SYSTEM COSTING OF USED FUEL FACILITIES

(S.C.U.F.F.)

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ABSTRACT

This paper describes the operation and use of a computer code that can model the entire used fuel program of Ontario Hydro, including the storage, transportation, immobilization and disposal phases. The computer code called SCUFF (an acronym for System Costing of Used Fuel Facilities) can provide yearly schedules of equipment, used fuel inventories, detailed costing schedules and overall cost summaries. The code can also be used to optimize any of the variables in the overall used fuel management program and with suitable modification could model the USA program, or that of any individual utility.

BACKGROUND

Ontario Hydro is a publicly owned electrical utility currently operating twelve nuclear power reactors with a combined output of 7.6 GW. By 1992 a total of twenty reactors will be in operation producing over 14 GW which will result in the accumulation of 1,700,000 used fuel bundles by the year 2000.

Ontario Hydro has a commitment to supply electricity to the Province of Ontario at the lowest possible cost, therefore it must reduce where possible all electricity production costs, including those for the storage, transportation and disposal of its accumulated used fuel.

Many research and development work programs have been initiated to optimize individual components within each phase of the used fuel management program and to optimize each phase as a whole. However, relatively few work programs have studied the interactions between phases or the optimization of the complete used fuel management program. The cost of the entire used fuel program of on-site storage, off-site transportation, immobilization and final disposal has been calculated for a number of specific scenarios[1], but these calculations must be repeated in full if just a single variable or assumption is changed.

To measure the efficiency of any used fuel concept, it is necessary to predict its effects on the entire used fuel program and to this end, Ontario Hydro has developed a computer code capable of evaluating the costs and schedules of all the significant items within the overall used fuel program. This code makes it possible to measure the effects of changes to one item on any other item. For instance, by changing the final disposal date, it is possible to study the effects this produces on the used fuel storage requirements or the off-site transportation schedule. In addition, resulting savings made in one used fuel phase can be compared with any increased costs in any other phase, to achieve the most efficient overall scheme.

Requirements and Limitations

A computer code was required to meet the following needs:

1. To model the entire used fuel program from storage, through off-site transportation, to ultimate disposal;
2. To be modular in design to allow for the addition of alternative concepts at a later date;
3. To be flexible in operation, allowing the user to select the output information required and the detail it is needed in.

A computer code with very few limitations could be designed to meet these needs, but would be very large and unnecessarily complex. To reduce both the size and complexity of the code the following limitations were set:

1. A maximum nuclear generation growth rate of 5 percent per year would be considered;
2. No more than 20 stations each having 4 reactors would be simulated;
3. The maximum simulation period would span 400 years.

The SCUFF Code

The SCUFF computer code was developed from a used fuel logistics computer code[2] written in 1983 at Ontario Hydro. This code was incorporated in SCUFF to predict the used fuel arisings at each nuclear station and additional subroutines were added to calculate capital and operating costs and to extend the simulation to the transportation, immobilization and disposal phases of the used fuel program.

The major principles used in the design of SCUFF were flexibility of output, simplicity of operation and modularity of construction. These points are illustrated below:

Flexibility

To suit the needs of many different users and various used fuel scenarios the following features were designed into the SCUFF code:

(a) Variable Outputs - The code allows the user to select the specific outputs required and the detail they are presented in. Every SCUFF output is therefore individual and specific to eacn users needs.

(b) Variable Scenarios - The code will allow the selection of a variety of alternative scenarios to cover all likely used fuel programs. Storage can be either water pool, or dry cask, transportation can be via road, rail or water and disposal can be in a pluton or beneath sedimentary rock. Any combination of these alternatives is possible giving many possible variations.

Simplicity

Tne code was designed to be as simple to operate as possible and the following features were added for that purpose:

(a) Onboard Reference Data - The code contains all the data needed to model any used fuel program, freeing the user from having to provide large amounts of input data. As each variable is displayed at the terminal the user can either accept it, or input an alternative value if required. The only input data required is therefore that which differs from the onboard reference values.

(b) Input Default Values - The user is only prompted for confirmation of the variables that directly relate to the output requested, otherwise reference values will automatically be assigned.

(c) Single Key Selections - Major used fuel program options can be selected by the press of a single terminal key.

