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SUBJECT: Proposed Multiple In-Pile Rocking Bomb
Experiment.

TO: Experiment Review Committee

FROM: R. J. Davis
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1. Purpose of the Experiment

The purpose of these experiments is to study the effects of reactor radiation at elevated temperatures on the stability and corrosive properties of aqueous fuel systems.

1a. General Description of the Experiment

The experiment is generally similar to the radiation corrosion bomb experiment presently installed in HB-5.

A semi-permanent hole plug containing 3 holes for individual experiments would be installed in the HB-5 beam hole. The individual rocking plugs would operate and could be inserted or removed independent of one another.

The semi-permanent three-hole plug is enclosed in a 61S-T6 aluminum tube of appropriate dimension to fit HB-5. The temperature of the inner end of the liner is monitored by two chromel-alumel thermocouples to protect against over heating and loss of water shielding. The inner 55 inches of the plug are filled with water to provide cooling and neutron shielding. This portion of the plug is connected through a 6 inch 61S-T6 aluminum plug to an approximately 72 inch section of Portland cement and lead or steel shot mixture (250 lbs/cu.ft). The remaining 11 inches are steel. Each of the three symmetrically located, 2 inch diameter experimental holes are lined with 61S-T6 aluminum tube, and provided with 3 dry bronze bearings. A 10 mil thick, 9 inch long, cadmium tube is located in each hole 6-13/16 inches from the end of the hole plug.

The forward 57 inches of each experimental plug is a 2" diameter aluminum tube containing the necessary electrical leads, cooling fluid lines and at the inner most end, the bomb and furnace-cooler assembly. This portion, which is replaced for each experiment, is connected through a $4\frac{1}{2}$ inch stainless steel piece to an approximately 83" long stainless steel tube. The void

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space in the stainless tube is filled with a mixture of Portland cement and lead or steel shot (density 250 lbs./cu. ft. or greater). The tubes which necessarily pass through the concrete section are spiraled to prevent an open beam to the reactor lattice.

Dummy plugs containing the same shielding material will be provided for use when experiments are not operating.

Each experiment consists of a cylindrical autoclave, 7/8 inches O.D., 9/16 inches I.D., and 4 inches long of the test material, containing a coupon holder and coupon specimens and located at the inner end of the rocking plug. A pressure leg from the bomb is brought back to the face of the reactor to a Baldwin SR-4 pressure cell, by means of a water-filled stainless steel capillary tube. The capillary tube and pressure cell are valved to allow venting of the active gases from the bomb prior to removal from the reactor, without contamination of the pressure cell. The temperature of the autoclave is measured by means of four iron-constantan thermocouples peened into the wall of the bomb. A fifth thermocouple monitors the temperature of the capillary a short distance from the bomb.

The temperature of the bomb is maintained by an aluminum tube assembly wound alternately with electrical resistance wire and cooling coils. Provision is made to cool by air, or a mixture obtained by injection of water into the air stream. The transition from one cooling fluid to another is accomplished automatically by the power recorder which monitors the power demand on the heater. Air cooling of the section of the capillary close to the bomb is provided to retard corrosion and plugging.

The temperature of one of two alternate thermocouples is controlled by a pneumatic controller, which operates the input voltage to the bomb heater. Both control thermocouples are symmetrically located on the bomb wall midway between the two ends of the bomb, and are expected to register the same

temperature even in the event that considerable temperature gradient occurs across the length of the bomb. To reduce the chance of losing the control thermocouple and giving a false high temperature alarm, provision is made to automatically switch to the alternate control thermocouple on high temperature. Reactor power reduction is called for only if the alternate control thermocouple verifies the high temperature.

The entire experiment, including bomb, furnace, capillary, Baldwin cell, etc., is sealed in a pressure tight container. Heater leads, pressure cell leads and thermocouples are brought out of the can through pressure tight cannon plugs. Appropriate lines are brought into the can to provide air and water cooling. The inlet and outlet air lines for cooling the capillary are the only openings into the can.

