# EXPERIENCES

OF

STUART McLAIN

January 1975

TABLE OF CONTENTS

# I. INTRODUCTION

I have had three experiences that were somewhat specialized in some respects. The first section and parts of the second section were written almost entirely from memory, but a journal and office files were used for most of the rest.

The experiences were:

a. Aberdeen Proving Ground
b. Nuclear Development
c. Start of a Business

A considerable portion of the work was classified as Confidential, Secret, and some as Top Secret, both in the Army and the Atomic Energy Commission. A few items that I believe are still classified are not mentioned.

This is a very personal account and no effort is made to describe how my work fitted into the larger programs of which my work represented a very small part. It was written in 1973 and 1974.

## II. ABERDEEN PROVING GROUND

### A. Preliminary Training

During my undergraduate work at the University of Michigan from September, 1925 through June, 1929, I took military training. Since I was a Chemical Engineering student, I was assigned to Army Ordnance. The training which I received at Ann Arbor was very elementary except for a minimum discussion of ammunition and artillery design and manufacture. During the summer of 1928 I was assigned to a six weeks training course at Aberdeen Proving Ground, Maryland.

The training at Aberdeen consisted of lectures and actual firing tests on weapons up to the French 155 mm Gun of World War I vintage, and observation of repairs and maintenance of all types of weapons and ammunition. Of great interest to me was the museum with its limited samples of tanks, guns, mortars, armor, etc.

On completing my undergraduate work in Chemical Engineering, I was commissioned a Second Lieutenant in Army Ordnance. On completion of my work for the Doctor's Degree in Chemical Engineering in 1932, Winifred and I moved to Detroit. During the next few years I completed enough correspondence courses to be promoted to First Lieutenant, probably in 1935.

#### 1. Rock Island Arsenal

In the summer of 1935 or 1936 I was ordered to Rock Island Arsenal for a two weeks training course. Winnie and the boys were left with her parents in Helmer, Indiana, and I went to Rock Island by train. I believe we were then living in Detroit and I was teaching Chemical Engineering at the University of Detroit.

The Rock Island experience was of interest as the Arsenal was actually manufacturing recoil mechanisms and assembling components.

#### 2. Savanna River Ordnance Depot

In the summer of 1938, I think it was, I was ordered to Savanna Ordnance Depot in Illinois for two weeks training. At that time I believe we were living at Fayetteville, Arkansas, where I was teaching Chemical Engineering. I believe Winnie and the boys stayed in Helmer, Indiana.

At Savanna the dozen or so reserve officers were on their own. Colonel John C. Brier, who was a Professor of Chemical Engineering at the University of Michigan at Ann Arbor, and an old professor of mine, was Commander of the reserves, and I was Assistant Commander. This meant that I had to give about half of the lectures.

The work consisted of about one half lectures and one half actual plant work. We were expected, in the two weeks, to have conducted personally all ammunition loading operations and to have written a critique regarding the plant and operations. This we did. The work included melting and loading shell with trinitrotoluol or TNT, ammunol or ammonia nitrate, etc. We loaded split shell, opened them and sawed the TNT loads to observe cavitation, destroyed TNT by burning, etc. TNT burns nicely! And safely!

One thing of note was that we corrected some of the poor installation of the TNT melter used in regular operations. We found that it did not work properly due to lack of proper air vents.

Then in the fall of 1938, I believe, I was promoted to Captain.

### 3. Picatinny Arsenal

In the summer of 1939 I was ordered to Picatinny Arsenal for two weeks. Again Winnie and Neal and Douglas were left at Helmer. And again Professor, or Colonel, Brier and I were the instructors. However, this course was unique and resulted in my learning more in two weeks than ever before or since. We lived in tents on the shore of Picatinny Lake near Dover, New Jersey. This was a beautiful setting even though we could only swim. No fishing was allowed as I remember it. As a result, bass and other fish were very commonly seen near shore and sometimes at night by being careful one could actually touch them. Living was of interest as it was easy to go swimming and go for long walks in the mountains. We ate at a barracks near the tents.

My tentmate, whose name I have forgotten, was a federal investigator assigned to check the income of the Mayor and rackets in Atlantic City. So we spent one weekend there.

In all there were twelve to fifteen officers present, including Brier and myself. All were highly educated and all, I believe, held very responsible positions. I remember one was Director of Research of Hercules Powder Company, and two were federal tax experts assigned to evaluation of railroads and dams for tax purposes.

We ran the classes by sitting around a large table with four on a side, and with the sixteenth place being occupied by an expert from Picatinny Arsenal in the area being discussed. We spent four hours in discussions and three hours in laboratory and inspections daily. Topics covered were loading and components of ammunition as well as long discussions regarding purity of materials, difficulties encountered, probability of fires and explosions, etc., etc. A most interesting two weeks of sessions. There was very little joking or extraneous discussion.

As customary, we were invited to the Commanding Officer's home for cocktails the first evening on the Post. The Commanding Officer was the same man that had been at Savanna Ordnance Depot when I was there. When we arrived at his home, not only he but his wife received us cordially as we all remembered one another. His wife offered us the usual drinks, starting with whiskey, cocktails, beer, etc. When I said, "I'm sorry, I don't drink," she asked, "How about hot chocolate?" And when I said, "Fine," she grabbed me by the arm and said, "A man after my own heart. Let's go to the kitchen." Of course, a half dozen others who preferred not to drink went along. And we all had hot chocolate.

## 4. Aberdeen Proving Ground

In the summer of 1940 I was ordered to Aberdeen Proving Ground along with Professor Brier and Professor, or Captain, Charles Selheimer, for three months, to revise and update Army Ordnance Reserve Training Manuals. Professor Selheimer had received his Doctor's Degree a couple of years before me at Ann Arbor and was teaching Chemical Engineering at Wayne State University. So we were all acquainted and all had had four or more years of Chemical Engineering teaching experience. It apparently appeared logical to order us in a group to Aberdeen for the assigned purpose.

Winnie, the boys, the dog and I left Fayetteville about one week before my duty began because we planned to drive leisurely to Aberdeen. On arrival we rented an apartment in Havre de Grace about eight miles from my assumed office, and got settled over the weekend. This apartment was of interest in its shabbiness, small size, etc., but it was light and airy. We believe it was an old slave quarters since it was in the loft of an old horse barn--long since converted to an apartment.

On Monday morning, as ordered, I reported at Aberdeen Proving Ground Headquarters. I was told that our assignments had been cancelled since it appeared war was imminent and the revised courses could not be printed before they would be of little use. Brier and Selheimer had received their revised orders before leaving home, while I had left earlier and had not been told to stay home.

I never understood why my orders were not immediately cancelled. I believe that my wartime assignment was to be Aberdeen Proving Ground; so I have always thought that General George Eddy (then Captain) simply said that I should stay at Aberdeen Proving Ground for the summer. At any rate, I was ordered to report to Captain John Cave at the Main Front while Headquarters got my orders cancelled. At the end of the three-month assignment the orders appeared to have been still in force because I was paid for the full three months.

### a. Organization of Aberdeen Proving Ground

At the time under discussion, or mid-1940, Aberdeen Proving Ground consisted of Headquarters and, I think, five main Divisions: Antiaircraft, Mobile Artillery, Small Arms, Trench Warfare, and Ballistics Research Laboratory. The Ordnance School was just starting. There had been a Coast Artillery Division, but apparently Mobile Artillery, Coast Artillery and Trench Warfare had been combined just before my arrival, and while the Division was officially called the Mobile Artillery Branch, it was informally simply called the Main Front.

Headquarters Division was just that, and consisted of perhaps a half dozen officers plus quite a number of civilian employees who furnished all services and maintained the museum. Services included not only the normal utilities but also the carpenter and machine shops, drafting services, measurements laboratories such as projectile velocity measurements, observations of impacts, maintenance of firing ranges, etc.

The Antiaircraft Division carried out the firing tests of ammunition and weapons and prepared the formal reports covering these tests. The Small Arms Division carried out development tests on their weapons, including the 37 mm Gun and prepared the formal reports. All hand weapons, including pistols, rifles and machine guns, are tested inside in closed ranges; so no production weapons tests were being performed at Aberdeen. Ballistic Research Laboratories carried out extensive research, prepared range tables, etc. They usually simply requested that the other firing ranges conduct their firing tests. They did have a static bomb test range.

The Main Front conducted the tests of the Trench Warfare weapons, all Field Artillery from the 75 mm Howitzer and larger, and included Coast Artillery, including the 16 in. Coast Defense Guns. This was a wide range of weapons and included Tank and Antitank Guns over 37 mm, all Field Guns and Howitzers, and many special weapons.

Main Front facilities in 1940 consisted of two warehouses about 40 x 140 ft, a powder storage building, a firing line of perhaps a quarter mile, and various weapons, tools, etc., and a small office. The types of tests being conducted consisted of tests of ammunition components, finished rounds, various guns and limited weapon development tests. All reports, etc. were sent to Headquarters for review, typing, etc.

The Main Front firing range faced southeast on the direct line from New York-Philadelphia-Baltimore to Washington. The socalled ranges or impact ranges which were equipped with concrete observation posts, telephones, etc., were located about 1, 2, 3, 5 and 15 miles down range or down the line of fire. The land area was several miles across but it was cut diagonally some 10 miles down range by the Bush River, so that to reach the farthest range required a 30 mile drive. On the right were the main lines of the Pennsylvania and Baltimore & Ohio Railroads. On the left was Chesapeake Bay. Between the Main Front and the railroads was the airport with some low level bombing ranges.

Firings of long range weapons were conducted by sending boats down the Bay and firing between ship passages directly into the Bay. As a result, firings were frequently interrupted and some troubles did arise during World War II.

b. Main Front Assignment

The Main Front personnel on my arrival consisted of Captain John Cave, three civilian proof officers, only one of whose names I remember, that of Louis Rhein, no secretaries, a civilian foreman and about eight civilian laborers or gun crew men. Trench Warfare included some five or six men. It is now necessary to turn to the Organization of the Ordnance Department to understand how our work assignments arrived.

I have very little conception, nor did I then, of the Organization of the Ordnance Department other than it was a Division of the War Department responsible for the development, issue, production and maintenance of all Army weapons and ammunition. The actual organization was huge and included the procurement of all Ordnance materiel, storage of the materiel, maintenance, field issue, recovery and construction of non-commercial items. This included all guns, their recoil mechanisms, carriages, tanks, all weapons and ammunition, and a host of similar items needed by the Army.

At that time and throughout World War II, the Development Division of the Ordnance Department that I was concerned with, operated on "Ordnance Minutes", or more truly, assignments agreed upon in meetings of the responsible officers and civilians in the Ordnance Development Board. Actually, proposals for the development programs or tests were prepared by the responsible officer or civilian and upon approval by a sort of Committee of the Whole, an Ordnance Minute would then become the legal document authorizing expenditures, development, construction and test of new components or weapons. Based on these Minutes, letters would be sent to the various organizations such as Aberdeen, authorizing construction of experimental weapons, ammunition, firing and road tests, etc.

(1) Case Tests

For the first several weeks that I was at Aberdeen I acted as a Proof Officer to help at first and later conduct routine firing tests. I believe the first was an "Acceptance Test of 75 mm Shell Cases". The test consisted of "firing seven rounds", consisting of seven sample cases loaded with regular weight shell and extra powder in a regular field 75 mm gun.

To understand the above statement requires a consideration of the reasons for the firing test.

Each "round", as issued to the field for use in war in the smaller field artillery weapons, consists of a brass or steel cartridge case, a primer or igniter, the necessary powder or propellant and the projectile or "shell". The projectile includes the fuse that starts the explosive train on impact after firing and the explosive or load in the projectile. The case for the 75 mm Gun consists of a copper alloy or steel tube some 14 in. high and about 4 in. in diameter, with an open top and a closed bottom with a hole in the center of the bottom for the primer. The primer consists of an igniter such as silver or lead azide, and a small charge of black powder in a paper lined brass tube, perhaps 2 in. long by 3/8 in. in diameter, in which several holes are drilled and which is brazed to a small plug. This primer is pressed into the bottom of the case. The lead azide is in the form of a pressed pellet about 1/8 in. in diameter and height, so placed that a thin copper shield may be compressed by the gun's firing pin, which in turn deforms or shatters the lead azide pellet, which in its turn explodes or detonates. This ignites the black powder which shoots flames throughout the regular pellets of 75 mm Gun powder in the case. The pressure rises rapidly due to the "burning" of the powder to perhaps 28,000 psi. Meanwhile the projectile is moving down the gun's barrel and increases in velocity until it leaves the gun at perhaps 1500 ft per second. Exactly these same processes occur in all pistols and rifles.

In the case of the test of "cases", seven cases were chosen at random from each lot or group of 10,000 to 20,000 cases made in sequence by a given manufacturer. These test cases were chosen by the Ordnance Inspector located at the manufacturer's plant. Each case was tested at 115% of the maximum allowable normal firing pressure. To pass the test, all cases must be rejected from the test gun freely. Failure consists of one or more cases expanding until it or they stuck in the gun breech. In the case tests cast iron projectiles were used to save costs. Similar tests were made on 105 mm Howitzer cases.

While not carried out on the Main Front, case tests were also conducted on certain Small Arms and Antiaircraft weapons.

The maximum pressure during the burning of the powder was measured by the amount of change in height or compression of a copper bar housed in a steel case with a small cup seal or piston. Each of these pressure gauges was about 3/4 in. in diameter by 2 in. in height. Normally 2 gauges were placed in the powder charge of each round fired.

(2) Shell Tests

During this same period I ran several acceptance tests of shell or projectiles of various sizes. These differed from the case tests in several respects. Five shell were selected from each lot of 10,000 shell. These were measured with a micrometer at several diameters. The shell were inert loaded with paraffin to regular weight as normally fired. They were then fired at, I think, 120% of maximum allowable firing pressure. The impact area was observed and each shell, as it landed, was marked by an observer and then dug up and later remeasured to make certain no deformation had occurred during the firing tests.

Since shell are rotated in flight to give them stability, they continue to rotate in the ground. However, the density of the earth is too great for stability and the direction of the shell changes. At an impact angle of about 15° the shell will turn direction and surface. If properly fired for the proper impact angle, most shell will surface and may be picked up very close to the impact position.

Live shell with inert fuses are sometimes fired as are live shell with live fuses to test for detonation, etc. Recovery of these shell is of course very hazardous, particularly those shell fired with live fuses which fail to detonate. Recovery is sometimes essential to determine causes of failures.

(3) Powder Tests

The test of the propellants for guns such as the 155 mm Gun is a very different matter. The powder for this gun consists of cellulose nitrate, which has been formed into pellets about 1 in. long by 0.25 in. in diameter, with 7 holes about 0.03 in. diameter, one in the center and 6 spaced half way from the center to the outside. Different size pellets are used for the different weapons.

In manufacturing, the cotton or other cellulose such as purified wood pulp, is reacted with nitric acid, washed and the cellulose nitrate softened with solvents, the mix is extruded, cut to short lengths, and the solvent is recovered by evaporation at slightly elevated temperatures, leaving the "powder" pellets. The powder is then blended by mixing for several recycles through large storage bins. The powder is then packaged in steel cans holding about 200 lbs each. Samples of these cans are chosen at random and used to "establish" the powder charges for the field firings. A "lot" consists of about 100,000 lbs of blended powder.

The powder charge is determined by firing projectiles of the standard weight and measuring the velocities. Low charges are used for the first two rounds, higher charges are fired until about 120% of the maximum pressure is measured at usually higher velocities than the field velocities. Then a 7-round group of charges is fired and a slight correction calculated for the powder weight to give the standard velocity. The entire lot can then be weighed into charges for issue to the field.

Since the powder varies considerably in rate of burning, the powder is always stored in constant temperature rooms, weighed as accurately as possible--usually to the nearest pellet or powder "grain", and fired before it becomes appreciably heated.

At the time in question velocities were measured by firing magnetized shell through coils of wire placed perhaps 20 to 30 ft apart. Velocities of 2,000 ft per second could be measured to within 1 to 2 ft per second. The weight of the projectiles was about 95 lbs.

During the summer of 1940 I ran 24 tests of 155 powder by firings in the 155 mm Gun M1. Each test consumed all of one day's work. A gun crew of five men and several other people were required to weigh powder, measure velocities, measure pressures, etc.

### c. Other Work

While I was at Aberdeen in 1940 an attempt was made for me to visit the other "Fronts" or "Firing Ranges" and observe regular and special firings. Two programs were of interest. These were the "Range Firings" of the 75 mm Howitzer and the 8 in. Howitzer.

#### (1) Range Firings

During a good part of the summer Louis Rhein was conducting the Range Firings of the 8 in.

Howitzer, M1. This weapon and the companion 155 mm Gun, M1, had been recently designed and the prototypes manufactured: the guns by Watertown Arsenal, the recoil mechanisms by Rock Island Arsenal, and the carriages by someone else, but I believe it was Watervleit Arsenal. Frankfort Arsenal had built the fire control instruments that were used for setting the elevation of the guns for firing.

The 155 mm Gun shell weighs about 95 lb while the 8 in. Howitzer shell weighs about 200 lb. The weapon is slightly shorter but heavier than the 155 mm Gun and the powder is slightly smaller grained.

The conduction of a Range Firing is a rather elaborate procedure in that every shell is weighed, measured and inspected. Each powder charge, as all powder charges were, was check weighed by two persons, one of which was the Proof Officer.

On firing a round in Range Firings the powder is kept at as constant a temperature as possible until just before loading, the projectile is loaded with as nearly equal force on ramming the shell into the gun as possible, etc., etc. When the weapon is elevated to give a longer range the elevation is checked by the gun crew foreman on the regular fire control instrument and by the Proof Officer on a second independent instrument.

(2) Firing Tables

On firing the projectile at a given elevation, velocity is measured and the exact location of the impact is marked and measured both in range and deflection. Other data collected at the same time are wind velocity and direction and meterological data. The above data are reduced to standard conditions by complex calculations. Even the effect of the rotation of the earth is taken into account. At the time we are discussing, these calculations were handmade by Ballistics Research personnel. Each round required about one month's work. Then standard tables were prepared for field issue.

It should be noted that the probable error in range at say 8,000 yds. for the 8 in. Howitzer was only about 6 yds and only 1 yd in deflection. Thus, it probably was the most accurate weapon ever developed.

In addition to the range tables, air

bursts were fired and the data on height of burst, range, deflection and time of flight measured.

Before I left Aberdeen I measured the shell and did the work necessary preparatory to range firing of the 75 mm Howitzer but I did no firings.

One firing may be of interest. I was firing a 75 mm Gun or 105 mm Howitzer down the Main Range on a foggy day. Just after a round was fired a Washington-New York airplane showed through the fog in my exact line and elevation of fire. Certainly a near miss.

B. World War II Assignment

In the fall of 1940 we returned to Fayetteville, Arkansas for the school year. In May, 1941 I received preliminary orders to transfer to Aberdeen Proving Ground as a permanent assignment. Accordingly I proceeded to Hot Springs to the Army Hospital for a medical examination to be certain that we did not move and then find that I was rejected for health reasons. As expected, I was found an acceptable risk from the health viewpoint.

So we proceeded to pack our furniture and prepared to leave for Aberdeen. Captain Cave had located a small house for us and we appeared to be all set. Actually, we left Fayetteville for Hot Springs about 25 May, 1941. On arrival at Hot Springs in accordance with my orders I reported to the hospital for a medical check and final approval. The surgeon looked at my record and informed me that a repeat of my medical examination was not necessary as I had been examined within the past 30 days. However, he informed me that my record would have to be formally approved by the Surgeon General in the Army Area Headquarters of Omaha. He stated this was routine and to report the next day for clearance.

We therefore rented a motel room and, I believe, went swimming. The next morning I reported to the Hospital Adjutant but the telegram approval had not been received. So I reported back at noon and no report. This went on for 27 days. Meanwhile, I had notified Aberdeen and was told my presence was urgently needed as work had been scheduled for me. Why I was held up I never knew.

Anyway, we swam, the boys enjoyed the vacation and Winnie and I rested. A month's planned vacation at Hot Springs would have been enjoyed with a few less worries, but nevertheless we did enjoy most of the time. I got a good mess of chiggers, probably from picking blackberries.

I have always regarded the holdup in Hot Springs as the most stupid thing that I ever encountered in Government, Army, or University work.

## 1. Initial Organization at Aberdeen

### a. Getting Settled

On arrival at Aberdeen we found the house that had been rented for us was a pathetic joke. Actually it was located about one mile south of Aberdeen, was furnished and too small for comfort. Nevertheless, we moved in and Winnie began to look for another house.

This first house was of interest in that it was a "Foreman's" home for transient workers which came through yearly to pick the shoepeg corn grown in the area for canneries. The other houses were like cattle sheds. Our house consisted of four very small rooms. Luckily we were able to move out in two months.

When our furniture arrived we simply had to store it at the Quartermaster Warehouse. By chance Winnie drove into Aberdeen--the whole business district was a block long--just as the truck arrived with the furniture. Winnie drove up by the truck just as the driver was getting out and said, "I'll bet you are looking for the McLains." Was he surprized!

In order to take care of the planned influx of people the Government was building many new houses east of Aberdeen near the Proving Ground. When these opened, Winnie found a half house for rent in Havre de Grace near the Bay. This half house was large and in an excellent location. When we moved in we found that the kitchen and basement were very dirty since the lady who had been living there could not keep the place clean and she also kept dogs. When the linoleum in the kitchen wore through she covered the old with a new linoleum--dirt and all--three times. Several half days work made both the kitchen and basement livable. We stayed about 2-1/2 years. Later we moved on the Post in a beautiful place overlooking Chesapeake Bay.

The Havre de Grace house was located only one block from the small park which was located at the mouth of the Susquehanna River where it emptied into Chesapeake Bay. We spent many hours in this park and it was almost a playground for the boys. Frequently swans as well as ducks, etc. were close inshore.

The house was also located about 3/4 mile from downtown and the bridge across the Susquehanna River. This bridge was of interest as it was an old single track railroad bridge which had been double decked and allowed single traffic each way. Some two to three miles up the river to the northwest is the town of Port Deposit which is located at the lower end of the old Susquehanna Canal. Houses and stores are close along the river.

Across from Port Deposit is a park and there are several parks near at hand. Also of great interest to us was the Conowingo Dam located a few miles above Havre de Grace.

Both the Pennsylvania and Baltimore & Ohio Railroads ran through Havre de Grace and Aberdeen. So I could, and frequently did, take the local Pennsylvania train mornings from Havre de Grace the five miles to Aberdeen, then the Proving Ground train from Aberdeen the three miles to the Proving Ground. At night I would take the Proving Ground train to Aberdeen and the local bus to Havre de Grace.

Of course, it was convenient to take the local trains to Philadelphia and Baltimore and Washington. The Capital Limited on the Baltimore & Ohio would also stop for Winnie and the boys to go to her father's home near Garrett, Indiana.

Neal started school in Havre de Grace and went there, I believe, for 2 years. Later he went by Government bus from the Proving Ground to Aberdeen to school.

b. <u>Personnel</u>

My work at the Proving Ground almost immediately became management. During my absence there had been a considerable expansion of the Mobile Artillery Office. John Bergman, then First Lieutenant, had reported in the summer of 1940 just before I left for Fayetteville, and I believe Ernest Huff had reported in February of 1941. Several other people had also joined. A male secretary was assigned to me on arrival as no women were allowed in the firing area at that time.

I was assigned responsibility for planning about one half of the Main Front projects. Actually, the responsibility included planning development tests on the Field Artillery weapons. After a few weeks we rearranged the office and were assigned regular staff assistants and female secretaries in a separate area from Major Cave's office.

On July 1 about 10 Reserve Officers and 10 recent Engineering Graduates hired as Civilian Engineers were assigned to me. I believe that the War Department went through the files of recently Commissioned Officers who were Engineering Graduates and selected the top 50 to 100 and ordered them to Aberdeen Proving Ground. At any rate, about 3 July, 1941 the Mobile Artillery personnel man, whose name I have forgotten, came into our office leading some 10 officers who had just been ordered to active duty.

Our office at that time and for the next year was located in an old warehouse just behind the Main Front firing line, about 50 ft behind an old World War I 155 mm Howitzer. As it was summer, all the windows and doors were open. We had perhaps 25 desks in the room with Louis Rhein's and my desks against and facing one another, with other desks against ours on both ends.

The new officers congregated around my desk and were introduced. I particularly remember Lieutenants Harold Kolb and Chester Johnson because both towered over me and both had very broad shoulders. After the introductions I welcomed them and assured them of their assignments at Aberdeen for the "duration" and urged them to obtain housing and plan to settle down.

Most of the officers immediately raised objections. As I remember it, none of them had had Ordnance Training. They were mainly Field Artillery and Infantry Officers. I then proceeded to make a short speech in which I informed them briefly of what our work would be and that they were assigned to Aberdeen and to this Section for the duration of the war which I suggested would be several years. I then told them to find suitable housing and report back to go to work. They were the saddest bunch of persons possible. Here they had had four or more years of training in specialized fields and low and behold they were told that they were assigned to Aberdeen and Ordnance Development for the next several years.

I have forgotten the names of several of these men. What I remember is outlined below:

(1) Chester Johnson. Chet had graduated from a University in Oklahoma and when ordered to Aberdeen had been Superintendent of Buildings and Grounds in a small college. He and his wife Marjorie rented an old house south of Aberdeen near Bush River. After the war he remained in the Army and recently retired with the grade of Major General, I believe. He now lives in Shawnee, Oklahoma. We still write at least at Christmas.

(2) Harold Kolb. I believe Harold had graduated in Mechanical Engineering and was working for Catapillar Tractor. After the war he returned to Peoria where he quickly became Head of Research and Development of Catapillar. He and Maxine believed me about housing and immediately contracted for construction of a house in Aberdeen. We write at least at Christmas and I see Harold and his brother occasionally when they come to Purdue to hire people for Catapillar.

(3) Lieutenant Richard Potter. Dick was unmarried. I have lost track of him but I believe he obtained a Doctor's Degree in Engineering at Purdue after the war.

(4) David Williams. Dave worked for me for about two years and then moved to Headquarters where he again worked for me when I became Division Director.

(5) Alfred Wilson. Al and his wife rented an apartment near us in Havre de Grace and we visited back and forth frequently. He has been with an aircraft company in Indianapolis for years.

(6) ______ Johnson. Another Lieutenant Johnson and his wife lived near us in Havre de Grace. We were good friends, but we lost contact after the war.

(7) ______ Marshall. Lieutenant Marshall

was a quiet unassuming man whom I did not know well personally.

(8) ______ Losco. Lieutenant Losco was unmarried. I don't know where he lived but I think it was Pittsburgh. At least he returned to Pittsburgh after the war and worked at Westinghouse in the nuclear field for a time. After a couple of years he became assistant to Chester Johnson.

(9) I have forgotten the names of the others. One of these who was unmarried tried to locate a room for rent without success. Finally he stopped by one of the old large houses south of Aberdeen and rang the doorbell. An old lady answered and he said, "You look as if you would have a room to spare. I will be glad to help with the lawn, etc, etc." He explained that he was a very quiet, studious character, etc. Finally she admitted that the large house was almost too quiet and too large for her alone. So she finally rented him a room. The next week her granddaughter came to visit and stayed for six weeks. By this time the officer and granddaughter were engaged and soon were married. The last I knew they had three children. He worked for me about one year too and then was transferred to the Design Section as Officer in Charge.

(10) Alfred Baldwin. Al was also ordered to Aberdeen before I returned in 1941. He worked mainly on administrative duties. After the war he worked for the Naval Test Laboratory in Washington. We have recently lost contact with the Baldwins.

(11) One other officer was responsible for some aircraft development work and assigned for several months. I have forgotten his name.

The next week the Personnel Officer brought in about ten civilian engineers. I talked to them in the same way. I have forgotten the housing arrangements of most of them but they were similar to the officers.

These 20 or so officers and engineers were all excellent men. Only one or two failed to become excellent development engineers and these became managers. Together they carried out the development firing tests on most of the field weapons other than small arms which were used in World War II. Great credit is due all of them.

It should be noted that Small Arms, Anti-aircraft, Automotive (a new Division for Tanks) and Headquarters were also favored by being expanded with excellent engineering officers and civilian engineers. I believe the War Department selected the best officers and engineers for Aberdeen in order to make sure the development of new weapons was given top priority.

About this same time we were assigned secretarial help and sufficient personnel were assigned to carry out the office work, gun crews and general labor such as stores, etc. Women, mostly overweight negroes, were assigned to Trench Warfare. I mention the color because we had "black" and "white" washrooms, etc, and because these negro women were always so happy and always laughing no matter how hard the work or how rushed the schedule. My secretary was the wife of an Automotive Division Officer who had been and is now at Chevrolet, Lieutenant Kaufman. She later told me that when she was brought in by the Personnel Officer and introduced that I grunted, nodded toward her desk and proceeded to dictate to her for four hours without a break. All I remember was that the first time the old Howitzer was fired outside the window which was open she jumped and turned white.

I quickly established Chester Johnson as my Executive Officer and Rhein as Technical Advisor.

It would seem appropriate to say something about the other persons mentioned previously.

George Eddy. Captain George Eddy was soon made Commander of the Proving Ground. After the war as Brigadier General he was transferred to the command of the New Mexico Rocket Range. During much of the war we worked closely together and I had great admiration for him.

John Cave. Captain Cave remained Chief of the Arms and Ammunition Division until transferred in 1944. I lost track of him. While very capable, he was difficult to work with. He was extremely conceited.

Ernest Huff. Ernest remained at Aberdeen, sometimes on special assignments, and after the war returned to Batavia, New York, to teach. He and Doris are now living near Naples, Florida.

John Bergman. John also remained at Aberdeen during the war, partly on special assignments. After the war he returned to work at Vancouver, Washington, with the Carborundum Company, but was later transferred to Niagara Falls. I believe he is now Vice President of Carborundum. We still keep in touch with Beryl and John.

Russell Carr. One other person that I should mention is Russell Carr. Russell became Director of the Small Arms Division. We worked together some, played tennis frequently, and were neighbors. After the war he and Madeline returned to Elmira, New York, where he became, I believe, Superintendent of Schools. They were literally washed out in the flood caused by the hurricane in the summer of 1972.

Some of the Civilian Engineers that I particularly remember were the following:

(1) Louis Rhein. Mr. Rhein had been an officer in World War I and had been assigned as a Proof Officer at Sandy Hook Proving Ground. When Aberdeen Proving Ground was opened in 1917 or 1918, he was transferred there. And he had remained as a Proof Officer as a civilian through World War II. I don't know when he was retired. Lou knew the answers to most of the questions that I knew enough to ask and I always suspected the answers to many questions that I was too ignorant to ask. He never had much to say but did a very efficient job of such things as Range Firing, etc. For most of World War II I kept him near me and I usually sought and took his advice.

(2) ______. There were two other Civilian Proof Officers but both of these did routine tests and I had very little

contact with them.

(3) Joseph Sporazzo. Joe was a very bright young man. He did special development programs such as the 105 mm Howitzer range problem all during the war. I lost track of him after the war.

(4) ______ Ramsey. Ramsey along with Sporazzo was one of the ten civilian engineers who worked for me most of the war. He also did special projects but I don't think any are mentioned below.

(5) ________. Another engineer conducted the Destruction of Fortifications Program but I have forgotten his name.

(6) William Hardesty. Hardesty worked on safety problems, and acted as Arms and Ammunition Division Safety Officer most of the war. After the war he worked for the Rocky Mountain Ordnance Depot at Denver as Safety Officer. I believe he retired in 1972.

2. Revised Organization

About July 1942 Captain Cave was transferred to Head of the Arms and Ammunition Division and I was made Chief of the Mobile Artillery Branch. Then about July 1943 the whole Arms and Ammunition Division was rearranged into Weapons and Ammunition Divisions and I was placed in charge of the Weapons Development and Tests. Later for a short time I served as Director of the Ammunition Division. In the summer of 1944 I was made Chief of the Arms and Ammunition Division. I left in August 1945 to return to the University to work.

3. Development Work

We were kept busy during the war in two general areas: Checking and improving the standardized weapons; and developing improved weapons.

Some idea of the magnitude of the checking and improving of the socalled standard weapons may be obtained from the fact that on the morning after the attack on Hawaii I counted 19 rough drafts of development reports in my desk.

During all four years my work was primarily to interpret Ordnance programs, assign work, supervise development programs, approve reports, attend conferences, etc, etc. I did very little administration work in the normal sense since I always delegated this to someone else, usually Major Baldwin. I always had an executive officer, an assistant officer and one or more secretaries, I normally worked six and one half days and three evenings per week. For two and one half years we lived on the post within easy walking distance, even to go home for lunch. For the entire period I had a jeep or car, and for much of the time even a chauffeur.

For three years, once nearly every month I attended one day conferences in the Pentagon. However, I had no time for the normal technical meetings in Chemical Engineering or even to attend meetings at other Ordnance establishments. I did essentially no traveling other than to Washington.

What is written below is what I remember of the most significant events. I have not attempted to indicate their relative importance. However, I suggest that perhaps the most important programs were the 105 mm Howitzer ammunition, 240 mm Howitzer, and the Destruction of Concrete Fortifications. I should note the development of the proximity fuse the most significant item tested at Aberdeen, but I had essentially no contact with it. Of course, I had no contact with the nuclear weapons until much later. The programs are discussed in somewhat ascending size or weight of the various projectiles.

