FIG. 1. A 55-gallon drum in which an excursion occurred. Critical amount of uranyl nitrate solution was introduced through plastic tube.

FIG. 2. Solution of 90% enriched uranium was inadvertently introduced into tank FSTK 6-2 and piping connecting tanks 1-2, 6-1, and 6-2. Subsequently, 6-1 and 6-2 were filled with water through hook for leak testing. When drain lines were opened, enriched solution preceded water into drum.

An accidental nuclear excursion occurred in the Y-12 Plant at approximately 2:05 p.m. on Monday, June 10, 1958. The following remarks summarize information obtained by the committee appointed to investigate the accident:

1. The site of the accidental nuclear excursion was a 55-gallon stainless steel drum located in the C-1 Wing of Building 9212.

2. On the basis of the available data, the following sequence of events is postulated as leading to the incident: a portion of enriched (~90% 235U) uranium-bearing solution, containing approximately 50 gms U/lt., flowed through a valve pipeline from an extraction product "safe" tank in B-1 Wing into C-1 Wing and partially filled "safe" tank 1-2 as well as the piping connecting tanks 1-2, 6-1, and 6-2.

3. Subsequent to this inadvertent transfer, tanks 6-1 and 6-2 were partially filled with water for purposes of routine leak testing following the monthly inventory clean-out.

4. Upon the sounding of the radiation monitor alarm sirens, plant emergency procedures were put into effect.

An examination of the drum loading facility located in another building showed that the drum was in Building 9212. By 3:00 p.m. of June 10, radiation monitor teams established that the incident had taken place in a drum located in C-1 Wing of Building 9212. At approximately 9:30 p.m., the drum was poisoned by an insertion of a cadmium block into Building 9212. The tankage facility was fabricated and installed in one of the Building 9212 shielded radio room facilities.

During the night of June 10, the contents of the drum were transferred to this improved storage site during the afternoon of June 11.

... went critical in this system ...
Five men received medium radiation doses

Following the accident, these men were hospitalized at the Oak Ridge Institute of Nuclear Studies where specialized medical attention was provided. The employees receiving the low doses were released from the hospital on June 26, 1958, and allowed to resume their normal activities. The other five were released on July 30, 1958.

6. The neutron and gamma radiation of personnel whose indium foil badges indicated significant exposure was determined by measuring the Na$^{22}$ in the bodies of those exposed. This was done in two ways: (a) by counting blood samples, and (b) by counting the total body in a whole body counter. The neutron and gamma doses measured in a mock-up of the excursion, carried out in the ORNL Critical Experiments Laboratory on June 18, provided necessary data to which the Na$^{22}$ values could be related.

7. Although it is unlikely that any future accidental nuclear excursion would exactly duplicate the incident sustained at the Y-12 Plant, there are certain aspects which would be common to all incidents.

Findings

Causes of the incident. It is believed that this accident was caused by a number of interdependent contributing circumstances. Although of uneven weight, no single happening can be said to be a principal contributor.

1. The process phase in which the accident occurred was a temporary arrangement encompassing portions of a new installation in the startup stage (B-1 Wing), and an old installation in the shutdown stage (C-1 and C Wings). This arrangement was necessitated by delays in the activation of new facilities in B-1 Wing for the conversion of uranyl nitrate solution to uranium tetrafluoride.

This temporary arrangement of old facilities combined with part of a new installation was a compromise between the customary detailed design planning of valving, instrumentation, and other safeguards, and a requirement for maintaining production during this interim phase. Also, the responsibility for the uranyl nitrate to uranium tetrafluoride operation was thereby split among three different supervisors in three physically separated areas, instead of being under a single supervisor as would be the case in the completed B-1 Wing. Communications were considerably complicated by this situation.

2. At the time of the incident the uranium...
processing areas had been concerned with the required monthly accounting of uranium in inventory, which necessitated a stoppage of operations. However, all operations were not stopped or started at the same time due to the complexity of the installation. The procedure of taking inventory varied with the form and concentration of the uranium. For example, where equipment contained dilute homogeneous solutions of uranium, a satisfactory accounting could be made by taking samples and computing the contents of known volumes.

In addition, it was recognized procedure to wash, dismantle and swab out these 5-in.-diameter "safe" tanks, collecting the washings in portable plastic "safe" bottles. . . . As reassembled "safe" tanks were prone to leak at the tank ends when placed back in service after the monthly inventory cleanup, leak testing of reassembled tanks by filling with water, checking and draining prior to their return to operation, was practiced. Leak testing with water was among the . . . routine duties that were not formalized and were carried out under the discretion and supervision of the process foremen.

