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7. Abstract <p>A temperature monitoring device needs to be developed for the tank core sampling trucks. It will provide an additional indication of safe drill bit temperatures and give the operator a better feel for the effects of changing drill settings. This document defines the criteria for the bit monitoring system, including performance requirements, information on the core sampling system, and other conditions that may be encountered.</p>		
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CRITERIA FOR CORE SAMPLING BIT TEMPERATURE MONITOR

PREPARED BY

PETER M. FRANCIS

Mechanical Design Engineer
Characterization Equipment

AUGUST 1994

TANK WASTE REMEDIATION SYSTEM
WESTINGHOUSE HANFORD COMPANY
RICHLAND, WA 99352

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ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
AC	alternating current
BTM	bit temperature monitoring
cm	centimeter
DC	direct current
ft	feet
hr	hour
in.	inch
lbf	pound (force)
kg	kilogram
kPa	kilopascal
m	meter
Ma	milliampere
min	minute
N	newton
R	Rad
rpm	revolutions per minute
SNL	Sandia National Laboratories
V	volt
WHC	Westinghouse Hanford Company

1.0 INTRODUCTION

This report defines the criteria for a method to monitor the drill bit temperature of the core sampling trucks at the Hanford Site. This bit temperature monitoring (BTM) device could be used as a safety feature during push-mode and rotary-mode core sampling. In addition, it could allow the operational limits to be expanded in order to improve sample recovery. In a previous research and design effort, numerous organizations were consulted to gather suggestions for monitoring the bit temperature (Johns, 1992). No vendor-supplied solutions were found, but some promising concepts were developed.

In a follow-on effort, research was conducted on the use of thermistor sensors rather than thermocouples (Francis, 1992). Thermistors would be more technically feasible, because they depend on a frequency response and are not affected by the voltage drop caused by a long (and possibly segmented) wire, which was a problem for thermocouples. A task team was assembled to develop the most promising concepts. In all, four designs were produced and evaluated based on feasibility, timeliness, and performance. The design by Sandia National Laboratories (SNL) was chosen and is currently being pursued. This document updates the criteria necessary for the development of the concept.

2.0 PURPOSE

2.1 BACKGROUND

The rotary-mode core sampling system is designed to sample liquid, sludge, and salt cake materials in waste tanks. The waste is to be collected in a universal sampler, which lowers down through the drill string into the core barrel and seals at the drill bit (Kelly, 1992). The waste is collected by either pushing or drilling through it. The universal sampler stays seated in the core barrel by the quadralatch, which can rotate with the drill. The sample section does not rotate because of bearings at the bottom and at the quadralatch. Between samples, the length of the drill string is increased by adding a 19-in. threaded segment.

When cutting through the salt cake material, friction and heat can be generated in the drill bit. Based upon tank safety reviews, it has been determined that the drill bit temperature must not exceed 180°C, due to the potential reactivity of tank contents at this temperature. Consequently, a drill bit temperature limit of 150°C was established for operation of the core sample truck to have an adequate margin of safety (Kelly, 1992). Many unknown factors, such as localized heating, cause this buffer to be so great.

The most desirable safeguard against exceeding this threshold is BTM, but no such devices have been developed. An envelope of operational settings was established through testing that guarantees that the bit will stay below 150°C. The settings are 0.85 m³/min (30 ft³/min) purge gas minimum while drilling, 5200 N (1170 lbf) maximum downforce, and 55 rpm maximum. Although this safety technique reduces the need for BTM capability, BTM continues to be desirable because of the resulting improvements in safety and sample recovery.

There are basically three steps required for a BTM system: sensing, transmitting, and receiving a temperature reading. Thermocouples were initially considered as sensors, because they gave a continuous temperature reading. The signal was to be transmitted by an undivided wire potted in the drill string, but the torque generated during drilling can tighten the drill string sections, which could rupture the wire. If the wire was segmented and connected across the drill string segments, the voltage drop would be too great, since the BTM system must use low power.

Thermistors were then considered since they operate on frequency response, not voltage. The signal could be transmitted via a segmented circuit, or over an infrared pulse (the concept suggested by SNL). The last step in BTM is to receive the signal and display it on the control panel. For a hard-wired system, this could be accomplished using a slip ring assembly or radio transmitter. A stationary receiver could be used for the infrared.