Earlier I mentioned the routine acceptance tests of cartridges, powder, including determination of the weight of powder per round, and shell tests. Of course these tests in very large numbers were going on all during the war and I was responsible for much of this work, including signing of the firing records. This last duty had to be delegated else I would have spent all day signing my name. Nevertheless, the routine tests required large numbers of personnel. As one of the Branch Managers I was responsible for about 50 officers and engineers and about 200 other employees. As Arms and Ammunition Director I was indirectly responsible for about 200 officers and civilian engineers and about 1200 other employees. As Branch Chief I delegated almost all responsibility for all personnel problems to Major Baldwin and another Major whose name I don't recall. As Division Director I had practically no personnel problems.

Reports were involved. In the first place the routine firing test reports were reduced to regular forms and, since failures were not common, the reports became simply routine records and certifications. Development reports were complex and varied from a few pages to hundreds of pages in length with weekly and monthly reports required on important programs. At one time in the weapons programs alone we had over 1000 programs on the books. Of course only a part of these could be worked on at one time.

a. Fuses

Fuses are small devices which contain an easily detonated pellet of lead azide or some similar material. When wet, lead azide may be shipped or handled safely, but when dry it is easily detonated by friction, pressure or simply violent vibrations. Many stories are circulated about detonators. I repeat only two here.

First, while at Picatinny Arsenal, one of the regular employees went from the "loading plant" up a board walkway about 100 yards to a storage vault. He carried a regular chemistry drying flask that would hold perhaps two quarts. It was not covered at any time. On reaching the vault he filled the flask but carelessly let a few small pieces of the powdered lead azide drop on the rim of the flask.

On his way back to the loading plant some of this lead azide on the rim dried a bit. About one mile away men were firing a 155 mm Gun. The concussion due to the firing of the weapon caused the dried lead azide to detonate but the wet material did not. I was a few yards away.

Second, among the facilities at Aberdeen that I was responsible for was the examination of projectiles or fuses that failed to detonate and the disassembly of foreign material. We had an isolated building, poorly equipped with safety devices, and poorly equipped with the most desirable equipment. It, along with the storage of powder, was my greatest worry. The man in charge of the disassembly building was very knowledgeable in what he was doing but a poor worker when it came to keeping the place clean. He had been a long time Sargeant, but I insisted on commissioning him.

One day he pressed a detonator out of a brass holder used in a complete fuse. Without thinking, he picked it up. The added strain due to the heat from his thumb and finger caused it to detonate. It did very little harm due to its small size, but it demonstrated the sensitivity of the dry material. Of course, it had just been stressed and probably retained some residual heat due to its compression on being pushed out of the holder.

Ordinarily fuzes were tested at Picatinny or elsewhere due to the small charges. In addition to lead azide pellets perhaps 1/8 in. diameter by 1/8 in. high, they contain larger pellets of tetryl which is easily detonated and provides the large detonation necessary to explode or detonate TNT, etc.

(1) Air Burst Fuses

Early in the war we did carry out many time or burning tests of fuses used for air bursts of shell. The test fuses were assembled into complete rounds and fired at night with measurements made of time of flight. The time of burning was originally the time for a powder train to burn and later mechanical time fuses were tested.

(2) Proximity Fuses

Some time early in the war someone suggested the development of a proximity fuse. Such a device should detonate a shell when the shell came within a preset distance of a solid target such as an airplane. I do not know when or by whom the suggestion was made. The first that I was involved was when John Hopkins engineers and physicists wanted to test such devices. The group included Dr. Lawrence Hafstad and Dr. Merle Tuve, this I know. The Ballistics Research Laboratory had also cooperated in the development. At any rate, we fired the first rounds but had no part in the development other than that.

When it came to test of the large numbers of fuses required in the Production Tests, a special group was set up on the eastern shore of Maryland for firing over water. I had only very nominal contact with that group.

b. Grenades

Ordinarily we did not test any hand grenades.

However, these were routinely tested at Jefferson Proving Ground, Indiana. Professor Brier, as Colonel Brier, was the Commanding Officer there. He told me of one of the men while setting up a test outside of a concrete barricade said, "There's something wrong with this grenade." Apparently as he took it out of the shipping box the fuse, which had a 5 second delay, came apart. Had he thrown the fuse instead of looking at it, he might not have been killed.

We fired numbers of unloaded but live fused hand grenades in demonstrations. Always I removed the fuse and checked to make sure that I had an empty grenade before I threw the fused grenade to demonstrate its functioning.

The ordinary grenade was about 2 in. diam and 3 in. long and made of cast iron or an alloy of some sort. The hollow space held enough explosive that the grenade was lethal for perhaps 6 ft. It was detonated by a small springset fuse that started a 5 sec delay train when thrown.

It was obvious that an improved grenade could be made by making a spherical device the size and weight of the conventional baseball with a thin metal cover. All kinds of devices were tried and tested. One of these included an impact detonated fuse that would arm when a small pin was withdrawn in the air by a very thin metal vane about 1 in. diam. Before throwing, the person handling the grenade had to remove a very small safety pin. On paper the device appeared excellent.

Several hundred of these grenades were made up for our test. Apparently many had been previously tested and the fuses had worked as designed. The Proof Officer, whose name I have forgotten although I worked with him for many months, did not like the grenade. He simply didn't have faith in the simple fuse perhaps due to its lack of complex safety devices. It did appear, however, to be safer than the fuse on the conventional grenade then used widely by the troops. And the fuse worked on impact.

We tested many of the grenades without any failures. Then the grenade was placed in production and we were supplied several hundred grenades for an extended test. The employee who was throwing the devices was throwing them from behind a low barricade but he was not completely protected since this was a "production" test.

After several hundred had been thrown, one detonated as it left his hand. A piece of the outer shell struck his eye and followed the nerve duct into his brain. Had it been 1/8 in. away in any direction he probably would have only lost an eye instead of his life. He was supposed to duck below the barricade as he threw each grenade.

Later the Proof Officer learned to throw the grenades so that frequent predetonations occurred. So the project was cancelled. I continue to believe that I was to blame for this man's death. I did not inspect the test during actual throwing of the production fuses but I had inspected the area previously and considered it satisfactory. The Proof Officer was one of the most intelligent men in the group and all of them were selected from many others. The man did fail to duck as ordered.

I can only say that the work was hazardous and we could never predict when accidents or ammunition failures would occur. We drive automobiles, knowing they are dangerous devices and that unknowingly, through our own carelessness, we may cause accidents which will result in one or more deaths.

c. Rifle

Following the European War between France and Germany in the late 1800's, the French set about developing improved weapons. Among their developments were the French 75 mm and 155 Guns and Howitzers and an improved rifle. These French 75 mm and 155 mm Guns and Howitzers were used by the U.S. in World War II. Even after Hitler's start of annexations, the United States moved slowly as we are doing now, in spite of the Russian moves into Eastern Europe, South America, Southeast Asia, etc.

The rifle which was designed by the United States in the late 1800's was the socalled Springfield 1898. This was designed and built at Springfield Arsenal. It was a beautiful weapon as were the larger French Guns and Howitzers. However, all these weapons were out of date due to improvements in manufacturing procedures and materials by 1940.

The 1898 Springfield rifle fired only five rounds per clip, was hand operated, etc. Why it was not redesigned before World War I, I don't know. Actually, it was well into World War II before it was redesigned. The redesigned rifle, known as the M1, fired the same shell as the 1898 model but it was automatic and fired large clips, I believe of 20 rounds. The only part that I had was to generally oversee the last stages of the tests after I became Division Director.

Three items amused me. These are:

(1) Early in the development General Marshall, Commander in Chief, visited the Proving Ground for a demonstration of the latest weapons. At that time I was involved in Artillery but I was along with the group at the time he was shown the M1 Rifle. One of the Small Arms Officers demonstrated the weapon by firing some 20 rounds at a silhouette target about 50 yards down range. To have hit this target would have been no great thing if one really tried and took careful aim. But the officer was discussing the weapon and occasionally shooting short bursts as he talked. At the end of his talk General Marshall said nothing but simply walked to the target and counted the holes. Luckily, most were bunched in the center and they were there.

(2) Early in the tests one of the officers suggested I fire a few rounds at a silhouette. I didn't do well as the rifle is not easy to hold in automatic fire at the start of a burst of several rounds. I did have a very black and blue shoulder for a couple of weeks.

(3) I had a WAC secretary-driver at the time and she wanted to shoot both a pistol and rifle. The pistol shooting went off all right. But one day just before a demonstration I suggested that she fire one round with the M1 Rifle, this she did. Afterwards she just handed the rifle to me and walked away. She never mentioned the firing again.

d. Recoilless Rifles

During World War II the Germans carried out experiments with recoilless rifles of various sizes. These are based on the principle of equal forward and rearward forces during firing the weapons. In an ordinary rifle the energy imparted to the rifle is equal to that imparted to the projectile. In larger weapons this energy is absorbed by shoving the weapon to the rear and by forcing oil through orifices and thus converting the recoil energy to heat. This latter principle is used on the recently introduced movable bumpers on automobiles.

The German weapons were very crude and not very important in the field.

(1) <u>57 mm Recoilless Rifle</u>

Two engineers at Frankfort Arsenal were assigned the design of a 57 mm Recoilless weapon. They produced a beautiful weapon. It was very soon placed in production and used extensively.

The weapon consisted of a tube about 6 ft long, light enough to be carried and fired by one man. The tube extends about 2 ft to the rear and 4 ft forward. The projectile is 57 mm diam by about 4 in. long and when shaped charges are used it will penetrate about 2.0 in. of steel; so it will stop a light tank when fired at the sidewalls or even break the tank's track.

Our work with these weapons was surprisingly simple as sufficient firings had been done at Frankfort Arsenal using inert projectiles that we found essentially no suggested changes in design.

We did proof test both ammunition and weapons.

(2) <u>75 mm Recoilless Rifle</u>

The next step was to develop the 75 mm Recoilless Rifle. Frankfort Arsenal, I believe, designed the weapon. It was simple, light enough to be carried by two men, and very effective. Again, we found very little to do other than to routine test the weapons.

Again, there was a great rush to proof test many weapons. These tests were carried out by Proof Officers from the Ordnance School and not by experienced engineers who had handled strange weapons for years. The three or four officers were warned against trying to correct any even slight deficiencies or difficulties, and all were especially warned never to step behind a loaded weapon under test, but to call for help. The inevitable happened.

The proof tests of firing the guns at normal and excess pressure were carried out with the guns suspended on chains in a reinforced concrete shelter with all firings carried out remotely from outside the shelter. Movements of the guns were observed through mirrors.

All went well for several hours. Then apparently a piece of dirt became lodged in a firing mechanism or a minor malfunction occurred during a test. This was on the night shift about 4 AM. The gun failed to fire. Apparently the officer went near the gun and may have started to remove the shell. We never knew. At any rate, the gun fired.

To provide the rearward force, four holes were provided in the rear of the breechblock. On firing, burning gases at a white heat escaped under pressures as high as 10,000 psi. The man's leg was struck by two of these streams of hot gas. His right leg was cut completely through in two places. Of course, the muscles were torn. He died in the ambulance on the way to the hospital.

I have always believed that I was partly guilty for his death. Certainly he broke his instructions, but had I taken more time his life might have been saved. The previous afternoon Lieutenant Potter had prepared the Safety Regulations for the tests and I had approved them just before I left for home in the evening. I believe Lieutenant Potter also believed insufficient instruction was given the Test Officers.

(3) <u>105 mm Recoilless Rifle</u>

I had very little to do with the 105 mm Recoilless Rifle since the first weapon was delivered for test just a few days before I returned to civilian status and returned to teaching.

e. <u>75 mm Gun</u>

In 1940 ten 75 mm Field Guns were built and thoroughly tested. Why, I never quite knew, as the 75 mm Gun was too light to be of much service. Perhaps it helped develop other weapons. I do not know.

f. <u>3 in. Gun</u>

In 1941 an attempt was made to convert the 105 mm Howitzer to an antitank weapon by replacement of the Howitzer tube with a 3 in. Gun tube, thus making an antitank gun. The 3 in. Gun has a much higher velocity, but lighter weight shell than the 105 mm Howitzer. The high velocity with armour piercing shell would have been effective against the German tanks then in use, but they were not effective against the later German tanks, and so I know no 3 in. Guns were ever used in action in World War II. They have been widely distributed about the United States and are frequently seen in parks, etc.

I was the Project Manager at Aberdeen. The work consisted of assembling a 3 in. Gun to the 105 mm Howitzer. This was quite simple. Firing tests consisted of simply checking all components to make sure all worked satisfactorily. This was very simply done.

g. <u>105 mm Howitzer, M1</u>

I had very little to do with development tests of the 105 mm Howitzer. We did have a long tube erosion program. This is discussed briefly under special programs below. We did conduct acceptance tests on many weapons and many lots of ammunition components.

It was during the tests of these weapons that we ran short of powder and had to have a fast shipment from Kansas City. I requested a car of powder be attached to a passenger train, but this was refused by the railroads. I then ordered the car by special freight--a one car freight overnight Kansas City to Aberdeen. I didn't dare ask the cost but it could not have been very great.

h. <u>4.5 in. Gun, M1</u>

A 4.5 in. Gun was developed along with a companion weapon, the 155 mm Howitzer. Both weapons used the same carriage and nearly the same recoil mechanism. The gun proved to be inaccurate and the projectile proved to be too small to be effective and the weapon was never built in quantity or used in the field.

i. <u>155 mm Howitzer, M1</u>

The 155 mm Howitzer, M1, was designed and the first weapon tested and range fired late in 1940, I believe. Great numbers of these were built and issued to the troops. In fact, they were still being used in Viet Nam and I believe other countries have followed very closely our design. I had little to do with the weapon except some powder tests were made at Aberdeen.

### j. 155 mm Gun, M1

The 155 mm Gun, M1 was designed in the late 1930's but production got underway only in 1940. I had nothing to do with the Gun except as noted in my summer work in 1940, I determined powder charges for some 24 lots of powder.

### k. 8 in. Howitzer, M1

The companion weapon for the same carriage as used for the 155 mm Gun was the 8 in. Howitzer. Rock Island Arsenal built the first 48 production recoil mechanisms for the 8 in. Howitzer in 1940. However, the first production carriage was not received until the summer of 1941. Previously a pilot carriage and weapon had been built and used in the range firings mentioned above. (See page 10.)

#### (1) Carriage Failure

In July 1941 the first production carriage was delivered for the 155 mm Gun and the 8 in Howitzer. This carriage was immediately used for tests of the 8 in. Howitzer recoil mechanisms.

The carriage for an 8 in. Howitzer consists of a rotating section with a large U-shaped welded piece in which the recoil mechanism with turnnions on the side frames is fitted. The weapon is elevated by a worm gear on the carriage which works against a large gear section on the bottom of the recoil mechanism frame.

The large rotating section may be rotated by a large gear in the bottom section by some 25° right or left. The bottom section and the top U-shaped section are connected through a heavy shaft and the U-shaped section operates on a roller bearing some 2.5 ft diam. The bottom section is in turn mounted on a heavy axle with large double dual tires on each side. Trails or long beams are attached to the sides of the lower section and these may be rotated about 25° from the center line to each side to give supports and absorb the rotating forces due to firings at different elevations. These trails are about 16 ft long and are supplied at the rear with spades that are set in the ground about 2 ft deep and 2.5 ft wide.

The recoil mechanism is about 1 ft deep and 2 ft wide. The main cylinder forces oil through orifices when the Howitzer is fired and moves to the rear about 4 ft. A second cylinder with a piston under about 2200 psi nitrogen pressure returns the Howitzer tube to firing position.

The Howitzer tube is about 16 ft long with a wall thickness varying from about 2 in. at the muzzle to nearly 8 in. at the rear. It is equipped with pins some 6 in. diam which fit into the movable section of the recoil mechanism. The breech ring is about 28 in. outer diam.

Before tests we went over the carriage and placed distance marks at various points in order to measure any deformations of the carriage components or trails.

After firing the first round Lt. Potter measured the carriage to check for deformations. It was seriously deformed. He and Rhein called me and when I put my hand on one of the trails to climb over it, I realized that my hand was on a curved instead of a flat area. They had not noticed that the trails had buckled. As a result the carriage had to be changed by specifying a steel with higher strength and all the carriages already built used for the 155 mm Guns.

This was one of the few examples that I remember at Aberdeen in which the stress analyses of carriages, guns, etc were off. The 76 mm Tank Gun discussed below was also miscalculated.

Later a large number of carriages for the 8 in. Howitzer were manufactured by American Locomotive at Schenectady. The first one to arrive was disassembled for an inspection of workmanship, etc. Of course they had been inspected and passed by the Ordnance Inspector at the plant.

On disassembly we found several places at which the machining had been done but the rough edges had not been smoothed over. In addition, we found perhaps a cup of machine metal chips in the bearing of the main rotation component. This was about a 5 in. diam pin that held the rotating part of the carriage and a roller bearing about 30 in. diam. The chips could enter the bearing race and indeed some were in the race.

When we called the American Locomotive people, they denied that such workmanship could occur in their plant. So we invited the President to come to Aberdeen. He did so with several of his staff. We then disassembled a carriage in their presence. We, of course, chose one that had just arrived and was still on the flat car. It was about the worst one of the lot. So we had no more trouble.

It is interesting to note that several years later I inspected the American Locomotive plant as a part of a Contract Selection Board. As usual, I thoroughly inspected the toilets first. They were dirty and ill kept as was the whole plant.

### (2) Breech Ring Failure

When we started routine tests of the 8 in. production Howitzers, we began to have failures of the breech rings. These breech rings, as noted above, are about 28 in. OD with threaded sections to thread on the rear of the tubes. The length of the threaded section is about 14 in. There is about 10 in. of steel to the rear of the end of the tube. This rear section is machined with threads to hold the breech block which is about 10 in. diam and opens to allow loading the shell and powder charge into the Howitzer.

The acceptance firing tests for Guns and Howitzers consists of firing a series of rounds at increasing maximum chamber pressures of something like 75, 90, 100, 105, 110 and 115% of the maximum allowable pressure for the weapon. The maximum pressure in each round is measured and checked.

The 8 in. Howitzers were tested in concrete vaults built with 2 ft of reinforced concrete. On failure the breech rings simply broke at the rear of the tubes and due to the high pressures of around 24,000 psi simply travelled to the rear with sufficient energy to go through the 2 ft concrete walls. Luckily, no persons were injured.

Analyses of the steel indicated that the ingots used in manufacturing the breech rings were improperly worked. New breech rings manufactured of a different alloy and properly treated passed the tests satisfactorily.

(3) Coppering

All the Howitzers, including the 105 mm, 155 mm, 8 in. and 240 mm are used normally for high elevation or plunging fire. Therefore various powder charges are used and the weapons are fired at different velocities, depending upon the targets. The 8 in. Howitzer was found to build up copper from the shell rotating bands at low velocities and clear the copper out in one or two rounds fired at high velocities. The initial rounds then after a change of zone firing varied and in range firings it was necessary to reject the first round's velocity when fired at a different velocity or zone.

(4) Accuracy

On page 11 the accuracy of the 8 in. Howitzer was mentioned. Stories were told of its use in service that confirm this. For example, it was noted that German officers were frequently seen entering a particular house in Holland some three miles inside the German lines. So our troops lined up an 8 in. Howitzer and when there apparently was a conference in the house they fired one round with a very slight delay fuse. The shell could be seen to enter the roof of the house. The house was fairly well blown to bits.

Later 8 in. Howitzers were mounted on tracked vehicles for rapid mobility. However, I was not involved in this project except to demonstrate them once or twice.

1. 8 in. Gun, M1

Two other companion weapons were designed and pilot models tested early in World War II. These were the 8 in. Gun, M1 and the 240 mm Howitzer, M1. The weapons were designed to use the same carriage and similar recoil mechanisms. The 8 in. Gun had a very high velocity and hence a long range.

We tested the 8 in. Gun at great length, using different powders, etc but the accuracy was poor. Finally, we tried different tubes with different angles of rotation, etc but the accuracy always remained poor; so that finally, I believe, the construction of the gun was abandoned. One memo that I dictated to outline some proposed tests required firing of over $2,000,000 of ammunition. Gun crews and all services probably cost another $500,000, all to no avail.

m. <u>240 mm Howitzer, M1</u>

The 240 mm Howitzer, M1 fires a projectile that weighs about 340 lbs. It speaks with authority. We had only one difficulty with this weapon and that was coppering of the tube. This effect had been noted on the 8 in. Howitzer, (see page 33).

I was embarrassed later since I did not recognize the coppering effect. What happened was that we were firing time of flight tests in the evening. When we changed zones the woman who was computing the velocities asked me what the velocities in the new zone of fire would be. I gave her a number but the first round velocity was off about 30 ft/sec. Why I didn't investigate, I don't know. Anyway, I forgot the incident until later.

A month or so later Lou Rhein carried out the range firings. The Ballistic Research Laboratory had arranged with International Business Machines in Philadelphia to carry out the calculations on punched cards. This they did. Actually, this was the first large scale program ever carried out by computers. Why I didn't immediately buy all the IBM stock I could is still a mystery.

Later Firing Tables were prepared and the Field Artillery Board at Ft. Bragg conducted firing tests but their results did not check the Tables prepared at Aberdeen. Aberdeen repeated the calculations and checked their previous results. This was Saturday. I suggested that I would spend Sunday going over the records, etc to try to find the cause for the discrepancy. I was actually laughed at by Bob Kent and others at Ballistic Research. However, when I plotted the actual firing data Sunday AM, the answer was very obvious so the last laugh was on Bob.

The 240 mm Howitzer was quite accurate. While the Americans were advancing up Italy from the south in World War II, they were held up by a mountain ridge on which there is an Abbey known as Cassino. This was declared open by the Germans and they claimed no Germans or supplies were using the Abbey. Observations indicated otherwise, so a 240 mm Howitzer delayed fuse shell was dropped into one end of the Abbey. Very soon many Germans actually in the Abbey left in a hurry in all directions.

n. 240 mm Gun

After World War II a 240 mm Gun was built. The heavy carriage and the heavy weight of the Gun made this weapon top heavy and impractical, and so far as I know no production models were built. It did have one use because originally it was the only land transportable weapon that could fire a nuclear device. Since then, of course, nuclear devices have been built for 5 in. Guns as well as the intermediate weapons.

The 240 mm Gun was tested with a nuclear device at the Nevada Nuclear Test area. At least, I believe it was a 240 mm Gun, although I am not certain my memory is correct.

At that time I was Chief of the Production Reactors Branch of the Atomic Energy Commission in Washington and as such I was sent to observe the test as an official observer. We were seven miles away from the air burst.

My observations were that the weapon was impractical for field use. Later, as mentioned, devices for use in weapons as small as the 5 in. Naval Gun have been developed. I have not followed these developments in detail.

o. Mortars

We tested various components of both 60 and 81 mm Mortars. Bent base plates, etc were studied.

I was always amused at one of the "gun crews" at Trench Warfare. I noted earlier this crew consisted of five greatly overweight negro women dressed in overalls who moved slowly but continuously, and always with laughter. And every time I came near I became the butt of all their jokes. Actually they worked hard and the lack of comments re Trench Warfare herein is really a tribute to them and the Trench Warfare staff.

One item that is of interest is that Lt. Wilson kept hearing about mortar crews being killed because rounds hit limbs of trees over the men and the shell detonated. He, with a little help from me, developed a safety device to build into the fuses to prohibit this type of accident. The cut away first production fuse is in my office exhibit case.

Just before I left Aberdeen we received 6 in. and 10 in. Mortars for test. I had nothing to do with these except I did observe some firings.

C. Special Tests

In addition to the regular acceptance tests and development of our normal lines of artillery weapons discussed above, we conducted many programs of a special nature. Many of these were closely related to the regular development programs. But many differed widely from these. I have discussed these tests and my part of the work in this section. It appears to be quite a hodgepodge!

I think it will become obvious that most of my time was spent on these special programs. In fact, after the first year I spent probably 90% of my time on the special tests. By that time the younger Proof Officers were carrying out the routine development work with very little instruction or supervision. I was responsible for approval of all the Formal Development Reports in my area.

1. Shaped Charges

Shaped charges were used in various types of ammunition and in destruction of fortifications.

A shaped charge consists of a block of explosive so shaped that a hollow cone is left at the business end within the explosive. For example, a round cylinder of TNT 10 in. diam and 14 in. long may have a deep cone in the top. This is lined with perhaps 1/8 in. steel sheet. On detonation at the bottom, the cone collapses and the steel and hot gases are blown forward through the cone at high velocity. Since pressures in such devices may approach 1,000,000 psi, the hot gases and steel are accelerated in a small stream to velocities approaching 5,000 ft/sec at perhaps 3,000 F. As such they become potent drills. In general, a shaped charge properly designed will develop a small hole about twice the charge's original diameter in armor plate and about seven times its diameter in concrete.

a. Rifle Grenades

Rifle Grenades with shaped charges were

under test when I arrived at Aberdeen in 1941. Other than routine tests, I had no part in the program. These weapons were fired from regular 30 caliber rifles, using blank cartridges. Their range was short but they would stop a German tank, then in use if the tank was struck on the side since their shaped charge would penetrate some 2 in. of steel.

b. <u>105 mm Howitzer, M1</u>

Many tests were made on shaped charges as fired from the 105 mm Howitzer. These projectiles, when set up and fired statically against armor plate at the correct distance from the plate, would penetrate nearly 10 in. However, when fired from a Howitzer or Gun, the rotation of the projectile resulted in dispersion of the gas--metal jet and multi penetrations to only about 5 in. of armor plate.

Theoretical and experimental work carried out by Ballistics Research Laboratories was to no avail. It was only recently that the problem has been solved.

In conjunction with this work we carried out spark photography of shell bursting. The theories stated that a statically fired shell detonated at the top would burst first at the top. This does not occur as the shell fails first at the rotating band and bursts quite uniformly. The first flame is seen at the top and at the rotating band areas simultaneously.

2. <u>Destruction of Concrete Fortifications</u>

Prior to World War II the French built a series of thick walled fortifications, consisting of mixed concrete and steel, along the French-German border. This was known as the Maginot Line. After Germany conquered France, Germany added fortifications to the French and their own previous line of forts known as the Westwall or Seigfried Line. They also built forts along the North Sea and elsewhere.

Several years after the war Winnie and I personally inspected a reinforced concrete building used to assemble submarines. This was located near Bremen. The walls and roof were 8 ft thick of very heavily reinforced concrete.

When the United States entered World War II, the development of means of destruction of these fortifications became a necessity and, it seemed to me, almost an obsession to some people. The problem was attacked on several fronts:

a. Shaped Charges
b. Artillery
c. Mortars

Unfortunately I was involved in all three programs. The first step was to decide how to proceed. The obvious thing was to build similar forts as well as special targets, and test the ammunition we had, and then to develop improved weapon systems. We set our goals as development of text books and training films. In both we succeeded.

The first step was to build various types of fortifications. We did not know how; so the Secret Service offered to get drawings of typical Westwall and German forts. When we agreed, the drawings duly arrived a few days later. The Corps of Engineers built five "forts" using the imported drawings and drawings that the U. S. Army made. These forts were located at the end of Plumb Point below Bush River 30 miles from the office.

This program was typical. The fortifications were built before the test program was written. Whether the proper forts were built and utilized in the tests was never asked.

We also built a number of walls of various materials and various thicknesses to use in developing a better knowledge of Terminal Ballistics.

Because of the importance of the program, I directed it through a Proof Officer and Ballistics Research assigned people. Special reports were prepared weekly and sent by special messenger to Washington, and frequently we visited Washington to discuss the program. Several Wednesday evenings we were still writing and typing the reports at 10:00 p.m., and they were in Washington the next morning at 8:00 a.m.

The various weapons which were developed, or attempts made to develop, are discussed first and then the actual tests to destroy the forts or bunkers are mentioned.

a. Shaped Charges

Shaped charges consisting of an explosive with covers properly shaped were made, as described above. These were some 10 in. diam by about 20 in. long. The idea was that a man might crawl up to a fort during darkness, set the shaped charge and detonate the charge after he had retreated an appropriate distance. Set properly and detonated, it was found that a hole a couple of inches diameter could be drilled through the 7 ft of concrete and steel, and enough hot gases would enter the hole to kill any person in the open in the fort.

The reader should understand that to develop such a charge and technique requires weeks of theoretical work and months of tests to obtain the optimum design and methods of use.

b. Artillery

The series of weapons tests, including artillery, required several months. We started with the smaller weapons, including machine guns, and increased caliber to be able to determine optimum weapons, their usefulness and how to use them. Actually in warfare the soldiers almost always have the least optimum weapons when and where they are and need them. So we started with machine guns of various calibers and projectiles.

During all tests we took detailed data, still pictures and motion pictures. As noted, weekly, monthly and final reports were prepared along with a training manual and film.

(1) Machine Guns

Tests were made with both the 30 and 50 caliber machine guns. The 30 caliber was of little use except in one way. If mounted near a fort, its crew would appear to be an easy target. But if mounted unseen and fired, it could shoot into open ports and possibly do damage inside the fort. It could, however, penetrate the porthole doors sufficiently that the doors frequently could not be opened without repair.

The 50 caliber machine gun was more effective in this same way. But neither were serious threats.

Machine guns might keep a single fort closed up in order to permit the use of shaped charges. As far as I know this type of attack did not occur by our troops in World War II in Europe.

(2) Small Caliber Artillery

I do not remember the details of all the tests. In general the smaller artillery weapons up through the 155 mm Howitzer were effective only when brought up to within one quarter mile or so of forts. Further, armour piercing shell were not available for these weapons except for the tank guns. Weapons such as the 105 mm Howitzer are effective only against port holes, and the weapons must be set up close enough to fire into the ports. Meanwhile interdiction fire would be expected to be serious.

Tests demonstrate that when close enough that direct impacts could be made on the gun and personnel ports, the small weapons such as the 105 mm Howitzer would damage or even penetrate the gun ports. Shaped charges did severely damage the gun ports and in some cases entered the forts. When detonated inside a fort, a 105 mm Howitzer shell would be expected to make life uncomfortable for those inside.

In general these smaller weapons were expected and were found to be not overly effective.

(3) Special Fuses

Ordinarily the weapons from the 105 mm Howitzer and higher are issued in the field with only one type of fuse. This may be set superquick or delay. The delay permits firing for ground richochet and air burst a hundred yards or so further on. This type of fire stopped the Germans at the time of their attack on the Anzio Beach beachhead.

When this fuse is fired either superquick or delay against concrete, the fuse is crushed and the shell detonates before it can penetrate the concrete. To correct this the Officer in Charge of Design at Aberdeen suggested an armour piercing nosed fuse. We made some up and found on firing that indeed such fuses would not break off or fire superquick provided that the shell were fired at low velocities. This meant that the ordinary Howitzer rounds could be used with a special fuse and field assembled as needed. At low velocities the 155 mm shell, for example, stops in the concrete before it detonates.

The advantage of the use of a detonating shell in destruction of concrete fortifications is that the shell carries enough explosive that on detonation, for example, of a 155 mm or 8 in. shell a wall several feet thick is cracked. A second round fired in the same area normally breaks through the wall (as built by the French and Germans) and explodes on the inside. The hot fragments of the shell body would set fire to any ammunition inside. The resulting fires would kill personnel who might have escaped the fragments of the shell produced by its explosion.

These fuses were used on shell used against a fortification in one of the harbors in France. The fort was, I believe, built of granite blocks. The first round cracked and broke the wall and the second shell detonated inside. Men ran out in all directions waving anything they could, and the fort surrendered.

These same fuses were used extensively in an attack on a portion of Manila but inspection after the fact indicated that they had been fired at high velocities and the armoured fuses broke off without detonating the shell. Apparently the officers did not read or did not believe the instructions.

Mr. Bass, who was in charge of our Ammunition Loading Section, suggested that the fuse be redesigned to use a Navy booster since this was shorter and would have allowed more threads and a better concrete piercing fuse. We suggested this to Colonel Cave, who informed us that he would make any recommendations for changes he thought should be made. I believe he should have been court marshalled. At least, I never spoke to him again whenever I could avoid it.

Bulova Watch Company set up a line and manufactured the special fuses.

(4) Large Caliber Artillery

The 155 mm Gun, M1, when firing armour piercing shell, could blast through the forts but this took several shots fired almost on top of one another. The reason was that the true armour piercing shell carry relative small explosive loads.

The main objection was that the large number of rounds required permitted the fort to return the fire, usually effectively, before sufficient armour piercing rounds could be fired to break through the walls of a fort.

With the special fuse the second round usually penetrated the fortification's walls.

c. Heavy Mortar

Someone, apparently at Ballistics Research at Aberdeen, suggested that if we built a heavy enough projectile that a single projectile landing on the top of a concrete bunker would break through the roof and destroy the bunker. So Ballistics Research people came up with the idea of a 36 in. mortar which was expected to fire a 36 in. shell loaded with a soft explosive that was expected to be exploded after it had flattened a bit on the top of a fort.

