Stephen H Shakeshaft Consulting Ltd
75 Mere Bank Davenham Northwich Cheshire CW9 8NB.
Tel- 01606 331558 Mobile- 07779 190087 Email- steve@shs-consulting.co.uk

Acid contamination of Lubricant causes breaking Piston Rods on a Reciprocating Compressor.

Introduction-

I was asked to visit a chemical manufacturing plant which had three, three cylinder reciprocating compressors installed. The machines had a long history (around twenty years) of intensive maintenance, but periodically a machine would break a piston rod. The machine would then be taken out of service and a standby machine put on line.

Machinery Details –

The double acting compressor cylinders were in a "W" arrangement with the outer cylinders of the "W" being both first stage cylinders and the centre one being a second stage cylinder. The pistons were double acting with lubricated piston rings. The pistons and gland packings had traditionally been lubricated with a mineral compressor oil but had recently been switched to lubrication with a Poly Alpha Olefin (PAO) type oil. The piston and gland packings being lubricated from a separate lubricator skid comprising of a small oil tank and an oil pump. The switch to a PAO type oil had been recommended by the local representative of the oil company in an attempt to reduce the carbonising inside the machines. In fact the change had no effect at all. The process gas was both flammable and toxic and came from the chemical process plant to the compressors through a drying tower before going back to the plant for further processing.

Background Investigation-

Upon my first visit to the plant and the compressor house I was immediately struck by the amount of used or broken machinery lying around. Of the three machines one was operating, one was standing by and one was stripped down under maintenance by the manufacturer's local service representative. Apparently, the plant had operated the machinery in this fashion for around twenty years and the compressor house was virtually the permanent place of employment for the service person!

I was advised by the service person and by a plant operator that the machines were regularly taken out of service due to carbon build up inside the machines cylinders and the valves of the machines. Sometimes, the end clearances inside the cylinders became so reduced that the pistons would touch the cylinder head and the piston rod would snap underneath the piston attachment. Usually, the contact took place on the downward stroke with the underside of the piston striking the head at bottom dead centre. See Fig1.

Stephen H Shakeshaft Consulting Ltd
75 Mere Bank Davenham Northwich Cheshire CW9 8NB.
Tel- 01606 331558 Mobile- 07779 190087 Email- steve@shs-consulting.co.uk

Fracture of Piston Rod Due To Loss Of Piston End Clearance Caused By Carbon Build Up.

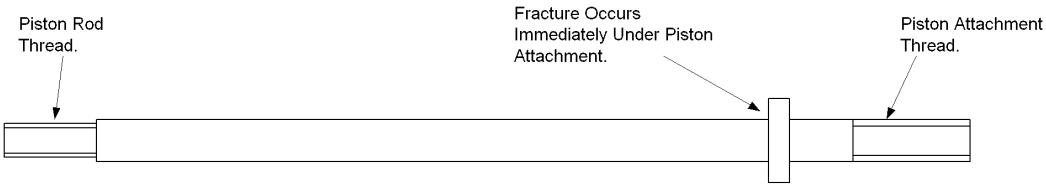

Fig.1

Somewhat surprisingly, when this happened the failed piston rod would push the piston back up the cylinder on the next stroke and the machine would keep running. The only clue to a piston rod breaking was pressure dropping off in the plant as the flow from the machine reduced. Although I was really rather concerned about this, the plant operator and the service person were not in the least perturbed as they saw this happen fairly regularly. They just took it as a sign that the maintenance of the machine was due.

Examination of Machinery Parts-

Inspection of all parts of a dismantled machine showed the very heavy carbonisation that had been a characteristic of these machines for all those years. All internal surfaces in the cylinders were extremely heavily fouled with oily, black, hard carbon deposits. The gas passages of the inlet and outlet valves were heavily choked. The gas packings were a lubricated metallic Babbitt type and were also heavily contaminated with the carbonised debris. The piston rods were extremely heavily worn by the carbon that was finding its way into the gas packings and subsequently wearing the rod surface away. An examination was made of a broken piston rod. The rod had fractured immediately below its piston attachment. What was readily apparent was a change in material characteristic about 3mm deep all round the periphery of the rod.

Upon taking the rod to a metallurgy lab and cleaning up the specimen it became clear that the apparent discolouration seen at the jobsite was in fact a very thick layer of Metallic Flame Sprayed build up. At first this seemed bizarre, but upon talking to the plant supervisor it became clear that they didn't put new piston rods in the machines because they didn't last very long. They sent them to a local workshop who metal sprayed them back to the original diameter and sent them back to the stores.

I went to talk to the local repair workshop who were preparing and flame spraying the rods. It soon became apparent that the repair workshop didn't know what the piston rods were or what they did. To them they were a worn piece of round bar with a thread at each end. They just prepared them with a coarse machined finish (perfect conditions for stress propagation to occur) and sprayed them and then turned them to a given diameter to finish off. The reclaimed rods were then put back into stores as supposedly fully refurbished items. It was notable that neither the plant nor the reclamation workshop understood what was required in refurbishing a piston rod or what the parameters might be to scrap the rod. The manufacturers representative gave no advice on the condition or refurbishing of the rods, he just used the parts he was given free issue by the client. In fact, the rod that was broken had a flame sprayed coating that was 3mm thick on a rod that was only 47mm diameter. So the effective diameter was reduced to about 41mm. See Fig2.