To provide wetting of the corroding surfaces and some agitation of the solution the entire can will rock through a 60° arc at about 9 cycles per minute.

To reduce the neutron flux at the bomb, without asking for reactor power reduction, provision is made to manually retract the three experimental plugs simultaneously. On retraction, the bomb will reside a greater distance from the reactor lattice and within the cadmium shield.

The approximate ranges in operating characteristics will be:

Bomb volume	10 ml
Solution volume at temperature	7.5 ml
Bomb temperature	225-300°C
Total bomb pressure	400-3000 psi
Excess oxygen pressure	50-700 psi
Stoichiometric gas pressure ($2H_2 + O_2$)	0-700 psi
Steam pressure	370-1250 psi

Fission power		0-250 watts
Solution composition	UO ₂ SO ₄	0-0.17 m
	CuSO ₄	0-0.05 m
	H ₂ SO ₄	0-0.05 m

The bombs will normally be made from type 347 stainless steel, 55A or 75A titanium or Zircaloy-2. The coupon material will include other alloys. Each bomb and capillary assembly will be hydrostatically tested at 4500 psia and 300°C before being accepted.

The primary data from these experiments will be the residual oxygen pressure and the corresponding temperature in the bomb. Precise determination of these quantities will require a reactor shutdown. A rough measure will, however, suffice during most of the operating time and this can be calculated from a comparison of observations made with the experiment in the normal position and in the retracted position.

An electric motor and a gear box mounted on the reactor face provide the power for rocking the plugs. Also at the reactor face will be a shielded box 39" x 24" x 12" containing the necessary valves and utilities for venting the bombs prior to removal.

2. Responsible People in Charge of Equipment

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3. Amounts and Kinds of Materials, etc.

The fixed three-hole plug is 1/8 inch thick 61S-T6 aluminum jacket fitting HB-5 and containing 55 inch water at the forward end, 6 inch of aluminum, 72 inches of concrete-lead or steel shot mixture (250 lbs/cu.ft) and 11 inches of steel. The three experimental holes are lined with aluminum

and contain a 10 mil thick 9 inch long cylinder of cadmium located 6-13/16 inches from the end of the plug.

The forward 57 inches of the experimental plugs are 2 inches in diameter, 61S-T6 aluminum tube. The 7/8 inches O.D., 4 inches long bomb, located at the forward end will normally contain 7.5 ml of 40 g $U^{235}/1 UO_2SO_4$ solution. The cooling tubes, etc., are of 61S-T6 aluminum and stainless steel couplings. Backing up the aluminum tube are $4\frac{1}{2}$ inches of stainless steel and an 83 inch length of stainless steel tube with the void space filled with a Portland cement and lead or steel shot mixture.

Drawings of the in-pile and external equipment as well as electrical services and piping are listed below:

MULTIPLE ROCKING BOMB LITR HB-5
Building 3005

E-24550	Layout of Equipment
D-24551	Schematic Flow Sheet
E-24552	Assembly of In-Pile Equipment
E-24553	Sub-Assembly of Fixed Three Hole Plug Sheet #1
E-24554	Sub-Assembly of Fixed Three Hole Plug, Sheet #2
D-24555	Sub-Assembly of Rocking Plug, Sheet #1
D-24556	Sub-Assembly of Rocking Plug, Sheet #2
E-24557	Details of Rocking Plug, Sheet #1
D-24558	Details of Rocking Plug, Sheet #2
D-24559	Sub-Assembly and Details of Test Bomb Model II
D-24560	Sub-Assembly of Heater-Cooler
D-24561	Details of Heater-Cooler
D-24562	Sub-Assembly of Details of Dummy Plug
D-24563	Assembly of Drive Mechanism
D-24564	Drive Mechanism Details, Sheet #1
D-24565	Drive Mechanism Details, Sheet #2
D-24566	Assembly of Sample Station
D-24567	Details of Sample Station, Sheet #1
D-24568	Details of Sample Station, Sheet #2
D-24569	Details of Sample Station, Sheet #3

