EXTERRAN™
Water Solutions

Deep Bed Nutshell Filter Evolution

20th Annual Produced Water Seminar

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A World of Energy Solutions

Agenda

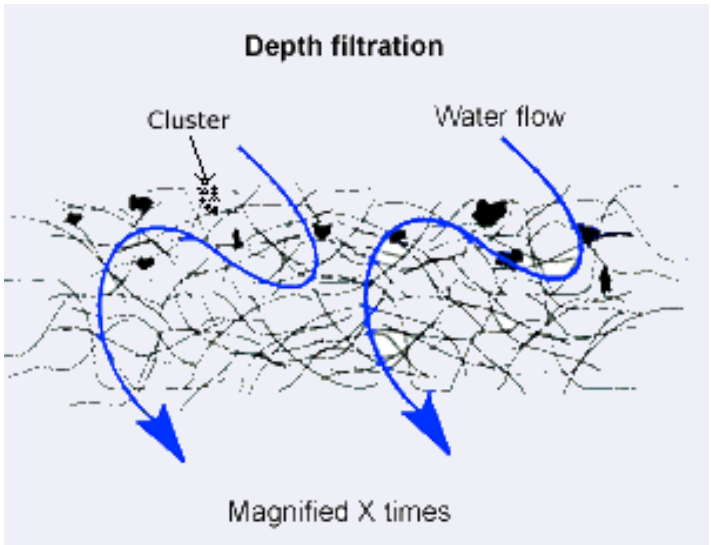
1) Types of Filtration
2) Depth Filtration
3) Media Types
4) Black Walnut Shell Media
5) Black Walnut Shell Filters

Introduction

Filtration – mechanical and physical operation

Surface filters (sieves)

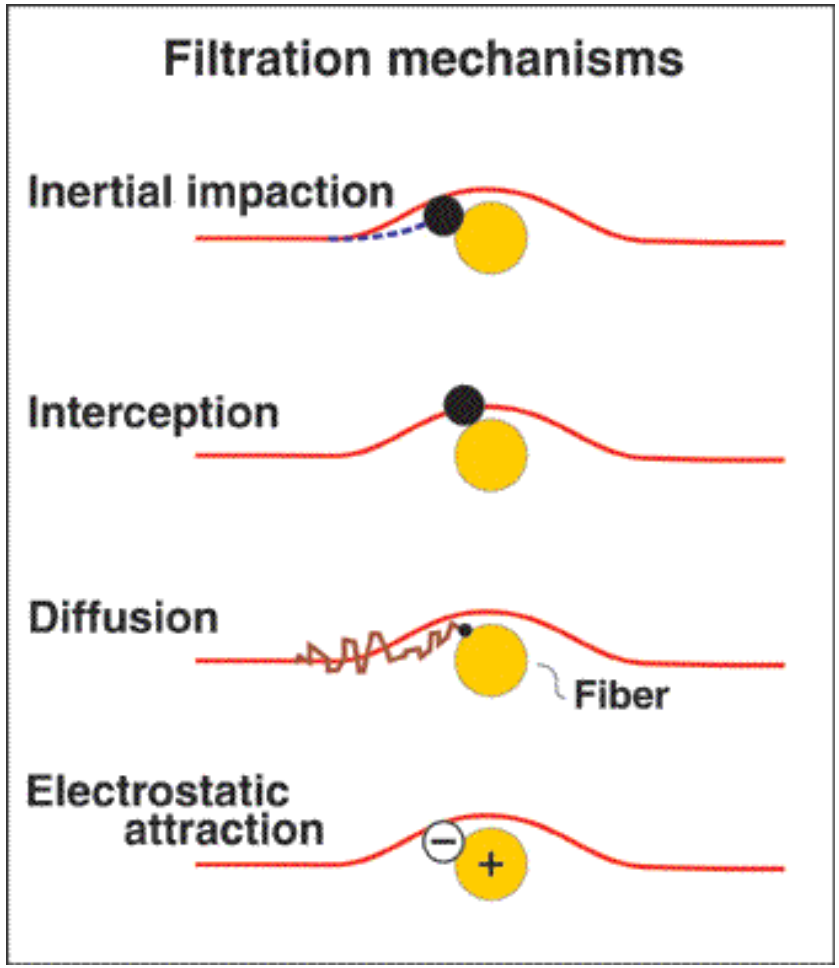
Deep Bed filters (Depth)



How does it work ???

