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DETECTION OF TUBE LEAKS IN PILESSUMMARY

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INTRODUCTION

The need for a method for the detection and location of leaks of coolant water from the pile tubes into the pile has long been recognized, and the possibility of using a chemical or radioactive tracer for this purpose has had continuing attention (1). The extreme dilution involved in finding a small leak, e.g. 5 gallons per day, out of a total pile coolant flow of about 140,000 gallons per minute, a factor of about 2×10^{-8} , requires a tracer of extreme detection sensitivity. For header-by-header or tube-by-tube testing, the sensitivity requirement is correspondingly reduced, but still formidable.

F. P. Brauer (HLO-CRO) has suggested tritium as a suitable tracer for this application, in that tritiated water is an ideal water tracer and because tritium can be detected at less than 1×10^{-8} parts per billion and is present in normal water at only 5 to 10 times that level. Some preliminary work in this direction has been undertaken by J. D. Ludvick (HLO-CRO) and will be reported by him. While such radioactive tracers can be detected at extremely low concentrations, they still require fairly massive injection quantities, which constitute a possible health hazard, or require involved detection procedures not easily adaptable to plant applications.*

Recognition of these difficulties has led to the further evaluation of methods employing nonradioactive tracers. While even the best chemical detection levels greatly exceed that of tritium, the spike levels also can be greatly increased, being limited chiefly by corrosion and cost considerations for substances otherwise compatible with pile operation.

AMMONIA TRACER

An investigation of the developed, commercially available instrumental methods of trace analysis has indicated that ammonia is probably the best tracer for this application, being detectable at less than 50 parts per billion, and appearing to be generally suitable with regard to corrosion and purging. Other possible tracers, such as S, Cl, O₂, etc. all appear to suffer from lower sensitivity, interference from pile atmosphere components or corrosion or pile poisoning effects.

(1) A. Russell, "Criteria for Leak Testing During Reactor Operation", HW-59704 (SECRET)

* The writer estimates that for a practical detection level of about 5×10^{-6} parts per billion in the pile gas, it would require about 0.03 mg tritium for each half-header injection to detect a 10 gallon/day leak, or about 3 mg (30 curies) per pile test. The MPC's for tritium are 0.1 $\mu\text{C}/\text{ml}$ in water and 2×10^{-5} $\mu\text{C}/\text{ml}$ in air.

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by

U. L. Upson

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Ammonia Tracer (continued)

Calculations from coolant flow and pile holdup data (see appendix) indicate that an injection of ten pounds of ammonia into the feed (riser-tap) end of a half-header should be sufficient to indicate whether or not leakage from all the tubes fed by that half-header totals five gallons per day or more. Thus, barring serious error in the assumptions or calculations, half a ton of ammonia (about \$50 worth at tank car prices) is enough to completely test one pile, including individual tube tests (at about 1/2 pound per test) in the indicated half-header sections.

Ammonia has many favorable features as a tube-leak tracer.

1. It is one of the most easily detected nonradioactive substances. By employing an ionization detector in a null-balance system, a continuous-flow direct-reading instrument sensitive to less than 50 ppb ammonia has been developed (Mine Safety Appliance Co., "Billionaire").
2. It is remarkably cheap--less than \$100 per ton in tank car quantities.
3. It is easy to inject. The vapor pressure of liquid ammonia is about 10 atmospheres at 25°C, sufficient to transport the liquid from the tank car to the injection point or pump location. A conventional boiler feed pump can be employed for injection, or the necessary pressure (600 psig) can be obtained easily by heating the ammonia to 81°C.
4. It is relatively noncorrosive, being even corrosion inhibiting to many metals at low concentrations. If injected at a maximum rate of 100 pounds/minute, e.g., a ten-pound injection in six seconds, the maximum concentration in the coolant would be only about 0.7 percent (0.4 M), and would decrease rapidly following the brief injection period.
5. It forms thermally instable salts, so should not cause substantial build up in the pile, and it is not a serious pile poison.

The disadvantages involved in using ammonia on a tracer are yet to be determined, but must include the hazard of injury or poisoning by rupture of a high pressure line or injector chamber, the possible corrosive effects at the injection points, and the possible build up of ammonium salts in the cool portions of the pile. It is felt that none of these are serious or insuperable difficulties, and that the use of ammonia as a leak tracer merits serious consideration.

