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MASTER

WATER REUSE ACHIEVED BY ZERO
DISCHARGE OF AQUEOUS WASTE

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Rocky Flats Plant
U. S. Energy Research and Development Administration

Operating Contractor - Rockwell International,
Atomics International Division

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Abstract

Plans for zero discharge of aqueous waste from ERDA's nuclear weapons plant near Denver are discussed. Two plants, a process waste treatment facility now under construction, and a reverse osmosis desalting plant now under design, will provide total reuse of waste water for boiler feed and cooling tower supply. Seventy million gallons of water per year will be conserved and downstream municipalities will be free of inadvertent pollution hazards.

Introduction

The Rocky Flats Plant is a producer of component parts for nuclear weapons. Originally built in 1952, it is entirely owned by the U. S. Government. From then until 1975 it was operated for the U. S. Atomic Energy Commission (AEC) by The Dow Chemical Company. In 1975 the AEC was abolished by act of Congress and all weapons functions and responsibilities were transferred to the new Energy Research and Development Administration (ERDA). Coincidentally, Dow management decided not to renew its operating contract after some 24 years of service. Subsequently, Rockwell International, through their Atomics International Division, became the new operating contractor for ERDA on July 1, 1975.

Rocky Flats is primarily a metal parts production plant and chemical processing plant. Activities involve the fabrication of components from plutonium, uranium, and nonradioactive metals such as beryllium, aluminum, and stainless steel. These operations are supported by a Research and Development Department, Health Sciences, Environmental Sciences, and all normal support functions such as Maintenance, Facilities Engineering, Utilities, Purchasing, etc. The present plant population is approximately 2 700 employees.

The plant is located on about 10 square miles of federally owned land, which until recently was surrounded by rural and largely undeveloped ranch land. It is almost equidistant from the Colorado cities of Boulder, Golden and Arvada and is about 16 air miles from downtown Denver (see Figure 1).

The land, at an average elevation of 6 000 feet, overlooks the valley of the South Platte River in which Denver (5 280 feet) and its northern suburbs are located. The plateau tilts from the foothills of Colorado's Front Range on the west at a 3% slope to the east, with a general terminus at Indiana Street. While quite flat in general, the eastern edge is cut by relatively gentle gulches formed by Walnut Creek and Woman Creek and their small tributaries. All natural surface drainage across the plant property is into these streams which eventually flow into the South Platte River (see Figure 2). Before reaching there, however, Walnut Creek empties into Great Western Reservoir (now the municipal water supply for the City of Broomfield), and Woman Creek empties into Standley Lake (now the municipal water supply for the City of Westminster). (See Figure 3.)

The Issues

It was recognized during the original design of the Rocky Flats Plant that provision must be made for the treatment of aqueous waste. Two distinct and separate systems were constructed in 1952 for the purpose of collecting and treating the two major sources which are defined as follows:

1. Sanitary waste water: water disposed into the plant's sanitary sewer system from toilet facilities, shower rooms (excluding radioactive decontamination showers), plant cafeteria sinks and drains, drinking fountains, janitor sinks and floor drains in non-process areas, and certain clean water such as steam condensate and dehumidifier condensate, as authorized for disposal to sanitary sewer by responsible personnel.

2. Process waste water: water-based effluents containing low concentrations of acids, bases, chemical salts (excluding most organics), and/or radioactivity disposed into the process waste collection system serving the process areas of the plant. This system also collects such potentially contaminated water as laundry water, janitor wash water from process areas, water from personnel decontamination showers, or any other potentially contaminated source as directed by responsible personnel.

Sanitary waste has been treated since 1952 by conventional processing. A small municipal type sewage treatment plant is located in the south fork of Walnut Creek. Originally it contained only a primary unit (settling basins) and a secondary unit (activated sludge process). The treated effluent discharges into South Walnut Creek. In 1974, a tertiary unit (chemical additives and filtration) was added to improve the quality of the discharged water. The plant is believed to be one of only two such advanced plants presently operating in the State of Colorado.

