CONSIDERATIONS FOR SITING AND OPERATING A NATURAL URANIUM INTERIM STORAGE FACILITY

[A CASE STUDY OF THE EDLOW INTERNATIONAL CO. EAST ST. LOUIS, IL SITE]

by

Daniel F. Hang, P.E.*

Dr. Barclay G. Jones **

Dr. James F. Stubbins, P.E.***

of

Urbana, Illinois

Consultants to

R. L. Mayall Capital, Ltd.

New York, N.Y. 10022

February, 1985

*Professor Emeritus of Nuclear Engineering, University of Illinois, Urbana
**Professor of Nuclear Engineering, University of Illinois, Urbana
***Asst. Professor of Nuclear Engineering, University of Illinois, Urbana

Table of Contents

O. Executive Summary

This report examines uranium fuel supply for fission power reactors to assess its nature and its potential impact on areas surrounding natural uranium storage locations. Primary consideration has been given to siting and operating interim storage facilities for natural uranium. Specifically, a detailed examination of the Edlow International Company source materials storage site in East St. Louis, IL has been conducted.

Initial processing and concentrating of uranium ore occurs close to the mines. The proximity of mills to mining sites significantly reduces the volume of material which needs to be transported to conversion facilities thereby minimizing the cost of the source materials for nuclear fuels. As with all energy producing systems, a reserve of fuel is needed to insure a smooth, uninterrupted supply of power. In the uranium fuel cycle, this point comes after the milling stage, or after the conversion of the milled yellowcake (U308) to uranium hexafluoride (UF6). Yellowcake is a powderlike solid substance with an extremely high melting point. Uranium hexafluoride is also a solid at room temperature but turns to a liquid if heated to 148 F (64.5 C). Uranium hexafluoride is reactive with moisture. The chemical reaction with water (H2O) produces hydrogen fluoride (HF) and uranyl fluoride (UO2F2). These two substances can be toxic if ingested or inhaled in large quantities. Thus, uranium hexafluoride is stored and transported in secure containers, which minimize the possibility of any release of this substance. Yellowcake is not reactive, but is toxic due to its radioactivity. It too must be properly stored to prevent any release of material.

Natural uranium is made up of three uranium isotopes. These are U 234 in trace amounts, U 235 at about 0.7 %, and U 238 at about 99.3%. All three isotopes have the same chemical properties, and all three emit radiation. To be useful for nuclear fuel, natural uranium must be enriched in U 235 content to between 1.8 and 5%. The "source materials" for the enrichment process are yellowcake and uranium hexafluoride with natural (ie. unenriched) uranium. Since all of the uranium isotopes emit radiation, source materials and enriched material must be handled with care. However,uranium isotope decay very slowly so their level of radiation is low. Nevertheless, sensitive radiation detection equipment can monitor the very low levels of radiation emitted from the yellowcake and uranium hexafluoride containers. Radiation exposure to humans can be minimized by 1.) proper packaging of radioactive materials, 2.) careful monitoring of radiation levels, and 3.) keeping safe distances from the materials. It is also important to note that there is a measurable level of natural background radiation from the sun and other sources which we all are subjected to every day. In addition, radiation is commonly used for medical and dental purposes. These everyday levels of radiation exposure are normally much higher than any exposure from materials in the nuclear fuel cycle.

It is common practice to store and transport yellowcake in 55 gallon drums. These drums must meet federal regulations if they are to be used for the transport of nuclear materials. Drums, usually in groups of 34, are packaged together in modular shipping containers to provide an additional barrier of protection and to facilitate the handling and shipping process.

Uranium hexafluoride is shipped and stored in steel cylinders which are pressurized to keep the uranium hexafluoride in solid form at all times. The cylinders are very robust and must meet stringent federal regulations.

Shipping and storage containers for U308 and UF6 have been in general use for more than twenty years. Although there have been a number of accidents in transporting and handling these containers, safety and clean up procedures are well established to deal with anticipated accident situations. To put the potential for danger to the population surrounding a source material storage facility into perspective, two hypothetical accidents where most of the contents of a UF6 shipping cylinder are released have been reviewed. These may be considered typical of the worst possible accidents which could be encountered at a source material storage facility, although the likelihood of such accidents is very, very small. Releases which might result from these hypothetical accidents are, nevertheless, not disasterous even though they approach established exposure limits up to a distance of 975 ft (300 m) from the point of the accident. Exposure levels would become insignificant at distances farther from the point of the accident.

Since source materials must be stored to buffer the flow of uranium to enrichment facilities, the selection of adequate storage sites is very important. In the selection of a particular storage site, it is not only important that the site be in the vicinity of the enrichment plants and have good transportation access, but it is also critical that it is safe and secure. Furthermore, adequate facilities for handling accident situations should be available. These include fire and police protection. In order for a storage site for source materials to be licensed by the Nuclear Regulatory Commission (NRC), it must comply with strict federal regulations.

In the opinion of the authors, the East St. Louis, IL site of the Edlow International Company meets or exceeds the above criteria. It has received a license from the Nuclear Regulatory Commission for operation as a source materials storage site from February 14, 1980 to February 28, 1985, and an application has been filed for a renewal of this license. The Edlow site has excellent security to prevent unauthorized access. It is located well with respect to transportation and truck access. The site is above the flood plain and is well drained. The storage locations at the site are located outside the warehouse building, providing a minimum fire hazard. A good working arrangement with the local fire departments provides for a strong response in the case of fire. A close working arrangement with the police in both the city and county provides a rapid and sure response to ensure security.

Based on the authors' review of the site operating procedures, the security and safety ties with the local fire and police units, and the site characteristics, it is concluded that the Edlow storage site does not create an undue risk to the surrounding community and appears to be a responsible part of the community.

I. Description Of The Nuclear Fuel Cycle

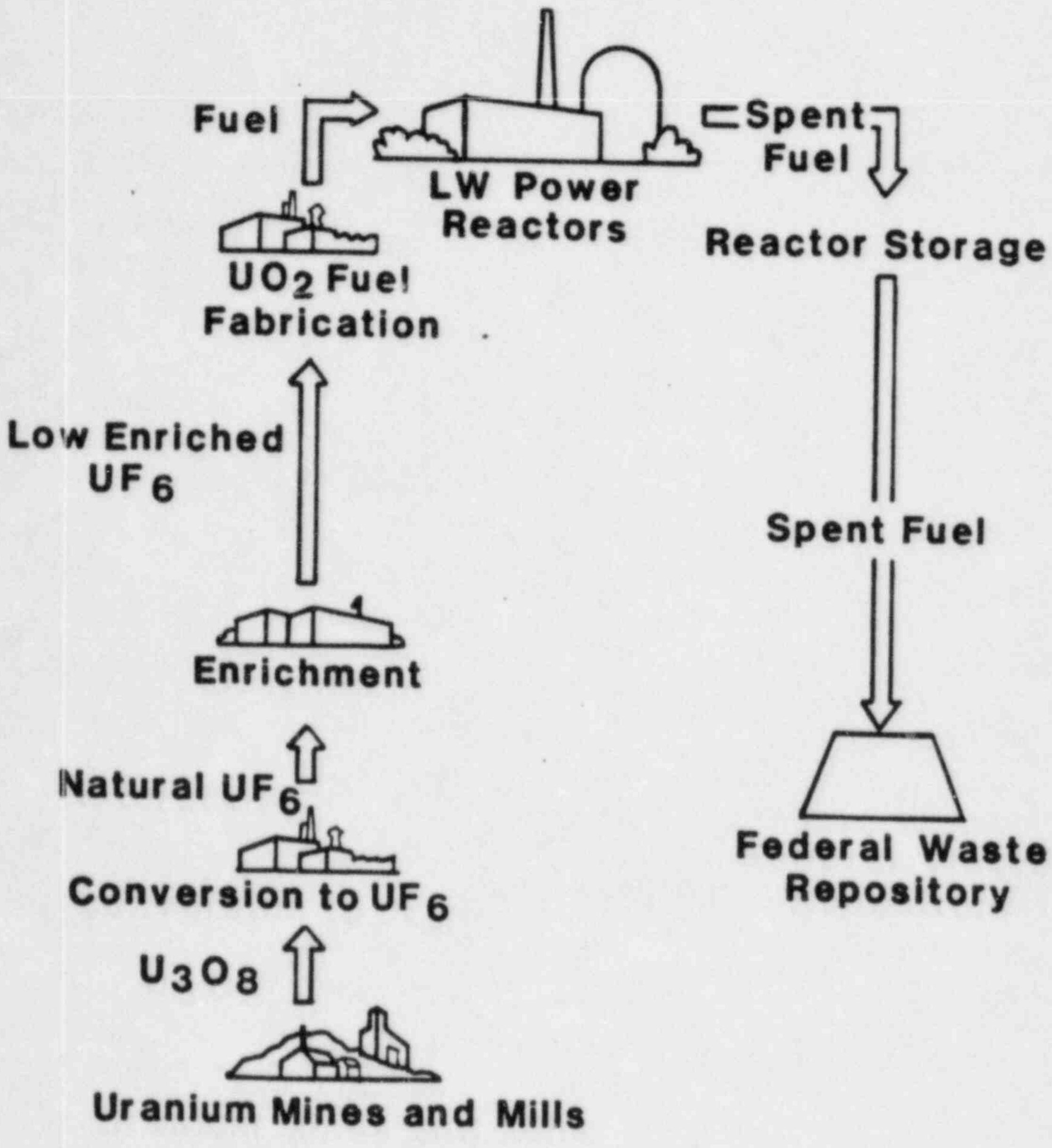
a. Background

The majority of electric power in the US is produced by turbogenerators that are steam driven. Steam is produced in boilers heated by fossil fuels (coal, gas, or oil) or in nuclear reactors that are fueled with slightly enriched uranium. In 1984, about 13% of the electric energy produced in the US was from base loaded nuclear power plants.

A fuel cycle is associated with each energy source. In the coal fuel cycle, for example, there is exploration for coal deposits, mining, crushing and washing of the coal, and shipping of coal by water, rail or truck to coal fired plants. At the plant, coal is pulverized for immediate use in the boiler. Excess coal is placed in large storage piles near the plant to ensure that the steady supply of coal is not interrupted by natural or deliberate means. For environmental reasons, filters are used to remove particulate matter and a flue gas desulfurizer (FGD) is employed to reduce the emission of sulfur dioxide (SO2) from the stack gases in coal fired plants. Solid and liquid waste from the FGD process and coal ash, both in significant quantities, requires a unique waste disposal system for each plant site.

Similarly, in the nuclear fuel cycle, there is exploration and mining of uranium-bearing ore, hauling of the ore to a nearby mill where a uranium concentrate in the form of U308 (yellowcake) is extracted (often along with other by-products). Yellowcake, in 55 gallon steel industrial drums, is hauled to a chemical plant and converted to UF6 (uranium hexafluoride). In this form, the uranium is enriched (i.e. isotope separation). The enriched UF6 from the diffusion plant is shipped to a fabrication plant where the uranium is made into fuel assemblies for use in the reactor. The JF6 is first converted to the oxide form, UO2, so it can withstand very high temperatures. It is then compressed into pellets and clad in zirconium alloy tubing, sealed and stacked in a square array of tubes called assemblies. These assemblies are shipped to the specific nuclear reactor for which it was designed. At the nuclear plant the fuel assemblies are loaded into the reactor core to form a cylindrical array. Through the fission process heat is generated, water heated, and steam formed that drives the turbo-electric generator to produce electric energy. Every 12 to 18 months the reactor is shut down for refueling. At this time a portion of the reactor core is replaced with new fuel assemblies. The spent fuel assemblies are stored at the reactor site in a deep pool of pure water. Depending on the reactor type, 1/3rd to 1/4th of the core assemblies are replaced during the refueling cycle. Whereas each reactor can store substantial spent fuel on site, ultimately spent fuel will be stored in government owned repositories. It is possible that in the future spent fuel may be reprocessed to recycle the valuable unused fissionable material. Presently, however, only the long term storage and disposal option is practiced in the US. The nuclear fuel cycle is illustrated in Figure 1.[1]

In the US it takes from 8 to 12 years to develop a uranium mine-mill complex and about the same time to build a nuclear power plant. Commercial uranium mines are not started without contracts for output, so delays in the start up of a new plant, uncertainties in the growth of



Light Water Reacter Fuel Cycle - Throwaway Cycle

FIGURE 1

the electric power load, or a change in a reloading schedule results in excess uranium in the form of U308 or UF6 that must be stored for an indefinite period of time. Storage may be for only a few months or for several years. Convenient storage locations on the main transportation path from the mill to the conversion site or from the conversion site to the enriching plant is a must for a utility. Generally it is not economic or prudent to ship this raw material to the reactor site for interim storage. Often a utility may find it economic to sell its present uranium holdings to another utility that may need a supply sooner. Both parties in the deal may gain financially on the sale, yet storage may still be required. The market for uranium is international, not just domestic.

