BPS

BLACK POWDER SOLUTIONS

THE SUSTAINABLE ALTERNATIVE

TO CONVENTIONAL FILTRATION

Black Powder Solutions

Black Powder Solutions Inc. (BPS) is a Canadian company that designs and manufactures patented magnetic separator systems as an inline, full-flow solution for removing Black Powder™ (black powder) contamination from hydrocarbon fluids and gases, refined products, petrochemicals and water.

BPS magnetic separator systems are the sustainable, optimal solution for contamination removal. They are designed to remove contaminants down to sub-micron sizes with 95+% efficiency insingle pass applications and they operate with a bare minimum of flow restriction. Our magnetic separators protect pumps, valves and process equipment from failure along all stages of the hydrocarbon value chain and eliminate the need for conventional, depth-media filtration.

Deployment of BPS technology will ultimately improve system operations, increase production, improve product quality, support safety initiatives and reduce environmental impact.

Black Powder Contamination

Black powder is an oil and gas industry term for the abrasive, reactive contamination present in all hydrocarbons and hydrocarbon derivatives. It is a mix of various forms of iron sulfide and iron oxide, along with other compounds and substances including chlorides, sodium, calcium, mill scale, sand, glycol and varying types of 'dirt', such as silica and other particulate. It is also known as rouge, black dirt, brown dirt, red dirt and various other names.

- Black powder initially forms as a sulfur-based corrosion product from microbial and chemical interactions.
- It continues to build as as iron sulfide and iron oxide through hydrocarbon pipelines and facilities.

Black powder originates in producing formations and precipitates out throughout the hydrocarbon value chain: during transportation, processing, storage, fractionation, refining, petrochemical production and loading and offloading.

Black powder removed from the suction of a kerosene product pump.

Iron oxide rust contamination built up in piping resulting from black powder.

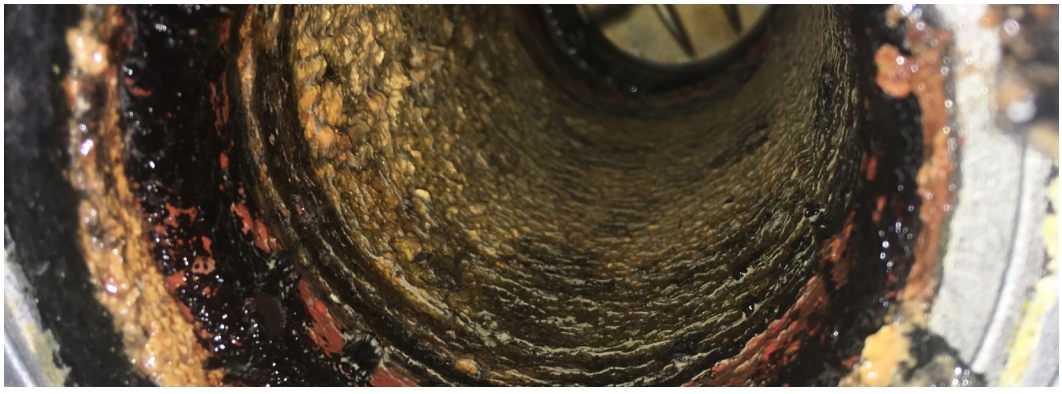
Sources of Black Powder

Corrosion

- Bacteria formation: Sulfur and acid producing bacteria are dependent on water and iron reactions to originate the formation of black powder contamination.
- Chemical formation: moisture, hydrogen sulfide and temperature and/or pressure variance are further catalysts for the development of black powder.

Erosion

- Once formed, black powder continues to build due to both corrosion and erosion as hydrocarbons progress downstream - all piping and equipment is vulnerable to its erosional impacts.
- If not removed at various spots in the hydrocarbon value chain, it will continue to build due to erosional forces and eventually plug off pipelines, meters, valves, heat exchanges, reboilers and other equipment, including conventional depth media filters.



Scale calcium carbonate and Corrosion product in main piping of Cooling water system

Technical Specifications

Introduction

Black Powder Solutions' (BPS) Magnetic Separator Systems are inline, full-flow systems for removal of ferrous and non-ferrous contamination (black powder) from fluid and gas systems.

