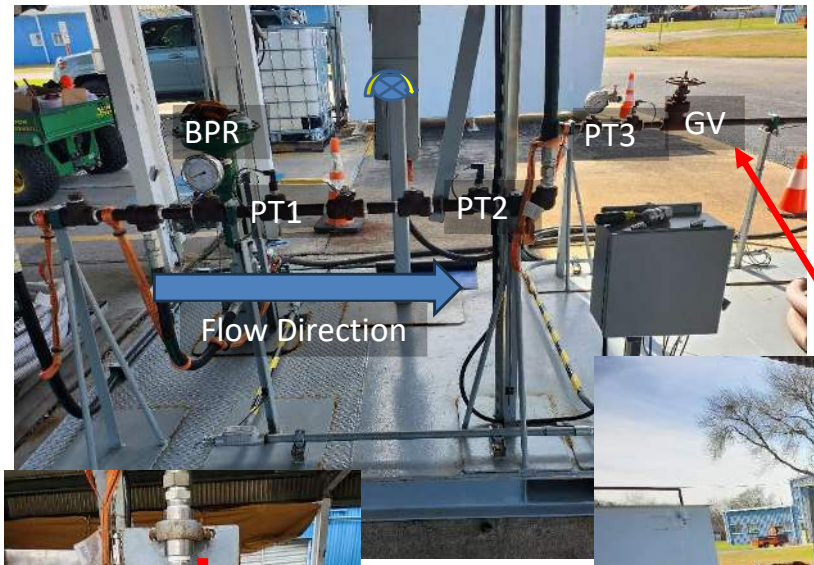
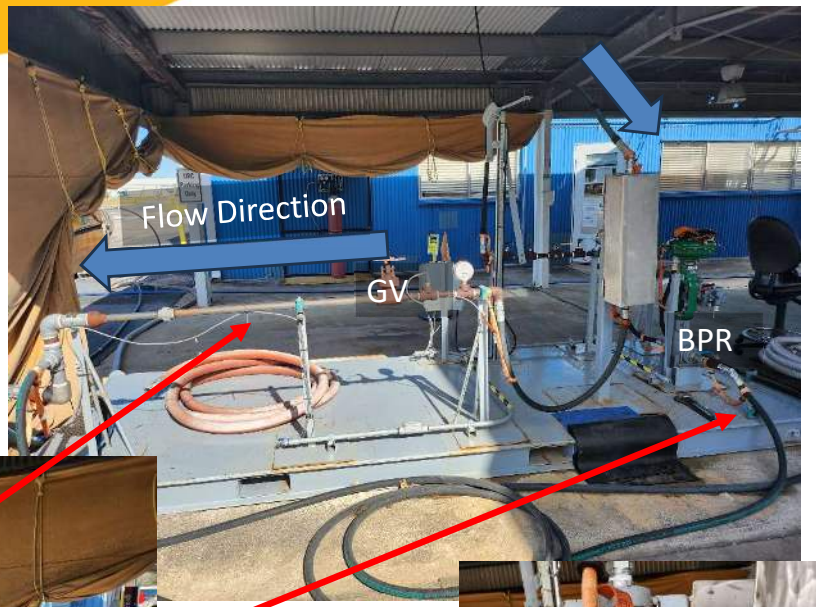
Back