The Edlow International Co. provides storage for uranium in two forms, as U308 and as UF6 at their East St. Louis storage site. Storage is limited to natural or depleted uranium. Neither enriched uranium nor spent fuel may be stored there. The site is less than 1 mile (6 blocks) from an interstate ramp that connects to the interstate hub of the St. Louis area. Several nuclear fuel facilities are on direct interstate routes that pass through St. Louis. For example, U308 from western US mines can be transported directly to a conversion plant in Gore, OK, before proceeding by interstate through the St. Louis hub to the Paducah, KY enrichment facility. Alternatively the U308 that bypasses Gore, OK may be converted to UF6 at Metropolis, IL which is just across the Ohio river from Paducah on the same interstate route.

Same site location data

b. Uranium Exploration, Mining & Milling

Major sources of domestic uranium production are from the bedded sandstone sediments deposited in the Triassic, Jurassic and Tertiary basins of the western United States. The principal producing areas are the Tertiary basins of Wyoming, the Jurassic sandstones of the Colorado Plateau, and sandstones of the Coastal Plains of Texas. Only minor US production is attained from other types of deposits [2]. More detailed information concerning uranium production may be found in the annually issued publication "Statistical Data of the Uranium Industry" GJO-100 issued by the US Department of Energy.

Exploration for uranium ore deposits is done by airborne prospecting followed by surface and subsurface evaluation. Airborne radiometric techniques delineate the most favorable places to drill. Surface measurements by gamma-ray spectrometers installed in cars can cover the ground in more detail than a plane. Several million feet of surface drilled holes are logged each year using gamma-ray techniques which sense the radiation from decay products of uranium. If the deposits are large and do not exceed 350 to 400 ft. in depth, open pit mining may be employed. For deeper deposits, underground mining is required. The production rate from underground mining is less typically than for open pit. Presently mined US uranium ore contains from 0.1% to 0.18% U308 (from 2 to 3.6 lbs. of U308 for each ton of ore mined). This sparce concentration of uranium dictates having a milling complex and concentration facility reasonably close to the mines. Otherwise the cost of transportation of the ore to the mill would be prohibitive.

Milling of uranium ore is used to separate uranium from the host rock and to recover other metals if available in the ore. The treatment method to produce a high grade chemical concentrate is determined largely by the composition of the uranium mineral within the ore, and whatever other minerals are present. The ore is crushed and ground either dry or wet depending upon subsequent processing. Two agents are used for leaching uranium from ore. They are acid and alkaline carbonate. Sulfuric acid is most often used for acid leaching, and a mixture of sodium carbonate and sodium bicarbonate or corresponding ammonium compounds are used for the alkaline leach. After ion exchange or solvent extraction processes, filtering, and drying, a powder of U308 (a dry concentrate) is packaged in 55 gallon, full removable-head, steel drums with ring closures. The purity of the concentrate depends largely on the millfeed composition and other variables. The purity may range from 75% to 100% U308. Permissible impurities depend upon subsequent refining process used.

The specific radioactivity of U308 (yellowcake) is much less than that of the ore body from which it was chemically separated. The half-life of U 238, the most abundant isotope, is 4.51 billion years giving off an alpha particle and a comparatively low energy gamma-ray (.048 MeV). The host ore contains radium which has a 1622 year half-life, also giving off an alpha particle along with a higher energy gamma-ray (.186 MeV). The radium is chemically separated from the uranium and is for the most part left at the mill in the residue which is known as mill tailings. Tailings are radioactive and treated as a hazardous substance which must be environmentally contained at the mill. The concentrate of U308, as a result, has a relatively low specific radioactivity. Very little radon gas emanates from this concentrate, much less than from the earth in general. It is just the radioactive decay of U 234, U 235, and U 238 in the 55 gallon containers that is of any concern. It would take thousands of years to build up any appreciable amount of radium (a daughter product of uranium decay) in the yellowcake during storage.

Uranium from domestic mines has found its way to the open international market and has been purchased for use in reactors in other countries. Likewise uranium mined and milled in other countries has been imported by US utilities for use in domestic nuclear plants. With slipped schedules for completion of some nuclear plants and cancellation of several others, uranium has become more available on the open market. Utilities and energy companies will purchase excess U308 because it is economic to do so. In some cases, it is wise to have a reserve supply at the present low price that previously was not affordable. Uranium ends up then at a storage facility until conversion and/or enrichment schedules dictate its movement elsewhere.

c. Conversion Of U308 To UF6

Conversion of U308 to UF6 is carried out commercially at two locations in the US [3] and at three locations abroad. Natural uranium contains only 0.711% of U 235, the fissionable isotope of uranium and the rest is mainly

U 238. There are trace amounts of U 234 which contribute to the radioactivity. Reactors built in the US require enriched U 235 as fuel. The enrichment process requires that the uranium is converted to UF6, uranium hexafluoride, a compound that can attain a gaseous form at elevated temperatures.

Commercially, U308 concentrate is converted into UF6 by two principal processes; dry fluoride volatility and refining-fluorination. In 1959, Allied Chemical Corporation began operating the first commercial dry fluoride volatility conversion plant at Metropolis, IL just across the Ohio River from the Paducah, KY gaseous diffusion enrichment plant which utilizes the UF6. The second US conversion plant, operated by Kerr-McGee, is the Sequoyah Facility at Gore, OK. This facility went into service in 1970 using the refining-fluorination process. The Dept. of Energy (DOE) has substantial conversion capability but it is not commercially available. Both conversion processes result in 99.5% pure UF6. Specification for UF6 to pass through the gaseous diffusion enrichment plant is stringent.

The shipping and storage container for depleted or natural UF6 is a steel cylindrical tank 48 inches in diameter and 10 to 12 feet in length. It can contain over 8 metric tonnes of UF6 and is transported on a flat bed truck. Enriched UF6 is also shipped in a steel cylinder but of a smaller size to prevent criticality of the material. The Edlow E. St. Louis source material site is licensed to store only depleted or natural UF6,and natural U308. } description of storage tank for UF6

There is competition for conversion of U308 to UF6 in the international market from Eldorado Nuclear's plant at Port Hope, Ont., British Nuclear Fuels Ltd. in the Manchester-Springfield area of England and the Comurhex plant in France. Coupled with the non-US enriching plants, many interesting combinations of uranium movement in the US becomes possible.

Some are:

1). US U308 converted & enriched in the US for US reactors
2). US U308 converted & enriched in the US for foreign reactors
3). US U308 converted & enriched abroad for US reactors
4). US U308 converted & enriched abroad for foreign reactors
5). Foreign U308 converted & enriched abroad for US reactors
6). Foreign U308 converted & enriched in the US for US reactors
7). Foreign U308 converted & enriched in the US for foreign reactors
8). Foreign U308 converted abroad, enriched in US for foreign reactors.

The possible combinations increase further if one considers the several US and foreign locations of conversion and enrichment facilitites. With such potential for international transportation of nuclear fuel materials, it is fortunate that it takes only about 18 truck loads of uranium to fuel a nuclear plant for one year. This is not much when compared to a coal fired plant that requires over 25,000 railroad carloads of coal to supply the same annual energy output.

d. Uranium Enrichment

The light water reactors used in the US require that U 235 content of uranium fuel be enriched from the naturally found weight percentage of 0.711 to a value between 1.8% and 5%, depending on the core load and reactor type. There are three enrichment facilities owned by the Department of Energy (DOE) and operated under contract by private corporations. The facilities are all gaseous diffusion plants and are located at Oak Ridge TN, Paducah KY, and Portsmouth OH. The first two are operated by Martin Marietta Energy Systems, Inc. and the last one by Goodyear Atomic Corp. The use of a centrifuge enrichment process is being considered in the US as it requires only 10% the energy used by diffusion. Atomic Vapor Laser Isotope Separation (AVLIS), however, is being developed and may supercede the centrifuge process before it becomes fully commercial. AVLIS is expected to require even less energy than the centrifuge and possibly have less mechanical maintenance.

Gaseous diffusion, a phenomenon discovered by Graham [4] in 1829, requires the passage of gas through small openings. Because of the greater average thermal velocity of the lighter molecules, U 235 will strike the walls of a vessel more frequently than the heavier U 238. Container walls that are porous allow more of the lighter gas (235 UF6) to escape in a flow stream. The flow streams are separated into an enriched and a depleted stream and the process is repeated in many stages in order to effect an appreciable enrichment. Huge compressors are required to force the high pressure gas feed stream through barriers with minute sized openings. Proper valving of streams, compression of gases, and cooling between cascade stages provides a gradual enrichment of the UF6. There is a corresponding depleted stream of UF6. This waste or tails stream is depleted to 0.2% or less of U 235. The chemical form of UF6 is the only one suited for enrichment as it is gaseous at temperatures over 150 F. Figures 2.and 3. show a stage and cascade of separation equipment of a diffusion plant.

Since the separation between stages is very small, several hundred stages are required to reach the enrichments needed for the US reactors. The Portsmouth, OH plant, having the largest number of stages, can develop a product of 97.65% U 235. The enriching process, measured in separative work units (SWU), cost about $30/kg in 1970 and is now about $150/kg of SWU [5]. Compared to the cost of coal, nuclear fuel costs have remained quite stable. With the advent of the centrifuge or AVLIS process, the price of SWU's is expected to level out at less than $100/kg (1kg = 2.2 lbs).

Expansion of the diffusion plant output has been undertaken in the past ten years, improving the output efficiency of the diffusion process, thus increasing the plant output [6]. A considerable amount of enrichment is done under contracts with foreign countries, a practice resulting from when the US was the world leader in nuclear energy. Presently all enriching enters at the Paducah, KY plant where the uranium is stripped (enrichment raised to about .9% U 235 and depleted to ~.2% U 235). It is then sent according to the DOE schedule to either the Oak Ridge or Portsmouth plant for final enriching. Enriched uranium product is shipped from there to the fabrication facility chosen by the utility to build fuel assemblies.

