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MODIFICATION AND EXPANSION OF THE EMIS
ENRICHMENT MANAGEMENT INFORMATION SYSTEM
FINAL REPORT

OCTOBER 8, 1982

MASTER

U. S. DEPARTMENT OF ENERGY

OFFICE OF URANIUM ENRICHMENT & ASSESSMENT

CONTRACT No. DE-AC05-82NE50008

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UNITED STATES DEPARTMENT OF ENERGY
OFFICE OF URANIUM, ENRICHMENT AND ASSESSMENT
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October 8, 1982

FINAL REPORT

INTRODUCTION

In May, 1982, the Office of Uranium, Enrichment & Assessment (OUEA) of the U.S. Department of Energy authorized The S.M. Stoller Corporation (SMSC) to effect a number of modifications to the Enrichment Management Information System (EMIS) and to perform other tasks in connection with EMIS. The EMIS Program was initially developed for OUEA by SMSC under a previous contract with DOE.

The contract specified three tasks:

- Task 1 - Modifications to EMIS Algorithms
- Task 2 - Update of the Fuel Cycle and Availability Data
Contained in the EMIS Data Bases
- Task 3 - Training OUEA Personnel in the Use of EMIS

That work has now been completed, and the principal products of that effort are contained in a modified version of the EMIS Program contained on Disc File No. D6084.S006.LIB(P60849), and an updated Data Base contained on Disc File No. D6084.S007.DATA, both located at the DOE computer facility in Germantown, Maryland.

In the balance of this report, we will document the changes that have been made to the EMIS Program and its associated Data Bases. We have also included a discussion of the derivation of the plant availability statistics contained in the EMIS Program.

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TASK 1 - MODIFICATIONS TO EMIS ALGORITHMS

Item 1 - Modified Treatment of Non-Natural Uranium Feed

The logic of the EMIS Program has been modified to eliminate from the separative work withdrawals and Triplets as calculated and reported by EMIS, consideration of the uranium and separative work contained in feed materials other than natural uranium. This was the result of the conclusion by OUEA that it is preferable to treat the impact of such non-natural feed independent of EMIS.

To facilitate this objective, provisions has been made for information on non-natural feed returns to the enrichment cascade to be contained in the Data Base. If such data is entered by the user, it is now processed in EMIS to develop a summary edit of the SWU and Triplet content of such non-natural feed by ordering entity for each fiscal year of the study period. These data are also accumulated and reported as a total value for all ordering entities in an EMIS run.

However, it is important to keep in mind that the principal EMIS output now refers only to total withdrawals from the cascade. The sum of the SWU and Triplets contained in the non-natural feed must be deducted in order to determine the net demand on the cascade.

Item 2 - Review of the Feasibility of Using Contract Appendix Data Rather *than* Fuel Cycle Data to Compute Triplets in EMIS.

Following an investigation of this topic, it was concluded that, while it would be feasible to utilize contract appendix data - where it exists - rather than fuel cycle data to compute triplets in EMIS, it would not significantly improve the accuracy of the computation to do so. In studying the advisability of this change, a series of edits were developed and have been incorporated permanently into EMIS. These include:

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- A. AFC Contract Appendix SWU, Triplets, average U-235 enrichments and feed requirements for each of the first twelve years of a run. These data are provided separately for each Ordering Entity and are also accumulated to provide a total for all ordering entities included in a run.
- B. Average U-235 enrichment and feed requirements for withdrawals under AFC Contracts as computed by EMIS (averaged over all histories in a run) for the first twelve years of the run. These are also provided separately for each Ordering Entity and cumulatively for all Ordering Entities in the run.

A comparison of these edits - and particularly of the U-235 enrichments - permitted evaluation of the differences inherent in the two approaches to Triplet computation under consideration. These differences stem from two distinct sources.

First, are those which arise from differences between the quantities of uranium and enrichment assays specified in the contract appendices and those contained in the fuel cycle data. Second, are the differences introduced by the need to advance SWU deliveries from future years to the current year in order to fulfill reactor requirements on those occasions on which the quantity specified in the appendix turns out to be less than the need for the year in question.

The fact that the appendix data contained in the Data Base cover only a six year period for each reactor, leads to the need to use fuel cycle data for all subsequent years in the calculation of Triplets when a long study period is being considered. Thus, it was concluded that the rather substantial effort which would be required to modify EMIS so as to use appendix data to calculate Triplets over the period for which they were available, was not warranted at this time.

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Item 3 - Review and Adjust the Mechanisms for Incorporating AFC Contract Flexibility into the EMIS Program

A review of the program revealed some minor inconsistencies between the flexibility provisions of the AFC contract as interpreted by DOE and the equivalent portions of the EMIS Program. Appropriate modifications were made to EMIS to bring it into conformance with the AFC contract.

Item 4 - Make Allowances in Triplet Calculations for Natural Uranium Fuel Used in Boiling Water Reactors

As originally constituted, the natural uranium contained in BWR fuel assemblies was considered by EMIS in the computation of Triplets. This resulted in an overestimate of the natural uranium feed projected to be delivered to the enrichment complex, since that natural uranium is incorporated directly into the fuel assemblies rather than first being processed by the enrichment cascade.

