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EFFLUENT SYSTEM CAPACITY
PROJECT CGI-883
INCREASED PROCESS WATER FLOW - 100-K

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EFFLUENT SYSTEM CAPACITY
PROJECT CGI-883
INCREASED PROCESS WATER FLOW - 100-K

by

M. H. Schack
Reactor Modification Design
FACILITIES ENGINEERING SECTION

November 18, 1960

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EFFLUENT SYSTEM CAPACITY
PROJECT CGI-883
INCREASED PROCESS WATER FLOW - 100-K

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EFFLUENT SYSTEM CAPACITY
PROJECT CGI-883
INCREASED PROCESS WATER FLOW - 100-K

INTRODUCTION

The process water flow rates at the 100-K Reactors will be increased as a result of plant modifications under Project CGI-883. The flow rates to be achieved by the project are 188,000 and 200,000 gpm under five and six 190 Building pump operation respectively. Preliminary studies have indicated that the K Area effluent systems will, for the most part, be adequate for the expanded conditions provided the reactor effluent is continuously and simultaneously discharged from two retention basins to the river by way of the basin overflow weirs. (1)(2) The third basin would be available for any necessary effluent retention or diversion of effluent into crib facilities. The purpose of this document is to present the results of an analytical study of the effluent system capabilities and to set forth the additional design work which must be performed in order to complete the detailed design of required alterations to the effluent system.

SUMMARY AND CONCLUSIONS

The results of this study indicate that the 100-K Area effluent system can be made adequate for the expanded flow conditions planned under Project CGI-883 by means of the following modifications:

- a. Replace downcomer orifice plate with one of less flow restriction.
- b. Reduce height of outfall structure overflow weir from 430 feet to 425 feet.

The above conclusions are based on continuous and simultaneous discharge of reactor effluent from two retention basins by way of the basin overflow weirs.

The design of the replacement orifice plate will be based on the results of field and model testing which has been initiated.

Calculations indicating the expected capacity of various portions of the effluent system should be verified by field measurements where possible, particularly at the basin overflow weir and collection chamber.

It is considered advisable to reduce the height of the outfall structure overflow weir in order to prevent overflow at the retention basin in the event of blockage of flow in one of the 84 inch outfall lines during flood conditions.

- (1) HW-66273 "Design Criteria, Increased Process Water Flow - 100-K Area, Project CGI-883", November 1, 1960, M. H. Schack
- (2) HW-45648 "100-K Area Water Plant Expansion Study - Feasibility Report" September 26, 1956, M. H. Schack

DISCUSSIONDowncomer and Effluent Piping to Retention Basins

An arrangement of the 100-K downcomer and effluent piping to the retention basin is shown by Figure 1. The downcomer has a cellular structure consisting of thirty closed channels (10 channels long by 3 channels wide in cross section). An orifice plate is located at the bottom of the closed channels to dissipate the excess energy of the effluent water. A rectangular approach section to the downcomer is provided to produce a level water surface at the downcomer entrance and a uniform filling of the cells. The orifice plate contains 308 holes drilled to 2.875 inches in diameter. The arrangement of the holes in the orifice plate matches the cellular pattern of the downcomer. The flow capacity of the downcomer was calculated for this study from the following equation: (3)

$$Q = F' C n d^2 \sqrt{\Delta H} \sqrt{1 - \left(\frac{d^2}{\alpha}\right)^2} \quad \text{where:}$$

Q = gpm of effluent water flowing through downcomer

F' = unit conversion and constant combination factor the value of which depends on effluent temperature. (3)

C = combined discharge coefficient for orifice and channel

n = the number of orifice holes filled by flow Q

d = diameter of orifice holes, inches

ΔH = Excess head dissipated by the downcomer, feet

$\alpha = 14.32$ = constant of proportionality between orifice area and approach channel areas

The diameter of the holes in the existing orifice plate was sized to dissipate the excess energy or head of the effluent water resulting from present flow rates. The excess head is the difference between the level of the effluent entering the downcomer and the level of the effluent at the base of the downcomer. The level or head at the base of the downcomer is that required to deliver the effluent to the retention basins through the effluent piping. Calculated values for this level versus effluent flow rates are shown by Figure 2. Values of the water level at the entrance to the downcomer using the existing orifice plate were calculated from the above equation and are shown plotted on Figure 3. It is desired that at least the tenth channel row be open for venting. As indicated by Figure 3, it will be necessary to decrease the orifice plate head loss for the expanded flow condition of 200,000 gpm in order to have the tenth channel row open for venting. It does not appear feasible to obtain decreased orifice plate head loss by merely increasing the orifice hole size. The present 2.875 inches diameter holes are about as large as can be accommodated by the present cellular configuration. It is planned to use the existing or a smaller hole size for the orifice plate and to increase its flow coefficient by rounding the entrance of the orifice holes. The correct orifice size and configuration will be determined by model testing of one of the cellular channels of the downcomer. Contract negotiations are in progress to conduct this testing at Washington State University.

(3) HW-38795 "Selection of Orifices for the 105-KW and 105-KE Downcomers, Project CA-512-R", August 25, 1955, T. F. Robinson

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Retention Basins and Effluent Piping to River

An overall arrangement of the retention basins and effluent piping to the river is shown by Figure 4.

The present method of operation, which allows two retention basins to continuously overflow into the effluent piping to the river, will be retained for the expanded flow conditions under Project CGI-883. This method of operation was started after the failure of the 100-KE outfall pipe in 1955 in order to prevent the pumping of air through the effluent piping. The effluent system was originally designed for a batch method of operation which provided for one retention basin to be filling while the second basin was holding and the third basin was emptying. Use of the batch method of operation under Project CGI-883 conditions would aggravate the previously experienced problems associated with this method of operation because at the higher flow rates a basin would be required to start emptying before one of the others had finished emptying.