Various concepts for BTM were evaluated in a previous study (Francis, 1992). At that time, it was recommended not to proceed with any of the designs because of cost and schedule concerns. Recently, sufficient priority and funding were established for this monitoring capability. The SNL concept was pursued, because it held the most potential for success. Consequently, the criteria for this project are being updated to reflect changes in the core sampling system and other conditions that may be encountered.

2.2 OBJECTIVE

The objective of the BTM system is to provide an indicator to the core sampling operators to warn them that they are approaching the 150°C limit. The temperature readout gives another indication of safe drill bit temperature while drilling. It is most desirable to have a continuous temperature indication, to give operators a better feel for the effects of changing drill settings, rather than the sudden alarm and shut down of the system at 150°C. If it can be guaranteed that the bit temperature is safe, the BTM system may also allow the operating limits to be expanded, which could improve sample recovery and efficiency.

For the push-mode truck, the possibility of rotating slowly without any purge gas would be tremendously beneficial. Sample recovery is poor in sludge that has the consistency of bread dough, but it could be improved by turning the bit slightly while pushing through. A BTM system would ensure that the push-mode bit does not reach an unsafe temperature. In summary, the BTM device will be used mainly as a backup to current temperature safety limit techniques and may allow more flexibility in the operational settings for the core sample trucks.

3.0 SCOPE

This report covers the design specifications for a BTM device for the core sample trucks. The rotary-mode truck is the primary platform for which the device will be designed. Functionality on the push-mode truck is also desired, and requirements for that truck will also be included in this report. One standard design for the temperature monitoring system should be developed for all the core sample trucks.

4.0 DESIGN SPECIFICATIONS

The bit temperature sensor must operate within the design requirements of the rotary-mode core sampling system (Kelly, 1991) (Johns, 1992). In addition to the criteria for the trucks, items specific to this task must be addressed. Operational, environmental, mechanical, and scheduling requirements must be adhered to by a proposed temperature monitoring system.

4.1 OPERATIONAL REQUIREMENTS

The following performance characteristics are required for a BTM system.

- The system shall provide a reliable signal for truck alarm and shutdown at 150°C.
- For the range between 140°C to 150°C, temperature sensing and readout shall have a maximum error of $\pm 2^\circ\text{C}$. Below 140°C, maximum error may be up to $\pm 10^\circ\text{C}$.
- The BTM system shall transmit and display two independent temperature signals to provide validation of the readouts.
- Temperature shall be indicated incrementally.
- Drill bit temperature reading is required outside the tank where the core sampling truck operators have easy access to the data.
- Sensors shall monitor the outer race of teeth on the bit, the hottest area of the bit.
- Bit temperature shall be monitored a minimum of once per second.
- Operation time shall be a minimum of 1000 hr before change-out of the BTM equipment is required.
- Device shall operate within the electrical configuration of the core sample truck. There are conduits of 120/240 V AC and 12 V DC available for use on the truck.
- The BTM system shall be intrinsically safe and shall not generate any spark that could cause ignition of the tank wastes.

- Signal shall be analog and feed directly into the data logger on the truck. An industry standard device should be used, with a signal of 1-5 V and 4-20 mA.
- Mechanical or electrical failure in the system shall provide a safe condition and signal.
- Verification of proper functioning shall be added, if possible.
- Operation and performance of the core sample trucks shall not be hindered by the bit monitoring equipment.
- Modifications to the drill string shall not weaken it in torque, compression, or tension.
- The BTM device shall be easy to use in the field, taking into account that personnel will wear protective clothing. Usage and installation of the device should require minimal time and effort.
- Operator safety shall not be jeopardized. Exposure to personnel during operation and transportation shall be kept to as low as reasonably achievable.
- Waste in the tank shall not be adversely impacted, either physically or chemically (see Section 4.2, Environmental Conditions).
- Waste generation should be minimized. Disposal of the system will adhere to current WHC policies and regulations. It is preferred to use disposal equipment and procedures currently in use for the core sampling system.

