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Chemistry - Separation Processes for Plutonium and Uranium

AEC Research and Development Report

RADIOCHEMICAL SEPARATIONS PLANT STUDY

PART I - SITE CONSIDERATION

by

R. J. Christl

Explosives Department - Atomic Energy Division
Manufacturing Division - Process Section

Wilmington, Delaware

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ABSTRACT

This report presents the type of information that should be considered in relation to a proposed site for a radiochemical separations plant designed to process a variety of power reactor fuels. The report includes a brief review of the data obtained previous to the selection of the site for the Savannah River Plant.

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INTRODUCTION

At the request of the AEC, a study has been undertaken to define the conceptual design and probable cost of a radiochemical separations plant designed to process a variety of power reactor fuels. In view of the widespread interest in establishing such facilities, the section of the report dealing with site considerations is being published prior to completion of the study. The complete study will be related to the processing of nuclear power fuels covering a range of core compositions and cladding materials.

This section of the report has been drafted at a period in the study when only the base case has been extensively studied. The base case calls for the processing of 10 tons per day of aluminum-jacketed natural uranium metal irradiated to a maximum of 5000 MWD/T of uranium. It may be noted that no fuel thus far processed has been irradiated to 5000 MWD/T, but with this exception, the design is based upon demonstrated technology as specified in the AEC request. Although very few natural uranium fuels are forecast for the nuclear power program, the base case serves the purpose of defining most of the auxiliary areas, which are affected very little by the type of fuel processed. Therefore, although the site considerations in this report were guided by the base case, it is not likely that later cases will cause significant changes even if the plant capacity is reduced by a factor of ten.

SUMMARY

Insofar as possible, it is believed that a plant for processing power reactor fuels should be designed within the principle of containment, anticipating that regulations governing the release of radioactivity will become more restrictive. Also, it has been assumed that potential sites may be limited in area and, possibly, near population centers. These assumptions have led to a conceptual design in which all effluents are discharged at, or below, the public zone maximum permissible concentration of radionuclides (MPC), which is taken as one-tenth of the occupational limit as defined in National Bureau of Standards Handbook 69, is consistent with AEC Regulation 10 CFR Part 20, Standards for Protection Against Radiation, and is based on annual averages at the controlled site perimeter. Beyond this it is thought that an additional dilution factor of at least ten is desirable on liquid effluents discharged to streams to allow for natural concentration factors that have not been fully evaluated.

DISCUSSION

Since the personnel involved in this study were acquainted with the Savannah River Plant site data, this information has been used as a basis for the study. A brief review of these data is given to indicate the type of information that will be needed as a basis for site selection. In general, the Savannah River area is characterized by mild winters and warm, humid summers with a gradual transition between. On the average, rainfall is greatest in July and least in October; this condition results in the main from the greater thunderstorm activity during the summer period. The winds are variable in direction and exceed 3.5 mph about 85% of the time, a factor that is favorable to dispersing any materials vented to the air. The frequency of showers, however, is a disadvantage, since rain can be expected to remove a relatively large proportion of any contamination from the air. Normal releases, therefore, are limited to those that will cause no difficulty under the most adverse conditions.

The Savannah River Plant site is effectively drained by the Savannah River and tributary streams that empty into the river within the boundaries of the site. Because of the sandy surface, the runoff is practically negligible except after heavy rainfall, thus the streams are fed from the ground water with quite uniform flow. The Savannah River is not used as a major source of drinking water until it reaches the city of Savannah, a distance of 125 miles.

The ground water occurs as perched water tables, normal water tables, and artesian aquifers. The perched water tables result from clay lenses of varying and indefinite extent in the subsoil. The normal water table is generally encountered at a depth of 30 to 60 feet, lying deeper for the upland areas. There is insufficient data to predict with any assurance the direction and the flow of the ground water at a particular location on the site. The problem is complicated by the variable and undefined layers of fat clay in the clay sands and sandy clays. It is further complicated by the cavernous zone, 50 to 70 feet thick, which lies at a depth of 50 to 100 feet and slopes to the Savannah River. This zone has been shown to result from solution of calcareous materials.