Back

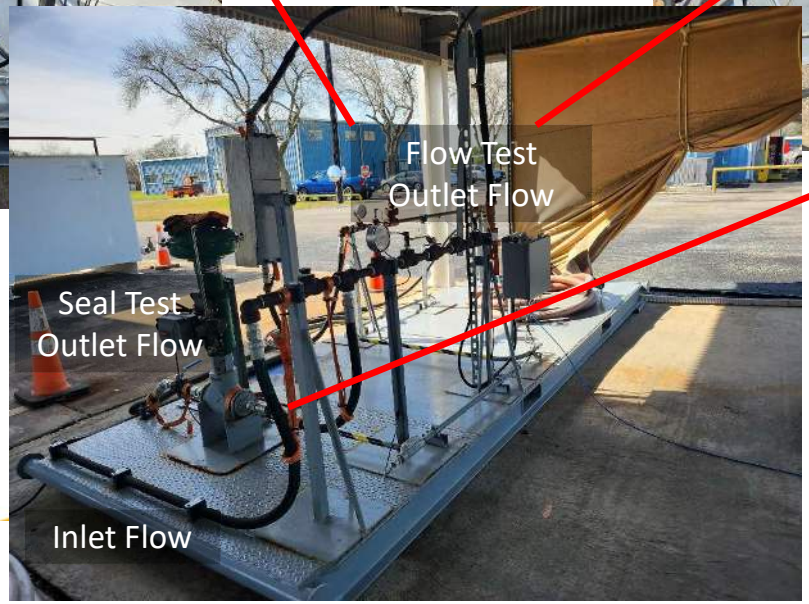
Front

Flow Loop





GLV Test Skid



Flow Test
Flow Into
Dart Tip

Seal Test
Flow Into
Spring

Model **B.A**

Water "Erosion" Results

What "good" looks like…

PT2 and PT3 do not equalize during the seal test

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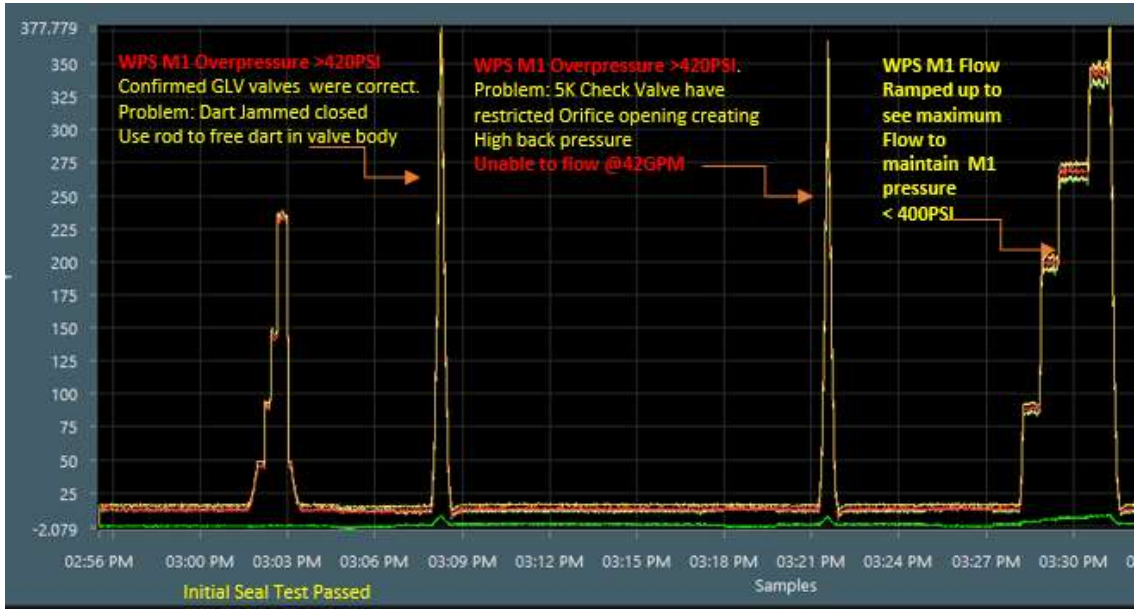
Water "Erosion" Results

Other failure had a "unique" sealing design, improvements identified

Make	Model	Size	Change	Assembly	Rnd	Date	Water
A	A.0	1	-	Single	1	Jul-23	Yes
	A.1	1	Coating	Single		Jul-23	Yes
	A.2	1	Coating	Single		Jul-23	Yes
	A.0	1	-	Dual		Jul-23	-
	A.1	1	Coating	Dual		Jul-23	-
	A.2	1	Coating	Dual		Jul-23	-
B	A	1	-	Single	1	Mar-23	Yes
	B	1	Materials	Single	2	Aug-23	Yes
	C	1	Geometry	Single	3	Feb-24	Yes
	D	1	Geometry	Single		Feb-24	Yes
	E	1	Geometry	Single		Feb-24	No
C	A	1	-	Single	1	Mar-23	No
	B	1	Pressure	Single		Mar-23	Yes
	C	1	Geometry	Single		Mar-23	Yes
D	A.0	1	-	Single	1	Nov-23	Yes
	A.1	1	Coating	Single		Nov-23	Yes
	A.0	1.5	-	Single		Nov-23	Yes
E	A	1	-	Single	1	Feb-23	Yes
	B	1	Geometry	Single	2	Jul-23	Yes
	B	1.5	Geometry	Single		Aug-23	Yes

Model **C.A**



5K(psi) check dart jammed in the body and had to be punched out, some had missing/broken springs. All others tested were 10K

