CHEMICAL HERITAGE FOUNDATION

NYLON: AN EYEWITNESS STORY

JOSEPH LABOVSKY
Laboratory Assistant to Dr. Wallace Carothers, Inventor

Transcript of an Interview
Conducted by

John K. Smith

at

Wilmington, Delaware

on

24 July 1996

(With Subsequent Corrections and Additions)

LABOVSKY, Joseph
#0148

THE CHEMICAL HERITAGE FOUNDATION
Oral History Program

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JOSEPH LABOVSKY

1912	Born in Kiev, Ukraine, on 10 September

Education

1931	Master Electrician, Bliss Electrical College, Takoma Park, Maryland
1934	B. S., Industrial Chemical Engineering, Pratt Institute, Brooklyn, New York
1935-1936	University of Pennsylvania Evening School; chemistry, psychology, German

Professional Experience

E. I. du Pont de Nemours & Co., Inc.

1930	Summer Chemist's Helper, Experimental Station, Wilmington, Delaware
1934-1937	Laboratory Technical Assistant, Dr. Carothers's Research Group, Experimental Station, Wilmington, Delaware
1937-1938	Foreman, Nylon Semi-Works, Experimental Station
1938-1939	Shift Supervisor, Nylon Pilot Plant, Experimental Station
1939-1941	Process Control Foreman, Seaford, Delaware, Nylon Plant
1941-1955	Quality Control Supervisor, Spinneret Laboratory Supervisor, and Textile Area Supervisor, Martinsville, Virginia, Nylon Plant
1955-1963	Training Supervisor, Textile Research Laboratory, Tyvek® Development Group, Chestnut Run Laboratory, Wilmington, Delaware
1963-1969	Management Training Specialist, DISA [DuPont International], Geneva, Switzerland
1969-1975	Training and Industrial Relations Supervisor, Chestnut Run Laboratory, Wilmington, Delaware
1975	Retired

1975-1979	Consultant, SNIA Viscosa, Italy Consultant, SNIA Viscosa, Ireland Consultant, Montefibre, Italy Consultant, Montedison, Italy Consutlant, Diamond Shamrock, France
1980-1985	Retired
1985-1995	Consultant, NILIT, Ltd., Israel
1996	Retired

Honors

1941	War Production Board Commendation
1997	Wilmington High School, Graduate Wall of Fame

ABSTRACT

Joseph Labovsky opens the interview with a discussion of his childhood in Ukraine and family experiences there after his father immigrated to the United States in 1914. Labovsky moved with his mother and siblings to Komarine, a village adjacent to Chernobyl on the Dnieper River, where the family survived the Communist Revolution, civil war, famine, and a pogrom which killed fifteen of twenty Jewish families there. In 1922, Labovsky's father was able to locate the family and make arrangements for a safe escape through Eastern Europe to the United States. Labovsky describes childhood interactions with the Polish and Red Armies in Komarine; impressions of settling in Wilmington, Delaware, where his father was a successful tailor; resuming his early education; and learning English. Next Labovsky recalls high school graduation and his father's successful efforts to secure him a job at DuPont, where he began working as lab assistant for Dr. Wallace Carothers' research group. He reflects upon his experiences and perceptions of early nylon work and relationships with scientists, particularly his mentor Carothers, who directed him towards a DuPont college scholarship. In 1930, Labovsky began training at Bliss Electrical College, but he transferred after one year to Pratt Institute, where he earned a degree in industrial chemical engineering. In 1934, he graduated and, after struggling in the Depression-era job market, happily accepted an offer to return to Carothers' research group and nylon development work. Labovsky details both the research group's work testing polymers and discovering polymer 66, and different work environments under Carothers and later George Graves. After discussing work to develop the fiber 66 commercial process, Labovsky shares recollections of Carothers and the circumstances surrounding his untimely death in 1937. Throughout the second half of the interview, he chronicles the commercial development and success of nylon, providing details on spinning, drawing, quality control, and commercial processing. Labovsky describes problems and solutions in the history of nylon, including his War Production Award and three-part "A" bonus for reducing nylon waste through procedures to repair spinnerets during the Korean War. He describes his career path from laboratory technician to process control foreman, to management training specialist for DuPont International—emphasizing the importance of troubleshooting, problem solving, and standard practice procedures throughout. The interview closes with comments on safety in nylon production and DuPont's overall safety record.

INTERVIEWER

John Kenly Smith, Jr., is Associate Professor of History at Lehigh University, where he has been a faculty member since 1987. He co-authored *Science and Corporate Strategy: DuPont R&D, 1902-1980*, published in 1988. He served with the DuPont R&D History Project from 1982 to 1986 and was Newcomen Fellow in Business History at Harvard Business School from 1986 to 1987. He received the Newcomen Prize in Business History for Best Book Published in America and is on the editoral board of American Chemical Society Books.

M. S. W.

STAROSTWO RADZYMIŃSKIE

Nr. 1771

Dnia 1 czerwca 1922 r.

L 9088

KARTA POBYTU

Przynależność państwowa b. Imperjum Rosyjskie

Narodowość żydowska

Wyznanie mojżeszowe

Zawód —

Miejsce i data urodzenia Komarym z. Mińska 1882 r.

Imię ojca Mojsze - Leyb

Imię matki Freyda

Stosunki rodzinne mężatka

Imiona i wiek dzieci od lat 16 znajdujących się przy nim Roza 13 l., Josif 10 l., Salomon 8 l.

Miejsce zamieszkania (obecne) Wołomin pow. Radzymiński

Wydane na zasadzie deklaracji Nr. 9088

Przedstawionych dokumentów i decyzji z dnia

Opłata marek 2000.- wniesiona za kwitem z dnia 26/V 1922 r. Nr. 2109/2430

do dnia 26 sierpnia 1922 r.

(w miejscowości) Wołominie

dla cudzoziemca b. Imp. Ros.

do deklaracji Nr. 9088

ważna do dnia 26 sierpnia 1922.

(prolongaty na odwrotnej stronie)

Nazwisko Laborwska

Imię Perla

Fotografja:

Rysopis właściciela:

Wiek 40 lat

Wzrost średni

Oczy piwne

Nos } prawidłowe

Usta }

Twarz owalna

Zarost —

Kolor włosów czarne

Łysina —

Znamiona szczególne —

Podpis własnoręczny Laborwska Perla

(Podpis przełożonego urzędu) [illegible]

Wyżej wymieniony obowiązany jest meldować się w biurze Policji Państwowej w Wołominie co 2 tygodnie terminie, do 26/VIII 1922 r. (termin) poczynając od dnia 2/VI 1922 r.

