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# Effect of Black Powder contaminants on Gas metering equipment

**Nikolaos A. Tsochatzidis** *

*Hellenic Gas Transmission System Operator (DESFA) SA,*
*207, Messoghion Ave., 115 25 Athens Greece*

## Abstract

Black powder is usually found in natural gas transmission and distribution systems throughout the world. The Hellenic gas transmission system was constantly subjected to large volumes of black powder, mainly pipeline corrosion product, originated upstream and carried in the gas flow. Due to amorphous nature of this powder, particles was breaking up to sub-micron sizes, flowed through filtration devices, agglomerated to larger sizes downstream and deposited in metering lines, instruments, analysers etc.
The impact of black powder on gas measurement equipment is examined at this case study. Metering instruments may deviate beyond acceptable tolerance due to powder contamination. Cleaning works of metering runs, impulse lines, transmitters and gas analysers are presented together with photographs of the operations. Maintenance best practices are described.

## Introduction

Solid contaminants found in natural gas transmission and distribution systems, known as Black Powder, are causing increasing concern in the natural gas industry worldwide. This detrimental powder can be created by chemical or biological reactions with steel found in natural gas pipelines, gas wells and associated facilities. Black powder can be detected in both dry and wet gas pipelines and in conjunction with other contaminants such as oil, grease, liquid hydrocarbons and sand [1].
Black powder is influencing the flow performance of the gas pipelines and also it can impair the function of installations such as valves and measurement systems. Therefore, the development of specific inspection and cleaning methods for black powder is an important challenge [3].

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* n.tsochatzidis@desfa.gr

The Hellenic Gas Transmission System Operator (DESFA) SA, founded in 2007 as 100 % subsidiary company of DEPA SA, is operating and expanding the national gas transmission system.

The Greek gas transmission system faced the first operational problems due to the existence of black powder in the imported natural gas some years ago [5]. A pigging operation performed that time at the first 12 km section of the Greek high pressure gas network, which removed 1000 kg of powder. During the following years, the carry over of black powder contamination into the network increased gradually as gas off-takes increased also. The powder was gathering in the gas piping and installations, resulting in reduced flow efficiencies, clogged and collapsed filters, depositions on gas measurement devices, clogging of instrumentation and increased deterioration of valves due to erosion. Although, the greatest accumulation of black powder was in the first segment of the network immediately downstream of the Bulgarian / Greek borders, flow migration of the powder in significant quantities was documented down the mainline pipelines to various downstream system lateral lines and customer delivery points.

The most common means to fight solid contaminants is filtering them at the entrance of processing plants or networks. However, due to the nature of black powder, particulates can shear easily to sub-micron sizes and pass through gas separation devices and filters. Consequently filtration, as a means of controlling black powder in flowing gas streams, is extremely difficult. The primary facilities to remove black powder from gas were two vertical cartridge filters at inlet of the Border Metering Station. The separation efficiency of these filters was 100 % for particles larger that 3 μm, and 99 % for particles 0.5 – 3 μm. Eventhough the maintenance staff was obliged to clean and replace the cartridges of these filters on an almost continuous basis, black powder deposits were found downstream of them. Other gas filtration devices along the gas network were plugged regularly and had to be replaced. The extra maintenance load on the new transmission system, due to the existence of black powder, was greatly increased workman hours to keep the system functional and safe. The economic impact on the newly constructed gas system was exorbitant and was mounting everyday.

In order to further protect the downstream system from the black powder consequences, the company installed two cyclones (centrifugal) filtration facilities, at the starting point of the Greek network, with separation efficiency 99 % for contaminants larger than 5 μm. Operation of these cyclone separators proved a very efficient way towards the removal of black powder. Additionally, a series of pigging operations were organized at the contaminated pipelines. Also, cleaning operations were performed by purging specific pipeline sections. All vented gas quantities were heavily contaminated with black powder. An extensive description of the harmful consequences of black powder existence at gas pipelines and the experience gained from the cleaning operations was reported elsewhere [5] [6].

