COAL GASIFICATION
DULUTH CAMPUS HEATING PLANT

MASTER

Grate Support System Failure

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Warren E. Soderberg
Project Manager

UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA 55455

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SUMMARY

On April , 1980, there was a complete failure of the grate support system. Two massive holes and numerous cracks finished the deterioration of the grate holder that had started on the fifth run of the gasification system.

The zero ductile casting was quenched with ash water during an emergency loss of blast air with the resulting depressurization of the producer. The cause of the failure was threefold - quenching of the hot cast iron, low ductility in the material used (Meehanite W-1), and high stresses set up in the casting at bolting locations.

To correct this problem the grate support system has undergone the following design changes:

1. The structural part of the grate holder will be a plate steel weldment welded directly (instead of bolting) to the ash pan. This will eliminate gasket leaks, give us a more ductile material for transporting the stress from the grate to the rotating ash pan, and give us better thermal conduction of heat (elimination of gasket thermal break) from the grate holder to water in the ash pan.
2. The grinding lobes will be cast iron wearing attachments bolted to the structural steel grate holder. The attachments will be made of a more ductile iron than Meehanite W-1. In the future, when the grinding lobes wear, they can be replaced without removing the entire grate holder.

GRATE HOLDER DESCRIPTION

As shown in Appendix I, the grate holder's primary function is to support the grate and transmit the Torque developed (from the ash pan to the grate) as the entire unit rotates (ash pan, grate holder and grate). The secondary function of the grate holder is to assist the ash flow from the grate through the ash pan and this includes breaking up of large clinkers. This is accomplished by the shape of the elongated lobes on the grate holder exterior. There is one lobe to each quadrant and they are shaped to practically screw the ashes down as well as smash clinkers between the lobes and the producer seal skirt. The grate holder was bolted to the ash pan but the grate was keyed into the grate holder and held down by a hold down rod and bar. There were no bolts or pins fastening the grate to the grate holder.

Also shown in Appendix I is the High, Normal and Low water seal levels. As the gasifier was pressurized the water level inside the seal skirt was forced down and caused the water level outside the skirt to rise to one of the levels depending on the pressure in the producer.

In Appendix II it is shown what happens when the ash pan is operated full under low pressure and the power fails causing rapid depressurization in the producer.

FAILURE DESCRIPTION

Cracks first were noticed after the fifth run. There were vertical cracks in the exterior, starting at the bolt holes in the bottom and extending upwards approximately three-fourths the height of the holder. None of those cracks went clear to the top. There were many hair line cracks in the bottom of the holder, starting at the exterior bolt holes and extending at an angle opposite to the direction of rotation of the holder. The vertical cracks were patched by welding steel plates and boxes on the inside and outside of the holder in three areas that were more than hairline cracks (three-fourths of an inch wide). The bottom was scaled off with 1/4" plate steel.

After the complete failure (seventh run) the grate holder was so badly burned that complete analysis was impossible. Two holes, one cracked out, the other burnt out, were at least 7" by 12" in size. The casting had undoubtedly been subjected to temperatures in excess of 1700°F. Appendix IV, V, and VI show the hole that cracked out. The vertical cracks extend to the four keys with out gussets at the top of the holder.

FAILURE ANALYSIS

Analysis of the damaged grate holder showed the Meehanite to have oxidized greatly, indicating it was subjected to extreme heat. 33% of the support wall was lost through oxidation. This undoubtedly occurred during the last run, when a torch effect was created by the blast of air pouring through the large holes in the grate holder into the ash area where there was a concentration of oxygen, both on the outside and inside of the grate support.

Analysis also showed that the Meehanite W-1 used for the holder had nearly zero ductility. This meant that it was very sensitive to thermal shock and concentrated stresses.

Although analysis did not indicate that there was leakage at the gasket, leakage in this area could have resulted in slowly pulling the fire down into the grate holder area, or at least close enough to create abnormally high temperatures. Until the massive holes occurred there was not enough temperature build up in the area of leakage to cause a fire. See Appendix III.