(Podpis) [illegible]

Adnotacja o meldowaniu się:

Rozp. M. S. W. z dnia 19. IX. 1919 r. zarejestrowani cudzoziemcy mogą wyjeżdżać z miejsca swego pobytu nie inaczej, jak na podstawie każdorazowego zezwolenia władzy, która wydała kartę pobytu.

PROLONGATY:

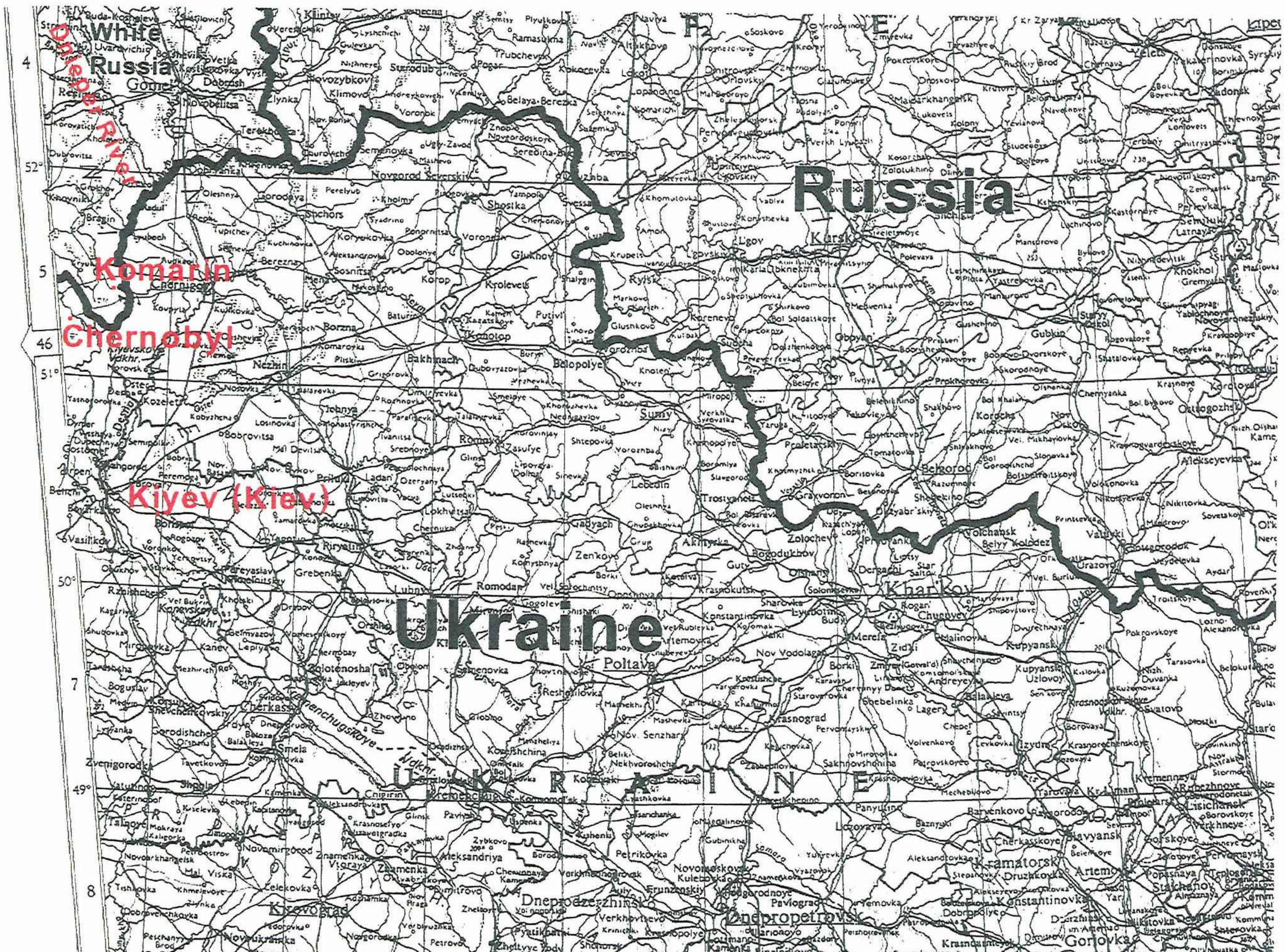
Sprolongowano dnia 1 września 1922 r.

do dnia 15 Listopada 1922 r.

(Podpis)

(Pieczęć)

Karta pobytu może być cofnięta z decyzji M. S. W. Niezjawienie się w terminie do którego ważna jest niniejsza karta dla prolongaty, jak również w terminie wskazanych do ponownej opłaty (1 lipca 1920 r.) oraz uchylenie się od meldowania i wogóle nieprzestrzeganie przepisów rozporządzeń o rejestracji pociąga za sobą wysiedlenie.



White Russia
Dnieper River
Komarin
Chernobyl
Kiyev (Kiev)
Russia
Ukraine
Kursk
Kharkov
Poltava
Dnepropetrovsk

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INTERVIEWER: John K. Smith

LOCATION: Wilmington, Delaware

DATE: 24 July 1996

SMITH: Mr. Labovsky, I know that you were born in 1912. I'd like to ask you about your family background. I understand you have a rather interesting family history. When were you born, and where were you born? How did you come to the United States?

LABOVSKY: Yes, my personal and family history is unique. I was born in the city of Kiev, Ukraine, in the year 1912, and I lived there for about two years. My father was a tailor, doing most of his tailoring work for the military. We were a family of five: father, mother, sister, brother, and I.

In 1914, my father decided to leave Ukraine. At that time Ukraine was part of Russia. The Russians came to help the Ukrainians obtain their freedom from Poland, and stayed for three hundred years!

After the Communist Revolution, in 1917, Ukraine became one of the thirteen USSR republics. And after the Communist collapse in 1991, Ukraine again became a free and independent nation. I lived to experience both the birth and death of Communism.