These systems employ a magnetic array within an engineered pressure vessel that maximizes dwell time and particulate removal capability with minimal pressure drop (~0 psi ΔP in a clean system). Each system is engineered to achieve 95%+ efficiency in removing black powder contamination by accounting for design parameters such as flow rate, pressure, temperature, viscosity, medium and others. BPS Magnetic Separator Systems have the option of manual and semi-automatic cleaning systems, require a bare minimum of consumables, require no fuel or power (manual cleaning) and have a 15+ year operating life.

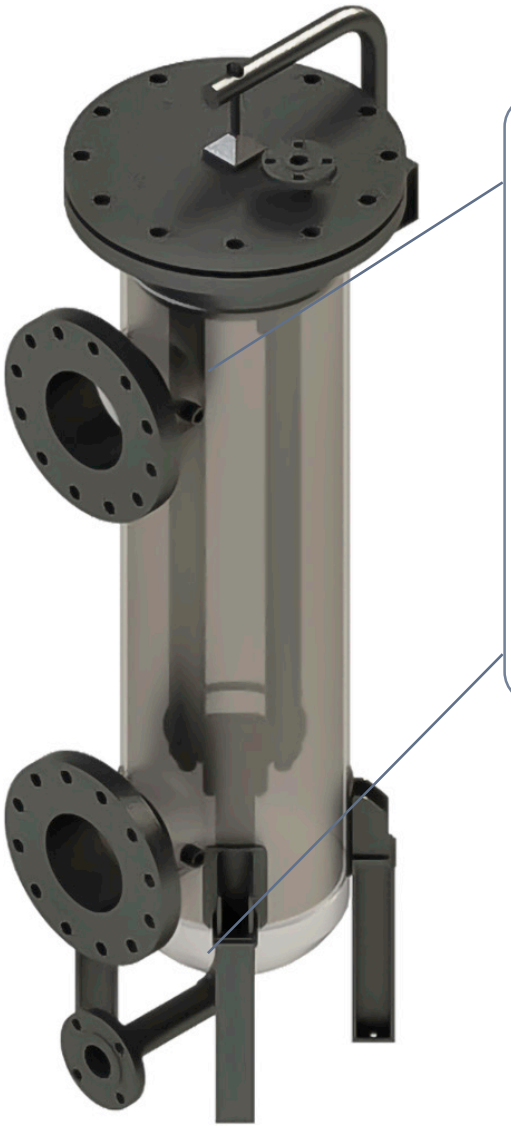
Application:

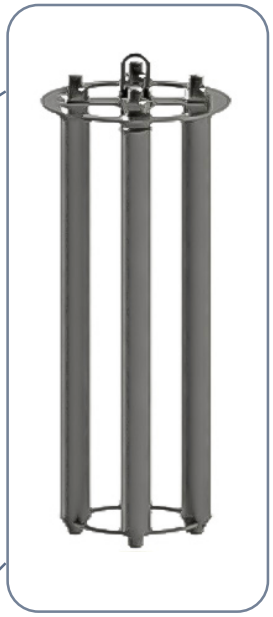
These modular systems are available for various applications in hydrocarbon liquids and gases; including applications in field separation, gas gathering and compression, gas processing, crude oil tank farms, underground storage, pipelines, fractionation, refining, finished product storage and handling, water process systems, and water process systems.

SPECIFICATIONS	
Material	304 SS, 316 SS, Duplex, Carbon Steel, exotic alloys
Engineering Certification	asme, U-Stamp, crn, ped, ce, other as requested
Configuration	Single, duplex, offset, inline ports, other as requested

Inlet / Outlet Size	Low	1" (Equivalent)
	High	72" (Equivalent)

Vent / Drain Size	Low	1" (Equivalent)
	High	12" (Equivalent)





4 x 2” OD magnetic separator elements in a 76” pressure vessel.

BPS 2” OD magnetic separator elements have a dirt holding capacity of 6.30 lb-ft.