Modularity

Tne SCUFF code consists of many separate subroutines linked by a single executive program. This structure makes later additions, deletions or modifications relatively easy to accommodate as any changes will be confined to only a few subroutines.

Operation of SCUFF

The basic structure of the SCUFF code is shown in Fig. 1. Each of the individual blocks shown, represents a separate subroutine which can be called into operation by the executive program named SCUFF.EXEC.

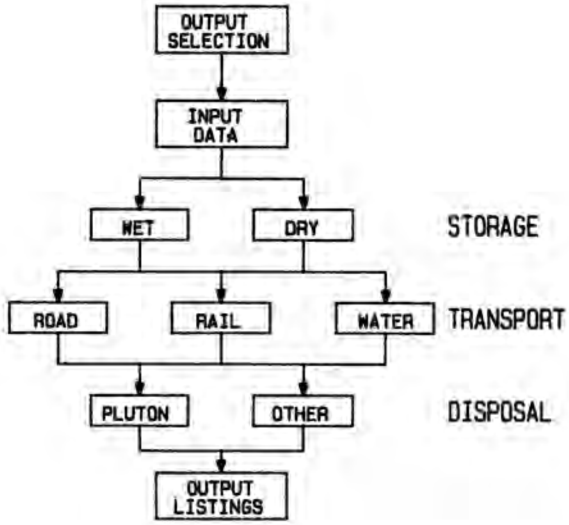

Fig. 1. Structure of Scuff.

The first subroutine called is the output selection subroutine which asks for, and records the output details requested by the user. These output details can be selected from the list shown in Fig. 2. From then on, the program works sequentially through the storage, transportation and disposal sections of the program presenting the user with a number of options in each particular phase.

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SCUFF CAN PRODUCE THE FOLLOWING OUTPUTS :

(1) STATION FUEL STORAGE INVENTORIES (TOTAL BUNDLES)

(2) STATION FUEL STORAGE INVENTORIES (AGED BUNDLES)

(3) TOTAL FUEL YEARLY PRODUCTION, RUNNING TOTAL AND AVERAGE AGE

(4) STORAGE COSTS

(5) TRANSPORTATION INVENTORIES (FUEL/CASKS/VEHICLES)

(6) TRANSPORTATION COSTS

(7) IMMOBILIZATION/DISPOSAL COSTS AND QUANTITIES

(8) SUMMARY OF OVERALL COSTS

COSTS CAN BE IN CONSTANT DOLLARS OR PRESENT WORTHED DOLLARS

Fig. 2. Output Selections.

If storage related outputs have been requested, SCUFF provides a choice between water pool and dry canister storage. Once selected, the appropriate storage subroutine is then used to model the storage phase of the used fuel program. If no storage output is required SCUFF uses water pool storage as its default mode for this phase.

If transport related outputs have been requested, the code offers choices between road, rail and water transportation. The appropriate transport subroutine is then used to model the transportation phase of the used fuel program. If no transportation output is required SCUFF uses road transportation as its default mode.

The disposal phase is dealt with in a similar manner, offering disposal in a pluton, or beneath a sedimentary sequence of rock as alternatives and using disposal in a pluton as its default option.

As it begins to model any one phase, SCUFF offers a number of additional choices relating to the variables used in that option. For example, having selected road transportation the choice is given to accept the onboard reference values for quantities such as site disposal distance, cask size, cask costs, loading time etc., or to provide any other specified values. Confirmation of variables is requested if a related output has been asked for, otherwise, default values will automatically be assigned. This operating principle requires the user to consider only those variables that could have an effect upon the output requested. For example, if no storage related outputs are requested, then no storage variables will be asked for and the onboard default values will be used during storage phase.

After completing the disposal phase subroutine, SCUFF prints all the assumptions used and the values assigned to all of the variables needed to produce the required output. Finally SCUFF prints all of the output tables that were requested for that run.

Typical Uses for SCUFF

Recently the SCUFF code was used to assess the sensitivity of a variety of significant factors on the overall cost of the entire used fuel management program of Ontario Hydro.

The maximum variations to these factors were modelled with SCUFF and those properties having the major impact on cost were identified.

The results of this analysis are shown in Fig. 3 which indicates the major factors that can reduced overall used fuel management costs as being:

(a) Discount rate;
(b) Disposal date;
(c) Size of the Nuclear Program.