In 1914, with World War I imminent, my father decided to leave Russia, because he knew once he got drafted by the military—especially if you were a craftsman, like a tailor, and being Jewish—the military would keep him as long as they wanted or until he died. He decided to escape and avoid the tsarist draft. It was very easy to leave Russia in those days. If you had the money to bribe the police and buy a ticket on a ship, you were free to leave Russia!

SMITH: Was this before World War I began? Before or after August?

LABOVSKY: Before. I think it was in May or June 1914.

SMITH: Before or after the war started?

LABOVSKY: Before the war started. The fear of war was already in the air. Russia was beginning to mobilize. In those days Russian mobilization was based on rounding up men. They would set out a cordon and grab all men, sort out whom they wanted and whom to let go. My father knew that he would eventually be drafted, because he was a military tailor. Family status meant little, especially if you were Jewish. He decided to go to Philadelphia, where he had an uncle whose name was also Labovsky.

SMITH: I see.

LABOVSKY: Somebody in his family told him he had an uncle in Philadelphia, so he left in hope and faith of finding him. That proved difficult, because his uncle had moved to New Jersey and changed his name from Labovsky to LaBove!

SMITH: Did he bring you? Did the whole family emigrate when he did?

LABOVSKY: No. We were left behind, which lasted nine horrible years. Because of World War I, the Communist Revolution, the Civil War, pogroms, and the closure of borders!

SMITH: He was the only one who emigrated at that time?

LABOVSKY: Yes. We stayed behind. He was hoping, like most immigrants, to come to America, get a job, earn enough money, and bring the family over. In our case the war had started, and by then it was impossible to get out of Russia. The war carried on, and Russia was knocked out of the war in 1917 by Germany. Then came the Communist Revolution in 1917. Then pogroms, civil war, chaos, and famine. When the Revolution started, I was about six years old.

SMITH: Do you remember anything about it?

LABOVSKY: Oh, yes, I do, very much so! There were famine, chaos, pogroms, and bloodshed. Ukraine was first invaded by the Germans around 1915. They marched through our place, the village Komarine. They were then driven out by the Red Army. The Polish Army came next. Poland declared its freedom from Russia in 1916, invaded Ukraine, and occupied it

for about a year. In the interim, the Red Army was fighting to drive them out. More bloodshed and famine. During all the fighting, the families lived underground in the forest.

As soon as my father left Kiev, my mother decided that Kiev was too large a city to live in, and we moved to a small village on the Dnieper River, approximately fifty miles south of the Kiev—a village called Komarine, where my father's family lived. Probably no one ever heard of Komarine. Five miles from Komarine was another place, called Chernobyl. The whole world heard of Chernobyl. How ironic! Today both places are in nuclear ruins. How tragic! What wars, revolution, and Communism did not destroy, $E = MC^2$ did!

SMITH: Yes.

LABOVSKY: As I said, five miles north of Chernobyl was the little village named Komarine. It's on the map, mostly farmland farmed by Russian peasants, and where about twenty Jewish families lived, in sort of a ghetto, a *shtetl*, among several hundred Russian farmers, *Muzhiks*.

We stayed there for nine years during World War I, the Communist Revolution, and the Civil War. One could grow food and raise small animals there. In Kiev it was not possible. We had three goats, enough to supply us with meat and milk. We also were able to grow some vegetables in our backyard. Thus, fortunately, we were able to survive war, revolution, famine, and a pogrom.

After Russia was knocked out of the war by Germany, the Communist Revolution began. There were two branches of Communists: one called *Bolsheviki* and the other *Mensheviki*. *Bolshe* means "more, majority," or *Bolsheviki*, plural for majority. *Menshe* means "less, minority," or *Mensheviki*, plural. It so happened the *Mensheviki*—the minority Communists—were more aggressive, more militant, and had more firepower. Thus, the *Mensheviki*—the minority—defeated the *Bolsheviki*—the majority—took over Russia, and the specter of World Communism was on the march!

As soon as the Communists took power, civil war started. The White Russians were those who were in favor of restoring the monarchy, and there were other factions fighting the Communists and each other. However, they were poorly mobilized and armed and could not defeat the Communists. So, for six bloody years, there raged civil war. Chaos, turmoil, and famine ruled Russia. During all those years we could not communicate with our father, or he with us. Later, we learned, he believed we were killed in the Komarine pogrom or the war or the Revolution.

I do remember, I was six years old when the Polish army invaded Komarine. The first thing the soldiers would do was look for the men. "Where's your husband? Where's your son, brother?" they would demand! They assumed the men were Communists and wanted them shot.

They asked my mother, “Where’s your husband?” “My husband is in America,” she answered. America was a miracle word with the Poles because America supported the Polish uprising and independence from Russia. Anything you said about America protected you. You were safe! Instead of killing us, taking our possessions, or making things unpleasant, the moment my mother used the word “America,” we were not harmed. The magic word “America” kept us alive during the time the Polish army occupied Komarine.

Immediately after the Polish army left Komarine, there was much chaos. There were the White Russian army and the Red Russian army, *Denikin* and *Petlura* armies, and all kinds of armed factions fighting each other.

Late one summer evening, I remember well, in July 1918, there was a tremendous amount of fear and confusion in the Jewish part of Komarine, the *shtetl*. Pro-monarchists were mobilizing and were going to Komarine to stage a pogrom. There was an indescribable amount of fear, panic, excitement, and concern. By nighttime, we heard definitely, “There will be a pogrom! The Ukrainian peasants will come and kill those who helped to overthrow the tsarist government—the Jews.” All that night my mother devised plans to save ourselves. By early morning, just about sunrise, there came very loud shouting, screaming, cursing, and shooting. The pogrom was in full fury! I still recall the Russian battle cry: *Bei zhidov spasai Rossia!* “Бей жидов спаСй россию!” “Kill the Jews and save Russia!”

Our house was just one room, I’d say about 25 by 20 feet, with a thatched roof and a dirt floor. The floor was always kept clean by sprinkling white sand on it. Several hours before the pogrom began, my mother decided to hide us children behind the brick oven, called a *pripochok*.

Later in the morning, there was more shooting and louder screaming and lots of confusion. I remember seeing peasants chasing Jewish women, men, and children, beating them on the head with pitchforks and wooden clubs. Some were shot and fell to the ground twitching in agony. Some escaped into the woods. My mother constantly warned us to stay put, keep quiet, not cry, and recite the *Shmah* prayer.