Operating Data for a Single Magnetic Separator Unit*

	Liquid	Gas
Flow Rate*	≤ 200,000 bopd	≤ 300 mmscfd

Design Pressure	Low	≤ ANSI 150
	High	≤ ANSI 2500

Design Temp.	Low	Cryogenic Service
	Upper Temp. Limit	< 600 ºF (Magnetic Element Array)

*Duplex magnetic separator systems are available to accommodate higher flow rates.

Magnetic Separator Mechanical Properties

Mechanical Based on a 2" OD Magnetic Separator Element	
Efficiency	>95% +
Clean Pressure Drop	< 0.5 psi
Operating Pressures	All industry standards
Vibration Resistant	Yes
Operating Temperatures	300 °F max (600 °F special order)
Magnetic Separator Element	Patented technology
Black Powder Separation	< 0.5 µm — > 500 µm

Design	
Design Code	Available upon request
Area Classification	Class I, Div I, Div II
Warranty	1 Year
Maintenance Interval	6-24 Months (average)
Operating Life	15+ Years
Modular Design	Scaled to flow and contamination requirements
Cleaning Mechanism	Manual
	Semi-automatic
	Fully-automatic

- Standard magnetic separator material is 304/316 stainless steel
- Specialty alloys are available for corrosive applications

Benefits

BPS Magnetic Separator Systems require cleaning rather than filter disposal; each system offers long life service and utilizes minimal consumables. The high loading capacity allows for extended maintenance intervals of 6 months to 1 year depending on the contamination in the particular system.

- **Extended life of critical operating systems**
- **Reduction in downtime and lost production due to higher efficiency contamination capture**
- **Reduction in downtime and lost production due to extended service intervals**
- **Improved product quality**

Cleaning options

Manual

The manual cleaning system is a full standalone system. The user removes the magnetic element from the vessel and installs it in the cleaning station. The magnetic element is lifted through the scraper plate allowing the contaminants to be collected in the containment bag.

Semi-automatic

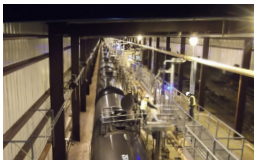
The motor and the gear box attach to the davit arm. The large and small blind flange are at the top of the vessel. The small blind flange removes, giving easy access to the internal screw and coupling. Rotation of the screw cap by the motor and gear box allows the BPS scraper plate to move up & down along the rods.

Deployment

Crude oil, condensate, NGL, LPG, natural gas, refined product and glycol pipelines

LPG & LNG loading facilities

Natural gas gathering, compression and processing facilities



Crude oil transloading

Fractionation and stabilization facilities

Pipeline pigging operations

Crude oil and petrochemical refineries

Water-based deployment in multiple, different applications

How Contamination Impacts Your Business

Operations

- Component, equipment and system failure
- Shorter service life
- Parts replacement

Production

- Degraded product quality
- Unscheduled downtime
- Production loss

Safety

- Labor required for Black Powder management
- Maintenance required for equipment failure
- Increased opportunity for injury

Environment

- Disposal of waste materials and supplies
- Consumables
- Emissions

Sample Station

Black Powder Solutions Inc. (BPS) designs and manufactures its patented magnetic separators to remove black powder contamination, below 1 micron, from liquids and gas, refined products, process fluids, water and other applications in all pipeline and facility applications to 95% plus efficiency. BPS also manufactures single magnetic element sample/test stations, where one/some of the following are required:

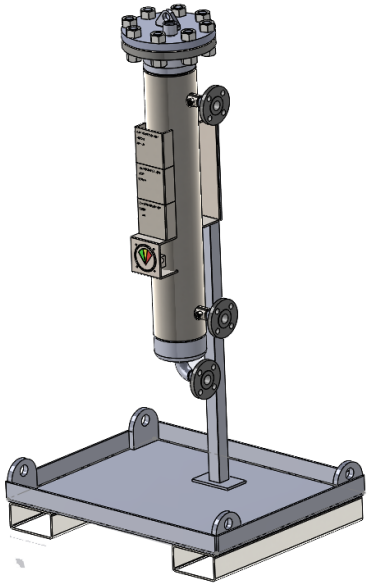
1. Identifying the source of the contamination, including policing 3rd party deliveries;
2. Capturing contamination for purposes of doing composition and particulate size analysis;
3. Determining contamination loading, such as Total Suspended Solids (TSS), at different flow rates; and/or
4. Determining the efficacy of magnetic separation in a particular application.