A contract was entered into between the Ordnance Department and a steel equipment manufacturing company in Pittsburgh to design and build such a weapon. This immediately became a major undertaking with very high priority.

The device, as it evolved, was something like the following. A very large steel frame was designed with plate sidewalls and bottom. In this was fixed a heavy frame which carried the base for the 36 in. mortar. Limited movement was allowed for small changes in aim of the weapon both in azimuth and elevation. A plunger type shock absorber was built in the bottom and the tube inserted. The tube was of course 36 in. internal diameter with wall thicknesses from about 10 in. at the bottom to about 4 in. at the top. It actually was an updated Roman Ballista.

The whole case was carried on double tractors, one fore and one aft. The device was set by digging a ditch some 100 ft long, 12 ft wide and 12 ft deep.

The projectile was a steel case quite spherical and which was expected to carry about 1000 lbs of a plastic explosive. The rotating bands were precut and the projectiles were muzzle loaded.

A company of soldiers was ordered in for labor. A detailed test program was prepared and I assigned responsibility to Rhein.

The device was considered so important that General Barnes, Head of Research and Development of the Ordnance Department, and Colonel Gearhart, who was responsible for artillery development, were frequently in to witness tests.

The preliminary tests such as determination of powder charge, were readily completed. Difficulties started when I began to suspect the projectiles were unstable. So I got off to the side a bit and observed the firings. The shell were so large that no special glasses were needed. Sure enough, the projectiles developed large yaws, up to 29°, but only for a few turns. This, however, made the accuracy questionable. It turned out a simple redesign corrected this defect.

On completion of the preliminary tests we had found that the accuracy was only fair--not at all as good as the 8 in. Howitzer--but possibly useful for destruction of fortifications. At least the explosion of a projectile near a fort would scare the persons inside.

Then Rhein set up to fire live rounds. He took great care that every person in the area was behind heavy concrete barricades. Well he did. The first round detonated at the muzzle. The weapon was completely destroyed. I called Colonel Gearhart but found him and the other ranking officers in a conference in General Barnes' office re the device. I told Gearhart what had happened. They came up the next day.

This killed the project. I never liked the device as it was too cumbersome and heavy for field use. I also thought the design was primitive and I think I was prejudicial because I thought that the armour piercing shell fired from mobile mounts would be more effective. The set-up times for the mortar were just too great, and the time between rounds would have permitted interdiction fire.

The only accidents we had was that one man was leaning on a crane as it turned and cut off the ends of three fingers.

d. Conclusion

Of course, I had no part in the conclusion. The air drop of the recoilless weapons, I am quite certain, made it possible for the Second Army's air drop to capture one of the Rhein River bridges and to erect the sign "Walk Across the Rhein, Courtesy the Second Army". The sign should have read "Courtesy of Two Civilian Engineers of Frankfort Arsenal". These men, who were named Kroger and Musket, had designed the weapon. We called it the "Crow Musket" for a time.

After reading the above Lugene Hungerford stated that after the war she dated the man who had been General Patton's pilot. He had told her that very large numbers of Germans had surrendered to "just a few Americans" who had been dropped across the Rhine.. I heard that the Germans thought what were 57 mm Recoilless Guns were actually 155 mm Guns; so they surrendered.

The destruction of the concrete fortifications, when necessary, proved to be simple. Of course, with nuclear weapons fortifications are out of date. Fallout shelters are something else.

### 3. Destruction of South Seas Fortifications

I had no part in the special program and group set up to study the destruction of the South Seas type of fortification. These were made from local logs, dirt and stone. The cocanut logs were tough. When a fort was struck it simply rose up and settled down again, so their attack has been very difficult.

### 4. Plate Tests

I have classed here as plate tests both tests of concrete and stone and armour plate. We built and tested various types of walls, including block granite. This proved to be most resistant. Actually, this was part of a large "Terminal Ballistics" program that we ran for a long time.

The armour plate tests were run continuously as routine checks of both the plate and test of the armour piercing shell. One series of tests included armour plate for soldiers. This may sound silly but it is not. In actual battle many soldiers are wounded or killed by richochets, small pieces of armour picked up by bullets, and pieces of shrapnel or shell pieces. Many of these stray pieces of metal can be stopped by very thin pieces of metal. So human armour plate was developed.

The most effective armour against the various types of shrapnel, etc on a weight basis was found to be a mixed rayon aluminum sheet. This has been used commonly since.

### 5. Tank Tests

Unfortunately the word "tank" is overworked as it means simply a container for water. By extension it means an armoured, usually tracked, motor driven vehicle, equipped with a considerable list of lethal weapons. It is in this last meaning that we are discussing the problem here.

If a tank is struck by a projectile that penetrates the outer armour, hot steel particles usually penetrate the powder cases of the loaded rounds in the tank. These burst into flame and burn very rapidly. The crew, if alive, has only a few seconds to get out, a maximum of 9 seconds in the American World War II tanks.

A long series of tests were run to determine how these loaded rounds could be protected. Use of armour plate and water tanks were tried. But as far as I know the problem remains unsolved.

D. Special Weapons

A number of tests were run on special weapons. These included tank, antitank, aircraft and coast defense.

1. 75 mm Tank Gun

In the summer of 1940 I did some firing of the 75 mm Tank Guns used on the General Sherman Tank, I believe. This was the tank used in such numbers in North Africa. The tank was so designed that the gun could only be fired in a limited azimuth. We always considered it a poor design.

2. 76 mm Tank Gun

The 76 mm Pilot Tank Gun was sent to Aberdeen for test. This gun was tested at excess pressure in accordance with our regular procedures. It was then mounted in the open and given a 2,000 round wear test. Periodically the wear at the front of the powder chamber or forcing cone was measured.

At about round 1,500 the gun failed. The whole rear half broke into fragments, some 8 to 10 in. on a side, and 2 to 2.5 in. thick. Now it has been known for a long time that when a gun fails in this way that the rear travels to the rear, the front of the tube travels forward, and the pieces left of the sides travel outward at various angles, but that there are 45° angle sections at the rear on either side that are reasonably safe.

In this gun failure there were, I think, three men standing in the socalled "safety angle" at the rear. Total injuries consisted of a piece of wood being blown against the leg of one man and causing a superficial injury. However, one piece of the gun flew between one man's body and his left arm, which he had swung outward as he fired the gun by pulling the lanyard with his right hand. The piece of steel was near enough his body to tear his shirt and one thread of his underwear.

I assigned Captain Losco to investigate this gun's failure. He visited Watertown Arsenal, reviewed the design and concluded for the steel used the safety factor was just about 1.0. The steel specifications were changed to provide a safety factor of at least 1.20. This compares with 4.0 to 5.0 for most pressure vessels, 5.0 for most bridges and 7.0 for mine cables. No further failures occurred.

Later the 76 mm Tank Gun was adopted and used very extensively. We proof tested great numbers of these. The only active part I had was that occasionally a gun would be boroscoped (optically examined on the inside) and inclusions or defects would be noted. Then I had to look at the tube and make the decision to accept or reject. Obviously the girls who boroscoped the guns were the experts so I always talked the case over with the girl who examined the gun, and if she indicated any opinion I sagely agreed with her. It was always a judgment. Anything over 0.5 in. I rejected.

## 3. Tank Gun Mounts

The utilization of the 76 mm Tank Gun required development of a different tank gun recoil mechanism. This was designed and turned over to the Ford Motor Company for production. Even the pilot mechanism was beautifully and correctly machined.

This type of recoil mechanism simply forced oil through a large orifice and a spring returned the gun into battery or firing position. Captain Kolb ran a 2,000 round test on one of these units with no trouble.

Before we entered the war, one American company had contracted with the British government for a large number of Tank Gun Mounts. These mounts included the recoil mechanisms and steel supports. As I heard the story, a group (possibly only one) of men in Wilkes-Barre had the idea that an old machine shop could be rented or perhaps they owned it, and machined parts could be sold to the British government. So they hired a high pressure salesman and he promptly sold something like $200,000,000 of goods at, I understand, 2% commission.

Anyway, the salesman sued for his commission. I never heard how this came out. But about the time production started the United States agreed to carry out the inspection of these components. The first mounts that came in were in very poor shape and we rejected them. Later they improved as the United States Plant Inspectors made their weight felt. Then a carload came in all oversize in some of their outside dimensions. I called the President and he agreed that the future shipments would be checked and corrected. The next carload came in in the same shape. The President apologized and said they had just left when I called him previously; so we ground them down. Then another carload came in. These we did not unload but sealed the car and shipped it back. I then called the President and so informed him. We had no further trouble.

4. <u>105 mm Gun</u>

We tested a larger tank gun which I believe was 105 mm. We had no trouble. I don't remember more.

5. <u>16 in. Gun Test</u>

In 1922 Japan and the United States signed a contract to limit construction of Naval vessels. The United States removed a number of 16 in. guns from ships and destroyed them while the Japanese proceeded to develop and build 18 in. guns.

We also scrapped many of our 16 in. Coast Defense Guns. Others were stocked.

Just before World War II Aberdeen was called upon to test one of these 16 in. gun tubes. Apparently in the nearly 20 years it had been forgotten that this tube had not been properly heat treated. At any rate, on test the first projectile tore most of the lands loose.

Then in 1942 one of my Ordnance friends, whose name I have forgotten, wrote an Ordnance note recommending dismantling all our Coast Defense facilities. This was approved.

6. <u>75 mm Aircraft Gun Mount</u>

The conventional fighter aircraft built before the War and during the War carried machine guns and 20 mm guns. These had a high rate of fire and a dozen of them on a plane can throw a lot of weight. Frequently heavier weapons have been suggested.

A 75 mm Gun Mount was designed to hold a short 75 mm Gun Tube and an automatic loader designed to fire, I think, 20 rounds at intermittent fire. We had all kinds of minor troubles getting this widgit to work perfectly.

Finally it was approved for construction. The Air Force finally, after great lengthy discussions, mounted one on an old bomber. The part that I heard of the story of what took place follows.

Two men took off in the old bomber from, I believe, the Phillipines, flew across the China Sea; met an ocean freighter, sank it; shot up a truck convoy on the coast; and near Burma caught a freight train entering a tunnel, wrecked the freight, and jammed the tunnel; and then flew back to their base, all in one sunny afternoon.

I believe the subject was dropped. Of course, rockets were mounted on planes but their accuracy was poor. With nuclear heads rockets need not be accurate.

E. Gun Erosion

Gun erosion is due to the action of the hot flowing gases and the wear of the shell on the forcing cone during loading and firing. I believe that a good part of the erosion occurs by the escape of gases past the rotating bands upon firing. At any rate, gun tubes wear out, particularly where the bands and grooves start and must be replaced. Machine guns are sometimes lined with more heat resistant steel than the ordinary steels in use for the bulk of the tubes or at the forcing cone. I learned later that work was done at Purdue University on this subject. Dean George Hawkins did some of the work on heat transfer.

We fired many rounds to measure the wear or erosion in the guns so that the people in the field could make measurements and correct their gun settings.

F. Fragmentation Tests

One test is of general interest. We statically detonated shell in sand, screened the sand and laid out the recovered pieces of the steel projectiles for study and pictures. Ballistics Research conducted many static bomb tests in the open to measure the pressure waves.

### G. Bomb Disposal

The Ordnance School, which was located immediately west of the Proving Ground, had responsibility for training Bomb Disposal Officers. Now disposing of bombs which have been dropped and which have not exploded on impact requires a very detailed knowledge of explosives and bomb fuses and their good and bad habits.

The School had asked the Proving Ground for a practice area. At the time early in 1942, I believe, I was not responsible for the Ranges. I do not know who issued the necessary permits. At any rate, several students and one or more of their instructors were permitted to enter an old storage area and "dispose" of some ammunition. This ammunition was World War I vintage shell which had been stored in the open in a damp area, probably for 20 or more years. The steel had corroded but of course the explosive had all its youthful vim and vitality.

At any rate, these people carried perhaps 20 155 mm shell from the pile and laid them in an area so that the shell could be detonated. They apparently laid standard 2 lb explosive packages next to each shell, moved away, and electrically detonated the small charges.

Then they came back to look at the remains. Two shell had not detonated. So all the soldiers gathered round. One then detonated. As luck would have it, I think only one was killed instantly, one lost one arm and leg and refused hospitalization as he said he would die no matter what the surgeons did, and others might be saved as others were injured. I think he was the only death at the hospital.

Of course, they violated two rules: a) Never move old rusty shell or old explosives of any kind; and b) never return to a detonation area after a blow until the next day.

I regretted that I did not call the Commanding General of the Proving Ground when I heard that the Bomb Disposal people were to try out their destructive procedures, and ask that this work be placed under my command.

I was in charge of the impact areas or ranges for two years. We had one accident in that period. One of the old civilian employees who had worked on the ranges for 20 years picked up a shell which he "recognized" as an inert loaded 37 mm Test Shell. These shell were simply fired for dead loads in case, powder and tube acceptance tests. The shell he picked up actually was an Italian 41 mm armour piercing, I think, which had been fired for some reason by Small Arms. The shell was lying at their rest area. He was sitting on a low bank. After looking at it he dropped it between his feet next to the bank. Due to the bank only his feet and lower legs were shattered.

The other "range man" that worked all during the War on the ranges was a Sargent who had been in the Army, I believe, to retirement age. At least he retired right after the War. Soon afterward he was working for a contractor who was "recovering" shell from the impact areas for scrap. That is all I ever heard except he was killed picking up scrap.

On the other hand, we examined all kinds of foreign materiel, including trick devices left by retreating troops, various types of trip devices, etc without trouble. Always one is on the edge of catastrophe and must tread softly and follow the rules. Never move an unknown shell unless a 2 lb charge has been detonated next to it and at least 12 hr have elapsed between the detonation and the movement of the shell.

### H. Foreign Materiel

One of our important functions was to study the foreign materiel sent to this country or captured. Captain Allan Wilson worked on this program at length and Captain Kolb spent a long time on study of the British 57 mm Antitank Gun. Others were also involved. In addition, we disassembled and examined devices like grenades, anti personnel devices, etc as noted above.

The disassembly of anti personnel devices involved some hazard. The Germans in particular devised several widgits that would explode on touching and others on disassembly.

Most of the foreign material we examined was British and German.

#### 1. Mortars

The German 81 mm Mortar and its ammunition was examined and test rounds fired. This weapon was so nearly like ours that the only item to note is that it had a somewhat heavier and stronger base plate. The British mortars were almost identical to those of the Germans.

2. 57 mm Gun

The British manufactured a 57 mm Gun for anti-tank use but no other country did so. Because this gun had done yoeman service in North Africa, there was pressure for us to adopt the weapon. Accordingly several were sent to Aberdeen for test. Captain Kolb carried out the tests and wrote the report. He concluded that the weapon was relatively ineffective.

The British 57 mm Gun fired, I believe, a 7 lb solid steel projectile at 2,800 ft/sec. This was a high velocity but the shell was too small to be effective.

In addition, we concluded the weapon was too complicated for high production. As I remember it, there were several pages of objections. Nevertheless, we did manufacture and test many of these weapons but I don't believe our troops ever used any of them.

This report led to an argument between Harold and me. As he said, he spent days writing the report to make certain that it was nearly perfect, and then I tore it to pieces. He stated, "You make me so mad. But I have to admit that tomorrow I'll say it's a better report." Harold still is a close friend.

3. 105 mm Howitzers

The British and Germans as well as the United States built 105 mm Howitzers in large numbers. We compared these weapons in respect to details of manufacture, ease of disassembly and assembly for repair, ease in loading, accuracy, etc.

It turned out that the ammunition for the three weapons was very much alike, the weapons functioned quite alike, but the manufacturing operations differed radically.

The British breechring was cut from a block of steel and machined on all surfaces. The German one was partially machined and the American was cast almost to shape and finished machined on the working surfaces. The

German wheel and axle assemblies were very involved and included many small parts.

We did not disassemble the recoil mechanisms as this was done by Rock Island Arsenal. Presumably they were much alike in principle. The American used tubes and the British drilled holes through a heavy forging. I have forgotten what the Germans did but I believe it was drilled from a forging.

In resumé, our weapons were very much cheaper to build and maintain as well as being lighter and more easily handled.

4. Russian Tank

A Russian tank was sent in and tested by the Automotive Division. We simply looked at the general vehicle and armament. It was well built, simple design, and had excellent operating characteristics.

I. Demonstrations

We conducted many demonstrations for special persons and special groups. The demonstration for General Marshall was mentioned above. In addition we had many important visitors, including President Roosevelt, and separately Mrs. Roosevelt, and many others. Of course, General Harris, Commander at Aberdeen, General Campbell, Chief of Ordnance, and General Eddy, Commander of the Proving Ground, acted as hosts for these people. I did the talking for less important people.

Some demonstrations were of interest. The demonstration for Mrs. Roosevelt was one. We had negroes and whites working together. These included labor, gun crews, engineers, etc. Since Aberdeen is located in Maryland, we had separate washrooms. When it was announced that Mrs. Roosevelt was coming in, word was given out to make certain that these washrooms were all alike as she was interested in the colored problem. We did nothing.

1. Chicago Editor

Colonel Robert McCormack, Editor of the Chicago Tribune, was brought in one day by General Barnes. Colonel Eddy and I spent the day with them and gave Colonel McCormack a full tour, including firing the 240 mm Howitzer. I considered this a waste of money, but enjoyable.

2. Women

A group of women were brought in for a partial demonstration which included the firing of the 240 mm Howitzer. These women were chosen by various groups of women employees who were helping out in the War work in munitions factories.

Before firing the 240 mm Howitzer, I warned them where to stand, how to hold their ears, and what might happen. On firing, the blast, even though they were all standing well behind the weapon and we used the lowest powder charge, blew their clothes tightly against their bodies. Actually, the blast would not knock anyone down but it was quite noticeable.

Everyone of the women looked stunned, everyone dropped her purse, and after about 5 seconds all started laughing at the others.

3. Employees' Families

In May, 1944 we arranged for a demonstration of most of the weapons to the employees and their families, as many of the employees in offices and shops had never been in the highly restricted firing areas. We also permitted every employee to bring his immediate family--about 5,000 in all. We did this on a Sunday, which turned out to be a beautiful day.

Each Proof Officer, both civilian and Army, was asked to discuss and demonstrate his particular weapon. Everything went off in fine shape and I'm sure the day was long remembered in the Aberdeen area.

J. Odds and Ends

1. Powder Pressures

Of course there were many other things that were of interest. Each Thursday we had a 1 to 2 hr movie of action pictures. These were front line movies and showed the worst part of the War. War is hell. Then there were many questions. One of these, I remember, dealt with several lots of 8 in. Gun powder. The maximum firing pressures were 2,000 psi high. Rejection meant burning some 2 to 4 million pounds of powder. I recommended accepting the powder for issue.

## 2. Invasion Plans

At the time the nuclear devices were dropped on Hiroshima and Nagasaki, I had the geologic maps of Tokyo Bay on my desk studying, along with others, the optimum point for an amphibious landing. We expected 1,000,000 casualties in the fighting in Japan. Actually, the Japanese casualties would probably have been much higher than ours if the civilian casualties would be counted. After all, 155,000 people lost their lives in the Tokyo fire bomb raid and the resulting fires. In addition, we knew all the interned Americans were to be killed immediately following the landings. This would have included Eugene Hungerford and thousands of others. So ending the War with nuclear devices saved hundreds of thousands of lives. I have always believed that some publicity about the nuclear explosives followed by a demonstration in Tokyo Harbor would have convinced the Japanese of the futility of further fighting. I realize how few weapons we had at the time but I think the demonstration, or request for a review by neutrals could have ended the War without the deaths that occurred. However, Nagasaki and Hiroshima may have done more to end wars than anything else could have.

## 3. Powder Storage

I mentioned above that powder storage was one of my worries. The Main Front had a Loading Plant consisting of a brick building perhaps 40 x 60 ft. About two-thirds of this building was open for general work while the other third was cut up by double brick walls into loading rooms. There were, I think, three smokeless powder rooms and one black powder room used for weighing charges, etc.

In each weighing room there was a table and racks for shell cases, a scale table and scale, and other tools. Powder in steel drums which held 200 lbs each would be brought in and charges weighed as needed. The powder rooms were maintained at 70° F. While we used very little black powder, some was used. This room was always scrubbed immediately after each use.

The regular smokeless powder was stored in a constant temperature reinforced concrete building designed for a maximum of 10,000 lbs of powder. During most of the War we had from 90,000 to 110,000 lbs in the building. Since some of this was rifle powder, a fire could have had rather serious consequences. Normally, while I was in charge of the Main Front, I tried to inspect this building daily. Mr. Bass, who was in charge of this area, inspected the building regularly. At no time did I ever find any spilt powder or grit on the floor. The powder was of course always sealed in the 200 lb steel drums.

In 1942 a second powder loading plant nearly identical to the one described, was built.

In respect to black powder, when I was at Savanna one of the officers had assigned a soldier to disassemble some old parachutes containing small black powder charges in flares. The soldier did not know the characteristics of black powder and when the officer I was with and I found him, he had it all over the floor. We simply called him to the door carefully and got him away. A spark could have caused a violent fire from which he probably would not have escaped.

As I stated above, there was some rifle powder at Aberdeen. We had only a negligible amount. But we got involved in tests of this powder due to fires. The rifle powders contain nitroglycerin, which will detonate by heat or friction. Dissolved in the smokeless powder, it increases the rate of burning. In large quantities under pressure, instead of burning with a flame it will detonate.

Fires occasionally occur in rifle powder manufacture. These are expected. However, in one instance the powder fire spread into two railroad cars and the powder on board these cars detonated; the railroad cars and contents simply disappeared. As a result we ran several tests of piles of rifle powder. We would pile up powder, say 2 ft deep, over a squib which could be used to light the powder, and burn the powder to see what the critical mass was. These tests entertained us for several Sundays.

4. Locomotive Tests

At the time in question, most European locomotives were steam operated. Partisans frequently blew up the locomotives by placing explosives on the tracks. The Germans got around this by rapid repairs of the damage and by pushing one or two old worn out cars ahead of the locomotives. So we had to develop counting devices that would count the wheels and then blow up the locomotives beyond repair. Telephone dial counters worked well for the wheel counters. All the partisan had to do was to set his explosives and wait until a train got in sight, count the wheels to be allowed to pass over the explosive, set his counter, and disappear.

We also developed means to make repairs very difficult. These tests occupied and entertained us for other Sunday mornings.

5. Weird Results

a. Antiaircraft

Two things happened that are of interest. The first of these is that a Proof Officer at the Antiaircraft Range was testing a 120 mm Antiaircraft Gun. During some of the firings at very high elevations of $75^{\circ}$ or so, the shell simply disappeared. Soon, however, we heard where they went.

All shell are rotated on firing to give them stability. These shell were over stable and when they reached their maximum elevation they did not turn over but came down backwards. Due to its right hand rotation a shell normally proceeds to the right. When coming down backwards, the shell proceeded to the left. As a result they landed across the Bay on farms on the Eastern Shore. Luckily no one was hurt.

b. Bombs

I had nothing directly to do with the bomb ranges or tests; so I had no part in the following.

The bomb ranges at Aberdeen were used for low elevation tests but with the advent of World War II planes flew much higher; so high altitude bombs were developed. Samples of these were inert loaded for recovery tests and one was dropped from high altitude. The bomb did not strike the bomb range but struck across Route 40 and the Pennsylvania Railroad near the Baltimore & Ohio Railroad. As a result the high bombing range near Death Valley was promptly opened.

6. Museum

During the middle of World War II the Museum at

Aberdeen was scrapped. It had been built up at great expense and included most of the weapons used in World War I along with various older and newer weapons, both U.S. and foreign. The excuse given was that the material was needed for the scrap iron.

I opposed the scrapping as it was useful for old test pieces like muzzle blast deflectors, etc. We had used it several times. Also I believed that its educational value was too great to permit its use as scrap.

7. Officer of the Day

Even with the work outlined above, I still had to take my turn as Officer of the Day. During the War Aberdeen Proving Ground consisted of the Proving Ground proper or Arms and Ammunition Development and Test, Ordnance School, Ordnance Training Camp, and Ordnance Field Supply Depot. I was attached to the Proving Ground and had no part in the Training or Field Supply programs. However, there were necessarily several Officers of the Day and one Field Officer of the Day. This latter was either a Major or Lieutenant Colonel. So there being only a limited number of these Officers, I had to serve my turn, usually on Sundays as there weren't supposed to be troubles on Sundays.

Several things happened which may be of interest. Some of them are listed but not in the order in which they occurred, as I have forgotten the dates.

(a) One night it was cold and rainy. I was out most of the evening on Inspections as we had to check all the Officers of the Day. Unfortunately, I had a bad cold and I was very tired. I should have called in sick but I didn't. Anyway the next day I went to the hospital for ten days with pneumonia.

When Winnie came to call on me at the hospital and found me in the ward with a high fever and pulse, she got me transferred to a private room. I had a good rest, which I very badly needed.

One other time I got a minor skin infection and the doctor wanted to give me a series of "shots"; so he put me in the hospital. There were practically no patients, so my room was usually filled with nurses who had little to do but give me back rubs.

(b) One of the first times I was Field Officer I was called about 1900 from Bush River. The Pennsylvania Railroad had a small depot there and local trains stopped. The ticket agent called saying a negro worker had just come in and said there are arms and legs all along the track. So I was asked if we were missing one or more soldiers and, if so, would I send out an ambulance for the arms and legs and presumably other parts.

What had happened was that a passenger train with a couple cars of draftees was going north from Baltimore to Aberdeen. It had slowed down at Bush River--actually Bush River is a mile wide branch of Chesapeake Bay--and one of the draftees had tried to get off. The train had probably slowed from about 110 to 50 miles per hour. The man had been dragged or rolled under the train. Also there was a freight on the next track soon after at probably 50 miles per hour. His body was cut into several parts.

It was also my duty that night to telegraph the man's folks and tell them that their son had been accidentally killed. I got the Adjutant to write the message.

(c) Another time I was about asleep one Sunday afternoon in Headquarters when the phone rang. The man calling spoke about as follows: "This is the Sheriff in Elkton. One of your MP's just shot a man. Do you want to send an ambulance for the body or shall I stick it in the morgue?"

What had happened was that one of the trainees had gone AWOL and gone to Elkton to see his girl. They had a large pyrotectics plant there with lots of girls.

An MP had been sent to arrest the man who was in civilian clothes. When the MP found him, the man ran. The MP then started chasing him and fired a warning shot. But as the MP fired he stumbled and the bullet struck the AWOL in the back, killing him instantly.

This time I got the Adjutant to handle the whole deal.

(d) Not all things end in such tragedies. Others are different. One night I walked into the MP dorm to inspect it. This requires explaining.

While at Aberdeen I had a continual feud with the MP's. Their Commandant was one of these super efficiency guys and I did not like him. Anyway his men were always arresting my men for speeding and minor traffic infractions. Since they had to go to the socalled Court to explain these things, it took them from work. So I refused finally to let them go and I would call the Court Clerk and explain what had happened. Then they started holding Court at night!

The MP's were always driving around the area at high speeds. One night four of them were in Aberdeen and I tried to catch them. If I had, they would have been in deep trouble but they turned into Post Road and the guard there waved them on and stopped me, quite correctly too.

Anyway, when I went into the dorm, a naked girl whom I had seen and recognized, was laying on one of the cots. She quickly covered herself. As I had seen her out of the corner of one eye, I inspected the dorm and walked out without letting anyone know I had seen her. The tragedy was that later I found out she had syphilis.

When Headquarters found out the girl had syphilis, they fired her. I called the Adjutant and tried to get her sent to the hospital. Anyway, she very soon married a young man that lived in Havre de Grace.

(e) Each time I was Field Officer the General sent me to a different place. He always read my reports to his staff but never anyone else's. I think I amused him. Three of the things I inspected were as follows:

(1) Guard House. I was sent to inspect the Guard House and eat dinner with the prisoners. I enjoyed it. The food was good and the men I talked to were all in for very minor infractions and short terms.

(2) Churches. They had three or four churches. So one day I had to inspect them--Sunday too. Major Gilbert Hyde, who lived in part of a duplex with us, was one of the Chaplains. So I enjoyed this too. However, I found many things wrong. Mostly they were dirty and they had not been maintained well.

(3) Stores. Once I was sent to inspect the Supply Depot. This was a mess also. The Colonel in charge was a good friend but I don't think he ever walked through the warehouses until I called on him to accompany

me. I wrote up a very damning report. Stuff was poorly catalogued; the place and equipment were dity; there were too many people involved, etc, etc.

(4) Officers' Club. The funniest job was inspection of the Officers' Club. And on Saturday night. In the Army there is almost always a formal dance at the Officers' Club on Saturday night, and all officers are supposed to attend and most do. However, this night was a bridge and game party.

So I walked into the Club at 2230 in the evening in fatigues and under arms. Or I was in regular work uniform, with cap--it is not removed while under arms-- and with loaded pistol and ammunition belt. There were guffaws from everyone. I proceeded to inspect the bar, etc. There were cockroaches and dirt everywhere.

Later I inspected the NCO Club and found nothing wrong. So my report was quite a contrast.

(5) Comments. Of course, I called all the persons in charge before I went to their areas. All of the Officers in Charge except for the Military Police and the Officers' Club accompanied me on the inspections. The man in charge of the stores asked me to return a second time to help straighten things out.

When we were inspected, which was not uncommon, I or Major Johnson accompanied the visitors.

8. Special Tests

There were several special tests that were conducted which I directed but which I believe are still classified. One of these required 60 hour weeks for the people involved. The General jumped on me about overtime. One other test involved loading airplanes and we were given from Thursday noon until Sunday to do the work and write the report. Chet Johnson, now retired Major General, then Captain, was in charge. He worked 23, 22 and 12 hours. I signed the report at 0330 Sunday A.M.

Comparative firings demonstrated only occasional short rounds. After much examination variations in thicknesses of the copper rotating bands, which are cut into the bands in the gun to rotate the shell for stability, were noted. It was then only a simple step to check the manufacturers for variations in procedures. It was found that the time of holding the pressure on the copper bands by the compression machine was important as the copper "flowed" slowly under the pressure. When properly compressed into the groove cut into the shell, the shell were compressed in diameter at the band area about 0.002 in. Correction was simple in that the proper delay time was easily determined and used.

D. Submarine Shaped Charge (II. C. 1)

We also ran tests of torpedo explosive shaped charges. These were tested statically in a special setup down range. Dur to the long instrument setup times, each detonation was delayed until nearly midnight, even though we started the actual installations in early morning.

The Commanding General climbed all over me for the long days. He seemed only worried about the labor and not the dozen engineers and officers.

E. Armour Piercing Shell (II. C. 4)

A test was run using tungsten carbide projectiles for armor piercing against tanks. This was top secret at the time. The high density material projectiles about 1 in. diameter were fired in three in. Guns with a detachable bottom so that very high velocities could be obtained. The high density resulted in very penetrating projectiles. On entering the vehicle the shattered, by then red hot, particles spread throughout the vehicle, killing the crew and igniting the propellants in the enemy tanks.

Of course, uranium or thorium metal would appear superior to the tungsten carbide since they would oxidize after entering the vehicle and remain red hot until completely oxidized.

A. Recoilless Rifles (II. B. 3. d (1)

One item of interest is that the 57 mm Recoilless Rifle was used to assist in the crossing of the Rhine River. At Aberdeen we tested all the available weapons and these were shipped by air. A "drop" was made across the Rhine. Something like 100 weapons were dropped. The Germans did not recognize that it was a new weapon and confused the noise with the 155 mm Gun. Accordingly a whole division surrendered as the Germans thought they were surrounded.

As a result the Americans were able to cross the Rhine with very little trouble.

After reading the above, Lugene Hungerford stated she had dated the pilot that took the American generals over Germany. She stated that he once remarked that they did not understand why the Germans surrendered the Rhine River bridge.

B. 60 Caliber Machine Gun

During the last part of World War II we were developing the 60 Caliber Machine Gun and firings were being conducted by Small Arms at Aberdeen. Great troubles developed because of the high pressure and high rate of fire. My part was simply to see that the work progressed.

What became of this program, I do not know.

C. 105 mm Howitzer Accuracy (II. B. 3. g)

When we entered World War II, there was a great expansion of ammunition production. Several contractors began production of 105 mm Shell. After a time it became obvious that occasional short rounds were occurring. In actual fact, many rounds had muzzle velocities 30 ft per sec below normal. This was enough to result in short rounds falling into our troops. I believe the actual invasion of Europe was held up for about six weeks while we looked for the source of trouble.

Joseph Sporazzo was the Proof Officer. The first step we took was to test a large number of rounds of shell lots supplied by the various manufacturers. These demonstrated that shell made by the Oldsmobile Division of General Motors were uniform. So this lot of shell was set aside as standard.

## III. NUCLEAR DEVELOPMENT

### A. Introduction

I knew there was a nuclear weapons development program during World War II but that was about all I did know about it. It was obvious what the magnitude of the project was because occasionally we lost people and I heard tales of strange cities, especially the one in Tennessee. When the first bomb was dropped we ran the motion picture of the Alamorgordo test that was released to study the bomb's magnitude and probable effects.