Later on, some of the houses across the street were set on fire to rout the Jews out to kill them in the street, or burn them to death in their houses. When my mother saw the house next to ours in flames, she said, “Let’s get out before we get burned to death.” I was so scared I could not move. The fear—the terror—made me immobile. My mother dragged me out of the house. I still remember my panic to this day, and will to my dying day!

Our house wasn’t on fire yet, but in fear it soon would be, we dashed out of the house. As we were about to climb over a fence into an open field, we saw dogs and pigs chewing on dead bodies there. My mother cried out, “Oh, no! Let’s go back in the house. Better to be burned to death than be eaten by pigs and dogs!”

We ran back into the house. The children hid in back of the oven, and mother hid under a bed facing the door. Within a few minutes there was a tremendous crash, and the door broke open! Three peasants with guns rushed into the house. They saw there was somebody hiding under the bed. They didn't know whether it was a man or a woman. They shouted Russian profanities. "Get out, get out fast, or we shoot!" Mother crawled out trembling and crying, "Please don't kill me. I have small children. My husband is not a Communist. He is in America."

I could see from the back of the oven, as my mother crawled out from under the bed, a purse hidden in her blouse fell out. The three peasants, *pogromchicks*, immediately dashed over to grab it and got into a fierce quarrel. Quarreling and cursing over the purse, they left the house. We were safe!

The pogrom lasted for about six hours. In that time period the Jewish *shtetl* of Komarine was devastated—houses burned, looted, Jews killed. Of the twenty Jewish families living in Komarine, fifteen families were massacred. We were one of the five families who survived. Why? Who knows? Was it fate or destiny that brought us to America? Maybe God knows.

Right after the pogrom, the Communists came into Komarine and took over the town with an iron hand. They set up their Communist-town Soviets and began rounding up peasants suspected of anti-Communism. After a brief interrogation, all suspects were shot. We later learned there were many pogroms against Jews in Ukraine and in many parts of Russia in 1918-1919. The *shtetl* Komarine was only one of many.

From the time my father left Russia in 1914 to about 1922, we had no communication with each other. We believed he was alive, but he had no way of knowing if we were. It wasn't until 1922 that he was able, through the State Department and through various agencies—HIAS—to search for us. In 1922 he discovered we were alive! That we, miraculously, survived World War I, the Communist Revolution, the Russian Civil War, famine, and a pogrom!

SMITH: Why did they attack Jewish families at that point? Were they seen as being in alliance with the Communists?

LABOVSKY: Yes. But anti-Semitism in Russia and in Poland had been endemic for centuries, and more so during the war. Some of the Communist leaders—especially Leon Trotsky, née Bronstein—were Jewish. Lenin started the Revolution, and Trotsky was the one who created the Red Army. For that, innocent Jews suffered and died. But the Russian peasants at the instigation of the government started pogroms whenever it suited them, for any pretext: religious, economic, a plague, bribes, and, in general, blackmail. The Jews were convenient scapegoats.

Anti-Semitism has been around since before the Crusades and became more virulent with the Spanish Inquisition. There has not been a century without pogroms against Jews. The twentieth century will end with the worst pogrom against the Jews—the Nazi holocaust. Six million Jews massacred. My relatives died in *Babi Yar*, a ravine in Kiev where one hundred thousand Jews were massacred. See the photo I took in 1991, when I visited Kiev: the end of Communism (1).

SMITH: History is recounted by the survivors.

LABOVSKY: That's right. I am a witness to prove it! My father came to Philadelphia in 1914 and found his uncle, who was also a tailor. He quickly found a tailoring job for three dollars a week. That was good money for a greenhorn tailor. In 1918 he heard through the grapevine of tailoring guilds, somebody in Wilmington, Delaware, was looking for a tailor. A custom tailor by the name of W. A. Webster, maker of custom-tailored suits for the carriage trade—like duPonts, bankers, and other rich people—was looking for a tailor who was able to do the cutting, fitting, and sewing of custom suits. My father came to Wilmington, was interviewed by Mr. Webster, and was hired. My father opened a tailor shop on East Eighth Street, in the Govatos building, to make suits for the carriage trade, starting at twenty-five dollars a week. Within two years, with more World War I rich people, business improved greatly. The tailor shop was expanded; my father hired more tailors and was earning more than fifty dollars a week! More importantly, he got acquainted with many DuPont executives who helped him to search for us.

SMITH: They still called it the carriage trade in the era of the automobile?

LABOVSKY: That's right—an oxymoron. My father was now a rich man and met many important and influential friends—customers—who helped him to become an American citizen and bring us, his family, to America. We came here in 1923. I think it was December 12, 1923.

SMITH: Your father sent you money?

LABOVSKY: Yes. Not only that, my father also sent an agent with the money to find and bring us to America.

SMITH: He sent an agent?

LABOVSKY: Yes. By that time he knew we were alive and in Komarine. After the war he wrote to Mother, telling her that he was going to send somebody to get us out of Russia. But getting out of Russia was almost impossible. The Communists closed all borders, and only experienced agents knew ways of getting people out—for a price. Father hired such an agent to get us out of Russia. This agent, through couriers, sent Mother instructions on how to leave Komarine and make connections with other agents as we traveled towards Poland, our destination.

The instructions were to go by wagon from Komarine to Chernobyl, from Chernobyl to Kiev by boat on the River Dnieper. In Kiev we would meet an agent at our old address who would give us further instructions for going to the Polish border. Rovno, Poland, was our destination. Rovno is on the border of Ukraine and Poland.

Now, I do recall an event that almost cost me my life. Our agent had connections with other agents, to move us from post to post. We left Kiev on a freight train going in the direction of Rovno; it was a night in November, and it was very, very cold. At the train station we were robbed of all our possessions—bundles. We got off the train before Rovno and got into a hay wagon to steal across the border to Poland. There were agents who bribed everybody on the way to make sure we got to Rovno. We were in the wagon hiding under the hay.

What I remember most about the hayride to Rovno is that it was bitter cold and I wanted to sleep. My mother kept waking me from a wonderful dream. I dreamed I was in a beautiful room with a fireplace. There was lots of bread to eat. I was in heaven, warm and happy. All that food to eat! But my mother would shake me, saying, "Wake up. Don't sleep! Don't sleep!" My mother kept me from freezing to death. Little did I realize, until now, that Mother kept all us children from freezing to death! We succeeded in stealing across the border to Rovno. We were quickly hustled out of the wagon and led to a farmhouse. It was still nighttime and bitter cold! We were safe!