However, irrespectively of the cleaning operations and filters' efficiency, small enough particles flowed through filtration devices and agglomerated to larger sizes downstream. Traces of black powder were detected in metering lines, fiscal metering instruments, analysers, density meters and control valves. At this case study the effect of black powder on gas metering equipment is presented and evaluated. Guidelines for checking and cleaning the instrumentation are given. A laboratory analysis of the black powder is also presented.

## Laboratory Analysis

Samples of black powder were extensively analysed for their chemical composition and particle size distribution. Samples were taken from debris of pigging operations or from filters' deposits. The tests results are tabulated on Table 1. It is evident that black powder consists mainly of magnetite (iron oxide), namely pipe corrosion product, a form of rust. As the name indicates the powder is strongly magnetic. All the other compounds determined by the analysis can be found in common dirt. The magnetite is most likely the result of chemical reaction between iron in the piping and water. Other elements in the chemical analysis may also be components of the pipe alloy (Mn, Mg). The bulk density of black powder samples was determined to be 1.7 $gr/cm^3$.

Consecutively, the black powder consists of approximately 80 % corrosion products and the remaining portion is typical soil minerals. The corrosion products were generated into the uncoated steel pipes upstream and mitigated later to the Greek network with the gas flow. It should be pointed out that the literature regularly associates the term black powder with the presence of iron sulphide [2]. However, the powder examined at this study contained practically no sulphur compounds.

The results of particle size analysis are varied due to the amorphous nature of the powder. A dominant peak at ~ 30 μm is observed. However, large particles together with sub-micron flakes are detected. Large particles are staying in the filters and dropout vessels, while the smaller ones are carried downstream and tend to agglomerate due to their magnetic properties [6].

## Contamination on Gas Metering Installations

As mentioned above, even though the cyclone and cartridge filters were operated continuously, black powder deposits were found downstream of them in metering lines, fiscal metering instruments, analysers etc. Irrespectively of the filters' efficiency, small enough particles flowed through filtration devices. An investigation was carried out to determine whether black powder had entered into the fiscal metering instrumentation and associated installations. All instruments and installations of DESFA's Border Metering Station (BMS) were examined and the results are presented in this study. Reported findings are mainly of the year 2001.

### *Orifice plates*

Gas quantity is measured at BMS by means of pressure differential devices (orifice). Heavy deposits of black powder were found on the upstream face of orifice plates. Figure 1 (*left side*) presents an orifice plate covered by a thick layer of black powder. This layer consists of black powder together with some oil or grease to give to the mixture adhesive properties. For comparison a clean plate is depicted also at Figure 1 (*right side*). This dirty orifice plate was removed from a metering line after about one month of operation. The upstream and the downstream face of the removed orifice plate had black powder deposits.

### *Metering Lines*

Contamination of black powder existed at the inner metering lines, which could affect their roughness. Contamination may shift the pipe roughness from higher to lower values, by filling the relatively rougher underground to a smoother surface. The alteration of inner pipe roughness upstream of the orifice plate is affecting the discharge coefficient, $C_d$, (see ISO 5167) thus increasing the overall uncertainty of the gas quantity measurement [4]. Such effect on $C_d$ factor is caused due to the fact that the shape of the flow profile alters. Furthermore, since this effect vary with time in an unpredictable way, it is very difficult to apply corrections retrospectively.

### *Impulse Lines and Manifolds of Instruments*

The instruments' arrangement of a metering line at BMS is depicted on Figure 2. At all metering lines the impulse lines feeding the pressure transmitters contained black powder. Also, all primary isolation valves of impulse lines contained black powder. Two isolation valves had to be changed for this reason. The 3-valve and the 5-valve manifolds of the fiscal pressure transmitters had sufficient black powder quantity on their valve seats. Some of these valve seats were permanently damaged.

