Burning Landfill Gas at NASA's Central Power Plant

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ABSTRACT

The National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC) located in Greenbelt, Maryland, USA began burning landfill gas in January 2003. GSFC is the first federal facility in the USA to implement a landfill gas energy project. Two boilers were outfitted with new burners and controls. Control issues include landfill gas delivery, ratio of landfill gas to secondary fuel, and response to volume and energy changes in fuel supply. The newly installed burners and controls have greatly reduced NOx emissions, and these reductions are quantified through stack test results.

INTRODUCTION

NASA's Goddard Space Flight Center (GSFC) is located in Greenbelt, MD USA approximately 10.5 kilometers from Washington D.C. GSFC is major a United States laboratory for developing and operating unmanned and scientific spacecraft. The Greenbelt facility of GSFC encompasses 514 hectares with 33 major buildings and more that 278,000 square meters of research, development, and office space.

The boiler plant provides 100-psig steam to the 33 buildings on Campus for heating, hot water, humidification, and some process heating. It has five 40,000 lb/hr-Nebraska boilers that were installed in 1995. Steam load varies between 30-90,000 lb/hr throughout the year. The boiler plant is staffed 24 hours a day, 365 days per year. Prior to burning landfill gas (LFG), the primary fuel was interruptible natural gas, with No. 2 fuel oil as backup. The interruptible supply for natural gas is a contractual agreement that allows the supplier to interrupt GSFC's natural gas delivery and GSFC is accommodated financially.

In January 2003, NASA began burning landfill gas (LFG) in its central boiler plant, piped from the Sandy Hills Landfill about 8 kilometers away. GSFC is the first federal facility to direct-burn landfill gas on site.

ENVIRONMENTAL

Existing Environment

In 1990 the Clean Air Act became federal law. The Clean Air Act stated that clean air must be attained throughout the Country, but it does not specify how clean air will be attained. Under the law the Environmental Protection Agency sets the minimum limits for the regulated pollutants. This means individual state may have stronger pollution controls, but states cannot have weaker pollution controls than those of the federal government.

States must develop state implementation plans (SIPs) that will govern how each state will meet the requirements of the Clean Air Act. The SIP is a collection of regulations a state enacts to bring the area into attainment.

Through this process, the Washington D.C. metropolitan area was designated a severe non-attainment for ground level ozone; which is where GSFC is located. The Clean Air Act of 1990 projected the date of attainment for the Washington D.C. metropolitan area as November 2005. Thus, the State of Maryland has promulgated various regulations to minimize nitrous oxides (NOx) and volatile organic compound (VOC) emissions. Through photochemical reactions NOx and VOCs lead to the formation of ground-level ozone. The State of Maryland was supportive of the project, because of the beneficial impact on the airshed. The LFG project allowed a way to reduce NOx emissions in the airshed and simultaneously turn waste into energy.

Benefits

Before the LFG project the average NOx emissions from the five boilers was 23 metric tons per year. After the LFG project, the estimated NOx emissions are 5 metric tons per year.

Based on stack testing, the new burner controls have reduced the NOx emissions by more than one-half, as illustrated below:

Burner Controls	Fuel Type	NOx (lbs/MMBtu)
Old	NG	0.1
New	NG	0.05
New	LFG	0.02

Table 1. NOx Emissions Before and After

While burning LFG, the reduction was immediate and significant. The operators take NOx daily readings on the boilers and post the results in a database. As you can see by Figure 1, the results are dramatic.

