The Application of Automated Fuel Rod Consolidation To Improve Storage and Transport Packaging Economics

G.T. Tjersland, G.C. Carver
NAC International, Inc.

J. McDaniels
Nu-Tec

INTRODUCTION

NAC International Inc. (NAC) has worked for over 15 years on the development of cost-effective and practical fuel consolidation systems for the disassembly and compaction of both PWR and BWR fuel assemblies. The fuel rod consolidation equipment design objective is to disassemble the non-fuel bearing components (NFBC) of the fuel assemblies; extract the individual fuel rods; place the fuel rods in a canister with a resulting compaction ratio of 2 to 1; and compact and store, or dispose of, the NFBC.

A number of cold (nonirradiated) and hot fuel consolidation demonstration programs have been performed over the last decade by a number of companies including NAC, Westinghouse, ABB/CE, and U.S. Tool & Die, Inc. The hot demonstrations were performed at both reactor facilities (Oconee, Maine Yankee, Milstone-2, and Prairie Island, fuel storage facilities (West Valley Demonstration Project), and at U.S. Department of Energy facilities (TAN Facilities at Idaho National Engineering Laboratory). (Bailey 1989; Fuierer 1989; Mascadini 1988; and NAC 1988.) These demonstrations have not always been fully successful and have had mixed results regarding equipment operability, compaction ratio achieved, radiation exposures to operating personnel, and fuel consolidation throughput.

Recent developments by NAC in a joint development program with the Empire State Electric Energy Research Corporation (ESEERCO) and Electric Power Research Institute (EPRI) have led to the design and component testing of a computer-controlled robotic system called the FUEL-PAC to cost effectively consolidate spent BWR fuel assemblies (NAC 1993).

Independently, NAC has also developed a FUEL-PAC system for PWR fuel assemblies.

As the need for additional at-reactor spent-fuel storage requirements grow, the potential economic benefits of consolidating spent fuel prior to placement into dry storage and/or off-site transport need to be reconsidered.

DEVELOPMENT OF THE FUEL-PAC FUEL CONSOLIDATION SYSTEMS

Prior to developing the FUEL-PAC Consolidation Systems, NAC evaluated the previous experiences reported on the cold and hot demonstrations. Although problems were reported for all at-reactor demonstration programs, the demonstrations did establish that fuel consolidation was technically feasible and that consolidation ratios of 2:1 can be achieved. One common problem identified by the programs was the difficulty in achieving acceptable compaction ratios for NFBC. (Note: A design target of 10:1 is normally established, which results in a net compaction ratio of 1.67:1 based on the consolidation of 10 assemblies into five storage locations with one additional storage location taken by the canistered NFBC).

To overcome the operational problems experienced with earlier fuel consolidation systems, the following features were identified for a successful fuel consolidation system (Lindquist, 1990):

- Fully automated
- Compact and manageable plug-in modules for ease of installation and maintenance
- High reliability
- Inherently safe with low personnel exposure rate
- Quick recovery from fault conditions
- Pool cleanliness
- Flexibility in storage of NFBC
- Minimal support of fuel handling bridge and operations personnel
- High production rate (eight BWR assemblies or four PWR assemblies per 10-hour shift)
- Consolidated fuel stored in sealed canisters with mesh screen openings

The BWR FUEL-PAC System meets these design requirements. The system is shown in Figure 1 and consists of four primary elements: the work table and its support structure, the tool support rack, the robot and the operator's control station.

The new component added to the fuel consolidation processes previously designed is the ABB Robotics Inc. IRB-6000 robot. The robot, which remains dry and free of contamination, is constructed of modules that are readily replaced. The robot is programmed to grasp the reach (operating) tools through the use of quick-change couplings that assure proper and rapid connection of the hydraulic and electrical circuits. A safety clutch is incorporated between the robot and the reach tool which trips the system in the event of any unplanned occurrence.

By replacing previously manual fuel disassembly and rod-pulling operations, the FUEL-PAC system eliminates manmade mistakes associated with repetitive processes and reduces the radiation doses experienced by the systems' operators.

The layout of the work table, which is shown in Figure 2, permits placement of four BWR assemblies in the work stations, which minimizes the need for plant operations staff involvement in moving fuel assemblies. Fuel and canister movements are only required twice per shift.

NAC also developed a mini-canister that can store the NFBC from two BWR assemblies in a canister that can be positioned directly on top of in-pool storage racks. The mini-canister is shown in Figure 3. The use of mini-canisters precludes the need from storing NFBC canisters in fuel storage locations in the rack, and therefore, the system can achieve a true 2:1 consolidation ratio.

