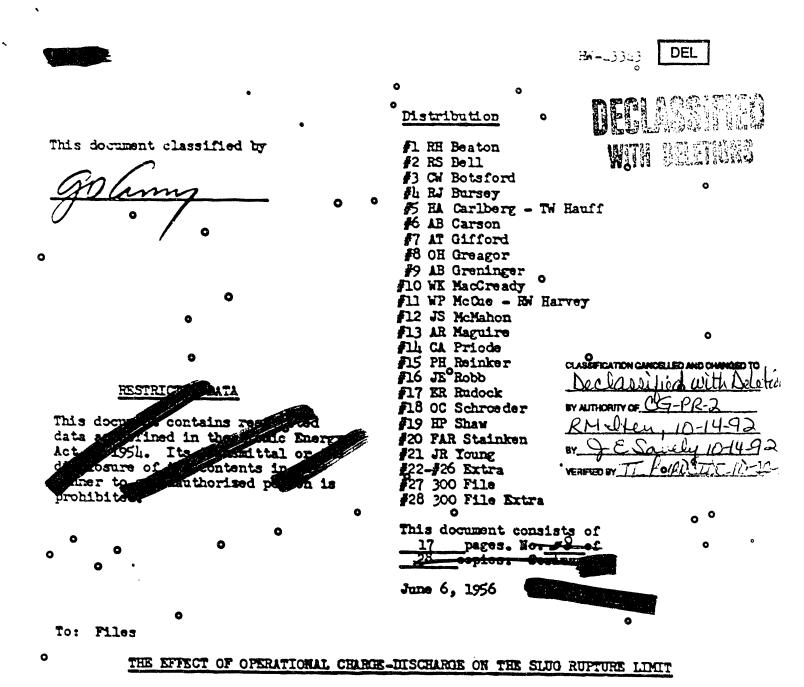
# NOTICE

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HW--43343-Del. IN DELETIONS RECORD CENTER FILE DE93 009996 SIFICATION 251 UATE GENERAL S EC June 6, 1956 COPY NO. AND SEHIES HANFORD ATOMIC PRODUCTS 1 OF 1. SERVES WA JUN^I 9 1956 DE XX RES DAI THIS OFFI ACT OF 0 100-D AREA TIT CLASSIFIED FILES SON 18 PROH ED . THE EFFECT OF OPERATIONAL CHARGE-DISCHARGE OTHER OFFICIAL CLASSIFIED INFORM ATION ON THE SLUG RUPTURE LIMIT T 141 % MATERIAL CONTAINS INFORMATION TIONAL DEFENSE OF UNITED MEANING OF ADE LAWS THE 0 U. S. C. , SECS. 793 AND 794. OR REVELATION OF WHICH IN ANY MANNER AUTHOR TO AN UNAUTHORIZED PERSON 00 LAW. J. R. Toung THIS DOCUMENT UST NOT. NHORIZED. τo SIFIED OF RAGE MIS DOCUME ROVIDED BELOW. O ROUTE PAYROLL NO. TOT LOCATION BIGNATURE 561 105 H 8 DISCLAIMER RECORD CENTER EILE This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their ۵ employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recom-0 mendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof. RECORD CENTER FILL C-3195-0 (11-54) APT 48 DECEMBER 844 TECHNICAT DISTRIBUTION RESTRICTED TO U.S. ONLY



### INTRODUCTION

The installation of operational charge-discharge equipment on the Hanford reactors has been proposed as a means of eliminating the reactor downtime required for charging and discharging the metal in the reactors. Additional benefits such as the minimization of the effects of slug ruptures, improved reactivity control, and improved metal ftilization have become apparent during the investigation of the use of the equipment. Since the minimization of the effects of ruptures has been considered only qualitatively in previous justification documents for operational charge-discharge, the purpose of this document is to evaluate qualitatively the effect of such equipment on operation with a slug reptore limit.

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The operational charge-discharge equipment currently is visualized as equipment which permits the charging and discharging of reactor fuel elements during operation. Specifically, it consists of new process tabe fittings and associated control equipment of such a nature that fuel elements may be charged into the front end of the process tubes and discharged from the rear end of the tubes during fall tube flow and power conditions. (9)









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### SUMMARY AND CONCLUSIONS

The primary benefits from the installation of operational charge-discharge are: (1) elimination of outage time for charge-discharge of fuel elements, and (2) reduction of the effects of ruptured fuel elements.

