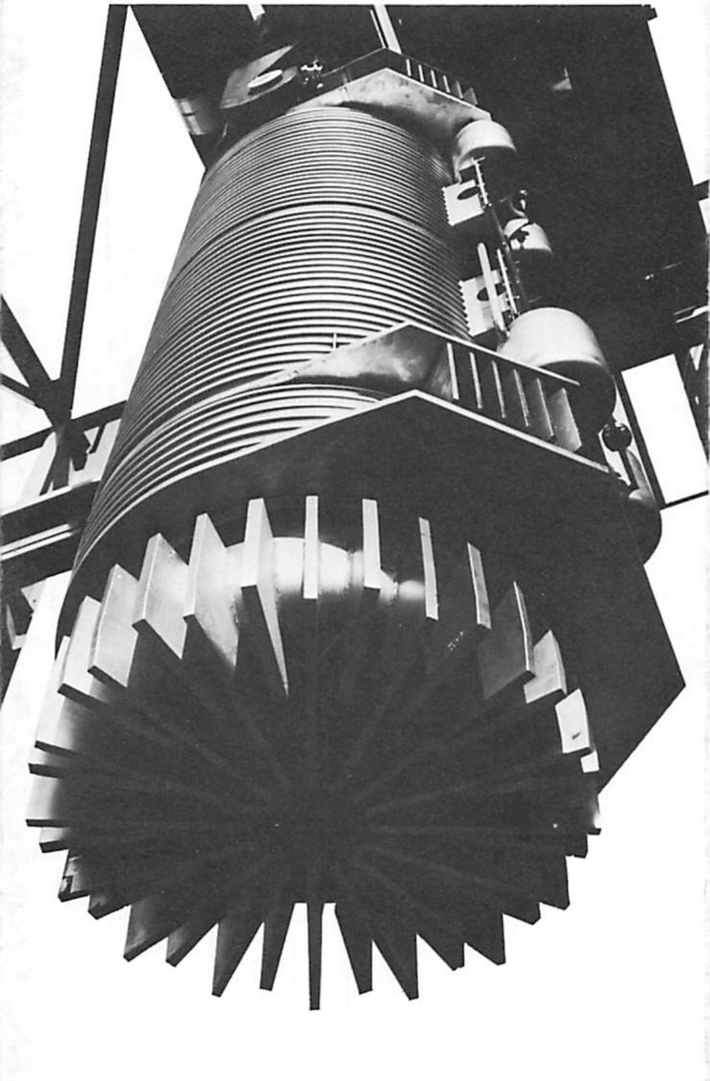
Shipping Nuclear Fuel



Safety in motion

No nuclear power plant is an island.

As with electric generating stations burning coal, oil or gas, its fuel must be brought in and its waste taken away.

And once removed from the multiple safeguards of a reactor for shipment over rail or highway, this nuclear material is subject to the same transportation hazards as any other freight or cargo.

Conditions of this environment cannot be *controlled.*

But they can be *predicted.*

Accordingly, multiple layers of protection surround the fuel to make certain that significant amounts of radioactivity will not be released, even during the most severe accident.

The same principle of defense-in-depth applied to every power reactor ensures also the safety of the public while nuclear fuel is in transit.

Need for transportation

In today's commercial reactor, the fuel consists of uranium dioxide pellets stacked into 14-foot long metal tubes.

A square array of these sealed rods makes up an assembly, from five to eight inches on a side, weighing from one-quarter to three-quarters of a ton. Several hundred assemblies in turn form the fuel core.

During reactor operation, Uranium-235 fissions to produce heat for the steam generation of electricity.

And the fragments of fission accumulating within the pellets and their cladding gradually reduce the efficiency of the chain reaction.

After approximately three years of producing power, therefore, the assemblies are replaced with fresh fuel. From one-fourth to one-third of the core — several dozen assemblies — is discharged each year.

This spent fuel, however, contains also substantial quantities of unfissioned U-235 and of newly formed plutonium. Both can be recovered and eventually returned to the reactor.

Delivering fresh fuel to the generating station, carrying spent fuel away for reprocessing, create the primary transportation link in the nuclear fuel cycle.

Packaging reduces risk

The other half lies in the principle of defense-in-depth.

Although every precaution is taken to avoid an accident, the primary safety factor in nuclear fuel transportation is the shipping container itself: even under severe stress it must ensure there will be no loss of radioactive contents, no significant increase in external radiation.

This protection minimizes the *consequences* of potential accidents.

Cold or unirradiated fuel on its way to a plant poses little radiological hazard: uranium dioxide fuel pellets may be held safely in the hand. Clamped and cushioned inside steel boxes or cylinders, its packaging is intended primarily to secure the assemblies from external damage.