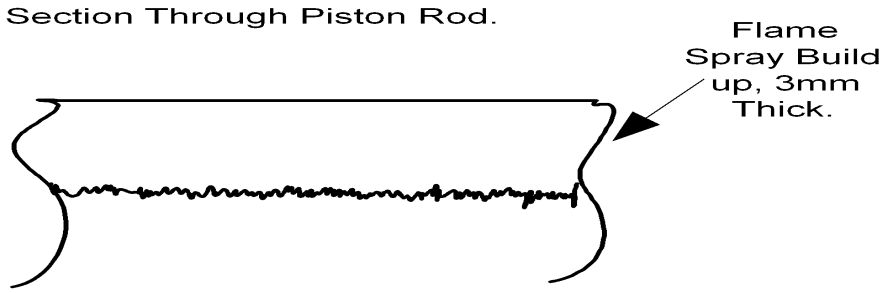

 Fig2

The workshop didn't think there was any limit to how thick the metal spray coating could be as long as the final diameter was as specified.

Further Investigation-

I was told by the Plant Manager and the Plant Chemical Engineer that the fouling of the machinery was due to "un-reacted carbon" carrying over from the process and had always been a problem. This theory had been accepted and went unchallenged despite the fact that there was another plant next door that had no problems with its (non lubricated) reciprocating compressors.

At this point I was unconvinced by the explanation. I knew there was a 98% Sulphuric Acid drying tower upstream of the compressors that the gas passed through on its way to the compressors. I also recalled being very impressed as a 14 year old high school pupil when the chemistry teacher turned sugar into a large piece of carbon by adding Sulphuric Acid.

Stephen H Shakeshaft Consulting Ltd
75 Mere Bank Davenham Northwich Cheshire CW9 8NB.
Tel- 01606 331558 Mobile- 07779 190087 Email- steve@shs-consulting.co.uk

Initially without discussing this with anyone in case I was completely wrong, I went to the site laboratory with a small jar of the PAO oil and asked if one of the chemists

would kindly add a few drops of 98% Sulphuric Acid to the oil. Immediately, the oil went black, and after a few more drops were added free carbon was produced from the acid/oil mixture. With this evidence I managed to persuade a Tribology lab to carry out some tests on the stability of the oil when mixed with concentrated Sulphuric Acid. A brief transcript of the findings is shown in Fig3.

XXXXX Tribology Ltd.	
Client-	XXXX Chemical Company Ltd.
Requested Testing-	Stability of PAO Oil With Sulphuric Acid.
Method-	1 Mixture of PAO oil and varying quantities of 98% Sulphuric Acid. 2 Spray of PAO oil and 98% Sulphuric Acid.
Safety-	To be carried out in Fume Cupboard. Client advises possible instability of Oil/Acid mixture.
Chemist-	XXXXXX
Results-	The sample of Poly Alpha Olefin Oil submitted for testing is unsuitable for service where contamination with Sulphuric Acid mist is present. A simple agitated mixture of Oil and Acid produces free Carbon readily. A finely divided spray of Oil when mixed with 98% Sulphuric Acid reacts producing Sulphur Dioxide fume. This lubricant is **not** recommended for the proposed duty.

Fig3.

During one of the tests, enough Sulphur Dioxide gas was liberated from the resulting reaction to cause the laboratory to be temporarily evacuated! Large quantities of carbon were produced from the acid/oil mixtures. At this point I felt confident enough to present the findings on my chemistry experiments to the Plant Management.

Conclusions-

1 Both a mineral based compressor oil and a premium quality PAO oil were both clearly unsuitable for use in a lubricated compressor cylinder where the gas was contaminated with a mist of 98% Sulphuric Acid.

2 The long standing theory of “un-reacted carbon” fouling the machines was shown to be false.

3 Neither the Plant nor the workshop understood what was required when

refurbishing compressor piston rods.

4 The manufacturers service department had taken this work for granted over many years and had made no attempt whatsoever to rectify the long term problems suffered by their client.

5 It was highly likely that the compressors when converted to dry running piston rings/cylinders and the machines and pipe work cleaned of oil would continue to run without the carbon fouling and the risk of broken compressor components.

6 The safety of the installation was enhanced and as a bonus the maintenance budget of the Plant could be greatly reduced.

Follow up-

Over the following months, the relevant staff were re-educated about the importance of proper refurbishment procedures and a full procedure for piston rod refurbishing was written and put in place.

The manufacturers service department was dismissed and a third party brought in for any compressor work.

A project was raised to replace the three old lubricated machines with two modern non-lubricated machines similar to the plant next door. This approach was thought preferable to converting the existing machines although non lubricated conversion was technically very feasible.

The plant continues to run profitably and the compressors now run all year with just an annual routine service.

There is now never any problems with “un-reacted carbon” clogging up the machines and the twenty year old stories about the process gas affecting the machines is steadily being forgotten about.

Stephen H Shakeshaft IEng MIMechE MIIE

20th May 2004.

About the author-

Stephen H Shakeshaft is a Mechanical Engineer based in the United Kingdom. He is the Principal Consultant and Director of Stephen H Shakeshaft Consulting Ltd., an

engineering consultancy specialising in the efficient use of maintenance resources, maintenance systems and machinery development projects. Stephen has over 30 years experience of working at the "sharp end" as well as the "back room" of manufacturing industries with clients in the chemical, utility, metals, industrial gases and pharmaceutical businesses.

Stephen is a registered professional engineer in the UK and is a corporate member of both the Institution of Mechanical Engineers and the Institution of Incorporated Engineers.

Stephen H Shakeshaft Consulting Ltd. can be found on the internet at-

www.shs-consulting.co.uk .

The consultancy welcomes contact from all who are interested in plant and machinery maintenance, systems and development.