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Future reactor power levels probably will be limited by the occurrence of ruptured slugs. It is hard to visualize at the present time the fabrication of fuel elements of such quality that the number of ruptures would be small then reactor power levels are increased substantially above forecast levels. As a result, one of the primary benefits resulting from operational charge-discharge appears to be the reduction of the effects of ruptured slugs by permitting more rapid detection and operational discharge of those slugs. The resultant gains are of two major types:

2.

- 1. Reactor power levels may be increased until the occurrence of ruptures again limits the total production.
- 2. The discharge concentration of the metal may be increased until the occurrence of ruptures again is limiting the production.

If the reactor power levels are increased as a result of installation of operational charge-discharge and the metal discharge commentration is not changed, the annual gain because of increased production is approximately \$13,300,000, and the installation cost of \$24,450,000 will be paid off in approximately 1.8 years. If, on the other hand, the metal discharge concentration is increased with no increase in power levels, the annual return, due primarily to reduced metal throughout, is approximately \$28,600,000 and the pay-off period is approximately 0.9 years (see tables I, II, and III). Additional benefits on which no economic value are placed at this time because of the many controversial and intangible aspects are:

- 1. Improved reactivity control.
- 2. Improved metal utilisation if product quality is important.
- 3. Reactor crash discharge in a very short period of time.
- 4. A decrease in reactor outages resulting in less reactor thermal shock and less nuclear hazard during reactor start-ups.
- 5. Better utilization of personnel.
- 6. Advancement of reactor technology.
- 7. Installation of new process tube fittings with the following advantages: a. Better gas seals on the rear face of the reactor.
  - b. Provision for increased process tube expansion at higher tabe operating temperatures.
  - c. Nozzles designed to facilitate future process tube replacement.
  - d. Rear face fittings compatible with pressurisation or boiling conditions.
  - e. Tube fittings designed to minimize maintenance costs.
- 8. Reduced personnel exposure due to radiation, particularly as the result of reduced reactor maintenance work and elimination of quickie and shutdown discharges.

If new fuel elements which result in a very minimum of ruptures are available after installation of operational charge-discharge, the primary benefit resulting from installation of operational charge-discharge then becomes a reduction of the reactor outage time required for charge-discharge of the fuel elements. In this case, it must be assumed that the reactor power levels will be increased until there is some





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definite limitation of the power levels. However, since there appears to be no definite limit to reactor power levels if we obtain relatively perfect fuel elements, it has been assumed that the power levels can be increased until they are double those obtainable as a result of the completion of Projects CO-558 and CG-600 at the six eld reactors. In this case the installation of operational charge-discharge can be amortized in approximately three years solely on the basis of the reduction of reactor cutage time for charge-discharge.

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The extra production resulting from operational charge-discharge equipment should also be compared to the capital investment for new reactor construction required to obtain an equivalent production gain. This required capital investment would vary from 48 to 126 million dollars for the three cases mentioned above as compared to \$24,450,000 for charge-discharge equipment for the same increase in production. (See Table III.)

### DISCUSSION

### Future reactor operating conditions

Because the operational charge-discharge equipment probably will not be installed until 1959 or 1960, it is necessary to forecast operating conditions that far in the future in order that the benefits resulting from this installation may be determined. It is anticipated that various improvements in the reactor equipment will be made over the next four to five years so that the reactor power levels will be much higher than at the present or they are anticipated to be in the near future. As a result it has been assumed that the old reactors will be operating at the Project CO-558 design water flow of 71,000 gpm and 120 degrees C maximum outlet temperature (1) (3). No revisions to the reactor water systems are anticipated to permit higher water flows on outlet temperatures. Similarly, the 100-C Reactor is assumed to be operating at a process water flow of 94,500 gfm (2), and the 100-K Reactors are assumed to be operating at a process water flow of 168,000 gpm. (4) It is also assumed that the metal discharge concentration will be 500 MWD per ton because of rupture considerations.

Results of Installation of Operational Charge-Discharge

### As General Types of Gain Bualized

1. Reduction of outage time for charge-discharge of fuel elements.

Installation of operational charge-discharge equipment should eliminate all reactor downtime required for loading fuel elements into the reactor process tubes and discharging those fuel elements which have not reptured. Equipment should be of such design that all of this work can be performed during reactor operation.

2. Reduction of the effects of ruptures.

Installation of operational sharpe-discharge equipment should reduce appreciably the affects of ruptures as a result of more rapid detection and discharge of the rupture material.