***Influence on Pressure Measurements***

The performance of instruments was affected by the presence of black powder. Fiscal metering instruments were subjected to a regular calibration, on a monthly basis, to verify their performance. Such calibration results for a representative Differential Pressure transmitter (Tag No FT 20101C) are depicted on Figure 3. The calibration range of this transmitter is 0 – 500 mbar and its tolerance is ± 0.0040 V. It is evident that the instrument's output exhibit a large hysteresis (shift) between ascending and descending applied pressures. The recorded hysteresis at the maximum range (100% of range = 500 mbar) is particularly high (0.0046 V), although these calibration results are marginally acceptable. In should be mentioned that a clean transmitter has a negligible hysteresis at the same test.

Based on above findings, it is highly likely that this instrument may deviate beyond acceptable tolerance, when it is put back to operation. Indeed, when this specific pressure transmitter was put to operation, a high DP deviation alarm was raised at the corresponding flow computer. The DP transmitter was dismantled and inspected. The manifold and associated impulse lines were heavily contaminated by black powder. Figure 4 presents this pressure transmitter as found during the inspection. Both diaphragms of this transmitter were almost blocked by black powder deposits.

***Water Dew Point Analyzer***

The inlet filter of the WDP Analyzer was approximately 80 % full of contaminant, which had passed into the pipe beyond the filter and found in the sample line just before the dew point sensor. The sensor had a porous surface and it was likely that the contaminant migrated into it.

***Gas Chromatographs***

Traces of black powder were detected at the inlet filters of the sample lines of the on-line gas chromatographs.

***Specific Gravity Meters***

The impulse lines and the pressure reducers were contaminated by black powder, as well as the catch pots.

***On-line Densitometers***

Figure 5 *(left)* depicts parts of a ball valve at the impulse line of an on-line densitometer. The seats of this valve were heavily contaminated by black powder. The inlet pressure filters of the densitometers were full of powder, as Figure 5 indicates (*right*). The low pressure internal filters were contaminated also and black powder had passed onto the sensitive vibrating cylinders of the densitometers. The densitometers were sent to the manufacturer's laboratories for maintenance. The manufacturer confirmed that the densitometers' sensors were contaminated with black powder.

## Corrective Actions

In order to prevent damages of the metering instruments, a regular inspection for black powder existence was performing together with the monthly inspection and calibration of fiscal instruments. During such checks the picture descript above was repeated. A large amount of black powder was detected at instruments of all metering lines. There was a danger of the impulse lines to be plugged by black powder contaminants.

In order to avoid abnormal operation of the instruments and reduce possible errors of the gas measurement, a regular cleaning program was applied. All transmitters, found in situation similar to this depicted in Figure 4, were thoroughly cleaned by blowing compressed air. The diaphragms of the transmitters were carefully cleaned with acetone solution.

Also, all manifolds and impulse lines were thoroughly cleaned during the monthly calibration process, before the re-installation and operation. The impulse lines were purged with air and nitrogen. Additionally, a special air tool was used to push pellets of cylindrical sponges into the tubes of impulse lines. The special air tool is presented at Figure 6 together with the pellets for the cleaning of the internal surface of the impulse lines. The white colour special pellets were turned to black colour after just one pass from an impulse line. This air driven pellet launcher is suitable to remove contamination of hoses, tubes or pipes.

## Conclusions

Fighting with black powder in gas flow is not an easy task. Gas metering facilities and other key installations must be protected by cartridge filters. Upstream cyclone separators are very effective to remove large quantities of black powder.

However, any filtering device is not capable to totally protect measurement installations. Particles can shear easily and break up to sub-micron sizes, which makes filtration extremely difficult. Large particles are staying in the filters, while the smaller ones are carried downstream, agglomerate due to their magnetic properties, and deposit to metering instruments and other installations.

To protect sensitive gas metering facilities additional corrective actions should be planned and executed with the most efficient manner. The key issue is which technique provides the most efficient and cost effective method for the physical removal of the black powder out of the gas installations. Before the application of any cleaning method, it is essential to gather comprehensive information about the nature of the problem. A regular dismantling and cleaning of the metering instruments, manifolds, impulse lines and associated facilities is necessary to keep the metering system in good operation.


