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MANHATTAN DISTRICT HISTORY

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SUPPLEMENT NO. 1

TO

BOOK II, GAS DIFFUSION PROJECT - VOLUME 5, OPERATION

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OPERATION OF K-25-27 PLANT
FOR
HIGH CONCENTRATION PRODUCTION

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OPERATION OF K-25-27 PLANT FOR HIGH CONCENTRATION PRODUCTION

1. Policy of Manhattan District.

a. From the beginning of the Manhattan Project in 1942, it has been the standing policy of the District, throughout all its operations, to make every effort to reduce costs and to effect savings, wherever it was possible to do so without detriment to the overall mission. This policy has applied to all phases of the project -- to research and development, design and engineering, construction and operation -- and it has been emphasized again and again by General Groves.

b. Until the attainment of success in the production and combat use of the atomic bomb, emphasis was of necessity concentrated on speed. Speed was of the essence of the mission of the Manhattan District. In general, any expenditure which would insure, or definitely promote, greater speed in accomplishment, was justified; correspondingly, any time-consuming efforts which might, in time, produce economies had to be postponed, if any chance was indicated that they would, even briefly, adversely affect the speed of accomplishment.

c. With the attainment of success in the primary mission, with the dropping of the first two combat bombs on Japan and the cessation of hostilities immediately following, although the District policy remained the same fundamentally, it underwent a change in emphasis. Production of atomic bombs and production of the materials required to make them continued to be the principal mission of the

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District, but war-time speed became less important and peacetime economy became more important. In plant operations, maintaining the highest rate of production reasonably possible was mandatory, but every encouragement was given to searching out ways and means of reducing costs without reducing production.

d. Because they consumed by far the greatest part of the plant operating costs of the Manhattan District, the Y-12 and the K-25 plants at Oak Ridge, from which the active material U235 was being obtained, obviously offered the most fertile field for improvements which might reduce the continuing costs of the Manhattan Project. This can be seen readily from examination of the cumulative expenditures for operations, to 30 June 1945 (Reference: 28, App. B1, "Monthly Budget Statement as of 30 June 1945"). The total combined operating expenditures to that date for Y-12 and K-25 (exclusive of plant construction, of housing and central facilities, and of special operating materials) amounted to \$153,542,000, whereas the total operating expenditures to the same date (but including operation of housing and central facilities) amounted, for Hanford Engineer Works (X-10), to \$41,214,000, and for Los Alamos (Site Y) to \$27,874,000. At this time, also, the monthly operating costs of these plants were running approximately as follows: K-25: \$3,841,000; Y-12: \$8,873,000; HEW: (including central facilities): \$1,273,000; Y Project (including central facilities): \$1,549,000. (Reference: 32.) Efforts were made at every plant to improve operations and reduce costs, but the greatest effort was made, and the greatest success has been attained, at the K-25-27 and the Y-12 plants, as

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described hereinafter.

2. Summary of Early Production History.

a. The K-25 plant started producing U235 of comparatively low concentration -- very low in comparison with later developments -- with the commencement of operation in March 1945; production continued at increasing purity of product until full operation was attained on 15 August 1945 (Reference: 29, p. 1.1; also, Reference: 23). The plant was originally designed for production of a specified quantity (1 kgm ^{per day}) of U235 at a specified purity or concentration (originally 90%, later 36%), but the plant was perfectly flexible and could be operated to produce a higher rate at a lower concentration or a lower rate at a higher concentration (Reference: 30, p. 172). Even before full operation was attained it became evident that plant performance was appreciably better than design estimates (do., p. 180); and it was predicted that an output of 1.54 kgm per day at 36.6% concentration, or an output at 27.5% concentration at 6 kgm/day could be attained (do., p. 180). The reasons why actual production exceeded the original estimate of production may be summarized as follows:

(1) The actual cell stream efficiency of 95 to 100% exceeded the assumption of 85%;

(2) A correction of 10% had been allowed in the estimates for surges, whereas surges actually had very little effect on production;

(3) The actual separating qualities of the barrier tubes in the diffusion stages were better than the assumed values.