Process waste has been treated since the beginning of plant operations in a custom designed chemical waste treatment plant. The original flow sheet was patterned after a similar plant in operation at the Los Alamos Scientific Laboratory in New Mexico. The process consists of a series of carrier precipitations from basic solution (pH - 11 to 12) using iron, magnesium, and calcium to remove radioactivity in the floc. After settling and filtration through vacuum precoat filters, rigorous radiometric analysis determines whether the clear effluent can be disposed off site via the sanitary waste system or treated further. The "hot" dry sludge is

shipped to the Idaho National Engineering Laboratory, Idaho Falls, for permanent storage. Shortly after operations began it was recognized that the soluble chemical content (mixed inorganic salts) in the waste stream could not be reduced by this method alone to meet U. S. Public Health Service discharge standards. In the mid 1950's a series of solar evaporation ponds were constructed to store and allow evaporation of the radioactively decontaminated salt water. These processes were the extent of the aqueous waste treatment program during the 1950's and 1960's while the plant's production activities were steadily increasing beyond original design intent of the waste treatment facility.

The first of a series of problems associated with liquid effluents became apparent by the early 1960's. The nitrate problem began with the radioactive decontamination by solvent extraction of 5N nitrate solutions resulting from the enriched uranium recovery plant and the subsequent storage of many tons of nitrate solution in the solar evaporation ponds. During this period research on the part of the U. S. Public Health Service showed that excessive amounts of nitrates could be injurious to health. In 1962 that agency added a limit of 45 ppm of nitrate to public drinking water standards. By this time the growing city of Broomfield, a northwesterly suburb of Denver downstream of the Rocky Flats Plant, purchased Great Western Reservoir for its municipal water supply. The reservoir is fed partly from Walnut Creek, which drains about 90% of the Rocky Flats property. Analysis of water leaving the plant boundary via Walnut Creek had occasionally exceeded the 45 ppm nitrate limit, although the maximum value ever noted in the reservoir was 5.3 ppm in 1966. The cause was attributed to leakage from the bottom of the solar evaporation ponds, wind-blown solution across

the berm onto the surrounding soil, and occasional pipeline leaks. These factors produced up to 20 000 ppm of nitrate in samples of subsurface ground water taken from the hillside northeast of the solar ponds before it drained into the creek. Interim measures were taken to reduce this potential hazard to the city of Broomfield water supply prior to a more permanent solution described later.

Another problem occurred in 1973 when low concentrations of tritium were discovered in Walnut Creek and subsequently in Great Western Reservoir. Again, although the release was inadvertent, it was not injurious to public health. It caused great concern to both Dow and the AEC and immediate planning was begun to find a permanent solution to such potential problems. A decision was solidified by the creation of the Environmental Protection Agency and the passage by Congress of the Water Pollution Control Act. The latter bill requires zero discharge of pollutants by 1985.

The Solution

The requirement of the Water Pollution Control Act for all facilities - industrial, government, institutional, and the like - to achieve zero discharge of pollutants by 1985 has already been subjected to much interpretation and debate. Since the Rocky Flats Plant has potential hazards far above the norm the issue of zero discharge was simply solved by ERDA and the Operating Contractor by looking for ways to avoid the discharge of all waste water, thereby achieving zero discharge of the contained pollutants. By 1971 the Operating Contractor had developed a conceptual design for a new process waste treatment plant with the goal of reusing the distilled product water as boiler feed to the steam

plant. This was followed in 1972 by an engineering study of the sanitary waste stream. The study indicated a favorable material balance by reusing the treated sanitary waste effluent in the plant cooling towers, followed by blow-down recycle. Research and development was already underway to determine the optimum desalting process under current conditions. The final choice was reverse osmosis (R.O.).¹

Plans for the two plants were subsequently approved and funded by ERDA. The process waste treatment plant is now under construction, and the reverse osmosis desalting and recycle plant is now being designed. Both plants are described briefly in the next section. The two units, when in operation, will achieve zero discharge of all waste water generated by the operation of the Rocky Flats Plant.

Several other smaller but noteworthy projects were completed in 1974 to improve the Rocky Flats Plant's environmental posture with respect to the Broomfield water supply:

1. Tertiary treatment process: Added to the sanitary sewage treatment plant to reduce suspended solids in the effluent (mentioned in section entitled "The Problem"); approximate cost, \$275 000.
2. Connect cooling tower blowdown water to sanitary sewer: Previously all blowdown was discharged to natural drainage leading to Walnut Creek. By tying to sanitary sewer, all suspended solids are removed by the new tertiary process. Approximate cost, \$155 000.