Depth Filtration mechanisms

- Direct collision
- Van der Waals or London force attraction
- Surface charge attraction / repulsion
- Diffusion



Depth Filters – Media

1) *Silica Sand:*
   - oldest media used – 1st municipal water treatment plant was built in Scotland in 1804
   - low cost material

but …

   - relatively heavy (SG ~ 2.6)
   - relatively small size of the media particles
   - relatively high ΔP which limits the flux rate and increase equipment size respectively
   - requires relatively high energy to fully fluidize the bed
   - has relatively high affinity to oil so that chemicals are required to clean the media bed satisfactorily during each backwash stage

Depth Filters – Media

2) PVC (Polyvinyl chloride)

- Relatively light (SG ~ 1.4)
- Can be of any size/shape desired
- Requires less energy to fully fluidize the bed

but…

- Highest affinity to oil so that chemicals are required to clean the media bed - $$$ satisfactorily during each backwash stage
- relatively high media cost

Depth Filters – Media

3) Anthracite

- Relatively light (SG ~ 1.3-1.4)
- Can be crushed and sieved to any size desired
- Requires less energy to fully fluidize the bed

but…

- is easily fractured into relatively flat flaky particles which blind off filter prematurely
- relatively high affinity to oil so that chemicals are required to clean the media bed satisfactorily during each backwash stage - $$$
- relatively high media cost

Depth Filters – Media

There are also other media …

- Granular glass
- Multimedia
- Chemically treated media
- etc …….

Depth Filters – Media

AND of course ….

Black Walnut Shells !!!

…. but WHY ???

Black Walnut Shells – unique filter media

Physical properties:

- Water-wet (easier backwashable)
- Light in weight (SG ~ 1.3-1.4)
- Strong material (Modulus of elasticity = 170000)
- Relatively Non-Abrasive

Commercial benefits:

- Media availability (natural occurrence)
- Can be crushed into any size
- Cost savings (NO solvents/surfactant required)
- Ability to re-use media
- Low attrition rate
- Reduced vessel size due to higher flux rates

Filtration Cycle

5 stages:

- Filtration
- Media agitation
- Backwash
- Pause / Sedimentation
- Pre-run Flush

Backwash

Triggered by:

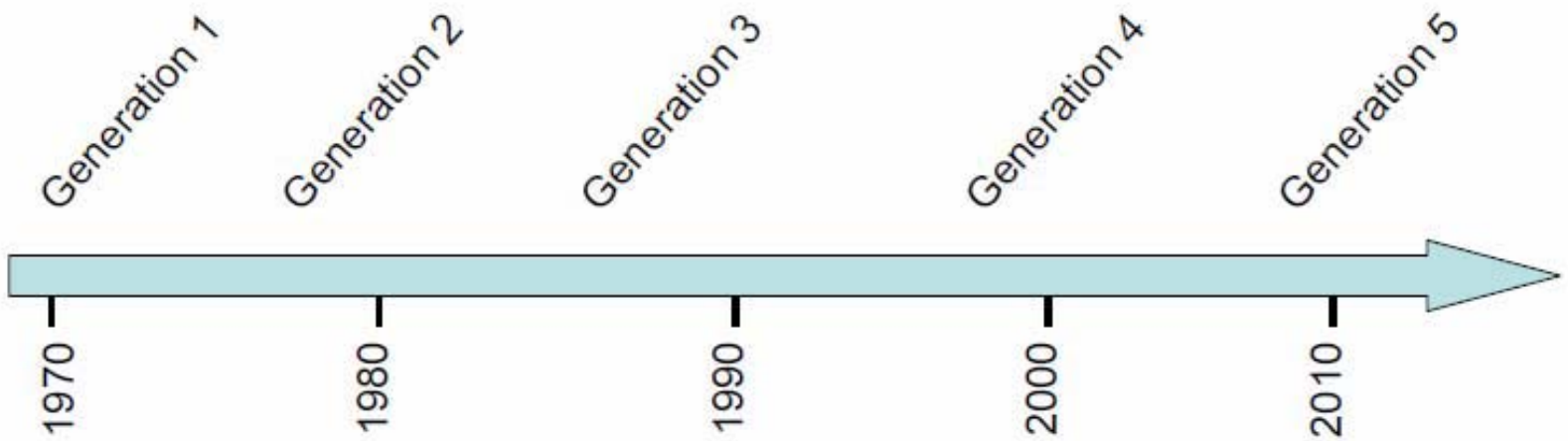
- Clean water outlet quality falls below a set point
- Preset ΔP across the filter bed is achieved
- Preset time for filtration stage is elapsed