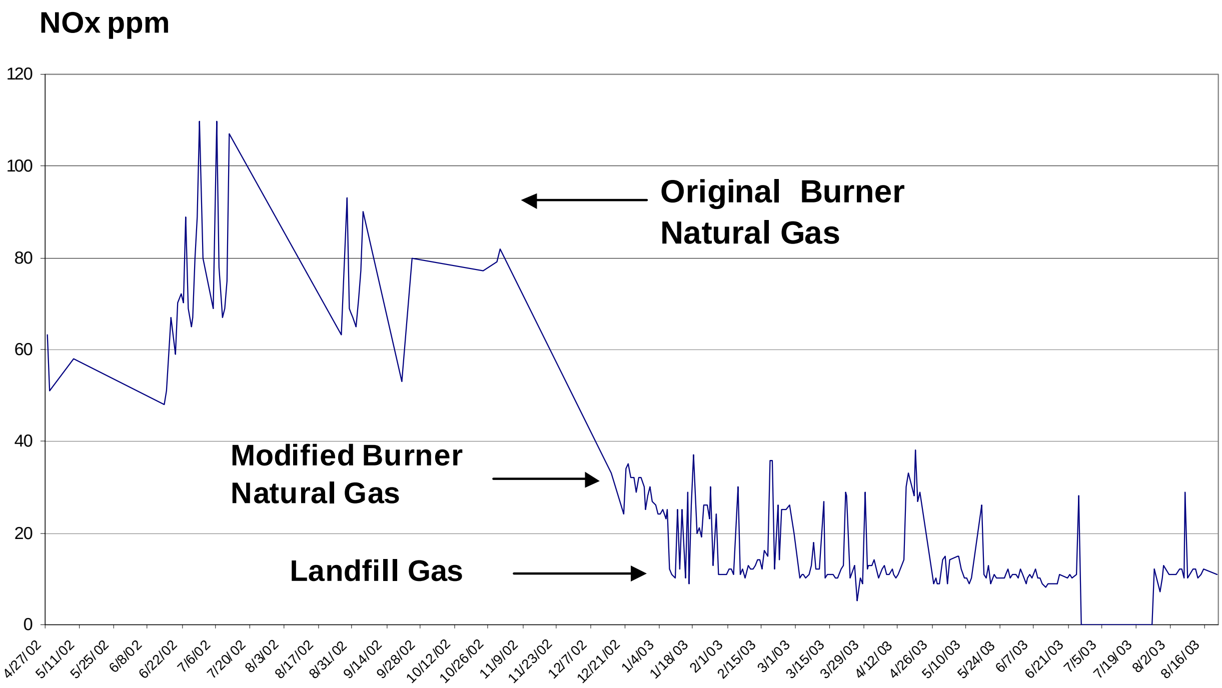

Figure 1. NOx Emissions

In addition to reducing emissions at the Goddard central plant, the landfill flare emissions have been sharply reduced and may be eliminated in the near future. Gas flares are generally inefficient, releasing raw methane into the atmosphere as well as products of combustion.
In the airshed the LFG project has had the same effect as:

Removing 1.6 metric tons of CO_2 over 10 years[1],
Removing emissions from more than 35,000 cars per year[1],
Planting 19,000 hectares of tree[1]

These benefits to the environment provided the motivation for GSFC to pursue this project.

FROM PROPOSAL TO CONTRACT

In 1996 Toro Energy of Dallas, Texas approached GSFC with a proposal to sell landfill gas to the boiler plant at significant savings over natural gas (NG). Toro would install a compressor at the landfill, a pipeline, and new burners and controls for two of GSFC's five boilers to burn landfill gas.
GSFC requested the U.S Environmental Protection Agency's (EPA) Landfill Methane Outreach Program to evaluate the proposal. In EPA's evaluation the landfill gas production was estimated and it was determined that GSFC's energy demands could be met. LFG is produced in a method similar to, though faster than, the production of natural gas from ancient organic matter. Based on analysis, the Sandy Hills landfill gas contains 50.1% methane, 40.2% CO_2, and 1.6% O2. The

LFG has about half the energy content of NG. LFG is collected via a network of pipes buried in the landfill, pulled out by a blower, and sent to a flare. The blower and pipes are designed to keep a slightly negative pressure on the landfill to minimize neighborhood odors. The suction is kept low to prevent oxygen from being pulled into the landfill, and affecting the flare operation. The Sandy Hills Landfill is a 140 hectares facility that received county municipal waste from 1978 to 2000 [2]. Approximately 2,300 cubic feet per minute (cfm) of a 50%-methane gas mixture was being flared at the landfill, which is almost equivalent to the November fuel needs of the GSFC boiler plant. After the landfill closed unexpectedly in mid-project, the new estimated LFG recovery rate was deemed sufficient to go ahead with the project. The amount of gas emitted by the landfill increased to 3,000 cfm after additional wells were installed and the landfill capping process began.