3. Backwash storage tanks: Designed as settling basins for the water used to backwash the sand filters in the Rocky Flats water treatment plant. The sediment was previously discharged to Woman Creek; now the clear water is decanted and returned to raw water supply and the sediment is trapped in drying beds. Approximate cost, \$165 000.
4. Laundry water transfer line: A temporary pipeline constructed from irrigation pipe was laid to a small reservoir that had been constructed previously in Walnut Creek for emergency run-off control. This affords temporary storage until the new process waste treatment plant is on stream, but it avoids discharge into Great Western Reservoir from this source. Approximate cost, \$19 000.
5. New emergency reservoir: Designed to contain a postulated 20 year flood in Walnut Creek, this reservoir will remain dry as an emergency catch basin. For example, if the heavily nitrated solar evaporation ponds were to rupture, the waste would be contained in this reservoir rather than flow into Great Western Reservoir. Approximate cost, \$225 000.
6. Relocation of McKay ditch: This irrigation ditch which runs through the Rocky Flats property carries Broomfield water rights from Coal Creek to Great Western Reservoir. It was relocated approximately half a mile north of its old location which traversed a populated area of the plant site. Approximate cost, \$20 000.

General Design Criteria

1. Process Waste Treatment Plant

It should be noted that the authorization for this facility was not justified solely on zero discharge and recycle principles. A new plutonium chemical recovery facility was urgently needed and was authorized by Congress in 1971. Since the old process waste treatment plant was almost obsolete with respect to capacity as well as process capability, its new counterpart was jointly funded with the new plutonium facility.

Figure 4 shows a simplified block diagram of the improved waste treatment process. Each stage of the carrier precipitation process can be expected to produce a decontamination factor of approximately 50 for the transuranic elements, or a total decontamination factor of more than 10^5 . Since plutonium must be separated for reuse down to a concentration of less than 1×10^{-5} grams of plutonium per liter (g Pu/l) of solution in the chemical recovery plant, this value becomes the starting concentration of the feed to the waste treatment plant. Applying a decontamination factor of 10^5 , therefore, produces an effluent from the waste treatment plant clarifiers of less than 1×10^{-10} g Pu/l. Under current ERDA standards, drinking water tolerance for plutonium is 5 000 picocuries per liter (pCi/l), which is about 7×10^{-8} g Pu/l, well within process capability.

The effluent from precipitation, as well as non-radioactive chemically contaminated waste water, goes to a four effect thermal evaporator where it is concentrated to about one fourteenth the original volume. The vapor is condensed and

returned to the steam plant as boiler feed water. Under normal operating conditions this plant will supply about two-thirds of the annual feed water requirement of the steam plant. It is excellent in quality: less than 10 ppm total solids and background in radioactivity. The concentrate goes to a spray dryer, where the dry salt is separated for disposal off site.

Figure 5 shows the general plant layout. Typical of nuclear processing facilities, the "hot" portions of the plant are specially designed to protect the environment from radioactive releases. Elaborate ventilation systems scrub the air exhausted to atmosphere and all liquids have secondary containment in case of leaks and spills. An example of this principle is shown in Figure 6. In normal industrial practice the large storage tanks located on the left side of the section would be located outside the building in a yard area. Here they are shown located in a leak proof bathtub type room, where the atmosphere is environmentally controlled.

An advanced design is employed in the new waste collection system which will transfer the waste streams from the various process buildings to the new treatment plant. The entire system contains inspectable and repairable transfer piping, the key to which is a series of valve vaults shown in Figure 7. The detection and prevention of leaks afforded by this new system should virtually eliminate any hazard of contamination to subsurface water which might find its way off the plant site.

Construction of this facility is valued at \$15 000 000. Although the "hot" portion (precipitation, filtration, sludge drying and shipping) is not expected to come on stream until 1977, the "cold" portion (evaporation, spray drying, and salt shipping) is expected to become operational by the summer of 1976. The first production assignment will be the evaporation of the waste water now stored in the solar evaporation ponds. They must be emptied in readiness for the sanitary water recycle project.

2. Reverse Osmosis Desalting Plant

The desalting plant is the necessary link to the success of the cooling tower blowdown - to sanitary waste - to reverse osmosis - to cooling tower supply recycle loop. A generalized material balance is shown in Figure 8. Some detail of the solids removal by reverse osmosis is given in Figure 9. The plant is designed to operate continuously with only part time operator attention by use of a programmable logic controller. An alarm system connected to the sanitary waste treatment plant control room will bring operator help when required. In addition to the water pretreatment equipment and reverse osmosis modules shown on the flow sheet, the plant will include small process balancing storage tanks, a chemical additive preparation area, and a local control room. The entire process will be housed in a simple 45 foot by 90 foot building, heated only enough to prevent freezing in winter time.