An optimal Backwash process should:

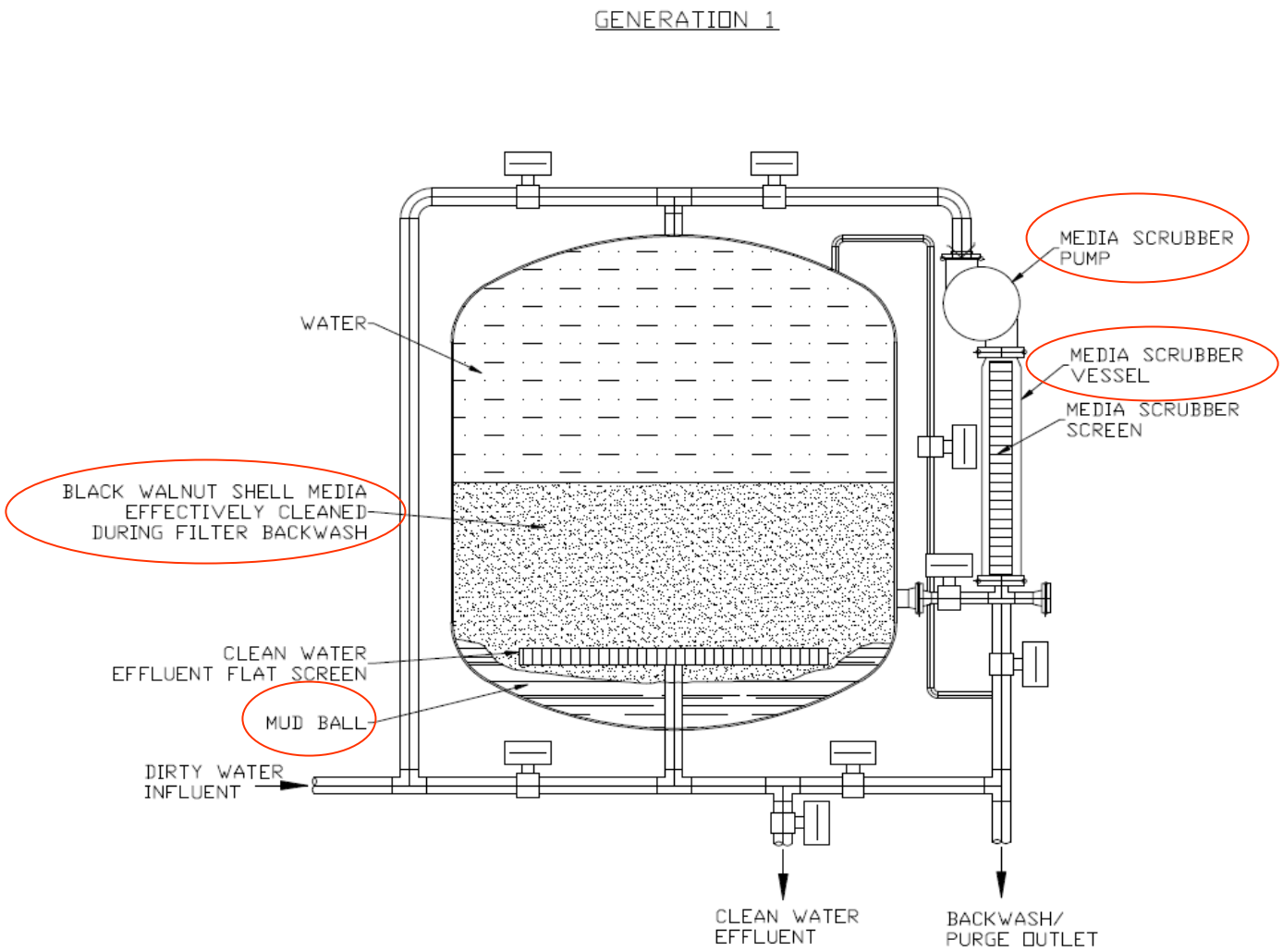
- Completely fluidize the filter bed
- Remove all trapped oil and solid particles
- Cause low stress & shear to the media granules
- Require a low water throughput
- Require a short cycle time
- Consume a low amount of energy
- Limit or eliminate rotating equipment or elements