On the other hand, the full spectrum of defense-in-depth — successive layers of protection — is provided for containment and shielding of the irradiated assemblies discharged from a reactor.

First of all, the fuel pellets within their metal rods are designed to retain more than 99.99 per cent of the radioactive fission products during high-temperature, high-pressure reactor operation. Similar driving forces would not be found in a transportation environment.

Then the assemblies are stored on-site in water-filled concrete pools for several months. When ready for shipment, about 95 per cent of their radioactivity at the time of power generation has dissipated.

Nevertheless, spent fuel is transported in the most carefully designed, fabricated and tested shipping containers used by man.

In one cask design, the assemblies are sealed into a water-filled stainless steel cylinder with walls one-half inch thick, clad with four inches of heavy metal shielding, enclosed by a shell of one and one-half inch thick steel plate, surrounded by five inches of water, encircled by a corrugated stainless steel outer jacket. The overall package measures 5 by 17 feet and weighs 70 tons.

This multiple barrier containment ensures that the public is fully protected from radiation during routine transport of spent fuel.

And to make certain that the cask preserves this integrity even during abnormal circumstances, its design must withstand a series of "torture tests:"

- a 30-foot fall onto a flat, unyielding surface,

followed by

- a 40-inch drop onto a vertical steel rod,

followed by

- exposure to a 1475°F fire for 30 minutes,

followed by

- submersion under 3 feet of water for 8 hours.

The container must undergo these destructive forces, *in sequence,* with no breach of containment, with no significant reduction in shielding.

Perfect record of safety

During more than 30 years of transporting nuclear material of all kinds, no one has ever been injured by the radioactive nature of the cargo.

Inevitably, accidents have occurred. Most have been minor, with only minimal damage to the vehicle. In one incident, however, a truck carrying spent fuel overturned, killing the driver. The cask remained intact.

Although every effort is taken to *prevent* such mishaps involving a shipment of nuclear fuel,

- Some 115 transportation incidents are nevertheless expected to take place over the operating lifetime of 100 reactors.

But defense-in-depth makes certain that the packages will *survive* the most severe abuse foreseen in such situations:

- In none of these forecast events is significant radiation damage to the environment or exposure of the public expected.

Conservative engineering design, careful operating practices — enforced by strict regulatory standards — ensure that shipping fuel to and from nuclear power plants will continue safely and efficiently as this means of generating electricity expands to meet our increasing energy needs.

Traffic flow minor

Shipments to meet these needs for a 1,000,000-kilowatt power reactor are much fewer than material transfers for many light industrial or even commercial facilities.

Assemblies of fresh fuel are forwarded by truck: some 20 trips for initial loading, about 6 for annual refueling.

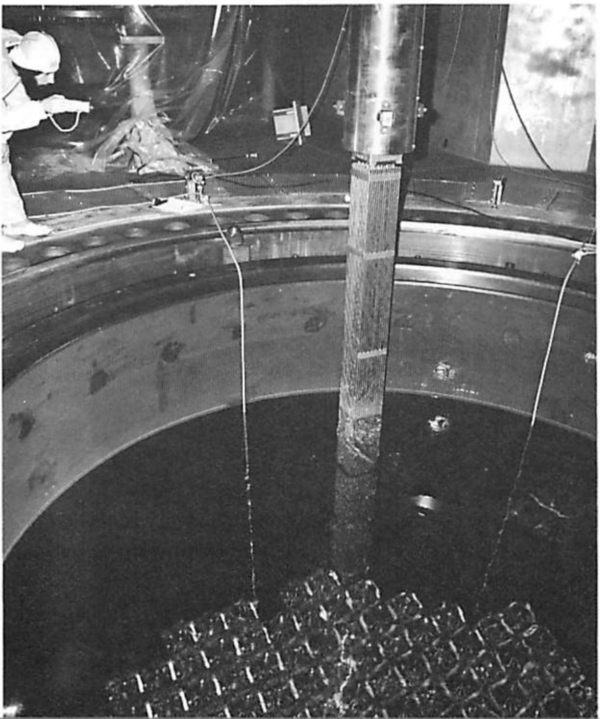
Assemblies of highly radioactive spent fuel are retrieved in massive, heavily shielded casks; with those of recent design, about 25 truckloads or 10 railcars will be needed each year.