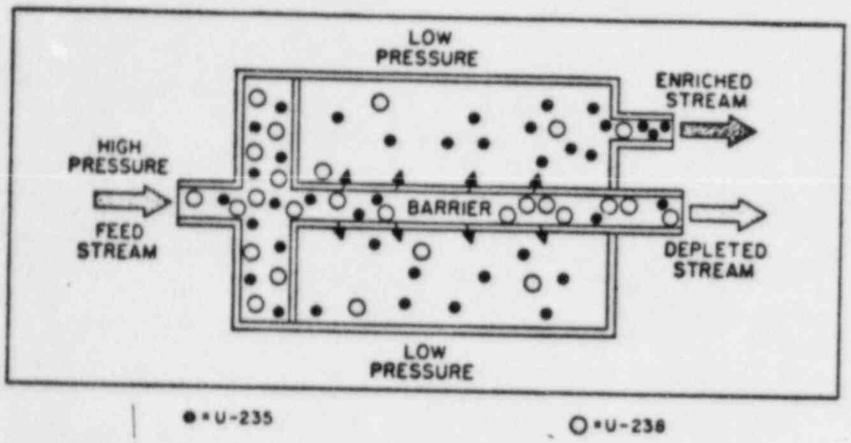


Figure 2. Gaseous Diffusion Stage

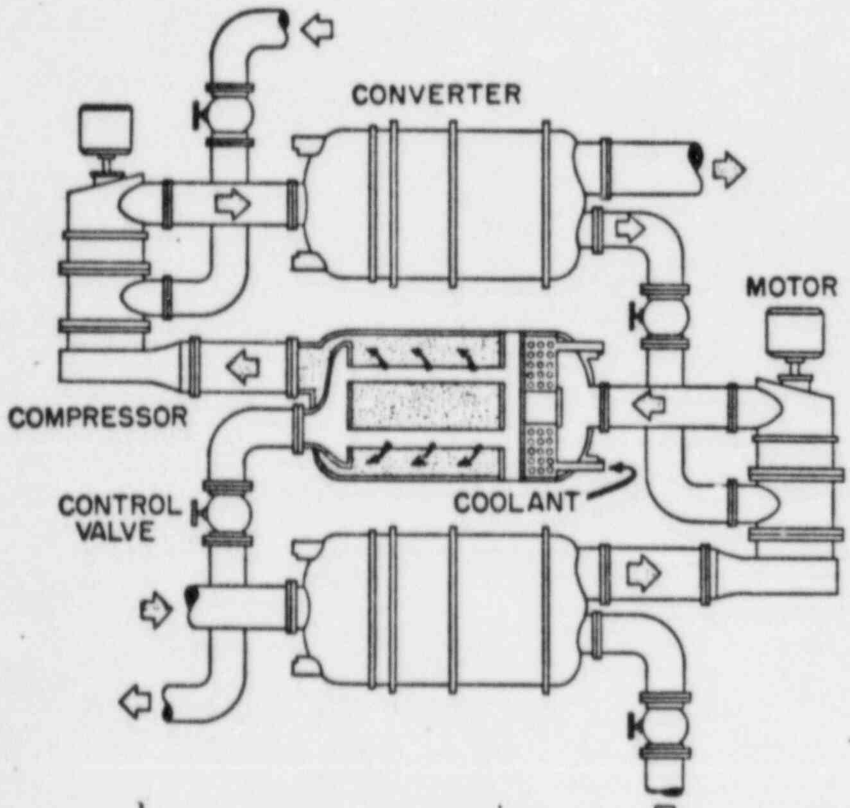


Figure 3. Gaseous Diffusion Process

e. Geographical Location Of Mining, Milling, Conversion, And Enrichment Facilities In The US with Respect To Edlow Storage Site

Areas of uranium production in the United States are shown in Figure 4. New Mexico and Wyoming are the major producers. The six states of Arizona, Colorado, Florida, Texas, Utah, and Washington produce the remainder of the US uranium [7]. Milling facilities that support the mines are shown in Figure 5 and are noted to be close to mining locations. The U308 concentrate is chemically converted to UF6 so that a separation process (isotope enrichment) in the gaseous diffusion plant can be performed.

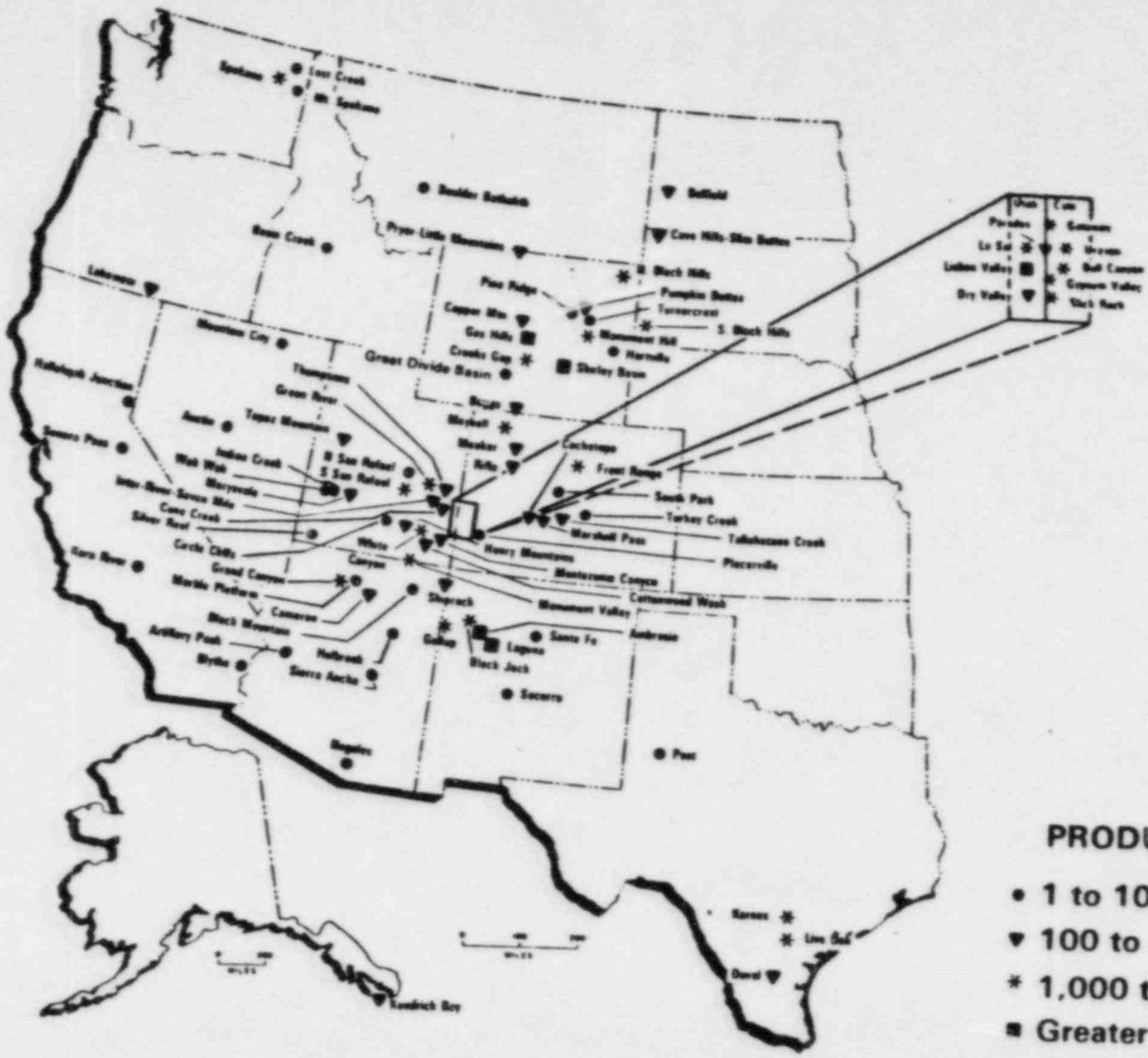
The larger producing mills are served by Interstates 80, 70, and 40, and interconnecting north-south interstates, for transportation to one of the two US conversion plants. These plants are located at Gore OK and Metropolis IL, a few miles from I-40 and I-24, respectively. The Edlow International storage facility provides a place for uranium to be stored enroute from the mill to the enrichment plant. Planned storage and delays in the fuel cycle are anticipated. Minimizing transportation exposure by having a storage facility on the direct route adds to the safety of the operation. It is also economic to stop the fuel cycle with the least dollar value added, if there is a delay in use. Contract schedules may stipulate U308 shipments that do not meet current fuel loading plans. In such cases, it may be more economic to store the U308 at this point than to add to the cost by continuing on to conversion and enrichment. Considerable numbers of U308 and UF6 sales are made as utilities adjust their inventory of uranium. Uranium purchases must be planned and contracts signed several years before the power growth of the system is realized. Power companies that experience faster growth rates look for the opportunity to purchase fuel on the spot market. There are other utilities with excess fuel material and find it necessary to sell. A compromise sale price may prove to be advantageous for both, offsetting impending shortages or financial losses.

Economic BASIS FOR LOCATION

The next destination of uranium stored at Edlow International's East St. Louis site depends on the form of the mineral.

In U308 form it is: Shipped via I-64, I-57, and I-24 to Metropolis IL to undergo conversion. From there to Paducah KY to be enriched. After enrichment to a fuel fabrication plant where assemblies are made for use in the nuclear plant.

In UF6 form it is: Shipped via I-64, I-57, and I-24 to Paducah KY to be enriched. The first enrichment is called a stripping process and takes place at Paducah KY where the natural UF6 is enriched to 0.9% U-235.



PRODUCTION THROUGH 1978

- • 1 to 100 tons U_3O_8
- ▼ 100 to 1,000 tons U_3O_8
- * 1,000 to 10,000 tons U_3O_8
- ■ Greater than 10,000 tons U_3O_8

Note: Uranium produced as a byproduct from the processing of phosphates, euxenites, etc., is not included

Fig. 4, AREAS OF URANIUM PRODUCTION IN THE UNITED STATES

FIG. 5.

URANIUM MILLS IN THE UNITED STATES OPERATING AS OF 1/1/79

10

Edlow requires U308 to be shipped and stored in large steel overseas shipping containers. Containers hold up to thirty-four 55 gallon steel drums of U308. By truck, they travel on flatbed trailers. The containers are unloaded in their storage yard where they remain until the owner requests continuation of shipment. This may be in a few months or up to several years. Natural UF6 (.711% U 235) or depleted UF6 is stored and shipped in 14 ton capacity heavy steel cylinders that are shipped on flatbed trucks. The present cradle design and tie-down methods used with these cylinders have shown that an accidental separation of the cylinder from the vehicle is unlikely [Ref. 6 pg. 2.3-170]. In this reference a serious accident is hypothesized where a truck and 14-ton cylinder is hit such that the cylinder is punctured. The truck and cylinder both are assumed to fall into a flowing body of water. Water reaction produces UO2F2 and HF. Radioactivity releases are given in curies Ci and amount to: 3.08 Ci for U 234, 0.13 Ci for U 235,and 2.86 Ci for U 238. The time it takes to empty the cylinder depends upon the water flow rate. A puncture in the cylinder without immersion in water may self-seal as the UO2F2 cakes around the puncture (see Section III). 1 Accident analysis.

The cylinders are unloaded in the Edlow storage area and generally not moved again until the owner requests continuation of the cylinder to the enrichment plant. Depleted uranium that is stored on site may travel elsewhere.

f. Free-world Conversion and Enrichment Facilities

Canada and Europe have conversion plants to convert yellowcake to UF6. Plants are located in Port Hope, Ont., in the Manchester-Springfield area of England, and in France. The multinational company Eurodif in France has a diffusion plant to enrich uranium. This plant is newer and more efficient at present than the DOE units in the US. There are three centrifuge plants for enriching in Europe, operated by Urenco Ltd. These plants are located in England, Netherlands and West Germany (under construction). These plants have excess separative work units of capacity and draw upon the US market for enrichment business. The price is obviously competitive as foreign enrichment of US uranium is on the increase at the present.

II. Radioactivity and Exposure

a. Radioactive Decay and Decay Products

Many naturally occuring materials are radioactive, that is, they decay or transform to a more stable material by emitting particles or rays. This process is known as radioactive decay. The decay products are usually 1.) an alpha particle, 2.) a beta particle, or 3.) a gamma ray. Alpha particles are helium atoms with the electrons removed. A beta particle is an electron, and a gamma ray is an energetic ray that travels much like visible light. Visible light can travel through some substances, such as glass, but is stopped by other substances, such as metals. Sunglasses allow some, but not all, light to travel through. The decay products mentioned above have similar properties. In some cases, they can be transmitted through certain materials, but not through others. It is also found that the thicker the material, the less amount of particles or rays can pass through. The alpha particle is the heaviest and the largest of the decay products and because of this it can not travel very far through any material. A thin glass or metal barrier is sufficient to stop all alpha particles. Beta particles are much smaller in size and weight, but still can be stopped in short distances in somewhat thicker plates of metal or glass. Beta particles have greater penetrating power than alpha particles, but shielding for protection from beta particles is not difficult. In general, the greater the energy the particle has, the further it can penetrate, or the greater penetrating power it has. This means that thicker shielding needs to be used for more energetic particles. Gamma rays are more penetrating than either alpha or beta particles. Much thicker shielding must be used to stop the most energetic gamma rays.

Since radioactive decay is a time related process, the amount of decays is directly governed by the half life of the material. The half life is related to the "decay constant":

half life = 0.693/decay constant.