At the same time I got an early draft of the Smyth Report and studied it in detail. It was obvious that the usefulness of ordinary weapons in a major war would be limited in the future. On the other hand, we considered ordinary weapons would be needed even though the main battles might be nuclear.

Very soon after the War we returned to teaching. In the late fall of 1946 I received an offer from Los Alamos to become head of the Materials Department. I talked to Winnie and since we had moved twice recently, and since Los Alamos was remote, I declined the offer. In retrospect we most certainly should have accepted and moved to Los Alamos. The offer was made at the suggestion of a previous University of Arkansas student who was Associate Director of the Materials Division--as he said, he was trying to hire his boss.

Several months later I received a letter from the Monsanto Chemical Company in St. Louis saying that they understood I had declined an offer made by Los Alamos and would I consider a position at Oak Ridge National Laboratory. I answered a polite no. About one month later I received a telegram requesting that I visit Oak Ridge for an interview. I called Miles Leverett, who had signed the letter from Monsanto. Miles was Director of the Technical Division at Oak Ridge and Monsanto was the contractor. He stated they wished to consider me as Assistant Director of the Technical Division in charge of the Chemical Engineering development programs.

So Thanksgiving weekend in 1947 I went to Oak Ridge. On the way from Knoxville to Oak Ridge the Oak Ridge driver had an accident. I was not hurt but the driver of the other car had two teeth knocked out. I was made an offer that interested me, and after much discussion I accepted.

Accordingly, I resigned as head of the Department of Chemical Engineering at Wayne State University and we moved to Oak Ridge as of the beginning of February, 1948. The actual move was made in a snowstorm, loading furniture, driving to Oak Ridge, and unloading.

## B. Oak Ridge National Laboratory

At that time Oak Ridge was a closed city with everyone requiring passes to enter or leave. Since we were used to and liked this manner of living, we had no objections.

We were assigned a large house almost on top of the hill overlooking the city and very occasionally letting us see the mountains across the valley. The Oak Ridge installations at that time consisted of the laboratories at X-10; the Uranium 235 Electromagnetic Separation Plant at Y-12; and the U 235 Gaseous Diffusion Plant at K-25.

### 1. Technical Division

The Technical Division of the X-10 laboratories consisted of about 90 engineers and scientists. It was broken into sections: the High Flux Reactor and Chemical Separations, among others.

By the time we arrived at Oak Ridge the administration of the Laboratory was being changed. Monsanto Chemical Company had taken over direction of the Laboratory some time previously from the University of Chicago. But the Atomic Energy Commission wanted to centralize direction of all Oak Ridge facilities under industry, preferably one organization. So Monsanto dropped out and the Commission contracted with Union Carbide and Chemical Company to operate all three Oak Ridge plants, including the laboratories. The Commission was probably wrong in that the scientists were happier under Monsanto. "Administration" was more direct but the "productivity" of the Laboratory was probably decreased--thus a wrong decision was made by the top "administrators".

Because of this Miles Leverett, Director of the Technical Division, resigned to return to his previous position with Humble Oil Company, as he had been on loan during the War from Humble. I do not know what his position had been. He was an excellent Chemical Engineer.

Poor Miles, after a few months at Humble, he gave up as he couldn't stand the lack of excitement, and returned to the nuclear field.

So I worked for Miles one month only. Merlin Peterson was Director of the Chemical Separations Section. Since I was completely new, he was made Division Director--in other words, he and I were reversed and he became my boss instead of the other way around. It was logical and worked as Pete knew what had been going on and I did not. For the immediate future he kept the Chemical Processing Development and I took charge of all the engineering work in the Division, including that of Chemical Engineering Development such as fluid flow, heat transfer, etc. I was happy as I never enjoyed administration. Pete is still doing it. Unfortunately his wife, Marion, died of brain cancer a few years ago.

Most of my work became associated immediately with the High Flux Reactor which was later renamed the Materials Testing Reactor. Actually, in addition to the engineering work I soon became sort of an Assistant Laboratory Director as I was made a member of the Laboratory Executive Committee and stuck my nose into laboratory wide projects. The Laboratory was so poor engineering wise that everyone seemed to welcome any help. Anyway, I always have offered my opinions whether asked for or not.

About half of the Technical Division staff was assigned to the Separations end of the Reactor Program and one half to the Engineering Development. There was also a 15 to 20 man Engineering or Drawing Section. All these people were occupied with the design of the High Flux Reactor and its associated fuel recovery facilities.

It would appear reasonable to mention a few of the persons that worked for me and with me. These included:

(a) John Huffman. John was an Assistant Director of the Technical Division. He was a Chemical Engineer who had worked with the Columbia Group before the War on Reactor work. At Oak Ridge he was in charge of design of the High Flux Reactor. After Miles left he continued the design for a time and then transferred to Argonne National Laboratory.

When the Steering Committee for the Materials Testing Reactor or MTR, was set up in June, 1949, I believe, John became Argonne's representative and was responsible for design of the MTR outside of the Reactor itself. Later he moved to Idaho and worked for Phillips Petroleum in Operations of the MTR.

A few years ago he retired and moved to Boston. Due to his consulting he and Bereneice now live in Philadelphia. Presently he is consulting on the design of a replacement power reactor for the Hanford area.

(b) James A. Lane. Jimmy reported to Oak Ridge the same date that I did. He had been an old du Pont employee with a Physical Chemistry Masters Degree. During the War he had been assigned to Oak Ridge but when du Pont pulled out he went back to Wilmington. He was on leave as Technical Advisor on the Alsos Project in Germany at the end of the War. Then he returned to Oak Ridge in 1948. He worked with me at Oak Ridge, later he worked for Marvin Mann on the Materials Testing Reactor, and still later he was transferred to the Atomic Energy Commission and we were both Branch Chiefs and worked together on an evaluation of reactor programs for the Commission with Dr. Laurence Hafstad. We still keep in touch.

(c) Charles Winters. Charles was in charge of a portion of the Chemical Engineering Laboratory. Later he was transferred to the rayon division of Carbide and I believe he is now a Vice President of the Carbide Company.

(d) Beecher Briggs. Beecher was an engineer in charge of a section of the Chemical Engineering Branch of the Technical Division. He is still at Oak Ridge.

(e) Floyd Culler. Floyd was a Section Chief in the Chemical Separations Branch. Floyd became Division Director, Assistant Laboratory Director, and he is Director of the Laboratory.

(f) ______ Jones. Jones was Chief of the Design Section. He was an excellent engineer.

(g) Jack Kger. Jack was in charge of the Metallurgy Division. Richard Cunningham and several others worked for him. They developed the aluminum clad highly enriched uranium fuel assemblies for the MTR. Similar assemblies have been used in many later reactors all over the world.

The detailed work being carried out by the Technical

Division is discussed below under the Materials Testing Reactor.

2. Union Carbide

As mentioned above, it was announced just before our move to Oak Ridge that Union Carbide and Chemical Company would take over operation of the Laboratory on 1 March 1948. So during February the Division Directors met with the Carbide representatives to establish policies. We had several two hour meetings. The net result was that many of the people were unhappy but on the whole I think tighter policies were necessary. Anyhow, Carbide is still running the place. But the production of new ideas probably dropped.

3. Organization of the Laboratory

The Carbide organization was the normal business type with the usual officials and staff meetings. Since I was the most talkative, I kept and wrote up the notes of the Executive Committee meetings. I also got stuck with some special jobs such as the installations of filters on the old Graphite Reactor.

Other persons of interest that should be mentioned was a Mr. Rucker who was assigned by Carbide as Director. He had an assistant whose name I do not remember, but for whom I had considerable regard and who, in my opinion, actually ran the Laboratory. He conceded one day that he did not like the personnel problems nor the publicity. But I believe he was a much keener man than Rucker.

Marvin Mann. Marvin was a member of the Physics Division and was occupied at the time in question with the physics calculations and critical mass measurements of the High Flux Reactor. He became a member of the three man Materials Testing Reactor Steering Committee representing Oak Ridge. Later he transferred to the Atomic Energy Commission where he has been most of the last 20 years.

Alvin Weinberg. Alvin was Director of the Physics Division. He became the Oak Ridge Executive on the Steering Committee. Later he was Laboratory Director until January, 1973 when he took leave of absence for six months. I do not know what he is doing at present.

### C. Development Programs

The main efforts of the Development Division were directed toward the High Flux Reactor. Since all aspects of this project were classified secret, I spent most of my time at first simply going over the reports and studying the research and development projects. At the time under discussion, very little information except the Smyth Report, had been released about the nuclear developments. The Oak Ridge Graphite and the Hanford Reactors had been built and were operating. In addition the Chicago Pile 3 was operating as were two small reactors at Los Alamos.

So when Miles Leverett left at the end of February I became responsible for the development and engineering of the project. Luckily I had an excellent staff. Peterson continued to direct process development of the Chemical Separations and Recovery of the U 233 and U 235 programs, while I directed the design of the full scale recovery plants.

#### 1. March Meeting

Due to low morale throughout the Laboratory when Carbide took over there was very little work done by the scientists during the early part of March. Even the engineers were affected. So I started Monday Morning Technical Meetings. For the first one I asked each engineer in the Division to submit proposals for the programs he thought should be pushed. As recorded in the official history of the Atomic Energy Commission, more suggestions were submitted than it was possible to carry forward. We decided to push those projects dealing with the High Flux Reactor. Unfortunately this left out Zirconium development which had been recommended by Charles Winters. To have done so was probably right but it may have been the poorest decision I ever made as the development of Zirconium might have been started one to two years earlier than was actually the case.

Morale in the Technical Division became excellent and continued to affect the other Divisions as most of the people went back to work.

#### 2. Materials Testing Reactor

Sometime later the High Flux Reactor was renamed the Materials Testing Reactor, but I have used the Materials Testing Reactor name or the initials MTR in this paper. The basic idea for the reactor had been suggested by Professor Eugene G. Wigner of Princeton University.

### a. Description of the Project

While the Project was classified at that time, it was completely declassified and a public description was made in 1953, I believe, at the Jenner Conference in Norway. But in 1948 the technology was held closely. The reactor was designed to produce a thermal neutron flux of $2 \times 10^{14}$ neutrons passing each square centimeter in the beryllium per second. This was about an order of magnitude higher than any reactor in operation at the time. The heat load was 30,000 kw.

The actual fuel for the MTR consisted of an aluminum-uranium alloy containing about 18% uranium by weight. The uranium was enriched to about 93% U 235. The alloy was made by reducing the oxide with aluminum to form an alloy of about 18% uranium by weight. The ingots were rolled to about 0.04 in. thick plates and these were clad by a picture frame process with aluminum. The plates were cut to about 2.75 in. wide by 24 in. long, clad with an outer plate punched to hold the alloy and clad top and bottom with aluminum plates about 0.02 in. thick. These were brazed, using an aluminum-silicon alloy, to form solid plates. Then 18 of these plates which were about 0.08 in. thick by 2.75 in. and 24 in. long, were bonded into aluminum side plates about 3 ft long. Suitable end boxes were then brazed on the fuel boxes to give the completed assemblies. The reactor core consisted of a 3 x 8 pattern of these fuel assemblies surrounded by beryllium reflector bars 3 in. by 3 in.

The critical mass or working load of fuel contained about 3 kilograms or 7 lb of U 235. The core volume was about the size of a suitcase. 10,000 gpm of water was pumped through this core at 30 ft/sec to remove the 30,000 kw of heat.

As designed the core was surrounded by an average of three layers of 3 x 3 x 40 in. beryllium pieces. Neutron ports were cut into the beryllium so that the whole thing looked like Swiss cheese.

The core and beryllium reflector were about 4 ft diam. These were enclosed in an aluminum tank which acted as the water inlet and outlet. Around this aluminum tank was a couple of feet of air cooled graphite balls and several feet of graphite blocks. Outside of this was a foot of steel thermal shield and 6 ft of concrete shielding. Complex instrumentation holes were spread all over the reactor. The graphite and thermal shield were air cooled.

The reactor was housed in a 120 ft square 90 ft high concrete slab building. Since it was an experimental reactor, we considered it proper to use an experimental construction or 2 in. of concrete, 2 in. of glass wool, and 2 in. of concrete slabs. One building, a small du Pont structure in Iowa, had previously been built in this manner. The main operating floor was built to carry heavy shielding loads and thus was built with 36 in. I-beams.

Auxiliary laboratories, heat dissipation equipment, etc added to the total project. It cost about $30,000,000 to build. It is now shut down.

As originally planned the Project included the fuel recovery plant for the uranium 235 and also a plant to recover uranium 233 from irradiated thorium. Actually the U 235 plant was eventually segregated and the U 233 plant was built later.

The following paragraphs list some of the more important development programs carried out at Oak Ridge National Laboratory. All except the Critical Experiments and Separation Processing came under my direction. In addition, I was charged with the design not only of the MTR but also the U 233 and U 235 Separation Plants.

The main justification for the reactor was that it was needed to form a beam of thermal neutrons so that the properties of neutrons could be measured in a beam one quarter mile long. This experiment has never been run. We did not install the beam but left openings for it but it was never built.

b. Heat Transfer

The heat transfer was higher than all others except a few special commercial installations, so extensive tests were carried out. To obtain the high heat rate of about 500,000 BTU/ft$^2$ hr$^o$ F required a water flow of 30 ft/sec. While not high today, both quantities were very high at that time. High purity water at room temperature was used at all times.

So we set up elaborate electrical heated mock fuel plates and tested them to prove that the design was satisfactory. Later designs like the Test Reactor at Oak Ridge produce much higher heat rates per cubic foot.

c. Fluid Flow

The pressure drop through the core of the reactor was measured by simply measuring the drop in pressure at various flow rates of the water coolant. The problem was complex since corrosion changed the aluminum plate surfaces, making the surface roughen and increasing the pressure drop.

d. Corrosion

The corrosion of the various aluminum alloys as well as pure aluminum was studied. Adequate corrosion resistance was found except at very high water flow rates. Above 50 ft/sec the aluminum oxide hydrates formed in corrosion tend to break off leaving frest aluminum surface which corrodes rapidly.

Since the beryllium was also cooled, it also had to be checked to be sure that the corrosion rate was low. In addition, there were some steel parts but due to the low temperature water stainless steel was used with essentially zero corrosion.

e. Vibration

The fourth problem involved in the reactor core was vibration. This problem was not serious except to make certain that all parts that might vibrate in the water were tested and checked.

f. Flow Mockup

In order to check the flow pattern we designed and built a mockup of the core and beryllium reflector with aluminum as a standin for the beryllium. This was a major undertaking as large pumps for 10,000 gpm, etc were required.

Aluminum bars machined to rather precise dimensions were used to represent the beryllium reflector. These bars were 3 x 3 in. by about 5 ft long. They were machined with cooling channels, etc. Even the procurement of these bars and the tanks cost tens of thousands of dollars. The core of the mockup was built of aluminum plates in lieu of the clad alloy plates described above.

The procurement of these aluminum bars involved concern. We went to Los Angeles to see a prospective contractor but finally contracted with a die manufacturer, I believe, in Detroit. The difficulty arose since aluminum warps readily on machining and it is difficult to meet close tolerances with large pieces.

About two years after completion of the flow tests, active fuel assemblies were placed in the reactor, the large pumps were replaced by smaller pumps, and the 30 in. diam piping was replaced by 2 in. piping. Shielding control devices were added. As such the mockup became the Low Intensity Test Reactor and was operated for several years. It served as the highest flux reactor until the MTR was in service. It has now been disassembled.

g. <u>Fuel Manufacture</u>

As indicated above, the fuel assemblies consisted of nearly square aluminum pieces, some 4 ft long and about 3 in. square. These were supported in a heavy grid plate.

The development of the fuel plates made the MTR possible. The same type of fuel is used in nearly all of the test reactors throughout the world today.

Actually, when I arrived at Oak Ridge the fuel assembly building was in operation and I had very little to do with the development or test of the fuel.

h. <u>Core Design</u>

I noted that there was a Design Section working on drawings for the MTR under Jones' direction. During the first month I paid little attention to this group. However, a few days after Miles Leverett left the Head of the Section brought into the office a roll of about 40 drawings and unrolled them on my desk. They were the detailed design drawings for the beryllium reflector pieces. I asked why bring them to me, and Jones replied, "You have to sign them."

After several hours of study of the drawings I became convinced that the close tolerances on the dimensions were not required. Actually, all dimensions were given to 0.0005 in. or half a thousanth. I finally got all dimensions released to 0.001 and most to 0.0025. I should have insisted all dimensions be released to at least ±0.01 in. The cost of the finer dimensions simply could not be justified.

Anyway, it was nearly six weeks before I would sign the drawings. All dimensions were released to ±0.001 in. and most to ±0.005 in. By the time we got into the manufacture we had released most tolerances to ±0.01 in.

The rest of the core design was quite straightforward. I got the tolerances on the fuel and other core components released to reasonable figures.

The core itself consisted of a 5 x 9 assembly of fuel assemblies with 8 of the places on a 1 to 1 pattern filled with control rods. Each of these rods contained fuel sections and neutron poison sections that could be moved in and out of the core during operations. This was necessary since the fuel burned up enough that it had to be replaced or replenished each two weeks. The gradual replacement of neutron poisons by fuel lengthened the life to nearly five weeks.

i. Cooling System

The reactor was cooled by pumping 30,000 gpm of high purity water through the core of the reactor at 30 ft per sec. Externally the cooling system consisted of the necessary pipes and pumps plus storage tanks, deionization beds, and flash evaporators. The steam was then condensed and the heat finally rejected by cooling towers.

When operated at 30,000 kw of heat, the fast neutron flux was about $5 \times 10^{14}$ and the thermal neutron flux was $2 \times 10^{14}$ with the total neutron flux about $10^{15}$ neutrons/cm$^2$ sec. As noted this was more than an order of magnitude above other reactors but it is now too low to be of value and the reactor has been closed down as obsolete.

j. Test Facilities

The most important test facilities were:

Six large beam holes to the core;
Six small beam holes to the core;
Provision for loop tests using special fuel assemblies;

Many low intensity test ports; and
Thermal column.

### 3. Fuel Recovery

Since only a small fraction of the uranium 235 fuel is burned or fissioned during the life of a fuel assembly, plans had to be prepared to recover the unused uranium for reuse. The actual critical mass of uranium 235 was about 2.5 kg or about 5 lb. About 20% of this amount was burned per cycle of two weeks. The value of the unused 2.5 kg was about $75,000.

The fuel was recovered by allowing the fission products to partially decay for a few months, chopping off the fuel assembly ends, dissolving in nitric acid, and separation of the fuel by solvent extraction. It was considered necessary to use three solvent extraction cycles.

Laboratory scale equipment was built at Oak Ridge and also a pilot plant was constructed and the process thoroughly developed. I had only nominal contact and responsibility for these operations. I did have some responsibility for design of the proposed full scale plant.

In addition laboratory development of the recovery of uranium 233 from irradiated thorium was under way as it was planned that production of kilogram quantities of U 233 would be a main function of the MTR.

As discussed later, the MTR and the U 235 Recovery Plants were built at the National Reactor Testing Station near Idaho Falls. The U 233 Recovery Plant was built at Hanford. But during this period I directed the design of both the U 233 and U 235 Recovery Plants.

## D. Special Projects

The Organization was quite stable from March through August, 1948. I was Associate Director of the Technical Division in charge of the MTR Design and Development and a member of the Laboratory Advisory Committee. During this period and extending into the fall I was involved in a few laboratory wide programs.

During this period I also edited the Monthly Reports of the Technical Division and supervised procurement for the mockup. One curious argument occurred soon after I started work at Oak Ridge in respect to procurement. I found myself arguing with the Purchasing Department at Y 12 about whether or not we had to take the lowest bid. On one item I refused to approve such a bid and was told that I had to do so. I then said there was no requirement for this since the proposed supplier was unsatisfactory. I was informed that it was necessary to make out an affidavit to this effect and a responsible person had to sign it. I informed the Purchasing Agent that not only would I be pleased to make out such an affidavit but I would be happy to sign it. I also informed the Purchasing Officer that it was my responsibility that the equipment operate satisfactorily and if they wished to tell me what equipment that I must use they could jolly well assume responsibility for its operation. The Purchasing Agent then replied, "Oh, if you'll take the responsibility, we'll be happy to do whatever you wish."

A similar argument arose with the Atomic Energy Commission people a little later. I specified a certain type and part number on an order for filters from American Air Filter Company. I was told that I had to write a specification and request bids. I informed the AEC Area Manager either he could do my job or he could stay out of my business, as there was only one qualified supplier. He did the latter. Later Sam and I became good friends.

### 1. Laboratory Administration Committee

When I first arrived at Oak Ridge, I was asked to attend the Laboratory Administration Committee even though the members were supposed to be the Division Directors. I found that I was the only one that took notes and dictated a record afterwards. So I soon became the recording secretary by default. As noted above, I probably did the most talking.

### 2. Reactor Accident

Around September 1, 1948 an accident occurred with the Oak Ridge Graphite Reactor. This reactor had been built during World War II for the purpose of making one gram of plutonium to test before the Hanford Reactors could be placed in operation. The plutonium was necessary to test the separations process; so next to the Reactor Building a Pilot Plant had been built. This Pilot Plant was later changed into the Pilot Plant for the MTR fuel or U 235 Recovery.

The reactor consisted of a concrete shielded block of graphite some 12 ft on a side through which were 2 in. by 2 in. holes on 8 in. centers. Uranium metal slugs about 1 in. diam and 4 in. long in welded aluminum cans were slid into holes in the graphite through holes in the front concrete shield. The holes were placed with the diagonals horizontal and vertical. Air was sucked through the holes from front to back and ejected up a tall stack.

Occasionally an aluminum can would leak, air would enter the can, and slowly oxidize the uranium which in turn would swell due to the lower density of the oxide. In severe cases the canned bars would swell until the cans broke open and uranium oxide with various amounts of fission products and plutonium would be sent up the stack and fall in the surrounding areas.

Several instances such as the above had occurred but it had been relatively easy to push the cans from each row soon after the failures occurred and very little uranium had been lost. These cans or bars, when they reached the rear of the block of graphite, fell through an open space inside the rear concrete shield into a water filled canal.

Soon after the first of September, 1948 a failure of a canned bar of uranium occurred and swelled enough to cause a lowering of the air coolant over adjacent slugs. Before this was noted at least one slug had become stuck so that when the operators tried to shove the bars out to the rear they became jammed. Before the incident was brought under control several bars had been broken and the uranium oxidized. Perhaps as much as 1 or 2 lbs of oxidized material with perhaps a gram or so of fission products and traces of plutonium had escaped up the stack. The exit area and inside of the stack became quite contaminated and the entire downwind area had low contamination.

Several of the scientists became greatly alarmed. Others were not worried. The hazard due to the gamma rays was certainly negligible but the danger of a particle being lodged in the lungs and the plutonium causing cancer was theoretically possible. At any rate, there was great fear on the part of several physicists. No one to my knowledge has ever had any ill effects due to this exposure.

a. Cleanup Operations

Somehow or other I fell into the task of cleaning up the mess and correcting the reactor design. A survey of the area indicated small traces of radioactivity over an area of perhaps two blocks from the reactor. Since the incident occurred at night, there was very little wind and I suspect there had been an inversion over the valley. So we organized cleanup operations as follows:

(1) We sprayed all buildings with fire hoses to wash the radioactivity to the ground as far as possible.

(2) We sprayed the paved roads for the same reason.

(3) We then worked the ground over to bury the radioactivity as much as possible. This, combined with the decay, reduced the background to very near normal.

(4) We then used fertilizer freely and sowed grass seed. I admit that I used the incident as an excuse to obtain the fertilizer and grass seed.

(5) The canal and reactor were cleaned up after air exhaust filters were installed.

b. Installation of Filters

As noted, the Oak Ridge Reactor had been built to produce one gram of plutonium for tests during the war. Since it was a large volume reactor, it was used after the war to produce many radioisotopes. At the time in question it was the main source of medical radioisotopes; so there was a push to get the reactor back in operation. At a meeting of the Executive Committee about 10 September, I promised to design and build a filter building and have the building completed within 30 days, provided a suitable budget was made available. A filter building so designed that the filters can be changed remotely is not a simple device. The building which we built is about 25 x 40 ft and 25 ft high with remote handling and packaging equipment.

It had been obvious for several months that either a new reactor must be built or filters installed on the Graphite Reactor. I had assigned the problem to one of the design engineers, "Murph" Jones, and he and I had actually visited the Garfield Refinery of American Smelting and Refining Company at the south end of Great Salt Lake to inspect and discuss the electrostatic stack gas purifiers installed there. We had also obtained data on the "ultimate" air filters developed during World War II for use on tanks. These filters used extremely fine asbestos fibers. In addition, we had looked at other types of filters. As a result we were in position to recommend installation of ordinary filters followed by the use of the ultimate type filters. These latter filters were known as Chemical Warfare No. 6 and were renamed AEC No. 1 filters. Ordinary American Air Filter Company No. 50 filters were specified for the roughing filters.

I believe on a Thursday the Atomic Energy Commission was requested to approve a budget of $500,000. Approval was obtained on Friday.

Luckily, the Austin Company had several people at Oak Ridge starting the design of the permanent buildings. We simply borrowed or requisitioned this group. I have forgotten the engineers' names. In addition, the Jones Construction Company was constructing some buildings at K 25, I believe. We also "borrowed" these people and their equipment.

On Saturday we had a meeting to establish the basic design. After discussions we broke up and both the Austin people and I sketched out what we thought would work. On comparison we found that we had very similar designs. The Austin people took over and promised to have preliminary drawings by Monday morning.

When I arrived Monday morning at 8, I found that grading for the building was well along but a telephone cable went through what would be the center of the building. Since a couple of days would be needed to move the cable, we decided to move the building. Twenty-five days later the building was complete but we let the concrete set a couple of weeks before starting up the Reactor and Filter Building. By 1 November radioisotopes were flowing again.

The building was designed so that the filters could be discharged into water canals and removed from the canals remotely for transfer to a burial site and burial.

E. MTR Steering Committee

As noted above, while the central ideas for the MTR originated at Oak Ridge National Laboratory, the actual inventor, if any can be named, was Eugene Wigner, Professor of Physics at Princeton University, who was a Consultant at Oak Ridge. Then the Commission, in late December, 1947, had decided to centralize reactor development at Argonne National Laboratory. This led to all sorts of confusion and discussions as outlined in Chapter 7 of "Atomic Shield, 1947/1952," by R. G. Hewlett and F. Duncan, Pennsylvania State University Press, 1969. This book is Volume II of the official "History of the United States Atomic Energy Commission" and is referred to in a few places in this section.

There was a long argument about where the MTR should be built and who should be responsible for it and even whether or not it was needed.

I kept out of the arguments as much as possible, but after I went to Oak Ridge I did try to keep the design and development under as rapid progress as possible.

Since I had been assigned to Aberdeen Proving Ground during the War, and since there was an argument where the MTR should be built, Wally Zinn and I almost in the same breath suggested that a Reactor Proving Ground or Testing Station should be opened. I think Wally won on the idea by a few seconds. At any rate, he called Laurence Hafstad immediately and Larry grabbed on the idea. He sent Warner out to look for such a site. Warner was probably the worst choice that could have been made. Warner and the Army came up with the Fort Peck area near Glasgow, Montana. This area was near Fort Peck Dam, so cooling water and lots of space was available. I never knew much about the geology so I never could judge the area. However, I had committed myself to move to the construction site and act as Superintendent of the MTR after construction was complete. So we were very interested.

Later it was suggested by the Geological Survey that the Commission take over the area west of Idaho Falls. This area, which extends about 100 miles north and south and 60 miles east and west is a lava plain. While it appears quite smooth from a distance, it is locally rough. The Snake River runs along the east side of the area. Due to the porosity of the lava a considerable volume of water runs through the rock--enough that a small power station operates on the springs at the lower end. Time for flow from the MTR area to the springs was estimated as 75 years.

The eastern half of the area was owned by the Navy and used for a testing range. When it was decided the Commission wanted the area, we asked the Government counsel what legal steps should be taken and they informed the Commission, to notify the Navy of the date it wanted to take over. It appears the Atomic Energy Act is broad enough to allow such action. After due consideration the Commission gave the Navy $1,000,000 for the property. Actually this was a piece of paper to make the Admirals feel better.

It was and is my opinion that the choices of areas, both Ft. Peck and the Idaho Plains, were very poor. The time and expenditure of effort in driving 50 to 55 miles to work just cannot be justified in Idaho or New York--Connecticut areas. At any rate, in August, 1948 the Steering Committee consisting of the following was established:

Walter Zinn, General Chairman, Director of Argonne National Laboratory;

Alvin Weinberg, Director of Oak Ridge National Laboratory;

Stuart McLain, Chairman;

Marvin Mann, Oak Ridge Representative; and

John Huffman, Argonne Representative.

Since the assignment from the Commission to design and build the MTR was made to Argonne, Walter Zinn was responsible. John Huffman had already transferred to Argonne, and I was allowed to establish my own steup. Actually, we moved to Argonne between semesters in February, 1949.

The move from Oak Ridge to Downers Grove, where we had rented a house, was made partly in a snowstorm, as was the move to Oak Ridge from Detroit a year earlier. However, in Oak Ridge we had accumulated another dog and a cat. The trip was made without trouble until we arrived at Argonne National Laboratory. It had been arranged that we would stay at the Club House.

As one approaches the Club House there is a slight hill on a curve. As we had the trailor, it slid off the road and we had to unhitch it and leave it until morning--it was late evening. We moved the doghouse from the top of the trailor and fed the dog. She immediately disappeared into the dog house as it was 18 degrees below zero. We fed the cat and kept it in the bathroom. The cat had been unhappy the whole trip as it was in a box in the rear of the car. It yelped every bump and continued to yell all night. Luckily we were the only ones in the Club House.

In the morning we got straightened out and drove to Downers Grove. We found the house satisfactory and the truck with the furniture arrived about 10:00 a.m., right on schedule in spite of the 6 in. of snow. We were nearly moved in by 11:30 when I noticed a woman coming up the sidewalk with a large coffee pot and a hugh plate of sandwiches. It was Mrs. Beck from next door. We became close friends of the Becks and their friends, the Moores, and still visit back and forth.

We agreed that Oak Ridge would continue design and development of the reactor to the edge of the shielding and Argonne would be responsible for all other design.

There quickly arose an argument about the estimated costs. John and I had estimated about $18,000,000 but the Commission asked the du Pont Company to review this. They came up with about $155,000,000 but this included the Reprocessing Plant for the fuel which we had not included. The Steering Committee again reviewed the costs and came up with $18,500,000 as the top. The actual total costs of construction were about $18,200,000.

We immediately set about contracting with an Architect Engineer to prepare the detailed design drawings. We interviewed several companies. But about that time the Idaho Operations Office was set up and the Manager threw out everything we had done and appointed a new Review Board. They recommended our second choice; so we did not argue. Blawknox Construction of Pittsburgh was selected for the design.

Then the Idaho Operations Office decided to obtain outside construction and operating contractors. I then quickly lost interest and, while I generally watched construction with three people on the job, I believed that I was only responsible that things worked. I also refused to act as Operating Superintendent for the operator, Phillips Petroleum Company and, in fact, I refused to work for them. Huffman did so for several years as Head of Research at Idaho Falls.

So from October, 1948 until June, 1950, I spent full time supervising development, design, review of the design drawings and specifications, and cursory review of construction. The drawings and specifications filled eight four-drawer filing cabinets and I personally checked and signed every drawing and specification. As a result there were practically no design changes during construction.

The Fluor Company of Los Angeles was the constructor; so I had to supervise groups at Oak Ridge, Argonne, Pittsburgh and Idaho Falls. I made no visits to the Fluor Company. Almost weekly I was somewhere to a conference.

Some of the specific problems involved are mentioned below.

1. Beryllium Problem

As noted above, the basic design of the MTR included the use of beryllium for the reflector. In retrospect this was probably a poor choice since it would have been cheaper to use aluminum and waste neutrons by burning more fuel. But in 1948 and 1949 this was not quite so obvious as it is now.

Beryllium had never been used in the quantities that we needed so far as I know. So a contract was given to Professor Kaufman at MIT to produce ingots. This turned out to be very difficult because when the ingots were extruded into machinable shapes, they cracked, etc. Rolling was out of the question.

So I called Hafstad and asked for $50,000 for an extrusion experiment. At the first meeting we had to raise this to $100,000. At any rate the budget was approved. Then at the suggestion of the Head of Metallurgy at Oak Ridge, we contracted with Professor Gregg of Cornell University, to conduct special extrusion experiments. Meanwhile, the Beryllium Corporation was improving the quality of the metal.

We then rented the use of an old heavy extrusion press in one of the Bohn Aluminum manufacturing plants located at Adrain, Michigan. I believe this press had been stolen from the Germans at the end of World War II. Tests were favorable and soon suitable bars were being made. However, Kaufman was working on powder metallurgy and the improvements came rapidly; so that the final bars were made from powdered beryllium.

Since Adrain was near my mother's home in Tecumseh, I used the Adrain tests as an excuse to drive to Tecumseh for lunch with her a couple of times. I borrowed the Superintendent's very large car which made an impression on her neighbors.

