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# IMPACT ANALYSIS OF SPENT FUEL JACKET ASSEMBLIES[1]

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## ABSTRACT

As part of the analyses performed in support of the reracking of the High Flux Isotope Reactor pool, it became necessary to prove the structural integrity of the spent fuel jacket assemblies subjected to gravity drop that result from postulated accidents associated with the handling of these assemblies while submerged in the pool. The spent fuel jacket assemblies are an integral part of the reracking project, and serve to house fuel assemblies.

The structural integrity of the jacket assemblies from loads that result from impact from a height of 10 feet onto specified targets has been performed analytically using the computer program LS-DYNA3D (ref. 1). Nine attitudes of the assembly at the time of impact have been considered. Results of the analyses show that there is no failure of the assemblies as a result of the impact scenarios considered.

## INTRODUCTION

The objective of the analyses presented herein is the determination of the response of the jacket assemblies as they experience an impact from a height of 10 feet onto postulated targets located at the bottom of the pool. These postulated accidents result from failure of the lifting interfaces of the jacket assemblies. The drop height is limited to 10 ft. since this is the maximum available clearance from the assemblies to the bottom of the pool when repositioning of these components is always performed under a submerged condition.

The components of the jacket assembly are two concentric tubes welded at the base onto a grating structure and supported at the top to an assembly that serves as interface with the lifting tool. The grating at the base and the design of the lifting assembly interface assures that there is free flow within the assembly. The lifting tool is a detachable component that is used to handle the assembly, and is removed after the assembly is positioned at the desired station. The assembly houses a spent reactor fuel element. The assembly is housed inside a silo that is a component of the pool reracking.

A solution based on an analytical approach was chosen to assess the integrity of the assemblies as result of the impact from a height of 10 ft. Two impact scenarios were considered, in the first it is assumed that the assembly impacts a flat unyielding target caused by failure at the interface between the lifting tool and the lifting device. The second scenario considers the impact between the assembly and a elastic obstacle at the base of the pool. This scenario is associated with the failure at the interface between the lifting tool and the assembly.

## CALCULATION AND ANALYSIS

The numerical analysis of the impact problem has been performed using the explicit finite element computer program LS_DYNA3D version 926. The computer program LS-INGRID (ref. 2) version 3.3 was used in the generation of the

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mathematical model, and the program LS-TAURUS (ref. 3) version 920.2 was used for post-processing of the results of the analysis.

The mathematical model of the jacket assembly was developed by taking advantage of a plane of symmetry that exists in the assembly. A typical model that represents one half of the symmetrical assembly has 5113 nodes, 1650 8-node bricks, 56 beams, 1348 4-node shells, 24 sliding surfaces that allow sliding and void formation, 2 shell edge to surface interfaces also with sliding and void generation capability, and one stone-wall (unyielding surface). The model has been discretized onto 23 distinct material components for ease in the postprocessing phase. Figure 1 shows the cross section of the jacket assembly used in the analysis.

## Analysis Assumptions

The following assumptions were made in the analysis:

- 1—The velocity at the time of impact that results from the accidental release of the assembly while fully submerged in the pool from a height of 10 ft. is assumed to be 22 fps. This velocity neglects the effects of friction between the body and the fluid and disregards the attitude of the body while moving within the fluid. This velocity is very conservative considering that the velocity in air from a height of 10 ft is 25.4 fps and that the velocity of a blunt free body falling in a pool of water from a height of 10 ft is 14.7 fps.

- 2—The initial acceleration in the assembly is assumed to be equal to the acceleration of a body outside the pool. The effects of buoyancy are not considered.

- 3—The material properties used in the analysis follow an elastic bi-linear plastic stress-strain relationship with isotropic hardening.

- 4—The mathematical model assumes materials that are homogeneous and isotropic for all the assembly components.

- 5—The analysis assumes an isothermal environment with a nominal temperature of 75°F.

- 6—The weight of the assembly used in the analysis is 10% more than the nominal design value.

