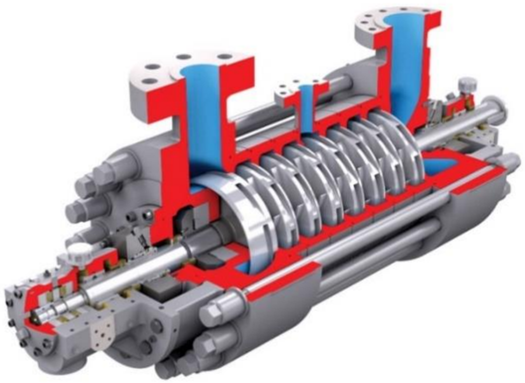
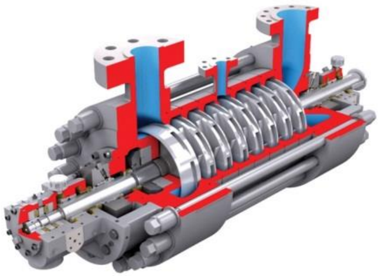
An Innovative Pipeline Sealing Solution

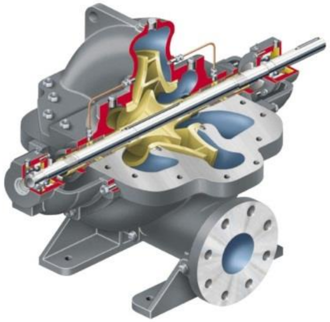
Presented By John Crane



Presenters

Presenter Name	**Raul Escontrias (North American Pipeline Manager)**
Presenter Name	**John Morton (Global Wet Seal Product Line Director - UK)**





Pipeline Application Considerations

Proper seal selection for a pipeline application must consider the combination and variation of conditions the seal will operate within:

- Specific Gravity
- Vapor pressure
- Operating pressure
- Shaft speed
- Dirt / solids
- Viscosity
- Temperature
- Equipment
- Hydrostatic flange pressure rating

Typical Design Challenges

- Multiphase Batch Operations
- Pumps in Series
- Seal Chamber Face Squareness to Shaft (horizontal split case pumps)
- High Viscosity Start-ups
- High Hydrostatic Pressure Ratings
- Remote Unmanned Pumping Stations
- Leakage Containment; no Flare or Disposal System

Pressure Limits for Mechanical Seals

API 682 defines three pressure terms relating to mechanical seals…

Static

- The highest pressure, excluding pressures encountered during hydrostatic testing, to which the seal can be subjected while the pump is shut down

Dynamic

- The highest pressure expected at the seal during any specified operating condition including start-up and shutdown
- Consideration should be given to maximum suction pressure, flush pressure, and the effect of clearance changes with the pump

MAWP

- Maximum Allowable Working Pressure
- The greatest discharge pressure at the specified pumping temperature for which the pump casing is designed

*Pressure ratings not defined by API 682

API 682 also defines the pressure casing as including the seal chamber but excluding the stationary and rotating members of the mechanical seal. This means that there is no requirement that the seal have the same maximum allowable working pressure as the pump.

Materials for Pipeline Seal

Faces and Secondary Elements

Carbon-Graphite

- Typically metal impregnated carbons (antimony or nickel)
- >900 psi g (62 bar g) requires evaluation
- Fluid limitations

Silicon Carbide

- Reaction Bonded or Self Sintered
- Extremely hard, highly wear resistant and good mechanical properties
- Exceptional PV (Pressure-Velocity) characteristics

Tungsten Carbide

- Nickel bound is most commonly used
- Extremely tough material with good wear resistance
- PV limited; susceptible to heat checking damage

Silicon Carbide / Graphite Composite

- Improved dry run survivability and thermal shock resistance
- Exceptional PV characteristics
- If pressures might exceed conventional metal-filled-carbon grade limits

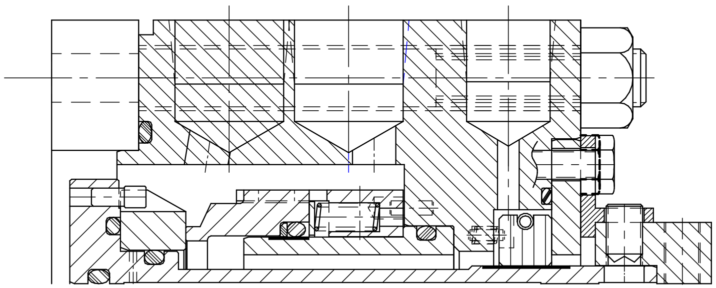
Secondary Elements

- Evaluate material compatibility by process
- >1440 psi g… higher durometer o-ring to prevent extrusion
- Special thermoplastic back-up rings and energized polymer seals

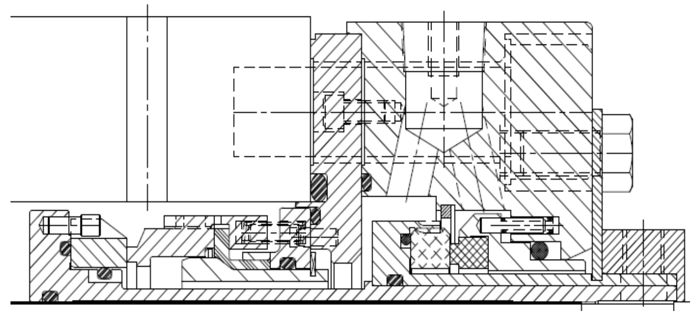
Crude Oil Applications

- Varying API gravity and viscosities
- High concentration of contaminates: sand, particulate, wax from process gathering
- Filtration and separators typically not effective
- Susceptible to hang-up and clogging
- Shuttling of pumps