Although discount rate is a major factor affecting costs, it is a property that we cannot directly control. However, changes in the disposal date have a major effect on total costs as do variations in the size of the nuclear program, and both of these variables are within our control.

		COST VARIATIONS
DISPOSAL COMMENCEMENT DATE	2010 TO 2150	-60 %
DISCOUNT RATE	2% TO 5%	-50 %
NUMBER OF REACTORS	20 TO 60	-57 %
TRANSPORTATION DISTANCE (KM)	250 TO 2000	+2 %

Fig. 3. Cost Variations.

SCUFF was used to identify how the cost components changed due to variations in the disposal commencement date. Figure 4 shows that delaying disposal reduces both the transportation and disposal cost. The on-site storage costs rise, but this is to be expected as additional storage capacity must be provided until the disposal commencement date is reached. The net effect of these changes is a significant reduction in total costs.

Further breakdowns of cost components can be made to identify each individual capital and operating cost on a yearly basis.

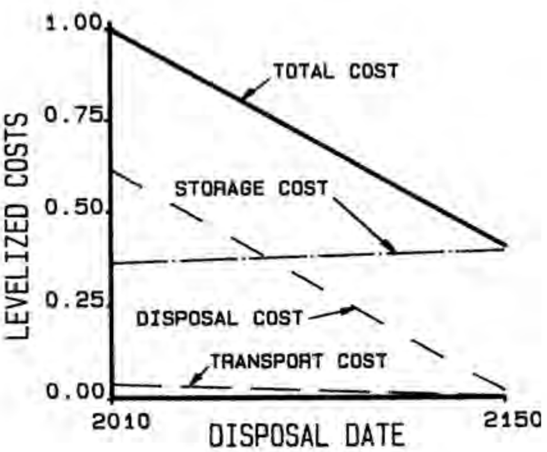

Fig. 4. Cost Component Variations.

Ontario Hydro has planned to use SCUFF in the following programs:

1. Integrated Container Optimization - A program to develop a single used fuel container which can be used throughout the storage, transportation and disposal phases is already underway at Ontario Hydro. The SCUFF code will be used to evaluate various alternative designs in order to optimize the entire system from storage to disposal;

2. Spent Fuel Cost Evaluations - Surcharges for future used fuel management costs will be verified using SCUFF;

3. Additional On-Site Storage - The SCUFF code will be used to identify both the timing and the costs associated with the introduction of additional storage facilities at Ontario Hydro's existing and planned nuclear stations;

4. Transportation Logistics - SCUFF will provide the transportation schedules for used fuel movements from each station to the final disposal site. This information will form the basis of a full environmental assessment of the disposal phase of the used fuel management program.

Future Developments

Currently the SCUFF code is operated using a mainframe UNIVAC 1182 computer, but the significant growth in the use of personal computers has prompted the down loading of the code for use on an IBM-PC computer. This work is still underway but should be completed by the summer of 1985.

At present Ontario Hydro's reference scenario of water pool storage, road transportation and disposal in a pluton can be successfully modelled with the SCUFF code. The other planned options have dummy subroutines included in the code at present, but these will be made fully operational by the end of 1985.

An additional feature presently being developed will enable the automatic optimization of any selected variable. This feature will be added during 1985 allowing any selected variable to be optimized in order to minimize any other specified cost or quantity. For instance, transportation cask size could be optimized to minimize either the total transportation cost or the entire used fuel program cost. This feature will be is operated by successively looping through the SCUFF code and modifying the variable to be optimized after each loop. When both increases and decreases to the variable result in an increased value the process will be terminated and the final optimized values and output printed.

Conclusion

The SCUFF code has enabled the entire used fuel program of Ontario Hydro to be simulated, allowing the effects of each individual component of the program to be studied.

Some additional capabilities will be added to SCUFF during 1985 and future work will focus on the application of the code to optimize Ontario Hydro's used fuel management program. This work will result in the identification of those components that form the most cost effective yet flexible used fuel management program for Ontario Hydro.

References

1. P. Pearson. "Preliminary Cost Estimates for Storage, Transportation and Disposal of Irradiated Fuel". Report Number 82485, Ontario Hydro (1982).

2. J.M. Cipolla. "MATFLOW: A Computer Code for Simulating Irradiated Fuel Inventories and Flows". Report Number 82355, Ontario Hydro (1983).