As part of the design process, GSFC hired a consultant and visited a number of similar sites that were burning landfill gas. It was extremely useful for GSFC boiler plant personnel to see actual operation of similar boilers running on LFG and to talk to the operators. The fears that it was explosive, that it was toxic, or that it smelled up the plant for miles around, were allayed by observing that LFG wasn't very different from natural gas or fuel oil. Another result of the site visits was that many of the lessons learned from previous projects were incorporated into the GSFC technical requirements.

Corrosion is the biggest problem with LFG, caused by moisture combining with sulfur or chlorine in the gas. Unlike some of the sites we saw, the Sandy Hill Landfill installed a chiller/drier that maintains the dew point of the gas at about 4^0C, well below the 15-21^0C temperature in the distribution line. The flue gas must be maintained above the temperature at which sulfuric acid condenses, around 138^0C. The sites we visited had installed insulated or stainless steel stacks. There was ongoing discussion on what was needed at GSFC. After the on-line stack temperature was measured at 58^0C on a cold January morning, it was decided the stacks would be insulated.

We saw some problems with carbon steel components at the other sites. The buried pipeline to GSFC is high-density polyethylene (HDPE). All wetted parts in the landfill header and trains are stainless steel. GSFC required a separate liquid separator at the boiler plant wall; this separator has proven its worth during upsets when moisture has collected in the pipeline.

Although we heard only one report of hazardous material in LFG ash or condensate, GSFC required the contractor to test the boiler ash before the first two annual inspection shutdowns and take responsibility for removing the ash if it was hazardous. In addition, GSFC put the responsibility for disposing of the LFG condensate on the contractor. Many sites discharge condensate to the publicly owned wastewater treatment plant, which is an option for the contractor. However, this action must be coordinated with the wastewater treatment plant. In addition, the amount of condensate collected at the separator has been approximately 20 liters that were taken back to the landfill.

The boiler plants visited all had close contact with the personnel operating the landfill. The landfill operators were regularly visited the boiler plant and were on 24-hour call. Boiler operators usually had the first indication of problems at the landfill when the gas pressure or methane content changed. Overall the boiler plants told us that LFG reliability was good. Most outages occurred due to commercial power outages at the landfill.

There was a noticeable odor at one of the plants due to problematic leaks in a firetube boiler face. The other plants were odor-free; in fact GSFC plant personnel only notice odors when venting gas, or when there has been a flange leak in the fuel train. Unlike natural gas, landfill gas doesn't need any additives to notify presence of a leak.

SANDY HILL LANDFILL

In order to capture the gas produced from the decomposition of the materials deposited in the landfill, wells are drilled into the structure to capture the gas. A manifold ties the piping network to a blower. The blower provides the differential pressure required to pull the gas from the ground and move it to a collection point. Each well is adjusted to draw the proper quantities of gas, keeping the field under slight negative pressure to control odor. The LFG produced is highly saturated with condensate and water. Sumps located along the piping network are used to provide initial drop-outs for water. The water is typically recirculated back into the leachate system of the landfill to help drive off more methane.
In the past the blower discharged 3,200-3,500 cfm directly to the flare. This project added a compressor, refrigerated dryer, and controls to maintain constant pressure on the landfill whether some or all of the gas goes to the flare or is sent through the pipeline to the boiler plant. A compressor surge curve is used to maintain adequate flow through the equipment at all loads in order to prevent compressor surges. A recycle valve is used to maintain the required flows. Once the gas is compressed, the gas is cooled through air foil coolers before being cooled in the refrigerated dryer to 5^0C. The cooled condensable constituents drop out in a separator. Then the gas is warmed through a recuperater heat exchanger that is used as a pre-cooler for the gas before entering the chiller exchanger. Once the gas passes the recuperater, it enters the pipeline heading to the facility.
The compressor provides a discharge pressure of roughly 32 psig after the chiller and gas coolers. This provides a system pressure of roughly 10 psig at the boiler plant when flowing 3500 cfm of LFG. Figure 2 provides a schematic of the landfill gas compression and gas processing at the landfill.