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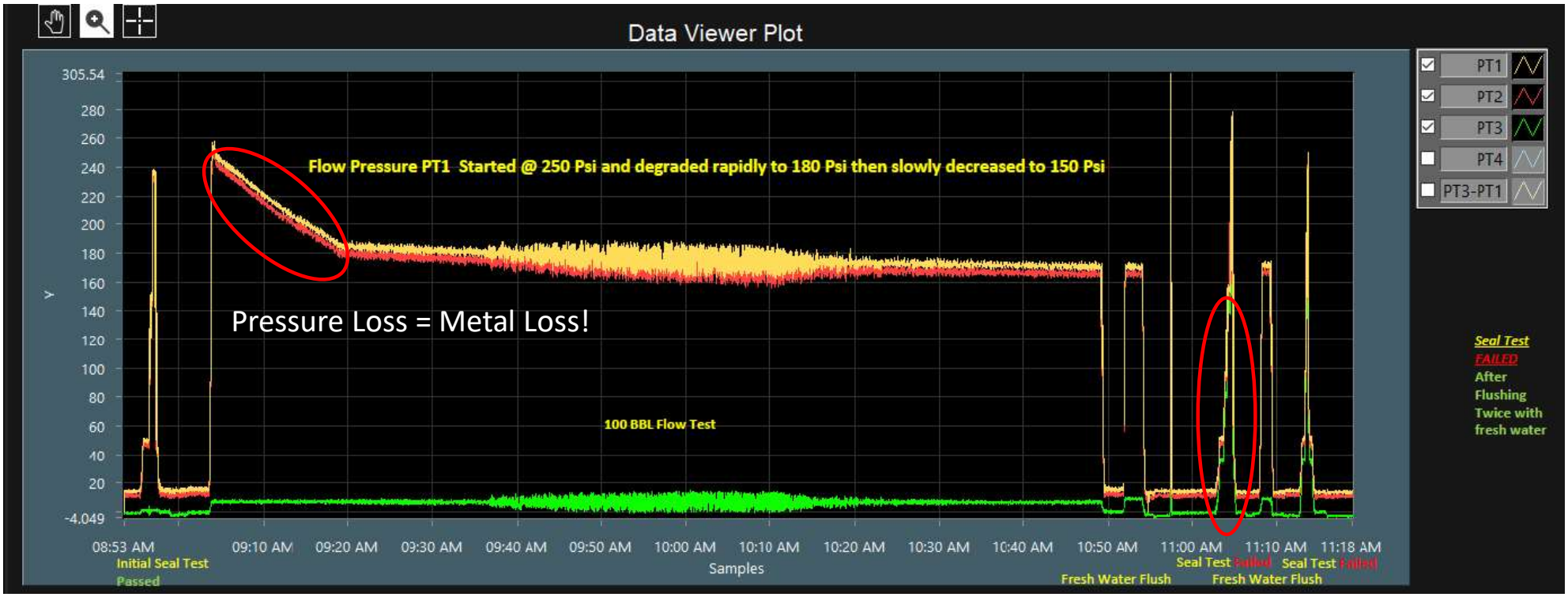
Model **E.A**