Over the 40-year operating lifetime of the 100 reactors expected to be on line by 1980, then, the total fuel transportation requirements would be:

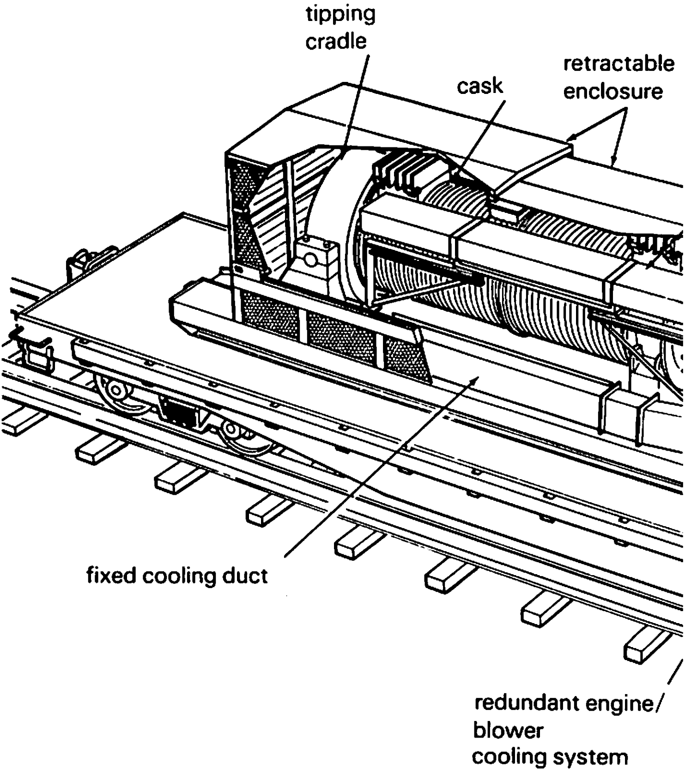
- Fresh fuel — for initial loading, about 2,000 truckloads; for refueling, some 600 annually.
- Spent fuel — with projected truck and train service, some 1,400 trips by highway and 400 by railway per year.

Compared to the *100,000,000* shipments of other hazardous materials — flammable, toxic, explosive, corrosive — that take place in this country each year, these few thousand movements annually are quite small.

Fresh fuel assembly being loaded into core



Spent fuel cask mounted for rail shipment



Accidents highly unlikely

Even smaller is the risk to public health and property from nuclear fuel on the move.

First of all, the *probability* of a vehicle conveying this freight meeting with a traffic mishap is extremely low.

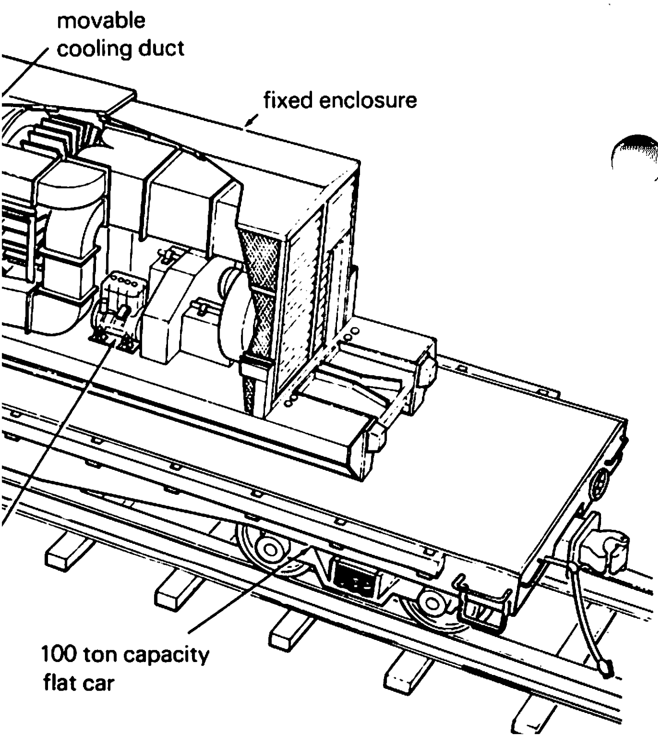
From the millions of shipments of all types of radioactive material made so far and the much more extensive experience with transferring other hazardous substances, the frequency of such incidents can be estimated.

Over the lifetime of 100 reactors, there may occur 35 truck accidents with fresh fuel, 66 with spent fuel; and 14 train accidents with spent fuel.

Just because a shipping vehicle is involved in a crash, however, does not mean radioactive materials will be released.

In fact, less than one per cent of these projected mishaps are expected to produce conditions severe enough to potentially damage the cargo.

These figures, however, tell only half the story: the extremely remote likelihood that a shipment of nuclear fuel may experience a serious accident.



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