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b. As indicated above, the original design specifications for the K-25 plant called for a product concentration of 90%. This specification was required at the time because the process was intended to be entirely independent of the other processes for uranium isotope separation -- the electromagnetic and the thermal diffusion processes. During the early stages of the project, the independence of each process was essential because no one could foresee what process, if any, would be successful; and this independence was maintained until the success of more than one process became reasonably assured. In line with this independence of design, engineering studies went forward on a diffusion plant to produce Uranium 235 in concentrations as high as 90%, until, as a first step, on 18 August 1943, the Manhattan District authorized the construction of those sections required to produce a 36% concentrate. Then, on 16 January 1945, the design contractor was authorized to proceed with work on additional sections required to produce an 85.5% product. This program, to which the name "Section Y" was given, proceeded in the design stage for two months, until it was cancelled on 16 March 1945, when decision was made to integrate the K-25 and Y-12 processes. It was apparent then that success could be attained more quickly by combining the K-25 and Y-12 processes, so that, both working on the same material, each would supplement the other, than by relying upon one or the other process, or both, acting separately. (Reference: 31, p. 5.) At about the same time, however, it was realized that for proper coordination of the two processes, and in order to insure a sufficient amount of product, an increase in capacity would be

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required. By that time, portions of the K-25 plant were in production, and the success of the process as a whole was assured; accordingly, decision was made to construct an addition to that plant, to which the name K-27 was given.

c. The K-27 expansion was authorized by the Manhattan District about 1 April 1945 (Reference: 31, p. 120), and ground was broken 3 April 1945 (do., p. 117). It was imperative that the completed plant be in operation by 1 January 1946 (do., p. 6); actually, the first units were operated 28 September 1945 and processing began 18 December 1945 (do., p. 5, footnote). This extraordinary speed was rendered possible by insistence upon making the K-27 expansion "virtually a Chinese copy" of a section of the K-25 plant, and authorization was given on this basis (do., p. 6). When K-27 was fully operating early in 1946, it supplemented the K-25 cascade, and the product of both, now increased to 30% concentration, was fed to Y-12 Beta (Reference: 23); the rate of production at this time averaged about 3.6 kgm/day. (Reference: 29, App.)

3. Increase in Concentration to 60%.

a. It had always been recognized that if the gas diffusion process could be made to work at all it could almost certainly be used to produce really high concentrations; the problem would consist, in its simplest terms, merely of providing a sufficient number of units or of circulating the material a sufficient number of times. The operation of the expanded plant, K-25-27, therefore, had scarcely begun, in January 1946, when the scientists and engineers were already beginning prelimi-

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nary investigations for increasing the concentration to values greater than 30%. This procedure had been urged by General Groves and Colonel Nichols in their efforts to explore all possibilities of improvement for the attainment of economies, in line with the emphasis on peace-time economy which now prevailed, as described above. The fact that the efficiency of operation had proved to be so much greater than the original predictions furnished further encouragement.

b. On 16 May 1946, a plan for operation to produce increased concentration had been worked out and was recommended. This plan was approved by Colonel Nichols and General Groves on 11 June 1946, and authorization was given to the K-25 Division on that date. (1st. Ind., 11 June 1946, from Manhattan District to Mr. R. W. Cook, K-25 Division Chief, to letter of 7 June 1946 from K-25 Div. Chief to District Engineer.) The approved plan involved primarily an increase of the "X" inventory in the cascade. The desired inventory was accumulated 12 July 1946 and fed into the cascade, and the cascade was then operated on total reflux. On 20 July 1946 the concentration reached 60%. (References: 23, 24.)

4. Increase in Concentration to More Than 93%.

a. With the attainment of 60% concentration in the product of K-25-27, a serious problem was posed to the Manhattan District. On the one hand, the Y-12 plant was not equipped to receive, handle and process material with concentrations as high as 60%. On the other hand, 60% concentration was too low for delivery to Los Alamos. Should the K-25-27 plant return to production of 30% material, or should it go further and seek 95% concentration? Those who were familiar with the gas

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diffusion process were convinced of the feasibility of producing still higher concentrations, and the operation which had successfully produced the 60% concentration had permitted the accumulation of data to prove this conviction.

b. Apart from the risk of failure to attain the desired objective -- and the consequent loss of time and loss of production which this failure would entail -- there was the potentially even more serious risk of undue hazards to the personnel and to the plant itself which might develop from the handling and processing of the highly concentrated material. As will be described more fully hereinafter, the possible hazards, and the safety precautions which might be required to combat them, were given most careful consideration. The conclusion was reached, on the best obtainable evidence, that with proper precautions, which were entirely feasible, the operations necessary to attain 95% concentration, more or less, could be carried out without undue danger. (See par. 6 below)

c. Authorization was accordingly issued by General Groves and Colonel Nichols to accumulate inventory for raising the concentration to 95%. Orally on 18 October 1946, and by letter from the District Engineer, initialled by General Groves, dated 14 October 1946, this authorization was transmitted to Mr. Clark E. Center, the Plant Superintendent of the Operating Contractor, Carbide and Carbon Chemicals Corporation, Oak Ridge, Tennessee. (Reference: 14; described also in 23, 24.)