Nutshell Filter Technology Evolution

1) Gerard P. Canevari (1984) US Patent: 4,481,113: Filter Media and method for cleansing entrained oils from oil-in-water emulsions;
2) Gene Hirs (1974) US Patent 3,814,245: Method of Filtering;
3) Gene Hirs (1976) US Patent 3,953,333: Method and apparatus for rejuvenating a bed of granular filter medium;
4) Clifford J. Hensley (1997) US Patent 5,635,080: Filter system with external scrubber;
5) Jerry Lester Hensley (1998) US Patent 5,833,867: System and method for backwashing multiple filtration vessels;
6) Robert Joseph Long (2004) US Patent Appl. No 10/277,276: Eductor circulated nut shell media filter;
7) Clifford J. Hensley (1985) US Patent 4,496,464: Filter Apparatus and Method;
8) Clifford J. Hensley (1990) US Patent 4,966,698: Filter System and Scrubber.
9) Jack R. Bratten (1992) US Patent 5,171,443: Granular Media Regeneration Apparatus.
10) Irving A. Dean (2001) US Patent 6,287,474 B1: Liquid Treatment Regeneration Apparatus And Process;
11) Doug W. Lee, Colin Tyrie, William Bateman (2007) Patent Application PCT/US2007/003507: A method and device for cleaning non-fixed media filters;



BWS Filters – Generation 1



BWS Filters – Generation 1

Changes to previous generation:

- Sand media was displaced by BWS media

Incremental Advantages:

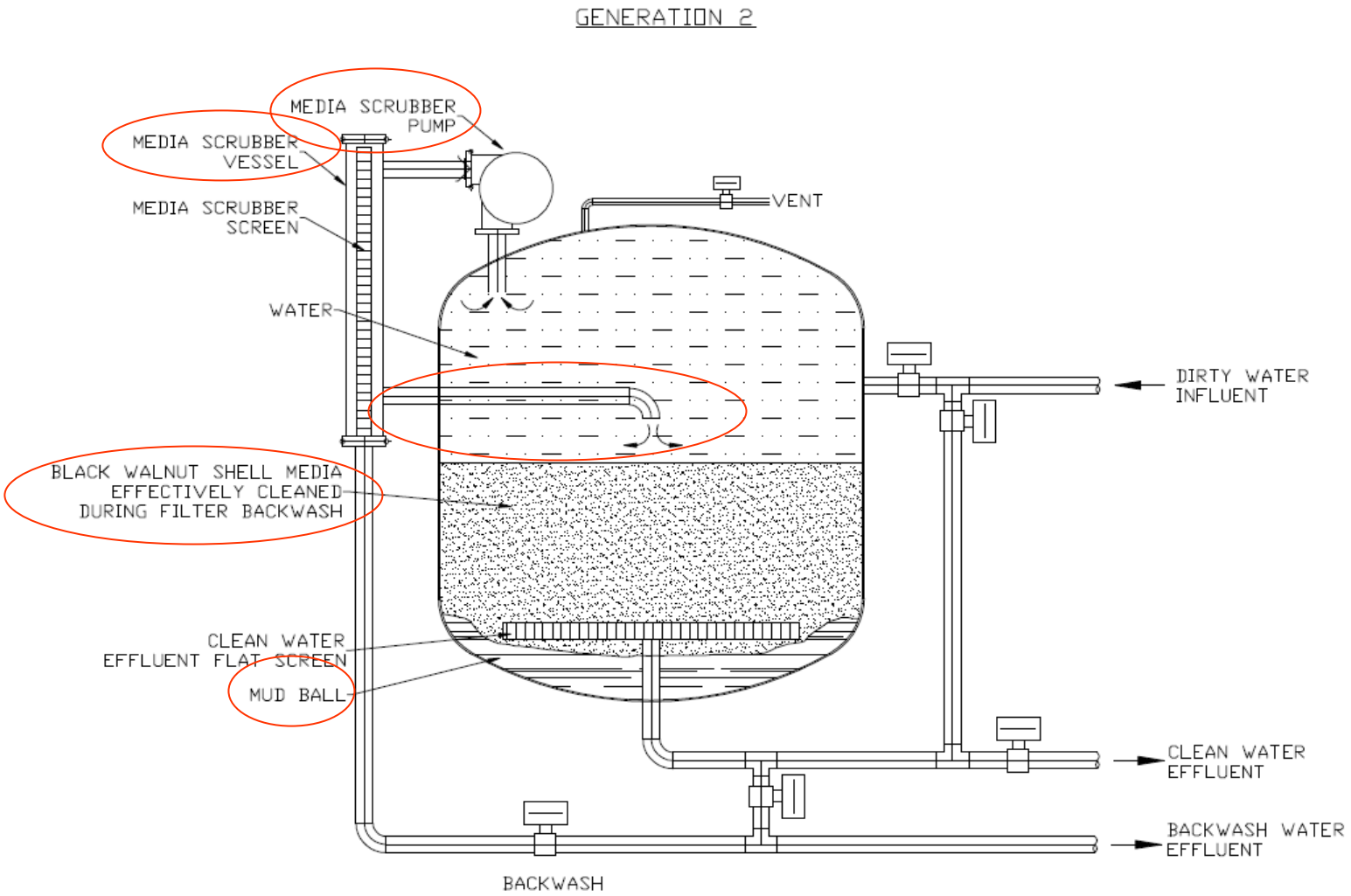
- New BWS media allowed to double the flux rate due to more favorable physical properties of BWS
- Reduced equipment size – cost, foot print
- Dramatically lowered backwash water flow
- requires less energy to fully fluidize the bed

