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INCIDENTS RELATED TO REACTOR SAFETY

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INCIDENTS RELATED TO REACTOR SAFETY

by

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Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

March 15, 1962

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

INTRODUCTION

The production reactors at Hanford have operated approximately one hundred reactor-years. In accumulating this experience, occasional incidents or accidents have occurred which have had reactor safety implications, and a few have resulted in relatively minor in-plant consequences. In no case have property or personnel external to the plant been affected by these events.

This report lists some of the more significant incidents in which personnel action, inadequate procedures or equipment failure have led to events of importance to reactor safety. In view of the substantial accumulated experience in operating the Hanford production reactors, these events may be typical of those encountered in the operation of a "mature" nuclear plant.

This report does not list all the incidents, either by quantity or type, that have occurred. Rather, it is more a listing of events that are typical of Hanford experience. In this regard, the report is responsive to an Atomic Energy Commission request.*

SUMMARY OF INCIDENTS

Ten operational incidents are summarized below, the consequences of which range in severity from an event in which a portion of the fuel charge was partially melted to events resulting in no damage or interruption of reactor operation. These events have occurred over the past few years and are fairly illustrative of other such events occurring during the operating period of the Hanford production reactors.

1. Partial Melting of Fuel Charge

   This incident occurred during the first 24 hours of operation of the reactor involved. The reactor power level was well below the design rating and was being gradually increased on a preplanned schedule. During the power increase, evidence was obtained of a sizable process tube water leak. An attempt was made to map the coolant outlet temperature of all process tubes so that the location of the leak might be determined. During this time, the reactor was scrammed by a flow monitor trip, and fuel rupture indications were received. The offending tube was identified by the flow monitor and rupture detection indications. Later, it was determined that a portion of the fuel charge and process tube had partially melted. A rubber blank, used to isolate some of the process tubes from the coolant system during pre-startup zero-power lattice physics tests, had been accidentally left in the rear fittings of the incident tube. The location of the blank not only blocked the cooling water flow of the tube, but also isolated the tube from its temperature sensor, causing the sensor to monitor the temperature of the water from adjacent tubes in the outlet crossheader. The gage monitoring tube flow had been improperly adjusted, causing the blanked off tube to appear to be receiving a normal supply of coolant.

* Letter, OR:MRS, A. T. Gifford to A. B. Greninger, "Fog Spray and Safety Incident Data for ACRS," dated January 12, 1962.

2. Partial Meltdown of a Poison Column

A pressure monitor impulse line fitting failed on a Poison Column Control Facility (PCCF) tube containing nuclear poison pieces. During attempts to discharge the tube, the reactor reactivity dropped sharply and the reactor was manually scrammed. It was later found that some of the poison pieces and a small spot in the tube had been melted. The blown-out fitting caused a sizable leak. Each time the flow to the tube was throttled for discharge operations, in-reactor flow stopped, and probably reversed. This reverse flow and/or boiling displaced the poison pieces from their normal downstream position to a more central location in the tube, decreasing reactor reactivity. Finally, when the tube rear closure (ball valve) was remotely opened, reverse flow was stopped, and the water flow from the rear crossheader passed directly out the rear nozzle. This lack of coolant caused the poison pieces and tube to melt.

3. Inlet Face Component Break

At the time of the incident, a Poison Column Control Facility (PCCF) tube had just been charged with poison elements. The charge face work platform was moved while the charging machine was still connected to a front nozzle. The front nozzle was broken off, and irradiated nuclear poison and aluminum dummy pieces were flushed onto the work platform. The reactor was scrammed and the pieces disposed of without further incident.

4. Total Loss of Electrical Power

All electrical power to a reactor plant was interrupted. The reactor at the time was operating at full equilibrium power level. The electrical power failure suddenly removed the source of primary pumping energy, and caused a reactor scram. The secondary coolant system performed as designed, and no reactor damage was experienced. The last-ditch cooling system was not called into service, remaining as an additional backup.

5. Reactor Startup with Safety Instrumentation Bypassed

A reactor was started up from a scram with both the pressure (flow) monitor system bypassed and the circuit that actuates the Ball Third Safety system on loss-of-water bypassed.

6. Localized Reactivity Gain

At the time of this incident, an attempt was being made to charge an empty Poison Column Control Facility tube with poison pieces. Flow to the tube was throttled and the charging machine was connected to the tube nozzle. The first piece charged, a perforated dummy, cleared the charging machine and stopped in the nozzle. The second perforated dummy lodged in the charging machine. An attempt was made to free the second piece by opening the charging machine. Water flowed out the front nozzle and personnel observing the rear nozzle through a viewing window saw a spurt of water and steam emerge from the open rear ball valve. A reactivity surge was noted in the control room and work on the tube was stopped; following this, the reactivity surge subsided. The operation was repeated a few hours later. This time, the reactivity surge was sufficient to cause a flux monitor trip, scramming the reactor. When flow to the tube was reduced by removal of the charging machine, the water boiled out, causing a rapid, local reactivity increase. Since the tube was in close proximity to the flux sensing instrument, the surge was sufficient to trip the safety circuit.