EMIS was modified so that when the fuel cycle data for BWRs specifies natural uranium in the fuel, that quantity of natural uranium is not included in the computation of Triplets.

Item 5 - Provide a Mechanism to Expedite User Modification of Default Values For Withdrawal Lead Time (the period between withdrawal of enriched uranium and the start of the associated fuel cycle).

In the original version of EMIS default values for lead times (the period used in the calculation if specific lead times were not included in the data base) were fixed. The program has been modified to permit the user to specify as input, the lead times for initial cores and reload batches.

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Default lead times may now be entered by the user on the options card in the EMIS input. If no such entries are made by the user, default values of 36 months for initial cores and 12 months for reloads are stored in the program and will be used by EMIS in its analyses. As in the previous version of the program, lead times specified in the Data Base for a particular reactor will be used for that reactor in preference to the default values entered by the user for a particular run or stored in the program.

Additional Items - (Not included in contract work scope)

In the course of the work under this task, a number of other modifications were made to EMIS to make the program more useful and to assist the user in its operation. Although not included in the contract workscope, these modifications were performed at no increase in the contract price.

1. Prototypical fuel cycle data and the associated AFC appendix data were revised to conform to the new default lead time mechanisms incorporated into the modified version of EMIS (See Item 5, above).

2. The treatment of partial terminations of Requirements Contracts was modified so that EMIS now assumes that separative work deleted from a Requirements Contract through partial termination will be replaced with an equivalent quantity of separative work from an AFC Contract held by the same Ordering Entity. The SWU are transferred from the appropriate AFC Contract inventory to the designated Requirements Contract reactor in the year the termination is effective and either used in that reactor in that year or, if the reactor has no requirements that year, held in the reactor's inventory until the next need arises.

3. The editing of EMIS output has been modified in the following respects:

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- a. Additional headings and labels for the output tables for each Ordering Entity were incorporated into the program for ease in interpreting the output.
- b. The utility SWU inventory is now listed in categories, domestic and foreign, AFC and Requirements customers, as well as given in total for all Ordering Entities. Negative inventories in any year are also identified.
- c. Output for the debugging option (ITEST = 1) was modified substantially to permit a clearer understanding by the user.

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TASK 2 - UPDATE OF EMIS FUEL CYCLE AND REACTOR AVAILABILITY DATA

Item 1 - Update Fuel Cycle Data to Include the Latest Information on Domestic Reactors Available to SMSC Under DOE's Disfuel Program. Fuel Cycle Data for Foreign Reactors Will be Updated to Include the Startup Dates of the Current Operating Cycles.

Through its role as a contractor to DOE in connection with the assessment of the quantity of spent fuel to be discharged in the U.S. each year (Program), SMSC receives periodically from each U.S. utility, forecasts of reactor operations including fuel cycle data. Data from the most recent survey were used to update the fuel cycle data base and this information is now contained on Disc File No. U8914LP. FCPR0J. DATA at DOE's Germantown computer center. Before being entered, the fuel cycle data were examined for consistency and reasonableness and modified if necessary. In some instances, direct contact was made with a utility to insure the data were correct.

Verification that the data input to EMIS was correct was accomplished by using the modified information in a series of EMIS runs. All input errors discovered in these runs have been corrected.

Item 2 - Update PWR and BWR Availability Statistics Incorporated in EMIS to Include Data Now Available for 1980 and 1981 Operation

Data on the availability of domestic BWR's and PWR's collected by SMSC for the years 1980 and 1981 have been incorporated into the EMIS Program. The original version of the program included these statistics only through 1979.

The availability statistics were used to calculate new availability distributions for BWRs and PWRs and these are presented in Tables 1 and 2. A slightly different grouping of operating years has been used in these

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correlations than had been the case in the past. The new format includes separate correlations for each of the first three years of reactor operation, a combined correlation for the fourth and fifth operating years and another combined grouping for all years after the fifth year of operation. The logic of the EMIS Program has also been modified so as to conform to this arrangement.

The procedures used by SMSC to collect and process availability data are described in Appendix A to this report.

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TASK 3 - TRAINING IN THE USE OF EMIS

During the week of July 12, 1982, Roger Gagne and James Staggs of OUEA visited SMSC's offices for a period of training in the use of EMIS. A number of cases were run during this period and instruction was provided in input preparation, operation of the program and interpretation of output.