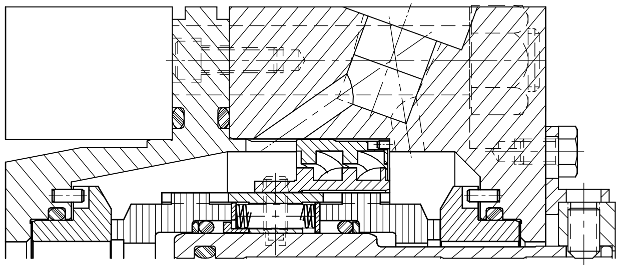
Typical Seal Arrangements



Single w/bushing



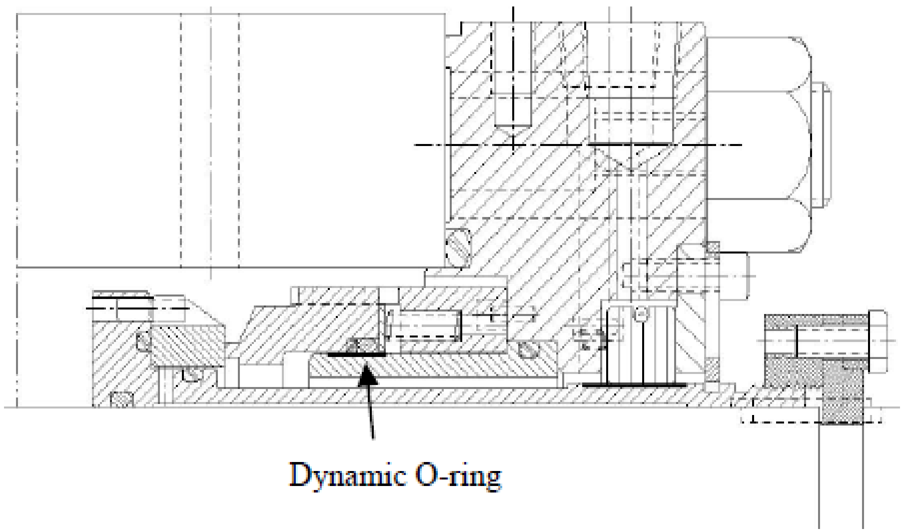
Dual Unpressurized



Dual Pressurized

Crude Oil Application

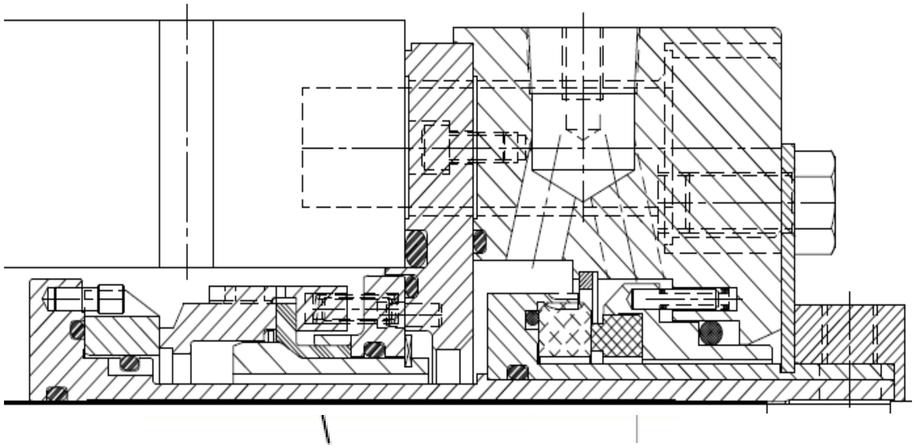
• Suction Pressure:	50/1200 psi g
• Discharge Pressure:	1480 psi g
• Temperature:	90 °F
• Speed:	790–1920 rpm
• Viscosity:	350-1000 cP
• Specific gravity:	0.83-0.93
• Vapour Pressure:	<15.0 psi a
• Pumps in series:	4
• Seal Size:	6.375”



Arrangement: 1CW-FL Type A

Crude Oil Application

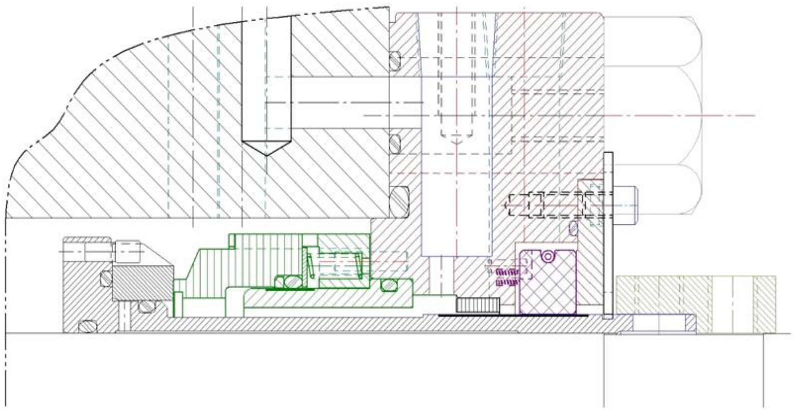
• Suction Pressure:	50/1100 psi g
• Discharge Pressure:	1440 psi g
• Temperature:	80 °F
• Speed:	900–1800 rpm
• Viscosity:	5.0-350 cP
• Specific gravity:	0.78-0.93
• Vapour Pressure:	<15 psi a
• Pumps in series:	3
• Shaft Size:	6.500”



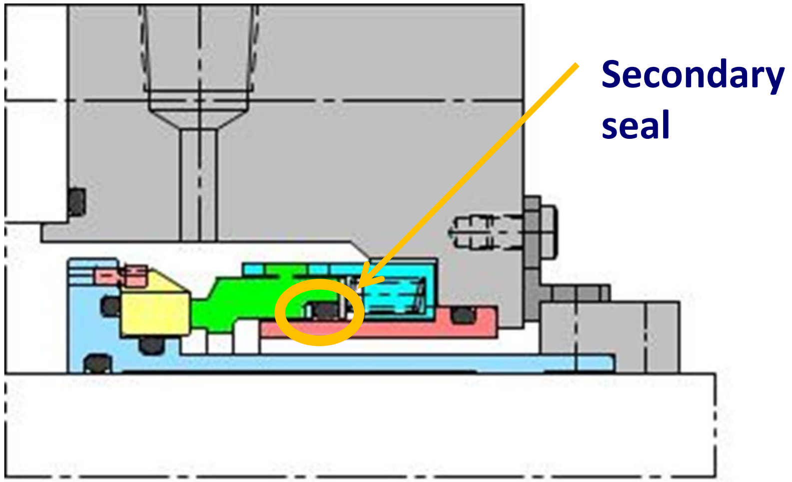
Engineered Secondary Sealing Element

Arrangement: 2CW-CS Type ES

Current technology: mechanism



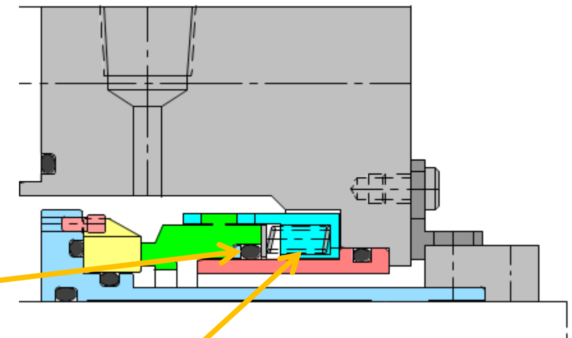
Known problem of o-ring fretting & wearing; designs based on “pusher” secondary seal concept

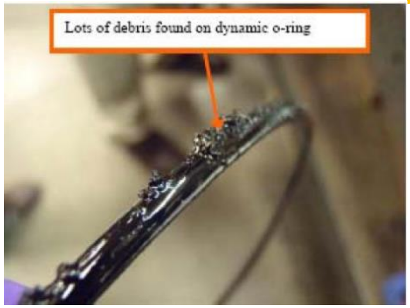


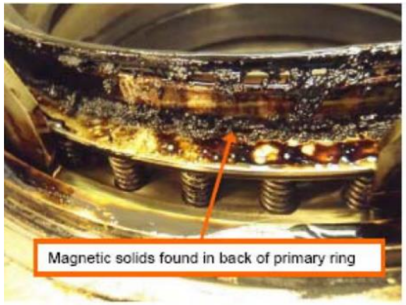
O-ring performance limits verified by feedback; repairs required to prevent primary seal failure

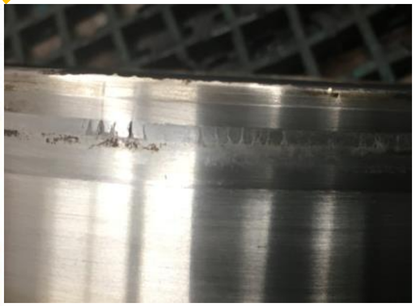
Current technology: results

- Observations point to solids & debris resulting in secondary seal damage and ultimately seal failure
- The pusher seal relies upon a dynamic O-ring and a stub-sleeve to provide sealing and flexibility
- Degradation wears the O-ring and stub sleeve making refurbishment more costly