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In addition to the present header sampling system, the proposed operational charge-discharge equipment will provide a separate system for monitoring the effluent water from each tube. This should result in the detection and verification of a ruptured slug and identification of the tube very soon after the rupture occurs. Discharge during operation of a major portion of the ruptured slugs should be possible before they have ruptured so seriously that they are stuck in the tube.

Verification of a rupture should occur sooner than with present equipment. The installation of a second monitoring system would result in two independent <u>signals</u> permitting not only identification of the tube containing the rupture but also earlier confirmation of the existence of the rupture.

Theodischarge operation is facilitated because discharging the material in the suspected reptured tube will consist simply of opening the ball valve on the nozzle and flushing the entire tube contents out into the discharge area. It seems reasonable to assume that the ruptured material could be discharged from the tube within a few minutes after verification of the rupture. The tube could then be recharged later after the necessary metal and equipment have been transported to the front nozzle of the tube.

In contrast, at the present time whenever a rupture occurs, it usually is several hours before the ruptured material is removed from the tube. The reactor may continue to operate for a considerable length of time after first indications before the rupture signal repeats often enough to justify action and the reactor shutdown to verify and identify the tube. Throughout this period of time the rupture condition is continually getting worse so that the possibility of a stuck rupture increases.

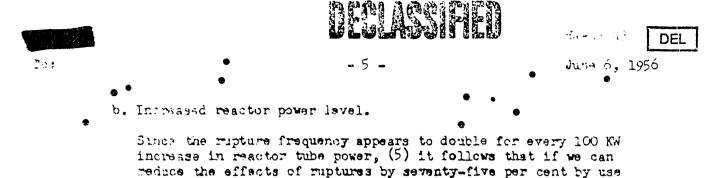
Since the time required to remove a rupture after it is verified should be reduced from a matter of hours to a few minutes by the installation of operational chargedischarge equipment and since verification should occur sconer, it is assumed that the effects of ruptures on reactor production efficiency will be reduced by 75 per cant.

Advantage may be taken of this benefit by increasing the severity of reactor operation until the occurrence of ruptures is again limiting reactor production. This may be done either by increasing reactor power level, i.e. tube power, or increasing the discharge concentration of the metal. These two possibilities are discussed below:

a. Increased metal discharge concentration.

At the present time, the rupture frequency appears to be dependent on the metal discharge concentration and to increase approximately 2 1/2 times for every 100 MMD/ton increase in the goal exposure of the metal. (5) Since the installation of operational charge-discharge equipment should permit the more rapid detection and discharge of ruptured material, it is anticipated that installation of this equipment will reduce the effects of ruptures by a factor of four. As a result, increasing the discharge concentration of the metal by approximately 150 MMD per ton to 650 MMD per ton should be possible.

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  - 3. Required capital investment.

increase of 200 KW is possible.

If increased reactor production is desired at the Hanford Operation, two general methods of obtaining this increased production are available. The first would be the construction of new reactors; second would be improvement of the existing reactors to get the same production gain. Consequently, we define the required capital investment as that investment in new reactors necessary in order to obtain the same additional annual production to be realized by improvements to the existing reactors. This cost for new reactors would be from \$48 to \$126,000,000

of operational charge-discharge equipment, we can then increase the reactor power level to that point at which ruptures again become limiting to total production. In this case, a tube power

- as compared to \$24,450,000 for charge-discharge equipment. (See Table III)
- 4. Miscellaneous benefits from operational charge-discharge.

There are several other benefits which can be realized from the installation of operational charge-discharge. However, the effects of many of these banefits are intangible and cannot be calculated with reasonable accuracy because of their nature. Consequently, it was decided to discuss these items and not attempt to determine the associated economic benefits. It should be realized though, that these items will result in additional benefits which should reduce the pay-off period for installation of operational charge-discharge.

a. Improved reactivity control.

Since material may be charged into the reactor process tubes during operation by the use of the operational charge-discharge equipment, it should be possible to adjust the flattening of the reactor to minimize production losses due to non-equilibrium operating conditions. As an example, the overall reactivity of the reactor may be adjusted during start-up so that the maximum possible power level canebe realized in a minimum of time. The effects of lack of control rod capacity and operating problems such as hot spots should be minimized, if not elimina-

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ted. Most of the gains that can be realized due to reduction of these losses will be realized by use of the prison column control equipment to be installed in the near future. Calculation of the gain that would be realized from operational charge-discharge would be very difficult be cause the benefits from poison column control cannot be determined accurately at present, but to provide the ability to use any of the reactor tubes for poison or metal charges without moving any equipment cannot help but be of great value.



b. Improve metal utilization if the product quality is important.