4.2 ENVIRONMENTAL CONDITIONS

Components of the BTM system inside the drill string shall operate under the following conditions (Dougherty, 1993) (Kelly, 1991) (Lourant, 1989).

- 620 kPa (90 lbf/in²) of pressure from the purge gas. (Device shall be tested under 930 kPa [135 lbf/in²] and show no damage.)
- Operating temperatures between -20°C (-10°F) and 150°C (300°F).
- Radiation levels as high as 1,000 R/hr, and a maximum total dose of 2x10⁶ R.
- Corrosive pH levels from 8 to 14. Contact with chemicals of nitrites and nitrates.
- Compressive force of 4000 N (1000 lbf) on parts above the grapple weight and below the drill string adapter (hard-stop).
- Vibrational forces due to drilling. This may be proven through functional testing of the BTM system.

- Complete submersion in water, up to 37 lbf/in², due to equipment rinses or the hydrostatic head fluid on the push-mode truck, which has a lithium bromide tracer (concentration: 0.3 molar).
- Airborne particulate in the drill string.

4.3 CONFIGURATION REQUIREMENTS

The push-mode and rotary-mode systems possess established design configurations. Component modifications shall be kept to a minimum, and their functions shall not be altered. The following list described the mechanical constraints of the core sampling systems.

- Drill string and bit will be rotating (maximum rotation 55 rpm).
- Drill string may bow approximately 2 ft on the radius from the vertical position while rotating.
- Drill string has an outside diameter of 5.72 cm (2.25 in.) and an inside diameter of 4.83 cm (1.90 in.).
- Drill string is extended in 48-cm (19-in.) sections for each core sample segment. The universal sampler is removed and replaced between each segment.
- Maximum length of core barrel readily available and approved for disposal is 1.5 m (5.0 ft). Longer sections could be manufactured, which would increase expense and complicate disposal.
- Nitrogen gas will be used for cooling the bit by flowing through holes in the bit at a maximum of 1.4 m³/min (50 ft³/min). Maximum purge gas pressure within the system before exiting the bit is 620 kPa (90 lbf/in²). The BTM system shall not decrease or affect the gas flow or pressure.
- Nitrogen is also used as the hydrostatic head fluid during sampler change-out on the rotary-mode truck.
- The push-mode truck uses water for its hydrostatic head fluid. The fluid contains a tracer of lithium bromide with a concentration of 0.3 molar.
- Rotary-mode drill bit is constructed of carbon steel and a carbide matrix. It has an outer diameter of 6.403 cm (2.521 in.) and an inlet diameter of 2.858 cm (1.125 in.). There are three races of teeth, and intermittent holes allow purge gas flow. Detailed dimensions and samples are available.
- Push-mode drill bit has a smooth, tapered shape. The inlet hole is 2.858 cm (1.125 in.) in diameter. Detailed dimensions and samples are available.

- The maximum downward force on the drill bit is approximately 5200 N (1,170 lbf) during rotary-mode sampling and 13,000 N (3,000 lbf) in push-mode.
- After the grapple assembly tops out at the drill string adapter and drops the pintle rod, there can be a compressive force of 4000 N (1000 lbf) on the grapple.
- The drill string, core barrel, and drill bit are used for only one core and then disposed.
- The core sampling truck will normally be stored outdoors. The BTM system shall withstand surface temperatures between -20°C (-10°F) and 90°C (200°F) while in storage.
- The maximum distance from the top of a tank riser to the tank bottom is 18 m (60 ft).
- Equipment fixed to the drill string or bit could be in the tank for up to 30 days; the universal sampler could be left in the drill string for six days.
- Equipment shall withstand corrosion and galvanic degradation from conditions in the drill string. Waste could potentially cling to the universal sampler when it is raised, which could leave clumps of waste on the pipe wall. Most of this will be cleared by the movement of the remote latch unit and the insertion of a new sampler. Some sludge may remain smeared on the pipe wall however.
- Components shall not be affected by material in the drill string that is a result of sampler removal or washing.

4.4 SCHEDULING REQUIREMENTS

- A prototype system will be available for demonstration and testing by September 30, 1994.
- Testing shall be completed by December 1994.
- The finalized BTM system and necessary documentation shall be ready for installation onto one of the core sample trucks by March 1995.

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