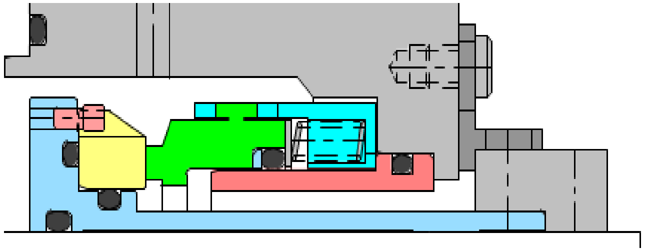


Response to typical field challenges…

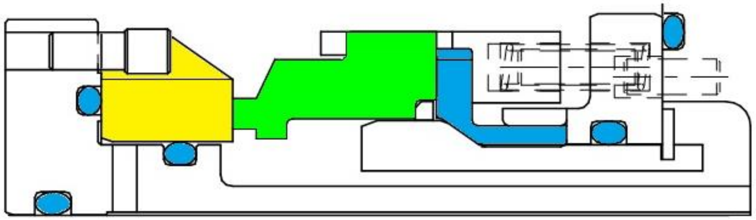
Seal vendors have looked to combat seal unreliability in many different ways. These solutions have included, but are not limited to:	Increasing the hardness value of seal faces
	Introducing lubricating regimes on seal faces
	Installation of strainers, cyclones, filters, (API piping plan 12 or 31), reverse circulation (API piping plan 13), clean flushes (API plan 32)
	Changing the dynamic secondary seal types / designs / styles / materials
	Changing the API seal configurations from a single Arrangement 1, 1CW-FX to dual unpressurised Arrangement 2, 2CW-CW or 2CW-CS, or dual pressurised Arrangement 3, 3CW-BB or 3CW-FB

New design concept

Yesterday



Today



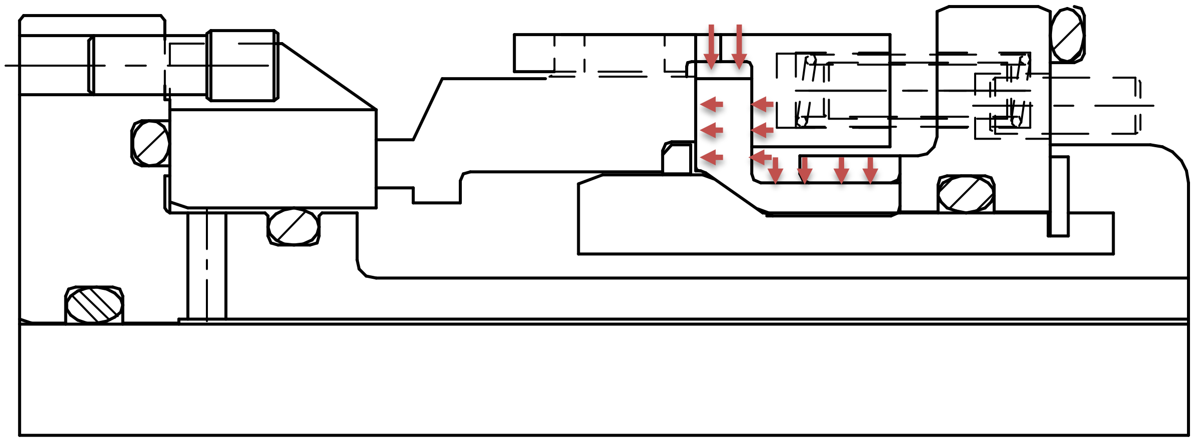
- Pusher seal design may be unreliable in dirty applications
- Solids, O-ring fretting can lead to hang-up and excessive leakage
- Fretting and hang-up can lead to stub sleeve wear and leakage

- Unique, non-pusher design eliminates need for dynamic O-ring
- Longer operational life and potentially lower cost maintenance
- Innovative design approach to extend seal life

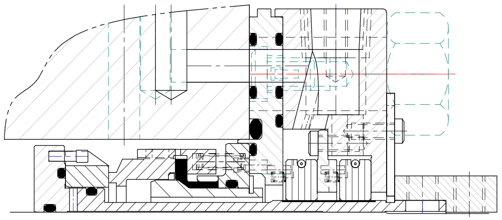
How it Works…

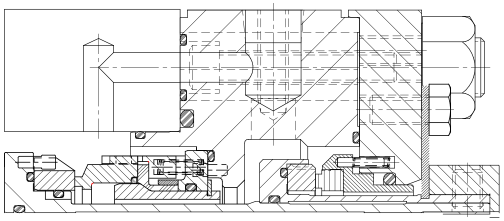
Non-Pusher Secondary Seal (NPSS) element pressure loading

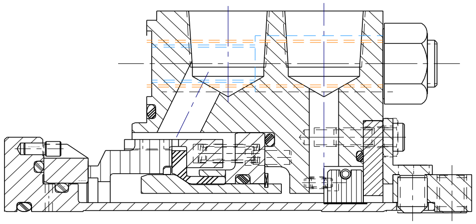
- No change in face loading
- No change in seal balance
- Flex along balance diameter (compared to standard elastomer bellows)

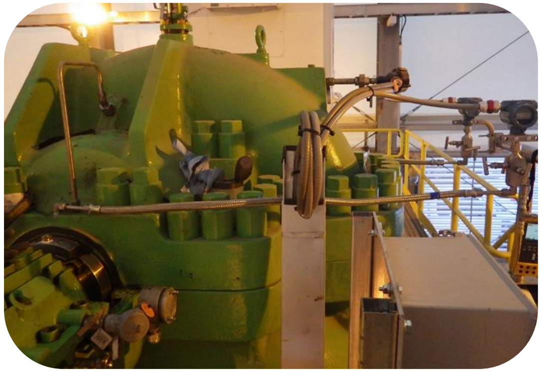


Field Installations









5.510” (140 mm) shaft

3 pumps to 1198 psi g (82 bar g)

720-1960 RPM

Installed November 2017

5.510” (140 mm) shaft

3 pumps to 1010 psi g (76 bar g)

890-1780 rpm

Installed February 2018

3.135” (79.6 mm) shaft

300 psi g (20 bar g)