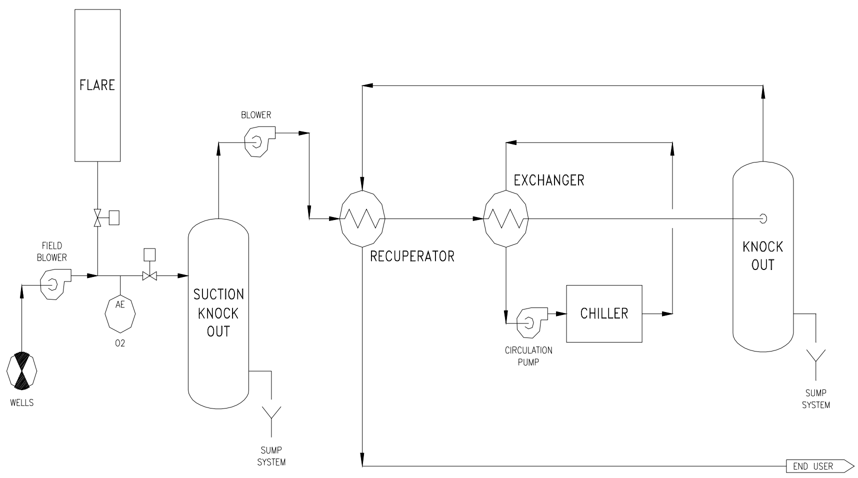

Figure 2. LFG Compression and Gas Processing

The flare at the landfill requires 525 cfm, which provides 3,00 cfm for the boiler plant. The heating value has normally ranged between 475-525 Btu/cf, with a maximum energy flow to the plant of 90 mmBtu/hr. A state permit application was submitted to turn off the flare at the landfill. A continuous pilot (40 cfm) would restart the main flare. Once the main flare is extinguished this will extend the life of LFG output.

To ensure the quality of the LFG an oxygen sensor is used to infer the methane concentration. In the event of a failure in the landfill pipe network, poorly tuned wells, or some other type of failure, a high oxygen reading will direct the controller to divert the gas to the flare away from the compressor. Air slugs in the LFG flow will disrupt the boiler burners, especially when burning 100% LFG.

In the event the chiller goes off line for any reason, the compressor is shut down once the discharge temperature of the gas reaches 18^0C. The high temperature shutdown will prevent liquids from entering the gas pipeline.

The pipe from the landfill is 25-centimeter HDPE. It was constructed cut-and-cover, except when drilled under roads and a wetlands area. There are no condensate drains installed at the low points, and after the startup period this has not posed any problem.

The landfill is not manned, but an operator is on-call 24-hours. However, if the boiler plant operators notice any problems with LFG supply, they notify the landfill operator.

GSFC BOILER PLANT

Receiving Facility

The 25-centimeter HDPE gas pipeline from the landfill leaves the ground just outside of the boiler plant wall, where it changes to stainless steel pipe and enters a separator vessel to drop out any liquids that may have accumulated in the pipe. The vessel includes a demister pad to help release liquids out of suspension in the gas. This vessel is the last defense to catch any liquids before entering the burners at the boilers. Typically, if any liquids do drop out in the pipeline, the gas is dry enough to re-absorb the liquids into the gas; thus no liquids reach the boiler plant wall.

The vessel is fitted with a high level sensor, which warns the operators that the vessel has received fluid. The high-high level sensor will switch the boilers off LFG firing. The vessel has a manual drain at the bottom to enable liquid removal by the landfill operators.