## Acknowledgements

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**Table 1.** Results of black powder analysis and characterization

**1.** Crystalline Phase Identification Analysis (X-ray diffraction, Siemens D-500):

| | |
|---|---|
| Major components: | Magnetite ($FeFe_2O_4$) |
| | Quartz ($SiO_2$) |
| Minor components: | Goethite (FeO(OH)) |
| | Bementite ($Mn_5Si_4O_{10}(OH)_6$) |
| | Manganese Oxide ($Mn_3O_4$) |
| | Albite ((Na,Ca)Al(Si,Al)308) |
| | Cordierite ($Mg_2Al_4Si_5O_{18}$) |
| | Butlerite ($Fe(OH)SO_4.2H_2O$) |

**2.** Qualitative Elemental Analysis (Jeol 6300 scanning electron microscope and Isis 2000 X-ray Energy Dispersive Spectroscopy analysis):

| | |
|---|---|
| Main components: | Fe, O |
| Minor components: | Si, Al |
| Trace components: | Mn, Ca, K, Na, Mg, S |

**3.** Particle Size Analysis (laser diffraction Malvern Mastersizer-S)

Bimodal particle size distribution with a dominant peak at ~ 30 μm and a secondary peak at ~ 0.3 μm.

*The analysis was performed with wet dispersion and with the use of ultrasonic*.

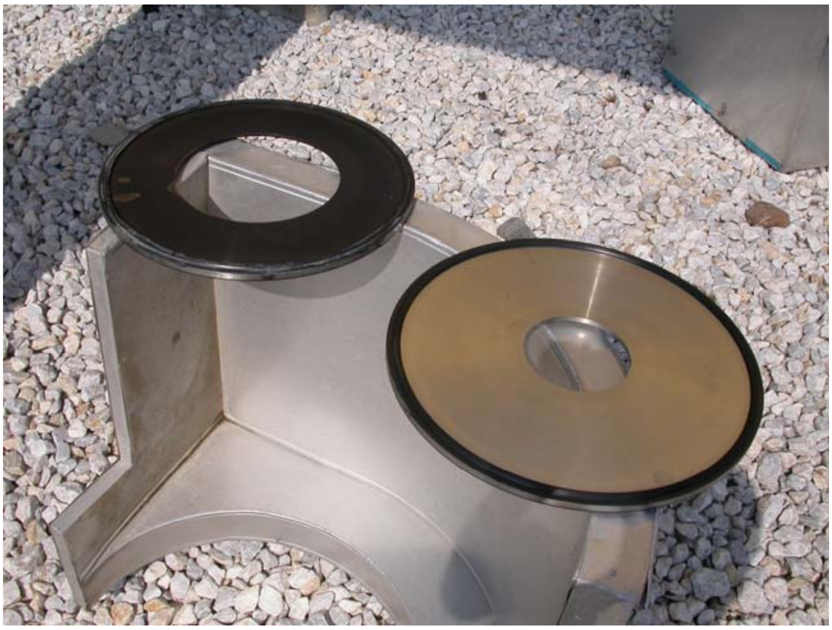

**Figure 1.** A contaminated with black powder (*left*) versus a clean (*right*) orifice plate. The bore diameter of the two orifice plates is different.