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APPENDIX

CALCULATIONS

The calculations upon which the above evaluation is based are given below and are based upon the following assumptions:

1. That location of tube (or Van Stone) leaks can be determined most economically by first making tracer injections into each of the 78 to 92 half-headers at the riser tap points, and by making some type of tube-by-tube test of each half-header section for which leakage has been indicated. Analysis for the tracer is to be made upon samples diverted or absorbed from the exhaust gas stream.
2. That for leaks of operational significance, practically all the leak will be vaporized and will quickly be swept into the pile gas exhaust system. It is assumed that Van Stone leaks, while maintaining a saturated atmosphere in the pile, are much less damaging than those occurring in the hot graphite, and that higher leakage rates can be tolerated in those locations from which tracer flow would be least direct.
3. That while test injections may be relatively short and intense, e.g., a few seconds' duration, diffusion and other transport effects will severely modify the concentration peak at the exhaust manifold. It has been assumed for these calculations that the maximum concentration at the detector will be that which without diffusion or absorption would be obtained by constant-rate injection of the same total amount of tracer over a five-minute period.
4. That practically all tracer material from previous tests will have been dissipated from the system by the start of each successive test period, or that the background level will have become sufficiently stable to permit detection of small changes in tracer concentration. It is assumed that to be of optimum value, successive tests should be possible at no longer than twenty-minute intervals.
5. That the following conditions are typical and may be taken as valid basis for these calculations:

A. Coolant flow per half-header	1800 gpm
B. Coolant flow per tube	70 gpm
C. Total gas system volume	25,000 ft ³
D. Gas temperature at exit	30°C
E. Gas moisture content	saturated
F. Gas pressure	1 atmos.

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The concentration of tracer in the pile gas, or in the pile gas condensate, is a function both of the leakage rate, R , and of the amount of tracer injected, T . For injection into a half-header at the riser tap, the concentration of tracer in the cooling water, averaged over a 5-minute period, is

$$C_h^i = T/5 (1800) 8.3 = 13 T \times 10^{-6} \\ = 13 T \text{ ppm}$$

and for injection into a single tube

$$C_t^i = T/5 (70) 8.3 = 340 T \text{ ppm}$$

where T is the amount of tracer injected in pounds.

Dilution in the pile by water vapor in the pile atmosphere reduces this concentration

$$\frac{5(8.3)R/24(60)}{25,000 (0.00189)} = \frac{0.029R}{48} = 6 \times 10^{-4} R$$

The net concentrations in the pile gas then is

$$C_h^{\prime\prime} = (1.3 \times 10^{-5})(6 \times 10^{-4}) RT = 7.8 \times 10^{-9} RT = 7.8 RT \text{ ppb}$$

relative to the total water in the pile atmosphere, or

$$C_h^{\prime\prime\prime} = 7.8 RT \left[\frac{31.8(18)}{31.8(18) + 728(4)} \right] = 7.8 RT (0.165) = 1.3 RT \text{ ppb}$$

relative to the saturated pile gas, for half-header injection. Similarly, for single-tube injection, the concentration relative to the saturated pile gas is

$$C_t^{\prime\prime\prime} = (34 \times 10^{-5})(6 \times 10^{-4}) RT (0.165) = 34 RT \text{ ppb}$$

The concentration of tracer in the pile gas condensate might be expected to be higher than in the dry gas, owing to the solubility of ammonia in water, and to the probably slightly acidic nature of the water due to CO_2 in the atmosphere. Further enrichment should be obtainable by treating the condensate with caustic and purging with an inert gas. This could be done on a continuous flow basis by employing a small packed column and counter-current gas flow, or by sparging gas through a caustic-condensate solution. Enrichment might be as high as ten-fold, but may not be sufficiently needed to justify the added procedure.

Whether pile gas or sparge gas is to be analyzed, it is probable that a caustic drier will be needed to attain the manufacturer's stated sensitivity. Allowing for ~30 percent loss in this step, and neglecting any possible enrichment by condensate treatment, the concentrations of NH_3 tracer in the dried pile gas (or dried carrier gas) may be taken to be

$$C_h = 1.0 RT \text{ ppb (half-header injection),} \\ C_t = 25 RT \text{ ppb (single-tube injection).}$$

and

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Assuming a reliable detection level in the dried gas of 50 ppb, as claimed by the manufacturer, the required tracer injection quantities can be calculated for various leak rate levels.

TABLE I

<u>Detectable</u> <u>Leak Rate, R.</u>	<u>Pounds of Ammonia Per Test</u>	
	<u>half-header</u>	<u>Single-tube</u>
1 gal. per day	50	2
5 gal. per day	10	0.4
10 gal. per day	5	0.2
etc.		etc.

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