Sand Erosion Results

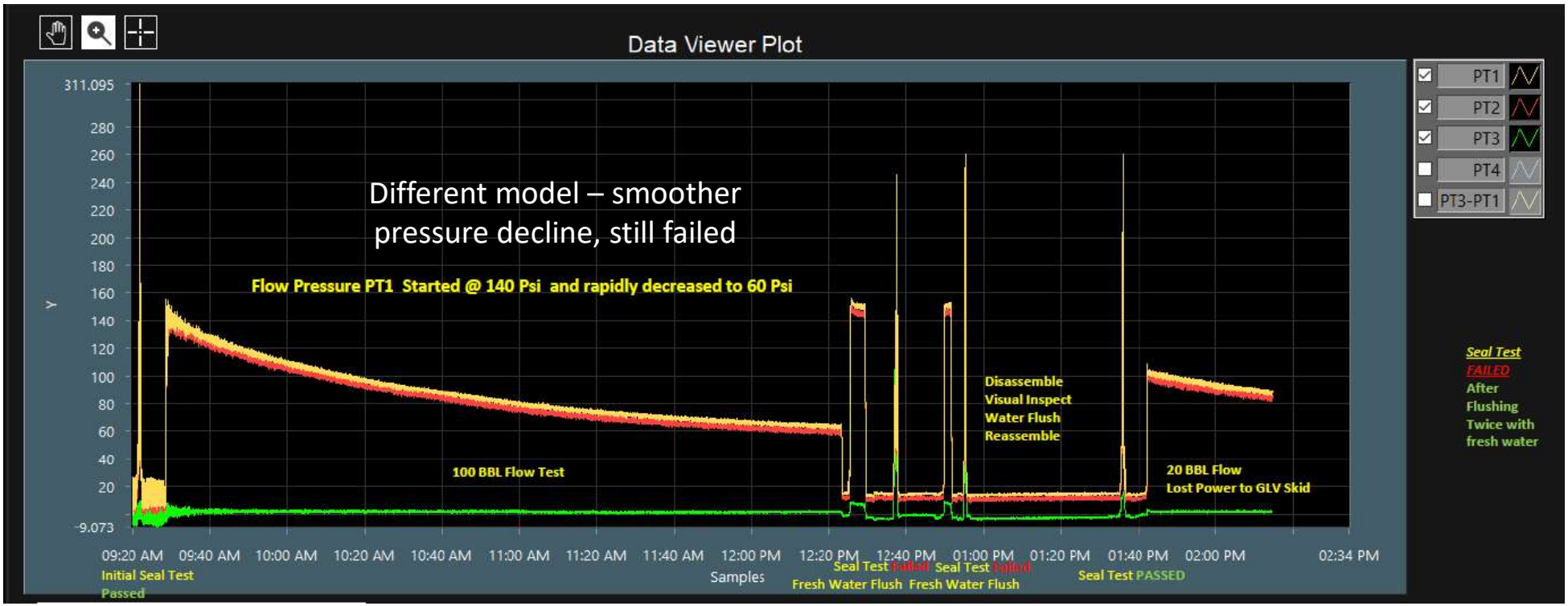
What wear looks like (1 bpm)…



PT2 = PT3 = No Seal

Sand Erosion Results

Model **B.A**



Sand Erosion Results – Not Passing

Make	Model	Size	Change	Assembly	Rnd	Date	Water	Pass? Sand 0.6	Sand 1.0
A	A.0	1.0	-	Single	1	Jul-23	Yes	No	-
	A.1	1.0	Coating	Single		Jul-23	Yes	No	-
	A.2	1.0	Coating	Single		Jul-23	Yes	No	-
	A.0	1.0	-	Dual		Jul-23	-	No	-
	A.1	1.0	Coating	Dual		Jul-23	-	No	-
	A.2	1.0	Coating	Dual		Jul-23	-	No	-
B	A	1.0	-	Single	1	Mar-23	Yes	No	-
	B	1.0	Materials	Single	2	Aug-23	Yes	No	-
	C	1.0	Geometry	Single	3	Feb-24	Yes	No	-
	D	1.0	Geometry	Single		Feb-24	Yes	Yes	No
	E	1.0	Geometry	Single		Feb-24	No	-	-
C	A	1.0	-	Single	1	Mar-23	No	-	-
	B	1.0	Pressure	Single		Mar-23	Yes	No	-
	C	1.0	Geometry	Single		Mar-23	Yes	No	-
D	A.0	1.0	-	Single	1	Nov-23	Yes	No	-
	A.1	1.0	Coating	Single		Nov-23	Yes	No	-
	A.0	1.5	-	Single		Nov-23	Yes	Yes	-
E	A	1.0	-	Single	1	Feb-23	Yes	No	-
	B	1.0	Geometry	Single	2	Jul-23	Yes	No	-
	B	1.5	Geometry	Single		Aug-23	Yes	Yes	Yes

General

- No seal after flushing = failure
- Sealing after punching free still = failure
- Failure modes mimicked those seen in equipment pulled from the field
- Dual checks did not solve the problem

Failure Modes

- Eroded/cut sealing faces
- Broken/missing springs
- Solids sticking (holding open)
- Bored/fluted flow paths
- Cascading debris

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Sand Erosion Results

Note check housing “fluting” in line with the flow ports; results shown at 0.6 bpm unless specified otherwise

Check Valve Assembly

Valve Housing

Dart & Washer Assembly

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Sand Erosion Results

Note dart erosion, polishing/wear and "unsticking" punch

Valve Seal Housing Assembly

Valve Body without Seal after 200BBL Erosion Test

Valve Body with Seal

Bottom Housing Assembly

Valve Housing Eroded

Inlet Top Housing

Polished Opening Eroded ~0.156"