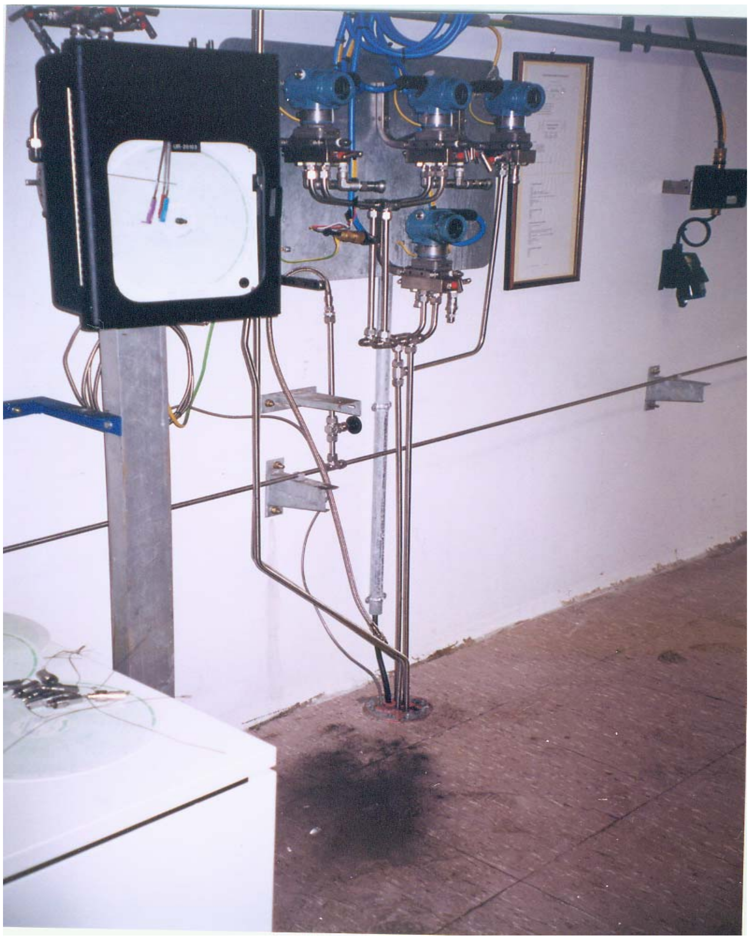

**Figure 2.** Instrumentation of a gas metering line. Black powder removed from only one pressure transmitter is appearing on the floor.

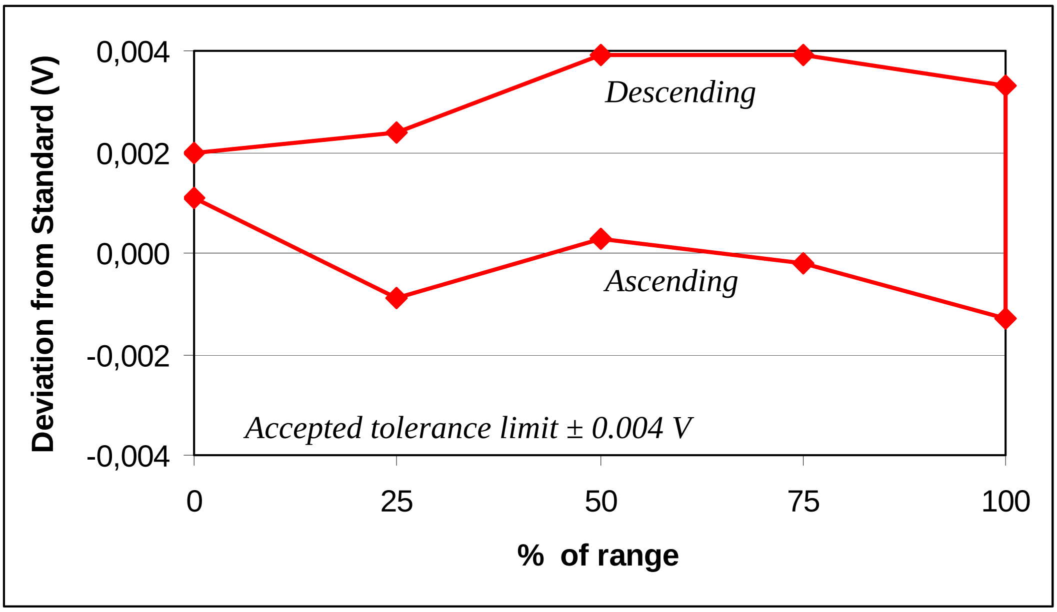


**Figure 3**. Calibration results of a Differential Pressure transmitter with black powder contamination. A large hysteresis is observed between response for ascending and descending applied values.