d. It was proposed that the increase in concentration

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would be tried out first as a test only, and that, if it were found to be successful, decision could then be made as to continuation of the operation in the future. It was estimated that the experimental test would require a period of between two and two and a half months. The accumulation of inventory started immediately and on 5 November 1946 the feeding into the cascade of the accumulated material, together with the normal operating feed, began. The period of total reflux extended from 5 November to 2 December 1946, and no withdrawals of material from the cascade were made during that time. On 28 and 29 November 1946, the concentration reached 94%, but it became apparent that the increase in U234 was limiting the final concentration of U235. When the plant had been operating at lower concentrations, the amounts of U234 which remained with the U235 after its separation from the U238 had been relatively unimportant, and the withdrawals of the U235 and U234 together had prevented its increase; with operation at the high concentrations and without any withdrawals, however, the increased percentages of U234 became a definite hindrance. The attempt to maintain at least 94% concentration of U235, and to limit withdrawals accordingly, had to be abandoned. On 6 December 1946 it was determined that a withdrawal rate of 2.56 kgm "X"/day would be maintained and concentration would be allowed to drop to a steady state. This procedure was followed, starting 8 December 1946, and as of 22 December 1946 withdrawal at the rate of 2.56 "X"/day had continued, with the concentration of U235 remaining practically constant at about 93.7% for about 11 days (since about 11 December 1946). (References: 23, 24; also, especially, chart of test

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attached to latter).

5. Continued Operation at High (More Than 93%) Concentration.

a. The success of the preliminary test operation to produce U235 at the K-25-27 plant at concentration of more than 93%, combined with other considerations, led logically to the next step; but, even so, the problem was not so simple as this brief recital of events might indicate, because the data upon which future action must be based were of necessity less complete than would have been desirable under less compelling circumstances.

b. Mr. Clark E. Center, Plant Superintendent, in a letter to the District Engineer, dated 18 December 1946, summarized the results obtained from K-25-27 plant data during the period of operation at high product concentrations, from 2 December to 15 December 1946, and stated: "In conclusion, we can say that the existing data indicates that the K-25 and K-27 plants can produce at a rate of 2.56 kgm X/day and at a concentration of approximately 93.6%." He then pointed out, however, that these data involved various uncertainties: lack of adequate information on corrosion and consumption; lack of desired accuracy in inventories and material balances; data based on a much too brief period of operation for accurate estimates; data based on a high stream efficiency (99%) and a period involving no major operational mishaps. (Reference: 22.) Even though this statement may be discounted somewhat, as representing the sound conservatism of an operating executive who was concerned with the one plant and not with the project as a whole, it indicates nevertheless the seriousness of the problem; because a decision had to be made,

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and made immediately, as further testing and research would have entailed losses in production and efficiency which would have been prohibitive.

6. The considerations, which led, as a result of the success of the preliminary test operation, to the next step, were, principally, the followings:

(1) The resulting material was a satisfactory product for delivery to the Los Alamos Laboratory. Its concentration was running at approximately 93.7% of U²³⁵ and approximately 1.9% of U²³⁴, and there was practical certainty that the concentration of the former would not drop below 93% and the concentration of the latter would not exceed 2.0%. (The operating contractor estimated that the final concentration of U²³⁴ would be 1.3% when the cascade reached equilibrium.) References: 23, 24.)

(2) The rate of production was satisfactory. The withdrawal rate had been for some days 2.56 kgm per day, and it was expected that it could be continued at an average of at least 2.5 kgm per day. This may be compared with the average combined rate of production of the X-25-27 and the Y-12 plants, working in series, of 2.462 kgm of U-235 per day, for the months of August, September and October 1946 (Reference: 24), the highest average production for any 3 months period to that time (Reference: 29).

(3) Procedures could be instituted which experts agreed would prevent undue hazards during operation, even if the high concentration operation were continued indefinitely (See par. 6 hereinafter).