ECONOMIC IMPACT OF STORING AND TRANSPORTING CONSOLIDATED SPENT FUEL

During early development of fuel consolidation equipment, it was believed that the cost of at reactor fuel consolidation would be in the range of $8 to $10 per kgU. Based on the difficulties experienced during the demonstration programs, these cost estimates have been revised upward. As reported by NAC as part of the ESEERCO and EPRI-funded FUEL-PAC development, the estimated costs of consolidating BWR fuel assemblies are in the range of $6,000 to $8,000 per space created. The cost-estimating method was changed to allow comparison to other types of spent-fuel storage additions such as reracking, concrete dry storage and metal cask dry storage. This cost estimate is comparable to the cost of reracking existing reactor spent fuel storage pools, which is currently around $10,000 per storage position added. However, reracking is a mature technology while robotic fuel consolidation lacks proven commercial experience. Therefore, to date, reracking has been the first choice by a majority of utilities needing to add additional on-site storage.

In the United States as delays to the Federal Waste Management System (FWMS) continue, the number of reactors requiring additional storage capacity and which can no longer rerack their existing spent fuel pools continues to increase. In most cases, concrete, storage-only systems are being procured at a cost of approximately $20,000 per space. Again, although this storage method is more expensive than fuel consolidation, it is perceived as an easier storage method to pursue. The continuing selection by utilities of storage technologies other than fuel consolidation has resulted in the effective termination of consolidation system development due to lack of both Federal and utility funding.

NAC is of the opinion that now, with additional delays in the FWMS ensured due to recent cuts imposed on the program by Congress, and with private industry now expected to take the lead in designing and implementing economical storage and transport systems, fuel consolidation should be reconsidered.

In an evaluation of the cost impact on the FWMS of accepting canisters of consolidated fuel (Johnson 1990), it was determined that savings to the program of up to $31.7 per kgU could be achieved depending on the age of the fuel, consolidation ratio, and whether intact or consolidated fuel was the preferred disposal form. The largest savings were expected for the consolidation of spent fuel cooled between 10 and 20 years, and if intact spent fuel was disposed. Therefore, from a total system approach (e.g., storage, transport, and disposal), fuel consolidation has measurable cost benefits. However, utilities, with the off-site transport and disposal elements removed from their economic evaluations, have not implemented a technology where they would not receive the economic benefit, only increased risks. From their standpoint, that is the intelligent decision.

As was shown by the E.R. Johnson study, savings, resulting from fuel consolidation occur during the storage, handling, transport, and disposal phases of FWMS. It should be noted that this study assumed that standard DOE-designed casks would be used to transport the consolidated spent fuel, therefore, the study did not review the actual cost savings of transporting consolidated fuel in a cask specially designed or modified for such a purpose.

There are no new technological developments required to design storage, transport, or dual-purpose systems specifically for canisters of consolidated spent fuel. NAC has licensed such a dry storage cask, the NAC-C28S/T. It was issued U.S. Nuclear Regulatory Commission (NRC) Storage Certificate of Compliance No. 1003 in August 1990. This cask is approved for the storage of the consolidated fuel pins of 56 PWR fuel assemblies. Similar designs can be developed for both vertical and horizontal concrete storage systems. The main design concern requiring resolution is the issue of rejection of the decay heat of the fuel. By designing casks based on the consolidation of the large inventory of 10- to 20-year-old spent fuel currently existing at reactors, this design consideration can be resolved. In addition, due to the effect of improved self-shielding and increased cooling times, capacities could effectively be doubled for both storage and dual-purpose systems.

NAC has recently obtained storage and transport approval from the NRC for the NAC-STC dual-purpose cask. The conservative structural design of the cask's body and basket would accommodate up to 26 canisters of consolidated PWR fuel. Although, the NAC-STC was not specifically designed for consolidated fuel, it could be relicensed for such service if there was an identified need for this capability.

CONCLUSION

Fuel consolidation technology has been developed to the point of commercial application. Significant waste management system savings could be realized for storage, transport and disposal of spent fuel as fewer storage units, transport casks, and shipments would be required.

Storage and transport cask design companies have the capability to design the required equipment to handle consolidated fuel.

It is perhaps time for the utility industry to reconsider fuel consolidation as part of the solution.

REFERENCES

Bailey, W.J., *Status of Rod Consolidation-1988, Pacific Northwest Laboratories, PNL-6603* (1989).