The decay constant gives the number of decays per second per atom. The "activity" of the material is just the decay constant times the number of radioactive atoms there are:

activity = decay constant x the number of radioactive atoms.

As the material undergoes radioactive decay, the radioactive atoms are converted to stable atoms. This means that the number of radioactive atoms decreases over time, and so does the activity of the material. The half life, which was mentioned above, tells the time it takes for the number of radioactive atoms to decay to half the original number. For instance, if we start with 1000 radioactive atoms, and find that it takes 3 weeks for this number to decay to 500 radioactive atoms, half the original number, the half life would then be 3 weeks. After 3 more weeks, there would be only 250 radioactive atoms left, so altogether after 6 weeks there would be only 1/4th of the original number of atoms. This process goes on and on so that after several months there would be few if any radioactive atoms left. It is important to remember that the number of radioactive atoms is always cut in half over each half life period. Since the activity of the material goes down with the number of radioactive atoms left, the activity decreases with time.

The fact that certain materials undergo radioactive decay is usually seen as a hazard. It does have its advantages, though. These advantages are: 1.) Sooner or later the material decays away and there is no hazard left. (This is not the case with many other toxic materials; they do not decay.) 2.) Due to radioactive decay, these materials are relatively easy to detect with radiation detectors such as Geiger counters.

b. Radioactivity in Uranium

As explained in Section I. of this report, uranium which comes from the mills as U308 or as UF6 in the converted form is comprised of natural uranium. Natural uranium is made up of isotopes 92 U 234, 92 U 235, and 92 U 238. These isotopes are all the same chemically, but differ by the number of neutral particles (ie. neutrons) in the nucleus of each atom. The useful isotope for nuclear fuel is 92 U 235 and the enrichment plant increases the concentration of this isotope to make the uranium viable for fuel in commercial reactors. Uranium is naturally radioactive, and Table II.1 shows the half lives and decay products for the three isotopes found in natural and enriched uranium. Enriched uranium has a larger abundance of U 234 and U 235 than natural uranium, but the same decay products and half lives.

TABLE II.1

Data for Isotopes in Natural Uranium

Isotope	Abundance	Decay Products	Half Life
92 U 234	0.0057 at.%	alpha, gamma	247,000 yr
92 U 235	0.72 at.%	alpha, gamma	713,000,000 yr
92 U 238	99.27 at.%	alpha, gamma	4,510,000,000 yr

Once fuel has been used in a reactor, the composition of the uranium changes. In addition, other radioactive elements are formed as products of the fission process or by conversion of the fuel material in the reactor. This "spent fuel" is stored separately at the reactor site for several years, and under present plans, will be stored permanently in DOE waste disposal sites. This spent fuel does not re-enter the fuel cycle, and is stored in highly secure areas. No spent fuel has ever been stored at the Edlow site in East St. Louis.

c. Exposure to Radiation

Radioactivity occurs naturally, and all of us are exposed to radioactivity every day of our lives. Some of this comes from the sun, from space, and from naturally radioactive materials on earth. In addition, we encounter radiation from certain man-made sources. For instance, dental and medical x-rays are radiation, radiation is emitted from TVs, nuclear fallout is still present, and some exposure comes from commercial nuclear power plants. This latter exposure is extremely small, and usually insignificant when compared to other sources. Even coal fired power plants emit radiation. Some of the material contained in coal is radioactive, and this is part of the smoke and ash which is left after coal is burned. Some levels of radiation exposure are shown in Table II.2. It

Table II.1

US General Population Exposure Estimates (1978)

Source	Ave. Individual Dose (mrem/yr)
Natural Background	100
Release of Naturally Radioactive Material	5
Medical (whole body equivalent)	90
Nuclear Weapons Fallout	5 to 8
Nuclear Energy	0.28
Consumer Products	0.03
Total	~200 mrem/yr

Taken from NRC Reg Guide 8.29 [10]

is important to note that the natural background level is half of the typical total exposure, and most of the rest is from medical applications. Very little of the typical exposure comes from nuclear power applications.

The doses are given in mrem/yr or millirem per year. A rem is a measure of the amount of radiation dose absorbed in tissue and the relative damage the dose could cause to the tissue. A millirem is one one-thousandth of a rem.

The Nuclear Regulatory Commision (NRC) is responsible for setting limits of dose to workers involved in dealing with radiation. These are covered in 10 Code of Federal Regulations 20 (10 CFR 20), and the reporting procedures are covered in 10 CFR 19. These limits to workers are further explained in the NRC Regulatory Guide 8.29, Instructions Concerning Risks From Occupational Radiation Exposure [10]. The guidelines for occupational exposure are shown in Table II.3. These are based on keeping the exposure levels As Low As Reasonably Achievable (ALARA). Some other health risks

Table II.3

Occupational and Public Radiation Exposure Limits

Type of Exposure	EPA (1981)	NCRP (1971)	ICRP (1977)
Occupational			
Whole Body	5 rem/yr 100 total career	5 rem/yr	5 rem/yr
Skin	-	15 rem/yr	-
Hands	50 rem/yr	75 rem/yr	-
Gonads	5 rem/yr	5 rem/yr	-
Lens of Eye	5 rem/yr	5 rem/yr	-
Thyroid	-	15 rem/yr	-
Any Other Organ	30 rem/yr	15 rem/yr	-
Pregnant Women	several other standards proposed		
Public			
Individuals	-	0.5 rem/yr	0.5 rem/yr
Average	-	5 rem/ 30 yr	-

Taken from Table 9.13 in Lamarsh, Introduction to Nuclear Engineering [11]

are compared to exposures of one rem (equal to 1000 mrem) and one rem/yr for thirty years in Table II.4. These are given in terms of estimated average days of life expectancy lost, that is the number of days shorter your life would be due to exposure of each type of risk.

Table II.4

Estimated Loss of Life Expectancy from Health Risks

Health Risk	Average Days Lost
Smoking 20 cig/day	2370
Overweight by 20%	985
All Accidents	435
Auto Accidents	200
Alcohol	130
Home Accidents	95
Drowning	41
Natural Radiation	8
Medical Radiation	6
All catastrophies	3.5
1 rem occupational exposure	1
1 rem/yr for 30 years	30

Adapted from Cohen and Lee, Health Physics, 36, June 1979; in NRC RG 8.29 [10]

It should be clear from the above information that there are several sources of radiation which we encounter every day. These sources tend to be much less dangerous than many other hazards we are subjected to in daily life.

d. Summary

The discussion above has centered on radiation and exposure to radiation. Of the three types of radiation products; alpha particles, beta particles, and gamma rays; the first two can usually be easily stopped by moderate shielding. Gamma rays are more difficult to stop, and require more shielding. Since alpha and beta particles stop in short distances in matter, they are most harmful if ingested into human tissue, and this must be avoided, that is, the material must be stored and handled in adequate containers. The amounts of these decay products depends on the amount of radioactive material present and its half life or decay constant.

It is clear that radiation exposure can have adverse effects to human health, and exposure should be limited as much as possible. Nevertheless, there is always exposure to radiation during our everyday life that cannot be avoided. Exposure from materials associated with the nuclear power industry is very low, and there are careful limits set on exposure levels. The fact that radiation is easy to monitor means that radiation levels can be determined and exposure limited. Many other hazards are much more significant in our daily lives than radiation from the nuclear power industry.

III. Nature and Properties of Materials for Producing Nuclear Fuel

a. Nuclear Properties of U308 and UF6

The two materials commonly used in the uranium enrichment process are U308 and UF6. U308 is an oxide of uranium which comes directly from the uranium processing mills. It is comprised of natural uranium and oxygen. UF6 is produced from U308, and is used in the gaseous form in the uranium enrichment process. Therefore, UF6 can be comprised of either natural or enriched uranium and flourine. Natural and enriched uranium consists of three isotopes: 92 U 234, 92 U 235, and 92 U 238. The enriched form has higher levels of U 234 and U 235 than are found in natural uranium. This is done intentionally since U 235 is the useful isotope for nuclear fission and power production. All of these isotopes decay by alpha particle emission followed by gamma ray emission. The daughter products can also be radioactive and decay by alpha or beta particle emission, again usually followed by gamma emission. The abundances, decay products and half lives of natural uranium are repeated below in Table III.1.

Table III.1

Data for Isotopes in Natural Uranium

Isotope	Abundance	Decay Products	Half Life
92 U 234	0.0057 at%	alpha, gamma	247,000 yr
92 U 235	0.72 at%	alpha, gamma	713,000,000 yr
92 U 238	99.27 at%	alpha, gamma	4,510,000,000 yr

Uranium enriched for commercial power reactors has a U 235 abundance of 1.8 to ~5 per cent, but the decay products and the half lives are the same as those shown above.

The decay chains for the uranium isotopes are shown below in Tables III.2 and III.3. These include the daughter products, their decay products, and their half lives. All of these decay products are found in U308 and UF6 as the uranium isotopes decay to their daughter products. It should be noted in Table III.2 that the U 234 isotope follows in the decay chain after U 238. Again, the half lives indicate how fast the daughter products decay. Long half lives mean long decay times.

Table III.2

Daughter Product Decay Scheme for U 238 and U 234

Radionuclide	Decay Product	Energy	Half Life
92 U 238	alpha	4.20 MeV	4,500,000,000 yr
90 Th 234	beta	0.19	24.1 days
91 Pa 234	beta	2.32	1.81 min
91 Pa 234	beta	1.31	6.7 hours
92 U 234	alpha	4.77	250,000 yr
90 Th 230	alpha	4.68	80,000 yr
88 Ra 226	alpha	4.78	1,620 yr
86 Em 222	alpha	5.49	3.82 days
84 Po 218	alpha/beta	6.00	3.05 min
82 Pb 214	beta	0.7	26.8 min
85 At 218	alpha/beta	5.51/3.17	19.7 min
84 Po 214	alpha	7.68	1.64x10 -4 sec
81 Tl 210	beta	1.9	1.32 min
82 Pb 210	beta	0.017	19.4 yr
83 Bi 210	beta	1.155	5.0 days
84 Po 210	alpha	5.30	138.3 days
81 Tl 206	beta	1.51	4.2 min
82 Pb 206	Stable		

Table III.3

Daughter Product Decay Scheme for U 235

Radionuclide	Decay Product	Energy	Half Life
92 U 235	alpha	4.56 MeV	710,000,000 yr
90 Th 231	beta	0.30	25.6 hr
91 Pa 231	alpha	5.046	34,300 yr
89 Ac 227	alpha/beta	4.94/0.046	21.6 yr
90 Th 227	alpha	6.03	18.17 days
87 Fr 223	alpha/beta	5.34/1.2	22 min
88 Ra 223	alpha	5.864	11.68 days
85 At 219	alpha/beta	6.27	0.9 min
86 Em 219	alpha	6.81	3.92 sec
83 Bi 215	alpha/beta	-	8 min
84 Po 215	alpha/beta	7.37	1.83x10 -3 sec
82 Pb 211	beta	1.39	36.1 min
85 At 215	alpha	8.00	1x10 -4 sec
83 Bi 211	alpha/beta	6.617	2.15 min
84 Po 211	alpha	7.442	0.52 sec
81 Tl 207	beta	1.44	4.79 min
82 Pb 207	Stable		

The abundance of the decay products depends on the initial number of uranium atoms and the rate at which they decay (ie. their half lives). Fast decay (ie. short half lives) means that daughter products are produced more quickly, and are thus present in higher levels. Since all of the uranium isotopes have long half lives, especially the most abundant isotopes, the amounts of daughter products produced during handling and storage are generally extremely small.