SMITH: Yes, hypothermia.

LABOVSKY: I still remember it vividly. Freezing is a pleasant way to die.

We were not permitted to stay in Rovno because it was a military border city with Communist Russia, and we were forced to move to a Polish village called Wolomin.

By means of bribery and political maneuvering, our agent got us special permission to stay in Wolomin and Warsaw. By then my father was an American citizen, and the Polish government had to be nice to us Americans! We stayed in Wolomin-Warsaw for about a year.

Here is the original document permitting us to be in Wolomin, Poland, giving every detail about the family (2).

SMITH: I see.

LABOVSKY: The year was 1922. Here is a photograph of my family: my mother; my sister, Rose, thirteen years old; I, Joseph, ten years old; and my brother, Solomon, eight years old (3).

SMITH: There's the photograph.

LABOVSKY: Oh, yes. We needed photographs and IDs wherever we went in Poland, mostly between Wolomin and Warsaw.

SMITH: Your mother looks very young.

LABOVSKY: At that time, 1922, she was about 34 years old, and beautiful.

SMITH: Yes.

LABOVSKY: She was a very beautiful woman, and wise, too!

SMITH: Yes.

LABOVSKY: Very beautiful. One more thing about my mom. She was also a good tailor. One more important reason for our survival in Russia is the fact that she could sew shirts and pants for men, and dresses for women. In return, she would get food. It was a barter system. Communist money was worthless. Farmers refused to accept it, though it was a crime punishable by death! My mother came close to being shot. That's another story I'd like to tell another time.

We were in Wolomin and Warsaw until we were able to get the proper documents to leave for America. Again, it was my mother's astuteness that made it possible to leave. When we left Poland, this was our itinerary: one, horse and buggy from Wolomin to Warsaw; two,

train from Warsaw to Berlin, Germany; three, train from Berlin to Antwerp, Belgium; four, train from Antwerp to Cherbourg, France; five, the ship *Majestic*, first class, from Cherbourg to Southampton, England; six, *Majestic* from Southampton to New York City, December 12, 1923. America! Freedom!

SMITH: Yes.

LABOVSKY: Well, in 1923 we finally got all the documentation and came to America! The one thing I regret is not going through Ellis Island. We missed it, because my father had gotten us cleared on the ship *Majestic*, the Cunard Line. We went first class, not steerage. Steerage passengers had to go to Ellis Island. Our health examinations were made by doctors on board the ship. We passed! My father met us on the docked ship, signed some papers, and we got off ship, free to go! Pop picked up our luggage—not much—got a taxi to take us to New York City's Pennsylvania Railroad Station for a train to Philadelphia, America, the cradle of freedom! We stayed with Uncle LaBove's family in Philadelphia for about two weeks.

After our odyssey of nine years of war, revolution, Communism, famine, and pogroms in Russia, Philadelphia was heaven! We then moved to Wilmington, 215 West Street, a magnificent brownstone building. O paradiso!

SMITH: Yes.

LABOVSKY: That's my background, before I came to America.

SMITH: That's very good.

[END OF TAPE, SIDE 1]

SMITH: Do you have any other memories of Ukraine?

LABOVSKY: Of course, there was always a German, Polish or Communist army in Komarine. There was always a terrible bombardment beforehand. When they moved into our place, they would drive the people out. Then the army would move in. There was a lot of looting and killing. Those who did survive the bombardment escaped into the forest.

When things quieted down, the soldiers moved in with their field kitchens and started bivouacking. Then the people in the forest would return like animals crawling out of a den—and come back to their houses, or ruins.

The military kitchen had an awful lot of food! There was a lot of cooking going on—potatoes and all kinds of meat. The parents would say, "Get close to the kitchen area and the soldiers and beg for food." You'd look very pitiful, and the soldiers would give you a loaf of bread, and you'd grab some potatoes or whatever you could. What wasn't given to you, you would steal—I mean take. [laughter] Russian shirts are open at the collar. You would tie a rope around the waistline. You'd pick up a potato, or whatever you could grab, and drop it in your shirtsack. You'd end up with a lot of food on you when you came home from shoplifting. It was routine work as long as the army kitchen stayed in town.

After a while, the Communists drove the Germans out. Then the Polish Army drove the Communists out, and occupied our village. Komarine, and also Chernobyl, were on the river Dnieper, a very important area to get military supplies in. So the Red Army and the Polish Army were constantly battling to drive each other out of Komarine.

I remember the times when we were told by the elders, "Listen, the next time you go to the military kitchen, if you happen to see a rifle, revolver, bullets, take them." Many a time, we did. Of course we would have been shot if we'd been caught. We were careful, young, daring, and challenging!

If there was a clip of bullets, I'd easily drop it in my shirt. If there was a revolver, I'd find a way of taking it. Looking back on it, it was a wonderful game. I was a hero. I'd come back with food, bullets, a revolver. I never could take a rifle because it was too big to hide. [laughter]

It became a game. As I look back, I kind of chuckle over it. It was so exciting. In retrospect, it was stupid and dangerous! So is war!

Those were some of my experiences, going shopping at the military. [laughter] That was not all. Komarine was alongside the Dnieper. Next to it was a lake. A lake in Russian is called *ozhora*. Soldiers would take a rowboat to go fishing in the *ozhora*. There was a little stream from the river into the *ozhora*. They would sit in the boat and would pick up some of us kids—five, six, seven, ten years old—and have us kids push the boat out of the little stream into the *ozhora*. A very strenuous job! They would then drop hand grenades in the *ozhora*, and the fish would come floating up. The torn fish were given to us kids as a reward.

I remember one scary incident. There were four soldiers in the boat, and their Ukrainian guide. They ordered us kids to pull the boat into the *ozhora*. The guide told us in Ukranian, "Don't do it. Run away." So instead of pulling the boat, we ran away. The soldiers started

shooting at us. They hit one kid. They didn't kill him; they wounded him. The rest of us ran like the wind! For the first time, I saw soldiers shooting at kids! I was scared!

SMITH: Well, you came to America in 1924.

LABOVSKY: We came to America in 1924; actually, December 12, 1923. Life was so pleasant, right from the beginning!

SMITH: It must have been an incredible shock to you.