Whenever it is desirable to produce a product of very high quality, such as the current low concentration material, substantial savings in metal cost can be realized if it is possible to discharge the material at the maximum permissible concentration. At the present time such discharge is not possible because the reactors have to operate for several days between metal discharge periods. However, if operational charge-discharge were installed, it would be possible to discharge the metal during operation at exactly the maximum concentration. The reduced metal consumption would result in a substantial cost savings. Since requirements for material of this type at the time operational charge-discharge will be installed is unknown, it is not possible to estimate the associated cost savings.

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c. Reactor crash discharge in a very short period of time.

The use of crash discharge has been proposed as a means of minimizing the damage to a reactor in the case of a predictable loss of cooling water or flooding of the reactor area by a disaster at Grand Coulee Dam. At the present time, a crash discharge is not possible in the time permitted before the area would be flooded or the disaster would occur because of the inherently slow methods available for discharging the metal in the reactor. However, if operational charge-discharge were installed, it would be possible to discharge any portion or all of the metal in a reactor within a few minutes so that a successful crash discharge could be accomplished.

d. A decrease in reactor outages resulting in less reactor thermal shock and less hazard to the reactor during startups.

Every time that a reactor is started up there is a thermal shock to the fuel glements and the reactor itself plus a nuclear hazard in that an excessive reactor power level could occur. Installation of operational charge-discharge would reduce the number of reactor outages, particularly for charge-discharge of the fuel elements, so that there should be less thermal shock to the reactor and less possibility of reactor hazards.

e. Better utilization of personnel.

Whenever a reactor shuts down, personnel must be moved immediately to that reactor to accomplish the necessary outage work so that the reactor may be started up as soon as possible. As a result, whenever

several reactors are shut down at the same time, personnel requirements are very large and usually cannot be fulfilled without having an excessively large force. Since the installation of operational chargedischarge would reduce the number of reactor outages, the frequency of several reactors being shutdown at the same time would be lowered and personnel requirements during such periods also should be lower. Certainly overtime work requirements would be reduced, and possibly

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the total force could be reduced.

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f. Advancement of reactor technology.

At the present time, one of the major obstacles to very high power levels for heterogeneous reactors is the amount of time required to charge-discharge the fuel elements during reactor shutdowns. Unless techniques are developed for performing the charge-discharge operation during the operation of reactors, it is possible that heterogeneous reactors may not compete with homogeneous reactors in the future. Installation of operational charge-discharge on a full reactor scale would be a substantial step forward in reactor technology, and if the use of the equipment is successful, this serious obstacle to the use of heterogeneous reactors might be eliminated.

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g. Installation at a minimum cost of new process tube fittings compatible with proposed future operations.

In order that operational charge-discharge may be installed on the • reactors, a substantial period of reactor downtime is necessary. At that time it would be possible to install at a minimum cost new process tube fittings of advanced design permitting maximum reactor production in the future. As an example, at the present time the reactor power levels are probably limited by the maximum permissible tube expansion at higher tube operating temperatures. New tube fittings could be installed permitting much greater process tube expansion so that much higher reactor operating temperatures would be permissible. Very little additional reactor outage®time over that required for the installation of operational charge-discharge would be required.

Other improved tube fittings included are: 1) Better gas seals for the rear face of the reactors, 2) Nozzles designed to facilitate future process tube replacement, and 3) Rear face fittings compatible with pressurization or boiling conditions.

h. Reduced personnel exposure to radiation particularly as a result of reduced reactor maintenance work and elimination of quickle discharges.

The major portion of the radiation exposure received by Reactor Section personnel occurs during reactor outages for reactor maintenance, discharge of ruptured slugs, and charge-discharge. Any reduction in reactor outage work, such as that which would result from the installation of operational charge-discharge, would result in a corresponding reduction of personnel exposure to radiation.

B. Possible increased operating costs resulting from installation of operational charge-discharge.

1. Increased maintenance cost.

Although the installation of operational charge-discharge equipment could increase the complexity of the tube fittings, installation of new fittings of proper design should not result in increased maintenance cost.



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If operational charge-discharge equipment were simply added onto the present process tube nozzle, the result would be more equipment and undoubtedly more maintenance of the reactor, particularly during reactor outages. However, as long as major alterations are to be made to the process tube fittings (9), it would be logical to install new tube fittings which would minimize or eliminate a major portion of the maintenance work presently required on process tube fittings. Typical examples are: 1) relocation of thermocouple wells to accessible positions, 2) quick-connect couplings for fast removal and replacement of rear face equipment, 3) installation of improved gas seals on the reactor process tubes so that leak testing and repair of the seals would no longer be required, and 4) installation of process tube fittings such that the Van Stone flanges are eliminated. In this latter case, repair of Van Stone flanges would no longer be necessary.

