Pipeline Pigging and Integrity Technology

FOURTH EDITION

Pipeline Pigging and Integrity Technology

FOURTH EDITION

John Tiratsoo, Editor

Pipeline Pigging and Integrity Technology
Fourth Edition

Published by
Tiratsoo Technical
(*a division of Great Southern Press*)
PO Box 21, Beaconsfield, HP9 1NS, UK
and
Clarion Technical Publishers
3401 Louisiana, Suite 255, Houston, TX 77002, USA

ISBN 978-0-9575310-0-0 (UK)
ISBN 978-0-9717945-8-0 (USA)

Library of Congress Control no.: 2012956267

Set in 10/12pt Goudy Old Style

Printed by KnowledgePoint, Earley, Reading, RG6 4UT, UK

Table of Contents

Note: the Table includes the substantive section headings from each section. Authors' contemporary affiliations are shown at the introduction of each paper: due to the passage of time, some of these have inevitably changed. The date given after each title is the date of the original presentation or publication.

Section 4: Failure assessment

Section 5: Integrity management

Section 6: New technology

Section 7: Operations

❖ ❖ ❖

List of contributors

❖ ❖ ❖

Preface

IT IS HARD to remember that when the first edition of this book was published, in 1988, the internet had not kicked-off, email was almost unheard-of, and txt msgs were a concept of which no-one had dreamt. In the world of pigging (almost considered an 'art' in those days, not the 'science' which it has become), the issues of high resolution vs low resolution were being wrestled with in the early developments of the inspection industry, and the difficulties provided by unpiggable pipelines were only just beginning to be acknowledged.

The intervening 25 years have, of course, seen massive advances in communications, as well as in this industry. But, surprisingly, some matters remain sources of concern, and some problems have got no closer to solutions than they were in the days of typewriters. The inspection industry is not in the latter category: superb high-technology solutions have been developed, using some of the most advanced and reliable technology, paralleling the aerospace industry, and feature assessments down to millimetric sizes are almost the norm. Inspection data interpretation has also developed to the stage where it's no longer a black art: survey results can be examined and analysed on a client's own PC or laptop, the thought of which was almost unheard of only a decade ago. But still some basic questions remain unanswered, probably the most basic of all being 'how clean is my pipeline?', and 'how best to design a pig launcher and receiver?'.

The pigging industry has developed a tremendous range of techniques and technologies, and it's probably fair to say that there are few pipelines that cannot be cleaned and inspected, although the success of such operations will sometimes depend on the available budget. There is, however, a fantastic global resource of expertise, equipment, and experience in the pigging and inspection industry, and its successful application is testified to by the rarity of pipeline failures and the safety with which millions of litres and cubic metres of hazardous materials are daily transported around the world without effect on the communities through (or under) which the pipelines pass.

This book, as with previous editions, provides an overview of some of the latest thinking and achievements in the area of pigging technology and integrity management. Its content is 41 papers from the series of conferences entitled *Pipeline pigging and integrity management* (now known as PPIM) that the publishers have organized in Houston and elsewhere between 2007 and 2012, chosen to represent a wide range of issues concerning the pipeline industry and maintenance of its integrity. I am most grateful to the authors of these papers, as well as to the others on our conference programmes, all of whom have been willing to share their thoughts and experiences, answer questions, and stimulate discussion.

As many readers will be aware, technology has not only moved on in great leaps in the pipeline and communications' industries, but also in publishing. This means that – more than ever – any errors in this book are solely the responsibility of the editor, and absolutely not that of the contributors. I hope very much that any that there are do not detract from the important issues being described.

Some readers will also know that I have been enormously privileged to be part of a superb group developing the 'pigging conferences', the chief members of which have been my good friends BJ Lowe and Gerri Ayers. Clarion's Traci Branstetter has been – and continues to be – an astonishing and dedicated administrator for our events, and other more recent additions to the group include Lyndsie Mewett (now Lyndsie Clark) and my colleagues from Australia, and Liz Foster in our UK

office. While it is my enormous privilege to have my name on the front (and rear!) cover, this is only possible as a result of the valued friendships and unselfish support these good people have provided.

In closing, I must acknowledge my thanks to two others from the industry. The first is Cees Bal, who gave us the original idea in 1982 to organize a conference on pigging, following his ground-breaking event in The Netherlands the previous year ('Pigging: an art...or a science?'). The second is someone who did more than anyone else to set the foundations for the way the industry has developed over recent decades: Jim Cordell. Sadly now no longer with us, Jim was a great friend and tremendous contributor. He was the founding father of the Pigging Products & Services Association, and guided its development for many years; he was a great speaker and trainer, and if the industry ever had an orator, Jim was it. He was also a generous supporter of the events mentioned above, and loved little better than having an excuse to talk – with irrepressible humour and great knowledge – about the astonishing and fascinating subject of pipeline pigging.

John Tiratsoo
January, 2013

Nam et ipsa scientia potestas est.

For knowledge itself is power.