LABOVSKY: Yes. The shock of having all the food and the freedom and security, the electric lights—what luxuries! I saw many automobiles. Komarine, where I lived, didn't have any. I was accustomed to seeing horses, mules, and oxen used for work and transportation. Not being hungry and afraid was like living in paradise. But this kind of shock was pleasant to experience.

SMITH: Yes.

LABOVSKY: I recall, we had a nice place to live in Wilmington, a beautiful brownstone house—215 West Street. There were two beautiful brownstone houses on West Street, now all torn down. I still remember how very elegant and stately looking they were. Our place was a six-room apartment on the ground floor. Compared to what I had in Komarine, it was unbelievable luxury!

Going to school was a bigger shock. I left Russia when I was about ten years old, and after two years of wanderings, I came to Wilmington at the age of twelve, completely illiterate, except for some Hebrew lessons. During the war, the Revolution, the Civil War, and all the chaos, schools were closed. Besides that, Jewish children were not accepted in Komarine schools. My only education was learning how to survive.

My first school was Number 3 School at Third and Jefferson Streets, now gone. I was twelve years old, and I was put in the first grade. I can still remember the embarrassment! I am not tall now; but when I was twelve years old, compared to a six-year-old kid, I was big. I couldn't speak any English. I felt awkward, and I felt ashamed. Kids called me "greenhorn." After school, kids would tease me and teach me cuss words. One incident I will long remember. It got me in big trouble! I was told to go to a little girl and say, "F_ _ _ you." I did and got into my first American street fight. From then on I learned English the right way.

After about a year living at 215 West Street, my father bought a house, 913 Lombard Street, so that he could be closer to his tailor shop at Number 8 East Eighth Street, and we children could attend a special school for immigrants, called The People's Settlement House, on Eighth and Lombard Streets. That was around 1925. The Settlement House is still there, teaching new immigrants.

In 1926, I went back to a regular grammar school. I learned quickly because I was older and hungry for an education, to get Americanized, and not be called greenhorn anymore. It was Number 1 School at Sixth and French Streets. The school is gone.

In 1926 I graduated grammar school, and I went to high school, Wilmington High School, on Delaware Avenue. The location is now an office building, Chase Manhattan. In seven years, I went from first grade through high school. Let me tell you something about high school. My best subject, would you believe it, was English. I still have some of my English compositions, graded As.

I learned English the proper way, not the street way. I learned English in a very systematic way, and I was able to write grammatically correct. The teacher was amazed. Sometimes, to my embarrassment, she would say to the American-born children, "How come Joseph can write so well for being in this country a short time?"

Ironically, the use of grammar correctly got me in trouble with the kids, because of an English test. The English test was to correct twenty-five ungrammatical sentences. One sentence was, "This ain't no good." The entire class wrote, "This isn't good." "This is no good." I wrote, "This is good." I remembered the rule: two negatives make an affirmative. After school a number of kids jumped me and beat me up for being a "smart-ass greenhorn." The irony is, I was beaten up for using <u>bad</u> English and <u>good</u> English. Experience is the best teacher.

I graduated from Wilmington High School in 1930. I did well in the sciences—physics, chemistry, biology. I liked those subjects. Then came the Big Depression in 1930. The stock market crashed in 1929. It so happened W. A. Webster, the custom tailor, the fancy carriage tailor my father worked for, played the stock market and was in bad financial shape. He borrowed money from my father, could not pay it back, went bankrupt, and disappeared. My father, too, was financially wiped out. There was no more carriage tailoring business. So he opened a tiny tailor shop at Number 3 West 13th Street with a fancy name, Boulevard Cleaning & Dyeing, doing mostly cleaning and repairing of old clothes. Years later, I jokingly called him a CPA—<u>C</u>leaning, <u>P</u>ressing and <u>A</u>lterations.

In 1930, just when the Depression started to take hold, I finished high school and jobs were scarce. My father before that time had contacts with DuPont people, management people who worked for the DuPont Company, and bankers. While working on a suit for a DuPont executive, my father said to him, "My son just finished high school. Can you give him a job

with DuPont?" "I'll see what I can do," he said. Within a week, I was told to go to the DuPont Experimental Station and ask for Mr. Bartleson. I did, and got a job as a chemist's helper at sixteen dollars a week—big money then. I was assigned to a chemist, in Building Number 173, who happened to be Dr. Wallace H. Carothers who, as you know, later turned out to be the inventor of nylon, synthetic rubber—neoprene—and synthetic musk. He also invented polyester and nylon-6—caprolactam—but these could not be patented by DuPont because of some technical oversight he made, I was later told.

SMITH: This would have been in the summer of 1930.

LABOVSKY: Yes, in the summer of 1930.

SMITH: I see.

LABOVSKY: Yes. I was very diligent and did whatever I was asked to do. It was usually running errands, setting up equipment for experiments, cleaning lab glassware, and keeping the laboratory clean and orderly. That was about it.

SMITH: You were doing experiments directly for him?

LABOVSKY: Not at the time, no. At that time, 1930, I would set up equipment for the other chemists, and also, for Dr. Carothers' tests, watch over them as per instructions, record data in a research notebook, and later witness his signature.

SMITH: Did Carothers actually do the laboratory work?

LABOVSKY: Yes, some. Mostly it was done by chemists under his direction. Now, I am referring to my recollections of the summer of 1930. After 1934-1937, the nylon years, I did testing. I also became more acquainted with Dr. Carothers. There were certain experiments he did himself, special experiments—see his research notebooks—but they were not many. You can see a photo of him conducting an experiment. From 1934, my job was to set up the apparatus for experiments, watch it, and afterwards break it down and clean it. There was very little conversation. His instructions were very curt, right to the point: "Joe, will you please do this and do that?" Very nice and polite. I had no scientific reasons for conversing with him,

except for instructions. I would see him before the test and after the test was completed, but not very often at first.

A few months later, he came to me and said, "Joe, I saw you at the concert at the Academy of Music in Philadelphia." "Yes," I said, "I was at the concert." He said, "I didn't know you liked concerts." "Yes, I do," I answered. The concert happened to be a very nice Tchaikovsky program; I think it was the Symphony Pathétique. Also, his piano concerto—all popular Russian music. Then Dr. Carothers started talking to me about music and what I thought of the program. "Yes, I enjoyed it." I was shy talking to him about music, because he appeared to know more than I did. After all, he was my big boss. I was cautious. Our conversation first began with music and music composers. Later on we had conversations about Russian literature. [Fyodor M.] Dostoyovsky and [Ivan S.] Turgenev, [Anton P.] Chekhov and [Alexsandr S.] Pushkin, and [Leo N.] Tolstoy. He would start the subject, and I would express my thoughts and feelings about the novels Dr. Carothers brought up. They were the well-known ones like *War and Peace* (4), *Crime and Punishment* (5), et cetera.