BPS test/sample stations are typically configured with the following specifications, or designed as per a client's specific requirements. All our sample stations utilize engineering stamped pressure vessels (U-Stamp, CRN, CE PED), are equipped with pressure differential gauges and are skid-mounted for ease of installation.

Magnetic Separator Vessel	Configuration	Pressure Class	Inlet / Outlet Drain / Vent	Flow Rate*	Pressure Differential
5" ID x 40" L	(1) 2" OD x 26" L magnetic element	150# 300# 600# 1500# (others)	2" OD 1" OD 3/4" OD (ORB, NPT, others)	≤ 1,400 bpd ≤ 1.0 mmcfd	≤ 0.5 psig (clean) ≤ 6 psig (full)

* The same test magnetic separator can be used in both gas and liquid; flow meter/totalizer available.

Our sample/test stations are also configured with sample ports in order to allow for product sampling before and after magnetic separation has occurred. The magnetic element is easily removed from the magnetic separator and can be weighed for purposes of determining contamination loading prior to the contamination being wiped from the magnetic element. We always recommend laboratory testing such as XRD, EDS, particle size distribution (PSD) and TSS of the before, after and removed solids samples from multiple separate tests to properly understand the particulate contamination in a given system.



Capturing Non-ferrous Contamination

Black Powder Solutions' magnetic separator systems capture black powder particulate contamination, which includes both ferrous and non-ferrous particles. It is well known that ferrous materials are attracted by magnetic forces; however, the capture of non-ferrous particles by magnetic forces is less understood.

Non-ferrous particles are magnetically captured due to cross-contamination with ferrous particles. All particulate contamination becomes electrostatically charged due to physical interactions with other particles and surfaces, such as in pipelines or in hydrocarbon processing applications. This electrostatic charge causes negatively and positively charged ferrous particles to adhere to positively and negatively charged non-ferrous particles. The ferrous particle in this particle pair is then drawn to the magnetic element within the magnetic separator system.

There are other forms of adhesion that also cause the pairing of ferrous and non-ferrous particles, including embedding and capillary forces, although static pairing is the largest contributor to this process.

How electro-static charge is induced

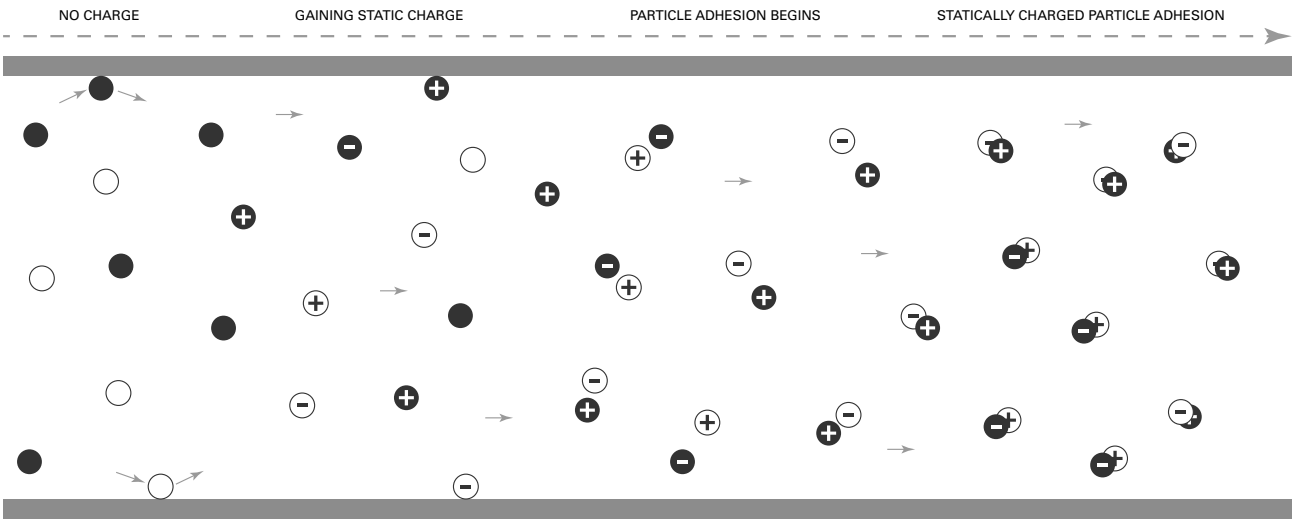
Electrostatic charge is generated whenever there is friction between two bodies moving relative to one another. Charge generation occurs on the molecular level at the interface of any two unlike materials, so a static charge will be generated in any moving fluid, with positive or negative charges moving from the fluid onto the bounding surface.