Dart & Seal Assembly

Seat Pad Assembly

Seal Pad Eroded Pattern at Dart Tip

Dart After & Before 200BBL Erosion Test

Punch Set Used to Free the Dart then Flush Assembly
Before Seal Integrity Test

Sand Erosion Results

Broken / missing springs
in after/before photos

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Sand Erosion Results

Dart & Washer Assembly

Seal Pad and Washer Worn After 400 BBL

After & Before 400 BBL

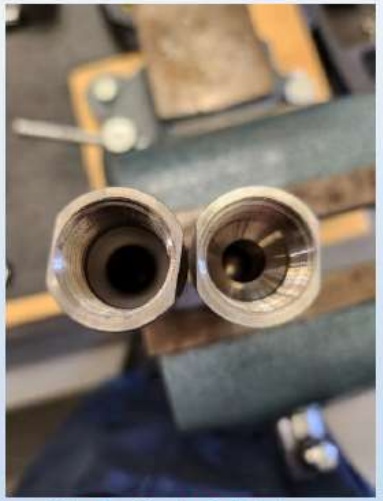
Check Valve Assembly

Dart Tip Erosion

After & Before 400 BBL

Check Valve Assembly After 400 BBL

Valve Housing



Valve Top Housing Polished

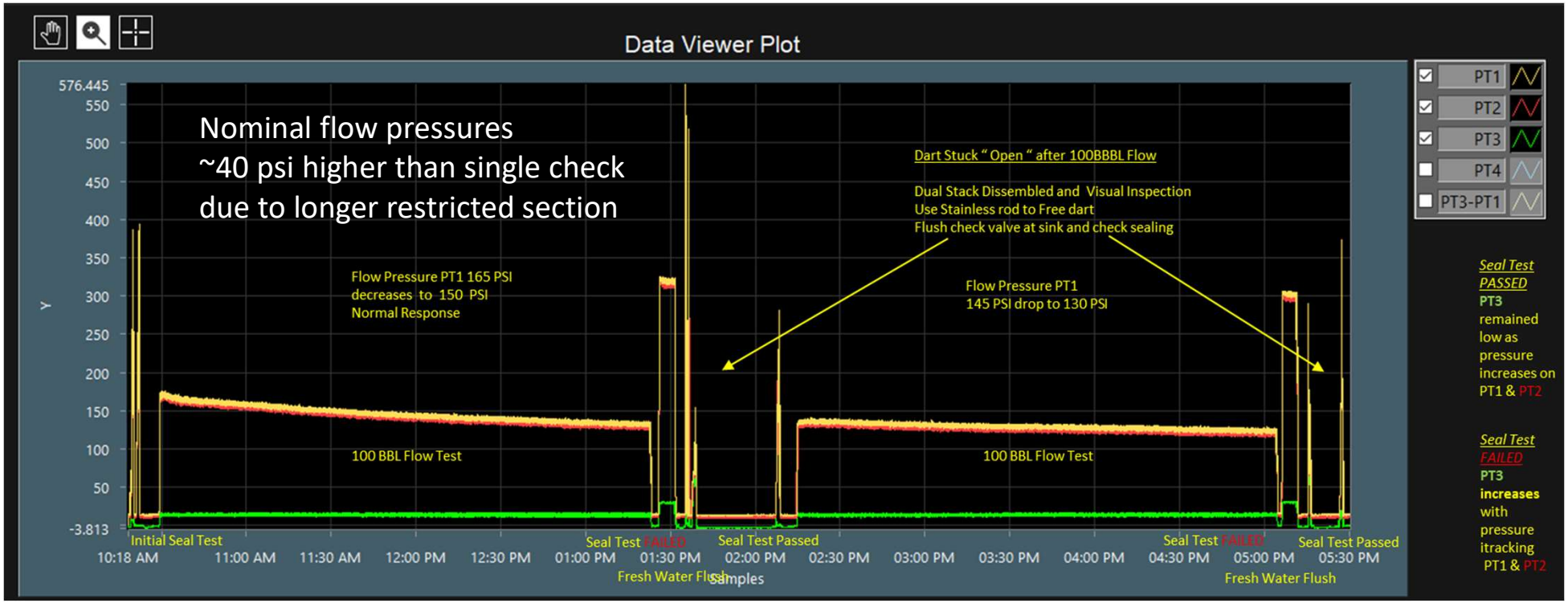
Note seal face changing from a sphere to a cone

After 400 BBL 1% Sand Erosion

Model **A.A.0**

Sand Erosion Results – Dual Checks

If one is good, then two are better, right?



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Sand Erosion Results – Dual Checks

- Higher injection pressure at same rate appears to have destroyed check springs more quickly
- Dual checks failed seal testing 200 bbl **earlier** (sticking) than a single check
- Broken upper spring parts could interfere with lower check
- Dual checks are not better than single for erosion resistance
- However, dual checks may still offer sealing redundancy if **fluids are clean**

Sand Erosion Results – Passing

							Pass?		
Make	Model	Size	Change	Assembly	Rnd	Date	Water	Sand 0.6	Sand 1.0
A	A.0	1	-	Single	1	Jul-23	Yes	No	-
	A.1	1	Coating	Single		Jul-23	Yes	No	-
	A.2	1	Coating	Single		Jul-23	Yes	No	-
	A.0	1	-	Dual		Jul-23	-	No	-
	A.1	1	Coating	Dual		Jul-23	-	No	-
	A.2	1	Coating	Dual		Jul-23	-	No	-
B	A	1	-	Single	1	Mar-23	Yes	No	-
	B	1	Materials	Single	2	Aug-23	Yes	No	-
	C	1	Geometry	Single		Feb-24	Yes	No	-
	D	1	Geometry	Single	3	Feb-24	Yes	Yes	No
	E	1	Geometry	Single		Feb-24	No	-	-
C	A	1	-	Single	1	Mar-23	No	-	-
	B	1	Pressure	Single		Mar-23	Yes	No	-
	C	1	Geometry	Single		Mar-23	Yes	No	-
D	A.0	1	-	Single	1	Nov-23	Yes	No	-
	A.1	1	Coating	Single		Nov-23	Yes	No	-
	A.0	1.5	-	Single		Nov-23	Yes	Yes	-
E	A	1	-	Single	1	Feb-23	Yes	No	-
	B	1	Geometry	Single	2	Jul-23	Yes	No	-
	B	1.5	Geometry	Single		Aug-23	Yes	Yes	Yes