SMITH: You had the sense that Carothers had read?

LABOVSKY: Yes, I believed, the way he phrased the subjects and the questions he asked. Frankly, at first I was nervous and afraid. With time I became more confident and at ease with him, and looked forward to our conversations. I started to bone up on Russian novels and music in anticipation of our meetings.

SMITH: He had read a lot of Russian literature?

LABOVSKY: Yes, I think so. He seemed interested in Russian literature and Russian music, which I also enjoyed.

SMITH: When had you read the Russian literature?

LABOVSKY: With music, I heard it from childhood and when I came to America. With literature, it was during my high school years, when I would spend my summer vacations reading all good literature, but mostly Russian. I enjoyed *War and Peace*, *The Brothers Karamazov* (6), *Anna Karenina* (7), Chekhov's plays, et cetera.

SMITH: Did you read these in English or in Russian?

LABOVSKY: In English.

I spoke Ukrainian, a dialect of Russian, but I could not read or write—or correctly speak—Ukrainian or Russian. When I was with DuPont in Geneva, Switzerland, the marketing people would bring Russian Communist customers to sell them nylon and would invite me, believing that I spoke Russian, but primarily to impress them that I worked for the inventor of nylon. After several embarrassing meetings, I refused to attend any customer meetings unless English was spoken.

SMITH: In what year did you go to Switzerland?

LABOVSKY: In 1963, thanks to Sam Carpenter. In 1935, Sam Carpenter III joined me in testing nylon polymers. In 1963, Sam Carpenter, who was then general manager of DuPont International (DISA), got me transferred to DISA, Geneva, Switzerland. By that time my nylon manufacturing assignments were over, and I became a training specialist. I was transferred to DuPont International and moved to Geneva, Switzerland, with the title, "Training Specialist."

Going back to the summer of 1930, Dr. Carothers got interested in me through our music and literature conversations. One day he asked me, "Joe, do you intend to get a higher education, go to college?" I said, "I would like to very much, but I have no financial means of doing it." "That's no problem," he said. Mr. Lammot du Pont, then president of DuPont Company, had a scholarship fund for deserving students. He suggested I write to Mr. du Pont and ask for financial assistance. I did, and received money to go to college! Now I had to make a decision what kind of education I wanted.

With the Big Depression on my mind, I wanted a practical education. At high school I had shown an aptitude for electricity. My mentor and instructor in electrical shop was Mr. Gass—yes, Gass. When I was told Mr. du Pont would grant me a one thousand dollar loan, I asked Mr. Gass for advice on getting a trade education. He advised me to apply to Bliss Electrical College at Takoma Park, Maryland—near Washington, DC—where I would receive good training in the electrical field like powerhouse, construction, or eventually I could set up my own business as an electrical contractor. I would receive a diploma as a Master Electrician in one year. It sounded very good to me.

I wrote to Mr. du Pont and told him the school I chose and why. Without any comment from him, I received a letter with a one thousand dollar check enclosed. I applied to Bliss and was accepted and enrolled in 1931.

I did well in my studies and got good grades, but in about six months I became disenchanted with the curriculum and realized that I had made a very serious mistake. With much embarrassment, I wrote a letter to Mr. Lammot du Pont explaining the reasons for the change and asking for his approval and financing to attend Pratt Institute's Industrial Chemical Engineering Program. I gave him the names of several Pratt graduates working at DuPont plants—Krebs Pigments and Chambers Works.

Again, without any comment, I received a letter, advising me that it was a loan, with a one thousand dollar check enclosed—the amount I asked for. I applied to Pratt, passed their entrance examination, and enrolled in 1932. That was just perfect. The one thousand dollars would take care of me for the first year at Pratt; and if I did well, I could obtain more scholarship money, I was told. I did well and received more money from Mr. du Pont to finish college. With credit for the time I spent at Bliss, and extra subjects, I graduated from Pratt Institute in 1934, in industrial chemical engineering.

SMITH: This was a four-year college?

LABOVSKY: Yes, a four-year college.

SMITH: Where is the Pratt Institute?

LABOVSKY: In Brooklyn, New York.

SMITH: Yes.

LABOVSKY: Yes, in Brooklyn, New York. Pratt Institute is also a college for art, design, marketing, sciences and architecture. Andy Warhol is a Pratt graduate. Regrettably, for economic reasons, Pratt Engineering School closed a year ago and merged with Brooklyn Polytechnic Institute, Brooklyn. Dr. Herman Mark, the world-famous polymer chemist, a DuPont consultant and friend of Dr. Carothers, taught there.

I graduated in 1934 and figured, knowing how to tan leather, make paint, make soap, and run industrial machinery, I was very confident of getting a job, in spite of the Depression. But much to my surprise and shock, wherever I applied, no soap. They were not hiring. I went to the Experimental Station Employment Office, applied for any job they had, and was told they were not even hiring people from Princeton and Harvard, et cetera. "Pratt Institute—where is that?"

I made one serious mistake, John. Before I went for an interview, I would study the product. If it was paint, I spent a whole day in the library reading up on the chemistry of paint, the machinery, and so forth. At the interview, I thought I would impress them with my knowledge. That was a bad idea, because in many cases I knew more than the interviewer, and I scared him. I was overqualified for an entry job and salary.

I went back to the Experimental Station; I figured people knew me there, but they weren't hiring anybody either. "Sorry, Joe. We have no vacancies!" I thought it would be useless to go to Dr. Carothers' Research Group, asking for a job, because I was not qualified for research. Besides, I was ashamed. False pride!

SMITH: That's too bad.

LABOVSKY: Every day for over a month, with a brown bag in hand, I sat in the Experimental Station employment room, hoping for a job vacancy to come up. The job interviewer got to know me and felt sorry for me. One day he came to me and said, "Joe, look, I hate to tell you this. There's a job available now for two weeks only. It's a two-week, pick-and-shovel job. It's not for you. They want somebody immediately. Someone didn't show up and they need a pair of hands. Can you go to work right now?" "Yes, I'm ready to go." With brown bag in hand, I went to work on a pick-and-shovel job, digging a ditch. A two-week DuPont job that led to nylon and lasted for 42 years!