BWS Filters – Generation 1

Remaining Disadvantages:

- Dead zone below filter bottom screen – “Mud ball”
- Rapid attrition of the filter media
- Specialty slurry pump, high HP motor required resulting in additional maintenance
- Bed-submerged cleaned media return nozzle with side entry creates unfavorable settling hydraulics
- It is impossible to check whether all of the filter media been removed / scrubbed and returned to filter vessel
- Design is only effective for a vertically oriented filter, therefore not applicable to flows > ~50,000 bwpd
- Additional equipment – cost, foot print

BWS Filters – Generation 2



BWS Filters – Generation 2

Changes to the previous generation:

- Placement of the clean media return nozzle above the media bed level

Incremental Advantages:

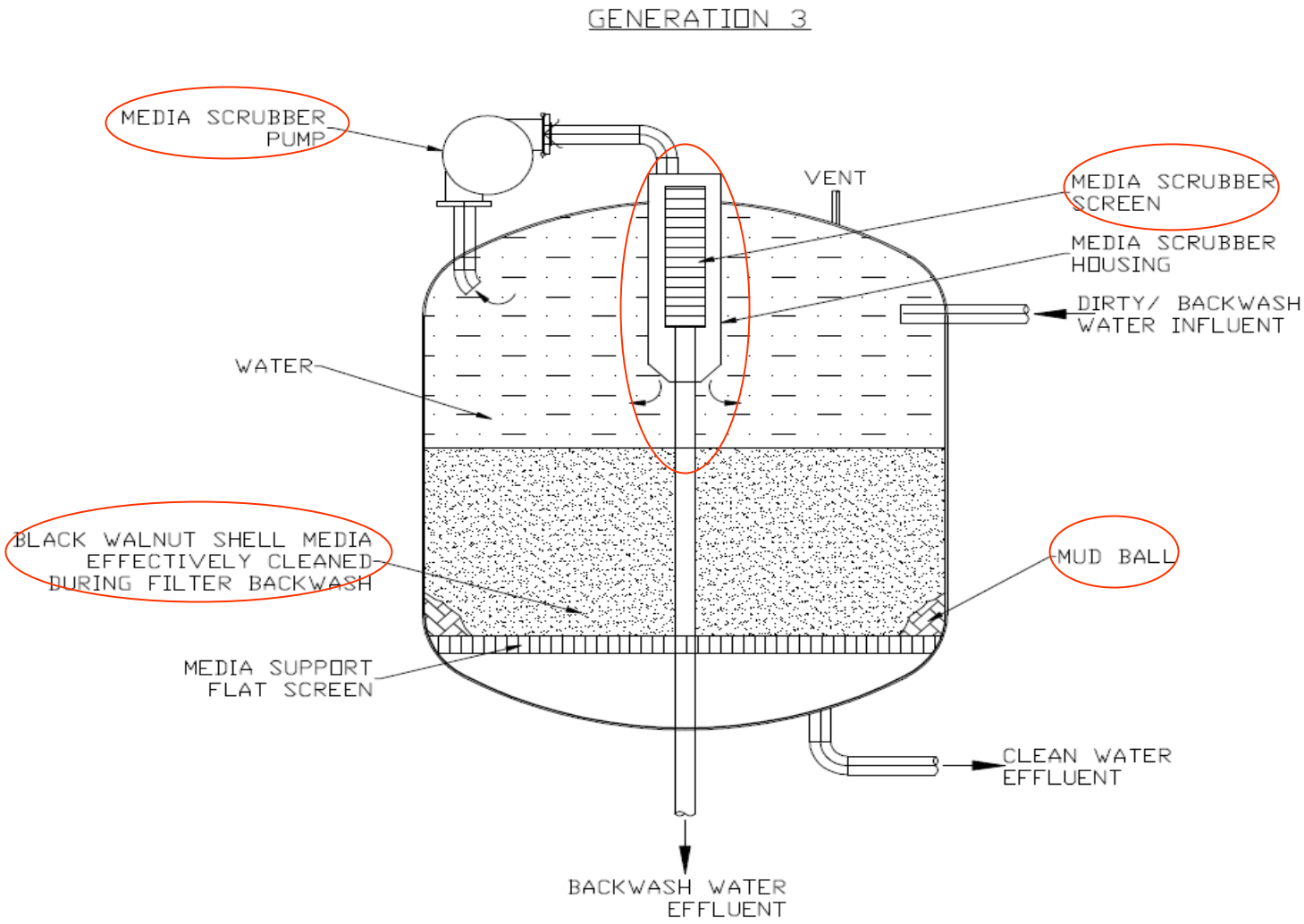
- Resolved the uneven settling of media

BWS Filters – Generation 2

Remaining Disadvantages:

- Dead zone below filter bottom screen – “Mud ball”
- Rapid attrition of the filter media
- Specialty slurry pump, high HP motor required resulting in additional maintenance
- It is impossible to check whether all of the filter media been removed / scrubbed and returned to filter vessel
- Design is only effective for a vertically oriented filter, therefore not applicable to flows > ~50,000 bwpd
- Additional equipment – cost, foot print

BWS Filters – Generation 3



BWS Filters – Generation 3

Changes to the previous generation:

- Scrubber vessel eliminated
- Scrubber element placed inside filter vessel

Incremental Advantages:

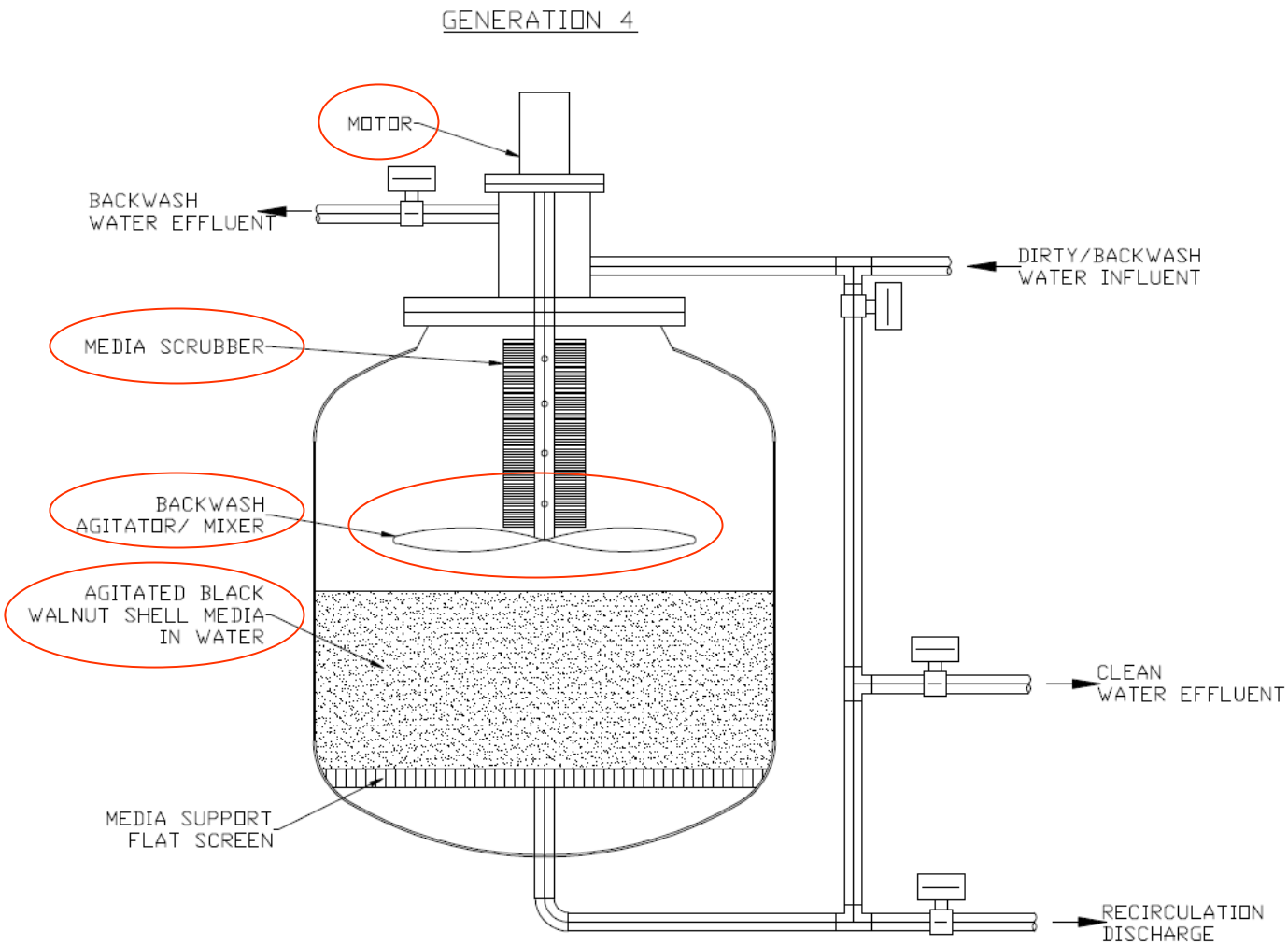
- No media is trapped anymore by the end of backwash stage
- Reduced foot print
- Reduced CAPEX

BWS Filters – Generation 3

Remaining Disadvantages:

- Dead zone below filter bottom screen – “Mud ball”
- Rapid attrition of the filter media
- Specialty slurry pump, high HP motor required resulting in additional maintenance
- Design is only effective for a vertically oriented filter, therefore not applicable to flows > ~50,000 bwpd

BWS Filters – Generation 4



BWS Filters – Generation 4

Changes to the previous generation:

- Removed slurry pump
- Added internal mixer attached to rotating shaft
- Media does not leave filtration vessel for backwash
- Abandoned fixed scrubber element
- Added scrubber/screen basket attached to shaft

Incremental Advantages:

- Reduced amount of b/w water flow by ~ 20%
- Reduced media attrition rate
- Eliminated “Mud Balling” in small vertical vessels