## 2. Argonne Program

Relatively little experimental work was done at Argonne. The Argonne design group under John Huffman and Arthur Schultz worked out the design of the shield plugs, their handling, experimental equipment, cooling systems, etc. They also checked the design of the cooling system, power, heat disposal, etc.

## 3. Oak Ridge Program

Several of the development projects conducted at Oak Ridge were mentioned above. These were continued. The mockup became of particular importance. All these projects were continued after I left Oak Ridge.

## 4. Construction Problems

Specifically I had no responsibility for construction as this was taken over by the Idaho Operations people. Previously we had conducted some geological studies and core drillings. These had the two purposes of checking for water and for blowholes or porosity. We were interested in the water for coolant and for blowholes to indicate the average strength of the foundations.

Of course, ample water was found and in addition the lava was nearly solid and of high strength.

We planned to locate the MTR about 15 miles from Idaho Falls on the eastern edge of the site. This area would have required considerable blasting for foundations. So the Idaho Operations Manager moved the site to about 55 miles from Idaho Falls in the gravel area along the Big Lost River. This was done to save construction money. But at what a cost! It certainly saved money in construction of the foundation but required that everyone drive 40 miles each way extra to work. It was one of the reasons that I refused to move to Idaho Falls. Total construction costs must have been higher than near Idaho Falls.

There were exceptionally few major construction problems. And the startup of the reactor was just about routine. Actually, this was true of the whole life of the facility.

Later a higher flux, higher power and larger reactor was designed and built next to the MTR and still later a still higher flux and even higher power reactor was also built alongside the other two. These later reactors were the Engineering Test Reactor and the Advanced Engineering Test Reactor. While they are in operation, the MTR has been shut down. Both of the later reactors use the same basic design as the MTR as do many of the test reactors built in other countries.

F. Savannah River Reactors

When we moved to Argonne I cut my strings at Oak Ridge and went on Argonne's payroll, but I was always separate from the Divisions and attached to the Director's Office. I was treated well and, in fact, it was the only time in my life that I have had an office with a desk and a large table with 8 upholstered chairs. From the first World War II assignment until I started consulting, I always had a secretary and at times two.

When the Steering Committee completed its tasks on the MTR, I naturally planned to leave Argonne and go elsewhere, as no one had said anything about a permanent assignment. About that time the Atomic Energy Commission had decided to go ahead with the socalled "Hydrogen Bomb Project".

My first real contact with the hydrogen bomb was in 1949. Dr. Teller and his group at Los Alamos had made sufficient calculations to indicate that such a device could be made provided tritium was used. Today this sounds like old hat but in 1949 it was surprising. So Dr. Teller recommended immediate action. There was the usual "We don't need it" and "It can't be done" canto. But the Commission decided to go ahead. So Dr. Hafstad called Dr. Zinn with the question of how much will it cost. Of course, several groups by this time were looking at possible devices to make tritium so we knew a little about things.

Wally Zinn is a very demonstrable man. On hanging up on Larry he rushed across the hall and into my office. As soon as he got into the office he started talking. "Stew, Larry just called. The Commission is going ahead with the Hydrogen Bomb Project. He wants to know what'll it cost." I stood up and thought for a moment and said, "I'll put Schultz and Winkleblack on it. We should be able to make a very rough estimate in two weeks." To which he replied, as he threw up his arms and walked out, "Hell, no. I promised to call Larry back by 2:00 o'clock." It was then after 11:00.

At any rate I got Huffman, Winkleblock and Schultz together and we decided that we knew the cost of the Hanford Reactors and their power levels, we knew the escalation of the dollar and we knew the ratio between the two productions. So we simply multiplied the Hanford costs by the dollar ratios and by the estimated conversion ratio for the heavy water and graphite moderators. The answer came out to be about $1,000,000,000. In reality this was a very good estimate as the actual cost of the construction for Savannah River was about one billion dollars. The money was appropriated and the plant built.

While we were still busy on the MTR, both Argonne and North American Aviation in Los Angeles had spent considerable time looking into the types of reactors that might be built to produce tritium. This general discussion phase is reviewed on pages 426, et seq of the "Atomic Shield".

Sometime early in 1950 representatives of du Pont visited Argonne. These included Lombard Squires, Charles Wende, and several others whose names I have forgotten. Most of them had been at Hanford and were old friends of the Argonne group, although I did not know any of them. There was a two day discussion. Zinn and Sam Untermyer did most of the talking. Most of Argonne's Division Directors were present including Arthur Barnes, Frank Foote, James Schumar and Stephen Larowski.

Sam and Wally were promoting heavy water cooled and moderated reactors. I attended these meetings simply as a member of the Laboratories Advisory Committee, as I had no idea of my future part in the act. Later the contract to develop the tritium production was awarded to du Pont for $1.00 per year plus direct costs.

Meanwhile we completed the MTR design and shipped all the drawings, etc to the reactor site and John Huffman agreed to join Phillips Petroleum as Technical Director. Kenneth Winkleblock had also moved to Idaho as my representative, and Arthur Schultz had died of a heart attack.

About the middle of May Curtis Nelson was moved from the AEC representative at Chalk River to Area Manager at Savannah River. I had met Curtis twice at Chalk River. As soon as his assignment at Savannah River was agreed to, he called me and offered me the Associate Area Manager's position at Wilmington. This would have been the AEC's representative with du Pont. I accepted on condition that I could take July as a vacation. So we left July 1 for a trip west. Curtis was soon moved to Savannah River and presumably we would have moved later to Wilmington.

As usual, we left out itinerary. Wally had been on vacation and came back the Monday after I left. When he found that I had resigned and we planned to move to Wilmington, he jumped on Norman Hilberry for letting me resign. Norman knew nothing about Wally's plans. Wally wanted me to coordinate Argonne's efforts on the Savannah River Project. So at each mail pickup there was a telegram and letter. When we returned, it was agreed that I would remain at Argonne as Coordinator of the Project.

1. Organization

I think I should mention several people and what their responsibilities were. They are:

a. Walter H. Zinn. Wally was a physicist who had been with the Columbia group working under Fermi. Wally was no doubt brilliant but like all excellent people, he was justly very opinionated. I had great respect for him. But he was difficult to work with as he was not an administrator. He gave me the job and refused to even let me report things to him unless he had to communicate specific information to the AEC or du Pont. Wally resigned just after I returned from Washington to form a reactor design group at Dunedin, Florida. Later this company was purchased by Combustion Engineering Company and Wally moved to Hartford. A couple years ago he retired as Vice President of Combustion and moved to Florida. Mrs. Zinn, or Jean, died several years ago and Wally has remarried.

b. Enrico Fermi. Fermi attended only a couple of meetings that I also attended and then he mainly wanted to discuss the Experimental Fast Reactor. I never knew him well.

c. Laurence Hafstad. Larry was a member of the John Hopkins research team under Tuve during the War and worked on proximity fuses. He was appointed Director of Reactor Development in 1949. I worked for him in the Commission. Later he became Director of Research for General Motors and I did consulting for him.

d. Norman Hilberry. Norm was Associate Laboratory Director at Argonne. Later I worked for him as Associate Director when he became Director. He now lives in Phoenix.

e. Arthur Schultz. Art worked for Huffman on design of the MTR. He died as a result of a heart attack brought on by a minor auto collision.

f. Kenneth Winkleblock. Ken worked as my assistant on the MTR at Argonne. Later he worked at Atomics International.

g. James Schumar. Associate Director of the Metallurgy Division. Still is there.

h. Stephen Lawroski. Director of Chemical Engineering Division and now Associate Laboratory Director. Steve and Helen bought and still live in the Frank Lloyd Wright house we owned in Naperville.

i. Frank Foote. He was Director of the Metallurgy Division. He is now retired and lives in Downers Grove.

j. Walton Rodger. Walt was Associate Director of the Chemical Engineering Division. Later he was a partner of McLain-Rodger Associates. Then he became General Manager of the West Valley Fuel Recovery Plant. He is now doing consulting in Rock Springs.

k. Samuel Untermyer. Sam was a Special Assistant to Dr. Zinn. Later he left to work for General Electric at Vallicitos. He is now a member of a consulting group, National Nuclear in Palo Alto. Sam is an idea man and one of the most brilliant people I know. He married Joan Strauss. They lived near us in Downers Grove. Unfortunately Joan died of cancer several years ago.

l. Arthur Barnes. He was Director of the Nuclear Engineering Division. He died several years ago.

m. Lombard Squires. Lom was a Division Director at du Pont. He was in general charge of the development and design of both the Hanford and Savannah River Reactor Projects.

n. Charles Wende. He worked for Lom. He also composed the famous song, "Lom and the Bomb".

o. Curtis Nelson. He was U.S. representative at Chalk River and later AEC Area Manager at Savannah River.

In addition to the above many others were involved at Argonne and elsewhere.

The organization established was quite complex in some respects but simple in others. The Atomic Energy Commission gave the du Pont Company broad authority, then restricted them by establishing all sorts of checks and controls. Curtis Nelson, however, was helpful and did not interfere with technical matters as the Idaho Operations Office did. I never visited the AEC offices in Wilmington or Augusta, and in fact never visited the Savannah River installation at all.

The du Pont Company accepted the contract on condition of no profits. That gave them extra leverage, I think, in arguments with the AEC. The du Pont Company estimated their losses due to the loan of their technical people at least at $1,000,000 per year.

The authority under which Argonne acted was simply a letter from the AEC. The authority under which I acted was also simple. I'm not sure of the wording but it was about a 6 line letter which in effect stated:

> "You are appointed Coordinator of the Savannah River Reactor Project. As such you will work as Argonne's representative directly with the du Pont Company and the Atomic Energy Commission. You will be responsible for Argonne's part in the design and experimental work needed to carry this project to a successful conclusion. To do this you have overriding priority on all personnel and equipment available to the Laboratory. You are also responsible for training such personnel as the du Pont Company may wish to send to the Laboratory."

The letter was signed by Walter Zinn, Director. I always considered that Wally considered this project a thorn in the side of Argonne and wished it was not there but he realized its importance and gave me a free hand. Everyone in the Laboratory was very cooperative. Dr. Turner of Physics stated he was opposed to letting me take over his people but he did no more than voice objection to the program and then cooperated wholeheartedly with me.

Actually, we took no one out of each Division but simply indicated to the Division Directors what work was needed. Only in a few cases did I name particular persons and then as suggestions or someone similarly trained.

We prepared monthly and quarterly reports on the project. In addition we received, assigned and trained people sent in from du Pont for training. The highest number of these engineers in training at one time was 141, I believe.

2. Design

The design of the Savannah Reactors was developed by many people but the basic ideas were suggested by Samuel Untermyer. Eugene Wigner and Walter Zinn also contributed many ideas.

During the early stages of the development Sam considered all types but soon settled on heavy water moderated natural metallic uranium as best since the reactors would produce not only tritium but also large quantities of plutonium. Sam suggested use of fuel movement for control rods rather than control by adding neutron poisons. This did not appear practical and lithium rods were used as poison control and at the same time to produce tritium. Heavy water coolant was also suggested by Sam and Wally and it was used.

Atomics International suggested very thin coolant channels with high velocity natural water. This design would have resulted in the necessity for a terrific amount of welding of aluminum tubes into headers and the probability of leaks.

When the du Pont Company came in it was soon agreed that the basic Argonne design would be adopted. Sam and Wally then proceeded with the basic design. What evolved was a tank some 15 ft diam by 10 ft deep of heavy water in which there were several hundred aluminum forms placed so that circulated heavy water flowed downward through the aluminum forms. It is difficult to describe these forms without drawings. They consisted of four tubes about 1.75 in. internal diameter coextruded with connecting strips between them which held the tubes about 0.25 in. apart. Such a shape is known in architecture as a "quaterfoil" and these were so named.

Fittings were provided at the top to direct incoming heavy water downward through these tubes. On the inside of each of the four tubes was coextruded four ridges at 90° apart and 0.25 in. high. These ridges in turn held the aluminum clad uranium metal rods centered in the four quaterfoil tubes.

Heavy water at about 130° F was forced downward through the quaterfoils to cool and uranium bars and exited at the bottom at about 210° F.

Uranium metal bars 1 in. diam by 8 in. long were clad with thin aluminum cans using an aluminum-silicon alloy braze and the cans topped and sealed by welding. Each tube in the quaterfoil was filled with about 12 uranium rods or bars.

The heated heavy water was pumped through large heat exchangers in which it was cooled to the 130° F and returned to the reactor.

The heavy water thus acted as coolant and also moderator to slow down the neutrons released in fissioning the U 235 in the natural uranium. The excess neutrons were used to produce plutonium in the uranium by reaction with the U 238 and to form tritium by reaction with the lithium 7 present in the lithium.

The natural lithium was placed in separate aluminum tubes. The lithium metal was clad with aluminum. These rods also acted as the control rods and were moved upward or downward by bars which entered the top of the reactor tank.

It is interesting to note we used some half length lithium bars that could be used to adjust the neutron flux and heat production. Several years later Westinghouse announced a new very important invention of partial length control rods.

The reactor tank was stainless steel and stainless steel piping was used throughout the external water recirculation system and heat exchangers.

Control of the power level was maintained by driving the lithium absorption rods from individual driven motors with long detachable rods. During reloading operations the drive rods were detached and withdrawn some 20 ft to allow a fuel handling crane to move over the reactor, remove a fuel assembly, and replace it with a fresh assembly.

The reactor tank was shielded on top by about 3 ft of steel and water, including the heavy water piping.

The whole building was built with several feet of concrete for shielding and the unloading crane was remotely operated. This meant that at least two cranes had to be in working shape over each reactor before unloading operations could begin and that all operations had to be remotely controlled. The walls of the reactor building were some six feet of concrete as was the ceiling.

It should be noted that everything had to be designed so a minimum of heavy water was lost--every bit had to be recovered as it cost at that time $28.00 per lb and hundreds of tons were and are in use.

Each reloading crane had to be designed to move the other to a repair area.

The heat exchangers were huge tanks filled with 3/4 in. diam tubes through which the heated heavy water was circulated. The heat was removed by clarified and treated water pumped from the Savannah River. The warmed water was sent to cooling ponds and then back to the river. These cooling ponds, because of their higher temperatures, soon became filled with fish, turtles, snakes, and alligators.

Recovery processes were known but improvements were desired. The uranium was dissolved and the plutonium recovered and the lithium bars were melted and the tritium removed under vacuum as a gas.

The Savannah River Project included five reactors and all the auxiliary fuel preparation and recovery equipment. The cooling water system was enormous as was all other equipment. Some 25,000 people were used in construction.

3. Development Problems

It should be noted that the du Pont organization designed and built the Hanford complex during World War II; so many of the problems had been solved in a similar manner before. In my case, I had little knowledge or Hanford experience and my Hanford experience such as it was, came after the Savannah River experience.

a. Physics Calculations

I knew too little about the physics calculations to enter into them. Bernard Spinrad and others in the Physics Division did most of the work done at Argonne. Close connection was kept with the physics people at du Pont. Professor John Wheeler and Professor Eugene Wigner of Princeton acted as consultants to du Pont.

b. Critical Assembly

Immediately on taking on the assignment in 1951, I began to move toward a critical assembly. This is referred to in the "Atomic Shield" on pages 552 and 553. Problems existed. First we had to develop the design and mockup the fuel assemblies. This was done by Spinrad and others in a few weeks. Then we had to order the materials. The tank was easy except it had to be handled in sections and welded together after arrival. One of our men was killed due to contact of the unloading crane with overhead wires as one of the parts was being unloaded. The aluminum tubes were also easy as we simply had to use tubes to get the same weight. We also obtained the uranium bars readily. But the heavy water was a different story. Argonne had available some and we quickly got 25 tons together. While this was enough to start operations, we had to wait until more was produced to obtain final design data.

Fortunately the old Wabash Ordnance Depot at Dana, Indiana, had some old equipment and a heavy water production plant was quickly placed in operation in six months. This plant was built using carbon steel. A larger permanent plant was built at Savannah River using stainless steel. I had nothing to do with these plants.

Once in operation the critical assembly was used only a few weeks before the optimum design data were obtained. These data were utilized to check the physics calculations. Along with this Argonne had built a computer which was also utilized.

c. Uranium Canning

The uranium rods were very similar to those used at Hanford and the canning operations were the same as those used at Hanford. However, when the du Pont people and I visited Richland and observed the canning operations, we were unhappy. The canning operations consisted of melting an aluminum-silicon alloy or AlSi in an electrically heated kettle, submerging the uranium bar in the kettle to preheat it, submerge the can in the kettle, drop the bar in the can under the surface of the AlSi, drop in the aluminum can plug, remove for cooling and machining the cap to size. This was described under the Hanford discussion. Actually, the operations appear simple. The control of temperature, etc at Hanford was poor. As a result frequent can failures occurred. And whenever a can failed the reactor had to be closed down and all the bars in a given hole had to be pushed from the reactor. The unloading operations at Savannah River were too complex to permit this procedure. So we had to improve the quality of the operations until essentially no failures occurred.

First, uranium goes through a transition from alpha to beta structure at about 600 C. This results in a change of dimensions unless the uranium is very carefully heat treated.

Second, uranium can be easily cracked on rolling; so the rolling and machining must be very carefully controlled.

Third, the canning operations must be very closely controlled.

We finally had a long series of meetings with the New York Operations Office of the Commission, as that office was responsible for the uranium procurement. Then the Fernal, Ohio plant, which was being built to supply the uranium bar stock, was arranged to meet our specifications. National Lead became the operator of this plant. As a result, acceptable uranium bars and canned stock was produced. Of course, this reflected back as improved operations at Richland.

At all times I always had Argonne's and du Pont's people's support. At one meeting I nearly threatened to take over the uranium operations from the New York Operations Office but this finally resulted in cooperation of the New York office. I didn't have any authority but I knew du Pont would back me and the New York manager did also.

Another phase of this same program was the inspection procedures. At the request of du Pont, Argonne started an inspection program or rather a non destructive testing program. Since Hanford was involved, we soon brought them in. Then laboratories came in and we set up a National Committee for Non Destructive Testing with me as Chairman. Soon this became a working committee with about 15 members representing all the different AEC installations. Information meetings with published books of their proceedings resulted in a few years. Then I had to resign due to the press of other work. The Committee is still in existence and has annual meetings open to the public.

d. Quaterfoil Procurement

When we evolved the quaterfoil design we were told it couldn't be extruded. So I got Jim Schumar busy. In Chicago there was a firm known as Skiacky Brothers that made extrusion dies. They were excellent and we had had dies made by them before. So I told Jim to get a die made and get some sample extrusions.

What Jim did is of interest. At that time aluminum was in short supply and a special federal permit was necessary to divert any stock to unauthorized needs.

First, on a Thursday, Jim went to Skiacky Brothers and showed them the quaterfoil drawings. They agreed to make an extrusion die over the coming weekend. Second, Jim went to see the President of Bohn Aluminum in Detroit. Jim had previously worked several years as a metallurgist for Bohn. Jim told the President that he wanted to run an extrusion test and the President agreed to cooperate. Third, the question of an allotment or government permit to withdraw the few tons of aluminum came up. Jim allowed he had not even applied for such a permit. So the President said, "Let's divert a full carload." There was still no contract or purchase order. Fourth, on Monday, the extrusion die arrived at Bohn early. So they drove to Adrain, put the die in a press at the Bohn plant there and extruded several quaterfoils. Then Jim came back to Chicago overnight. Fifth, on Tuesday morning, Jim walked into my office with a piece of beautiful quaterfoil. It was not quite to dimensions but this was easily corrected by simple die changes.

The first thing Jim said was, "Stew, you have to get me out of trouble. I broke every government regulation and committed the Laboratory to purchase a carload of aluminum, plus use of an extrusion press and the manufacture of a die."

The quaterfoil was adopted and I believe is still in use.

e. Reloading Mechanism

The method of reloading was discussed briefly above. While the basic ideas were simple, the actual equipment became complex due to the necessity of nearly absolute certainty of operation and the further requirement of certainty that a second unit could move an operating unit into a repair area in case of failure of the first unit. Of course, the fuel assemblies had to be cooled once removed from the reactors, and all the drops of heavy water recovered.

While du Pont was responsible for the plant layout, we undertook to design and build a quarter scale model. The time schedule for this was very tight since the overall dimensions had to be specified as early as possible since these dimensions had a direct effect on the dimensions of the foundations of the first building.

So I asked the Remote Control Division at Argonne to design, build, and test a quarter scale model of a suitable device. I allowed them 30 days to have the device ready for a demonstration, including a motion picture of the equipment in operation. Harvard Hull was Director and Raymond Goertz was Associate Director of the Division.

In 30 days we demonstrated the equipment to the du Pont staff and furnished them with a motion picture film of the device in operation.

The reloading equipment, as designed, consisted of a regular crane which operated on fixed rails at the sides and near the top of the reloading room. In use the control rods are disconnected and retracted above the reloading equipment. Its operation consisted of moving over a preset fuel assembly, locating to within a few hundredths of an inch, removing the top plug, reaching into the reactor and attaching to the fuel assembly, raising the fuel assembly above the top of the reactor, recovering the small amount of heavy water clinging to the fuel assembly, cooling the fuel assembly while it was in the air, relocating to allow a new fuel assembly to be lowered into the reactor, placing the assembly in the reactor, replacement of the top plug, transfer over the fuel discharge area at the end of the room, and discharge the fuel assembly. At all times the fuel assembly being removed and the new one being placed in the reactor had to be held within about 0.050 in. of vertical in a length of several feet. The reloading equipment had to handle the control rods also.

After our developments the du Pont Company contracted with a design company to prepare drawings and a full scale model. I believe few operational difficulties have occurred.

f. Recovery

The natural uranium bars, after removal, were of course allowed to decay for a few months, dissolved and the plutonium recovered in the usual procedures. We had essentially no part in this work.

The lithium bars were simply melted and the tritium recovered as a gas, as noted above. Again, we had essentially no part in the work.

G. Atomic Energy Commission

Along with the Savannah River Project the Commission was also expanding the facilities at Richland by building additional reactors and by building improved plutonium separation plants and improved fuel canning facilities. At the same time Argonne was building permanent facilities as well as those at Oak Ridge, Los Alamos, and Brookhaven. But the reactor development program had not been pushed in the sense that no long term power development program had been agreed upon. Most attention had been placed on production of weapon materials.

Suddenly the Commissioners realized the above situation. As usual, they started yelling at Hafstad and Cook. Cook was Director of the Production Division. At a meeting early in January, 1952 the Commission pushed Hafstad for a program of reactor development. He had none as the whole staff had been too busy on other problems. George Weil had been heading up the Development Reactors Branch. So Larry pushed him aside and called me and James Lane to move to Washington to develop a program.

Unfortunately Winnie had been spending months looking for a house and she had found one about Thanksgiving time and we got possession and moved at the end of January, 1952. Actually we moved from Downers Grove to Naperville on Friday and spent all weekend getting settled. So Monday morning when I walked into the office the phone was ringing. It was Larry transferring me to Washington.

I should point out perhaps that I had had many long distance telephone calls; so the regular long distance operator knew my schedule. Once much later a call came in when I was visiting Argonne several years after I left there. At 8:30 the phone at the checkin desk in the Nuclear Engineering Building began ringing. She had a call for me. When the girl at the desk was asked for me, she said there was no one there. Actually, I had just opened the door and walked in. The operator told the girl that I must be there. Finally the girl said, "Are you McLain?" I asked the operator how she knew where I was. She replied, "For several years I have located you all over the country, so I have just learned your habits."

After agreeing to move to Washington I commuted from February through June in order for the boys to continue in school in Naperville. Commutting means I took the Capitol Limited to Washington Sunday night and back Friday night. We moved to Bethesda in June.

Jimmie and I undertook to develop a program for the Commission. Jimmy and I both were on leave and both planned to return to our previous locations at Oak Ridge and Argonne.

Zinn objected to my transfer to Washington, as he then told me he wanted me to take over responsibility for Argonne's facilities at Idaho Falls. I don't know as we wanted to move there but we never had to decide except in reference to the Materials Testing Reactor.

In addition to my assignment in the Reactor Development Division I was also appointed an Assistant Director in the Production Division with responsibility to raise the power levels of the Production Reactors.

1. Development Division

In 1952 the Atomic Energy Commission was divided into many divisions. The main ones of interest to me were the Production, under Mr. Cook, and the Reactor Development Division, under Dr. Hafstad. The other divisions had to do with weapons, their test and storage, research, engineering, biology and medicine, etc. The Production Division supervised the U 235 Separation Plants at the Reactor Installations at Richland and Savannah River.

Some of the prople with which I had contact were:

a. Lawrence Hafstad. Larry had been at Johns Hopkins; I believe he was a physicist by training but he thought like an engineer. After his stint with the AEC he went to General Motors as Director of Research until his retirement a few years ago.

b. Donald Loochridge. Don was Associate Director. Later he became Dean of Engineering of Northwestern University. I took his place for a few weeks before resigning from the AEC.

c. James A. Lane. His name was mentioned above. He, Helen and the children moved to Washington on leave from Oak Ridge and stayed the one year we were there. He was Chief of the Reactor Evaluations Branch. He is still active in evaluation work at Oak Ridge.

d. Hyman Rickover. Rick was a naval officer in charge of the Naval Reactors Branch. I knew very little about his background. He still has the same position or is retired. His wife was a lawyer and wrote many things for him. She died some time ago and he remarried just recently (1974).

e. Louis Roddis. Lou was Rick's assistant and a naval officer. When Larry left Kenneth Davis took over as Director of the Division and asked Lou to be his assistant. Lou is now President of Consolidated Edison.

f. Leonard Reichli. Len was Larry's assistant and handled the financial part of the work. Later he went to EBASCO Services in New York where he heads up their Nuclear Department.

g. Kenneth Davis. At this time Kenneth Davis was working for California Research and Development Corporation in San Francisco. He was working on the MTA which is discussed later in this section. When I left Washington Larry asked Ken to move to the AEC to take my place. Later when Larry left, Ken took his place as Director. Ken is now Director of the Nuclear Division and Vice President of Bechtel, a design and construction company in San Francisco.

h. I have forgotten the name of the man that headed up the Aircraft Reactors Branch.

i. ----- Peterson. Pete worked directly for Larry on special projects. Later he went to Cleveland to work for a steel company and still later to Chicago.

j. John Landis. John worked for Pete. Later he went to Babcock and Wilcox to head their laboratory work. He is now President of Gulf-Shell Atomics in San Diego.

k. James Pickard. Jim worked for John Landis. He left the AEC about the time I left and started consulting in Washington. Since then he has been a member of Pickard-Warren-Lowe and has done very well with NUS. They tried to get me to join them but that meant living in the Washington area.

In 1952 when I arrived in Washington the Reactor Development Division was divided into the Production Reactors Branch, Reactors Evaluation Branch, Aircraft Reactors Branch, and Naval Reactors Branch. I was in charge of the Production Reactors Branch and Jimmy Lane of the Evaluation Branch. So we worked very closely together.

2. Production Reactors Branch

I was responsible for programming, budgeting, and supervising the development of new reactors. This included those under construction and in operation, including the following:

My main responsibility in cooperation with Lane was to plan a new program for reactor development. This program was to include new production reactors, if needed. So our first task was to determine the direction we should move.

In addition, I was responsible for a large part of the budgets of Brookhaven, Argonne, and Oak Ridge National Laboratories. As indicated below, I had responsibility for a few other special projects. The Argonne and Oak Ridge responsibilities included nominal guidance of the MTR and Fuel Reprocessing Plants in Idaho.

All the above meant a great deal of travel, most of which I did by train. Some trips ran something like this:

Leave Washington on Capitol Limited on B&O for Chicago overnight;
All day at Argonne;
Leave Chicago on overnight and all next day on Chicago and Northwestern-Union Pacific for Idaho Falls;
Overnight at hotel;
All day at MTR or other facilities;
Overnight to Richland;

One day at Richland;

Two nights and a day to Chicago and on to Washington.

A few times I went from Richland to San Francisco and Los Angeles or Los Alamos and home via Oak Ridge. Such a trip required two weeks.

I had a couple of interesting things happen during travel. One time I rode with Senator Church of Idaho all day across Wyoming, etc. I never met, to the best of my knowledge, a less intelligent man.

On another trip just outside of Chicago I went into the club car and started reading. A little later a Jewish couple came in and sat down opposite me. They were 60ish. When the woman got settled and realized I was intently reading, she kicked my foot and when I looked up she said, "Whatcha readin'?" I replied, "Durant's History". I think it was. She got up and moved across next to me. "What do you do?" I told her very briefly. She then said to her husband, "Come over on the other side of this man. He's been around." She and he turned out to be quite wealthy New Yorkers that had also been around. They insisted on my having dinner that night and lunch the next day with them. I really enjoyed their company. I think she was surprised when a man in uniform and sidearms, etc met me at Pocatello and took my bag as I got off the train.

### a. Reactor Development Program

As stated, the main work of Lane's group on Reactor Evaluation and my group on Reactor Development, and later Pete Peterson's group, was to develop a program for reactor development. When the assignment was given to Lane and me through Hafstad, we were unclear what the objectives of the program were to be and after all these years I do not know. The Commission wanted a program but the Commission could not write a set of objectives. Had we realized this, we would have acted differently and perhaps we would have refused to go to Washington.

Nevertheless, as so often in Government, one proceeds. The real truth is that the program was already so complex and there were so many opinions being expressed by knowledgeable people that it was difficult to sift out what should be done. After all there are many different types of nuclear reactors and even today after years of development and actual large scale construction and operation, no one knows what is the most economical or even the safest type. Probably the ones being built are not the best. There are simply too many variables. This is easier to say today and more obvious than it was in 1952.

### (1) Los Alamos National Laboratory

Los Alamos had already operated two very small reactors, one of which was a Fast Reactor of very low power. Both of these were soon closed down and larger ones built for their experimental work. I had nothing to do with these.

Los Alamos, separate from the Reactor Development program, was attempting to develop a high temperature homogeneous reactor which required gold plating of all operating surfaces. It turned out to be a nearly impossible job and eventually the project was abandoned.

### (2) Oak Ridge National Laboratory

Oak Ridge National Laboratory was following two lines of development. First, and most important, was the Homogeneous Reactor. This development was well along. A small scale experiment had been built and operated successfully in spite of the marriage of the heat production in the reactor to the fuel reprocessing plant. In this reactor the fuel is dissolved in the coolant and pumped through the reactor which in reality is just a tank built in a coolant system. A neutron reflector is wrapped around the main tank. They were working on a two liquid system separated by a zirconium sheet. Corrosion abetted by hot spots finally caused failure of the zirconium.

A breeder type reactor using uranium 233 is still under development at Oak Ridge. My nephew, Howard McLain, has been working on it for years. While the Commission has stopped the work, EBASCO Services are talking of a full scale power reactor.

It appeared in 1951 that the Homogeneous Reactor had sufficient promise that we kept it on the development list.

Oak Ridge was also designing and constructing a gas cooled graphite moderated reactor using $CO_2$ coolant. This was well along and I had no part in it. After short term operation it was dropped. It should be noted that the British kept on developing gas cooled reactors. However, they have not pushed the High Temperature beyond just operating it. So their Chief Engineer came to this country. As a result Gulf-Shell Atomics has pushed the development and have sold several High Temperature Gas Cooled Reactors, using helium coolant and a solid fuel made of coated pellets in a graphite matrix. I predict more sales as it is an excellent reactor.

Since Oak Ridge was well into the development of gas cooled and homogeneous reactors, we made no change in their program.

Later I was criticized for not shutting down both reactor development programs. I believe that one does research and development work at early stages of an industry in several directions. No one can tell what is best. But I believed then and now that light water cooled reactors were the poorest.

(3) Argonne National Laboratory

Argonne National Laboratory had been designated by the Commission as the Power Reactor Development Center. Dr. Walter Zinn, Director of Argonne, and his group had designed the Chicago Pile #3, which was a small heavy water test reactor known as CP3.

CP3 and the original Graphite Reactor CP2, which was a larger rebuilt version of CP1, the first critical reactor which had been built under the west stands of the University of Chicago's football field, had been built at Palos Park in a federal forest reserve. The forest reserve did not want these as a national monument and we had to tear them down and bury the parts we couldn't recover. I thought this was about the second most stupid decision I ever heard of in the Government.

Dr. Zinn was interested in two reactors. One was a larger test and development reactor which was built as Argonne's test facility and called CP5. It is still a very important test facility. Wally was also interested in the fast reactor.

Soon after the close of the War, Zinn and others at Argonne started development of a Fast Reactor called originally CP4, and later the Experimental Breeder Reactor I, or simply EBRI.

The Los Alamos Fast Reactor had become critical late in 1946. It was a mercury cooled plutonium reactor of very low power level. It was useful in providing physics data only.

On the other hand the EBRI was designed to give engineering data and, if possible, provide a demonstration of breeding. The power level was low, 1400 kw of heat. This, however, was sufficient to provide some basic engineering data. It was cooled by a sodium potassium alloy called NaK and two cycles of NaK cooling were used. The primary coolant transferred the heat to a secondary NaK coolant and this in turn boiled water at pressure which in turn drove a small turbine. However, this was large enough to demonstrate production of power by lighting the town of Arco and to demonstrate breeding by producing more plutonium than the uranium 235 burned. This reactor also used electromagnetic pumps.