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2. Increased chemical cost for water treatment.

Increased reactor water plant chemical costs undoubtedly would result from the installation of operational charge-discharge. The increase in reactor operating efficiencies and in water flow rates would result \_ in the delivery of additional process water to the feactor. Since water plant chemical costs are proportional to the amount of water delivered to the reactor increased chemical costs would result. Cases of Future Reactor Operations Considered In This Document

A. deneral

Consideration of future operating conditions indicates that the reactor power levels will be determined primarily by the frequency of metal ruptures. The reactors probably would be operating at the maximum power levels possible without excessive production losses due to removal of metal ruptures. Since atothe present time it is not possible to predict quality of the metal being used after the installation of operational charge-discharge equipment, it appears necessary to evaluate the benefit from the operational charge-discharge as if 1) there is a rupture limitation on power levels, and 2) there is no such limitation. If the metal quality is assumed to be good enough that there is no rupture limitation on power levels, then it must be assumed that necessary plant modifications in order to permit higher power levels will be performed. As an example, the reactor effluent systems could be pressurized to permit higher process tube outlet water temperature or the water plants could be modified to permit much higher reactor cooling water flow rates.

In order to evaluate the benefits to be realized from the installation of operational charge-discharge equipment, it is necessary to define six cases of future reactor operation. Cases I and V are base cases representing future reactor operation without operational charge-discharge, with a rupture limitation on power levels and with no rupture limitation of the power levels, respectively. Cases III, IV, and VI represent operation after installation of operational charge-discharge equipment. Case II represents an intermediate or supplementary case necessary in order to determine the reduction in metal costs in Case III as a result of a higher metal discharge concentration. A detailed description of these cases is on the following page. Also, see Tables I andeII.



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B. Cases Considered

Case I

Case I represents operation of the reactors with a rupture limitation on power levels and without operational charge-discharge. It is assumed that the reactors are operating at the maximum cooling water flow rate permissible after completion

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of Project 03-558, and at the maximum tube effluent temperatures permissible without pressurization of the effluence systems. A rupture limitation on power levels is assumed, and consequently the metal discharge concentration is reduced to 500 MWD/ton in order to minimize the effects of ruptures.