Meditationes Sacrae (1597) 'Of Heresies'
Francis Bacon (1st Baron Verulam and Viscount St Albans) 1561-1626
English lawyer, courtier, philosopher, and essayist

Section 1: Cleaning and black powder

Black powder migration in gas pipelines and associated problems

by Dr John S Smart[1] and Robert Winters[2]

1 John Smart Consulting Engineers, Houston, TX, USA
2 Champion Technologies, Lafayette, LA, USA

BLACK POWDER, a mix of iron sulphides, oxides, and other material can represent a serious threat to the integrity of gas pipelines by plugging pipelines, eroding compressor components, plugging instrumentation and pipeline drips, preventing valid in-line inspection by in-line inspection (ILI) tools, and causing damage to customer equipment. The velocity to cause movement of dry black powder in gas pipelines can be calculated, and is in the range of 12 ft/sec for 24-in pipelines. Once black powder starts to move, it will continue to move until the flow rate is reduced or the gas is compressed. Examples of black powder problems in the field are presented, and rules of thumb discussed about cleanliness in gas pipelines. Black powder can be partially controlled by using corrosion inhibitors, by using slug catchers or cyclones, or cleaning the line by pigging.

BLACK POWDER is the least understood but most prominent contamination problem in gas pipelines [1], and is a problem that is increasingly being recognized. Black powder is the name given to the mixture of iron oxides and sulphides found in gas pipelines, and can also include salt, sand, clay, mineral scales such as calcium carbonates and gypsum, strontium and barium sulphates, NORM (naturally occurring radioactive material), and metal powder. The sources of black powder include millscale, corrosion products, salts and scales from gas wells and wet gas gathering systems, and atmospheric rusting [1]. The variability of black powder is illustrated by reports of the powder being completely iron sulphide [1] to completely iron oxide [2]. Figure 1 shows an electron photomicrograph of magnetite black powder. Red rust (rouge) can be present both from atmospheric oxidation of pipe not properly stored nor cleaned, or from air oxidation of pyrophoric iron sulphide. Dry iron sulphide powder will spontaneously ignite if exposed to air,

Fig.1. SEM photomicrographs of black powder. Particles range from about 100 microns and smaller. SEM Photomicrographs courtesy of Edgar Zapata, Anderson & Associates, Inc., Houston, TX.

and represents a safety, storage and disposal problem. This paper will illustrate that the problem of black powder is as much one of powder movement as one of the presence of black powder.

Black powder movement in gas pipelines

Wicks [3] has developed a theory to predict the movement of dry black powder in pipelines based on drag by fluid velocity. The velocity required to pick up and move black powder solids depends on gas density and viscosity, particle size and density, and pipe inside diameter. The theory is based on lifting particles out of a bed of particles to form a single powder particle that then can be moved by gas flow. The analysis has been presented by Smart for movement of solids in liquid and natural gas pipelines [4, 5]. Once freed, powder will continue moving in a pipeline as long as the velocity is high enough. The nature of particle motion depends strongly on gravity, but also on particle shape and the roughness of the surface over which the particles move.

- Rounded particles roll, especially if the surface is smooth.
- Long thin particles slide if the surface is smooth or may tumble if it is rough.
- Rough or irregularly shaped particles move in a succession of bounces called 'saltation flow'.
- Flake-like particles can move like leaves in the wind if they can be lifted by viscous forces or pushed by pigging.

Black powder can consist of many compounds, and Fig.5 shows the gas velocity to move various compounds in a 24-in pipeline at 1000 psi and 60°F. The velocity is slightly different for each compound, and in the balance of this paper, the velocity for magnetite (millscale) will be used, being slightly higher than iron carbonate and iron sulphide.

Gas velocity to move solids in a pipeline

The velocity to move 1-micron diameter black powder (magnetite) in a 24-in gas pipeline at various pressures, as calculated by Wicks' model, is shown in Fig.6. For a 1000-psi pipeline with 1-micron diameter magnetite particles, the velocity is 12 ft/sec for dry powder, and perhaps an additional

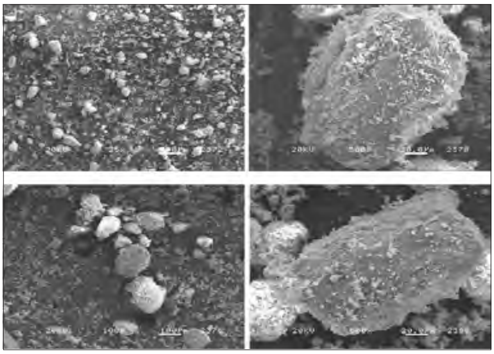


Fig.2. Salt in a gas pipeline with encapsulated black powder, likely the result of a producer unloading a well into the line leaving salt deposits.

Fig.3. Black powder plugging gas filters.