7. Minor Reactivity Surge During Operation

An operator, undergoing training, withdrew a horizontal control rod, causing a surge in reactivity. The event was noted by a regular operator, who took the necessary corrective steps and avoided a reactor scram. It was later estimated that the reactor power increased largely in a local area near the control rod that was moved, and process tube outlet water temperatures were increased only moderately above normal, but below limiting values.

8. Neutron Flux Perturbation

An operator attempted to shut a reactor down by near-full insertion of two partially inserted half-rods. Only the tip end of half-rods are strongly poisonous. Driving the rods all the way in can actually increase reactivity. When the half-rods were further inserted, a process tube temperature monitor trip was received. While efforts were made to take corrective action, temperature monitor alarms on a number of other tubes were received, and the reactor was manually scrammed.

9. Fast Startup

A startup following a scram from sub-equilibrium power levels was being attempted. The power level increase to a high level was more rapid than normally allowed. The reactor was shut down by a pressure (flow) monitor low-trip. A temporary rate-of-rise meter had shown the power level to be increasing at normal rates. However, this instrument was later found to be reading low. Further, a calibration switch was found in the wrong position, causing the instrument to indicate low by about a factor of two. The pressure monitor trip was believed to be a low-pressure trip. This could have been caused by an increase in tube flow rates that result from reduced viscosities as the temperature increases. Such pressure transients with increasing temperature are normal.

10. Fuel Element Fire

A fuel failure occurred in a process tube that also contained a thin metallic ribbon of nuclear poison, called a "spline." Rupture removal was attempted by pushing the tube, charge and spline out of the reactor together. Part of the tube was pushed and was broken off, but was held up by the spline. Sparks were then noted by observers at a remote viewing window, followed by a flame which persisted for about ten seconds. The remainder of the tube was later pushed out without further incident.

DISCUSSION

In reviewing the events summarized above, and other similar events that have not been included here, four general classes of factors contributing to the incidents can be identified. These are: personnel actions, equipment deterioration or failure, changes of procedure, and design or equipment changes. Of the various factors listed, the actions of personnel are found to be involved in most of the events, with equipment deterioration or failure frequently contributing to or initiating an event that becomes more severe through personnel error or action based upon inadequate information. As another general observation, it is usually difficult to isolate any one of these factors as having completely influenced any specific incident. More frequently, it is found that a series of two or three of the factors is necessary to develop an incident of the type reported here.

The following specific observations arise from investigations of the above listed incidents.

1. Perhaps the most crucial time in the operation of the reactors occurs while they are being started up, either initially or from an outage. The preparations for and the actual startup operations involve many details, small and large, each important by itself. The number of such details, and the fact that many of them must be concurrently considered, creates a natural opportunity for oversight. Interlocking instrumentation and controls and procedural guides can, of course, be of value in avoiding such oversights, but the inability to make such precautions absolutely prohibitive of error still leaves an exposure to mistakes.

2. Even for those events initiated by equipment failure, the ultimate consequences of the incident are usually determined by the actions of personnel following the failure. In these circumstances, corrective action is immediately required, and must sometimes be initiated without the benefit of a complete investigation. Without full information of the failure and its relationship to reactor systems, these corrective actions will sometimes appear later to have been ill-advised.

3. The urgency of an emergency situation, and sometimes the press of startup operations, when coupled with a personal association of operating personnel to the reactor facility, creates a potential source of procedural violations that is basically motivated by an interest in doing an efficient job.

4. To establish a well thought-out organizational structure does not automatically guarantee that the responsibilities assigned by the structure will always be carried out as planned. Emergency conditions will sometimes cause individuals to improperly assume responsibilities, or cause others to improperly abdicate their responsibilities.

A discussion such as this tends to lose sight of the fact that the production reactors at Hanford have been operated for a hundred reactor-years without an incident that has resulted in more than relatively minor in-plant consequences.

This impressive record of safe operation has in large degree resulted from sound policies and practices that provide for:

1. A design and operational philosophy that limits the effect of a single failure or error of judgment. The benefit of this approach is demonstrated by the fact that two, three, and even four failures of equipment, procedure, or personnel, each individually having very low probability, must be combined to lead to incidents of the type summarized above.

2. An organizational policy that separates prime responsibility for reactor operation from reactor safety, and assigns these responsibilities to different organizational components. Thus, the component having responsibility for establishing reactor safety limits and restrictions upon critical operations such as reactor startups does not also have operational responsibilities. Reactor operation is monitored by both components for compliance with established safety limits and operating restrictions.

3. Thorough training and continual retraining of operating personnel that not only teach the details of the job, but also acquaint personnel with new reactor equipment and procedural changes, describe the relationship of the various reactor components to reactor safety, and emphasize the importance of their activities to safe reactor operation.

4. Review and demonstrated proof of the safety adequacy of new or modified reactor equipment of a critical nature before adoption.

5. Routine preventive maintenance and periodic inspection of reactor components, with high standards of quality.

That these policies and practices are sound is proven by the number of critical operations such as startups, process channel refuelings, the amount of maintenance of critical reactor components, and the continuing high performance of the reactors successfully completed while amassing one hundred reactor-years without serious incident.

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