Artesian water is obtained from the Tuscaloosa formation, which lies about 240 feet below the upland surfaces and about 80 feet below the bed of the Savannah River. The static head reaches about 30 feet above ground at the Savannah River bottom, but is about 110 feet below ground in the upland areas. The Tuscaloosa flows from the site toward the Atlantic but is not a major source of water until it reaches Savannah. The estimated rate of movement is 100 to 500 feet per year.

The clays encountered are generally kaolinitic and have a low exchange capacity compared with the montmorillonites. A limited amount of work has shown that the characteristics of the soil are such that it could be expected to hold some radioactivity for extended periods of time. Over-all, the conditions appear to indicate that accidental spills will be retained to the extent that no danger to the public area will be encountered but that the soil should not be relied upon for the routine disposal of large quantities of activity.

More detailed site information is contained in DP-383, Preliminary Hazards Evaluation of the Heavy Water Components Testing Reactor, March 1959.

With respect to selection of a new site, an intensive site survey for a period of a year or more prior to start of operations is very strongly recommended. Such a survey will make it easier to determine the effect of operations on the environment and will provide background proof in the event of litigation. It should include consideration of the plant location and area, the geology, hydrology, and meteorology of the area, and the services that will be required by the plant. A discussion of each of these factors follows.

LOCATION

A policy of total containment would, theoretically, permit selection of a site adjacent to population centers. It is impossible, however, to absolutely guarantee that discharges of radioactivity in excess of the public zone maximum permissible concentration (MPC) will not occur.* Selection of a site remote from concentrated population centers or food raising areas, therefore, could result in investment economies by reducing the number of safeguards required to ensure protection against radiation and would, undoubtedly, reduce the off-site monitoring effort. The SRP processing areas were selected primarily on the basis of reactor operation, but the 15-mile minimum separation from cities and 6-mile minimum separation from other communities permit the use of weekly or monthly average concentrations for control rather than requiring each activity release to be below the MPC. For a commercial operation the disadvantages of isolation must be balanced with the economics of absolute control.

AREA OF PLANT

The area required for the separations plant facilities will undoubtedly be only a small proportion of the area that must be controlled. Shipment of high level radioactive wastes and highly contaminated equipment is not considered practical because of the heavy weight of the shielding required and the ever-present risk of spreading contamination in the event of an accident. Because of this, an area allowance must be made

*The public zone maximum permissible concentration of specific radionuclides in air and in water (or food) is taken as one-tenth of the occupational limit for a 168-hour week as defined in the National Bureau of Standards Handbook 69.

for waste tanks and burial grounds over the entire life of the plant. The area so defined, including the separations plant, must be considered as requiring perpetual ownership, since there are presently no practical means of fixing wastes or decontaminating equipment to the extent that they can be left unsupervised. In addition, it is felt that a minimum distance of 1/2 mile from the primary facility boundaries must be owned or controlled during the active operation of the facility to avoid uneconomical operations. For example, it is practical to bury failed equipment that has been decontaminated with acid to remove soluble impurities but may retain fixed activity to the extent that the radiation exceeds hundreds of roentgens per hour. Unshielded handling of such material could require the evacuation of areas to the 1/2-mile limit to avoid liability. Also, the distance recommended contains the point of maximum concentration at ground level for airborne contaminants under most occasions of adverse meteorological conditions.

GEOLOGY

As a result of shielding requirements, primary buildings will be heavy and a minimum soil bearing load of 4000 pounds per square foot is desirable to avoid excessive piling and spread footings. The substructure should also be stable and the area should have a low incidence of earthquakes to minimize the possibility of structural failure and the possible resultant release of activity.

Either a rather impermeable soil or a moderately permeable one with good ion exchange properties is acceptable. A very permeable soil (such as sand) close to a water table is unacceptable. While routine disposal of radioactivity by way of seepage basins is undesirable in any soil, and particularly so where minimum site area and monitoring costs are a major consideration, it must be assumed that trace contaminants will reach the soil surface in the ordinary course of plant operations. The clay soils, because of their ion exchange properties, offer a protective barrier.