3580 rpm

Installed March 2018

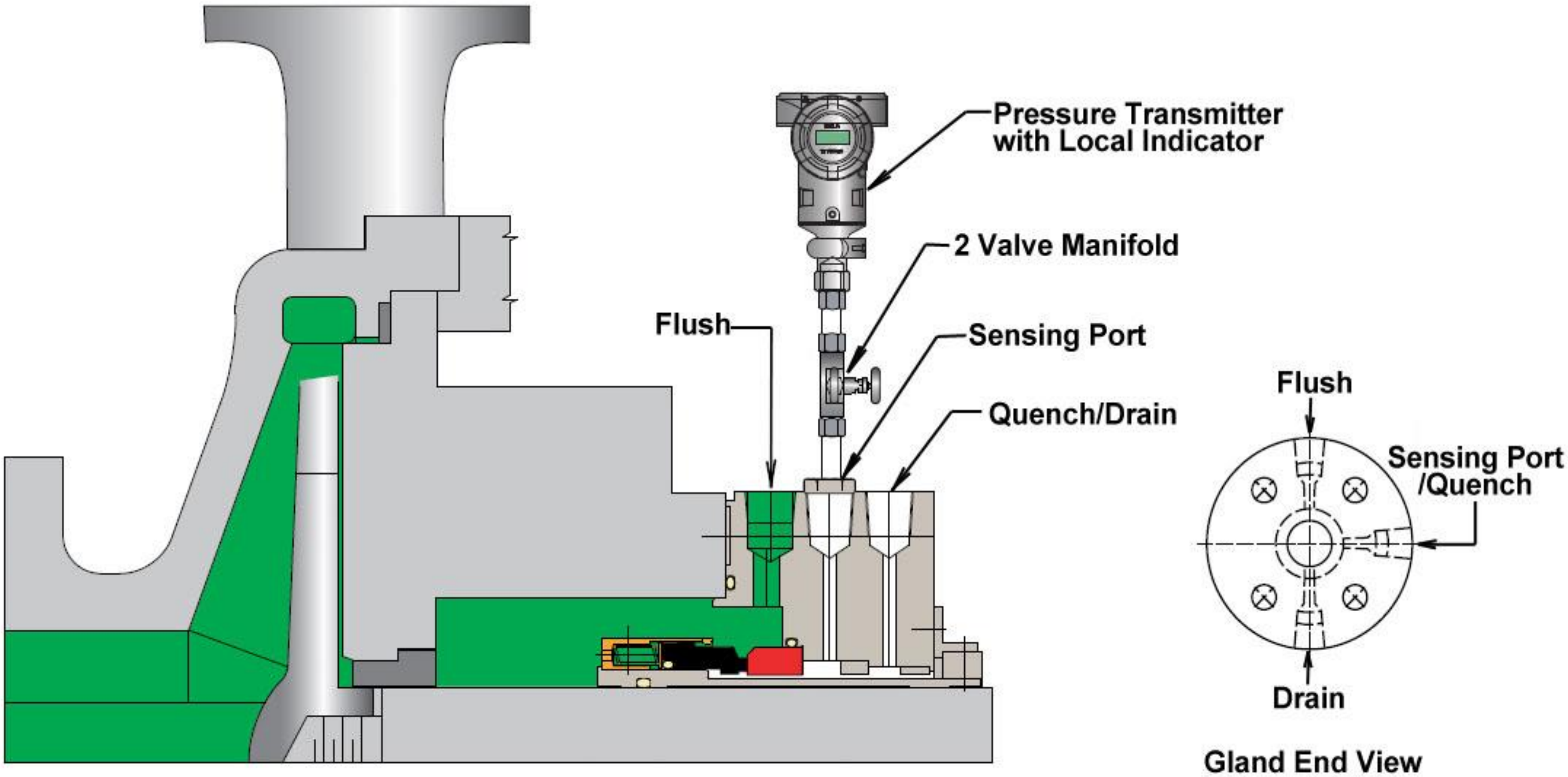
Current field installations

Arrangement	Flush Plan	Seal Size	Temp F (C Approx)	Suction Pressure psig (Kpa)	Discharge Pressure psig (Kpa)	Specific Gravity	Visc. (cP)	Speed Range	Current Installed Qty.	Original Install Date	Number of Failures
Single	11 / 66A	6.500"	50.-100 (10 – 38)	35 - 1198 (241-8259)	1440 (9928)	.94	350	720 - 1800	4	November 2017	0
Dual	11 / 75	6.500"	50 – 110 (10 – 38)	100 - 1100 (689-7584)	1480 (10204)	.927	41 – 280	880 - 1800	12	February 2018	0
Dual	11 / 52	6.500"	60 - 80 (15 – 27)	50 - 900 (350-6205)	1480 (10204)	.806	5	900 – 1800	24	February 2018	0
Dual	11 / 75	6.500"	50 - 100 (10 – 38)	50 – 1098 (350-7570)	1480 (10204)	.82	11 – 15	900 – 1800	24	March 2018	4 (Bearing Repair)
Single	11 / 65A	4.125"	40 – 100 (4 – 38)	30 – 300 (206-2068)	1440 (9928)	0.78 - .86	4 – 12	3580	10	April 2018	0
Single	11 / 65A (Mod)	4.125"	40 – 100 (4 – 38)	35 – 500 (241-3447)	1400 (9652)	.82	4	1800 -3580	6	May 2018	0
Single	11 / 65A	4.750"	35 (1.5)	750 (5171)	1200 (8273)	.82 - .89	11 – 15	1800 – 3920	7	June 2018	0
Dual	11 / 65A (Mod)	4.750	75 (24)	70 - 739 (482-5095)	1398 (9638)	.87	3 – 15	3580	42	July 2018	0
Single	11 / 65A	6.500"	50 (10)	50 (350)	1440 (9928)	.927	329	1060 – 1980	12	August 2018	0

* 15 more applications over 7 sizes currently in production (150+ units)

New API Leak Detection Plan 66A

Plan 66 - Leakage Containment and Detection



API Plan 66A

API Plan 66 - Defined

- Piping Plan
- Single seal (Arrangement 1) with dual bushing
  - Inner segmented floating carbon
  - Outer solid floating carbon
- Leakage detection system
- Limit leakage on seal failure
- Minimize leakage leaving gland
- Pressure monitor indicates seal failure

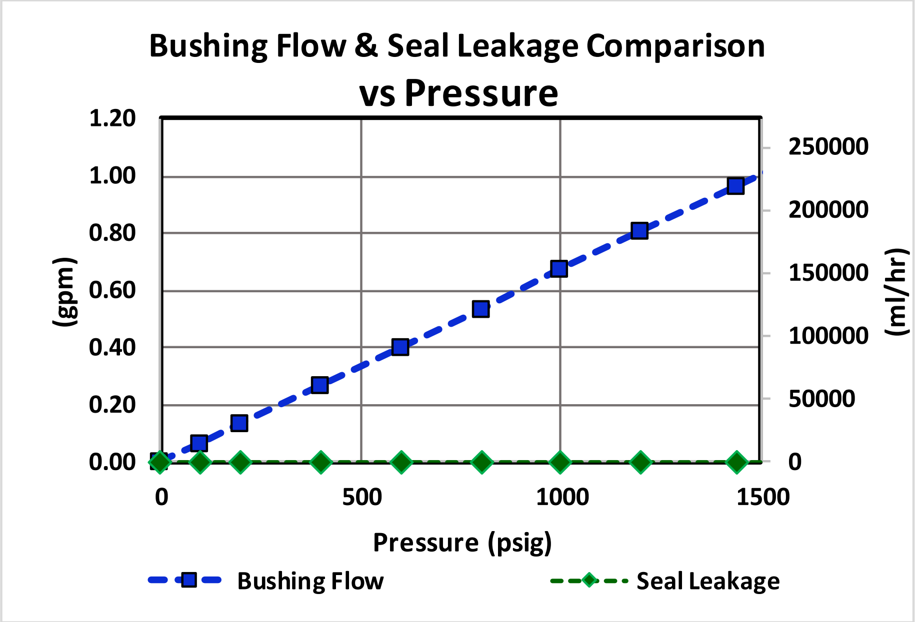
66A for Crude Oil Pipelines

Performance Requirements

- Allow all normal seal leakage to drain without generating pressure.
- Prevent normal leakage from exiting pump case and directed to drain.
- Provide a pressure signal when the primary seal is compromised.
- Restrict full pressure dynamic leakage during detection & shaft coast down.
- Restrict full pressure static leakage during pump isolation.
- Restrict leakage from pump case during catastrophe and post catastrophe.
- Structural and operational integrity up to of 150% of maximum process pressure.
- Optionally restrict leakage past the secondary bushing in the event of primary seal failure and primary bushing failure during full pressure dynamic and static operation.