The radioactivity of uranium, and thus UF6, depends on the degree of enrichment. As the materials is further enriched, the amount of U 234 is also increased and accounts for most of the radioactivity. In naturally occuring uranium, the specific activity is roughly 1.5 disintegrations per minute per microgram of material or 2.43 mCi per gram. Highly enriched uranium has an activity about one hundred times higher, almost all due to U 234. A rule of thumb for the activity of uranium with enrichment is:

specific activity (mCi/gm) = 1.22 + 1.72 x Amount of U 235 in wt%.

b. Chemical Activities

U308 and UF6 have different chemical and physical properties. U308 is a solid which transforms to solid U02 at 1300 C (2372 F). It is normally produced by the mills in a powder or flake form, something like the consistency of powder sugar to corn flakes. Because of the high conversion temperature and high melting point of U02, there is an extremely small possibility that U308 would ever be turned into a liquid or a gas. Furthermore, U308 does not react with water or air at room or outdoor temperatures to form products that could be harmful. Normally one must be concerned only with the solid powder being dispersed somehow. Such dispersions can be cleaned up by vacuuming, or more often by shovelling the powder (and whatever dirt or other substance with which it is mixed) into a suitable container. The exposed area can then be surveyed with radiation detectors to insure that all of the radioactivity has been removed. Procedures for handling such clean up operations are spelled out in the operator's license application.

Analysis of U_3O_8 Hazard

U308 is converted to UF6 prior to the enrichment process. The enrichment process uses UF6 in the gaseous form, but UF6 is transported and stored in the solid form. There are special shipping and storage containers used for this material. These cylinders allow UF6 to be stored and shipped under pressure to insure that it remains in the solid state. At room temperature, UF6 is a white, volatile solid which sublimes (ie. evaporates) very slowly. At higher temperatures and pressures, UF6 becomes a clear, dense liquid. Shipping cylinders are filled with UF6 in the liquid form, but the material is solidified in the tank for normal handling. UF6 has a melting point of 64.5 C (148 F). Unlike U308, UF6 can turn into a gas if it is heated sufficiently, and UF6 is reactive with water, moist air, ether, and alcohol. UF6 is also corrosive to some materials, but the steel containers used to store solid UF6 are basically resistant to corrosive attack by UF6. Nevertheless, these containers, which are heated routinely for filling and emptying, should not be heated excessively, since the UF6 may undergo a phase change from the solid to the gaseous form and exert high pressures in the cylinder.

Analysis for UF6 Hazard

UF6 undergoes reaction if exposed to moisture. Thus leaks in the containers can allow either humid air or water to reach the UF6. The chemical reaction is

$$2\ UF_6 + 4\ H_2O \rightarrow 2\ UO_2F_2 + 8\ HF.$$

Large releases of UF6 and HF can result in skin burns and temporary lung impairment. UO2F2 is a soluble compound and is toxic to the kidneys if ingested or inhaled in large quantities. UO2F2 forms a white colored gas cloud on release. A concentration of one milligram of UO2F2 per cubic meter is visible. Clouds from larger releases can obscure vision. This is nevertheless an advantage since larger releases can be quickly identified and avoided. A single ingestion of 150 milligrams of soluble uranium normally has no visible effects. Prolonged breathing of UO2F2 in a large release can result in temporary lung impairment soon after exposure and possibily mild, but repairable, kidney damage within a few days.

UF6 Hazards

To put the above information into perspective, the potential effects of a large release of UF6 and its by products is considered in detail in section III.d later in this report.

Normally, when UF6 is exposed to moisture, the resulting UO2F2 cakes together to fill the leak and stop the ingress of moisture. Thus, small cylinder leaks tend to heal themselves until further measures can be taken. This also limits the amount of HF and UO2F2 which can be released during any accident. Obviously, the rupture of an entire shipping cylinder would result in larger releases and this is considered below in section III.d. Procedures for dealing with leaks in UF6 cylinder are given in the operator's license application. In addition, each UF6 container is checked periodically with swipes and Geiger counters to insure that no leaks are present, and that no UF6 or UO2F2 has collected on the outside of the shipping cylinder.

c. Exposure Limits

Exposure limits to irradiation have been discussed in Section II.c. of this report. Exposure from U308 and UF6 is limited to gamma rays from radioactive decay. There are also beta particles emitted by some of the daughter products and these must also be accounted for in the assessment of potential exposure. The alpha particles and many of the beta particles emitted during radioactive decay are stopped in the confines of the shipping containers. These decay products normally have very short stopping distances in any solid material. The level of the beta and gamma decay can be readily measured with Geiger counters. Other monitoring techniques, for instance the use of TLD detectors, can be used to ascertain the levels of irradiation over longer periods of time, usually over a period of three months. Swipes are used to detect levels of alpha particles, and these swipes must be made on the surfaces of the shipping containers periodically.

The storage and shipping cylinders for UF_6 can have a higher level of radiation associated with them when they are empty than when they are full since many of the decay daughter products are left behind in the container when the UF_6 is liquified to empty the container. These isotopes tend to line the inner walls of the containers and their beta and gamma emission can be significant. Also, the self-shielding effect provided by the UF_6 is absent.

Exposure to radiation from the shipping containers can be maintained at a minimum because of the stopping power of the container to alpha and most beta particles. Furthermore, exposure to gamma rays can be controlled by maintaining a safe distance from the cylinders and containers. This is aided by adequate perimeter controls. On the other hand, if radioactive material is somehow ingested or inhaled, it presents a more difficult radiation exposure problem. The maximum permissible concentrations of U 235 is shown below in Tables III.4 and III.5 [11]. As discussed later in this report, the liklihood of ingestion or inhalation of UF_6 or U_3O_8 in normal storage and handling is extremely small.

Table III.4

Maximum Permissible Concentrations
(microcuries per cubic centimeter)

Radionuclide	Occupational Air	Occupational Water	Public Air	Public Water
U 235	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}

Table III.5

Limit on Annual Intake by Workers
(microcuries)

Radionuclide	Oral	Inhalation
U 235	14	0.054

d. Effects of Hypothetical Accident Senerios Involving Source Materials *

To put the potential for danger to the population surrounding a source materials storage facility into perspective, we have examined the potential effects of a "worst possible accident" at a source materials storage site. While the possibility is extremely small that an accident would occur leading to substantial releases of HF6, HF and UO2F2, the consequences of such releases have been examined [6]. A report by the US Energy Research and Development Administration (ERDA), which is now the Department of Energy (DOE), on "Expansion of US Enrichment Capacity" [6] looks at several possible accident senerios with UF6 shipping casks. The nontransportation accidents are assumed to occur at enrichment facilities where handling of UF6 is commonplace. The transportation related accidents are assumed to involve a single UF6 shipping cask where nearly the entire contents of the cask would be released. The transportation related accidents seem to be more applicable to the source materials storage situation since no handling of the contents of the containers is carried out at the storage site. Three transportation related accident senerios are examined: I.) a puncture of the cask followed by an intense fire, II.) an intense fire surrounding a cask followed by cask rupture, and III.) a puncture of a cask which then falls into a river. These senerios are worked out for both source materials and for reactor return materials. Since the Edlow site and other such sites store only source materials, we will deal only with those aspects of the senerios considering source materials.

These scenarios look adequate for the types that might occur at Edlow

The transportation accident cases I. and II. seem to be the most relevant to storage situations. Table III.6 [6] indicates the types and amounts of materials released in these hypothetical accidents.

Table III.6

Summary of Release in Transportation Accident Cases I and II

Character of Release	Case I	Case II	
Material Released, UF6	10,000 kg	12,700 kg	
Materials Dissipated			
UO2F2	8,899 kg	11,123 kg	
HF	2,311 kg	2,889 kg	
Release Duration	1.7 hr	4 hr	
Radioactivity Released		Air	Ground
U 234	2.46 Ci	0.31	2.77 Ci
U 235	0.11 Ci	0.01	0.12 Ci
U 238	2.28 Ci	0.29	2.57 Ci

The consequences of these types of accidents have been calculated at 300 m (975 ft) from the accident point. Table III.7 [6] gives the dose in rems (see section II) for each senerio.

? How far is storage of cylinders at side away from perimeters

Table III.7

Estimated Dose At 300 Meters From The Point Of Release

Organ	Radioactive Materials	Dose (rem) Case I	Case II
Whole Body	U 234,235 & 238	0.23	0.25
Bone	U 234,235 & 238	1.9	2.15
Lungs	U 234,235 & 238	1.2	1.34

These numbers can be compared to the values for dose limits given in Table II.3. It can be seen that these exposures are approaching the allowed levels of exposure, but do not consititute an abnormally dangerous dose level. These are levels at 300 m (975 ft) from the release. The levels would be lower as the distance from the accident site increases.

An additional concern is the amount of HF released in such hypothetical accidents. These amounts are listed in Table III.8 [6] in terms of the concentration in air.

Table III.8

Estimated Concentration of HF in Air Following Types I and II Releases
(Values for a distance of 300 meters from the point of release)

	Type I	Type II
Amount of HF	2,310 kg	2.89 kg
Concentration of HF in Air	6.58 mg/m3	4.91 mg/m3

Although these concentrations of HF will persist for only a short period of time and are calculated for 300 m (975 ft) from the accident site, they do fall into the range of 2.5 to 100 mg/m3 which may affect man. The daily occupational exposure limit is 2.5 mg/m3 with tolerable exposures of 25 mg/m3 for several minutes at a single period. Lethal limits are 1000 mg/m3. The levels of exposure from the postulated worst accidents are well within acceptable limits. The exposure of surrounding vegetation to levels of HF of greater than 0.001 mg/m3 may cause certain of the less robust foilage to die out, but the levels of F remaining in the soil will be well below natural background levels, and subsequent planting of vegetation will not be effected by the initial levels of HF from the hypothetical release.

In summary, two hypothetical accidents where most of the contents of a UF6 shipping and storage cylinder are released have been examined. These may be considered to be typical of the worst possible accident one could encounter at a source materials storage facility. The releases are, nevertheless, not disasterous, even though they approach established exposure limits at a distance (300 m) from the point of the accident. Exposure levels become smaller as the distance from the point of the release increases.

e. Summary

The nature and properties of U308 and UF6 are different. Of the two, UF6 presents the more difficult handling problem. It can react with moisture to form UO2F2 and HF, which can present problems if living materials are exposed excessively. Thus, these materials must be handled with care and be contained in proper shipping and storage containers. Furthermore, these containers must be checked periodically for leaks or other defects. Proper clean up and safety procedures must be maintained if a spill, leak, or other release occurs. These procedures must be specified in the operator's license application and approved by the Nuclear Regulatory Commission (NRC) before the license is issued.

IV. Materials Storage and Handling

a. Storage Containers

During the transportation and storage stages of the fuel cycle, U308 and UF6 must be stored in adequate containers. The U308 containers need not be as complicated in design or as robust as the containers for UF6 due to the more difficult handling and saftey problems associated with UF6. Nevertheless, the containers for both types of materials must be secure and prevent spillage or release of the materials both during shipping and during storage.

U308 is normally contained in 55 gallon drums which are capped and sealed. These drums can then be handled individually or handled in lots. The use of standard (modular) shipping containers allows several (about 34) drums to be packaged into a single container which minimizes handling problems and provides a protective barrier to any release of the material stored in the drums. The weight of each drum can vary from 600 to 1000 lbs. A typical shipping container would hold about 28,000 to 30,000 lbs. of U308.

There are several types and sizes of shipping and storage cylinders which have been approved for UF6 handling. The reason for this variety is that UF6 may contain uranium in the natural, the depleted , or the enriched form. The enrichment level varies depending on the intended use of the material, for instance, which type of reactor it will fuel. It should be obvious that highly enriched material will be stored in small cylinders, where as, natural or depleted uranium will be contained in larger cylinders. Guidelines for container sizes and usage are given in the Department of Energy (DOE), formerly the Atomic Energy Commision (AEC), publication ORO 651, Uranium Hexaflouride: Handling Procedures and Container Criteria [12], and subsequent revisions. Typical UF6 cylinders data from these reports are given in Table IV.1.

Table IV.1

Standard UF6 Cylinder Packaging Limits

Model	Cylinder Diameter	Construction Material	Maximum % U 235	Weight, lb. UF6
5A	5 inches	Monel	100.0	55
8A	8	Monel	12.5	250
12A,12B	12	Monel	5.0	450
30A	30	Steel	4.5*	4,800
48A	48	Steel	3.0*	20,250
48F	48	Steel	2.0*	28,000
48X	48	Steel	natural	20,000
48Y	48	Steel	natural	28,000

* without moderation control these are 1.0% U 235

The largest containers listed in this table are capable of handling natural and depleted uranium since the Weight % U 235 (column 4 in the table) is 0.711% in natural uranium and even less in depleted uranium.