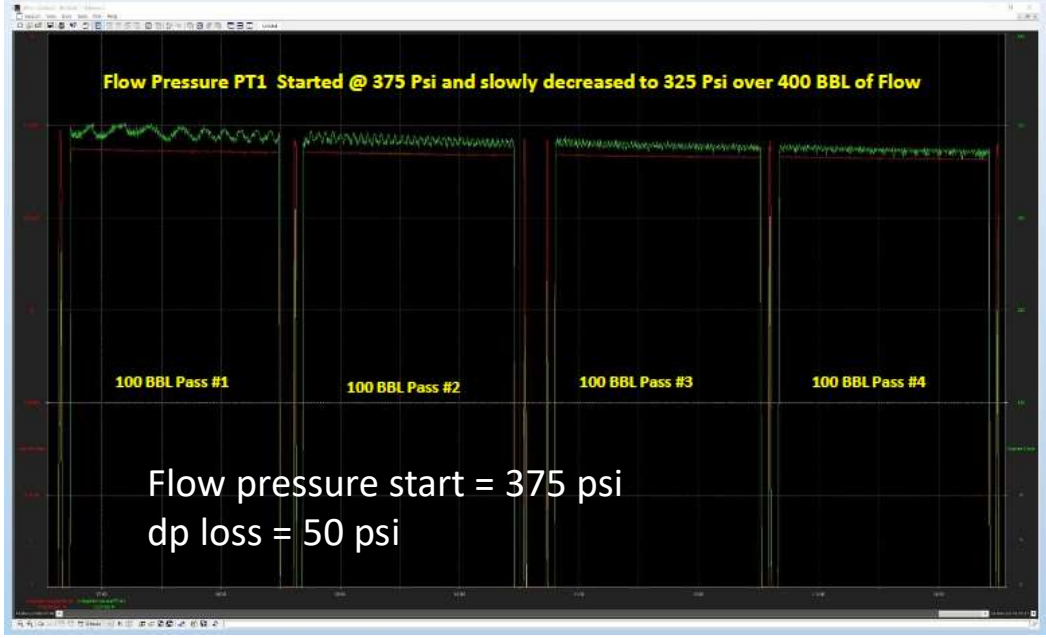
Success…partially

- 3 passed the 0.6 bbl/min test, but…
- Two were 1.5” checks!
- These were “bonus” tests – but they did show something interesting
- More on the 1.0” check later…

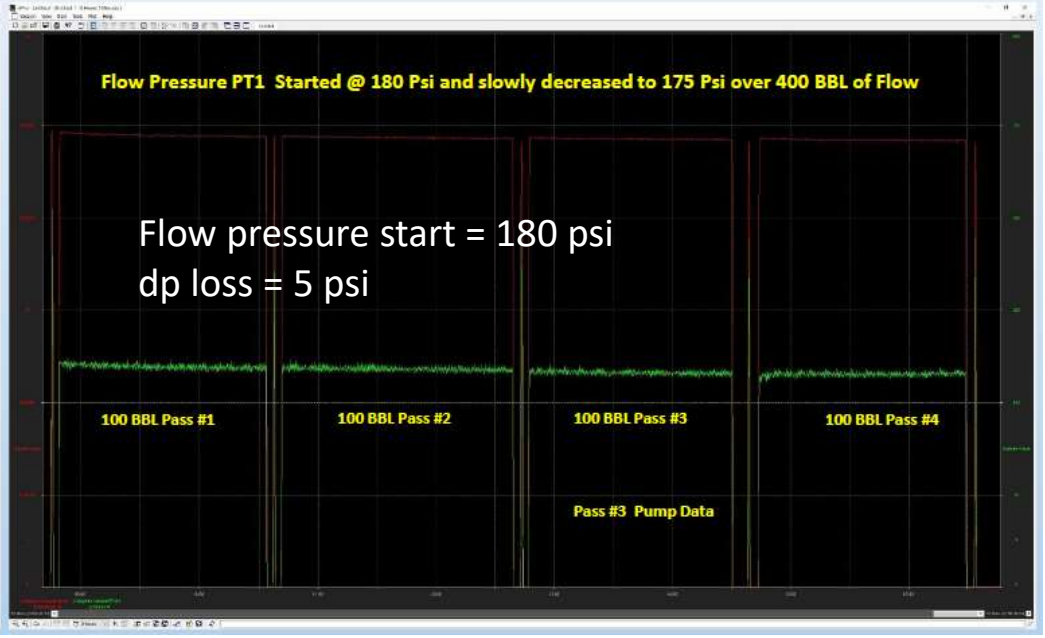
1.5” GLVs in EM Bakken 7” csg. have had minimal solids-related issues