Although this leak testing had considerable difficulty, as practiced it deviated from the intent of two mandatory area procedural rules by the incorporation of a 55-gallon drum to collect water drained from "safe" tanks after the leak testing. These rules are:

(a) Process liquids are never to be transferred from a geometrically "safe" container to a geometrically "unsafe" container.

(b) "Unsafe" containers used to collect dilute liquids (such as mop water) must contain a charge of cadmium nitrate (a nuclear poison).

An unfortunate interpretation of the above rules was that they did not apply to the leak testing of the 5-in.-diameter "safe" tanks, since the tanks were clean and only water was used in the operation.

The significance of the foregoing, with regard to the accident, is that it furnished the mechanism whereby an "unsafe" geometry container (i.e., the 55-gallon drum) was separated from concentrated uranyl nitrate solution by only a single valve (V-1). 3. The dismantling, cleaning, reassembly, and subsequent leak testing of the C-1 Wing "safe" tanks involved a number of different employees, including both maintenance personnel and chemical operators, and usually required several eight-hour shifts for completion.

Under these circumstances, it is evident that good communications were necessary. The leak testing practice included the following pertinent routine safeguards:

(a) The process foreman, either personally or through instructions to his operators, checks all valves connecting the tanks to be tested with other process areas and determines that it is correct. In addition, the pneumatic liquid level indicators are checked to determine that the tanks are empty.

(c) During the draining of the leak test water from the "safe" tanks into a container (i.e., in this case a 55-gallon drum), an operator performed additional adjustments to the container to observe the flow of water, and safeguard against any unusual development.

4. Shortly before 2:00 p.m., the leak test was made on tanks 6-1 and 6-2, which had been completed on the previous Friday. This operator stated that the standpipe had been drained. Upon investigation, Foreman "Y" found that solution was slowly leaking through valve V-2. Foreman "Y" tightened this valve, stopping the leak. . . . Foreman "Y" was aware at the time that the B-1 Wing secondary extraction systems were in operation producing uranyl nitrate product, but believed that the leak testing of the 6-1, 6-2, and 1-2 tanks had been completed on the previous Friday.

The closing of valve V-2 allowed the uranyl nitrate solution, which had been leaking into the pH adjustment station standpipe, to back up into the C-1 Wing "safe" geometry storage tanks . . .

The accounts of whether Foreman "Y" notified Foreman "X" of the above mentioned uranyl nitrate leakage during the previous shift varied. In any event, no mention was made of it in the operating log.

At 7:00 a.m., June 16, Foreman "X" relieved Foreman "Y." The accounts of whether Foreman "X" notified Foreman "Y" of the above mentioned uranyl nitrate leakage during the previous shift varied. In any event, no mention was made of it in the operating log.

At 8:00 a.m., Foreman "W" came on duty. One of his jobs was to complete the leak testing of the C-1 "safe" tanks including tanks 6-1, 6-2, and 1-2. He assigned Operators "A" and "J" to this work. Foreman "W" was completely unaware of the circumstances of the uranyl nitrate leakage observed on the previous shift. He was, however, quite certain that the "safe" tanks 6-1, 6-2, and 1-2 had been dismantled and cleaned during the previous week and that no operations had been started in C-1 Wing since that time. This information had been logged and had also been given him on the preceding Friday by Foreman "U." On the basis of this previous knowledge, Foreman "W" did not deem it necessary to check the tank level indicating panel nor did he attach any significance to the open or closed condition of valve V-3 at the bottom of tank 1-2 during his piping check. Being aware of the fact that B-1 Wing was in operation, he did, however, instruct Operator "J" to check valve V-1 in the line from B-1 Wing. Furthermore, Operator "A" was stationed at the 55-gallon drum in the "safe" tank drain line operations.

Subsequent investigation indicated that valve V-3 was at the bottom of tank 1-2 was open and that this tank contained a substantial quantity of concentrated uranyl nitrate solution. This solution had been formed by Operators "A" and "J." Operator "J" opened drain valve V-1 to draw these tanks into the 55-gallon drum and temporarily left the C-1 area. Operator "A" remained by the drum. At 2:00 p.m., an accidental nuclear excursion took place in the drum. Subsequent investigation established the following facts:

(a) The excursion took place after the concentrated solution in the drum reached a height of 9 inches.

(b) The solution drained from tank 1-2 into which it had previously flowed from B-1 Wing. This was indicated by hydraulic tests. . . . which showed that liquid drains from tank 1-2 in preference to the liquid in tanks 6-1 and 6-2; it was supported by chemical analysis which showed that the liquid in tanks 6-1 and 6-2 had contained a negligible amount of uranium.)