D-24570 Assembly of Dismantling Shield
D-24571 Details of Dismantling Shield, Sheet #1
D-24572 Details of Dismantling Shield, Sheet #2
D-24573 Details of Dismantling Shield, Sheet #3

D-24574 Details of Dismantling Shield, Sheet #4
D-24575 Miscellaneous Details Sheet #1
D-24576 Miscellaneous Details Sheet #2
D-24577 Assembly and Details of Transport Carrier Dolly

E-24578 Assembly and Detail of Transport Carrier
D-24579 Transport Carrier, Detail Sheet #1
D-24580 Miscellaneous Tools
D-24581 Details of Sample Station Sheet #4

C-24582 Sample Station Painting Instructions
D-24583 Miscellaneous Details, Sheet #3
D-24584 Modification of Dismantling Cell
D-20908 Service Piping and Details - Plan and Details

D-20909 Service Piping - Sections and Details
D-20910 Service Piping Front Elevation
C-25360 Monorail Location Plan
D-25863 Power Plan and Elevations

D-27336 Air Conditioning
TD-D-4661 Instrument Flow Sheet
TD-E-4662 Control Circuit Schematic
TD-E-4663 Control Panel Layout

TD-D-4665 Relay Rack No. 1
TD-D-4666 Relay Rack No. 2
TD-D-4669 Relay Rack No. 3
TD-D-4670 Relay Rack No. 4

TD-D-4672 Piping Schedule
TD-D-4682 Wiring Diagram Panel No. 1
TD-D-4683 Wiring Diagram Panels No. 2 and No. 3
TD-D-4684 Wiring Diagram Panels No. 4 and No. 5

TD-E-4685 Reactor Safety Relay Rack
TD-D-4699 Pressure and Thermocouple Connections

4. Utilities Required

Electrical	75 amps at 110 v.
Air	15 SCFM
Demineralized Water	5 gpm
Hot off-gas	15 SCFM
Process Water	1 gpm

5. Duration of the Experiment

The duration of this series of experiments will probably be at least two years.

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6. Frequency of Removal of Experiments

An insertion and a removal is expected to occur, on the average, once per week.

7. All necessary shielding and handling equipment will be provided by the experiment operations group (see sections 8 and 9).

8. Insertion Procedures

The following three types of insertions will be encountered during routine operation of the experimental facility:

1. Insertion of a dummy shielding plug after removal of an experiment.
2. Insertion of a new experimental unit after removing an experiment.
3. Insertion of an experiment after removal of a dummy plug.

In cases 1 or 2, the shielding plug or experiment package will be inserted through the special venting and disassembly shield by means of suitable remote handling tools. In case 3, the experiment package will be inserted from an adjustable plug cart similar to the one currently used for insertion into HB-5 and HB-6 at the LITR.

9. Removal of a dummy shielding plug with attached flux monitor:

Dummy shielding plugs will be withdrawn onto a shielded plug cart.

The front one foot of the plug and all of the flux monitor will be shielded by 2-3/4" of lead.

9a. Removal of Irradiated Experiment:

1. After a suitable delay (probably several hours) for decay and collection of data, the experiment will be cooled to approximately ambient pile temperature.

2. A small tube jumper will be used to connect the vent fitting on the experiment to a shielded vent line leading to the sample station.

3. After completion of appropriate leak checks, the venting and disassembly shield will be moved into place and the active gas will be vented to a hold-up tank in the sample station.

4. After venting the active gases, the bomb and capillary will be flushed by successive pressurizations with low pressure (50 psig) nitrogen until the radiation level at the capillary stops decreasing. The bomb and capillary will then be evacuated to near the vapor pressure of the solution of the bomb.

5. After disconnection of the venting capillary, the experiment will be withdrawn until the reference mark on the container is behind the disassembly shield. The container will be cut open and separated to allow the service lines to be cut and to allow the capillary to be clamped and cut.

6. When the experiment package has been opened and separated, the irradiated portion of the experiment package will be drawn into a shielded transfer carrier which is lowered into place from the overhead monorail.