The causes of electrostatic charging include the following examples:

- **Friction caused by fluids and gasses flowing in pipelines**
- **High fluid velocities**
- **Passage of fluids or gasses through filter elements or other microporous structures**
- **Turbulence created by pumping or compression, particularly centrifugal units**
- **Fluid discharging on to the free surface of a storage tank**

Contaminants gaining charge

The amount of charge generated by the flow of a hydrocarbon liquid and filtration is related to several fluid and filter properties. Charge generation typically strengthens with increasing flow, reducing fluid conductivity, with certain additive packages and with increasing viscosity. Charge accumulation increases with lower fluid conductivity, lower temperatures and higher viscosities.



Refinery - Diesel Fuel Cracking Column

Gulf Coast Refinery, USA / 2016-2017

Problem

Minimal quantities of black powder would plug the suction screens in front of the product pumps. This could happen multiple times per shift leading to constant swapping of pumps, insulation removal, and pipe disassembly to access cone strainers for cleaning. Often, the line leading to the strainer would also plug off, and the pipe required manual cleaning to the back of the valve.

Solution

Install an inline magnetic separator system upstream of the product pump.

Result

The magnetic separator system holding strength allows for extended cleaning intervals, and reduced the maintenance requirements for cleaning the witch hats; outages were successfully prevented.

The magnetic separator system also prolonged the coaleser change intervals; the clay filter elements' operating lives were extended so that 15 sets of changes were eliminated annually. Additionally, the resultant product cleanliness allows for the diesel fuel to be sold at a premium.

Crude Stabilizer - NGL

Texas, USA

Problem

NGL product has high levels of black powder contamination coming out of the stabilizer column. The contamination was causing damage to the pumps, meters, and valves downstream; off-spec product was getting rejected by third party pipelines.

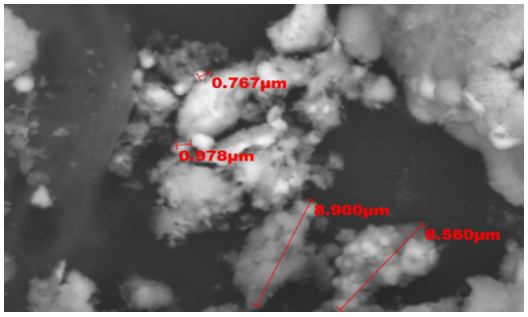
Solution

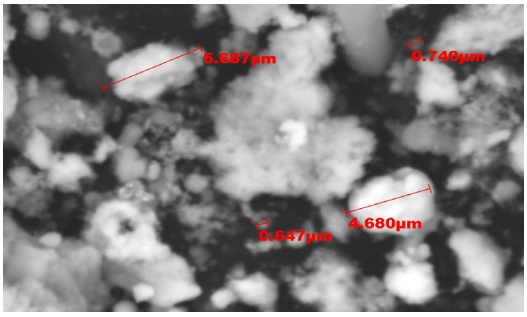
A magnetic separator system was installed in the discharge of the NGL going to the pipeline pumps.

Results

Analysis of the contamination determined a composition of 83% iron oxide, 9% carbon, 7% dust, as well as dirt, fibers, a grass seed, and trace amounts of chrome, manganese and titanium.