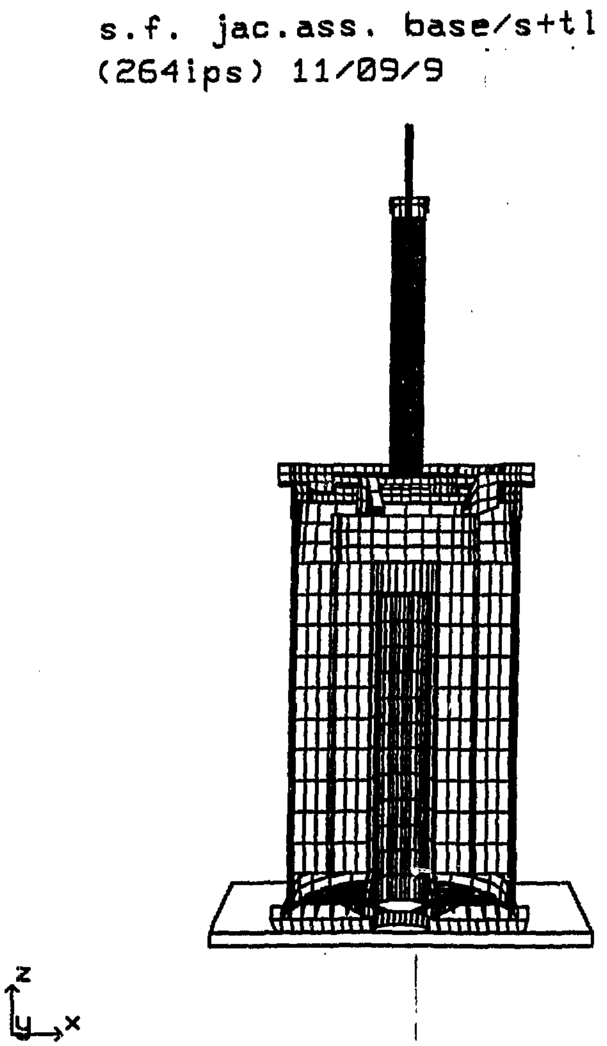


Fig. 1. Mathematical model.

## Material Properties

There are two materials in the fuel jacket assembly. The upper structure and some of the components of the lifting assembly and the fuel elements are made of 6061-T6 aluminum. All the remaining components have properties that correspond to 304L stainless steel. The input parameters for these material obtained from the Lawrence Livermore Laboratory program STRAIN (ref.4) are listed as follows:

| | |
|---|---|
| Stainless Steel: | |
| -Modulus of elasticity | $28 \times 10^6$ psi |
| -Poissons ratio | 0.29 |
| -Yield Stress | 34,000 psi |
| -Strain at failure | 0.31 in/in |
| -Ultimate Stress | 90,000 psi |
| 6061-T6 Aluminum: | |
| -Modulus of elasticity | $10 \times 10^6$ psi |
| -Poissons ratio | 0.33 |
| -Yield stress | 42,000 psi |
| -Strain at failure | 0.05 in/in |
| -Ultimate Stress | 45,000 psi |

The densities of the components have been adjusted to obtain the desired assembly weight used in the analysis.

The shell components of the assembly have been modeled using a failure model that allows for the representation of structural failure when the maximum strain in components made with this material is reached. Three integration points through the thickness are used in these shell elements.

### Analysis Procedures

Two sets of analyses have been performed. The first analysis considers the cases when the jacket assembly impacts a rigid unyielding surface at the bottom of the pool. The second analysis considers the cases when the assembly impacts an elastic structure (a rail or the rim of the storage silo). Depending on the attitude at the time of impact, the lifting assembly may or may not have been included in the analysis. When the lifting assembly is included, the accident scenario is associated with failure at the interface of the lifting assembly and the exterior lifting media. When the lifting assembly is not included, it is assumed that failure at the interface between the lifting tool and the upper assembly lifting structure has occurred.

Nine cases have been considered to determine the impact response of the jacket assembly, these cases are:

- 1—Impact of the assembly, including lifting tool, in a vertical attitude, base first, onto an unyielding surface,
- 2—Impact of the assembly, including lifting tool, in a horizontal attitude onto an unyielding surface,
- 3—Impact of the assembly, including lifting tool, in an oblique attitude with assembly base striking an unyielding surface,
- 4—Impact of the assembly, excluding lifting tool, in an oblique attitude with the assembly top striking an unyielding surface,
- 5—Impact of the assembly, excluding lifting tool, in a vertical attitude, top first, onto an unyielding surface,
- 6—Impact of the assembly, excluding lifting tool, in a horizontal attitude onto the top edge of an elastic silo,
- 7—Impact of the assembly, excluding lifting tool, in a vertical attitude such that the base of the assembly impacts the top edge rim of a silo,
- 8—Impact of the assembly, excluding lifting tool, in a horizontal attitude onto the top of a 10 in. wide elastic rail,
- 9—Impact of the assembly, excluding lifting tool, in a vertical attitude, base first, onto the top of an elastic 10 in. elastic rail.