9b. Disassembly

The highest radiation levels will be encountered during disassembly of the experiment. During this time, there will be essentially no shielding between the beam from the reactor beam hole ($2\frac{1}{2}$ " in diameter) and the portion of the experimental package where the separation will be made. It is expected that the intensity of this highly collimated beam will be between 500 and 1000 R/hr. The radiation beam will exist until a new experiment or dummy plug is inserted into the hole.

9c. Disposal of Radioactive gases

After a short hold-up period to allow separation of entrained particles and droplets, the active gases from the experiment will be

released to the LITR off-gas system.

9d. Disposition of Irradiated Experiment

The active portion of the experiment package will be transferred directly to the hot cell facilities in Bldg. 4501. The reuseable portion of the experiment package will be stored in one of the storage racks in the east room until transfer for decontamination.

9e. Storage of Dummy Shielding Plugs

Dummy shielding plugs will be stored in an especially equipped shielded storage rack in the east room of the LITR.

10. Hazards

Two types of hazards to personnel seem to be typical of reactor experiments; i.e., the shielding between the radioactive material and the operator can become displaced or the radioactive material can be displaced to in front of the shield. Both dangers are present in this experiment. One other hazard typical of aqueous in-pile systems is the presence of high pressure due to the steam and the explosive mixture of hydrogen and oxygen present.

The use of water as a fast neutron shield in the forward end of the fixed plug presents an inherent danger of high radiation.

The possibility of a leak in the pressurized system exists. Activity would be admitted into the pressure tight can, and vented out the capillary air cooling outlet line to hot off-gas. The danger of contamination is minimized by the experiment being enclosed in a partially evacuated can, but as much as 1000 curies of activity might be vented through the unshielded line in one burst or over a long period of time presenting, of course, a radiation hazard.

High bomb temperature is primarily a danger because it could

lead to high pressure, possibly a bomb rupture and a radiation hazard. Furthermore, many of the solutions to be tested are not stable at high temperatures, i.e., some of the fuel precipitates or falls to the bottom as a second liquid phase. The fuel thus concentrated could lead to hot spots and ignition of the stoichiometric gas.

Low bomb temperature is hazardous because it markedly decreases the activity of the recombination catalyst which would lead to high radiolytic gas pressure.

High pressure is dangerous in as much as it could lead to a bomb rupture, especially if it is largely due to radiolytic gases.

Low pressure is considered mildly dangerous only because it indicates malfunctioning.

High temperature or loss of cooling of the capillary close to the bomb, is considered mildly dangerous if it continues for a period of several hours or more. Air cooling of the capillary is provided to reduce corrosion in the capillary and hence the frequency of plugged capillaries and the associated loss of pressure monitoring and the hazards of removing the experiment without venting.

Loss of heating or cooling on the bomb is dangerous inasmuch as low or high temperature would result.

Stoppage of rocking is dangerous because of gamma heating of non-wetted parts which could lead to hot spots and ignition of the radiolytic gas. This is a serious danger since the coupon rack in the bomb projects above the solution and many experiments are operated with a vapor composition in the explosive region.

11. Safeguards and Alarms

The rocking plugs are continually vented under a pressure of

several inches of water to the LITR off-gas system. Indication of the sub-atmospheric pressure in the rocking plug is given locally.

Low water flow (flow switch) through the fixed plug gives an annunciator locally. High temperature (thermocouple) on the forward end of the fixed plug alarms locally and calls for a fast setback.

A monitron located in front of the beam hole annunciates locally and scrams the reactor on high radiation.

High bomb temperature (thermocouple) initiates the following series of events. The control thermocouple which gives the alarm is automatically switched to an alternate couple with local annunciation. If the alternate couple verifies the high temperature condition a local and control room annunciator is given. A still higher temperature calls for a fast setback and local annunciation. If the temperature still rises a local alarm, reactor scram and furnace shut-off occurs.