The project requires some piping renovation of the existing solar evaporation ponds, underground transfer piping and pump stations, and the necessary utility support. Completed project cost will run around \$3 000 000. It is currently projected to go on stream in the spring of 1978.

The symbiotic relationship of the two plants described above with the steam plant and cooling towers is shown in Figure 8. The balance is completed by pond evaporation and spray dryer losses to produce the dry salts. The monthly usage rate varies widely with the season of the year: cooling towers require the most make-up water in summer; the steam plant requires the most feed water in the winter. The fluctuating difference is accommodated in the storage ponds, which have a combined capacity of over 11 million gallons (41 600 m³).

The anticipated operating cost is always of interest to management faced with similar environmental waste disposal problems. The current process waste treatment cost is approximately 9.4 cents per gallon. This includes operating labor, overhead, chemicals, power, and drumming of the sludge for controlled burial at Idaho National Engineering Laboratory, Idaho Falls. While the cost may appear very high compared to some conventional practices, it is accepted as part of the cost of doing business in the nuclear industry. When the new process waste plant comes on stream the unit price per gallon may drop somewhat due to a more efficient process, but the total cost may increase by as much as 25%. This will result from total forced evaporation versus substantial solar evaporation carried out in the past.

Operating costs for the recycle of treated waste water to the cooling towers will not be estimated closely until plant design has been firmed up. At present the raw water acquisition cost is 27 cents per thousand gallons. Guesstimates for the operation of the reverse osmosis plant run from 50 to 90 cents per thousand gallons processed. Subtracting the cost of the raw water saved by recycle, the increased cost to the operation of the cooling towers is not unreasonable.

Summary and Conclusions

With the advent of the Environmental Protection Agency and the Water Pollution Control Act (Amendments of 1972), the past practice of discharging some chemically treated process waste and all conventionally treated sanitary waste water offsite was discontinued after several inadvertent releases of contaminants occurred. In order to alleviate the fears of the municipalities downstream of ERDA's Rocky Flats nuclear weapons component plant, planning was begun on two new facilities which would achieve total reuse of the waste water.

First, a new process waste treatment plant was designed to remove all contaminants as dry solids for appropriate disposal and return the distilled product water for reuse as boiler feed for the steam plant. This waste treatment plant is now under construction. The first phase will be operational in the summer of 1976.

Second, research and development was undertaken to determine the optimum method for desalting treated sanitary waste water. Reverse osmosis proved to be the most suitable method. A plant is now being designed to desalt all cooling tower blowdown as well as the treated sanitary effluent in order to recycle this water to the cooling towers. (The brine generated by the R.O. process becomes a waste stream sent to the process waste treatment plant.) Construction of the reverse osmosis facility is scheduled to begin in 1977 with completion set for early 1978.

Completion of these two facilities at Rocky Flats will result in the zero discharge of all aqueous waste and contained pollutants by 1978, well in advance of the 1985 goal required by the Water Pollution Control act. An important byproduct of the two facilities will be the reuse of approximately 70 000 000 gallons per year ($265\,000\text{ m}^3/\text{yr}$) of pure water in a region where water is not normally abundant. Although the Rocky Flats Plant operating budget will sustain an increase in order to achieve total water recycle, the additional cost is currently estimated to be less than half of one percent of the operating budget.

References

1. Reverse Osmosis Pilot Plant Studies for the Purification and Reuse of Effluent from a Sanitary Waste Treatment Plant, C. E. Plock, D. E. Hausburg, and D. R. Horrell, The Third National Conference on Complete Water Reuse, June, 1976.

Figure 1
GENERAL LOCATION OF THE ROCKY FLATS PLANT

Figure 2
ROCKY FLATS PLANT DRAINAGE

Figure 3
AERIAL VIEW OF ROCKY FLATS PLANT,
LOOKING EAST

FIGURE 4. SIMPLIFIED WASTE TREATMENT FLOWSHEET

FIGURE 5. WASTE TREATMENT FLOOR PLAN

FIGURE 6. WASTE TREATMENT PLANT CROSS SECTION

FIGURE 7. VALVE VAULT SECTION

FIGURE 8. WATER RECYCLE FLOWSHEET (ESTIMATED START-UP RATE, MILLIONS OF GALLONS/YEAR)

FIGURE 9.
SIMPLIFIED REVERSE OSMOSIS FLOWSHEET
(DESIGN RATES)