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(1) Very substantial savings in overall operating costs could be effected, estimated as amounting to more than \$2,000,000 per month. (See par. 7 hereinafter)

d. Based on these considerations, it was decided, on 23 December 1946, to continue operation of K-25-27, at 93% or more concentration and at maximum production; and to reduce operation of Y-12 Beta to one Beta track and auxiliaries, for use principally for process development and improvement. Supplementary decisions were: to continue the stable isotope separation program; to continue standby maintenance of Y-12 facilities; to continue final chemistry for processing K-25-27 product and such product as is obtained from one Beta track; and to continue process improvement and development work at Y-12. (Reference: 24.)

e. Final decision on all these procedures was given by General Groves on 23 December 1946, by indorsement on the memorandum of that date from Colonel Nichols, in which the past history of the plan of operation of K-25-27 at high concentration was briefly reviewed and the recommended future procedures were enumerated. General Groves' indorsement read as follows (signed "LRG-23 Dec. 46")

"To Col. Nichols:

"1. The above memo is a good summary of what has transpired over many months.

"2. Approved.

"3. You will take effective steps to insure that the safety precautions recommended by the Bradbury-Felbeck-Keith Committee are observed." (Reference: 27.)

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5. The curtailment of operations at the Y-12 plant began on 26 December 1946, upon the delivery of a letter dated 21 December 1946 from the District Engineer to Dr. F. R. Conklin, Y-12 Works Manager, which formally authorized the procedures to be followed. The employees and the general public were advised on the same day. In a press release issued on 26 December 1946 it was explained that improvements in processes for concentration of Uranium 235 at Clinton Engineer Works would permit considerable savings in operating costs and a reduction in employees. It was stated also: "Results of the test operation were discussed with the Atomic Energy Commission, which will take over operation of the facilities on January 1, and the Commission has concurred in the proposed reduction in force."

6. Operation Hazards and Safety Precautions.

a. Each increase in concentration of the product inevitably increases the potential hazards of operation. This principle applies to important parts of the K-25-27 plant, and it was recognized at all stages throughout the history of that plant. When the most serious step, of producing material with concentration greater than 60%, was contemplated, careful new studies of the potential hazards and of means for their avoidance or control were instituted.

b. Under date of 15-25 August 1946, Dr. Clifford Beck, at that time Technical Consultant to the Plant Superintendent, submitted a report entitled: "A Brief Description of Equipment and Procedures in

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Critical Accumulations" (Reference: 1). In the preparation of this report Dr. Beck was assisted by: H. G. Bower; J. O. Deming; J. E. Eliot; W. C. Hartman; J. R. Largey; G. E. Newlon; L. P. Pasquier; H. M. Preuss. As evidence of the thoroughness with which this subject was studied, as well as the conclusions reached by the investigators, the following excerpts are quoted from the Beck report (underlining has been added):

(1) From the "Abstract" (p. 6):

"It is intended herein to present a factual statement of the equipment dimensions, capacities and connections, of the operating procedures, and of uranium U235 and contaminant inventories and distribution, for all those portions of the plant in direct contact with U236. Mention is made of the various emergencies which could arise, what the effects would be and how the situation would be handled. All these emergencies have occurred at one time or another in the history of plant operation, except a major in-leakage accompanied by a total power failure and a sustained atomic chain-reaction. It is believed that the plant could be operated at 90% product purity, without greatly increasing the hazards involved in an occurrence of these emergencies.

"A brief statement is made of the critical masses of U235, and of the application of this information to the safety of the plant."

(2) From the opening statement on "Emergencies", Section VII (p. 31):

"A number of disturbances could arise causing serious upsets in normal operating schedules of the cascades. Practically

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all of the situations which could happen, causing major upsets of the cascade, except a sustained atomic chain-reaction, have occurred at one time or another in the history of the plant, even total power failure to the entire plant.* Operating procedures have been worked out in advance by which these emergencies can be handled, and these procedures have been tested and adjusted by the emergencies which have occurred."

(3) The following is a list, by headings, of the principal emergencies which are enumerated, with the operating procedures which would apply, in Section VII:

- A. Total Power Failure -- Constant and Variable Frequency.
- B. Variable Frequency Failure
- C. Coolant Failure
- D. Stuck Control Valve
- E. Failure of Nitrogen Supply
- F. Failure of Dry Instrument Air
- G. Seal Exhaust Failure
- H. Major Inleakage
- I. Major Inleakage Accompanied by Total Power Failure.
- J. Sustained Chain-reaction

* Footnote: Under VIIA, p. 31, it is stated that a total power failure occurred on 8 February 1946; that constant frequency power was restored in 45 minutes and all auxiliary equipment had resumed operation in about one hour.