Low bomb temperature (thermocouple) calls for local and control room annunciation. Continuing temperature drop gives a local alarm and a reactor fast setback.

High bomb pressure (Baldwin cell) first gives a local and LITR annunciator. Higher pressure gives a local alarm and a fast setback. If the pressure still insists on rising a local alarm, reactor scram and furnace shut off occurs.

High capillary temperature (thermocouple) gives a local annunciator.

To protect the furnace, provision is made to automatically switch (solenoid valve) to air cooling on high heater power. Low heater power automatically switches back to water cooling of the bomb. Either action gives a local annunciator.

The rocking monitor depends on closing a microswitch at either

extreme of the rocking cycle. If either switch is either permanently closed or is not closed periodically the alarm is given. The alarm gives a local annunciator and scrams the reactor. Since there are visualized experiments or portions of experiments during which operation without rocking would be desired and not dangerous, provision is made to by-pass the rocking monitor. The by-pass switch is key operated, the key being kept by reactor operations personnel. The by-pass gives a local panel light.

To take care of the times when only one or two experiments are operating, a key operated switch is provided for each panel section which disarms that set of alarms. Reactor operations personnel will have the key and again a local panel light is lighted when the by-pass is in effect.

Local annunciation is given if the LITR safety plug is out or in case of air pressure failure.

In order to make precise pressure readings, the pressure signal is transferred to a precision indicator. Simultaneously the pressure recorder is shorted to prevent false high pressure alarms. If the operator neglects to replace the selector switch back to normal before three minutes pass, and a local and LITR annunciator is sounded.

12. Alarm Values and Safety Circuit Diagrams

Exact values of alarm settings and normal operating values on the various indicators, recorders, and controllers will change with experiments and will be provided with each experiment.

The following table gives estimated operating data for a typical experiment and provides a synopsis of the preceeding two paragraphs.

See section 3 for circuit diagrams.

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Indication	Sensing Element	Indicator	Normal Reading	Alarm Value	Alarm	Purpose of Alarm
LITR plug out	relay sw.	--	plug in	plug out	HB-5 Ann.	Insure safties in
LITR scram	Sc. relay	--	Clear	LITR Sc.	HB-5 Ann.	local in-
LITR FSB	FSB relay	--	"	" FSB	" "	formation
LITR Ann.	Ann. relay	--	"	" Ann.	" "	" "
Override	relay sw.	--	P selector normal	Selector on P	LITR, HB-5 Ann. 3 min. T.D.	Alarms By-passed
Lo Inst. Air Press.	P. sw.	--	20 psi	>15 psi	HB-5 Ann.	Local Infor-mation
Lo Demin. Flow	Flow sw.	Rotameter	0.5 gpm	.3 gpm	LITR, HB-5 Ann.	High temp. loss of shielding
Hi Plug Temp.	Thermo.	Sym-ply-trol	40°C	>60°C	FSB, HB-5 Ann.	Hi temp., loss of shielding
Hi radiation	Monitron	Monitron	Low	>10 mr/m	Sc, HB-5 Ann.	Hi radiation
Rocker	Micro sw.	Visual	Rocking	Not rocking	" "	Hot spots in bomb, possible gas ignition

(Following are in triplicate - one for each rocking plug).

Bomb Temp.	Thermo T1	Multipoint Recorder	255°C	--	--	--
	Thermo T2	Pneumatic Recorder Controller	250°C	>260°C	HB-5 Ann. Sw. to T3	Verify alarm condition
				>265°C	LITR, HB-5 Ann.	Warning alarm
				>275°C	FSB, HB-5 Ann.	Hi bomb temp.
				>280°C	Sc, HB-5 Ann. Furn shutoff	Hi bomb temp.