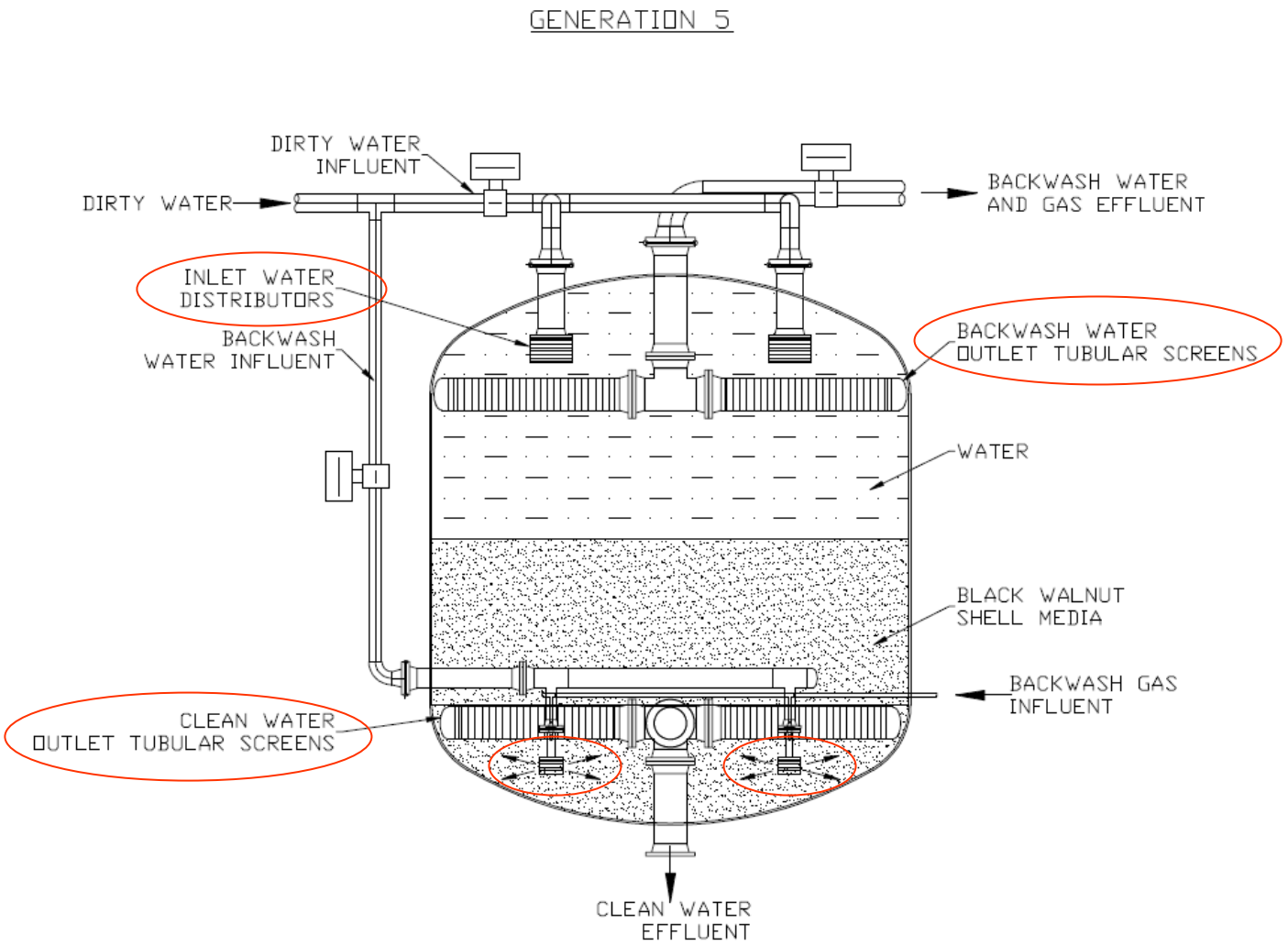
BWS Filters – Generation 4

Remaining Disadvantages:

- High HP motor required – additional maintenance
- Design is only effective for a vertically oriented filter, therefore not applicable to flows > ~50,000 bwpd

There is still some work to do here……

BWS Filters – Generation 5



BWS Filters – Generation 5

Changes to the previous generation:

- Eliminated motor with mixer
- Used Water + Gas fluidization and backwash
- Removed bottom flat screen
- Used tubular screens instead
- Multiple inlet nozzles improved flow distribution

Incremental Advantages:

- Ability to built high capacity horizontal filter vessels (up to 150,000 bwpd)
- Reduced costs – no additional equipment
- Requires less maintenance – no mechanical seals
- Reduced surge capacity required upstream due to use of inlet feed to complete backwash
- Simple control philosophy, easy to operate

BWS Filters – Generation 5

Remaining Disadvantages:

- NONE

Conclusion

- 40 years of development and commercial implementation
- Wide acceptance of Nutshell Filters now by Industry
- Produced Water volumes increasing dramatically
- Increasing demand for high performance filters with unprecedented flow rates
- 5th generation – refined design of Nutshell filter has overcome limitations of earlier designs for:

Flow Rates
Backwash Water Volumes
Attrition Rates
Rotating Equipment

Q & A

Thank you!