It is desirable that major rock formations be more than 50 feet below grade to permit economical excavations for buildings and waste tanks. A hard, impermeable rock stratum at greater depths may prove advantageous for later disposal of wastes in mined caverns, dependent upon favorable results from studies currently in progress.

As a caution, it is desirable to avoid sites with deposits of natural radioactivity, since such deposits would make environmental monitoring more difficult. The use of aggregates from such a site for material of construction would also cause difficulty, particularly if they were present in the vicinity of counting rooms.

HYDROLOGY

Primary importance must be placed on avoiding contamination of aquifers used as a source of drinking water. This implies either that such aquifers do not exist, that relatively impermeable soils essentially eliminate the possibility of contamination, or that other conditions make the possibility of contamination remote. Accidental releases, such as failure of a waste tank, must be considered in addition to planned releases.

A low water table is also of significance when construction costs are considered. It is undesirable to build waste tanks and to bury wastes below the level of maximum local high water tables. In the case of waste tanks, additional costs will be incurred for heavier construction and waterproofing, and in both cases, the cost of monitoring to detect the spread of contamination will increase substantially. Also, buried materials would be more effectively leached of activity and would tend to float if submerged.

It must be assumed that some contamination of the ground surface will be experienced. Any drainage to small surface streams, therefore, should be evaluated with the preference that such streams drain within the controlled area to a larger stream or river providing suitable dilution.

METEOROLOGY

This study does not provide for the recovery of radioactive gases, such as krypton, released during fuel dissolving. These gases are released to the stack, diluted with ventilation air and dispersed. Also, there always will be a small amount of particulate activity passing through or bypassing filters. In site selection, the prevailing wind should always be away from populous centers. Actually, a uniform wind rose offers the best possibility of avoiding localized contamination problems. Preferably, the wind velocity should exceed 3 mph a large portion of the year to obtain maximum dispersion and dilution of activity releases. A high incidence of atmospheric inversions is to be avoided.

One problem that has not received attention in the published literature is the disposal of tritium, which only recently has been identified as a product of fission* and which appears primarily in the aqueous effluents. This problem will be treated more fully in the section of the report that discusses waste disposal. With respect to site location, however, it can be stated that it will be difficult to find suitable dilution power in surface streams for the tritium released in any major separation operation. A favorable site from the

*Phys. Review Letters 3, No. 6, 274-5 (1959) meteorological standpoint will permit disposal by vaporization and discharge to the atmosphere via the stack.

It has been proven that rainfall carries airborne activity, so areas having excessive hours of rain or fog should be avoided. Also, areas having long periods of snow coverage could be expected to offer difficulties since activity would remain on the surface of the ground and accumulate during the winter rather than being removed more or less continuously.

A low incidence of tornadoes is also desirable. Although the buildings that contain the greatest amounts of radioactivity may be considered "tornado proof", it is uneconomical to contain all regulated equipment in such structures. Acid recovery, solvent washing, etc., although normally handling low level materials, could spread contamination well above public zone MPC if disrupted by a tornado. Hurricanes are probably less of a design problem but it would be well to avoid coastal areas that bear the full brunt of such storms.

SERVICES

A separations plant requires normal commercial utilities. From the standpoint of activity control, all off-site returns must be monitored. This implies that closed cooling water circuits will be the easiest to control.

The required shielding for fuel shipment dictates the use of heavy shipping containers (AEC Regulation 10 CFR Part 72 Proposed). It is probable that access to rail transportation offers the only economical means of receipt. Easily accessible highways are required for receipt of chemicals, shipment of products, and personnel transportation.

Electrical supply must be augmented by emergency units, primarily to maintain control of ventilation. Steam-driven units tied to a reliable steam supply are acceptable as back-up to normal power to prevent the spread of contamination that could render a facility inoperative for long periods of time and, possibly, result in serious off-site contamination.

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