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TABLE 1

DISTRIBUTION OF ANNUAL THERMAL CAPACITY FACTORS BETWEEN REFUELINGS

Percent of Units with Capacity Factors Equal to or Less Than
Specified Values

PRESSURIZED WATER REACTORS

<u>Percentage of Units</u>	<u>Year of Operation</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4-5</u>	<u>6 +</u>
0	10.99	10.10	21.04	7.05	0
5	11.86	39.16	23.70	36.01	35.69
10	16.54	44.33	38.92	50.55	53.34
15	17.72	47.71	51.87	57.81	62.21
20	20.95	51.97	59.42	61.53	65.07
25	24.48	59.18	67.43	67.53	68.01
30	29.80	61.48	70.90	69.53	69.82
35	35.16	61.95	74.34	73.43	74.56
40	39.81	63.84	76.37	76.92	75.53
45	45.74	64.75	78.40	79.59	78.64
50	48.20	68.48	78.97	82.46	81.79
55	48.74	69.95	81.51	83.24	82.35
60	49.49	70.91	82.67	85.11	86.20
65	53.19	73.54	84.44	86.42	89.09
70	56.15	79.84	86.57	88.70	90.46
75	58.91	81.98	88.02	89.80	92.20
80	61.18	83.13	88.28	93.77	93.78
85	67.27	86.85	88.35	95.83	94.38
90	69.58	91.31	92.00	98.62	97.48
95	74.65	93.91	94.75	100.00	100.00
100	95.02	98.22	96.22	100.00	100.00

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TABLE 2

DISTRIBUTION OF ANNUAL THERMAL CAPACITY FACTORS BETWEEN REFUELINGS

Percent of Units with Capacity Factors Equal to or Less Than
Specified Values

BOILING WATER REACTORS

<u>Percentage of Units</u>	<u>Year of Operation</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4-5</u>	<u>6 +</u>
0	12.83	0	0	17.42	28.48
5	13.72	17.94	28.07	33.09	51.53
10	15.70	36.75	48.64	37.64	57.98
15	20.85	41.35	53.27	58.17	62.39
20	23.47	46.62	55.50	59.25	68.47
25	24.83	53.75	57.40	61.45	70.87
30	28.73	54.14	58.80	64.59	72.72
35	29.15	55.22	59.90	66.29	75.12
40	30.00	56.04	61.92	71.05	77.49
45	31.38	58.68	62.64	72.06	78.24
50	32.21	59.33	64.69	74.07	79.41
55	32.98	63.88	66.87	75.76	79.97
60	35.59	65.11	68.99	76.65	81.69
65	39.71	67.22	69.99	77.17	83.12
70	46.02	68.16	71.11	78.97	84.58
75	47.98	71.35	74.35	81.75	86.59
80	49.55	72.34	75.15	83.27	87.42
85	51.43	73.51	77.39	85.83	88.92
90	53.33	78.27	79.68	88.34	89.91
95	57.79	81.69	91.15	92.72	94.36
100	65.07	86.25	94.84	94.38	99.48

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APPENDIX A

DERIVATION OF AVAILABILITY DISTRIBUTIONS

The primary sources of the statistics used by SMSC to develop data on the availability of reactors in the U.S. are the Nuclear Regulatory Commission's reports designated NUREG 0020*. These documents report the thermal energy generated by each operating reactor in the U.S. for each month covered. The monthly generation for each unit is then divided by its licensed thermal power to determine a thermal capacity factor for the appropriate month.

If the monthly thermal capacity factor has been reduced by "non-plant factors" (e.g., the unit has operated at less than full capacity when on-line) the loss of capacity factor attributable to these factors is also tabulated. Note is also taken of any refuelings which have occurred.

For each operating unit, operating years are measured from the month in which the initial criticality occurred (as specified in the NUREG 0020 reports). Having thus established a twelve month period, the thermal capacity factor and the "non-plant factor" loss in thermal capacity factor are determined for the interval by summation of the data for the individual months.

If no refueling has taken place during the operating year of interest, an annual capacity factor and an annual non-plant factor loss are obtained by dividing the individual sums by twelve. The two quotients are then added together to obtain an overall unit capacity factor for the year. This presents the data as if all units were base loaded and operated at full power whenever available.

* NUREG 0020; Operating Units Status Reports - Licensed Operating Reactors; U.S. Nuclear Regulatory Commission

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If a refueling outage occurred during a specific operating year, it is assumed that the refueling outage extends for a period of two months. In these instances, the two sums of the monthly data are divided by ten before being added together to obtain the overall annual capacity factor.

This latter procedure occasionally leads to annual capacity factors in excess, of 100%. This would occur for units with very high capacity factors when operating and a refueling outage of less than the assumed two months. In such cases, the overall annual capacity factor is reduced to 100%.

It should be noted, that the annual capacity factors so derived are those which apply to the period between refuelings. An allowance for a refueling outage of two months duration is introduced by the EMIS Program during its generation of simulated reactor histories.

Mean values for capacity factors of all reactors for each of the operating years are calculated and operating year groupings are made. This consists of combining consecutive years for which the mean capacity factors are equal or approximately so. This process led to the current groupings of individual operating year data for each of the first three operating years, a combination of the fourth and fifth operating years and a combination of the sixth and all subsequent operating years.

Having established the operating year groupings, the individual reactor capacity factors for each operating year group are arrayed in order of increasing capacity factor. From this array the percentile data contained in Tables 1 and 2 in the body of the report can be developed. These tables indicate the percent of reactors with capacity factors equal to or less than a specified value for each operating year group. The specified capacity factors are presented in increments of 5% between 0 and 100%.

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These data are then input into EMIS and used to calculate the reactor operating histories. The details of these calculations are contained in the EMIS manual forwarded to OUEA in December 1981.

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