The DOE document ORO 651 also explains how cylinders are to be filled and emptied, how cylinders are to be weighed, how the material is to be sampled (primarily for documentation of the level of U 235 contained in the material), shipping procedures, and safety considerations. The filling process is accomplished with liquid UF6 which is then solidified in the container. Proper filling procedures eliminate any possiblility that the internal pressure in the cylinders could exceed the design values. This procedure is checked at the processing plant.

b. Labeling and Sealing of Containers

All containers used for storage and shipping of nuclear materials have to be properly sealed and labeled. Sealing of the U308 containers is accomplished similar to the normal sealing procedure for 55 gallon drums. These drums are then loaded into the modular shipping containers and these shipping containers are sealed just as they would be for any cargo. The drums and the shipping container are labeled so that their contents are identifiable and traceable.

The UF6 containers are also labeled. The valve systems for these cylinders are an extremely important part of the containment vessel. Filling and emptying must be carried out through the valves, and these valves are potentially vulnerable to breaks or leakage. The large vessels, that is the 48X and 48Y cylinders, require a valve protector to fit over the valve. This valve protector is sealed with leaded seals to insure that there is no tampering with the valve during transportation or storage. The cylinders must also be identified with a stainless steel nameplate welded to the cylinders. This nameplate includes the cylinder owner's name and serial number, and the manufacture date of the cylinder. These cylinders must be checked every five years (or after unloading, if they were used for storage past the five year limit) for pressure tightness and recertified for use.

c. Radiation Monitoring [8]

When utilizing materials which emit radiation, means of measuring the level of such radiation are essential to the safe handling and storage of these materials. Since each such material emits its own level and kind of radiation, specific detecting instrumentation can be selected to match this radiation. In the case of unused (non-irradiated) nuclear reactor fuels the radioactive material is uranium, which contains three isotopes: U-238, U-235, and U-234. As indicated in Section I-b, the contribution from radon associated with processed uranium fuel is generally at or below background, thus the only emitters of consequence are the three uranium isotopes.

The natural decay schemes, isotope abundances, and emitted decay products are tabulated earlier in Section II. Thus, instrumentation must be sensitive to alpha, beta, and gamma radiations. Each has its own characteristic behavior and, thus no single sensor is optimum to measure all three radiation levels. In addition, for field use instruments must be portable and rugged. They must respond rapidly and display visually if quantitative measurements are required. Further, a wide range of sensing levels is required to cover trace amounts of material as well as larger amounts, which could result from container releases.

At storage sites both immediate, short time, rate measurements and long term accumulative measurements are required. The former are typically determined by portable instruments, while the latter are usually determined by use of film badges which are read remotely and only after periods of weeks or months of exposure.

A survey instrument which satisfies these monitoring criteria is the portable Geiger Counter, which is sensitive to beta and gamma radiations when the shield over the thin window of the chamber is in place and additionally is sensitive to alpha radiation when the shield is removed. Further, this instrument can be used as a pulse-type detector which can provide audible pulse signals to the user. This mode of operation is particularly useful for low level survey work where the count rates are so low that quantitative measures are not needed. However, for rates of significance (i.e. above background) the quantitative values can be displayed on an output meter. Such counters provide good utility for regular monitoring locations within a radioactive control area.

Where count rates are low and regions need to be monitored for contamination by radioactive materials, smears are collected from surfaces and the activity levels and characteristics are determined from a centralized monitoring system. Such techniques are particularly useful for detecting the effectiveness of clean-up and decontamination following release of radioactive materials.

For long term, environmental, radiation dose level determination, the use of thermoluminescent dosimetry (TLD) materials is convenient. These detectors use materials such as LiF which, when subjected to radiation bombardment, have ionization trails left in them. The number of trails accumulated, over a given period of time, is measured and compared to a standard, from which the average rate of exposure at a given location can be determined. Locating these rugged sensors at selected positions around a site enables regular determination of the radation levels present for that period. These devices are sensitive to both gamma and beta radiations. This makes these detectors particularly suited for following long term site radiation levels and alerting staff to the presense of changes over the period. They, further, provide regulating groups with data to insure that site operating staff are complying with environmental radiation standards under which the facility is licensed.

The use of portable monitors and smears allows containers to be carefully scrutinized to determine container integrity. Using regular scheduled container inspections with Geiger counters will enable staff to determine if above background concentrations of radiation are present. If such are found, procedures for determining their origin and cleanup can be initiated.

During direct shipping and handling of containers the Geiger counter type portable monitors, referred to above, provide a means of determining the presence of above average radiation levels either on the containers or in the storage area.

As with all measuring equipment, on site calibration verifiable for each use of instruments is desirable. For example, portable Geiger counters can be checked for both beta and gamma sensitivity using technetium and cesium calibration sources, respectively. Regular off-site recalibration is desirable at extended intervals.

As with all radiation controlled areas, personnel should also have their accumulated radiation exposure determined over weekly or biweekly monitoring basis by personal film badges. These should be sensitive to both beta and gamma radiations. Using a commercial service is a convenient means of providing verifiable levels of radiation exposure of personnel.

d. Transportation and Handling of Containers

All shipments of nuclear materials are regulated by the US Department of Transportation (DOT) and the Nuclear Regulatory Commission (NRC). The standards for packaging and transportation by DOT are given in Title 49 Code of Federal Regulations parts 170 to 179 (49 CFR 170 to 179). The regulations by the NRC are given in Title 10 CFR 71. (The postal service also has regulations regarding shipping of nuclear materials by post.)

Nuclear materials are grouped by type into seven transportation groups, I to VII. Natural, depleted, and enriched uranium fall into Group III. Each of these Transportation Groups has a limit on the amount of radioactive material which can be shipped. Below certain activity levels, the material is exempt from shipping container requirements, but above these levels shipping containers Type A or Type B must be used for materials transportation. Large quantity shipments are also identified. Table IV.2. shows the limits for all seven groups of materials.

Table IV.2.

Quantity Limits for the Seven Transportation Groups

Group	Exempt	Activity Level (Ci)		Large Quantity
		Type A	Type B	
I	< 10^{-5}	10^{-5} to 10^{-3}	10^{-3} to 20	> 20
II	< 10^{-4}	10^{-4} to 0.05	0.05 to 20	> 20
III	< 10^{-3}	10^{-3} to 3	3 to 200	> 200
IV	< 10^{-3}	10^{-3} to 20	20 to 200	> 200
V	< 10^{-3}	10^{-3} to 20	20 to 5000	> 200
VI	< 10^{-3}	10^{-3} to 10^{+3}	10^{+3} to $5 \times 10^{+4}$	> 5000
VII	< 25	25 to 10^{+3}	10^{+3} to $5 \times 10^{+4}$	> $5 \times 10^{+4}$

Most material is shipped in either Type A or Type B containers. Type A containers must meet the standards for construction in 49 CFR 173.24 and 49 CFR 173.393. They also must not lose their contents and maintain their shielding capabilities when subjected to a series of tests designed to simulate package stresses found during normal transportation. Type B containers must be more robust. They must also meet 49 CFR 178.104. They must be capable of surviving 1.) free fall from 9.2 m (30 ft) onto a flat surface, 2.) free fall of 1 m (39 in) onto a steel plunger, 3.) a fire for 30 minutes at 802 C (1475 F), and 4.) fissile materials only, immersion in water to 0.91 m (3 ft).

These containers have also been designed for handling during loading and unloading, and for tie down during shipment.

The number of radioactive materials shipments is estimated to be between one and two and a half million per year in the US [13,14]. Of course, most of these involve small quantities of nuclear materials. About 50,000 of these shipments are Type B packages, the rest are either Type A packages or Exempt packages. Accident experience with nuclear shipments has been reported by Grella [14] for the period 1971 to 1975, and by McCluggage [15] for the earlier period 1949 to 1970. Of the 32,000 accidents involving all hazardous materials between 1971 and 1975, only 144 involved radioactive materials: 74 from air carriers, 65 from highway carriers, and 5 from rail carriers. The general experience has been that the incidence of accidents has been low, and releases limited to small quantities. Since Type B packages are extremely robust, they can survive most any accident condition without materials release.

Several Nuclear Regulatory Commision (NRC) guides deal with packaging and shipping nuclear materials. Some of these are Regulatory Guide (RG) 7.1 Administrative Guide for Packaging and Transportaion of Radiologically Contamintated Biological Materials, RG 7.3 Procedures for Picking Up and Receiving Packages of Radioactive Materials, RG 7.4 Leakage Tests on Packages for Shipment of Radioactive Materials, 7.5 Administrative Guide for Obtaining Exemptions from Certain NRC Requirements Over Radioactive Materials, and 7.7 Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Materials.

V. Nature And Selection Of A Nuclear Material Storage Site

A natural uranium storage facility provides room for the slack in the timely flow of nuclear material as it moves from the uranium mill and proceeds through the steps of conversion, enrichment and fabrication of new fuel assemblies for use in a reactor. Any delay in having new fuel assemblies available for a new reactor translates into the delay of its commercial operation. Similarily, the delay in the refueling of an operating reactor because fresh fuel assemblies are not available requires that the utility replace the electric power the reactor would have produced using another plant (or plants). Generally, the utility has a loading order in which the plants that produce electricity the most inexpensively are loaded first and the most costly are loaded last or saved for standby operation. The difference in fuel cost represents the extra cost of replacement power. For a large reactor, this extra cost can be prohibitive and steps are taken to avoid a delay or shut down of a nuclear plant.

To illustrate this penalty, consider a 1000 Mw(e) (megawatts electric) nuclear plant that operates at an average 65% capacity factor. If it is delayed in startup or forced to shutdown because of fuel shortage, electric energy would have to be supplied by reserve generation, or purchased from another utility. The cost may range from 2 to 8 cents more per kilowatt-hour in incremental cost. This places an extra daily cost of replacement power to range from $320,000 to $1,248,000. This assumes replacement fuel was coal and the range of cost from new to old plant, respectively. If oil was used as replacement fuel, the daily replacement cost would be even greater. The important considerations for the selection of a nuclear materials storage site are identified and explained in the following section.

a. Proximity To The Processing Plants

A uranium storage site that stores both U308 and UF6 that originate in the U.S. should be located somewhere on the interstate system between Gore OK and Paducah KY. The U308 would originate from the mills located in western states or Texas that do not utilize the conversion service at Gore OK and the UF6 would be coming from the conversion plant in Gore OK. Final destination of UF6 from such a storage facility is the enrichment plant at Paducah KY. Final destination of U308 is also Paducah KY, except that it would pass through Metropolis, IL for conversion before entering. Given two sites of equally safe design, being close to the enrichment plant is not necessarily an advantage. Consideration should be given to the minimum ton-mileage exposure of the fuel during its transportation as it can factor in on the minimum cost of storage.

Some electric utilities have found excess separative work units (SWU) of enrichment available from foreign enriching plants at attractive prices, therefore UF6 may be shipped out of the US from a uranium storage site. Foreign enriching is available from England, Netherlands, West Germany and France, all of which countries have newer and more energy efficient plants. On occasion US utilities have been able to purchase and import natural U308 or UF6 at competitive costs. Upon entering the US this fuel would be enriched at Paducah KY much like uranium that originates in the US.

Imported enriched uranium would be shipped directly to a fabrication plant, not requiring storage in the US as it is at this stage much too expensive to just sit around for any amount of time.

b. Transportation Access

Easy access to an interstate highway system is important for a uranium storage facility. Reducing the miles of secondary road travel would reduce the exposure of US originated source material to an accident. Most of the US ports of entry are close to the interstate highway system, hence easy access to the storage site is the only consideration of transportation access.

c. Security Including Fire, Police, Services, Etc.

A nuclear material storage facility by license is required to maintain adequate 24-hour security and radiation monitoring surveillance. The site should be serviced promptly by an adequate police force and have an experienced and trained fire department available at a moment's notice. The fire department should be trained to handle nuclear materials and have the proper chemicals on hand to put out any blaze with minimum spread of source material.