5. Operator "A" was an experienced (one year of college training, six years in a uranium processing operations), was assigned to the 55-gallon drum observing the slow flow of liquid. It appears that this assigned hydraulic experiments, performed after the accident, established that approximately one quart of an hour was required for the liquid in the drum to reach the level at which it became critical. In addition, the yellow color of concentrated uranyl nitrate is distinctive and was well known to Operator "A." It would thus appear that Operator "A" had an opportunity to stop the flow of solution prior to the accident.

Radiation alarm system. The utility of the previously mentioned hydraulic experiments, performed after the accident, is summed up by stating that they are important after an accident in indicating the radiation hazard then prevailing, but in general, they have no value in predicting that a nuclear excursion is imminent.

There were six radiation alarm monitors in the general area of Building 1213 which encompassed the site of the accident. These monitors actuated alarm noises at the dose rate at the instrument of 3 mR per hour. However, it was determined that a period of 3 to 5 seconds was required after actuation of the radiation monitor.

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for the alarm sirens to reach multiple sites.
The first several seconds are the period of
greatest danger to a criticality accident.

Since the emergency procedure demanded
that personnel should leave by the nearest
building exit and since the radiation moni-
tors are incapable of pinpointing the site
of an accident, the possibility exists that
personnel could receive serious additional
exposure if the sources of radiation were near
an exit.

Conclusions
Causes of accident. This accident is not
attributable to the action of any single indi-
vidual, but rather, it arose out of a combina-
tion of circumstances involving the charac-
ter of the facilities as well as the behavior of
individuals.

An abstract, yet significant, contributing
circumstance was the interim status of the
enriched uranium recovery facilities as dis-
cussed in the section entitled “Findings.”
For example, the fact that the facilities for
converting concentrated uranium nitrate into
uranium tetrafluoride were spread over
three areas seriously complicated the com-
 munications problem. Furthermore, C-1
Wing had for years been operated under the
principles of administrative batch control
of nuclear safety. The extensive use during
these years of equipment not of “nuclear
safe” dimensions due to its size and shape
had previously conditioned plant personnel
to the unchallenged acceptance of a 55-gal
drum as the “safe” tank for the C-1 Wing
“safe” tanks with water.

In addition, the complete exchange of
significant information among personnel
was not assured, nor was the potential sig-
ificance of several observations, now recog-
nized as highly pertinent to the occurrence,
adequately appreciated.

It is highly likely, if not certain, that the
accident would not have occurred in the
absence of any one of several factors.
Among these are the use of the 55-gal
drum, the inadvertent flow of unidentified
solution between areas, and the absence of
drainage of this solution into the 55-gal
drum without recognition of its composition.

It seems reasonable to conclude that the
accident resulted largely from an accumula-
tion of observable physical conditions which,
though unknown in null, are any individual at
the time, should have prompted preventa-
tive action.

The committee also concludes that, al-
though the environment in which this event
occurred and the performance of some indi-
viduals might have been improved, a nu-
clear accident will always be within the
realm of possibility whenever potentially
serious accidents are being handled.

Nature of accident. The accident took
place as a result of the inadvertent intro-
duction of concentrated uranium nitrate solu-
tion into a 55-gallon drum. The energy re-
lease was coincident with the accident oc-
curred during an interval of minutes in which
the effective reactivity and the power level
oscillated a number of times. The nuclear
reactions were ultimately stopped by the
additional flow of water into the drum. No
solution was forcibly expelled from the
drum during the power evolution, other
than an arousal. It is evident from a review
of the accident that very slight differences
in any one of several controlling factors
would have resulted in an energy release
several orders of magnitude greater than
that observed. The energy release was
however, about two times greater than that
resulting from previous accidents of this
type.

Emergency procedures. The emergency
procedures previously established to pro-
vide for incidents of this nature and magni-
tude are considered to have been adequate.
The number of people involved over large
areas, as might be expected, introduced a
degree of confusion, causing some delay.
However, work progressed, information was
obtained and coordinated, and the basic
principles of the evacuation plan (that is,
personnel evacuation, personnel monitoring,
medical assistance, and radiation area iso-
lated) progressed in a satisfactory manner.

Dosimetry. The sodium activation of
the blood provided the best estimate of the
radiation dose received by exposed pers-
sonnel. The sodium in the blood provided
the best estimate of the dose received by
exposed personnel. The sodium in the
blood provided the best estimate of the
dose received by exposed personnel.