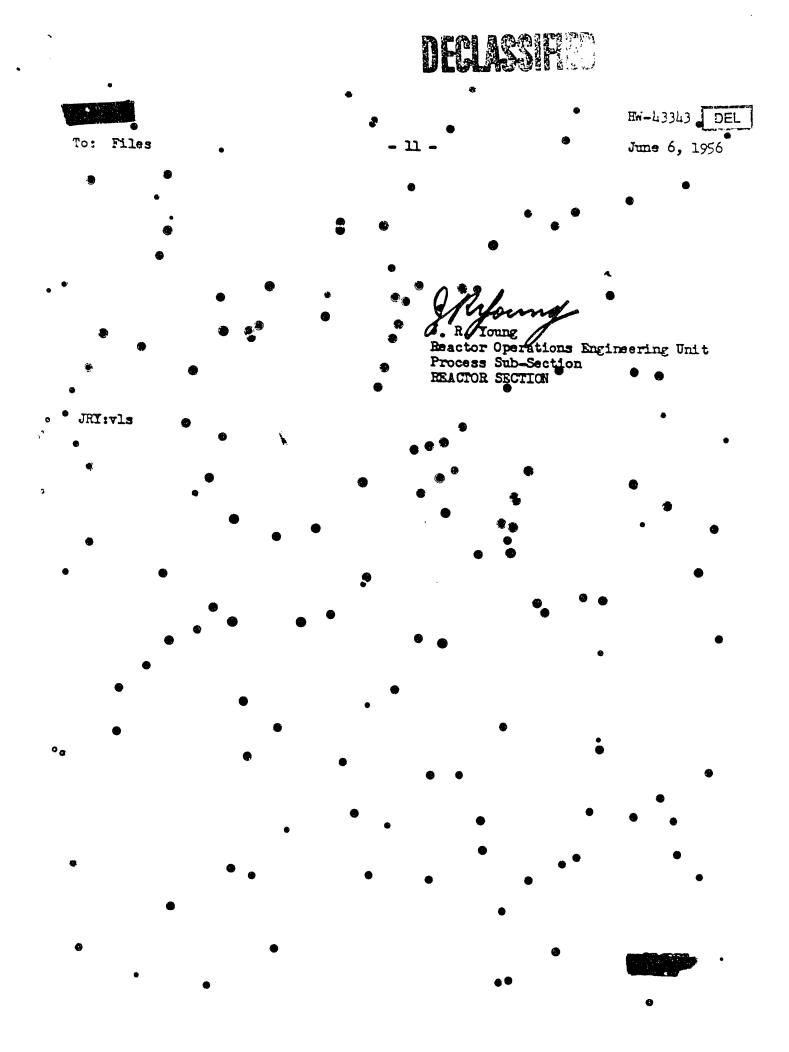
## Cases II and III

If we install operational charge-discharge on Teactors which have a rupture limitation on power level, it is possible to increase the discharge concentration of the metal because the operational charge-discharge equipment reduces the outage time caused by ruptured slugs. In addition there is the benefit of reduced reactor outage time for charge-discharge of the fuel@lements.

- Operational charge-discharge equipment should permit increasing discharge concentramation of the metal from 500 MWD per ton to approximately 650 MWD per ton. Investigations
- of ruptures in the reactors has shown that the rupture rate increases by a factor of 2.5 for every 600 MwD per ton increase in the discharge concentration of the metal. (5) Since it is assumed that the installation of operational charge-discharge equipment will reduce the effects of ruptures by a factor of four, it follows that the discharge concentration of the metal can be increased by 150 MwD per ton.
- Determining the benefits resulting from assuming that the metal dischafte concentration can be increased requirer the use of a Supplemental case. Calculation of the setal required after installation of the operational charge-discharge equipment and increasing the metal concentration and then comparison of this amount of metal to that required in Case I would result in incorrect information concerning the actual reduction in metal requirements. This occurs because the higher reactor operating efficiency after installation of operational charge-discharge results in an increase informatal concentration. Consequently, at is necessary to calculate tons of metal required at the lower (500 MND per ton) metal discharge concentration but with the higher operating efficiency. The amount of metal required if the metal discharge concentration is 650 MND pwer ton. Case II represents this intermediate condition where the reactors are operating at the higher operating efficiency, but are discharging metal at 500 MND per ton concentration. Case III represents the condition for the reactors operating at the higher operating efficiency, but are discharging metal at 500 MND per bon concentration. Case III represents the condition for the reactors operating at the higher operating efficiency and discharging metal at 500 MND per ton.

Then, in order that the total benefits realized from installation of operational charge-discharge equipment can be determined, the tons of metal used in Case III are compared to the tons of metal used in Case II, but the total reactor production in grams for Case III is compared to the total reactor production in grams in Case I. The productions in grams must be compared rather than in MND's because the change in the metal concentration at discharge results in a different conversion ratio for the product.