The site should not stand out or attract unwanted attention. Services that are necessary involve the use of a crane to load and unload truck shipments, repair and clean-up of damaged cargo containers, available truck repair to accomodate breakdowns. The site boundaries that are accessable should be within radiation exposure limits.

d. Water Drainage, Flooding, Flight Path, and Other Considerations

Natural or depleted uranium stored at a site does not pose a criticality safety problem regarding water. Water and flooding does interfere when it comes to security and other disruptions it can cause. A storage site should have good drainage and lie above a flood plain. It should not be in the direct flight path of a major airport even though the added damage caused by such a crash in a storage facility would be minor.

whole page simply says what good site should have

e. NRC Licensing Requirements

The Nuclear Regulatory Commission (NRC) requires anyone who plans to use, transport, store or process nuclear materials to obtain a "Source Material License" pursuant to the regulations in Title 10, Code of Federal Regulations, Chapter 1. Part 40. Application form NRC-2 must be filled out completely with filing fee.

In filling out the application form, the applicant soon realizes that the NRC intends that the applicant be knowledgeable in all aspects of the chemical and physical form of the source material; that the applicant sets up and maintains trained and experienced personnel and supervisors responsible for the radiation safety program; that the applicant describes all the chemical, physical, metallurgical or nuclear processes in which the source material will be used, indicating material amounts used in each step and a thorough evaluation of the potential radiation hazards associated with each step of those processes; That the applicant describe the equipment and facilities it will use to protect the health and minimize the danger to life and property; that the applicant will describe the

radiation detection and related instruments it plans to use, how it will periodically maintain calibration and what standards it will use for this calibration. The applicant is asked for a detailed description of its radiation survey program and emergency procedures in the event of accidents which might involve source material. Should they apply, the applicant is asked for details concerning ventilation equipment as it may apply to fumes, dust, mists or gases, including plan views of such protective equipment.

The qualifications and sincerity of the applicant definitely shows up in the quality of the application that is filed as this document becomes the guide lines under which the applicant is expected to operate. An application for a storage facility has less steps to consider than one that involves a process, however, the procedures used in the operation require the same attention to detail and documentation of compliance.

VI. Suitability Of The Edlow East St. Louis Site

The Edlow International nuclear source material site is located in an industrial area at 3131 St. Clair Ave., E. St. Louis, Il. 62202. Situated on about 11 acres, the rectangular area is bounded by St.Clair Ave. on the south, a railroad track and I-64 on the north and undeveloped land on the immediate east and west. The outer fence encloses less than 10 acres of the site as the south fence line is set back about 100′ from the road. A lone business, a tire dealer, has a building that fronts on St. Clair and is located just east of the storage site entrance gate. The drive into the Edlow site doubles as the west entrance or exit from the tire business. Since the Edlow site is unmarked and the fence is set back, it is easy to pass by the site only noticing the tire dealer and the large pile of used tires behind his building. The outer fence is an 8 feet high cyclone type capped with barbed wire slanting outward above the fence. A large swinging gate that is always locked except for controlled access faces south and is visible from a small office building that adjoins a complex of connecting wasehouse buildings. This office is for the site supervisor. Observing the site from the gate is the warehouse complex, the small office building, some concrete foundation of a previous warehouse building and several overseas type steel shipping containers, all placed in rows. Some containers were just within the outside fence (empty containers) while others were enclosed in a second set of wire fences that formed the main storage compounds. Each compound had large swinging gates that were locked and secured for intrusion detection.

Without prearrangment, it would be impossible to gain access to the site. Upon the authors′ first visit to the site (we had made an appointment) we were required to show positive identification that agreed with our credentials and expected time of arrival.

The tire dealer has the building near the street on a low-rent "good neighbor" basis. The business doubles as the abode for the proprietor, providing nusiance surveillance on the south perimeter of the fence for much of the day and night. The front gate and east storage area is visible to the supervisor from his desk at the office building.

a. Type Of Site

Interstate I-64 passes over and exits on to 25th Street just 6 blocks to the west of the Edlow site. St.Clair Ave. parallels the interstate and intersects 25th Street a block south of the interstate at a traffic light. Prior to the completion of I-64, St.Clair Ave. was US-50, an east-west highway accustomed to heavy truck traffic.

The area enclosed by the perimeter fence is barren and mostly gravel. Vegetation is sparce to cut down on maintenance and discourage ground animals that can disturb the surveillance system. The area is quite clean of paper and other burnables. There is evidence that the area had been a storage yard for metal in previous years as a few small chips of aluminum and copper show up among the gravel. In the double fenced area where storage is intended, the gravel is newer and elevated a foot or two as a result. It has good drainage regarding local down pours, should they occur. The site is located between the levee and the Mississippi river but above the flood plain.

The railroad traffic while passing along the north boundary of the Edlow site does not have high speed travel , greatly lessening the damage that can occur from a derailment.

Truck transportation is provided by the least expensive, reliable trucking firm available at the time of shipment. These companies must be experienced and licensed to haul source materials such as U308 and UF6. The shipments are scheduled and planned well in advance of the shipping dates. This provides for efficient control of the shipping operations and adequate traceabilility of the materials being shipped. Being an industrial area, suitable cranes with special handling rigs can be scheduled on site with little delay for loading and unloading containers and cylinders of source material. Using experienced personnel reduces radiation dosage and minimizes accident potential in the whole operation.

The flight paths from local airports was checked by consulting the chief pilot of flight training, Omer Benn, at the University of Illinois Institute of Aviation at Willard Airport in Champaign, IL. The Edlow site is located ~15 miles east-southeast of Lambert St.Louis International Airport and ~17 miles west-northwest of Scott Air Force Base, a Material Air Command (MAC) group. There is a local Bi-State Parks Airport about 4 miles southwest of the site. All of these airports have runways in the northwest southeast direction (nominally 300 and 120 degree directions). The Edlow site is not in a direct flight path to the runways on clear days. To Lambert, the path is about two miles to the north and the plane altitude at this point 3500′ above sea level (St.Louis is ~500′ above sea level). Under instrument conditions (ILS) a plane coming to the airport from the south may be traveling to the northeast (229 degrees) and about a mile from Edlow running a vector to the Troy radio transmitter that is 26 miles due east of Lambert. Planes on this path are from 5000′ to 8000′above sea level. Traffic patterns for planes arriving from other directions are not near at all to Edlow. Scott Air Force Base′s direct path is about 3 miles north of Edlow and 17 miles from the airport hence at a higher expected altitude. Edlow being further away from Scott and not in a direct flight path, ILS condition vectors are more remote and higher in altitude. The Bi-State Parks Airport is for small planes and is not set up for instrument landing. There would be traffic of small plane practicing take off and landing procedures that may pass over the Edlow site at above 2000′ on occasion. The threat of a small plane accident from Parks into the Edlow site is indeed remote.

b. Types Of Materials Stored On Site

No enriched or spent fuel, but only natural U308, natural UF6, and depleted UF6 are stored at the Edlow facility. All of this material is stored outside in double fenced compounds. As the name Edlow International implies, their customers are world wide. The U308 stored on their property may be domestic in origin or it may be imported. Canada, Australia, and other countries have uranium available for sale. The owners of this uranium can vary greatly. It could belong to US electric utilities, to US companies that fabricate nuclear fuel assemblies, to US energy companies, to energy authorities of foreign countries, or to foreign fabricators of fuel assemblies. The destination of this material is equally varied. The U308 is uniformly stored in overseas steel containers that can hold several 55 gallon steel industrial drums. Each drum contains from 600 to 1000 lbs. of yellowcake. Except to check the shipment for integrity and radiation level, there is no reason to unload the large containers while at Edlow.

The natural UF6 stored on site can have about the same range of ownership as noted previously for U308. Destination of UF6 is generally to an enrichment plant. Their locations were noted in sections Id.and If.

Depleted UF6 stored on site may have owners as noted for natural UF6. The use of depleted UF6 is a bit more difficult to contemplate. It has use as blanket material in breeder reactors, but only the French are presently building breeder power reactors. Since depleted uranium does not have much value, the owner may soon find more permanent storage.

c. Adequacy Of The Site Security

The E. St. Louis city boundary line includes only the west half of the Edlow site, the part that contains most of the warehouse structures. The eastern portion is just in St.Clair County. The uranium, being stored outside is on the east half of the property,thus only in the county. There is no Illinois tax on temporarily stored property based on its value, so the location of the storage on the site is not tax motivated. Property tax on the warehouse and land is supported by Edlow through its lease payment to the property owner, DRK Properties.

The East St. Louis Fire Department and Police Department are located about one mile from Edlow. They service the site through special arrangements. The fire department has been trained on how to handle fire around uranium and have special chemical extinguishers to combat fire around this material. The police from both the city and the county service the Edlow site. Edlow has a printed Warehouse Operations and Procedures manual that they follow. It is up-dated periodically to get current names, addresses, telephone numbers of key people in case of emergency. Copies are distributed to the police and fire departments and to others on a need to know basis.

The city line boundary being where it is, Edlow does pay for the city fire department to answer all site calls. Edlow even insures that proper chemicals are on supply at the fire station by purchasing it whenever it is low, for whatever reason.

No uranium is stored inside the warehouse building. This precludes a potential hazard of a building fire causing a release of material from U308 and/or UF6 containers. Storage in the warehouse is limited to empty shipping containers, spare 55 gallon industrial drums for clean up and repair, equipment to handle radiation monitoring, decontamination equipment, leak repair equipment and waste disposal containers and clothes. The warehouse in general is clean, orderly and nearly empty.

The Edlow International Company "Warehouse Procedures Manual" is in the possession of the site supervisor [9]. The manual covers Instructions for Geiger Counter Use, Emergency Procedures and Radiation Detection Procedures with Reference to Source Material Storage, Warehouseman's Operating & Administrative Procedures, Operating & Administrative Procedures-Edlow International, Basics of Radiation-Training Course Outline, Quality Assurance Procedures, and Reports and Forms.

The Manual is complete and very informative. It categorizes emergency into two types 1) fire or threat of fire and 2) no immediate fire threat. In each case, instructions are clear and specific. Items explicitly covered are fire, damage to U308 drum, and leaking UF6 cylinder.The most vulnerable part of a UF6 storage cylinder is the 1" valve on the end that is used to fill or empty the container. The valve has a heavy cover that protrudes. To protect this from shearing, the heavy cylinder wall has a protective skirt on the end to take the brunt of any mishandling. Whereas the valve is protected, it is the part of the cylinder most likely to leak. As stated in section IIIc, when UF6 is exposed to moist air it reacts chemically forming UO2F2 that cakes together to fill the leak and stop the ingress of moisture. The emergency kit to repair a UF6 cylinder valve contains all the items, including wood plugs, that are needed to carry out the repair. The procedures tell you what to expect, what to wear, how to reduce contamination should it be a problem, and how to clean up when you are through. In general, Edlow has people trained to carry out cylinder valve repair and cope with other storage and container movement damage. Initial safety measures are taken to secure the area, and trained personnel from the Edlow International Co. in Washington DC are sent to supervise any longer term repair and clean-up operations.

Receiving, unloading and storing new material is spelled out in the Operations Manual. This includes such things as the measurement of radiation on the containers, documentation of container serial numbers and protective clothes to wear.

Edlow promptly notifies warehouse personnel of upcoming shipments and provides an update by phone of its progress. Warehouse personnel arrange for crane and/or fork lift trucks as needed for the shipment to be received. The crane company is notified promptly of the types of containers and cylinders that will be received to insure proper rigging and fittings are brought with crane. Crane operators experienced in handling Edlow material are requested. Only warehouse personnel trained to operate under 10CFR19.12 are allowed to handle the material. Cylinders of UF6 are checked before unloading the truck using Geiger Counter equipped with beta probe. Smears are taken at 5 specific locations on the cylinder. If within limits, serial and seal numbers are verified and recorded. Cylinders are unloaded with a crane and rigging and placed on railroad ties in its stored location. Cylinders are not lifted over one another and are not stacked. Names of all personnel used in the operation are recorded along with their job function and time spent handling the material.

The resident warehouse supervisor conducts a daily visual check of the site that takes up to one and one-half hours to complete. A daily log of all activity on the site is kept. The who, when and why of all that entered and left the site is logged. There are weekly, monthly and quarterly radiation measurements and checks made and documented to insure the safe storage, receiving and shipment of the source material at the Edlow site.