Recommendations
It is recognized that extensive study and
evaluation are required to improve existing
radiation control practices and procedures
if each action is to be taken without (a)
establishing undue rigid controls which
would seriously interfere with code oper-
ating efficiency, or (b) embarking on large ex-
penditures for equipment and facilities
which might not have an important role in
preventing or coping with a similar incident
in the future. Accordingly, a study group,
comprised of representatives from AEC in-
stallations operated by the Union Carbide
Nuclear Company and the Goodyear Atomic
Corporation, has been established.

A report will be prepared and issued
recommendations regarding means of avoiding
the occurrence of radiation emergencies and of
providing adequate preparation for handling
such emergencies if they do occur. Sub-
jects being considered include: equipment
design philosophy, operating procedures,
nuclear safety education, radiation detec-
tion and warning devices, dosimetry, and
emergency planning.

Nevertheless, the committee feels that,
in keeping with the purpose of this inves-
tigation, the following general recommenda-
tions should be made at this time in the hope
that they may be applicable and of value
to other processors of fissile material.

Equipment design philosophy. Nuclear
safety can be enhanced without compro-
mising economy by the extension of present
control methods and, perhaps more
significantly, by the utilization of other well-
known nuclear concepts which thus far have
not been extensively applied to production
operations. Examples of these methods are
included in the following recommendations:

1. Within the bounds of economic prac-
ticability, nuclear safety should be incorpo-
rated into the design of the plant, taking
full advantage of the characteristics of the
material and process

2. Within the same bounds of economic

After over a year's extensive testing
and comparison with other units.

SMITHSONIAN INSTITUT
selected the unit pictured above
in its satellite tracking stations loc-
ated around the earth. It was estab-
lished that this unit will keep time
1/10,000 second per day. We sta-
tant a stability of 1 x 10^-17 and
ploy a continuous record to prove
NOT BUY ANY FREQUENCY
STANDARD CLAIMING "STABILITY UNLESS THE
PLOTTED CURVES.

50 other Models of FREQUENCY

1. SUBASSEMBLIES
Models 51, 56, 62, 124, 126
others not listed here.

2. GENERAL PURPOSE UNITS
Models 61, 63, 65, 67, 128

3. MOTOR AMPLIFIERS
Models 71, 101-135, 103, 104,
141, 200-12M, 201-18M.

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practicability, if materials of different isotopic enrichment are to be processed simultaneously or in campaigns in a single facility, the entire facility should be designated for the highest level of enrichment.

3. Transfers from a processing train which relies on safety on equipment, construction to one which relies on administrative control should be avoided unless no practical alternative is available. Transfers, if made, must be conducted under extremely rigid control conditions. For example, no single analytical determination should be dependent upon the limitation of a batch size.

An investigation of the use of fixed neutron absorbers in process equipment to implement nuclear safety should be actively pursued. The properties to be investigated should include the necessary configuration and concentration of the absorbers, and their mechanical and chemical stability. Information from such tests will allow future design decisions to be based on economic and technical considerations.

Operating procedures. The use of portable unsafe containers in operating areas incorporating "safe" processing equipment should be held to an absolute minimum.

The means of communication between shifts, between operating and maintenance groups, and between production and staff groups should be more highly formalized than is customary in the chemical industry.

Nuclear safety and health physics education. It is recommended that the importance of nuclear safety in fissionable materials processing plants be restated and re-emphasized periodically to all personnel working in the processing areas. Although primary dependence for nuclear safety lies in equipment or procedural restrictions, it is clear that only by creating a constant awareness of nuclear safety can unusual and unexpected circumstances be viewed in terms of their possible nuclear hazard.

Likewise, management and all plant personnel should be retrained periodically in the health physics aspects of potential nuclear emergencies.

Dosemetry and radiation detection. The incident has underlined the urgent need for personnel dosimeters at installations which handle fissionable materials. Records of dosimetric findings should be kept for each individual. Only by requiring that the best dosimetry available be employed routinely can one be sure that accurate dose values will be obtained in case of accidents. It is recommended that a single personnel dosimeter packet be used.

1. The personnel dosimeter should be capable of measuring both the gamma and neutron dose. A film type badge dosimeter which fulfills these requirements is available. It contains the following: (a) A film sensitive to gamma energies ranging from a few milliroentgens to thousands of roentgens; (b) An NTA film pack and approximately 1 gram of sulfur for fast neutron detection; (c) Indium foil for rapid identification of individuals who received appreciable neutron doses; (d) Bare- and cadmium-covered gold foils for slow neutron detection (the gold plates scanning over several days).

Where economically feasible, Hurs

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