Water Testing – 1” vs. 1.5” Checks, 1.0 bbl/min

1” Model **D.A.0**



1.5” Model **D.A.0**



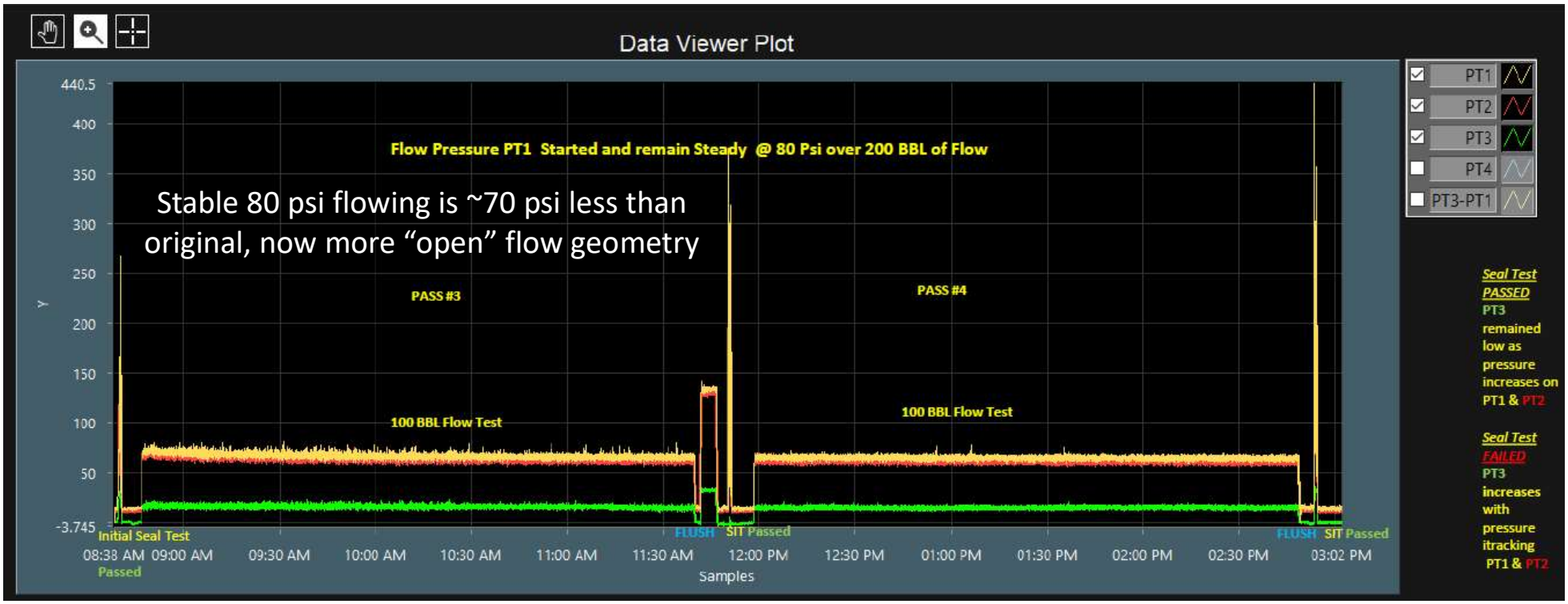
0.32” ID = **167.5 ft/s**

Smaller flow path = **2.5x** higher velocity = More severe erosion!