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c. On 28 August 1946, the District Engineer, acting for General Groves, appointed the following as members of a committee:

Dr. N. E. Bradbury, Director, Los Alamos Laboratory;

Dr. G. T. Felbeck, Vice President, Carbide & Carbon Chemicals Corporation;

Mr. P. G. Keith, President, Hydro Carbon Research, Inc. (Formerly, President, Kellogg Corporation).

Each member of this so-called Bradbury-Felbeck-Keith Committee was requested to review the data prepared by Carbide and Carbon Chemicals Corporation, concerning operation of the K-25-27 plant at 95% purity, and to make recommendations as to safety of operations at this purity (References: 2, 3, 4).

d. Each member of the Bradbury-Felbeck-Keith Committee expressed his views, and, in addition, Dr. Bradbury obtained the views of two of his associates at Los Alamos: Dr. Edward Teller and Dr. Carol Froman. Although there were some minor disagreements on methods of procedure, all were in general agreement on the most important question involved. They agreed, in general, that the K-25-27 plant could be operated at 95% concentration without undue hazard provided certain precautions were taken (References: 24, 23). In practically every opinion which was expressed the importance of taking proper precautions was emphasized.

e. In view of the seriousness of the considerations involved, it is desirable to record the views of the individuals upon whose combined advice the further action was taken. The following are pertinent

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excerpts from the communications received, for the most part addressed to the District Engineer:

(1) Dr. H. E. Bradbury (Reference: 5): "It is my opinion that it is safe to proceed with the operation of X-25-27 at the concentrations suggested. The continuance of such safe operation is dependent upon continual study of the problems involved, including critical mass experiments." He agreed with Dr. Teller's comment "that a local staff continually concerned about these problems is essential"; and he emphasized "The concern which was expressed at the meeting of this committee that one of the most effective safeguards . . . will be a continual scrutiny of the incoming and outgoing inventory."

(2) Dr. Edward Teller (Reference: 6), while qualifying his statement by explaining the incompleteness of his study of the subject, wrote: "I should state, however, that in my brief study I did not find any indication of special hazard." He issued a definite warning of the necessity for taking the most careful measures to avoid accident, as, he said, "There is a considerable chance that in the course of time an accident involving a direct chain reaction will occur." (Dr. Teller's comments are evidently based on a study of the Beck report referred to previously herein).

(3) Dr. G. I. Felbeck (Reference : 7), after expressing concurrence with Dr. Bradbury's opinion that it is safe to proceed and in Dr. Bradbury's views on the safety program which should be carried out: "It is my opinion that there is no immediate hazard in the operation of X-25-27 at higher concentrations." Dr. Felbeck expresses the same concern

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as Dr. Teller about long-term operation, and he quotes Dr. Teller's statement regarding the chance of accident in the future (summarized above). Dr. Felbeck also requests approval of "the formation of the necessary staff of physicists and their training at Los Alamos."

(4) Mr. F. C. Keith (Reference: 9): "It is my opinion that the risk involved in operating the K-25 plant at product concentrations up to 95% for a short period of time is negligibly small provided:

"(1) These operations are followed by a staff of physicists, responsible to the operating company, who are thoroughly familiar with critical mass phenomena.

"(2) A procedure for making material balances on U-235 of known precision is in effect at the K-25 plant, and operations at the high concentration are terminated before the unaccounted losses of U-235 plus the cumulative uncertainty in the material balance exceed the critical mass." Mr. Keith states further, after pointing out the difficulty of determining the risk involved in long period operation. (because of absence of periodic overhaul to prove absence of dangerous accumulations): "I should say that the risk involved in running the K-25 plant at high concentrations for long periods of time is very small, provided the material balance is used to follow the probable accumulations of U-235 within the plants, but there is some element of risk involved."

(5) Dr. Darol Froman (Reference: 10), agreed with Dr. Teller's opinion that most careful measures must be taken to avoid accident. He expressed the following opinions: that the measures taken should consist of such activities as continuous checks on input and output; that

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accurate determination of critical masses was not necessary; that he saw no reason to train a group of physicists to carry out an extensive series of experiments for such determination; that he emphatically disagreed with a reason given by Dr. Felbeck for a proposed additional program of experiments; that the suggestion that those at Los Alamos help with the proposed experiments was not feasible and the experiments were not worth while anyway; that the reassuring "demonstration" suggested by Dr. Felbeck would be dangerous, wasteful of valuable material and possibly misleading; that the principle of having competent physicists who know about critical assemblies on the staff of K-25 was "surely a good one," but that it would be more profitable for them to expend their efforts on insuring against unsafe accumulations of active material than on the proposed experiments.