Bushing Flow versus Seal Leakage

Pressure (psig)	Bushing Flow (gpm)	Bushing Flow (ml/hour)	Seal Leakage (ml/hour)	Seal Leakage (gpm)
0	0.0000	0	0.0	0.00E+00
100	0.0672	15263	2.0	8.66E-06
200	0.1342	30480	3.2	1.40E-05
400	0.2684	60960	6.2	2.74E-05
600	0.4027	91463	10.1	4.43E-05
800	0.5368	121921	14.7	6.48E-05
1000	0.6710	152401	20.1	8.87E-05
1200	0.8052	182881	26.4	1.16E-04
1440	0.9662	219448	34.9	1.54E-04
1800	1.2076	274276	49.9	2.20E-04
2200	1.4759	335213	69.6	3.06E-04



Implications

- 66A uses pressure/flow of bushing to provide info on seal
- 66A cannot indicate seal health as function of pressure
- Discrepancy in sensitivity and range (Pressure vs Flow for Seal and Bushing)
  - Measure displacement of an active geological fault with a speedometer !!
- Cannot detect normal, low or variations in seal leakage rates
- 66A limited to detecting seal upsets/failure warranting shut-down
- Seal health best indicated by other means
- Collection vessel fills/drainage over time (volume, flow trends)
- High tech sensors
- Dual or safety containment seals

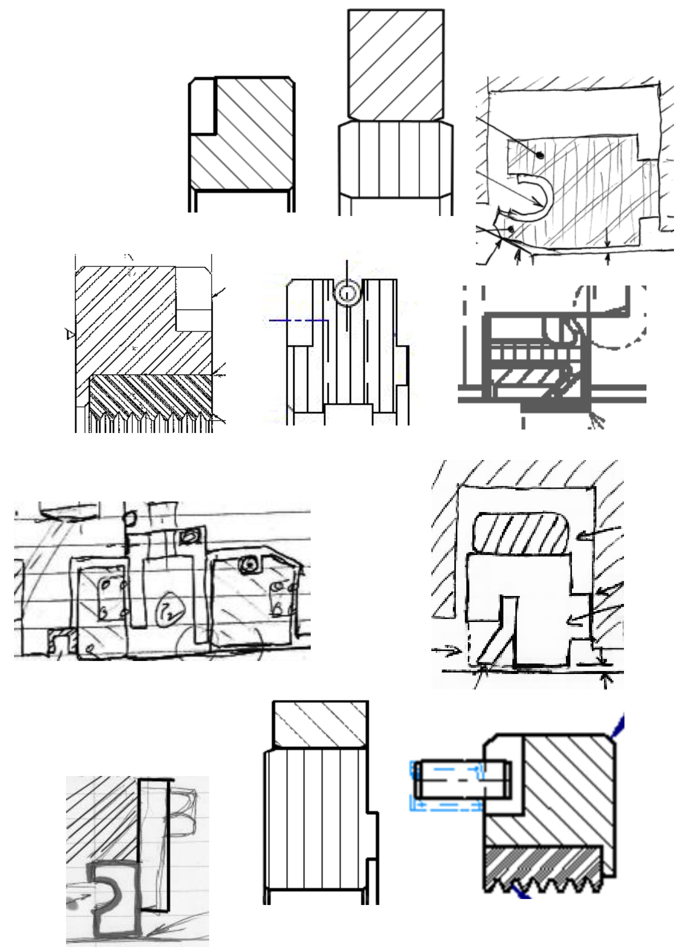
Development Concepts

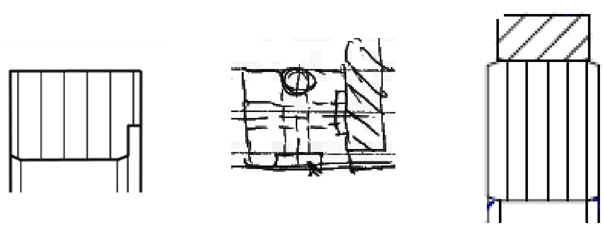
Idea Solicitation & Evaluation

- Ideas to meet performance requirements
- Reviewed weighted selection matrix
- Focus initial prototypes

Tested Variations

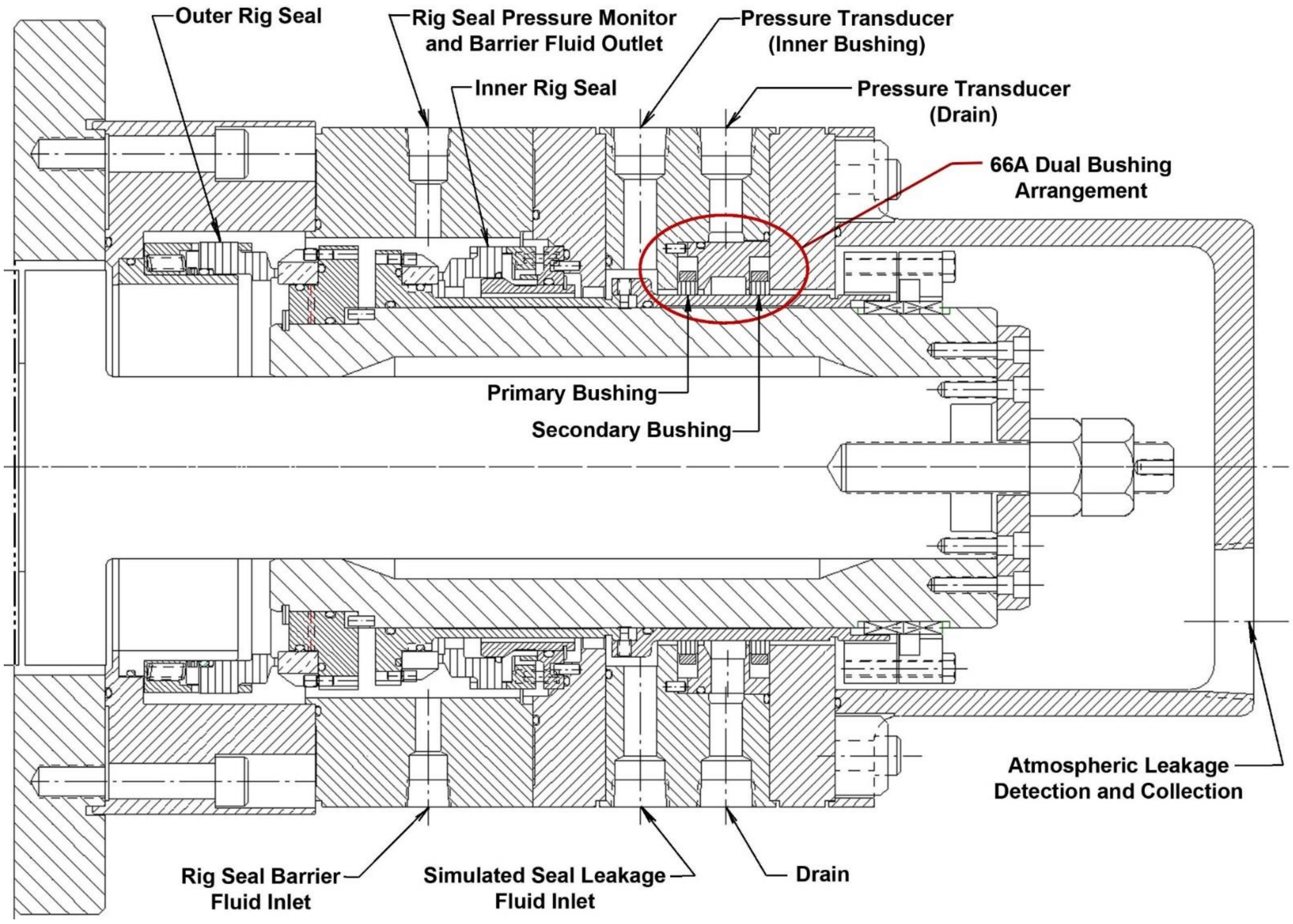
- Split / Solid
- Spring Load Variations
- Pinned / Floating / Shear Pins
- Banded / Un-banded
- Various ID hydro features
- Plain / Seal Face
- Different Materials