Application Data	
Operating Fluid	NGL
Operating Pressure	200 psi
Operating Temperature	90° F
Max. Flow Rate	200 gpm





Refinery - Desalter System

Gulf Coast Refinery, USA / 2016

Problem

Black powder contamination prevented the desalter system from efficiently purifying process water; rather, the facility required expensive, deep well injection of the crude-contaminated water. The Pentair system had been increased to 25 microns in order to get a 5-8 day cleaning schedule, at a cost of $13,000 per element change out and disposal. As a result, the Pentair unit was unable to protect the MycelX VOC, rendering it out of service.

Solution

Install parallel, dual-inline magnetic separators between the desalter vessel and water tanks, prior to the Pentair system. This system is designed for continuous filtration during cleaning.

Results

After initial installation, the systems caught ~24 lbs/day of black powder. With magnetic separator protection, the Pentair filter was changed to a 5 micron polishing filter. Pentair filter change outs have extended to 130 days, eliminating 65 change-outs annually. The levels of solids loading dropped significantly, allowing the MycelX unit to operate.

Currently systems catch ~20 lbs/day of black powder.

Total Annual Equipment Cost Savings

$2,000,000

Black powder collected on the first magnetic separator element after 18 hours of operation.

Kerosene Pump Around Loop

Gulf Coast Refinery, USA

Problem

Crude oil feedstock entering the refinery is loaded with high volumes of black powder contaminants. The entire unit was experiencing issues with black powder building up and plugging the suction screens in front of pumps.

Solution

Deploy a magnetic separator on the kerosene pump around loop to protect the pump.

Result

During a recent cleaning, the magnetic separator system protecting Pump 104 had collected not only black powder, but a group of piping knockouts from a recent facility upset. Had they entered the pump impeller and become stuck, the facility would have had to replace the pump resulting in lost product on unplanned maintenance.

Black powder collected after six weeks of operation.

Application Data	
Operating Fluid	Kerosene
Operating Temperature	450° F
Max. Flow Rate	1500 gpm

Natural Gas Fuel Dispenser Inlet

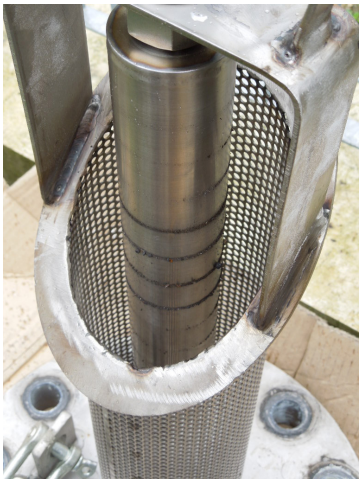
Italy

Problem

Black powder contamination was damaging meters, valves, and compressor seals. Costly monthly maintenance was required to repair and clean the piping system and compressor components.

Solution

Install a high-pressure magnetic separator upstream of the compressor.



Analysis of the contamination collected indicated high levels of non-ferrous particulate caught by the magnetic elements

Results

After the initial cleaning, a significant amount of ferrous and non-ferrous black powder was captured. The magnetic separator system is still currently installed and operating at full efficiency. No maintenance crews have been required to repair the compressors since its deployment.

Particle Composition (ppm)			
Iron	> 2000	Silicon	417
Chromium	3	Sodium	46
Nickel	11	Vanadium	<1
Molybdenum	<1	Potassium	41
Aluminum	58	Calcium	196
Lead	20	Magnesium	60
Copper	13	Phosphorus	154
Tin	< 1	Zinc	93
Silver	< 1	Barium	< 5
Titanium	5	Boron	10