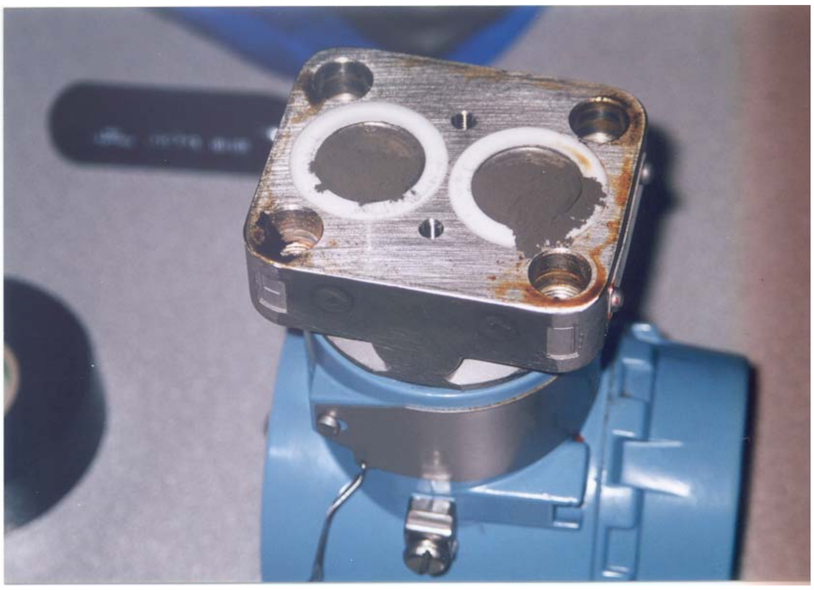

**Figure 4.** Pressure transmitter almost blocked by black powder deposits.

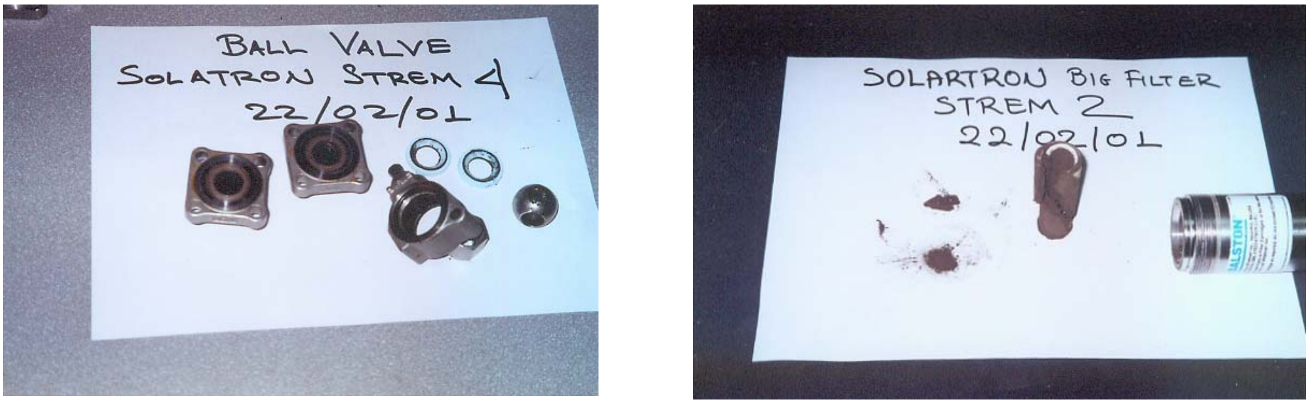


**Figure 5.** *Left:* Parts of a ball valve at the feeding line of an on-line densitometer heavily contaminated by black powder.
*Right:* The inlet filter element of an on-line densitometer covered by black powder.

**Figure 6**. The pellet launcher *(left)* used to remove black powder from gas metering impulse lines, and the special pellets used *(right)*. The white colour pellets were turned to black colour after one pass from an impulse line.