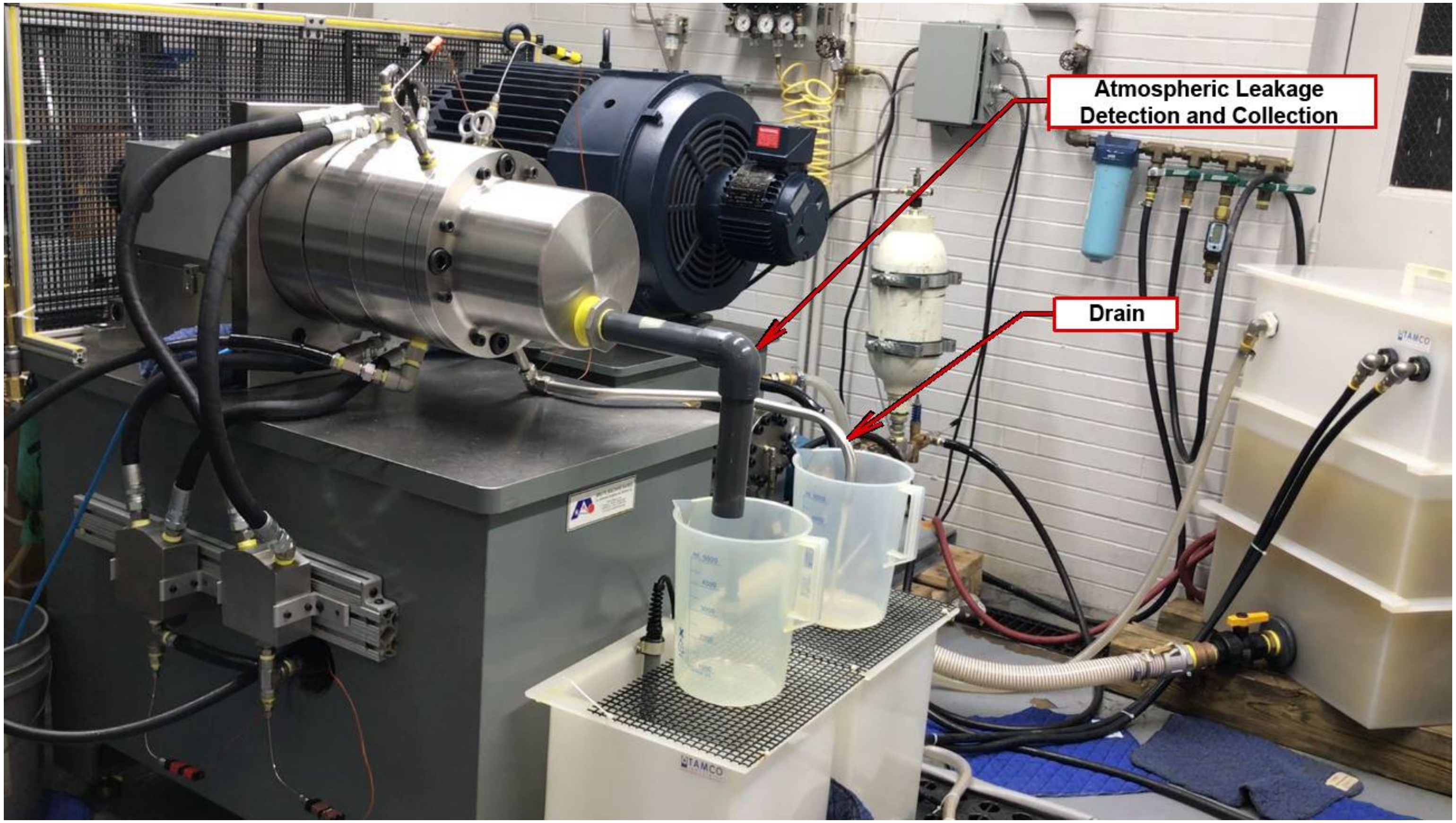
High Pressure Testing

- Horizontal
  - Similar to field installs
  - Capture all leakage
  - Primed internal fills
- Operating Regimes
  - Dry Run
  - Controlled Flow
  - Controlled Pressure



High Pressure Testing

Catastrophe Simulation



F7(X), F8(↓), F9(↑)

w Recorder

w/o Recorder

Time, Event
0:00, At Speed
0:27, Apply Full Pressure
1:45, Vessel Contents
2:50, Reduce Speed
4:25, View Belt Rotation
4:55, Vessel Contents
5:10, Belt Skipping
5:35, 0 rpm

Testing - 6.625 inch Bushing Diameter

66A
Flow Data

66A Oil Test									
Distressed Seal Simulation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
13:20	1800	0	110	300	1320	0	0	300	0
13:25	1800	0	110	300	1320	0	0	300	0
13:30	1800	0	110	300	1320	0	0	300	0

Distressed seal leakage is **60X** greater than normal leakage.

Testing - 6.625 inch Bushing Diameter

66A
Flow Data

66A Oil Test									
Distressed Seal Simulation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
13:20	1800	0	110	300	1320	0	0	300	0
13:25	1800	0	110	300	1320	0	0	300	0
13:30	1800	0	110	300	1320	0	0	300	0
Low Pressure Dynamic Operation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
13:40	1800	1	145	60	8700	0	0	60	0
13:43	1800	2	220	60	13200	0	0	60	0
13:46	1800	3	284	60	17040	0	0	60	0
13:49	1800	4	390	60	23400	0	0	60	0
13:52	1800	5	440	60	26400	0	0	60	0
13:55	1800	6	500	60	30000	0	0	60	0
13:58	1800	7	550	60	33000	0	0	60	0
14:01	1800	8	587	60	35220	0	0	60	0
14:04	1800	9	655	60	39300	0	0	60	0
14:07	1800	10	705	60	42300	0	0	60	0

Low pressure operation indicates flow in alarm setting range.