Radiation checks on the site are three fold:

1. Smear tests for alpha particle emission are made on each UF6 cylinder that is received or shipped out. In addition they are made quarterly while in storage. This smear test will detect a minute leak.

2. Geiger counter is used monthly to take perimeter and interior fence and building readings. Counters are calibrated every 6 months.

Readings are taken within 3, 10, and 20 feet from all source material stored. This defines the radiation source accurately and these periodic readings quickly signal any change that may need attention.

3. TLD's are used to measure the total radiation dosage about the perimeter of the site, on the interior fences and at the building (to establish background radiation).

The 13 TLD site locations are serviced and read by an independent organization, Eberline Instrument Corporation on a quarterly basis.

This independent check provides assurance that the site is being operated within licensing requirements.

Physical and electronic means are used to protect the material in storage. The 8 ft chain link fence topped with barbed wire around the perimeter of the site, with a second fence of similar construction to form the storage compounds constitutes the physical restraint. No cranes are left on site after shipments are complete. Locks and intrusion alarms on the fences alert a local security company. The supervisor in making his movements about the yard must log his activities and clear them with security, so that his movements are not mistaken for a site intrusion. Uncleared alarms with security bring a quick response.

The Nuclear Regulatory Commission requires that the proper codes of federal regulation regarding radiation detection, safety, training and emergency procedures are met by source material licensees and upon approval issue a license. The NRC conducts regular visits on an announced and unannounced basis. Fines are assessed by the NRC for the slighest infraction or misinterpretation of the regulations.

d. Licensing History

Edlow was granted a license by the US NRC to store source material at the East St. Louis site on Feb.14,1980. This license, SNM-1377 expires February 28,1985. A renewal of this license has been filed with the NRC. Edlow has also possessed a warehouse license #77000 from the Illinois State Department of Agriculture. A warehouse license is required in Illinois to store personal property for a fee. The Illinois Department of Nuclear Safety (INDS) is also aware of the Edlow source materials storage and are contacted by Edlow in cases of emergency. IDS conducts periodic visits to Edlow in line with its safety mission in Illinois. On Dec. 7, 1983, a fire destroyed the east most warehouse building (there are two left now). At that time UF6 was being stored in the buildings, however, no breach of containment resulted. Now , NRC requires all uranium, including UF6 cylinders, to be stored outside. Mr. David Ed, investigator for IDS, had praise for Edlow staff in response to the fire and investigation that followed.

VII. Summary And Conclusions

In this paper, the need for interim storage of natural uranium fuel in the form of yellowcake (U308) and uranium hexafluoride (UF6) has been established, and its location in the fuel cycle has been reviewed. The procedures for transporting and storing these materials have been examined along with the their physical properties and their environmental implications. Since the supply of uranium is international, not just domestic, a broad variety of transportation modes exist in moving the materials from mining locations to enrichment plants. Thus, centrally located sites for interim storage provide efficient ways to facilitate the necessary movement of these source materials.

Since natural uranium is a weakly radioactive material, it must be properly packaged for handling, shipping, and storage to prevent its release to the environment. Close surveillance of material containers to monitor their integrity can be readily handled through the use of radiation detection methods. These methods are sensitive to minute traces of radioactive material and are available in portable units so that direct measurements of the containers and their surroundings can be regularly documented to show compliance with licensing requirements.

In selecting an interim storage site for natural uranium materials, several criteria beyond the proximity of processing plants and transportation access are important. Adequate site drainage, absence of flooding, and separation from potential local hazards are necessary. In addition, community services for both fire protection and security play an essential role in site selection and operation.

The Edlow International Company nuclear materials storage site in East St. Louis, IL meets all of the site selection criteria mentioned above. The materials stored at this site include only natural U308 and UF6 or UF6 with depleted concentrations of U 235. No enriched uranium or spent fuel materials may be stored at this site. The Edlow International Company has obtained a sources materials storage license from the Nuclear Regulatory Commission to operate this site, and thus has met the federal requirements for such operations. The adequacy of this site is also overseen by the Illinois Department of Nuclear Saftey, the only cabinet level state agency in the country dedicated exclusively to radiation safety.

In the opinion of the authors of this report, the Edlow International Company, East St. Louis, IL, Source Materials Storage Site is operated well within the letter and spirit of Federal and State regulations governing such operations. The site security, including fire and police protection, radiation monitoring, safety procedures and practices, and hazards control meet or exceed all requirements. Thus, this site presents no undue risk to the surrounding public; and, in fact, represents a resourceful use of the existing properties.

VIII. References

1. Brandfon, W.W.and Hang, D.F., "LWR Recycle-Economic At What Price U308?," Atomic Industrial Forum, Fuel Cycle Conference 80, New Orleans, LA, Apr. 1980,

2. Youngberg,E.A., "Uranium Exploration, Mining & Milling", Ch. V of "Education & Research In The Nuclear Fuel Cycle", Editors-Elliot & Weaver, Univ. of OK. Press, 1972.

3. Levin,R.W., "Conversion & Enrichment In The Nuclear Fuel Cycle", Ch.VI of "Education & Research In The Nuclear Fuel Cycle", Eds.-Elliot & Weaver, Univ. of OK. Press, 1972.

4. Benedict and Pigford, "Nuclear Chemical Engineering", Mc Graw Hill Co. Inc, 1957.

5. "A Comparison of Future Costs of Nuclear and Coal-Fired Electricity", by Study Group of the Committee on Financial Considerations, Atomic Industrial Forum, Bethesda, MD, Nov., 1984.

6. "Expansion of US Uranium Enrichment Capacity", ERDA-1543, April, 1976.

7. "Statistical Data of the Uranium Industry" GJO-100(79), US Dept.of Energy, Grand Junction, Co.

8. Foster and Wright, "Basic Nuclear Engineering", Allyn & Bacon, Inc., Fourth Edition, 1983.

9. "Warehouse Procedure Manual", Edlow International Co., Washington, DC, 1984.

10. "Instruction Concerning Risks from Occupational Radiation Exposure," Regulatory Guide 8.29, Nuclear Regulatory Commission, July 1981.

11. J.R. Lamarsh, "Introduction to Nuclear Engineering," 2nd ed., Addison Wesley Publishing Co., 1983.

12. E.L. Keller, et al., "Uranium Hexaflouride, Handling Procedures and Container Criteria," ORO-651 and revisions, Oak Ridge Operations Office, 1966 and after.

13. "Shipments of Nuclear Fuel and Waste...Are They Really Safe?," WASH-1339, USAEC Division of Waste Management and Transportation, Aug, 1974.

14. A.W. Grella, "A Review of Five Years Accident Experience in the USA Involving Nuclear Transportation," in "International Seminar on the Design, Construction and Testing of Packing for the Safe Transport of Radioactive Materials," IAEA-SR-10/5, Aug, 1976.

15. W.C. McCluggage, "The AEC Accident Record and Recent Changes in AEC Manual Chapter 0529," in "Proceedings of the Third International Symposium on Packaging and Transportation of Radioactive Materials," BNWL-SA-3906, Aug, 1971.

Edlow International Company
1815 H Street, N.W., Suite 910
Washington, D.C. 20006 U.S.A.
(202) 833-8237
WUI 64387

W. Gibson
→ Bruce Hallett - "Edlow White Paper"

The Honorable Carl Officer
Office of the Mayor
City of East St. Louis
East St. Louis, IL. 62205

February 25, 1985

FYI
pls return

Dear Mayor Officer:

As you know, the Edlow International Company has frequently expressed its sensitivity to the concerns of certain people regarding its natural uranium interim storage facility, located in an industrial zone in East St.Louis, Illinois.

We have voluntarily met with East St.Louis city officials, with key members of various citizens organizations, as well as with many residents, and believe we have contributed to putting many of their apprehensions to rest by our efforts at an earnest and open dialogue regarding this quite ordinary storage facility. However, despite even the added assurances of the monitoring Nuclear Regulatory Commission (NRC) as to the facility's safety and security, misunderstandings about the storage warehouse continue to circulate, creating cruel and unnecessary anxiety amongst local families.

Because of this, we made a further effort to arrive at a universally credible evaluation of the facility. We asked outside consultants to commission a fully comprehensive, scrupulously-objective professional study of the warehouse.

Acting independently of Edlow, the consultants selected three distinguished nuclear experts from the University of Illinois, at Urbana, Professors Daniel F.Hang; Barclay G. Jones, and James F.Stubbins, all scholars of impeccable professional standing, and residents of illinois.

Their wholly unbiased, critical study, conducted during the months of December 1984 thru February 1985, tracks and examines Edlow's East St. Louis facility from every aspect.

Their findings are contained in the attached report. We felt it was important to place the study in your hands immediately ---as it should answer once and for all those continuing questions raised by the remaining critics of the facility.

Sincerely,

Robert Rich

Robert Rich
Executive Vice President

Attach.

OUTLINE & EXTRACT OF INDEPENDENT EDLOW STORAGE FACILITY STUDY

Title: Considerations for Siting & Operating a Natural Uranium Interim Storage Facility (Case study of the Edlow Int'l. Co. East St. Louis, Il. Site)

Authors: Professors Daniel F. Hang, P.E.; Barclay G. Jones; James F. Stubbins, P.E. - Nuclear Engineering Dept., University of Illinois, Urbana, Il.

For: R. L. Mayall Capital, Ltd., New York

Date: February, 1985

Contents:

Findings: "Only natural U308, natural UF6, and depleted UF6 is stored at the Edlow facility. No enriched uranium or spent fuel is stored..." (VI.,34/b.1)

"...natural uranium is a weakly radioactive material..." (VII.,38/2)

"Two hypothetical (worst case) accidents (involving contents of a UF6 shipping cask) were reviewed...the releases (would not be) disastrous...the liklihood of such major accidents (at Edlow) is very, very small." (iii/2)

"In the opinion of the authors, the East St. Louis, Il. site of the Edlow International Company meets and/or exceeds all of the (required) criterea...has excellent security... storage locations are outside the warehouse building providing a minimum fire hazard. A good working arrangement with the local fire depts. provides for a strong response in case of fire. A close working arrangement with the police in both the city and the county provides a rapid and sure response to insure security. (iii/4)

not true — For U_3O_8

"Based on the author's review of the site operating procedures, the security and safety ties with the local fire and police units, and the site characteristics, <u>it is concluded that the Edlow storage site does not present an undue risk to the surrounding community, and appears to be a responsible part of that community."</u> (iii/4,5)

what criteria did they use?

"Without prearrangement, it would be impossible to gain access to the Edlow site. Upon the author's first visit (we had made an appointment) we were required to show positive identification that agreed with our...expected time of arrival." (VI.,33/2)

"The flight paths from local airports was checked... the Edlow site is not in a direct flight path to the runways...traffic patterns for (aircraft) arriving ...are not near at all to Edlow." (VI., 34/3)

"The resident warehouse supervisor conducts a daily visual check of the site that takes ~~up to one and~~ one/half hours to complete. A daily log of all activity...is kept...there are weekly, monthly and quarterly radiation measurements and checks made and documented to insure safe storage...' (VI.,36/c9) — need to put this in their backup

"The Nuclear Regulatory Commission (NRC) requires that the proper codes of Federal regulation requiring radiation detection, safety, training, and emergency procedures are met...(NRC) conducts regular visits on an announced and unannounced basis." (VI.,37/3)

"The Illinois Dept. of Nuclear Safety (IDS) is also aware of the Edlow storage facility, and are contacted by Edlow in cases of emergency...Mr. David Ed, an investigator for IDS, had praise for Edlow staff in response to the (12/7/83) fire and investigation that followed." (VI.,37/d1)

"In the opinion of the authors of this report, the (Edlow) source materials storage site is operated well within the letter and spirit of the (Federal & State) regulations governing such operations. Site security, including fire and police protection, radiation monitoring, safety procedures and practices, and hazards control, meet or exceed all requirements. Thus, <u>the site presents no undue risk to the surrounding public; and, in fact, represents a resourceful use of the existing properties.</u> (VII.,38/5)

###

<u>Note:</u> Extracts footnote ref ( ) = section, page, paragraph, corresponding to attached report.