While we recognized that development of the breeder reactor involved a very extensive program, its long time importance due to its negative fuel requirement, its high temperature operation, etc required that its development be continued. Thus, the Experimental Breeder Reactor II was conceived.

While I was in Washington I had the pleasure along with Wally of announcing that breeding had been achieved in the EBRI. While this was expected from the physics measurements, the actual achievement was important. Of course, I actually had nothing to do with it.

I mentioned in discussion of the MTR that aluminum cladding and structural materials were used. Since aluminum is high in the electromotive series, it at least in theory when molten, can react with water. Serious explosions of hot aluminum and water have occurred. So Sam Untermyer, may his name be blessed, see III, F. 1, began an investigation of what would happen when aluminum clad fuel assemblies are melted in water. Sam found that very little happened most of the time.

Sam then proceeded to ask what would happen if we allowed boiling to occur in the core of a reactor. Previously physicists had claimed that the least boiling would upset the neutron control and very likely cause failure or that the temporarily uncooled fuel would melt. So Sam tried it and nothing happened. He then proposed that we build a "Boiling Water Reactor". Zinn concurred.

So Wally proposed they build a small

reactor with minimum facilities and use it in boiling water experiments. Wally suggested that it be built so that large excess reactivity could be added in very short periods or that we set out to find out just what would happen when failure did occur. So Wally sent us a proposal for a small experiment to be built in Idaho near the EBRI to test the Boiling Water Reactor idea. By that time I had used up most of my budget; so the Aircraft Reactors Branch helped and we got the $500,000 together and approved Sam and Wally's proposal.

The experiment was run in the next few months. Everything ran fine. The last experiment was to make the device supercritical by adding a large amount of excess reactivity very quickly. When this was done the core melted, large volumes of steam were formed, the top of the core was blown out the top of the reactor. However, the experiment had shown that boiling water reactors were safe. So we added the Experimental Boiling Water Reactor II to our proposed program. Thus the Boiling Water Reactors were invented by Sam and their feasibility demonstrated by Wally. Many power plants based on these experiments are in operation.

(4) Atomics International

Atomics International had been developing sodium technology. So it was natural that they should continue in the sodium cooled reactor. They suggested that a sodium cooled graphite moderated reactor be built. It had sufficient promise that we added this to the list.

It was my idea that this reactor would help in the Fast Reactor Technology as I believe it has. However, since it has been discontinued I have been criticized for including this reactor in the test program.

(5) Light Water Cooled Reactors

The use of pressurized light water as a coolant results in poor neutron economy but has several advantages such as known technology and a rather compact core due to the very high efficiency of light water as a moderator.

Since several utilities and manufacturing facilities were talking of building light water cooled reactors, we decided to assist these instead of the Government building smaller experimental plants. Pete Peterson had been brought in by Larry and John Landis was transferred to work with Pete.

We got into trouble. One of the Commissioners thought that only Rickover could handle reactor projects. It was true that the Submarine Reactor was being developed using light water technology and Westinghouse was pushing the light water cooled reactor. The Commissioner stated once that only Rick and Westinghouse could build a project of this size! I don't think he had ever heard of Savannah River or Hanford.

Meanwhile, Pete and Commonwealth Edison were discussing a small scale production reactor. This was to have been the Pressurized Light Water Reactor which was built by the combined Government-Westinghouse-Pittsburgh group and known as the Shippingport Reactor. But when the Commission decided to go the Rickover way, Commonwealth and General Electric proceeded with design and construction of the Dresden I Reactor independent of the Government. Several other utilities contributed funds but the Government did very little toward this project. I think the Commission acted very stupidly.

The Shippingport Reactor was very expensive. Thus Dresden I became the first power reactor to be economic. Both are still in operation and both have been very successful technically.

I still think Shippingport was unnecessary and a financial fiasco. Because of this and other reasons, we left the AEC and I returned to Argonne.

(6) Resume

The Power Reactor Development Program then became the following:

(a) Homogeneous Reactor II
(b) Experimental Boiling Water Reactor II
(c) Experimental Breeder Reactor II
(d) Sodium Graphite Experiment
(e) Pressurized Light Water or Shippingport Reactor

This was supported by the private utility program for the Dresden I Reactor which actually was time-wise behind the others so that operating data on the EBWR was available before Dresden was placed in operation. Five men from the Dresden staff actually attended a lecture course I gave after my return to Argonne. In summary, I probably added little to the program. It certainly was not McLain's program.

b. Plutonium Fabrication Facility

One problem that had been recognized for some time was that of the manufacture of fuel assemblies containing plutonium. Argonne had placed a line item in their budget request. This was for, I think, $900,000. My viewpoint was that this was too little. So immediately on my arrival in Washington I called Wally and suggested that this be revised upwards. Wally had not studied the item but when he did so he called back and asked that it be deleted. The next year the item was again placed in the budget for $5,000,000. When I returned to Argonne, I became Project Manager.

c. Fast Reactor Technology

California Research and Development had put together an excellent staff for the Materials Testing Accelerator described below. When this project was cancelled it was suggested that the staff be used to develop sodium technology. This we tried to do but the budget figures came out very high and the Bureau of the Budget cancelled the project. I believe that it should have gone forward. Argonne has not done its job as well as it should have.

The trouble with the budget for the California Research and Development Company was that we were too honest and included the things which should have been included in the first budget rather than overrun our budget and cry for help later.

3. Materials Testing Accelerator

Ernest O. Lawrence was a terrific idea person. Among other things he invented the accelerator. At the same time many of his ideas were impractical but practical or not he pushed them.

One of his ideas was that an accelerator could be used to produce plutonium. At the time there was a general idea that natural uranium in minable concentrations was very rare so to get fissionable materials we either had to use breeder reactors or manufacture plutonium in some other way. His idea was that if we accelerate deuterons to a sufficiently high energy and let these deuterons plunge into a uranium metal block, the deuterons will cause spallation of the uranium producing among other things neutrons. These neutrons can then be utilized to form plutonium by reaction with U 238. A deuteron at 350 mev will release on the average about 16 neutrons on impact with a uranium target.

Anyway, Lawrence suggested a Pilot Plant to check this proposal and sold the idea to the Commission. He was also a convincing salesman. So some $18,000,000 was appropriated. The California Research and Development Company, a subsidiary of Standard Oil Company of California, was brought into the picture and given a contract to design and build a test facility. A design was prepared, an area near Livermore purchased, and the device constructed.

The whole project was secret. It was also handled by the Production Division of the AEC.

The first I heard of the project was about a month after I got to Washington. Even then I heard only that the project existed and I saw no reports. About one month later Hafstad, in a hurry as usual, opened my door and stuck his head in and said, "Stew, the Commission just decided to transfer the MTA from the Production Division to the Reactor Development Division. I'm assigning the responsibility for the project to you." He then slammed the door as he left.

So, the next day I went down to the Production Division and found a four drawer filing cabinet filled with secret reports. I got these transferred to my office and began to study them. The Pilot Plant was described and plans for a full scale production facility with an estimated cost of $150,000,000 were included. The whole thing amazed me. I later estimated the cost, based on my Richland and Savannah River experience, as $450,000,000.

After due consideration I proposed to Larry that he and at least one of the Commissioners, actually Keith Glennan, and I take a trip to California to see the pilot widgit and to have the California R&D people tell us what it was all about and to talk to Lawrence, Alviriz and others at the University at Berkeley. This was duly arranged and we spent two days at Livermore and Berkeley.

Kenneth Davis led the discussions at Livermore and made such a good impression that Larry hired him to take my place when I left Washington. Alviriz also made an excellent presentation. And we visited the Pilot Plant.

The Pilot Plant consisted of a huge shed type building in which the pilot accelerator was built. The accelerator consisted of an ionization chamber for deuterons, a preliminary booster, and the accelerator proper which consisted of 10 or 12 drift tubes operated at several million volts and a target. The whole widgit was placed in a vacuum tank some 18 ft diam by 80 ft long. But it worked and neutrons were produced in the uranium target.

There were two immediate problems. These were that the RCA high voltage AC-DC converter tubes still needed development and that there was uncertainty as to the neutrons produced per impact as a function of the voltage. So after some cogitation I recommended continuing the tube development since these tubes have commercial uses and it did not seem reasonable to not finish the program as well over 50% had already been paid out, the job was nearly 80% complete and the Government would have had to pay at least the 80%.

A different situation existed in respect to the neutrons versus energy data. The highest voltage accelerator at that time was the large cyclotron at Berkeley. I believe this was about 184 in. in diameter. Of course, this is peanuts compared to the 5 mile diameter one now at the National Accelerator Laboratory southwest of Chicago. But the 184 in. was the largest then in existence, I believe. But it had been calculated that the power level of the 184 in. unit could be doubled by stronger magnets and these could be installed at a nominal cost. So I recommended that these be installed and the data obtained. Both programs were completed.

I reviewed the information on the larger or production accelerator. The following table presents a rough comparison between the pilot and proposed production models:

| Purpose | Pilot | Production |
|---|---|---|
| Name | Mark I | Mark II |
| Tank, vacuum, ft | ~10 x 100 | 60 x 350 |
| Voltage, mev | 25 | 350 |
| Amperes, milliamp | 50 | ?? |
| Cost, $10^6$ $ | ~15 | 65(1) |
| Power, kw | ?? | ~150 |

(1) Estimated by Lawrence. My estimate was 450; California R&D people estimated 150.

After about the third trip to Livermore I reported to the Commission on my findings and recommendation. Henry Smyth, one of the Commissioners, spent two hours after my presentation questioning me. He was a physicist and I was not. But after a few minutes I realized he was asking questions that he thought I could answer and not ones to embarrass me. I recommended cancellation of the entire project. Later the evaluation people under Manson Benedict concurred. But the Commission acted at the meeting right after my presentation and killed the project.

Several years later Bennett Lewis at Chalk River reinvented the idea but as a neutron source. But he couldn't quite believe what we had done until Ken Davis sent him some of our declassified reports. Actually the only publicity when we declassified the project was a short note in Popular Mechanics.

4. Production Division

As I noted above, I was also a member of the Production Division. My duties were to attempt to develop new ideas for increased power levels at Savannah River and Richland. Actually, I did practically nothing toward increased power levels at Savannah River. I did quite a bit toward raising the power levels at Richland. Basically the Hanford design permitted increased power levels rather easily.

a. Savannah River Reactors

As described earlier, the Savannah River Reactors were heavy water cooled and moderated. Since the heavy water was cooled by passage through stainless steel tubed heat exchangers and the heat transferred to clarified Savannah River water, the heat exchangers placed a real limit on the possible power levels of these reactors.

Since we had designed into the reactors sufficient heat production capacity to reach the limit of the heat exchangers, there was not much more that could be done. Savannah River also developed a very competent staff that has moved continuously ahead. In actual fact, we calculated before construction started that each reactor could be raised to 4 times its design power level. This has been done. The heat exchangers and fuel were designed for these higher power levels but the Savannah staff has done other things as well.

b. Hanford Reactors

The situation with the Hanford Reactors, however, was just the opposite. The original reactors had been designed during the War on a very conservative basis and this design had been followed in subsequent reactors.

Soon after I went to Washington there was a meeting with several of the Richland staff in Washington. I sat in the back and said very little until just at the end. Then I asked why they were not trying the use of zirconium tubes in place of aluminum tubes. No one answered but all of the Hanford people looked surprised and wondered who I was.

Then for several weeks I studied what reports I had time to read and learned how the reactors were built and operated. Of course, I had visited Richland and had seen the reactors several times.

(1) Visit to Richland

So Frank Pittman, who was Deputy Director of the Production Division, and I went to Richland. While there we spent I think two days talking to the Development Engineers, one day on inspection and a short time with the AEC, including talks with the Area Manager, David Shaw.

As I remember it, Dave took a dim view of what we were there for but he never said so.

When we asked Dave why there was not a greater push to higher power levels he stated that General Electric Company, the operating contractor, would only move to higher power levels very slowly. Then when we discussed the problem with General Electric officers they stated that their contract with the Atomic Energy Commission required that General Electric was responsible for any damage to the reactors that might occur in operation at higher power levels.

We did not push this point at the beginning, but after spending the two days talking to the engineers and attempting to evaluate if the reactors had the potential as we believed for higher power levels, we did push it.

(2) Technical Program

In looking at the technical program we

simply went through the laboratories and talked to the engineers and asked what they were doing and then tried to put all their ideas together into a program.

What is written here is not in chronological order of the contacts we made as I have forgotten the details. I believe we first asked for a presentation of the various power levels, the flux levels, etc. I remember that in this session I started asking questions of the engineers, why they were not moving to higher power levels and what they thought the limits were. They were enthusiastic and everyone thought that what he was doing could be used to produce higher power levels.

(a) Fuel Rods

The fuel rods that were in use were natural uranium metal rods about 1.30 in. diam by 8 in. long. These were clad with aluminum using an AlSi alloy bond as described in the du Pont discussion, see III, F., 3, c. These were cooled in the reactors by treated Columbia River water being pumped around them.

We asked why holes could not be drilled in the rods and internal as well as external cooling used. This had not been tried. Actually a few years later it was tried and adopted.

(b) Water Velocities

We asked about higher water velocities. This had led to erosion and other troubles.

We then asked why higher temperature drops were not being used. This led to the fact that the exit water of the hottest tubes in the center of the reactors was near the flash point of the exit water. So nothing could be done. So we asked why not increase the exit pressure to stop vapor formation in the tubes and let the hottest tube exit water mix with the cooler water from the outside tubes. This would require higher pumping power. But this was small, we stated. Actually, in a vew weeks this was being done and much higher power levels were being obtained at a relative low cost. Later much larger and higher power pumps were installed.

(c) Zircalloy Tubes

I mentioned above the question of use

of zircalloy tubes in place of the aluminum tubes. Since no one at Richland seemed interested, I actually ordered six tubes and had them made to the size of the Richland aluminum tubes and shipped to Richland.

These zirconium tubes were made by rolling the pure zirconium metal, then rolling the thin sheet into tubes and welding the seams. So when I asked why these tubes weren't being tried, I got the answer that they were welded tubes and the General Electric people considered that it was not safe to use welded tubes in a reactor. I stated that this was foolish as it could easily be shown that the zirconium tubes had at least twice the strength of the aluminum tubes. But we got nowhere.

This discussion had an interesting sequel. Max Carbon, one of the engineers, was interested. Max was working on heat transfer. So sometime later Max tested the tubes, became enthusiastic and finally all Richland became interested. At any rate a combined power and production reactor was built at Richland, using zircalloy tubes. This operated for several years. Presently a replacement pure power reactor is being designed. John Huffman is acting as a consultant.

Max left Richland to go to the University of Wisconsin. I believe he is presently Head of the Nuclear Engineering Department there.

(d) Other Changes

Several other engineers had ideas and these were all useful. However, I have forgotten the details. One suggestion that I made was important but I believe it is still classified.

(3) Final Discussions

Before leaving Richland we had another discussion with David Shaw. In this discussion we briefly outlined what we had found. We also told Dave that the General Electric believed they could not take the risk of pushing to higher power levels as they would have to pay for any possible damages to the reactors. We further stated that we agreed with General Electric as their contract with the AEC was very specific. We then stated that we wanted the contract changed at once. Dave was quite surprised, I think, at being told by a person that he had probably never heard of to rewrite his biggest contract. I then indicated that I was responsible to the Commission and had agreed that power levels could be increased and no further reactors would be needed. We left on a rather sour note that either the contract would be changed and the engineers and our ideas for higher power levels instituted in the near future, or we would have a new Area Manager. Frank Pittman said little but he did back me up.

Several years later I again met Shaw. He had left the AEC and was President of United Nuclear. United Nuclear had offered to purchase Nuclear Engineering. I was a large stockholder and member of the Board of Nuclear Engineering. When we met again, Hy Federman was introducing the Nuclear Engineering Board members to him. He simply said, "We've met before." We both smiled but neither had a chance to refer to our only previous meetings.

## (4) Report and Changes

On the train back toward Chicago Frank and I discussed what we had accomplished. Frank also started a report based on the idea that higher power levels at Hanford could best be obtained by a large number of small changes. On return to Washington we prepared a rather complete report with the recommendation that the AEC change the contract with General Electric to relieve General Electric of responsibility for the damages that might occur in case of damages to a reactor as the power level was increased. Since, when any change is made, the power levels are raised very slowly, we considered that any damage that might occur would be small. We also stated we believed that the power levels could be raised very substantially without any danger to the reactors, and further this increase in power levels would provide sufficient plutonium that no additional reactors would be required.

Actually, the power levels were raised very substantially over the next few years. Almost immediately after we left pressure valves were installed on the exit tubes to raise the exit pressures and thus permit higher exit temperatures with the higher power levels. Calculations were immediately started on my suggestion. New pumps were ordered. As a result not only higher power levels were attained with small capital costs but the morale of the people also improved.

As a result, the only additional reactor built was the combined plutonium production-power reactor. As noted, this reactor will soon be replaced. I believe both Richland and Savannah River reactors will soon be closed as we have ample stocks of explosives. Tritium for fusion power plants may be required. The higher power levels cost very little compared to the billions of dollars for more reactors. Also operating costs would have increased had additional reactors been built.

5. Odds and Ends

A few times the Commissioners had luncheons with Hafstad, Richover, Lane and me to discuss our problems. These were interesting as usually it was Rick that was quizzed.

There is one problem that always bothered me but no one else. Since the power companies produce large quantities of plutonium, why not use the gas centrifuge to separate out the plutonium 239 from the mixture of isotopes produced by the power plants? So far I have been unable to interest the Commission in this proposal.

We also had frequent contacts with the Joint Committee on Atomic Energy of Congress. A Mr. Walter Hamilton was the liaison person and acted as Secretary to the Joint Committee's staff. After we had developed the socalled five reactor program, the Commission adopted it but the Bureau of the Budget, as I remember it, did not believe the test reactors needed to be built. This was also the opinion of one of the most influential of the Commissioners. He wanted Rickover to boss all the work. So I called Hamilton one day and suggested that it might be of interest if we just happened to meet in the 3rd floor hall of the Atomic Energy Commission Building at say 11:00 a.m. the next day. He, of course, knew of the suggested program and its temporary demise.

Anyway, we met just around the turn in the hall at the front of the building on Constitution Avenue. I told him that I thought the cancellation of the experimental reactor program was a great tragedy and I suggested that Congressional hearings might be of interest. He agreed and we parted.

Several months later Congressional hearings were held and strange as it may seem, the same old program slightly updated became the law of the land.

One other item about Congress. Senator Anderson of Arizona was a member of the Joint Committee for Atomic Energy. One night he and Keith Glenman asked me to have a sandwich with them. Senator Anderson was full of questions but his mind was made up. He wanted no answers to his questions that deviated the least bit from his opinions.

During the summer of 1963 Hafstad and one other man and I had attended a meeting at Chalk River. Hafstad and I agreed that the MTR was essentially all declassified but we were not certain that the details of the fuel assemblies were completely declassified. So I took the cross sectional drawing of the core and cut out just the fuel section. At Chalk River Hafstad reviewed the program evolved at Washington and I presented the discussion of the design of the MTR.

On return to Washington I was accused of presenting classified information. When I showed the cut up drawing and testified that I had divulged no classified data in Canada, the subject was dropped.

Also in that summer there was an International Conference at Jenner, Norway. I was asked to go and planned to do so. Since I was going Dr. Zinn suggested that I present the paper on the CP-3 Heavy Water Reactor at Argonne, and it was reasonable that I should present the paper on the Materials Testing Reactor, including a discussion of the fuel assemblies, heat production, neutron flux levels, etc. So I prepared both papers. However, when we decided to leave Washington and return to Argonne, I asked Dr. John West of Argonne to present the CP-3 paper and Dr. Alvin Weinberg of Oak Ridge to present the MTR paper. This was done. The MTR paper created a sensation as it disclosed the tremendous heat production--for which I had not been the designer.

## H. Educational Programs

### 1. Return to Argonne National Laboratory

After about 18 months in the Atomic Energy Commission we had completed our basic assignment of establishing a new development program in reactor technology; so James Lane and his family returned to Oak Ridge and we returned to Argonne. Meanwhile Neal had graduated from high school and entered the University of Michigan. So in August of 1953 we returned to Downers Grove, Illinois to live and I reported back to Argonne about the first of September.

Wally Zinn simply assigned me to an office and told me to get interested in anything I wished to except those things he was interested in. I started to look around a bit and to read the recent reports. Almost immediately I got a call from Mr. Boyce, the head of the educational programs and a visit from Frank Foote. I have forgotten Mr. Boyce's first name.

Boyce wanted me to give some special lectures to Argonne engineers, and Foote wanted me to act as Project Manager of the proposed Plutonium Fabrication Facility. These two things occupied me for about three years.

2. Assignments

a. Plutonium Fabrication Facility

As mentioned in the AEC budget discussions, we had raised the budget for the proposed Plutonium Fabrication Facility to $5,000,000. Then I became Project Manager.

Los Alamos had been fabricating plutonium metal into components for weapons; so the general properties of plutonium were well known and handling methods had been worked out. Also a weapons components plant had been built north of Denver on the rocky flats area and was operating as the Rocky Flats Plutonium Fabrication Facility under contract with Dow Chemical Company.

The use of plutonium as a nuclear reactor fuel however involved different basic shapes and it was thought probably different alloys. So Frank Foote, James Schumar and I had a number of discussions on the problems involved. Two engineers, Larry Kelman and Art Schuck, were assigned full time to the project.

The first question was to decide whether the building should be alpha or gamma. Plutonium emits alpha rays which are easily stopped even by a sheet of paper or the dead skin on a person's body. Beta rays, or electrons are quite penetrating and gamma rays are very penetrating. Gamma rays require several feet of concrete for shielding. After several discussions we decided to proceed with an alpha building. This meant that glove boxes could be used and workers could see and feel through rubber gloves what they were doing.

In retrospect this decision may have been wrong since the building and its facilities are now out of date as most work is done on a mixture of materials that emit sufficient gamma rays that heavy shielded areas which had to be built later must be used. At any rate, the facility was used very successfully to develop plutonium fuel technology.

Los Alamos had developed techniques for handling the metal as required for the rather simple shapes used in nuclear weapon devices. Their equipment was simple and easily operated and maintained. The safety specifications at Los Alamos were not adequate in some respects to cover the requirements necessary for the more complicated and more flexible equipment we were thinking of installing. Our requirements in specifying the operations to be performed were to cover the gamut of all plutonium metal, oxide, and possibly nitride combinations and various types of fuel components. Foote and I went to Los Alamos to see their facilities. Kelman had previously visited there.

As soon as we decided to adopt an alpha building, we were able to use glove boxes or the operators could work with their gloved hands directly on the equipment and materials, albeit, limited due to the requirement that only arms' length and arm strength with suitable tools could be used. However, these limitations at the time appeared reasonable since we were to be doing experimental and not production work.

So Art developed a glove box 4 ft wide, 6 ft high and 8 ft long. This was made from hollow aluminum extrusions welded together for a frame, plexiglass sides, aluminum plate ends, top and bottom with glove box ports on each side. With suitable connections for utilities this has become quite a standardized item. Presses, saws, drills, lathes, etc could be installed in these glove boxes. In addition a reasonable amount of development work permitted installation of furnaces and plutonium alloy casting and metal working equipment except rolling mills. A conveyor through several glove boxes permitted setting up a full line of operations.

Then Art started to design a rolling mill for glove box operations. Actually, he designed the rolling mill and its drives so that only the rolls and the roll changing equipment were inside the glove box and the glove box components were machined to fit the rolling mill frame essentially vacuum tight. A contract was let to a Brooklyn company to make the mill. It worked well. So the Brooklyn company is still advertising the mill and presumably selling copies of it.

(1) Building and Equipment

Once the necessary dimensions and numbers of glove boxes were established we laid out plans for the building. Two glove box lines some 80 ft long were specified. In addition a vast array of utilities was listed. All items such as piping for air, vacuum, helium, nitrogen, water, sewage, etc had to be specified and built in; and built so that the facilities not only could be used but also could be repaired and maintained.

Actually we divided the building and equipment and contracted for the building while the equipment included in the glove boxes with the boxes and their immediate and attached equipment could be made a separate contract.

Ventilation equipment included inlet filters, temperature and humidity control, and discharge filters. The inlet filters included the AEC #1 filters described in the Oak Ridge Filter Building, and the exit filters included roughing and ultimate or the AEC filters with the proviso that they had to be built so that they could be discharged into plastic bags for external handling and burial.

A contract was let with an architect engineer. They designed the building and utilities. But they grossly under bid the job and we finally opened the contract and increased the contract price from $90,000 to $177,000, I believe. They also made detailed drawings of the glove box utilities and components. The utilities, etc required that the drawings had to be similar to those used in submarine design. In other words, the piping had to be drawn in three dimensions to scale and not as single line drawings, which are usually used in building designs.

Space had to be provided for joints and for making the joints, etc. Then we contracted with a building contractor to construct the building for $900,000. The contractor did an excellent job.

We then asked for bids to build and install the glove boxes and their equipment. As I remember it, we received one bid and that was for something like 4.5 million dollars. Since all the design work had been done, we considered this excessive and the bid was rejected. Argonne then built and installed all the equipment with their own personnel at something like $450,000.

What the total plant cost was, I do not know, as Argonne purchased equipment, etc under many different orders. I estimate that the cost was about

$1,600,000, including Frank Foote's and my time.

(2) Operations

The plant was operated very successfully for several years. It was then closed down and I believe is presently in standby. Meanwhile Argonne built a so-called gamma facility but this too finds little use today as the technology has been thoroughly developed. The industrial companies which manufacture fuel assemblies containing recycled plutonium have designed and built plants for this work. Thus, the use of recycled plutonium is now a reality.

b. Argonne Lectures

A few weeks later I started a series of one hour lectures at 0830 Monday mornings. About 50 Argonne and 5 Commonwealth Edison engineers and scientists attended. The lectures were issued in a classified report and were widely read at Argonne and later a declassified version was widely distributed literally around the world as they were almost the earliest record of how actually to design the engineering aspects of nuclear reactors. The theory of the physics of reactors was not classified but there had been no concerted effort to tell how to design a reactor such as the Hanford reactors in a logical sequential manner.

Included in those that regularly attended the lectures were the 5 Commonwealth Edison people. These included the future Superintendent, Assistant Superintendent and Head of Health Physics of the Dresden I operating personnel. Also Eugene Bailey attended part of the lectures. Bailey was one of the very high engineers of Commonwealth.

These lectures were repeated the following two years to smaller groups.

In retrospect I should have been ashamed of them as they were so primitive. But it is easier to rewrite a poor text into a good text than it is to try to organize a series of lectures on a new subject which I was doing.

The preparation of these lectures occupied quite a bit of my time. Then declassified copies were sent all over the world and I had to autograph copies in Spain. At a recent ANS meeting five Professors stated that they are still using my old lecture notes.

c. <u>International School</u>

In 1955, I think it was, President Eisenhower made a speech in which he stated the United States would declassify much of its nuclear technology and would present this to engineers around the world. He didn't realize what he was getting me into.

Anyway, it was decided by the Commission that Argonne would set up an International School. Wally Zinn delegated responsibility to the Assistant Director, Dr. Norman Hilberry. He agreed to be major domo or director of the school and then appointed another engineer to act as operating head. And it was decided that Kenneth Winkleblock would give the lectures in reactor engineering. But a few days before the school was to start Winkleblock decided to go to Atomics International. You can guess the rest.

Anyway, I hurriedly moved some materials over to the school and began to think about an outline for a course in reactor engineering. Besides my course there were to be others in health physics, metallurgy, reprocessing, and the physics of reactors. Actually health physics had always been declassified and a good part of the physics had also been declassified. So I had to give a series of lectures to these people.

About 30 nuclear engineers arrived from all over the world. Jodra and one other from Spain, two from France, I think, two from Germany, Sweden, two from Australia, including Wilson, two from Brazil, including Gimbleris, Mexico, Greece, India, two from Japan, Indonesia, Thailand, Switzerland, etc. Anyway, there was a big to-do including a welcoming turnout. But who gave the first lecture and lectured from then on to classes for, I think, three years?

Anyway, all I could do was to update and remove classified information from my Argonne lectures. This I did and also added problems. It turned out that about half the group was made up of live wires and very excellent students. Others were slow to catch on. Almost all except the Australians and Jodra had language difficulties. If someone couldn't understand my English, someone else would translate it into French. All except me seemed to understand French.

The Japanese gave me a worry. Japan had been a bit treated to nuclear explosives, so these men were quite wary of what was going on. President Eisenhower had said we would help all nations but justly or not the Japanese were apprehensive. Also they had been told by the Communists that this school was just a trick to permit the United States to take them over. At any rate, about six weeks after the course started one of the Japanese men came into my office and started talking. Neither had hardly spoken before. He said that they had been warned to look for the tricks we would be sure to pull on them, and to look for false information as what we would say would be designed to cause failures in any future plants they might build. He said that they had decided there were no hidden tricks and that we were really trying to help the other nations. When he returned home, he sent Winnie a beautiful scarf. In the fall of 1973 I met a Japanese engineer at the Atomic Industrial Forum meeting in San Francisco. He insisted on taking my picture so he could report back to the Japanese engineers what I was doing, etc. He stated that they frequently refer to my lectures and notes.

One other item is of interest. Since these men were all young and in most cases this was their first trip "abroad", and since they had never visited American homes, I suggested to Winnie that we entertain them. Since with the other staff members there were well over 50, we asked half of the group on each of two succeeding Thursday evenings for dinner. There were about 35 each night, including the staff people. The two office girls agreed to help. Winnie served a goop of crab, lobster, shrimp and fish which she could easily serve. She had potatoes and vegetables and, I believe, apple pie for all.

On arrival at the house they spread all over and many took pictures. They looked at everything. While Winnie and the girls were serving the food, several took pictures of every move Winnie made as well as of everything in the kitchen. One man admitted he had taken a full roll of 36 pictures in the kitchen.

d. International Visitors

Since a number of people met me at the school, I was frequently asked to meet and show international visitors around the Laboratory and to discuss their proposed programs with them. After I left the school Hilberry insisted that I continue to act as host to many of these visitors. He stated once in a talk to several foreign visitors that I was the Atoms for Peace Program.

e. <u>University Contacts</u>

Dr. Zinn resigned while I was at the School. When Dr. Hilberry was appointed Director of the Laboratory, he appointed me Associate Director of the Laboratory in charge of education. Dr. Boyce had held the position but he had also resigned.

I really was too busy with my other duties to do justice to the University contacts. The International School was going along okay but I did very little with the American universities. The Dean of Northern Michigan at Houghton insisted that I visit their campus; so I did, I think three times. But I did little elsewhere.

f. <u>Ann Arbor Conference</u>

Sometime in 1952, I think, I suggested to Professor George Granger Brown at Ann Arbor that the University sponsor an International Conference on Atomic Energy. He agreed and a committee was set up with me as Chairman.

We planned a broad program and invited the AEC commissioners and the commissioners from other countries. The program was excellent. The U.S. Commission took no notice of the meeting and no U.S. Commissioners attended. Several foreign commissioners attended.

Due to the large attendance and the interest from the Europeans particularly, I believe that the Commission suggested to President Eisenhower that a broad international meeting be held and the United States would declassify as much material as possible for that conference. This was done and the 1955 Geneva Conference was well attended. The highlights were Wally's motion picture of blowing up the Boiling Water Test Reactor and his results of the EBRI work. I did not go because there was very little engineering discussions but rather physics and descriptions.

g. <u>Odds and Ends</u>

We continued to have university contacts and to operate the International School. In addition the program was widened to train industrial people by assignments to various laboratories, etc. In addition, the number of international visitors continued at a high level. Since I had to direct all these programs, I was kept busy.

3. Committees

I also served on several committees. Four of these should be mentioned. For a time the various organizations of the AEC, particularly Richland and Argonne, were presenting courses to industrial people.

a. Educational Committee

So we set up an Education Committee to coordinate our work. One member was from Oak Ridge, Hanford, and two or three other places, with me representing Argonne as Chairman. The Committee was active for only a few months and had only three meetings, but we did circulate some lecture notes, problems, etc. I have always regretted that I did not have time to do more with this Committee but there is not time to do all the things needed to be done.

b. Non Destructive Testing Committee

I mentioned above the Non Destructive Testing Committee in reference to the Savannah River Project. I organized this Committee and served as Chairman for three years. It had some 15 members from the AEC installations and later some industrial people joined. Since then it has grown until there are annual national meetings, and there must be several hundred members. They publish a book covering each meeting.

c. National Academy of Sciences

In 1955 I think the National Academy of Sciences set up a national committee to study handling and disposal of radioactive wastes with emphasis on the high level wastes. A professor from Johns Hopkins was Chairman and all the AEC installations and several industries were represented. Floyd Culler represented Oak Ridge; Phillip Sporn represented the electric power industry. In all there were about 15 members.

We issued a very blah report at the end of several meetings. In addition, the Committee had begun the study of the disposal of high level wastes in salt mines. I objected to both things, so I resigned.

Later the Committee fostered the AEC's work at Oak Ridge National Laboratory on burial of high level wastes in the salt beds at Lyons, Kansas. I have always been opposed to this project. Several years ago I wrote a letter to the Commission objecting to the burial of the wastes. This letter was based on work at Richland on the value of the materials in the wastes. I am convinced that in 50 years we will be recovering platinum and other metals from the wastes.