(6) Dr. G. T. Felbeck (in another communication, Reference: 11), agreed with Mr. Keith's opinion that a staff of trained physicists should be maintained to monitor the plant at all times (described under (4) above), and also that a precise material balance should be kept. He took exception, however, to the "second part of Keith's second provision for the detection of critical mass accumulations which may occur over long periods of time"; he maintained that "there is always a finite time of plant operation for which the accumulated uncertainty of inventory becomes greater than any given critical mass", and that this criterion would be of little value. Dr. Felbeck stated further: "The possible condensation of process gas as UF-6 over long periods of time is considered not to constitute a serious hazard"; and after citing the

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methods previously used for insuring safe operation (periodic check of diffusers, analysis of waste materials, and use of diffusers as filters in the downward flowing "B" stream) stated: "These methods, we feel, are much more reliable as guides to safe plant operation than dependence on inventory figures, however accurate. Future improvement in these methods and any others that may be developed later with the previously proposed investigation of the nature of a fission reaction, it is felt, will reduce the probability of any critical mass accident during plant operation to such a degree as to become almost negligible. To date our tests have revealed the accumulations only of grams of material whereas very much larger quantities are necessary to constitute a hazard."

Dr. Felbeck ended his letter with the following:

"In view of the foregoing factors, hope you will find Keith in agreement with us and rest of committee you appointed that operations at higher purity should now be authorized by you and that satisfactory safety considerations can be maintained."

(7) Dr. N. E. Bradbury (Reference: 12) brought the written discussion of the committee members to a close with comments on the carrying out the proposed training program, stating that they would be ready for it probably in about four months; he questioned the necessity or the desirability of conducting a long and extensive series of critical mass studies at Oak Ridge; he doubted the importance of "defining the critical mass itself with the greatest accuracy" and approved "Teller's more general statement of the training physicists should get"; he expressed a strong negative opinion on "the suggestion that an actual

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supercritical assembly of UF₆ be constructed", stating that it would be extremely dangerous in a populated area and that it was doubtful if the results would justify the work involved in conducting such an experiment at a place like Alamogordo.

(8) Colonel E. B. Kirkpatrick, Deputy District Engineer, (Reference: 13, to the District Engineer) summarized the opinions of the members of the committee, Dr. Bradbury, Dr. Felbeck and Mr. Keith, that "Undue risk will not be involved if proper precautions are taken". (In this letter Col. Kirkpatrick also outlined four different schedules of operation, one pair for Y-12 operation and one pair for K-25-27, contingent upon whether or not the proposed test operation proved successful.)

(9) Colonel K. D. Nichols, District Engineer (Reference: 15, to General Groves) summarized the opinions of the Bradbury-Felbeck-Keith Committee as follows: ". . . the general consensus of opinion of this committee is that there is practically no risk for the experimental period. Also, their opinion is that the risk is negligibly small for long-time operation provided certain precautions are taken. These are:

"a. The operations are followed by a staff of physicists, responsible to the operating company, who are thoroughly familiar with critical mass phenomena.

"b. Greater effort be made to determine more precise balances in order to assist in detecting possible concentrations of material due to unaccounted-for losses.

"c. Periodic checks be made of the condition of the diffusers and other parts of the plant at various positions in the

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cascade to determine if dangerous concentrations are being built up at any point in the plant."

Colonel Nichols then added another recommendation, as follows:

"I would add a fourth condition which would be to review periodically the operation of the plant by a committee of the same caliber as the Bradbury-Felbeck-Keith Committee". (See also Reference: 14; both these letters of Col. Nichols were approved by General Groves.)

f. The communications summarized above, with respect to their bearing on the questions of hazard and safety, comprise those which were written prior to the preliminary test operation, which was authorized 18 October 1946. It will be noted, however, that they dealt with the hazards and the safety precautions not only for the test operations but also for the continued long-time operation which was authorized later. Additional documents of later date, which concerned (among other matters) the questions of hazard and safety for the long-time operations at high concentration, include the following:

(1) Mr. Clark E. Center, Plant Superintendent (Reference: 20), described the groups functioning in the plant who were concerned with control, inspection, studies of "Special Hazards", etc.; he enumerated 12 members of the "Special Hazards Committee", who met as required to consider problems submitted by the Uranium Inspection and Control Department. He recommended the retention of a committee of physicists, as consultants, for reviewing the problems presented through summary reports issued by the Department and Committee previously described. He stated that Drs. E. T. Booth and Phillip Morrison had consented to serve

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on the consultant committee and that Drs. J. R. Oppenheimer, E. Fermi and R. P. Feynman would be approached.