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Case IV	
operational charge-discharge may also p In Case IV we assume that after the open installed, the effects of ruptures has quently it is possible to raise the por production.	actor power levels, the installation of permit increasing the reactor power levels. erational charge-discharge equipment has been been reduced by a factor of four, and conse- wer levels until ruptures again limit total
for every 100-K increase in the react that the installation of operational c effects of ruptures by a factor of fou power by 200 K. The two major benefits resulting from in Case IV then become (1) increased r elimination of downtime for charge-dis because of higher permissible reactor	es that the frequency of ruptures dcubles for tube power. (5) Since we are assuming marge-discharge equipment will reduce the ar, it is possible to increase reactor tube installation of operational charge-discharge reactor operating efficiency because of the scharge and (2) increased reactor production power levels. Since no change in metal this case, total production is compared to
Case V	
reactors should then be operating with tion. Since there doesn't appear to h which cannot be relaxed by appropriate it has been assumed that the reactor w Case I. In order that the seepower lev necessary to increase the capacity of effluent systems to permit higher wate	ture limitation on reactor power levels, the power levels determined by the next limita- be any limitation on the reactor power levels a feasible reactor or water plant alteration, will be operating at twice the power level of vels may be realized, it probably would be the water plants or to pressurize the reactor er temperatures. However, the incentive for rs are sufficient that undoubtedly such work