0.50” ID = **68.6 ft/s**

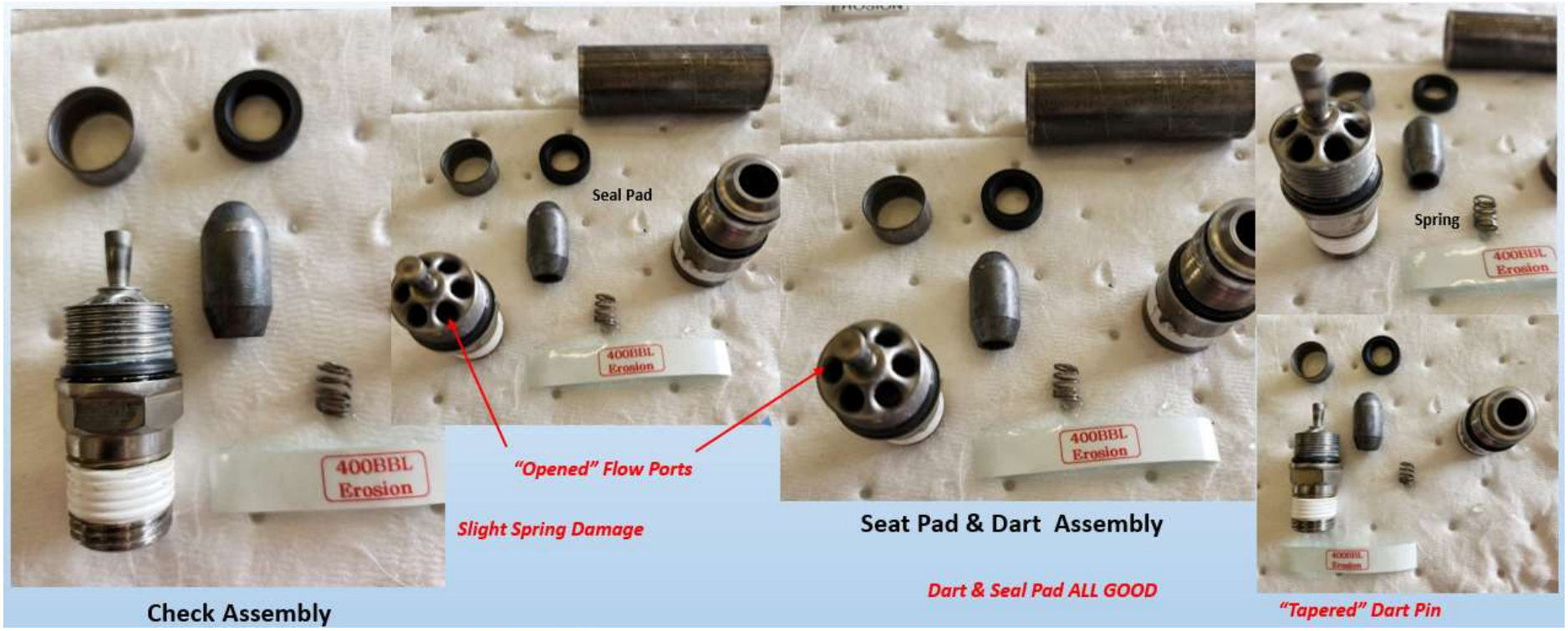
Sand Erosion Results – 1” Passing at 0.6 bbl/min

Model **B.D**



No need to punch the dart free between passes!

Sand Erosion Results – 1” Passing at 0.6 bbl/min



Worn, but functional. Improved materials, shielded spring

Model **B.D**

Sand Erosion Results – 1” Almost at 1.0 bbl/min

Component debris led to housing failure following 300 bbl check

Sand Erosion Results – 1” Almost at 1.0 bbl/min

- Flow ports worn but intact, seal pad failed
- Dart, post, and spring in good condition
- Internal blockage led to housing ID point erosion
- Almost survived…

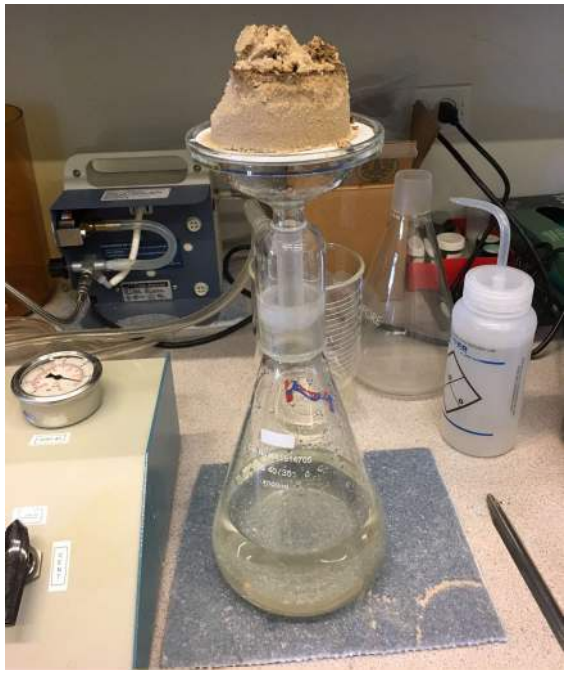
Summary and Next Steps

Summary

- Fine frac sand is difficult to remove from producers
- GLVs and API 19G2 reverse flow check testing were not designed for wells with entrained sand
- >20 checks were tested with 1% sand in a modified API procedure
- Only **one** survived the 400 bbl, 0.6 bbl/min test…so far
- 1.5” checks are more resistant to erosion, 5Ks and dual checks are not

Next Steps

- Geometry and material changes have shown the most promise, upgrades could also be applied to offshore / critical service 1.5” GLVs
- Keep improving until 1 bbl/min test is passed…or the flow loop wins!
- (Keep recommending 7” casing—1.5” GLVs and SPMs are nice)



1% wt sand content
in 5 gal of mixture

Questions?

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