Boiler Modifications

The objective for the boiler system was to be able to operate on either natural gas (NG) or #2 fuel oil (FO) as primary fuels and Landfill Gas (LFG) as the secondary fuel. The systems were designed to burn either primary fuel and LFG at all possible ratios or LFG alone up to 94% capacity of the boiler. When the full capacity of the boiler is required, primary fuel supplements the boiler to meet capacity. 94% capacity was selected in order to prevent the necessity of replacing the FD fans on each boiler.

The two boilers selected were fitted with a Todd Combustion axial-flow Low-NOx burner capable of firing the three fuels. The burner draft loss had to be matched to the existing FD fan and windbox. The burner was installed into the existing burner wind boxes and utilized the existing combustion air fans and ducting. The refractory in the burner firebox was modified to accept the new burners. No other mechanical modifications were required internal to the boiler.

The existing removable oil gun is used when firing oil or oil/LFG.
The burner was selected to provide 0.07 lb of NOx /mmbtu emissions while firing NG with no flue gas recirculation. The predicted NOx emissions on firing LFG was 0.03 lb /mmbtu, however upon completion of the project and testing, the project was able to obtain 0.013 lb of NOx/mmbtu when firing LFG and under 0.05 lb of NOx/mmbtu when firing NG. The reduction of NOx emissions is substantial over the previously fired burners. The previous emissions limit was 0.1 lb of NOx/mmbtu while burning NG on the old burners.
The burner was designed to fire LFG with a heating value of 425 btu/scf and higher alone and a heating value of not less than 350 btu/scf in conjunction with a primary fuel.
Each boiler was fitted with a 304 stainless steel LFG fuel train assembly, flame safety valves, flow meters, and dual range flow control valves. Each LFG fuel train was fitted with a flame arrestor. This flame arrestor provides a high degree of protection for the pipeline. It also provides a safe means of purging the air out of the pipeline directly into the boiler during initial start-ups after maintenance has been performed on the pipeline. The pipeline mixture of combustibles, oxygen, and inert gases passes through the combustible range before reaching the normal operating low-O2/high methane range where it is not explosive.
The existing NG and FO fuel trains were both converted to fully metered systems and modified to accept the combustion controls. A schematic of the fuel train is provided in Figure 3.