Mr. Center discussed the question of accurate material balances and reviewed the history of this subject, starting with recognition of its importance as early as January 1945, and studies and analyses starting in April 1945. He stated: "To date, there have been only slight deposits of uranium compounds disclosed by inspection of equipment removed for repair."

(2) Mr. Walter J. Williams, Director of Plant Operations (Reference: 23), after describing the Bradbury-Felbeck-Keith Committee and the agreement of its members that operation at 95% concentration is safe, but that continued safe operation would be dependent upon continual study of the problem with special attention to incoming and outgoing inventory, stated: "The Operating Contractor is following out the suggestions of the committee as evidenced by the attached letter from Mr. Clark Center to the District Engineer dated 13 December 1946. It is believed that the operation is safe and that present methods of operation together with planned hazard investigations and checks will keep it safe."

g. It is evident from the record that, before the decisions were made, first, to operate the preliminary test to obtain product at high concentration, and, second, to continue operation at high concentration, the following occurred: The possible hazards entailed were carefully investigated and studied by all concerned, including experts who were called upon especially for the purpose; it was unanimously agreed that these operations could be safely performed; and general agreement was

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reached on the precautions which should be taken to insure continued safety during long-time operation in the future. It is evident also, however, that the word "safety" as used in this connection must be defined relatively. Any operation of the K-25-27 plant at any concentration of product, whether it is high or low, is from its very nature subject to hazards and dangers to some degree, and the opinions of the experts must be interpreted in this light, as meaning that the hazards involved in high-concentration operation will be no greater than those involved in low-concentration operation, if the recommended precautions are taken. All concerned have agreed that it is of the utmost importance to exercise extreme care at all times to insure that these precautions are continued.

7. Savings in Personnel and Costs of Operation.

a. As previously indicated, the major purpose of the plan of operation of the K-25-27 plant for high-concentration production was to effect improvements which would result in economies, in accordance with the standing policy of the Manhattan District in carrying out its mission. The actual economies have not yet been determined at present writing, but careful estimates have indicated that they will exceed \$2,000,000 per month. (See par. 5 c. (4) above).

b. The economies to be effected are concerned entirely with those resulting from the curtailment of operations at the Y-12 plant, and they comprise principally the payroll reductions thus made possible. Although there are likely to be certain additional economies, from materials saved in reduced operation, these are not considerable --

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the great saving is in the labor required for operation, and for repair and maintenance of equipment. Certain indirect savings are also possible, such as making available housing for other personnel, but these are indefinite and no allowance was made for them in the estimates. On the other side of the ledger, the operating costs at X-25-27 are likely to be somewhat increased, primarily on account of the cost of the additional precautions made necessary for the high-concentration operation of that plant; but these are not significant and are more than offset by the increased rate of production. All things considered it is believed that the estimated savings produced by the reduction of personnel at the Y-12 plant represent with reasonable accuracy the total net savings of the new method of operation.

c. The most detailed estimate of these savings was made by Colonel Gerard J. Forney, Y-12 Operations Officer, before continued high-concentration operation was authorized (Reference: 21). At the time that this estimate was made full-scale Beta Plant operation and stand-by maintenance of Alpha Plant were in effect and it was estimated that the personnel required for this operation amounted to 3,460, with costs totalling \$3,289,000 per month. It was further estimated that the force could be reduced to 1,876 personnel and the costs could be reduced to \$790,000 per month, representing "the estimated personnel required and operating costs for the reduced operation including full operation of the final chemistry department, Alpha and Beta stand-by maintenance and the stable isotope separation program per month". This would indicate a reduction in personnel of 6,584, and in costs of just about \$2,500,000.

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d. Estimates of this kind are necessarily uncertain, and experience shows that actual savings from reductions of personnel are usually not so great as deductions from past statistics seem to indicate. It is believed, however, that something in excess of \$2,000,000 per month will certainly be saved.