<ul> <li>rupture limitation. It has been assuring increased to a higher value represent.</li> <li>Frimary effect of this higher metal constallation of operational charge-disconcentrations, there would be less to the second se</li></ul>	ut operational charge-discharge and without a med that the metal concentration has been ative of the optimum operating conditions. concentration is to reduce the benefits from scharge, since at higher metal discharge ime required for charge-discharge of the metal less increase in reactor operating efficiency re-discharge equipment.
Case VI	•
ruptures probably would not result in discharge concentration. Consequent installation probably would be the el is this case upon which mearly all of	ischarge equipment on a reactor not limited by a any increase in reactor power level or metal by, the only major benefits resulting from this limination of downtime for charge-discharge. It the previous economic analyses have been based, a slug aspects as represented in Cases I, II,
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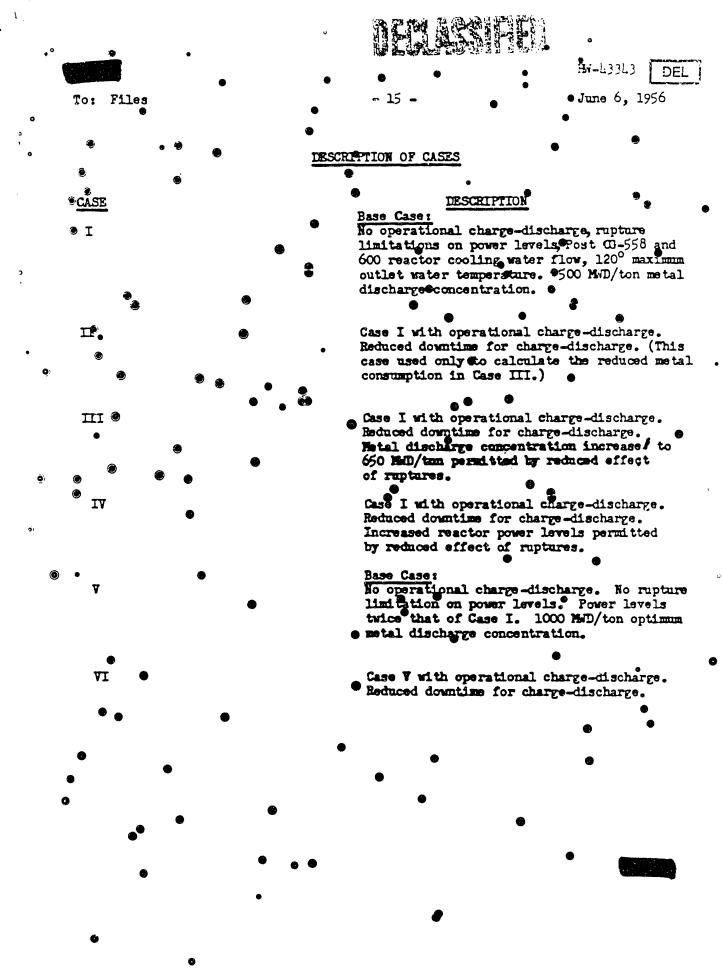
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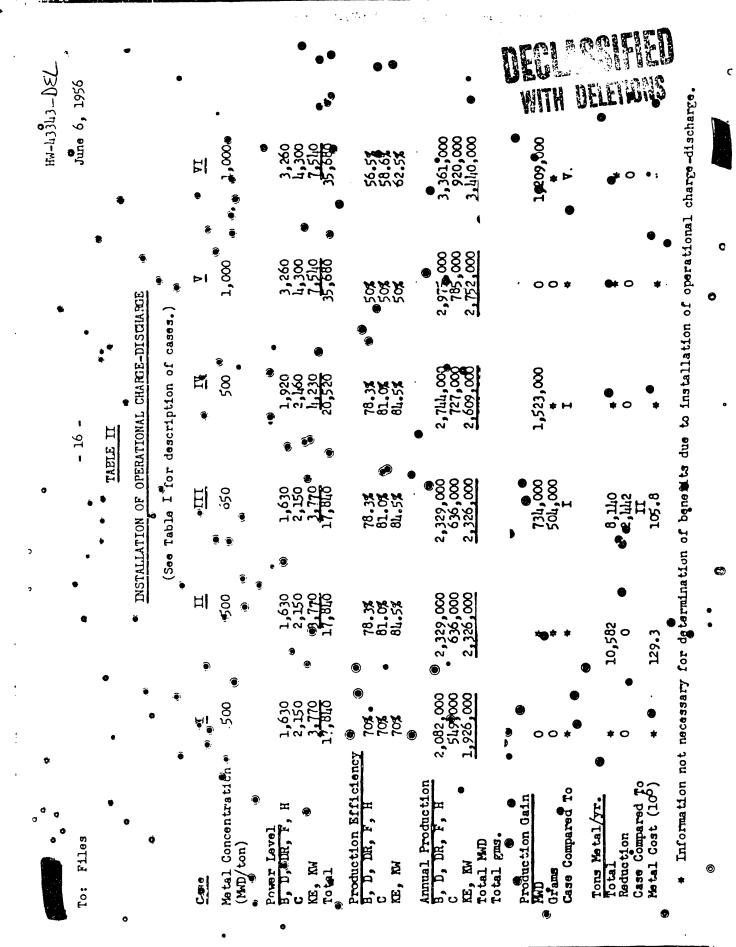
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•	2.	The reactor p 50 per cent i operating com	ncrease in dition. 7	n power 1 Chis assu	evel over mes a ma	the Proj or effort	ject CG-550 5 will be a	B ♥ ● ♠ made in
		order to mini level is incr ment could be	reased. A	s an cxan	iple shate	down char	ge-dischar	ge equip-
	3.	Shutdown char • per@day.	rge-dischar	rge rate	for all 1	reactors 1	<b>will be</b> 36	O tubes
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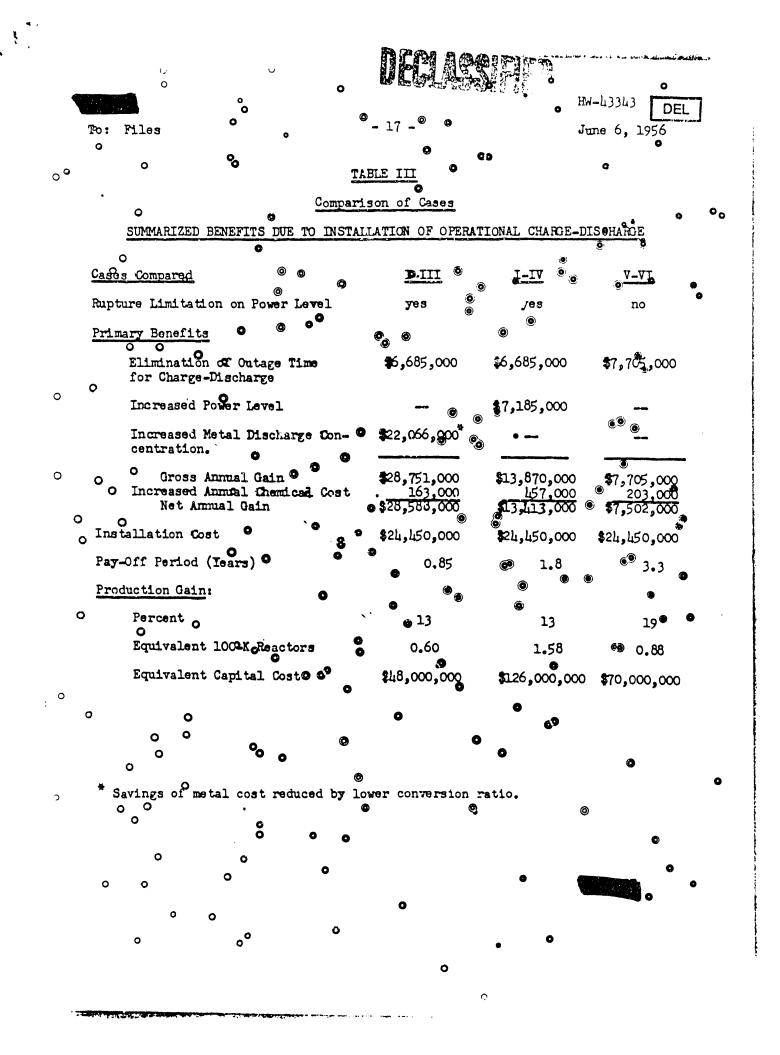
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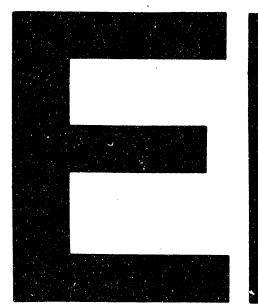
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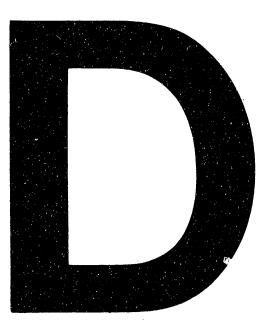


STATE OF STREET









DATE FILMED 6/1/93