Since Kansas objected to burial in the salt beds at Lyons, I suggested burial in salt beds at the potash mines in New Mexico. Lugene Hungerford and I actually visited one of the mines and obtained logs of the drill holes in this area. We selected a suitable bed at one of the old shafts near Carlsbad and suggested its use. Nothing came of this at that time but now (1975) it is an active project.

Recently the Commission has decided to store the solidified high level wastes in concrete buildings above ground, as I had previously suggested, but for different reasons. They arrived at this decision after all the trouble about the Kansas site as another alternative.

I do not know whether or not I should have resigned from the Committee when I did but I believe that the recommendations of the Committee were wrong, not on the basis of the troubles encountered later in Kansas, but on the basis of the need to rework the wastes for valuable metals. As yet no process for reworking these wastes has been worked out. I have always been convinced that the wastes could be safely buried in the Kansas salt mines.

### d. Pressure Vessels

In 1911 the American Society of Mechanical Engineers set up a Pressure Vessel Committee to prepare standards and specifications for steam boilers and other pressure vessels. By 1955 this Committee had become very important and their rules and standards had become accepted as standard worldwide and were required by all municipal and state regulatory bodies in the United States.

In March of 1955 the Society established a Special Committee on Nuclear Power. Members of the original group included:

Frank Williams, Chairman, Taylor Forge;
Perry Arnold, Chicago Bridge and Iron;
Eugene Bailey, Commonwealth Edison;
Frank Davis, AEC, Washington;
Harvey Wagner, Detroit Edison Company;
B. F. Langer, Westinghouse Electric;

C. W. Wheatley, ------------; and
plus about 10 or 12 others from the various industrial plants which manufactured pressure vessels.

Bailey, Wagner, Frank Davis, and I were the only ones really familiar with nuclear reactors and their problems.

We met about 8 times a year on Mondays in New York. Usually I would pick up Bailey in LaGrange and drive to the 63rd Street Station or the airport, and we would meet Arnold from U.S. Steel Research and go to New York together, and then frequently return together the next evening or on the overnight train.

The first few meetings were planning and educational. As always, I was expected to do most of the talking. Bailey, Wagner, and I constituted a sub-committee on definitions and a separate sub-committee on containment.

The first problem we faced was that the Special Committee should include the containment, heat exchangers, and all pressure components in the primary cycle in our jurisdiction. The heat exchangers were required to be built on the primary coolant side to the rules set up by the Special Committee and on the other side they could be built to the requirements of normal steam generators.

At one of the early meetings the question of welds came up. The codes had previously required all welds be given an efficiency factor of 90%. I asked why and stated that I believed welding had developed to an extent that the welds should be given an efficiency factor of 100%. This was immediately agreed to and the Main Committee so voted for all pressure vessels, including nuclear.

The Special Committee began to work by use of "cases". When a company wished to have an approval of a given design not in keeping with the regular American Society of Mechanical Engineers codes, a letter request was made to the Committee and we would consider the application and issue a "case" or brief requirements note which could be later used as a paragraph or so in a definite Code for Nuclear Vessels as a section of the regular ASME Code.

As noted above, the Code is incorporated into all state and city codes and laws of the United States and into the laws of many countries. Later our cases were incorporated into a new section of the Code, Section IX.

After about three years on the Special Committee it was proposed that I become Chairman of the Special Committee. Acceptance of this assignment would have made me a member of the Main Committee on Pressure Vessels. This would have meant nearly a week eight times a year in New York. Since Argonne refused to sponsor this, I resigned from the Special Committee as I could not stand the financial burden. Commonwealth people have criticized me for my decision, but Commonwealth did not offer to finance the travel and expenses. I would have been willing to have spent the 8 weeks per year time plus all the time to review the cases.

One of the interesting problems was that of nozzles. At the suggestion, I think of Bailey, the Chairman of the Special Committee appointed a sub committee with Bailey as Chairman. They came up with the suggestion that all nozzles must have equal strength with the body of the vessel and that all the additional metal be welded integral with the main pressure vessel.

We also considered the heat treatment of the vessels, bolts, and heads, etc.

These vessels have increased in size to the point that vessels 12 in. wall thickness, 16 ft diam by 44 ft high have been built.

As a result of interest of the Special Committee and others a heavy plate project was set up by the Committee. Edward Miller, whom I hired at Wayne State University and who came to Oak Ridge to work for me and who stayed at Oak Ridge and whom I asked to be my alternate on the sub committee, and then who was promptly made a member of the Special Committee, directed the program. The problem was the rolling, heat treatment, and testing of the heavy plates and welds. Ed remained on the Special Committee until he died of cancer a few years ago.

Southwest Research Institute at San Antonio has done considerable experimental and development work on pressure vessels. Frank Davis worked on this project for several years.

4. Handbook

In 1955 the Commission published a Reactor Handbook. Then Harold Etherington edited a Handbook that was published commercially in 1958. This Handbook was written by a number of people, particularly those at Argonne. This Handbook was entitled "Nuclear Engineering Handbook" but in reality it was more a Source Book of Physics Data than an Engineering Handbook. So the Commission decided to publish a revision of the 1955 Reactor Handbook. I ended up general editor of this revised Handbook.

I outlined what I thought should be covered and asked engineers and others to act as editors of the physics, materials, and fuels reprocessing volumes while I retained the editorship of the engineering volume. I then lined up section and chapter editors.

We had several meetings of these people. However, it took several months to get started and actually 3 to 4 years to finish the job. I spent several months editing the engineering volume. During that time I reduced the text about half. Then John Martens did the detailed editing and the volume finally got printed in 1964. It comprised about 850 pages of double columns in fine print. Meanwhile the other three volumes were published.

Al Amorosi gave me a pleasant compliment when describing the Engineering Volume. He said that McLain's Handbook was different than other handbooks because when you use it you get the right answers.

### 5. Universities' Professors Courses

In 1955 or 1956 I think it was, I began to be worried about the lack of interest on the part of the American universities in nuclear technology, including reactors, fuel reprocessing, and metallurgy. It appeared that the nuclear physics and health physics were finding places in university curriculae but the nuclear reactor design courses were being ignored by most universities. This was not the case at Purdue University, as will be discussed later; but it was the case at most universities. So I talked to Hilberry and suggested that we try to talk the Atomic Energy Commission into fostering a six weeks Nuclear Engineering course the next summer. The objective was to present enough engineering background that the various universities would become interested and establish courses in Nuclear Reactor Engineering.

So a few days later Norman Hilberry and I went to Washington to the AEC and made an informal verbal proposal that Argonne National Laboratory do this. We pointed out that the facilities of the International School could be used. This proposal was accepted.

Oak Ridge had a school but this was classified and was intended primarily for engineers and others who expected to work at Oak Ridge. Later Oak Ridge did train many physicists, engineers, health physicists, and others. Richland also trained many faculty people, but I believe they followed our example.

At any rate, we organized a school for 8 weeks for the following summer for about 40 engineering faculty members. We arranged to house and feed the people at the college dormitory in Naperville. Professor Valmar Bergdolt and Professor Robert Eaton of Purdue, attended these classes.

Everything went well except on the arrival night the Sunday before classes were to begin, Hilberry, as Laboratory Director, was to present a welcoming speech. But he forgot to attend the meeting. So instead of just introducing him, I had to give the welcoming talk. To say the least, it was brief.

The next summer Purdue took over the presentation of this work. This was possible since Purdue had built some facilities and had begun to develop a faculty as discussed in the next section. For the eight weeks Winnie and I came down and lived in a house rented from one of the Electrical Engineering faculty. I presented the Nuclear Engineering lectures. This same Summer Institute was repeated for the following three summers. All of these summers we lived in married student quarters.

After we had presented training courses for five summers we concluded that sufficient university personnel had been introduced to the work.

Also by this time a large number of universities had begun Nuclear Engineering Departments.

### 6. Purdue University

My relationship with Purdue University began while I was teaching at the International School. Dean George Hawkins and the Assistant Dean, Paul Chena (he took Hafstad's place as Head of Research and Development at General Motors when Larry retired), and I believe Professor Bergdolt, came to Argonne and asked me to act as a consultant to Purdue.

#### a. Nuclear Engineering Committee

At that time Professors Eaton, Bergdolt, and

Trabant were presenting courses. It was proposed that a sort of Steering Committee be set up and I act, I think, as Chairman. Further, it was requested that I come to Purdue two days a month. After due consideration this was arranged.

As a result we did plan a curriculum and facilities, including a small teaching reactor and other facilities. To me it was an excellent arrangement as most of the time I was doing consulting and this work fitted into my program very well. Only twice were difficulties encountered.

One afternoon we left Lafayette about 1:00 PM as it was snowing. As the weather got worse we decided to go as far west as possible to skirt west of the Lake. We did encounter very bad roads and had to help two cars get straightened out. But the roads were open and we got home about 6:00 PM. Had we gone up Route 41 we would have been snowed in overnight.

Once later we started from Downers Grove to Lafayette in a snowstorm. It was drifting badly. We followed the expressway around Chicago to Route 41, only to find that it was blocked with cars and trucks. So we drove back home. A neighbor of ours, Mr. Keeley, was caught on Route 41 and spent the night in his car. He said that the only really bad thing about it was that the McLains had sense enough not to get into the trouble while he did not.

This Committee lasted for several years even after we had moved to Lafayette. It really was disbanded only when Dr. Phillip Powers came to Lafayette as Head of the Department. I had refused to become Head.

b. <u>Reactor</u>

During the first few years of the program we wrote the specifications for a small training type reactor. This was funded and built. I believe that it has been quite satisfactory although I have always believed Purdue should build a larger, more powerful reactor.

One problem encountered at Purdue is that the Physics Department is interested primarily in high energy physics and its needs are best filled by the accelerators. I have always regarded high energy physics as a dead end, but I understand that there are other opinions.

Later we discussed such a larger reactor but very little interest was shown by anyone at Purdue.

One of the programs that I was interested in was non nuclear. It involved the use of light to grow bacteria in sewage and the use of the bacteria to grow fish and chickens for human food. With some of the agriculture people we demonstrated acceptable growth rates and then we proceeded to design a small pilot plant. The University sent in the proposal to the Federal Government but it got no emphasis. I think we asked for too much money the first year. We actually fed chickens and a rat on the food. The rat became the healthiest critter around.

We also did some work on design of a food irradiation facility but this got no help from the agriculture people. They had objected to our food production proposal.

Then later we redesigned the food production facility into a complete self regenerating food station for use on the moon. Even this created no interest. Later the Space Agency contracted with General Electric, I think, to develop such a process. Now General Electric is trying to develop such a process to dispose of cattle manure and to produce a cattle food.

### c. Other Work

For several years I worked part time at Purdue University. Most of this work was outside the nuclear field. However, as discussed below, I did do some additional work in Nuclear Fuel Management.

## 7. Speeches and Publications

During the years at Argonne I was frequently called on to make speeches. While I presented no papers at the Ann Arbor meeting mentioned previously, there was a national meeting held in Cleveland the following year while I was at the International School. I was asked and presented talks on Reloading of Reactors, and on other subjects, but I have forgotten the subjects. The paper on Reloading of Reactors was presented again to a group in New York. This was amusing as I had two short 16 min films that showed actual operations. However, facilities to show movies weren't the best. The talk was given in the Grand Ballroom of one of the more famous New York hotels. But it was summer, the windows were open and we could not close two of them. Consequently the curtains were blown inwards and the sun shone in so that the pictures could barely be seen.

With Ray Brittan I wrote an article on Safety of Nuclear Reactors. This was presented twice. I have forgotten where it was published but after presenting the paper to a National American Society of Mechanical Engineers meeting the ASME refused to publish the paper due to its prior publication. This paper was probably the most important paper I ever published because it pointed out and explained how great the inherent safety of the reactors actually is.

I was asked by the Society of Electrical Engineers to present a review paper of the reactor program. This turned out to be quite long but it was published in their Journal in complete form as written plus several pictures.

During this time I also edited, I believe, three volumes of papers such as the Geneva Papers. The Handbook is mentioned above. Later Walton Rodgers and I wrote a chapter for the AEC's "The Technology of Nuclear Reactor Safety," but this has just been published (1974). The article dealt with radioactive wastes.

## I. Consulting

Sometime about 1957 Dr. Walter Zinn, John West, and a few others resigned from Argonne and moved to Dunedin, Florida, to set up a design and consulting company. Wally asked me to join them but I refused to do so. Later their firm was bought by Combustion Engineering and Wally became Vice President of that company. He has now retired and John West, I believe, is Vice President.

About one year later I resigned to do consulting. And about one year later Walton Rodger and Joseph Thie joined me as McLain-Rodger Associates. This partnership broke up after one year due to the fact that Nuclear Fuel Services Company hired Walt to act as General Manager of the design and construction of the Nuclear Fuels Reprocessing Plant at West Valley, New York. Joe has continued to work some with me and we both continued as consultants for several years. Joe is still doing consulting.

The discussion of various companies and countries presented below is in somewhat of a chronological order but there was a considerable overlap.

While I was still at Argonne a New York firm, American and Foreign Enterprises, asked me to help them in some discussions in Germany and I actually talked to some engineers from Gummersbach, Germany.

Also while at Argonne I had to do a lot of official entertaining. This was especially true the year after Wally left. Of special interest was a visit of Dr. Otero and General Vital and others from Spain. It was due to their visit and Jodra's statement to Otero that we later visited Spain.

1. EBASCO Services

Sometime in 1955 Leonard Reichli resigned from the Atomic Energy Commission and went to EBASCO Services to organize a nuclear group. EBASCO Services is the construction end of Electric Bond and Share Company, which is a utility holding company particularly in Mexico and South America.

Reichli and others had the idea that at least one small nuclear power plant should be built in Latin America, even though it probably would not be economical. This would introduce the company to the problems of nuclear power.

So Reichli hired James Lane and me to act as consultants. We had several meetings on weekends in New York. We suggested a small boiling water reactor of 30,000 kwe or so be built. We worked out some cost figures, etc. The question of site came up. The most promising areas included one near Havana in Cuba and one near Pueblo in Mexico. Since Winnie and I were planning to take a vacation in Mexico, they asked us to contact the power company in Pueblo and discuss the subject with them. On arrival in Mexico City we called the Superintendent of the Pueblo area and he sent a car to Mexico City for us.

On arrival at Pueblo they took us to the proposed site to see if it was adequate. Actually it was very close to the city and not at all suitable. However, west of Pueblo were open areas that we suggested might be adequate.

While in Pueblo we visited the Cathedral and the old Bishop's Library. Also they gave Winnie a beautiful Mexican tablecloth. When I asked to see the Bishop's Library the Superintendent was surprised as he had never heard of it and was less than two blocks from his office.

The other proposed area near Havana was abandoned when Castro took over. And by that time the company decided that small plants were too costly.

Reichli is still working at EBASCO Services and the company has done some contract work but is not very active. I think they have submitted some bids and may have done some construction. They believe they are about to contract for a large plant based on the Fused Salt Reactor at Oak Ridge.

Later I visited Mexico and presented a discussion relative to the use of a heavy water research reactor like the CP 5.

2. Junta de Energia Nuclear

While I was still at Argonne, Professor Otero and the head of the Spanish Atomic Energy Commission, General Vital, who was a friend of Franco, visited there. I spent two days with them. Also Jodra had strongly recommended that I be asked to visit Spain and present the series of lectures that I presented to the International School.

On return to Spain Professor Otero had asked me to suggest a program for their Atomic Energy Commission. One evening I dictated a long letter rather offhand. This was adopted as the official Spanish program. However, one part was not carried out but most of my suggestions were followed. I had suggested a reactor designed to test fuel assemblies but the Spanish utilities later found this unnecessary and opposed it.

The next year Winnie and I spent three months in Madrid. I gave three lectures per week at the University to about 35 people. I also helped them what I could in fuels and fuel recovery work.

When we arrived they had a cocktail party for us. Then they took us to a Hai Lai game and to Spanish dances. Later many of the people entertained us. We also were taken on a trip to the south of Spain to the uranium mining area. While on the trip we stopped at Cordoba and Seville. Then we visited industry in the north of Spain, especially Bilboa, Eobar, and other industrial areas. Later we stopped in Barcelona to visit the industries there. It was our conclusion that Spain could build many of the components or entire nuclear power plants.

The Junta gave an extended contract to Burns and Roe of New York to assist in evaluation and plans. Burns and Roe sent Sy Baron and one other engineer to Madrid and we all worked together for an extended period. Sy and I became good friends and after Winnie left we had fun eating at different restaurants and evaluating them. The usual highly touted and advertised restaurants like Horchers did very poorly in comparison with the pensions both in price and quality.

They subsequently carried out an extended development of organic cooled reactors. However, most of the reactor work was dropped when the utilities insisted on buying complete plants from Westinghouse and General Electric.

The fuel manufacture and the fuel recovery plus the mining and ore processing was continued and full scale plants built.

3. Germany

Following the first trip to Spain Winnie and I flew to Frankfort at the request of American and Foreign Enterprises of New York. We were met by people from Gummersbach who entertained us over the weekend. These people owned a heat exchanger manufacturing plant and were interested in the components they could build. We talked to them twice also in this country.

On the Sunday we were there they took us for a ride to Koln and Bonn on the Rhine. Later we went to Hamburg, Hanover, and Dusselsdorf. While at Dusselsdorf the phone rang one night just as we were going to bed. It was the manager of the power company at Bremen. He said he had just heard at that late hour that we were in Germany and would we come to Bremen. I told him we were leaving for Holland in the morning and we could not do it. But he insisted. He said their travel person would take care of the changes in our tickets, etc. Further, he pointed out that a plane left Dusselsdorf in an hour and they would meet it. So we went.

It was a rainy night. But we hurriedly dressed and packed a few things and caught a cab to the airport. We had a few minutes to spare. On arrival at Bremen two men met us and took us to a midnight lunch and then to a hotel. They met us for breakfast the next morning also.

What they wanted was someone with a knowledge of nuclear power plants to look at a site on which the power company had an option and to tell them whether or not it was suitable for a nuclear power plant. They drove us several miles out of Bremen to a river site. On the site was a building in which the Germans had assembled submarines during the War. It was one floor with a canal along one side. The inside was perhaps 500 ft long, 300 ft wide and 50 ft high. The walls and roof were heavily reinforced concrete 8 ft thick. After the War the British had practice bombed it with armour piercing bombs; so the roof was a shambles.

We walked into the building and the manager asked my opinion. I simply said, "No." Then he said, "I thought that would be your answer but we did not want to release our option on this area and building until we got our opinion confirmed. Let's go have a drink."

They took us for a ride around the area, to lunch in the 16th century wine cellar of the City Hall, and back to the airport. Winnie was tired so they spruced her up with wine. Finally I billed them for a day's work and expenses.

4. Textron

While I was still at Argonne I was asked to visit Yellow Springs, Ohio and present a talk to a meeting relative to combined school-work or cooperative programs. The reason for this was that Argonne had developed a part of the program and had some cooperative students.

Afterward there was a banquet. When I walked in I immediately ran into Jerry Ottmar of Metals and Controls of Attleboro, Massachusetts. He had been working with Arthur Matheson and James Dutton. Metals and Controls had a Navy fuel assembly contract and wanted to expand into power plant reactor fuels.

Jerry asked me to sit with him as he wished to discuss possible consulting. Then a man and woman came in and she introduced herself as, "I'm Mary Pickford." I almost said, "I'm Andy Gump." She then turned and said, "This is Bruce Rogers, my husband." She then sat down next to me. I introduced them to Jerry. She then started quizzing us about our work. Then she got up and asked me to move over next to Bruce so she could better talk to Jerry and me.

Mary was well to do and, it turned out, that one of her pet projects was support of the college at Yellow Springs. She was also very well informed and very intelligent. She claimed her age as 67.

Later in the evening Jerry and I had a long talk. I agreed to visit Attleboro regularly and discuss their problems and present a series of lectures. This I did over the next several months. Afterwards I visited Attleboro less often but the total time was something like two years. Then Metals and Controls was bought by some other company.

Jerry left and my contract was dropped. Jerry then became Vice President of Textron Company. Royal Little was just putting Textron together; so Jerry asked me to act as consultant to Textron on acquisitions. This I did for about three years.

### 5. Pickard-Warren-Lowe

I worked with James Pickard in the AEC. William Lowe I met at the shipbuilding yards at Bath, I think it was called the Bath Iron Works. Fred Warren worked in the AEC, I believe, also.

About the time I left the AEC Jim left and set up as a nuclear consultant in Washington. He had one contract I think at the start with A. O. Smith and Company of Milwaukee. Jim did very well and soon Fred joined him and a little later Bill also joined the group. They asked me to consult with them and this I did for several years. They also asked me to join the group. I would have liked to but for Washington traffic. Life is too short let alone fighting with Washington traffic.

I worked for Pickard-Warren-Lowe about one day a month for several years. Then they set up Nuclear Utility Services, and expanded into a number of related businesses. They got money from one of the liquid air companies for finance. All their companies have done very well.

One interesting thing happened. One day I was working at the office of Pickard-Warren-Lowe when there was a heavy snowstorm. Some 6 inches of snow fell. So about 3:00 PM everyone went home, including the janitor of the office building I was in. I thought nothing about it as I planned to take the overnight pullman to New York.

Since the train did not leave until near midnight, I simply stayed in the office and worked until about 10:00.

Then I packed up and planned to get a cab or walk to the depot and go to bed. When I got to the front door of the office building, I found it locked and there was no emergency way to open it except kick it down. So I had to go back to the office and get the front door key. But the office was locked and I had left the key I had used in the secretary's desk. To get in the office I had to either break the door in or something. Since there were transoms, I stood on the door handle, broke the transom, and got in. After getting the key I left a note and took the key with me after getting out the front door.

Several months later Pickard-Warren-Lowe's office was robbed by someone breaking in through the transom. So I was assumed guilty.

## 6. Gibbs and Cox

Dr. Harold Mott-Smith of Gibbs and Cox asked me to help Gibbs and Cox in respect to the application of nuclear power to ships. They had a contract with the U.S. Government to develop means of protection of reactors in ships involved in collisions.

The problem became one of analyzing the damage to ships that resulted from collisions and then designing hulls to minimize the damage in those parts of the nuclear ships in which vulnerable components might be located. So, first, a design of a nuclear powered ship of 80,000 dead weight tons, I believe, was evolved. The location of the critical items was indicated. Based on this study we subcontracted with a ship salvage company to review the data available on ship collisions involving the central portions of the hulls, in order to estimate the extent of possible damage to the nuclear components. Then we designed energy absorbing structures to limit the damage in the critical areas.

The review of the collision data indicated that a ton of steel torn from a ship's structure absorbed nearly a constant number of ft lbs of energy. We then designed oak and steel bulwarks to absorb the maximum amounts of energy. This program involved nearly two years part time study.

It was interesting since Gibbs and Cox was one of the world's leading ship designers. Mr. Gibbs at that time was, I believe, well over 70 and yet every day he sat on a stool all day at a drafting table and while he drew he dictated enough to keep two secretaries busy. He also kept a little black book in which he wrote his own thoughts about things such as the design of the Andrea Doria, which he had at the time of its construction loudly condemned. He also designed the United States. This ship was built with steel bulkheads that required lots of stair climbing to move between parts fore and aft except on the top deck.

The United States was a powerful ship as she was designed for conversion into an aircraft carrier. We crossed the North Atlantic heading into a 53 mile per hour gale with 50 foot waves. Even on her we felt seasick and the nurse gave us pills in the morning. But it was beautiful.

The Queen Mary lies dead on her side in Hongkong Harbor, a rusting hulk. She was burned. The people in Hongkong claim at least seven fires started at once and they claim Communist agents set the fires.

7. General Motors

When Lawrence Hafstad went to General Motors as Head of Research, he took Donald Loughridge with him. And he asked me to act as a consultant. We really didn't do much, however. General Motors did make a bid on design and construction of the Gas Cooled Reactor built at Oak Ridge. We also discussed the possibility of semi mass production of small power plants with the Cleveland Diesel Division. But this was quite impractical due to the high costs of auxiliaries and the low unit fuel power production.

8. Curtiss-Wright

Curtiss-Wright had built an isolated Research Laboratory on a mountain near the center of Pennsylvania some 30 miles north of Black Moshannon Airport and north of Phillipsburg. The reason for the location of the laboratory was that it was built to test jet engines. Curtiss-Wright then made the sad mistake of trying to place multiple engines on the larger planes rather than building the supersized engines now in use; so they lost out.

In order to make use of the facilities they started work at the laboratory on various other things, including nuclear energy. They did get contracts on a couple of training reactors and then the design of part of the Brookhaven Test Reactor. In this case the entire nuclear group resigned so that Combustion actually ended with the design contract.

In the midst of this program I was asked to act as a consultant. Finally I actually served as Director of the Nuclear Branch for a time. We did have a few isotope use programs that paid expenses.

The President of the company had been told there was a great future in design and construction of nuclear power plants. At a meeting in New York I was asked what such a development program would cost and how many years would be required before such a program could be profitable. I could not answer the first question other than to say over $100,000,000 and seven years was a conservative answer for the second question. The President simply said, "We can't do it." I agreed that they should not try.

About that time Curtiss-Wright did buy the Western Hemisphere rights for the Wankel engine with the idea it could be developed for lawn mowers, etc. They are now cashing in on this engine.

Three humorous things happened while I was working with Curtiss-Wright. Normally I took the evening plane to Pittsburgh, stayed overnight and took the Allegheny Airlines local plane from Pittsburgh to Black Moshannon. At Black Moshannon I rented a car and drove to the plant. One morning on arrival at Black Moshannon it was clear and warm with no snow. So off I went. But as I climbed into the mountains I ran into snow and I got stuck. Supposedly there were chains in the rear but I couldn't get the trunk open. Finally a truck driver stopped and together we did pry it open. The chains were there and I soon got going.

Another time it was raining in Pittsburgh when we left. And at Black Moshannon it was snowing enough that we simply overflew the airport. Also at Williamsport and Wilkes-Barre the same thing happened. Finally about 11:30 we arrived at Newark. So I leisurely had lunch and got the 1500 train to Chicago and home.

And one evening the wife of the Director of the place, Mrs. John Dickey, had asked me to dinner as I was staying two or three days. In the afternoon her folks who lived some 30 miles north called and said they would like to come for dinner. She told them that was fine as she was having Stew McLain for dinner. When I walked in they had quite a laugh.

## 9. McLain-Rodger Associates

After I had been doing consulting for about three years Dr. Walton Rodger suggested we join. Walt was a Chemical Engineer and he had spent several years on Nuclear Fuel Reprocessing at Oak Ridge and later at Argonne. He was Associate Director of the Chemical Engineering Division. So we set up the partnership as McLain-Rodger Associates.

Soon after we organized Dr. Joseph Thie also joined us. Joe is a theoretical physicist with a very high IQ.

### a. Atomkraftkonsortiet Contract

The first sizeable contract was a nuclear fuel cycle study for Atomkraftkonsortiet of Stockholm for the Simpevarp 50 mwe Reactor. This was easily done but the study led us into a study of fuel cost calculations, and a suggested revision of the Atomic Industrial Forum's Manual on fuel costs. This Manual had been prepared by Bill Lowe but I had not studied it. Walt ran into the first troubles and then we both spent several days on it.

We also did a study for the Simpevarp Reactor relative to higher power levels. We also reviewed the proposals submitted for the reactor.

### b. Insurance at Sandia

We were next called on to make a study of insurance risks at Sandia to assist the Zurich Insurance Company to make a bid. I evaluated the risk as less than that for private companies doing general work. Nevertheless, Zurich did not get the contract.

### c. International School

We prepared a series of lectures and Walt presented them to the International School. These covered radioactive wastes and their disposal.

### d. Illinois Institute of Technology

Walt presented a course on Radioactive Wastes at the Illinois Institute of Technology.

e. Nuclear Fuels Services

The State of New York Atomic Energy Department asked Walt to assist in locating a suitable site for an irradiated fuels recovery plant. Actually, we did relatively little work on this. Later Nuclear Fuels Services contracted with us for assistance on design of the radioactive waste portion of the plant that was built near West Valley, New York.

At about the same time the company building the West Valley plant asked Walt to become General Manager. We talked it over and we all recommended that we break up the partnership. Walt took the position at West Valley, I assumed more responsibility at Purdue and we soon moved to Lafayette, and Joe continued his consulting.

Walt remained as General Manager until the West Valley plant was in operation. He did most of the flow sheets in a few months after the partnership disbanded. Then he and his family moved to West Valley. After the plant began operations he left and with one or two other men moved to Rockville where he heads a consulting company.

Joe has remained in the Chicago area. As indicated below, we have worked together some since the partnership broke up.

f. Aluminium Laboratories, Ltd.

One consulting job that took quite a bit of time was with the Aluminium Company of Canada. This work was divided into two completely different parts. Both were non nuclear.

The first dealt with the seals on a pump used to handle liquid aluminium chloride, $AlCl_3$. All commercial seals failed in minutes or at most hours. So we suggested a loose non load carrying seal backed by a gas pressure with gas leakage into the $AlCl_3$ and the gas chamber backed by a conventional seal. Another suggestion was the possible use of a frozen seal. The latter was tried almost in minutes and worked perfectly. Actually the clearance was adjusted later by experiments over a few days. Of course, frozen seals had been used extensively for liquid sodium and were not new. Leakage was less than 2 $cm^3$ per hour.

The second problem was a bit more involved. They wanted to go back to carbon or carbon monoxide reduction of the aluminium ore. This was used by people prior to Hall to produce small particles of aluminium. They had a complicated process in mind, using an aluminium chloride intermediate step for purification.

Their chemists and physicists had carried out successful experiments at Arvida. So they designed a pilot plant. The layout was something awful. I suggested elimination of about one half the piping and most of the valves. This was not done. So the plant was built and it was a mess. Then they shut it down and the last visit I made to Arvida they were removing all the mechanical valves and most of the excess piping. They used frozen seals from then on. I never knew whether they ever built a production plant or not.

### g. Other Work

During the period that we had the partnership, I continued my consulting for several companies and membership on the ASME Special Committee for Nuclear Power. I also worked some on the Handbook.

## 10. Other Consulting Contacts

At various times I carried out consulting from one day to several days for several other companies, as listed below. I believe there were others but I have forgotten their names.

- Skidmore, Owings & Merrill (with Walt Rodger, I think)
- Austin Company
- Giffels and Vallee
- Bendix Corporation
- American Machine and Foundry
- Martin Company (this included work on the Antarctic reactor)
- Commission Nacional de Energia Atomica, Buenos Aires (two weeks in Buenos Aires)
- Nuclear Development Associates
- Stanley Engineering Company
- Notre Dame University (shielding design)
- Nuclear Industries
- Burns and Roe

Following is a typical travel schedule while I was consulting, for one month, June, 1961:

| | |
|---|---|
| 5 June | O'Hare 4:50 PM Capital 248 Pittsburgh 7:29 PM<br>Motel Pittsburgher |
| 6 June | AMS Meeting Penn Sheraton, Pittsburgh<br>Motel Pittsburgher |
| 7 June | 7:30 AM Allegheny 600 Phillipsburgh<br>Curtiss Wright<br>8:02 PM Allegheny ? Newark 9:50 PM<br>Commodore Hotel |
| 8 June | Parsons Brinckerhoff, Quade & Douglas 9:30 AM<br>Burns and Roe 11:00 AM Dr. Seymour Baron<br>Chase Manhattan 2:00 PM % Dr. Paul Genachte<br>5:30 PM Idlewild to O'Hare |
| 11 June | 4:30 PM O'Hare Mexicana 801 7:30 PM Mexico, D.F. |
| 12-13 June | % Dr. Victor Flores Maldonado<br>170 Oriente 64<br>Col. Moctezuma<br>Mexico 9, D.F., Mexico |
| 14 June | 2:15 PM American Airlines 52 O'Hare 6:40 PM |
| 16 June | To Ann Arbor by car |
| 17 June | Ann Arbor |
| 18 June | Detroit 6:20 PM American Airlines 640 New York<br>Hotel Commodore |
| 19 June | ASME Special Comm on Nuclear Power<br>6:15 PM Northwest 227 Detroit |
| 20 June | Ann Arbor--Lafayette by car |

It is sometimes amusing when you have a travel schedule like the above one to talk to some of the less experienced travel agent people. I offer three examples as follows:

(a) In Downers Grove I used a travel agent that was experienced and thought nothing about my capers. But one day a new girl came to the desk and asked to help. She had a pad and started to write but she soon stopped and stared. I wanted to turn in two unused airline tickets and a pullman and train ticket. Then I started to say what I wanted, which included a few airline tickets plus some train tickets. Of course, travel agencies are not supposed to handle railroad tickets.

So one of the regular girls walked up to her and said, "Just don't stand there woman. Bawl him out. He stays awake nights thinking up these things for us to do."