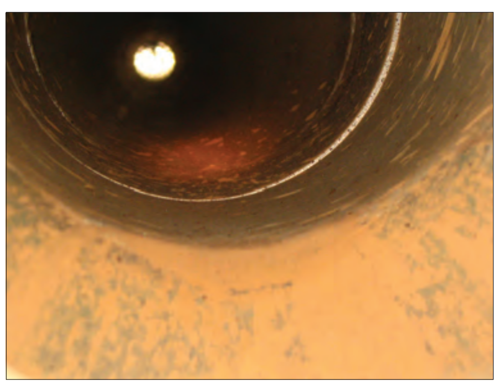
10% to move solids uphill. Lower pressures require higher velocity to move solids. Figure 7 shows, however, that the flow rate to move black powder is lower at lower pressure. Since the flow rate required to sweep solids decreases as the pressure decreases, once a solid particle begins to move, it will continue moving until either gas is withdrawn from the pipe to lower the flow rate or the gas reaches a compressor or wide spot in the line. If the gas velocity is not high enough to move solids, they will accumulate in the pipeline until the bed height of solids has reduced the cross-sectional area for flow enough to raise the gas velocity to the solids sweep velocity

Tsochatzidis [2] and others have reported that black powder fractures and becomes very fine as it moves in a pipeline. Finer particle size reduces the sweep velocity, but the effect is not significant until the particle size is less than about 0.1 microns, as shown in Fig.8. Thus fines may be swept through a pipeline even if larger particles of black powder are not moving, and this represents a particularly difficult filtering problem requiring sub-micron filters.

Black powder deposits in pipelines

At velocities less than the sweep velocity, beds of particles will accumulate in the pipeline. Operators have reported that some pipelines develop black powder deposits of significant height, such as perhaps half full, which increases the gas velocity to the point where movement occurs and increases pressure drop through the pipeline [6-8]. Wicks' theory also can be used to predict the bed height for powder based on the remaining cross-sectional area for flow. Movement of black powder lying in beds wetted by compressor oil or glycol, or powder treated with corrosion

Fig.4. Rouge, finely divided hematite or red rust, is found in a new pipeline left exposed to air. Rouge is a polishing compound and is highly abrasive in pipelines. Rouge will not form in natural gas pipelines due to the low oxygen content of natural gas. Large particle sized hematite is coloured black and can be differentiated from millscale because it is not magnetic.



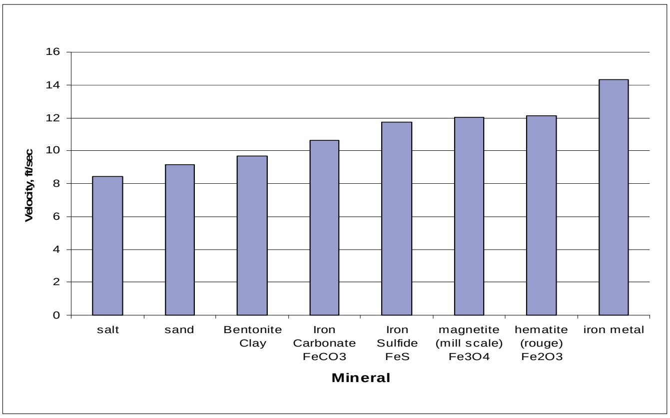


Fig.5. Velocity to move 1-micron black powder constituents in a 24-in pipeline at 1000 psi and 60°F.

inhibitor, will require higher velocity to move, as these particles are 'stuck' in the beds and require higher velocity to lift them out. This will lead to higher bed height and even greater pressure drop and efficiency loss. An additional velocity increment of up to 10% is required to move solids up-hill, likely causing deeper beds in up-hill sloping sections of the line in a manner similar to water accumulation in wet pipelines. If a pipeline is operating at less than the solids'-sweep velocity, black powder deposits will accumulate if solids are in the line. For the 24-in pipeline used as the example in Figs 6-8, at 1000 psi the sweep velocity is 12 ft/sec. If the velocity is reduced to 8.7 ft/sec, the bed height can be up to 5.75in, and at 4.4 ft/sec, the pipe can be up to half full of solids. Deposits of this type obviously can have severe consequences in pipeline operations, including high pressure drop, very difficult pigging, and prevent inspection pigs from operating. A 24-in line half full of solids has a pressure drop 3.45 times that of a clean pipe.

If a pipeline is operated at a velocity below the sweep velocity, black powder can accumulate in the line. If the flow rate is then raised or the line pigged to loosen the powder, high concentrations of black powder can travel down the line, plugging filters, damaging compressors, and potentially damaging customer equipment.

How clean is a pipeline?

The question of what is a clean pipeline is an interesting one, with as many different answers as people in the discussion. Engineers and operators have advised that they consider a pipeline clean when:

- the friction factor is less than a certain value
- solids are not evident in the receiving pig trap ahead of a pig
- there is less than 2 lbs powder/MMSCF gas
- pipeline filters do not have to be cleaned very often
- an intelligent pig inspection can be made obtaining valid data in the line
- a bare foam pig run through the line arrives 'clean', that is it has less than 0.5in penetration of dirt into the foam
- pipeline flow efficiency is improved and compressor fuel usage decreased.

There are no industry standards for black powder in pipelines. Some companies have an operating definition of 'commercially-pure' for gas delivery [1], while some commercial codes specify that the product be harmless to the customers' equipment. Pipeline black powder problems may have been aggravated when the US FERC Order 636 (The Restructuring Rule) was passed. FERC Order 636