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Indication	Sensing Element	Indicator	Normal Reading	Alarm Value	Alarm	Purpose of Alarm
Bomb Temp.	Thermo T3	Multipoint Recorder	250°C	>235°C	LITR, HB-5 Ann.	Warning alarm
				>230°C	FSB, HB-5 Ann.	Lo bomb temp.
				--	--	See T2 switchover
	Thermo T4	"	245°C	--	--	--
Capillary Temp.	Thermo T5	Sym-ply-trol	100°C	>150°C	HB-5 Ann.	Capillary corrosion danger of plugging
Bomb Press.	Baldwin Cell	Pneumatic Recorder	1000 psi	>1500 psi	LITR, HB-5 Ann.	Warning
				>2000 psi	FSB " "	Hi bomb pressure
				>2500 psi	Sc, " "	Hi bomb pressure
Heater Power	Wattmeter	Pneumatic Recorder	Reactor Pwr zero, 150 w	>100 Watts	HB-5 Ann. sw. to air	Avoid htr. overload
			Reactor Pwr 3 Mw, 60 watts	<50 Watts	HB-5 Ann. sw. to water	Avoid over heating
Inlet Water-flow	Rotameter	Rotameter	On water cooling, 0.2 gpm	--	--	--
			On air cooling, small	--	--	--
Inlet Air-flow	"	"	On water cooling, 0	--	--	--
			On air cooling, 3 SCFM	--	--	--

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13. Requirements on Operation of Reactor

Precise pressure and temperature observations can only be made when the reactor is down because of the variable radiolytic gas pressure on the one hand and temperature gradients due to gamma heating on the other. It is planned that, with rough intermediate readings with the experiment in the retracted position, the normal weekly shutdown will suffice. During particular experiments more frequent shutdowns will probably be desirable.

A sudden reactor start up will give our experiment a momentary increase in temperature of 10-15°C provided it is in the inserted position. This action tends to put some of the corrosive fuel solution into the capillary and initiates the formation of a plug in the capillary. Normally a reactor start up from N_L to full power in 5 minutes or longer is required. If the experiments are retracted on start up there would be no requirement on reactor start up procedure.

Sudden power reversals momentarily drop the temperature 10-15°C.

14. Influence of Utility Failure

Loss of electrical power will shut off the bomb heater and within several seconds the bomb temperature would fall below the alarm condition. Also the experiment would stop rocking because of lack of power to the rocking motor. Due to the fail safe philosophy in wiring the alarm panel, loss of power gives a reactor scram, fast setback, and annunciator. When the power returns, the rocking motor and heater would have to be turned on again. As soon as the bomb temperature reaches temperature equilibrium, reactor power could be accepted.

Loss of suction on the LITR off-gas system would give a positive gauge pressure in the experimental can enclosing the rocking plug. Air would continue to be forced through the plug at a somewhat lower rate. As

a result of the lower flow, the capillary temperature would rise, but probably not to the alarm point. Loss of off-gas suction would reduce the bomb cooling capacity if the experiment was using air cooling at the time of the failure. The decreased cooling would lower the power demand, perhaps to the set point which automatically shifts to water cooling. When normal suction on the off-gas system is reinstated, the bomb cooling medium should be checked.

Loss of air pressure is serious, inasmuch as the instrumentation includes numerous pressure switches and air operated recorders and controllers. Automatic switch to water cooling is affected. Various alarms are given including low temperature, low pressure annunciators, a low temperature fast setback, a rocking monitor scram and a local indication of low instrument air pressure.

Loss of demineralized water will stop flow through the fixed beam hole plug which gives a local alarm. If the condition continues for some time the plug would heat up and give a high temperature fast setback. If the no-flow condition leads to loss of shielding, perhaps due to boiling, the monitor in front of the beam hole will give a reactor scram. If the bomb is using water cooling when the failure occurs, all the cooling capacity will be lost and high bomb temperature will result leading to alarm, fast setback, and if the temperature goes high enough, a reactor scram and furnace cut-off. If an operator was immediately available when the failure occurred, he could prevent total loss of cooling capacity by manually switching to air cooling. When the water failure is rectified the experiment would be ready to accept reactor power provided the heater was not shut off by a high temperature alarm.

Loss of process water flow to the air and water separator, for several minutes or more, would allow the steam produced in the bomb cooling system to go on out through the off-gas line.