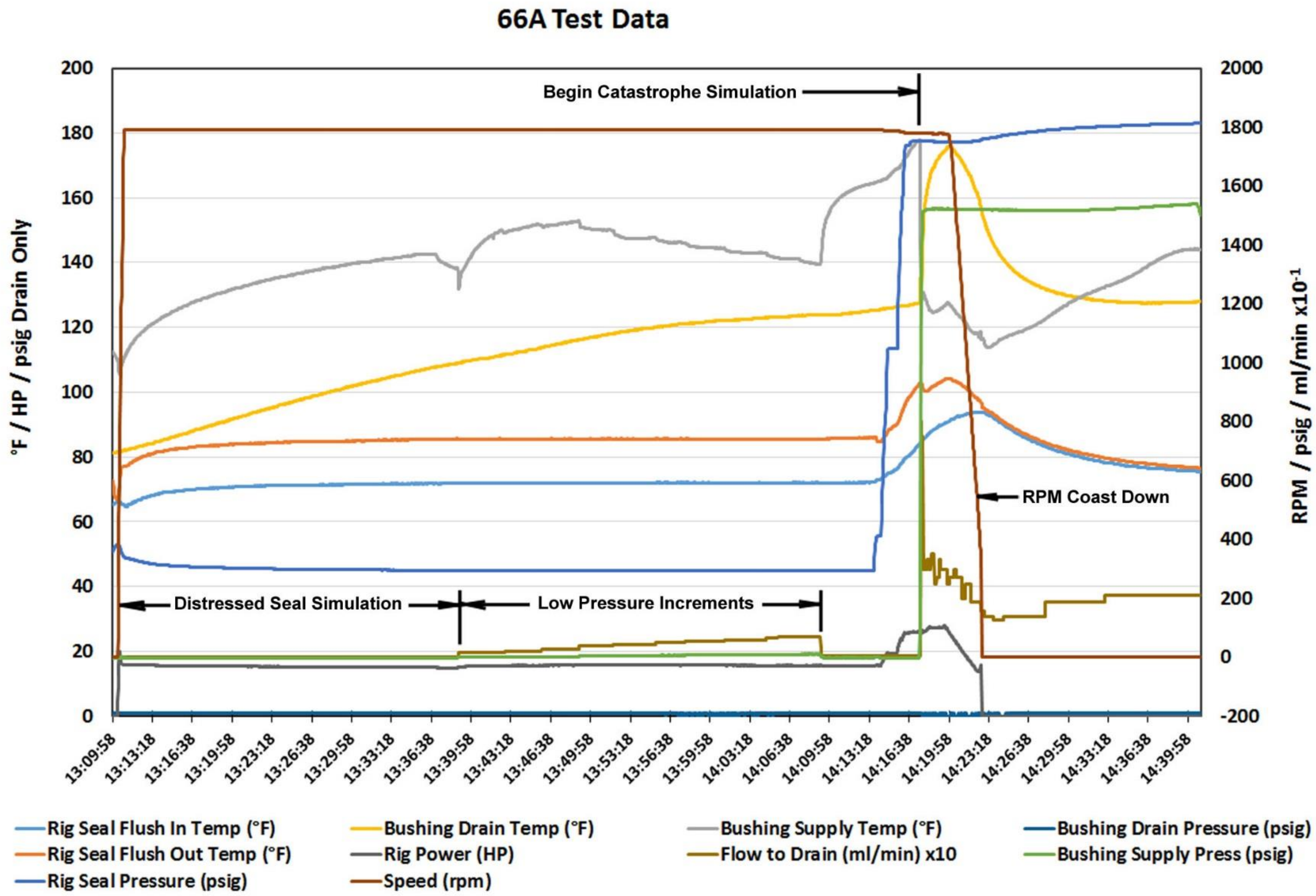
Testing - 6.625 inch Bushing Diameter

66A
Flow Data

66A Oil Test									
Distressed Seal Simulation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
13:20	1800	0	110	300	1320	0	0	300	0
13:25	1800	0	110	300	1320	0	0	300	0
13:30	1800	0	110	300	1320	0	0	300	0
Low Pressure Dynamic Operation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
13:40	1800	1	145	60	8700	0	0	60	0
13:43	1800	2	220	60	13200	0	0	60	0
13:46	1800	3	284	60	17040	0	0	60	0
13:49	1800	4	390	60	23400	0	0	60	0
13:52	1800	5	440	60	26400	0	0	60	0
13:55	1800	6	500	60	30000	0	0	60	0
13:58	1800	7	550	60	33000	0	0	60	0
14:01	1800	8	587	60	35220	0	0	60	0
14:04	1800	9	655	60	39300	0	0	60	0
14:07	1800	10	705	60	42300	0	0	60	0
Catastrophic Failure Simulation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
14:17	1800	1500	5000	107	168224	0	0	120	0
14:19	1800-0	1500	7500	198	136364	0	0	180	0
Post Catastrophe Simulation									
		Primary Bushing				Secondary Bushing			
Time	Shaft Speed (rpm)	Pressure (psig)	Vol to Drain (ml)	Duration (seconds)	Rate to Drain (ml/hr)	Pressure (psig)	Vol to Atm. (drops)	Duration (seconds)	Rate **(ml/hr)
14:23	0	1500	6850	300	82200	0	0	30	0
14:28	0	1500	9340	300	112080	0	0	30	0
14:33	0	1500	10550	300	126600	0	0	30	0

**Approximate conversion is 20 drops per ml

Testing - 6.625 inch Bushing Diameter



Testing – Results

Performance Evaluation

- Normal Leakage to Drain – No outboard drips
- Data for alarm trigger – Low Pressure Confirmation
- Contains process during catastrophe - 5 min
- Post Catastrophe Containment – 15 min