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APPENDIX - REFERENCES

The pertinent documents upon which this Supplement to the Manhattan District History has been based, including all those to which reference has been made in the foregoing text, are listed below. They are all on file in the Manhattan District Files at Oak Ridge.

1. "Beck Report." "A Brief Description of Equipment and Procedures in the K-25 Plant Relevant to the Possibilities of Critical Accumulations," 15-25 August 1946; by Clifford Beck; with the assistance of: Bower, H. G.; Deming, J. G.; Elliot, J. E.; Hartman, W. C.; Largey, J. R.; Newlon, C. E.; Pasquier, L. P.; Preuss, H. M.
- 2., 3., 4. Letters (3, identical), Col. Nichols, 28 August 1946, to: Dr. N. H. Bradbury; Dr. G. T. Felbeck; Mr. P. G. Keith.
5. Letter, Dr. N. H. Bradbury, 17 September 1946, to Col. Nichols.
6. Memorandum, Dr. Edward Teller, 14 September 1946, to Dr. Bradbury.
7. Letter, Dr. G. T. Felbeck, 26 September 1946, to Col. Nichols.
8. Letter, Dr. Felbeck, 26 August 1946, to Mr. W. J. Williams.
9. Letter, Mr. P. G. Keith, 30 September 1946, to Col. Nichols.
10. Memorandum, Dr. Darol Froman, 3 October 1946, to Dr. Bradbury.
11. Letter, Dr. Felbeck, 7 October 1946, to Col. Nichols.
12. Letter, Dr. Bradbury, 10 October 1946, to Col. Nichols.
13. Letter, Col. E. E. Kirkpatrick, 11 October 1946, to the District Engineer. "Operation of K-25-27 at 95% Concentration."
14. Letter, Col. Nichols, 14 October 1946, to Mr. Clark Center; initialled by General L. R. Groves.

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15. Memorandum, Col. Nichols, 14 October 1946, to General Groves; indorsed O.K. by General Groves. "Operation of K-25 Plant at Concentrations up to 95%".

16. Memorandum, Col. Kirkpatrick, 23 October 1946, to the District Engineer. "K-25 Operations at Higher Purity."

17. Letter, Col. Kirkpatrick, 27 November 1946, to the District Engineer, "Operation of K-25-27 at 95% Concentration".

18. Letter, Mr. W. J. Williams, 6 December 1946, to the District Engineer, "W Concentration of Final Product".

19. Letter, Mr. W. J. Williams, 11 December 1946, to the District Engineer, "Concentration of Final Product".

20. Letter, Mr. Clark E. Center, 13 December 1946, to the District Engineer.

21. Letter, Col. Gerard J. Forney, 16 December 1946, to Col.

Kirkpatrick. "Estimated Personnel and Cost of Research and Development for Electromagnetic Isotope Separation"; with five organization charts attached.

22. Letter, Mr. Center, 18 December 1946, to the District Engineer.

23. Memorandum, Mr. Williams, 18 December 1946, to the District Engineer, "Resume of Information Pertaining to Plan to Produce High Purity Product K-25-27"; with seven charts attached.

24. Memorandum, Col. Nichols, 23 December 1946, to General Groves. "Recommended Plan of Operation for K-25-27 and Y-12"; with indorsement in ink by General Groves (see below) and several attachments which are

Included either above or below.

25. Chart, "Status of Test at K-25", showing daily "X Concentration," "W Concentration", and "Product X", from 3 November, carried forward, in pencil, to 22 December 1946. (Attached to item 24. above.)

26. "Draft of Release for Announcement of Reduction Force at CEW", undated.

27. Indorsement, General Groves, 23 December 1946, to Col. Nichols; on item 24. above.

28. Manhattan District History, Book I, General-Volume 5, Fiscal Procedures.

29. Manhattan District History, Book II, Gas Diffusion Project - Volume 5, Operations (Draft dated 18 January 1946.)

30. "Completion Report on the K-25 Gas Diffusion Plant (Contract No. W-7405-Eng-23) January 1, 1946" - The M.W. Kellogg Company, and the Kellogg Corporation - Volume II, Section III, K-25 Development, pp. 130-473.

31. "Completion Report on the K-27 Gas Diffusion Plant (Contract No. W-7405-Eng-23) January 1, 1946" - The M. W. Kellogg Company, and the Kellogg Corporation. "Compiled by: H. B. Levey, J. F. Hogerton"

32. Monthly Budget Statements, 31 May 1946 and 30 June 1946.