CONCLUSIONS

I. Many factors are involved in establishing the cause for the failure of the grate holder. These factors are as follow:

1. Meehanite W-1 was selected as the grate holder material for its long use in operable gasifiers overseas. These were on low ash pan units (27") compared to the high ash seal (60") on the Duluth producer. The higher surge of water during failures (loss of producer pressure due to power loss on blast air) and emergency stoppage of gas at the builer gas train proved to be very destructive. With more foresight, a more ductile material should have been selected. I am certain the grate holder has been hit with water many times in previous runs when the unit was put on hot standby. This was the longest pressured run we had had and build up of temperatures were greater, increasing the potential of cracking when quenched with water. From initial start up, O_2 leaks had been a problem in the ash pan and skirt gasketed joints. Initially, holding the ash pan water high lessened the amount of gas bubbling up from the ash pan.
2. The grate holder was bolted to the ash pan during the coldest weather of the 1977-78 winter. Both the grate holder and ash pan were well below freezing temperature. To my knowledge, none of the nuts were retorqued prior to start up.
3. The selection fo the gasketing method was poor. The installation of a rope gasket woven in front of one bolt and behind the next left a possibility of minor leaks at the bolt holes from the blast air to the oxygen-free ash pan area adjacent to the grate holder. This would occur if minor cracks developed at the stud locations. We could have had minor blast air leaks from startup on.
4. During the fifth run, on an emergency shutdown, ash pan water surged up and hit the bottom of the grate holder. Since we were operating at about 25" H_2O below the design pressure, we should have held the water level down (12 to 13") in the ash pan, but to that point, it had been an operating practice of keeping the ash pan full at all times.
5. Since the sixth run with the patched grate holder was successful, we started up the gasifier for a seventh run. We did not realize how close to complete failure we were with the grate holder. During the seventh run, the cracks undoubtedly opened up more and we obtained extreme temperatures in the grate holder area of the ash pan. With these high temperatuers (producer skirt got red hot), the grate holder carburized so badly it proved difficult to thoroughly analyze the material for sequence of damage.

II. I am certain the severe cracking was caused by quenching the bottom half of the casting with ash pan water. Cracking might not have been as severe if temperatures were normal in the ash pan just prior to quenching. It is my belief that blast air leakage caused a lowering of the fire zone in the area just above the grate holder. I also believe that if high stresses had not been set up in the bolting area of the castings that the cracking would not have been so severe. Therefore I list the causes for failure in the following priority:

1. Quenching of the casting.
2. Abnormally high operating temperatures in the grate holder area.
3. High stresses in the casting developed at the stud connections.
4. Low ductility of the material selected.

CORRECTIVE MEASURES

As corrective measures were reviewed, there were many that would have been less costly but the long term solution seemed to continually point to a welded grate holder with bolt on wearing lobes. See Appendix VII. Some of the alternatives are listed below.

1. Because we had the pattern for a Meehanite casting, the cheapest repair would have been to replace the grate holder with a new four section casting. In addition an attempt would have been made to automate the water level control for the ash pan with the pressure in the producer.

Since overseas gasifiers are now abandoning cast iron grate holders we were convinced that replacing with a duplication of what we had was a poor choice. We also felt that over a period of time (without quenching) cracks could occur due to high stress points in the casting caused by torque transmission at the bolt holes.

2. Switching to a cast steel grate holder was considered, as many overseas gasifiers are doing this. This would require a very expensive new pattern. This alternative was the most expensive corrective procedure.

3. An entirely welded grate holder was considered. The fact that it required extensive surface hardening on the wearing areas made this a costly correction. This alternative was the second most expensive corrective procedure.

4. The modification selected was a welded steel grate holder with cast iron wearing attachments.

The grate holder is a 6' 7" O.C. 1 1/2" steel plate cylinder with a 1 1/2" key ring welded on top. The key ring will be reinforced with a 1" x 2" ring. The cylinder will be reinforced with eight 1" gussets and two 1 1/4" gussets as well as a 1" x 12 3/4" ring. The bottom of the grate holder will be made of 1 1/2" plate and contain two oblong access panels.

The cast iron attachments will be cast in quadrants, with four attachments required. The material to be used will be a high ductile cast iron. The castings in each quadrant will be bolted on with 12 bolts (48) required. To relieve the stress on the bolts, a shear bar will be installed (4 required) on the cylinder, one for each attachment.

There are many advantages with the corrective modification selected:

1. There will be no high stresses developed in the castings. A shear plate will take up any stress, not the bolts.

2. A very difficult gasketing requirement will be eliminated. Some heavy members that require gasketing for attachment are extremely difficult to get gas tight. Heavy members that have been gasketed and are steel to steel have been seal welded. This 8000 pound cast iron grate holder was gasketed to a heavy steel plate ash pan. Blast air leakage at the gasket has been suspect and monitored since the initial startup. Gasketing should be eliminated wherever possible in the entire system. The high temperature swings from down conditions to full operation create high thermal expansions throughout the producer and its supporting auxiliaries and piping.

3. Replacement of worn grinding lobes has been simplified. The producer will not have to be partially dismantled to replace lobes. Upon unbolting, the cast iron attachments can be removed through the access port. Also the new attachments can be brought in through the access port.

4. We will be going to a more ductile material for the cast iron attachments. Since replacement for wear has been simplified, wearing characteristics no longer predominate in the selection of materials. A loss in wearing characteristics can be sacrificed for resistance to stress and shock.

A-I
Grate Holder

LLL - WATER LEVELS UNDER LOW
PRESSURE BUT FULL ASH PAN
LEVEL

DLL - DEPRESSURIZED LEVEL UNDER
THESE CONDITIONS

A-V
Failure Pictures

Failure Description

A-VI
Failure Pictures

Failure
Description