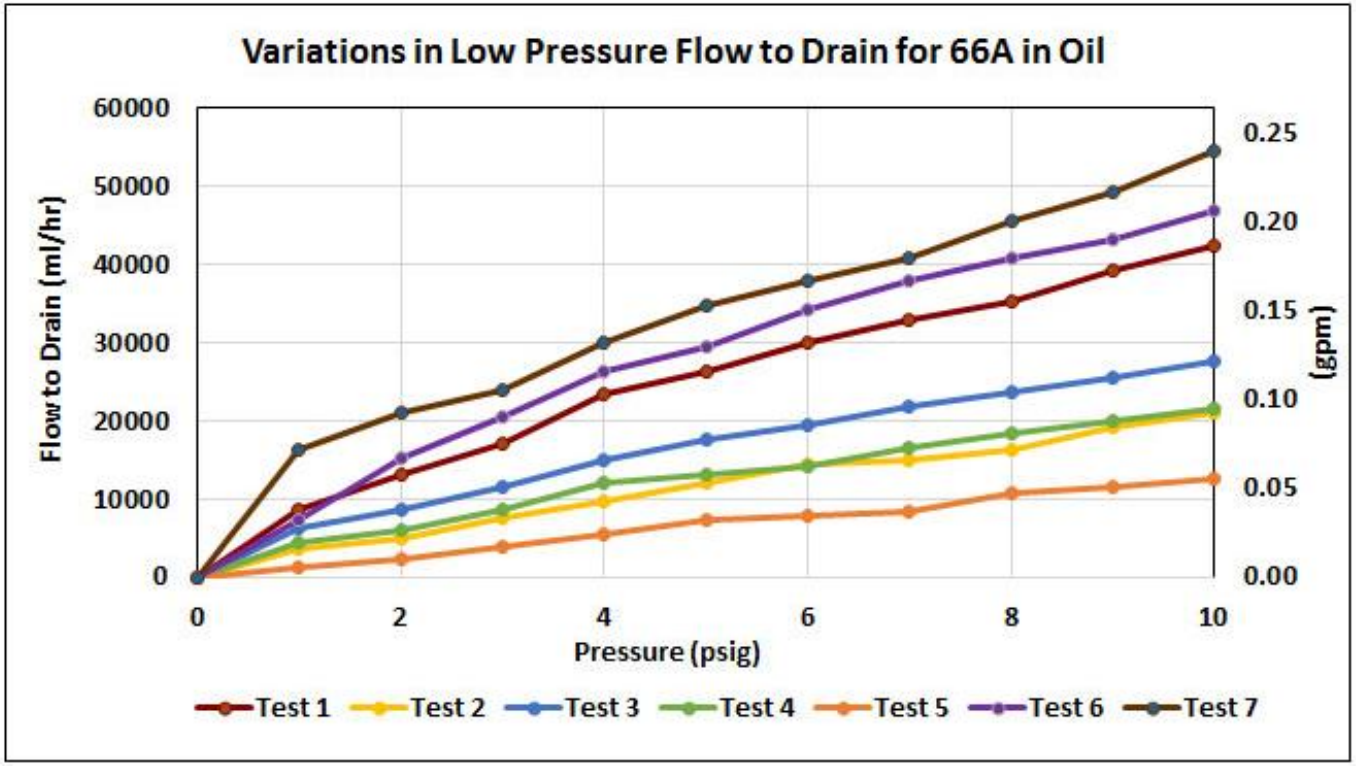
Pressure Variations

- Performs at various pressure 60, 600, 1500
- Structural Integrity to 2200 psig
- No dimensional change

Endurance Testing

- 500 hours at normal operating conditions
- 1200 coast downs / restarts (30 sec / 3 sec)
- Negligible wear
- Maintains performance capacity

Low Pressure Dynamic Flows (Trigger Alarms)



Test Summary

- Normal operation & catastrophe simulation 150% (2200 psi) static pressurization
- 500 hr. run, 1200+ stop/start & catastrophe simulation
- Met performance objectives

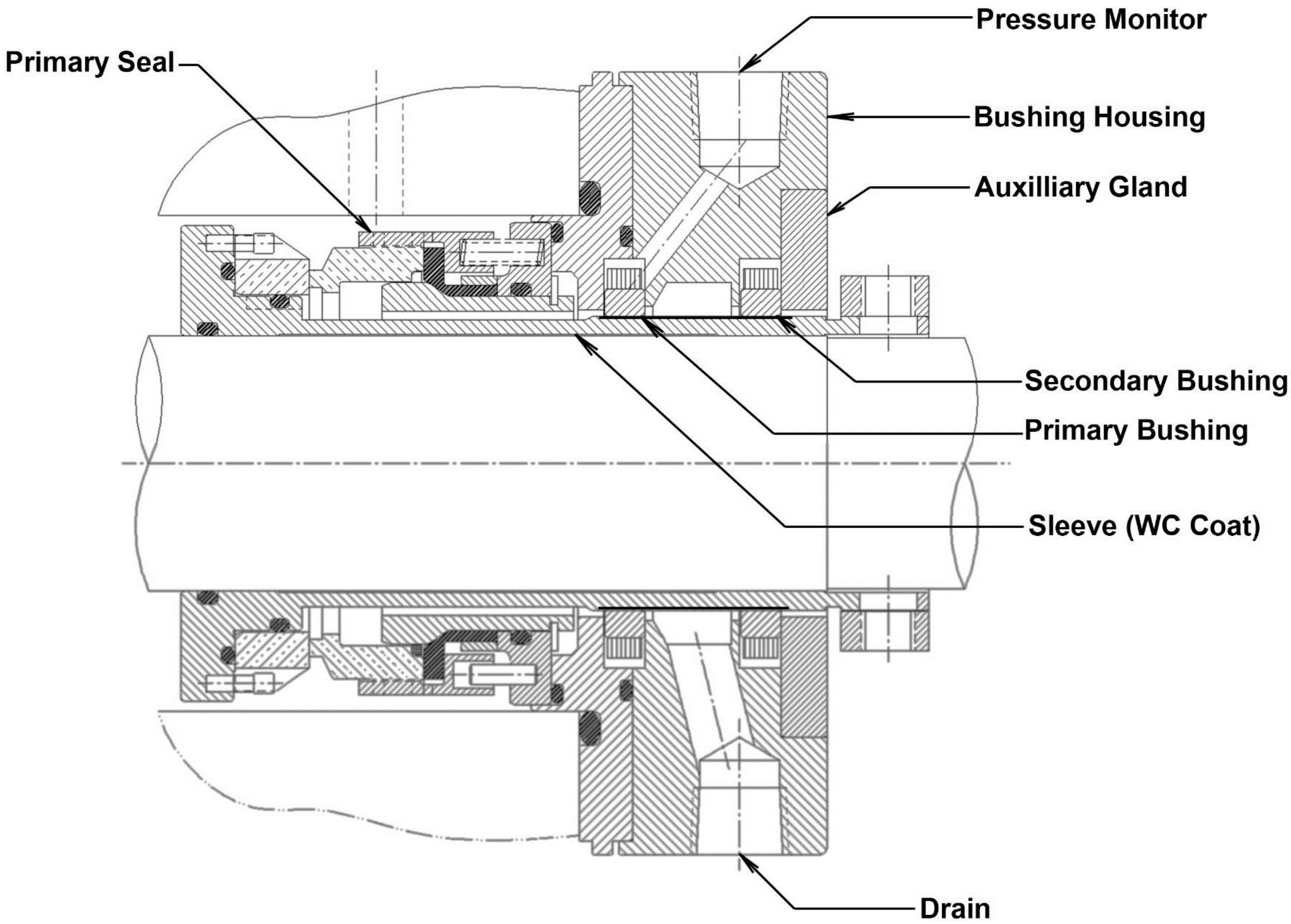
Summary

- 66A function
  - Bushing flows can be significant & variable
  - 66A as upset or failure detection
  - Low pressure indicates upset (extreme seal leakage)
  - Directs leakage / flow to drain
- Limit duration
  - Full pressure dynamic operation (minutes)
  - Shut down & isolation activities
  - Single use catastrophe containment
- Consider alternate method for seal health
  - Volume or flow rate measurement (considering application conditions & trends)
  - New (sensor) technology
- Consider dual or safety containment seals

API 66A Re-Defined

- Piping Plan ✓
- Single seal (Arrangement 1) with dual bushing ✓
  - Inner ~~segmented floating carbon~~ "Bushing"
  - Outer ~~solid floating carbon~~ "Bushing"
- ~~Leakage~~ Upset detection system
- ~~Limit leakage~~ Restrict & direct flow on seal failure
- Minimize leakage leaving gland ✓
- Pressure monitor indicates seal failure ✓

Pipeline Seal with 66A



Key People Involved with the R&D Projects

- **Jim Wasser** (Director Design Engineering - Chicago)
- **Tom Steigerwald** (Senior Principle Engineer R&D – Chicago)
- **James Spiegelman** (R&D Test Engineer)
- **John Morton** (Global Wet Seal Product Line Director - UK)
- **Raul Escontrias** (North American Pipeline Manager)
- **Derek Hirtle** (Regional Sales Manager – Western Canada)
- **Chris Ausford** (Technical Sales Representative)
- **Key Customer Support : Enbridge and TC Energy**

Thank you