Natural Gas Transmission Line

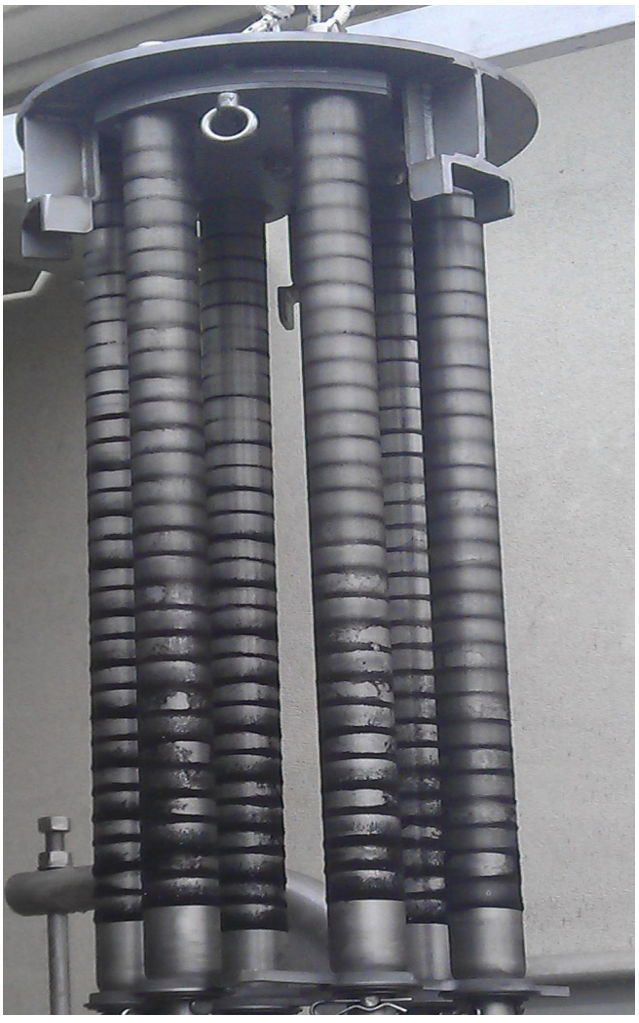
Portugal

Problem

High volumes of black powder contamination in natural gas feed stock were plugging off conventional filtration systems on a 6” OD natural gas transmission line with a flow rate of 2,500 m3/hr.

Solution

Install a magnetic separator system upstream of the depth media filters to remove both ferrous and non-ferrous black powder down to sub-micron levels without impeding flow.



Results

The photo shows contamination removed after the system’s first week of operation. Conventional filters downstream remained clean, helping to identify that 95+% of the black powder was removed by the magnetic separator elements.

Petrochemical Facility - Feedstock

South Korea / 2016

Problem

A petrochemical facility in South Korea needs to protect their facility from condensate feedstock loaded with black powder contamination. The contamination was coming from the refinery and tank farm upstream.

Solution

Install and operate a magnetic separator system on the inlet feed stream to remove black powder from product flowing at ~70,000 bopd.

Result

Up to 200 lbs/day of black powder was collected; the magnetic separator system was designed to be oversized for maximum contamination holding capacity. The system continues operation with focus on the refinery upstream. If the data is extrapulated, it can be determined that 10,037 lbs (4.55 tonnes) of contamination was collected in the span of 1 year.

Application Data	
Operating Fluid	Condensate
Operating Temperature	463.7° F

Magnetic Separator	
Vessel	48” OD x 100” L
Magnetic Elements	32 x (2” OD x 74” L)

Pigging: Condensate Pipeline

Saudi Arabia / 2016

Problem

Black powder contamination in the condensate stream leaving a fractionator is accumulating on the pipeline walls. During pigging operations, the contamination is liberated back into the product.

Solution

As a proof of concept, the customer installed a 5" OD, 300#, 316 SS magnetic separator skid, on a 1" OD slipstream line, off of a 14" OD pipeline, for 8 days to test:

(1) Removal of black powder in post-pigging operations vs. conventional filtration, and
(2) Dirt holding capacity of a BPS system vs. conventional filtration.

The BPS system was tested after pigging operations, and 2.9 kgs of black powder was captured.

After the 8 days, testing showed the conventional filtration plugged off and caused a 25 psi pressure drop. In comparison, the BPS system registered 0 psi pressure differential while loaded with contamination.

LPG Loading Terminal – Loading Arms

Texas, USA / 2017

Problem

The plant inlet conventional filters allow black powder contamination to enter the facility and in turn, damage pump and compression equipment. During the loading process, small quantities of black powder plug off the basket screens, extending loading hours, and creating costly downtime and demurrage penalties. Missed loading windows lead to an averaged $50,000/incident, and ~$250,000/annual demurrage.

Solution

Install a magnetic separator system upstream of the conventional filters.