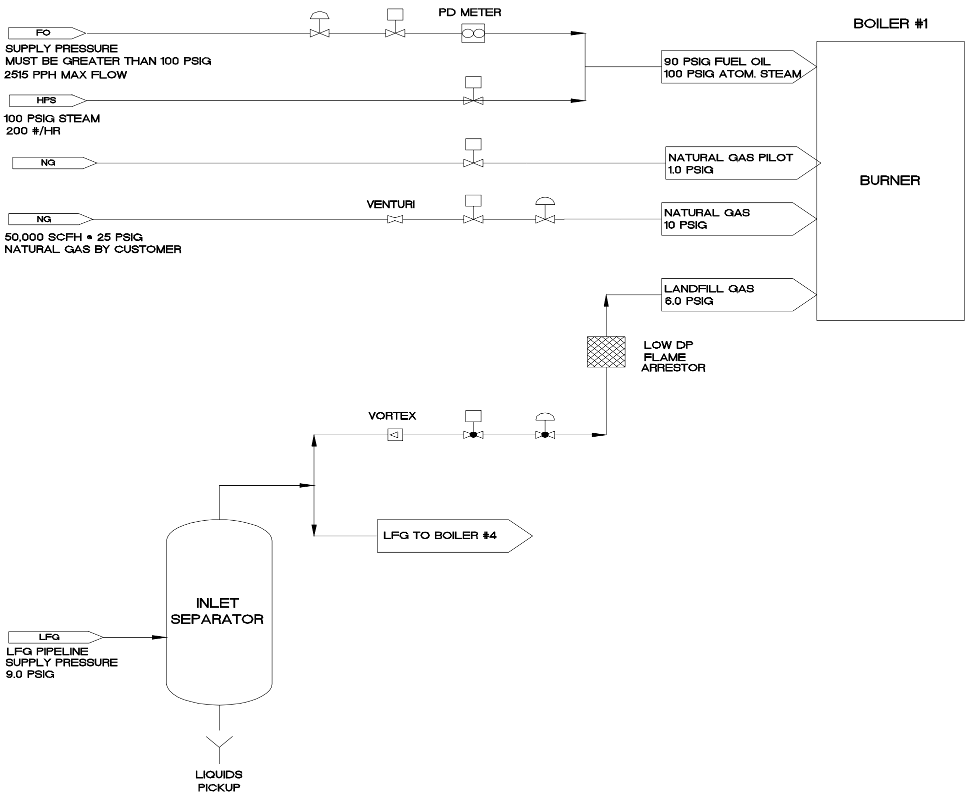

Figure 3. Fuel Train.

Controls

The existing boiler controls used single loop controllers for drum level, fuel flow, and O2 trim, with panel indicators and chart recorders. The existing boiler instrumentation was re-used where practical.
The two boilers were fitted with Allen Bradley Control Logix 5000 Programmable Logic Controllers (PLC) for both combustion controls (CCS) and burner management systems (BMS). The controllers were tightly integrated over Ethernet to an HMI station in the operator control room. Each existing boiler panel on the front operating aisle was fitted with a flat-screen operator terminal tied to each set of controllers. The Allen Bradley control system was selected due to the programming capabilities of the new controllers. The new generations of PLC’s lend themselves quite well to handle complex control problems with real-world solutions.
The CCS and BMS are designed with a high degree of integrity and reliability. Reliability is commonly defined as the ability of a system to continue operating with one or more failures. Integrity is the ability of the system to shutdown when a failure compromises safe operation. The systems are tightly integrated with watchdog timing between processors, communications links and processor functions. If the CCS or the BMS does not respond properly, the watchful controller will shut the boiler system down through hardwired interlocking. The BMS system includes an external discrete hardwired watchdog timer to monitor controller and Input/Output (I/O) health.
Redundant PLC input cards are used on the BMS for interlock detection integrity. The external watchdog timer toggles spare inputs on each card every 1.5 seconds. A card failure will freeze one set of inputs, causing the watchdog timer to interrupt the power supply to the safety valves and take the boiler down.

Redundant outputs to the fuel safety valves are placed in series in the BMS for interlock performance integrity. These outputs are normally open contacts held closed by the BMS. A failure (fail open or fused closed) in either output will bring the boiler down.

Operator Interface

The operator controls and monitors the boilers through two completely redundant devices, the Local Operator Terminal and the Control Room Supervisory Station.

Local Operator Terminal

The existing boiler panels were fitted with local flat-screen operator terminals that enable the operators to start/stop and operate each boiler. The existing digital indicators, annunciators, and chart recorders were maintained, either reading sensors that were not part of the boiler modifications or reconnected to the new controllers.
In practice, the operators carry out all actions from the local panels, where all pertinent boiler information is provided.

Control Room Supervisory Station (CCRS)

The system includes a PC-based workstation running Window NT and Wonderware. The PC based system works as a backup to the Local Operator Terminals as well as additional functions.

The CRSS system includes all of the graphics of the Local Operator terminals as well as dynamic trend screens for critical process variables and a historical logging system that records critical data and stores the values in a log file. The log file is maintained on the computer hard drive for up to six months, and downloaded to CD for archival storage.

CONCLUSION

To bring LFG to GSFC was a challenge; however it was worth the effort. This project has benefitted the surrounding community and given a sense of pride to GSFC personnel. Through site visits to other facilities we were able to avoid some common problems. The new controls not only burn the LFG efficiently but also NG and FO. This has allowed us to decrease our NOx emissions significantly from the facility. In addition, the new boiler controls on the two LFG boilers are a significant improvement on the previous installed package.

REFERENCES

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