An arrangement of the retention basin overflow weir, collection chamber and drain to the effluent piping is shown by Figure 5. Figure 6 is the calculated rating curve for the overflow weir. The existing weir should be adequate for the CGI-883 flow conditions of 100,000 gpm over each weir. The rating curve indicates a weir head of 1.1 feet and a free board between the water surface and the basin top of 1.4 feet.

The depth of water in the weir discharge collection chamber depends on entrance losses into the collection chamber drain, friction loss in the effluent piping and the height of the water level in the outfall structure. Likewise, the height of the water level in the outfall structure depends on the losses in the 84 inch outfall lines and the river elevation. Figure 7 is an arrangement of the outfall structure. An assumed "worst" condition is when the river is at a flood stage of 411 feet. Figure 8 is the calculated rating curve for one of the 84 inch outfall lines when it is flowing full due to a river elevation of 411 feet. It is assumed that each of the outfall lines must carry a total effluent flow as follows:

Reactor Process	200,000
Backwash	20,000
Service Water	<u>12,000</u>
	232,000

At this assumed rate of flow the water level in the outfall structure is given as 424 feet by Figure 8. The water surface is six feet below the crest of the overflow weir in the outfall structure. After having established the water level in the outfall structure, the water level in the overflow collection chamber at the retention basin is determined as follows:

$$H_2 = H_1 + \Delta H_f + \frac{V_1^2}{2g} \quad \text{where:}$$

H_2 = water level at collection chamber, feet

H_1 = water level at outfall structure, feet

ΔH_f = losses between collection chamber and outfall structure, feet from Figure 9

$\frac{V_1^2}{2g}$ = velocity head in 84 inch outfall piping, feet

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The KW Area would have the highest water level because of the slightly greater pressure drop in the longer effluent lines. At the process water flow of 200,000 gpm, 100,000 gpm through each of two retention basins, and with a 424 foot water level in the outfall structure, the calculated water level in the collection chamber is: $H_2 = 424 + 33.5 + 2.5 = 460$ feet. The water surface elevation of 460 is 4.5 feet below the crest of the retention basin overflow weir and fills the collection chamber to a depth of about two feet at the location of the drain connection. Calculations indicate that both the weir and the collection chamber of the retention basin should be adequate for the CGI-883 flow conditions. Field measurements should be obtained to check the validity of these calculations.

A problem situation could arise in the case of failure of the 84 inch outfall lines. In this event, the effluent would overflow the weir at the outfall structure and would flow to the river by means of the emergency spillway. Capacity of this overflow weir is given by Figure 10. The water level in the outfall structure would be about 435.5 feet or 5.5 feet above the weir crest at the total effluent flow of 464,000 gpm. As a result, the calculated water level at the retention basin collection chamber would be: $H_2 = 430 + 5.5 + 33.5 = 469$ feet. This level is above the top of both the basin and the collection chamber and an overflow condition would exist. To prevent overflowing of the collection chamber it would be necessary to reduce the height of the weir in the outfall structure from 430 feet to 423 feet: Weir Height = 462 ft. - 5.5 ft. - 33.5 ft. = 423 ft. If it is assumed that only one 84 inch outfall would fail at any one time then the level in the outfall structure at flood stage of 411 feet would be about 433 feet or three feet above the weir crest at a total effluent flow of 464,000 gpm. The water level at the collection chamber would be: $H_2 = 430 + 3 + 33.5 = 466.5$ feet. This level is above the top of the retention basin weir crest and would probably cause overflow of the collection chamber. To prevent overflow for this condition it would be necessary to reduce the crest of the outfall structure overflow weir to about 425 feet or 5 feet below its present elevation of 430 feet. The case considering failure of only the one 84 inch outfall line appears to be the most reasonable condition for design. It is therefore recommended that the crest of the overflow weir in the outfall structure be lowered to 425 feet in order to prevent overflow at the retention basin for conditions which do not exceed the following:

Total effluent flow, 100-KE and KW	464,000 gpm
River water level	411 feet
Outfall lines out of service	1

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FACILITIES ENGINEERING SECTION

100K AREA
DOWNCOMER

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FIG. 1 - DOWNCOMER & EFFLUENT ARRANGEMENT

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FIG. 2 - RATING CURVE - DOWNCOMER EFFLUENT PIPING

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FIG. 3 - RATING CURVE - DOWNCOMER

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FIG. 4-Schematic layout of 100-K effluent system

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ELEVATION

SECTION

FIG. 5 - RETENTION BASIN OVERFLOW WEIR & COLLECTION CHAMBER

FIG. 6 - RATING CURVE - RETENTION BASIN
OVERFLOW WEIR

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— CROSS SECTION ELEVATION —

FIG. 7 - OUTFALL STRUCTURE ARRANGEMENT

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FIG. 8 - RATING CURVE - OUTFALL LINE

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FIG. 9 - RATING CURVE - EFFLUENT PIPING -
RETENTION BASINS TO OUTFALL STRUCTURE

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100K AREA
RATING CURVE FOR
27 FT OVERFLOW WEIR
1908 BLDG.

HEAD ABOVE WEIR CREST - FT.

6

5

4

3

2

1

0

100

200

300

400

500

FLOW - GPM IN THOUSANDS

FIG. 10 - RATING CURVE - OVERFLOW WEIR -
OUTFALL STRUCTURE

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