Fuierer, A.A., *Spent Nuclear Fuel consolidation and Characterization, Final Report ESEERCO Project EP85-4* (1989).

E.R. Johnson Associates, Inc., *Acceptance of Canisters of Consolidated Spent Nuclear Fuel by the Federal Waste Management System, ORNL/Sub/86-SA094/7 (JAI-322)* (1990).

Lindquist, K.O and Haley, T.C., *Considerations for the Consolidation of BWR Fuel, EPRI-6783* (1990).

Mascadini, R.L., *Fuel Consolidation Demonstration Program: Methods Development, Testing and Design Analysis, EPRI NP-5945* (1988).

Nuclear Assurance Corporation, *BWR Fuel Consolidation: A System Design, EPRI TR-101985* (1993).

Nuclear Assurance Corporation, *Spent Nuclear Fuel Consolidation and Characterization at West Valley, New York, ESEERCO Project EP85-4* (1988).

Figure 1
BWR FUEL-PAC System

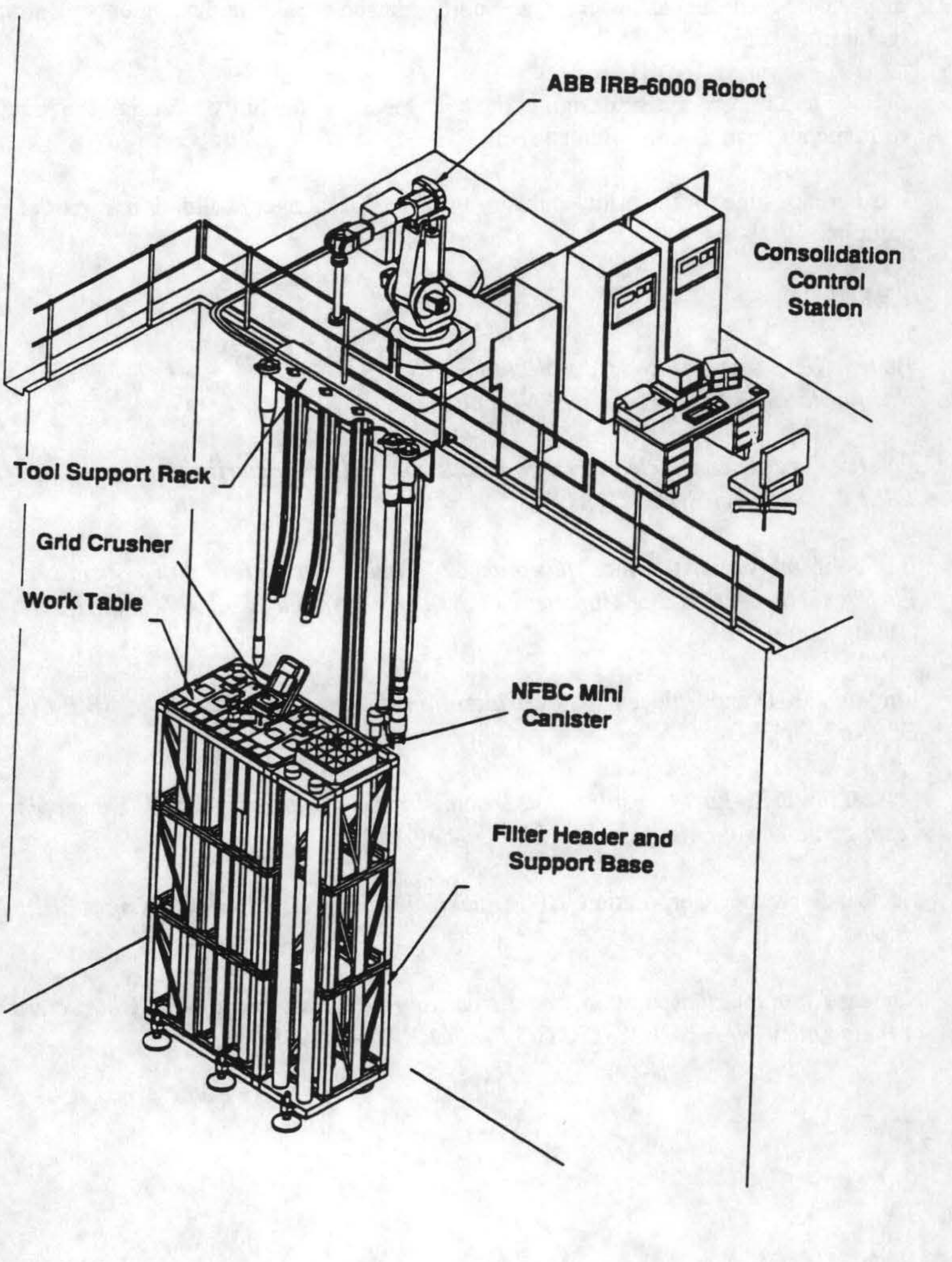

Figure 2
FUEL-PAC Work Table
for BWR Fuel Assemblies

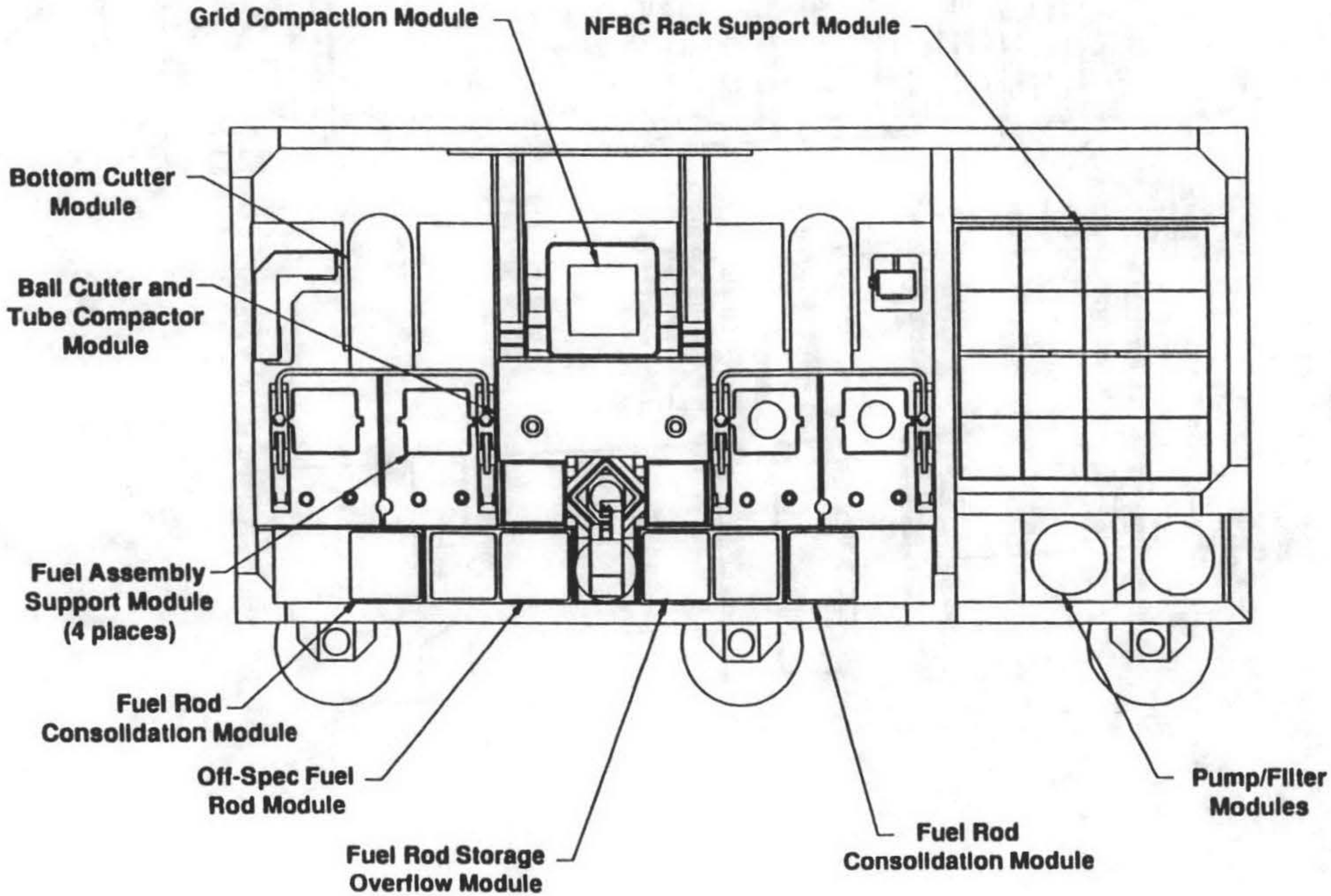

Figure 3
BWR Mini-Canister