(b) This and the next one are similar. Fred Beierle and I were in Joplin, I believe, one Friday evening and we had caught a local plane to Omaha. Since we did not know our schedules, we had no reservations out of Omaha. Of course, all planes were filled. Fred said he wanted to go to Portland and I said I wanted to go to Chicago. We couldn't, so Fred says how about Denver. No Denver, so how about Chicago. By that time the girl asked Fred, "Do you men know where you want to go or do you just want to get out of Omaha quick?" The girl next to her said, "Of course, they know. Put one on standby on Flight ---- to Chicago, and one on standby on Flight ---- to Denver." We both got home without further troubles--he to Richland and I to Downers Grove.

(c) Fred and I were in Chicago one Sunday night and seemingly all flights were filled. After several questions the girl trying to sell us tickets also asked, "Do you men care where you go?" The girl next to her almost shoved her aside and said, "May I help you?" Then she turned to the other girl and said, "Frequently men come in like this. They know where they want to go during the week but they will start in any direction."

In recent years my consulting has dropped to near zero as I have been too busy to do much outside work. Actually, I did do only $1,000 in 1972 but I now refuse any work.

## 11. Kuljian Corporation and India

Soon after I left Argonne National Laboratory I got a call suggesting that I talk to a Mr. Harry Kuljian, President of the Kuljian Corporation in Philadelphia. This meeting was arranged by the editor of one of the nuclear trade magazines whose name I have forgotten, (Mr. Norman -----). Sometime later I had a meeting with Mr. Kuljian, his Chief Engineer, Mr. Livonian, and their nuclear man. It was agreed that I would act as consultant when called upon.

Later, after the partnership of McLain-Rodger Associates was broken up and we had formed the firm of McLain Associates in Lafayette, I got a call suggesting that we meet Mr. Kuljian in Chicago. This meeting was a bit difficult to work out as Mr. Kuljian said he would be at the Palmer House, I think it was, but when Winnie and I arrived he apparently had not checked in as the information clerk had no room assignment for him. It was the hotel's error because he had checked in on schedule. So we sat in the lobby for an hour and then ate lunch and finally just as we were leaving the lunch room Mr. Kuljian, Mr. Livonian, and Mr. Harry Kuljian, Jr. came into the lunchroom.

Mr. Kuljian stated that they wished to bid on an assistance program to the Government of India on a nuclear power plant. Would we supply the nuclear backup? I had previously done several days of consulting for the Kuljian Corporation and I knew their personnel and organization, so I agreed. I also had working agreements with Joe Thie and others whom I might need.

The Kuljian Corporation, I believe, is nearly all owned by Mr. Kuljian and Mr. Livonian. I have never seen their financial reports. The company consisted at that time of about 20 engineers in Philadelphia plus offices in several other countries, one of which was India. In fact, the office in India is the largest Kuljian office and I believe one of the largest engineering design offices in India. It has an excellent director and reputation.

The Indian government was interested in building a power plant north of Bombay. Since this was to be the first nuclear power plant in India, they wished to have an American built plant and American consultants. They also wanted American financial help.

### a. Conferences in Calcutta

There were, of course, many meetings and discussions. These included trips to Washington and San Francisco and to Calcutta and Bombay. The trip to India was my first trip there. I flew via Cairo and Bombay. On arrival at Calcutta where I went first, I was met by the Indian Manager of the Kuljian office.

We drove from the Calcutta airport into town late in the afternoon. This was a very interesting trip as every family was cooking dinner. We arrived on the last plane allowed to land at Calcutta for several weeks as an influx of refugees from East Pakistan (now Bangladesh) had just started.

Calcutta is hot most of the year. So to sleep out of doors in a park is no great hardship such as it would be here, for example. It does not cool appreciably at night, to 75 F perhaps.

The area of Calcutta between the airport and downtown is low and at that time very wet. Most of the people live in huts about 14 ft square. They cook on charcoal braziers out of doors most of the time in the dry season. The huts are close together and there is a real neighborliness by necessity, as your neighbors can see what's in your rice pot. If you are poor, you may have a candle for a time in the evening, but if you are a little better off you may have a 40 watt bulb. All days are nearly 12 hours long with 12 hours of night.

Calcutta is located on the Houghly River, which is one of the mouths of the Ganges-Brahmaputra systems. Due to the construction of railroads and roads with their built up embankments, there is no easy way for flood waters to flow to the sea. Also the area seems to be sinking. When I was there the first time there was water seemingly everywhere but it was only inches deep.

At the time I was there they were building a barrage or dam on the Houghly to control flooding of Calcutta and its environs. This probably was successful but must also have added more flood water to Bangladesh.

The refugees were the poorest lot of people that I have ever seen. Each man carried the worldly goods of his family. In most cases this consisted of a roll of tattered clothes about 8 in. in diameter on the end of a stick. Nearly every person was almost skin and bones. The upper arms of most of the men were as small as my wrists.

These people were simply given places to sleep on the ground in the parks. Luckily the British cleared several sizeable areas for parks--Queen Victoria Park is a mile or more by about a half mile. Soup kettles were set up and food prepared for these people.

Every person was clean. I noted uncleaned fingernails and toenails but the flesh and clothing was uniformly clean. They took baths daily by scrubbing themselves at the public water "fountains". These fountains consist of a pipe and valve from which you can draw water.

Toilets consisted of most anywhere at any time.

I tried to get statistics on numbers. Everyone had different numbers. In the first two migrations of which I saw a very small part of the second, officially there were about $2.2 \times 10^6$ people. Unofficial estimates given me by people that I considered very knowledgeable, were just 10 times the official figures.

Imagine if a number of destitute people equal to the population of Lafayette walked into Lafayette next July between the first and fourth. What would we do? The people in Calcutta fed them in their parks, let them sleep on the ground--cattle keep the grass mowed and supply fuel--and then processed them and found homes for most of them in a few weeks. I admire the Calcutta people.

Later when I was in Calcutta there was no evidence that anything had happened. This last fall they would not let us off the plane at the airport due to our backing of Pakistan.

The next day I spent at the Kuljian Indian office. They had over a hundred engineers and others. We reviewed what might be done and got acquainted. We had lunch with several other visitors and several Kuljian staff people at the Old English Club. In the evening the Manager and one other engineer and I flew to Bombay.

## b. Conference in Bombay

We stayed at a motel near the airport on the Arabian Sea. And of course had lobster dinner and an evening swim and sat on the beach and talked until after midnight.

The next day we met with the Head of the Indian Atomic Energy Commission and the man in charge of the power project, Mr. Chadravardi. I presented something of my background and outlined how we would handle consulting for them by review of the drawings and specifications.

The following day I spent walking around Bombay and taking a private tour. I told the clerk at the hotel I wanted a guide and a taxi. A university girl showed up as the guide. She was quite good. First we went to the university which she attended. She was a Junior, I think, in economics.

Then we went to the Museum to see the relics of the Harappa Period. I then wanted to see the railroad and ship yards and markets. She refused to take me to the fish market as too smelly but we did visit the rest. Then she insisted on showing me the tourist things, including the place where the Zorostrians leave their dead to be eaten by the vultures. She also took me into a Zorostrian church. A rather tired old man was playing a piano. In front of him were two rows of women sitting on the floor. Each had a stick about 1 ft long in each hand. As they sang they would keep time by hitting the opposite person's sticks. I remarked, "It looks like fun," but the guide didn't appreciate my humor.

Bombay is a different city from Calcutta. Rather than a mass of huts with a minimum of larger buildings as Calcutta is, Bombay is an industrial center with large modern office buildings and high rise apartments. Other than more antique automobiles on the average, downtown Bombay is just like Chicago with the exception that it is always 72 to 74° F.

In Calcutta much of the goods are moved by wagons pulled and pushed by men. In Bombay there are trucks and cars everywhere.

c. Contract Negotiations

The actual contracts involved General Electric to design and construct the nuclear portion of the plant, the Kuljian Corporation to design the non nuclear portion of the plant, the Bechtel Corporation to design the utilities and to construct the plant, Nuclear Utility Services as consultant on the non nuclear portion of the plant, and McLain Associates as consultant on the nuclear portion of the plant. Since the Administration for International Development was furnishing the capital they went over the various contracts in detail. In fact, it was AID that required NUS and McLain Associates as consultants.

Finally, the contract was approved on 10 November 1964. So representatives of all the organizations met at the Indian Consulate Office in San Francisco to sign the various contracts. Our portion amounted to about $35,000.

At the final contract negotiations in Washington with the Administration for International Development and the Atomic Energy Commission, the negotiations nearly broke down. I had always insisted that Kuljian sign for complete responsibility. I took the view that McLain Associates was a consulting firm and not a responsible engineering firm. If we should be sued we, as individuals, were responsible and we did not have limited responsibility. On the other hand Kuljian wanted me to sign for the areas named in the McLain Associates contract.

Mr. Chakravarti requested that a single engineering firm sign and finally Kuljian did so.

d. Design Work

General Electric Company had the major portion of the work. They designed and built two nuclear power plants and accessories for 150,000 kwe each. The contracts were about $150,000,000 but this amount included the design and construction of all the buildings and utilities.

In order to review the drawings and coordinate the work of Kuljian, McLain Associates, and NUS, an office was set up in San Jose a few miles from the General Electric design offices. Provision was made for two Kuljian engineers, two NUS, and two McLain people, plus secretaries, supply cabinets, and auxiliary equipment.

I had contracted with Joe Thie to check the physics calculations, etc while I planned to review the layout and process drawings. The Kuljian Company sent two engineers from the Calcutta office. These were excellent men. NUS sent one man even though their contract was larger than ours.

It turned out that Joe was so efficient that he did not have to work full time. I spent only one week a month at San Jose rather than the expected two weeks.

The Indian government people were given an office by General Electric. Besides Chakravarti there were 10 or 12 men in their group.

e. Reports

We issued reports whenever we completed review of a set of drawings, specifications, etc. Usually at the end of each week's work in California we had a conference with Chakravarti and his staff. What they did with our reports in respect to General Electric was the business of the Indians. Most changes we suggested were adopted. However, one recommended change was not adopted.

Two of the most significant arguments are discussed below. Most other arguments were minor and we were usually able to compromise or the changes were accepted by everyone with minor corrections. This was the case in perhaps a hundred or more minor changes that we recommended.

The first argument arose during the review of the initial layout drawings prepared by General Electric. General Electric had designed and built the Dresden I Reactor. This design was based on the Experimental Boiling Water Reactor II built at Argonne and a smaller boiling water reactor built at Vallicitos. I never saw the Dresden I drawings.

Anyway, the layout drawings showing the piping arrangement for the primary cycle, including the steam and water piping was an unholy mess. There were simply too many valves and too many pipes. I don't know what part Sam Untermyer played in the design of this reactor. He had invented the Boiling Water Reactor, had designed the Experimental Boiling Water Experiment in Idaho, and had a lot to do with design of EBRII, and the Vallicitos reactor.

I criticized the drawings and recommended removal of about half of the piping and most of the valves. I also recommended rearrangement of the locations of several pipe lines. When we got the revised set of drawings, I found they had followed essentially all my recommendations except for the location of one of the small emergency cooling lines. This was actually placed where I wanted it by a field change during construction.

I found out later that about half of the General Electric engineers had argued almost the way I had about the piping layout and valves.

The second important argument that I got into dealt with the radioactive waste disposal system. The radioactive waste system, as designed by General Electric, was, I believe, unworkable. It consisted of an automatic centrifuge, a discharge into barrels on a chain platform, a remote header operation for the barrels, and remote handling. I predicted that addition of solidification materials would be impossible, spills would be frequent, and cleanup almost impossible. Nevertheless, it was built as designed. Then after it was built, they tested the system on non radioactive wastes. Of course, it was necessary to use a cellulose material instead of Portland cement, as specified, to absorb the excess water; the centrifuge worked but there was no possible method of repair without excessive radiation doses to the repair people; the discharge from the centrifuge dropped in chunks which spread radioactive particles around the impact point; the barrels became contaminated on the outside; etc, etc. As the Kuljian engineer that supervised construction said, "It's worse than Stuart predicted." It never ran as designed.

When they got into trouble during the non radioactive tests, they called me and asked me to go to the plant as quickly as possible. So I flew over that next weekend. I stopped in Bangkok as my plane, a Pan American, went to Delhi instead of Calcutta.

When I got off the plane in Bangkok, the Kuljian Calcutta Manager met me. I was very surprised. He was in Bangkok on other business. As it was about 0200, we drove to the hotel and talked to 0400. As we were going to our rooms he said, "I've set up a breakfast with the editors of the local papers for 0900."

So the next morning I had breakfast with the local newspaper editors. The meeting was called to discuss a paper plant but the discussion was 90% re Communism and Vietnam. The editors all agreed that it was essential for the United States to stay in Vietnam no matter what the cost. They also said that if we should pull out of Southeast Asia, it will all go Communist. And we have partially pulled out!

I'm not sure that the American people realize that one of the potentially richest areas in the world is Southeast Asia.

To come back to the Tarapur Project, I caught the 1100 plane to Calcutta. We flew over the mouths of the Ganges-Bramaputra Rivers and what is now Bangladesh as well as earlier over parts of Thailand and Burma. All the low land areas were paddy with the usual wood shacks and canals.

On arrival at Calcutta I went to the Kuljian office for the rest of the day. I stayed at the Victoria Hotel and on Tuesday flew to Bombay. I was met by Prakash and spent part of the day in the office in Bombay. In the evening I took the train up to the plant site near Tarapur.

The Tarapur plant is located on the Arabian Sea and uses sea water for cooling. The area surrounding

THE WALL STREET JOURNAL,
Tuesday, March 18, 1975

**SOUTH VIETNAM decided to abandon three provinces to the Communists.**

In its worst defeat of the war, Saigon said it would evacuate the Central Highlands provinces of Kontum, Pleiku and Darlac and leave them to the North Vietnamese. "The decision was made to cut losses now because the North Vietnamese were putting so many troops in the region and there was no way to supply the South Vietnamese troops," a Saigon official said. Officials said South Vietnamese troops were trying to fight their way out of Pleiku eastward.

*Capture of the area has long been a major goal of the North Vietnamese. It gives them a massive supply and staging area from which to attack the coastal cities and practically cuts the country in half.*

**Cambodia** will get an extra $21.5 million of weapons and ammunition without congressional approval because it was overcharged for military materials in fiscal 1974, the State Department said.

**A Cambodian arms** aid bill of $82.5 million that provides for an absolute cutoff of assistance June 30 cleared the Senate Foreign Relations Committee, 9-7. Meanwhile, Ford's advisers asked the House Foreign Relations panel to approve the same compromise bill halting aid June 30 as a method to get the bill to the full House. Ford still opposes an arms aid cutoff.

**The American Embassy** in the besieged Cambodian capital of Phnom Penh burned documents and told refugee agencies to pare down to essential personnel, apparently in anticipation that the city may soon fall to Communist-led insurgents.

* * *

**Thailand** will normalize relations with China and seek withdrawal of the about 25,000 American troops and 350 aircraft there within 12 months, Premier-designate Kukrit Pramoj said. Political observers said the statement was aimed at winning left-wing support to insure that his proposed government wins a parliamentary vote of confidence tomorrow.

* * *

the plant is very poor. They simply harvest the native grass for hay, bale the hay, and ship it by rail to near Bombay where it is used for cattle feed. The people have a reputation of being very lazy and backward. The hay is cut by scythes and moved on bullock carts to the baling machine which was also operated by bullock power.

Bechtel had built a few houses, a small motel like hotel, swimming pool, etc near the plant. The Kuljian representative, Mr. Prakash, lived in one of the houses and of course I stayed at the motel.

When we got to the plant they arranged a meeting of the Bechtel and General Electric people and the Indian representatives first. This meeting was of interest in that General Electric tried to impress on me that the waste system could be made to work. So I said, "Just don't try to make it work. Take the equipment out before it becomes contaminated and sell it and let us design a workable plant."

We then proceeded to a demonstration. On inert stuff it did work after a fashion and the young General Electric engineers had done an excellent job of attempting to make it work. After the demonstration we went over the equipment. It was easy to point out what additional protection in the way of guards, replaceable covers, etc should be installed. For example, the conveyor drive was uncovered. A metal cover that could easily be cleaned has kept radioactive materials out of the chain.

Mr. Prakash told me later that not only all the bad things I had said came true but there were others also.

Later we had a meeting of General Electric, Bechtel, and Indian AEC people to discuss changes in the whole plant that the operating staff wanted. Apparently before I arrived they had agreed I would be arbiter and whatever I said would be accepted. But they didn't tell me this. They had perhaps 40 different things listed on several sheets of paper. The Chairman, who was an Indian government person, would read the item, each side would offer comments, and all would turn to me to ask my comments. After the first two or three I caught on that I was the arbiter.

Most of the items were trivial. I pointed out that the cost of the salaries of the people present at the meeting for the time involved in the discussions were greater than the cost of the changes. So I was quite arbitrary on most items in telling the Indians to accept the plant and then have their plumbers make the minor changes. There were, I think, three rather large items. So I suggested we go to their locations in the plant and have a more detailed discussion. This was done. I think I ruled all three against General Electric. But everyone seemed satisfied. Apparently General Electric and Bechtel had fought all the changes but were willing to correct those changes that I suggested were their responsibility. And, of course, to the Indians "face" was important. Even if I ruled against them they could blame me without loss of "face".

One change that I could not settle dealt with installation of an air conditioner in the instrument room. It was too hot for human comfort but not for the instruments. I finally said to the Indians that it was their responsibility.

General Electric and Bechtel had their own set of problems. The steam cycle used was the same as at Dresden I. In this the steam produced in the reactor goes directly to the turbine but water is withdrawn also from the reactor, passed through heat exchangers to produce lower pressure steam, and back to the reactor. The tubes in the heat exchanger had not been properly heat treated and all of them had to be replaced before the plant could start.

One item of interest was that Bechtel brought in British welders only to find that they were very limited in the amount of welding they could do per shift. So they tried Indian laborers who proved to do better work and were not limited by unions in numbers of tubes they could weld per shift; so they did 2 to 3 times as much work. The British welders were promptly sent home.

Also, when I went through the plant, I found that the condenser had been built and tested several months previously and that it had been left filled with sea water. I was worried that the tubes might be corroded. An inspection proved they were not harmed. But they immediately filled the condenser with purified water treated with anti corrosion agents.

Since the plant has been in operation its on-line efficiency has been low. One or the other of the reactors has given almost continuous trouble. I am not familiar with the specific details.

The last night I was at the plant Mr. and Mrs. Prakash asked me to dinner. She had told the houseboy not to add more than a touch of curry to my food. But even then I could hardly eat the chicken.

The next weekend I flew home.

Part of my contract was to provide assistance in fuel management. So after I returned to the United States, Joe Thie and Clifford Zitek went to Tarapur. Joe was responsible for the startup tests and bringing the reactor to power. Afterwards Joe spent quite a bit of time helping the Indians get their fuel codes in operation on their computers, so they could handle their own fuel management.

Clifford Zitek had been Associate Director at Dresden I. As mentioned above, he attended classified lectures which I gave at Argonne. Later he helped build, startup, and operate Dresden I Reactor and to design Dresden II and III Reactors. While it was not in my contract with the Indian government, I asked Clif if he would go to Tarapur for two weeks during the start up tests and advise the Indians on operations. This he and Commonwealth Edison agreed to. So I paid his travel and salary for two weeks as a gift to the Indians. But Joe had worked so fast that my profit on the contract was greater than I had expected.

## 12. Argentina

Just after I left Argonne and started consulting, the President of the Argentina Atomic Energy Commission invited me to go to Argentina to the Commission's set up at Mendoza, some 600 miles west of Buenos Aires, and give a series of lectures. When we got down to practical questions of who pays for what, Argentina wanted our government to pay my salary plus travel to Buenos Aires. Since I was not a government employee, our AEC refused to pick up either the travel or pay checks. And I didn't want to go badly enough to pay my own expenses and make a gift of my time. So I did not go.

Several years later Argentina began to consider a nuclear power plant seriously. Frank Foote and James Schumar of Argonne and several other Americans were invited to spend from a few days to a month in Buenos Aires with the Atomic Energy Commission. Both Frank and Jim suggested that I be invited and Presidente Sorbata, Head of the Metallurgy Division, I think, asked me to spend two weeks in Buenos Aires at the Laboratories. The purpose of the visit was to review data on possible power plant locations and to assist in selecting the type of plant to be built. They offered all expenses plus consulting pay; so I agreed to go.

On arrival I was met and housed in one of the better hotels in Buenos Aires. At the same time one of the engineers from the European Atomic Energy Commission staff in Brussels was there. I have forgotten his name. We had met in Gummersbach and at meetings. He and I ate dinners together and spent quite a bit of time walking about in downtown Buenos Aires. He was German by birth but in addition to German he spoke English without an accent, and he spoke French, Spanish, Portugese, and Italian, but I couldn't judge his accent.

The work consisted of two parts. The first was a brief study of sites. We considered the geology, cooling water, and distribution system of two areas. One area was near Cordoba and the other just upriver a few miles from the suburbs surrounding Buenos Aires. We all recommended the site near Buenos Aires.

Buenos Aires is located on the Platte River near its mouth. Here the river is 75 miles wide but very shallow, only a few feet in many places. It has been necessary to dredge the river from Buenos Aires to the ocean.

We also considered the type of reactor that might be built as well as size. The Argentine Atomic Energy people wanted to use an American design, preferably boiling water. Actually there was very little difference between the boiling and pressurized water in our evaluation. However, after I left Argentina their AEC issued bids to French and German companies as well as U.S. Both the French and Germans undertook to "buy" the contract by underbidding. Actually, the contract, I believe, was awarded to the Germans.

Since then Argentina has purchased another reactor, I believe, and bids are out for a third.

While in Buenos Aires I was entertained by the Kuljian people there. I enjoyed all the people we met.

We also enjoyed the food. Lunch was served at the Commission. They certainly overfed us as a "portion" of the meat served was enough for four people. Of course, only beef is considered meat, so when they embargo meat shipments or have a meatless day, it only means beef. Lamb, pork, and fish are always super abundant.

The Sunday I was in Buenos Aires I spent walking through their parks. These are spacious and since the weather is warm, there are lots of flowers. The suburbs were very poor in many areas and very rich in others. Railroads for freight are primitive but one or two roads had reasonable passenger service. Now most travel any distance is by air.

J. Nuclear Fuel Management

A year or so after I moved to Lafayette, I began to think more and more about what the utilities knew about their nuclear power reactors. Nuclear Utility Services was set up to aid the utilities in calculating the fuel depletion, the program for movement of the fuel within the reactors, etc. But I believed the utilities should have their own staffs trained for this and other work such as how to compare a nuclear and a coal fired power plant before chosing one or the other. So I wrote a letter to several power companies and power plant design companies. Only two replied: Bechtel and Commonwealth Edison. Bechtel replied immediately, saying they would cooperate and that we should proceed. No one had good ideas how, least of all me.

But several months passed. Then one day I saw Eugene Bailey, Administrative Engineer for Commonwealth Edison Company. He said, "You remember the letter you wrote about fuel management? Well, it has been the basis for many discussions within our company. Someday we will answer it." After several weeks he did answer it. He asked that members of the Purdue staff meet members of the Commonwealth staff for discussions relative to nuclear fuel management.

We set up a meeting, I believe, in Hammond. Phil Powers and I represented Purdue University, and several Commonwealth Edison people, including Eugene Bailey, Robert Bowers, Treasurer of Commonwealth, two people from Dresden, I think, Zitek and Al Veras, and two Vice Presidents, represented the Company. I expressed my thoughts and indicated the reasons why Commonwealth should proceed with their own fuel management.

After about three weeks the same group met again, and again after about three more weeks. This third meeting started off by Commonwealth people stating that there appeared to be no economic advantage to their doing the fuel management as General Electric was doing it at reasonable cost for them. I then turned to the board (it was a classroom we were meeting in), and showed them their fuel cost for Dresden I was about $2,000,000 per year higher than it should have been. This ended the argument and the next fall we started fuel management courses at Commonwealth

Edison Company.

Commonwealth asked the other utilities near Chicago to join and send people. Actually the following companies sent people:

Commonwealth Edison, Chicago
Iowa Power and Light, Davenport
Northern States Public Service, Minneapolis
Consumers Power Company, Jackson
Arthur Anderson, an accounting company, Chicago
Sargent and Lundy, a design company, Chicago

We had about 40 men, mostly engineers. I gave most of the lectures. We did ask James Lane from Oak Ridge, Walton Rodger, and one of the Professors from Ann Arbor, Milton Edlund, to give lectures. Most of the lectures were background and dealt with the uranium supplies, manufacture of fuel for reactors, costs of reactors, etc. We then turned to questions of fuel life, how to charge off the fuel cost over its life of several years, cost of money, etc. We then set up a code for fuel management cost studies. This was done partly by Professor Edlund from Ann Arbor and one of his graduate students worked out the detailed computer program.

This code we named CINCAS after the first letters of the companies represented. Since then, many other codes have been developed but CINCAS is in extensive use today particularly for accounting purposes.

It is interesting to look back on this course. Our predictions for the growth of the nuclear power industry have not been realized due primarily to the suits and objections raised by socalled environmentalists. However, the numbers of reactors appear to be only about two years behind schedule and the lack of fossil fuels will, I believe, result in a great increase in orders this and next year. Last year's orders were up to schedule (written at end of 1973).

James Lane and others emphasized the low amount of uranium available. He stated that prices for uranium would increase by 1970 and considerably by 1980. I was asked my opinion and I disagreed because I thought many ore bodies would be found. This led to considerable discussions but I have been proven to be right.

The fuel management course was presented at the Commonwealth Edison offices every other Thursday. I think

6 people came from Minneapolis to the first course. Anyway I had to drive from Lafayette.

I did a very poor job of teaching the course because of lack of time. I was spending only half time at Purdue and this course was only part of my duties. I was also acting as President of California Nuclear. I should have spent full time on the course.

The course was repeated the following two years at Commonwealth Edison. Later James Fulford gave the course in a shortened form, I believe, three times at Purdue, and in November 1973 we had letters from two companies asking that it be repeated.

Lugene Hungerford has consulted for a group of Texas oil companies for several years. They asked her why uranium couldn't be found by higher earth surface temperatures. She rather quickly replied that infra red spectra should work but it would only under certain conditions. Based on her suggestion they have found several large deposits of ore which have not been announced.

Another oil company was drilling for oil and located a large deposit in one of their dry holes. So we believe there is lots of uranium ore.

### 1. Commonwealth Edison's Moves

Commonwealth Edison asked Professor Gailor from Purdue to assist in working out a more detailed physics code for a nuclear power plant. When this was done Commonwealth established a subsidiary Fuel Management Company, capitalized at $10,000,000. They are now doing about $30,000,000 of business per year.

Commonwealth, in cooperation with General Electric and with Westinghouse, has constructed two training centers, one for Boiling Water Reactors and one for Pressurized Water Reactors.

### 2. Nuclear Management Centers

Lugene and I suggested that the utilities combine efforts and build and jointly own Operator Training Centers. If they did this, the centers would be tax exempt. They have followed General Electric's and Westinghouse's lead.

K. Lew Kowarski

Over the years, both at Argonne and Purdue, I have met many of the more widely known foreign nuclear scientists and engineers. I have not made an effort to attend any of the International Conferences since the Ann Arbor Conference.

One man with whom we have become friends is Lew Kowarski. His wife, Kate, and Winnie are also good friends.

During World War II Lew worked in England and later at Chalk River where he designed and built the first heavy water Critical Experiment. Later he returned to Europe and still later became Head of the Mathematics Department at CERN in Geneva where he still works. He is now Head of the Computer Division of CERN.

In 1963 he decided to take a Sabbatical leave and come to the United States. Since he knew Alvin Weinberg, he wrote to him and requested help in locating a position at a university for the school year 1963-64. So Alvin wrote to various people, including Phil Powers at Purdue (Phil had just become Head and I had moved over to the Laboratory). When Phil got the letter, he called me and when I arrived at his office, he read Lew's letter. I recommended that Phil check with Dean Hawkins and immediately call Lew. This he did and Lew accepted an assignment as a Visiting Professor of Nuclear Engineering for one year.

So that fall Lew came to Purdue. Later he spent another year at Purdue and has made several visits since. Steve Gage, then one of our graduate students and since then a Professor of Nuclear Engineering at the University of Texas, has arranged for Lew to visit Austin for 3 or 4 extended visits and lecture periods.

Soon after getting settled in Lafayette, Lew and Kate asked the Powers and us to dinner. I did not know Lew's background, so I asked him to tell us about himself and Kate. This, then is what I remember of what Lew told us. Of course, Kate served the typical European dinner, including three kinds of wine, flam, etc.

Lew told us the area in which he was born but I have forgotten it. I think it was east of Moscow. Anyway, by the time he was ten he was a waif living in the streets of Moscow. Apparently he had lost all contact with his family.

At 10 he went to Vilna and at about 18 he went to Cannes, and later to Brussels. Just when he decided to get a high school education, I don't know but at about 18 or 20 he went to the University of Lyons and took a degree in Chemical Engineering. Later he apparently went to the University of Paris, although I am not sure, and became interested in nuclear physics. Just when he received his doctorate I don't know. Anyway, he began to work for Joliot just before World War II started.

Kate was born in Berlin but I don't know much about her education. She is intensely interested in flowers, trees, etc, as is Winnie and our secretary, Irene Backus.

We then asked Lew about Joliot and this is what he told us. Eve Sladowski, when she came to Paris to work for Professor Curie, turned out not to be exceptionally talented as a scientist in spite of the fact that it was she who has been given the credit for the discovery of radium. She worked hard and deserves credit. However, in Kowarski's opinion, Professor Curie was a much more talented scientist and should have gotten most of the credit for the discovery of radium.

Of their daughters, Irene was extremely talented and much more so than her mother. Eve had no real scientific talent and became the family historian. Irene did not get along well with her mother in respect to Irene's proposed marriage with Joliot. As Kowarski stated, Joliot's background was not of the bourgeois. Thus, when Irene decided to marry Joliot, this apparently led to considerable friction with her mother.

Joliot's background was of the lower class in that his grandfather was apparently a merchant of some sort who made quite a lot of money. His father apparently spent his time spending the money he inherited. His chief fame was that of writing tunes for fifes for fox hunts.

When Joliot was a young boy, a school was opened for the common people to train them for such positions as technicians. Joliot entered this school and graduated but early in life did not get the usual technical university education. As I remember it, later he did. Several years after leaving the school, someone at the Radium Institute asked that this school recommend some people as technicians and Joliot was recommended. He joined the Radium Institute as a technician but he soon recognized that he was a much better scientist than any of the people working at the Institute. This seemed to have led to considerable friction and he was never accepted by the bourgeois because he was from the lower class. His marriage with Irene did not help apparently and he continued to be quite largely rejected.

At the beginning of the War, Halbin, who is a Swiss, and Kowarski were working with Joliot, who was by then Director of the Institute, as his assistants. Both had just taken out French citizenship papers. At the Institute the main interest was in determining if fission occurred in uranium, and after this was verified by several laboratories, the French group turned to measurement of $\nu$ and $\eta$. They soon determined that they needed a better moderator than light water and turned their attention to heavy water. (Part of this discussion here was given in another lecture by Kowarski at Purdue University.) They were able to obtain almost the whole supply of heavy water from Norway in spite of the Germans since the heavy water plant was owned by a French banking company. The 182 kilograms of heavy water arrived at Paris just before the Germans broke through the Maginot Line. Halbin and Kowarski along with Joliot went south and started to set up their laboratory in a prison. Then it became obvious that the Germans were going to continue further south. The French previously had thought that the Germans had stopped just outside of Paris in order not to arouse the enmity of the rest of the world. When it became apparent they were moving on south, Halbin and Kowarski took their heavy water and uranium and drove to Bordeaux. Joliot elected to remain in France. Kowarski stated that on the night before they left for Bordeaux, Joliot reviewed his prognosis of the War. He stated that he believed the Germans would stop at Paris and not over-run all Paris at this time because this would arouse the enmity of the rest of the world. Next, the Germans would attack Great Britain and would be repulsed. Next, there would be a stalemate which would finally be broken by Russia and America entering the War with the complete destruction of Germany.

As is given in the public record, after the Germans took over Paris, Joliot turned more and more to the Left and after the War became an outright Communist. Kowarski's explanation for this was that he had always been rejected by the people with whom he was working and never accepted on the basis of his scientific accomplishments. Kowarski stated that he believed Joliot would have been much better off to have left France with him and Halbin as all three of them had developed international reputations and were well known and accepted in Great Britain.

On arrival at Bordeaux Halbin and Kowarski found the port still open. The Germans were dive bombing everything that went to sea to cross to England. Nevertheless, they found that a very eccentric British nobleman had commandeered an old hulk of a British ship in the harbor and was loading this ship for a run to England. Lew stated the Britisher had no real authority but since he assumed command everyone followed his orders. So they loaded the heavy water and uranium on the ship. There was also a barrel of industrial diamonds rescued or stolen from Belgium.

Anyway, the old ship took off for England. German dive bombers flew over it but apparently the German pilots considered their bombs as worth more than the ship as it was not attacked. On arrival in England Halbin and Kowarski soon found friends and became important scientists in the nuclear development program.

Later Lew and Kate were transferred to Chalk River where he supervised design and construction of the Chalk River Heavy Water Reactor, the world's first. I don't know when he returned to Europe but he is now in charge of the computer calculations at CERN and they live in Geneva.