## SUMMARY OF RESULTS AND CONCLUSIONS

The analyses were performed to assess the structural integrity of the jacket fuel assemblies subjected to impact loads. An unacceptable response is one in which the fuel elements are dispersed within the pool as a result of one of the following scenarios: failure of the enclosing shell structure, failure of the weld between the shell structure and lower jacket structure, failure of the interface between the shell structure and the assembly upper assembly. For structural failure, the effective strain was used as the parameter of merit to judge the structural integrity. Exceedance of the effective strain beyond the strain at failure is consider as failure at the location were the exceedence occurs.

Results of the analyses indicate that, in all the cases considered, there is no failure of the fuel jacket assembly. There are two cases which result in significant loads and local failure without resulting in a condition where the fuel element integrity is breached. These cases are: the fuel jacket assembly in an oblique base corner attitude impacting a rigid unyielding target so that the base assembly cross members make initial contact with the target (case 3 in section 2.3), and the case when the fuel jacket assembly impacts the rim of a storage silo when the base assembly cross members make the initial contact with the silo rim (case 7 in section 2.3).

Figure 2 shows the configuration of the jacket assembly at the end of the simulation (40 msec after impact) for case 3 (base corner impacting rigid surface). The analysis shows local failure of the shell structure at the interface with the lower assembly that results from large deformation of the shell due to the impact loads. As result of this large deformation the shell structure undergoes a mode of deformation similar to buckling of a shell. There is no formation of a free path from the exterior of the assembly to the fuel element.

Figure 3 shows the final configuration of the jacket assembly at the end of the simulation (40 msec after impact) for case 7 (base corner impact onto the rim of the storage silo). This case shows significant deformation of the lower cross member assembly and grating structure. The analysis shows that the stresses in the welds at the interface between the low assembly and the shell undergo local failure. There is no loss of confinement of the fuel element that results from the failure of these welds.

In conclusion, the analyses shows that the integrity of the fuel jacket assemblies is maintained when this structure is subjected to the 10 foot impact.


## ACKNOWLEDGEMENT

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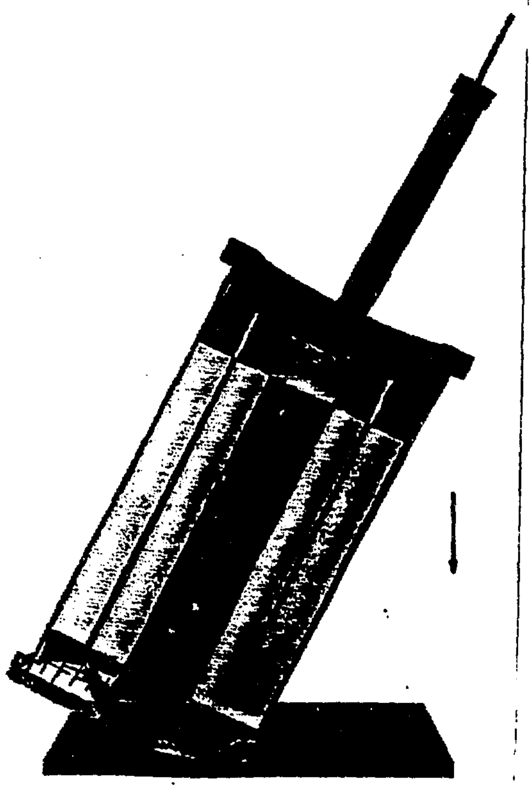

Fig. 2. Impact on base corner, final configuration.

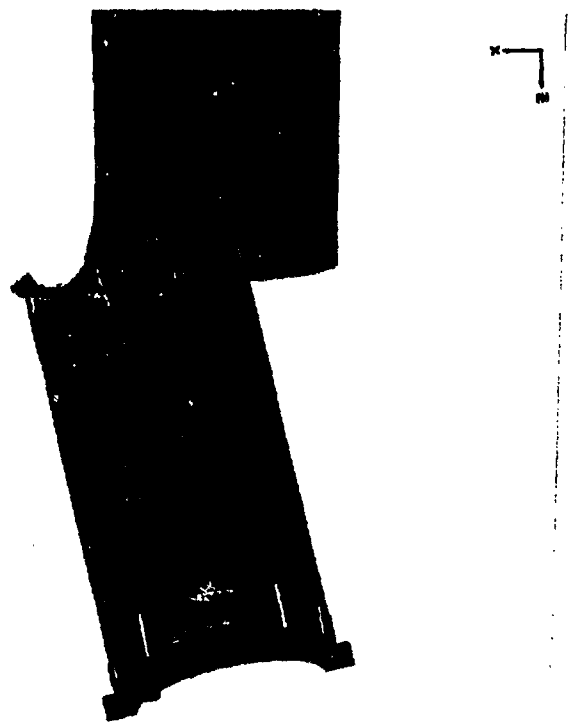

Fig. 3. Base impact on silo, final configuration.