Result

In one year, there were no unplanned shutdowns during loading. This eliminated demurrage and excess labor costs required for the isolation, venting, purging, cleaning, and venting of the screens. The facility owner/operator has since ordered a number of additional BPS Magnetic Separator Systems for deployment in various NGL applications.

Glycol Circulation Pumps

Italy / 2013

Problem

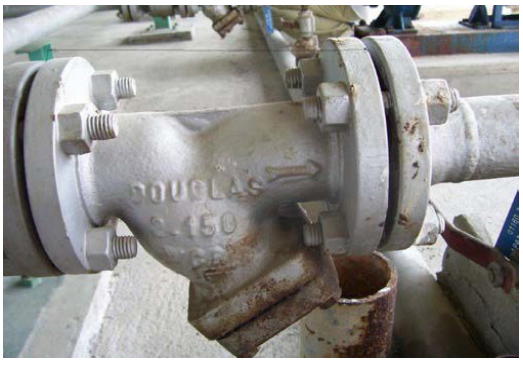
High concentrations of black powder contamination in the glycol system composed of particles too small for a y-strainer filter screen to remove. This corrosion resulted in abrasive iron sulfides and iron oxides reducing the life of the glycol, and wearing on the circulation pumps and components.

Solution

Install a magnetic separator upstream of six pumps to test its capability of removing black powder contamination to sub-micron levels.

Results

A significant amount of black powder was removed from the glycol system that otherwise would have easily passed through mesh screens. Since installing the magnetic separator systems in 2008, the pumps have operated at full efficiency without failure.



Power Plant Heated Water Line

Calgary, AB / 2018

Problem

Conventional basket strainer filtration was unable to remove corrosion contamination from a heated water line.

Solution

Install magnetic separator elements into existing basket strainer as a proof of concept.

Results

Contamination shown in the pictures was collected after 3 months of operation. Now the unit has been installed for 1.5 years, and the customer is looking to install BPS magnetic separator systems on their glycol systems and heat exchangers.

Total Refinery Protection

Gulf Coast Refinery, USA / 2015 -2019

Problem

Crude oil received by barge and pipeline is highly contaminated with black powder contamination. It enters the crude unit and causes (1) increased energy use to heat the crude feedstock, (2) lower product recovery efficiency, (3) trays to fill up, plug off and collapse, (4) more frequent and intensive turnarounds (TARs), which take longer to complete, and (5) contamination to move further into refinery process equipment.

Solution

Initially deploy BPS magnetic separator systems on all major pumps downstream of the atmospheric distillation column to remove contamination and lower energy use, prevent unscheduled downtime and facility upsets, extend the TAR cycle and improve product quality.

Results

The crude unit and overall facility is running much more efficiently with minimal downtime with BPS magnetic separators in place. As of June, 2019, there are BPS magnetic separators on the desalter process water, on the pumps identified in the table below and the refiner is looking at additional deployments on pumps and in the crude feedstock.

Refinery Magnetic Separator System Deployment			
Pump 102	Crude Reflux Pump	660 gpm	245° F
Pump 104	Kerosene Product Pump Around Unit	300 gpm	450° F
Pump 105	Distillate Product (Diesel) Pump	150 gpm	550° F
Pump 107	Distillate Product Pump Around Unit	1200 gpm	550° F
Pump 108	Kerosene Product Pump Around Unit	1200 gpm	450° F
Pump 110	Crude Reflux Pump	260 gpm	145° F
Pump 111	Crude Column Overhead Water Drum Pumps	15 gpm	140° F
Pump 115	LPG Product Pump	6 gpm	120° F

Pump 108 Kerosene

Crude oil in the refinery feedstock, loaded with black powder contamination.

Pump 107 Diesel Fuel

Contamination collected from finished distillate product: diesel fuel and kerosene, after 6 weeks of operation. The magnetic separator systems cleaned the product to the standard that it did not require clay-filter color removal.

Black Powder Solutions

MAGNETIC SEPARATION TECHNOLOGY

Effective removal of contamination in upstream, midstream,
and downstream facilities and operations.

www.blackpowdersolutions.com