During the second week, as I was working, I spotted a man walking down the pathway. "Oh, that's Dr. Carothers." I recognized him. But I spotted him a bit too late to hide. He also spotted me. He stopped and looked at me. I tried to pretend that I didn't know him and kept on digging away. "Aren't you Joe La-bosk—?" He could not get my last name right. "Yes, Doc, I'm Joe Labovsky." "What are you doing here?" "I'm working," I said. "I thought you were in college." "Yes, I graduated. This is the only job I could find." After about two or three minutes of small talk, he left.

The next morning the yard superintendent came over to me and said, "Come with me!" I thought, "Oh, my God, I'm in trouble or something." I trembled. "I'm fired!" I thought, "My job didn't even last two weeks. They caught me goofing off—talking to somebody."

Again, he said, "Come with me!" So I got out of the ditch, dropped the shovel, and followed him down a narrow sidewalk. He took me to the office of Dr. Carothers. "Gosh, what a relief." I was not getting fired. I remember Dr. Carothers saying to me, "Have a seat, Joe." I sat down. We had a brief conversation. "Joe, how would you like to work for me again?" "Oh," I said, "I would be delighted." My two-week job was about over. And besides, it was

getting cold outdoors. Any indoor job would be much better. Working again for Dr. Carothers would be a pleasure!

SMITH: This would have been in the fall of 1934.

LABOVSKY: Yes, in the fall: November 1934.

[END OF TAPE, SIDE 2]

SMITH: You're in Dr. Carothers' office, and he wanted you to work for him again.

LABOVSKY: Yes. He said, "How would you like to work for me again?" I said, "I would be delighted, Doc." I was back in the laboratory, where it's nice and clean and warm. That was really heavenly, John. I was twenty-two years old; my feelings were those of a kid, I was so elated. I felt like I was just floating. "I got a job working for Dr. Carothers!" I had no idea at that time he was very famous. I learned later of his achievements, of having invented synthetic rubber, et cetera.

Dr. Carothers was the group leader of a special elite research group, facetiously called Purity Hall. He told me that I would also be shared with Dr. Donald [D.] Coffman, and by anybody else in the group who needed me. The following day he introduced me to the research people: Dr. Paul J. Flory, Don Coffman, Dr. [Gerard J.] Berchet, Dr. [Edgar W.] Spanagel. Berchet impressed me because he spoke with a very nice French accent—very melodious! He was the liveliest of all. He was so cheerful. The rest were serious and gloomy; Don Coffman especially always appeared nervous. Dr. West [Wesley R.] Peterson, I remember, was walking around with his shirttails sticking out. Dr. Flory, young looking and serious. I met all these chemists, and Mr. [Crawford H.] Greenewalt, later.

My first assignment was with Don Coffman. They all talked to me, each and every one, trying to size me up, whether or not I'd be qualified to work for them. I spoke intelligently, and correctly. They'd ask me about my education—what did I know, how much they could trust me doing certain things, how much responsibility they could give me. The conversations, later on I discovered, were more probing to what extent I could be given certain responsibility. I was not qualified to do research work, but I could pick up the practical workload. I now recall I spent the first day on the job weighing 100 test tubes on the analytical balance to the 0.0000 decimal point. Dr. Coffman plotted the weights to check my accuracy. The horseshoe curve—bell curve—looked normal.

I remember well Don Coffman. He was a tall, blond guy—very polite, but a nervous fellow. He spoke to me kind of haltingly and slowly, to make sure his instructions were understood. The first thing he said was, "Joe, I'd like for you to go to the library and get a research notebook in your name. All the work that you will do for me will have to be recorded in that book." I have a copy of my research notebook, number 2286. I think about eighty polymers were tested and recorded. One of them was nylon 66. That's quite an honor, for a technician to get his own research notebook.

SMITH: To have his own laboratory notebook.

LABOVSKY: Yes. I felt important and had the confidence of the research people, that I could be trusted to correctly record information and data on experiments. The time was November 1934.

SMITH: What about the secrecy? Did they ask you not to discuss nylon with anybody?

LABOVSKY: No. I was surprised. Nobody said to me that the work I was doing was very confidential, I was not to discuss it with anybody not in my group. At that time there was not really anything secret.

SMITH: They didn't say, "Don't talk to anybody about this?"

LABOVSKY: No, no. Nothing. I was just testing things they called "rayon fiber," at one time. There were no secrecy admonitions because there was nothing of importance discovered until 1935. When polymer 66 was discovered in 1935—adipic acid and hexamethylene diamine, which became fiber 66—then secrecy was tight, and how! Fiber 66 became the code name. And when Dr. George D. Graves took over, secrecy became extremely tight!

John, it was amazing. Later on, guys were fired for talking outside about our work. But before 1935, it was all academic work. There was academic discussion. There was nothing of importance, and there was no need for secrecy. It was not until 1935, when Dr. Berchet finally hit on the polymer 66, later called nylon. I tested and recorded it in notebook 2286. But it was in 1930 when Dr. Julian [W.] Hill first discovered a fiber-forming polymer later called polyester. It wasn't practical then. DuPont had first discovered polyester. Unfortunately, Dr. Carothers discussed his research finding at an American Chemical Society meeting in Buffalo, New York, in 1931, and DuPont lost the patent rights. There's more to the story of the polyester discovery told elsewhere.

At that time, Dr. Carothers' work was fundamental research and of interest to academia, with no company restrictions for publication. Thus, inadvertently, nylon-6 was lost to I. G. Farben. Afterwards there was a very strict review before publication, and I think, rightly so. Dr. Carothers remarked that caprolactam could not be polymerized. Dr. Paul Schlock did!

SMITH: Right.

LABOVSKY: It's amazing. DuPont discovered polyester and caprolactam, nylon-6, and lost their patents to others. That proves the importance of research secrecy until patent rights are obtained.

SMITH: However, Coffman had made the first polyamide fiber in May of 1934, so they were on to polyamides.

LABOVSKY: Right, right. I tested it. There is talk that Dr. Berchet was the one who made polymer 66. Whoever it was, it was a group project. Dr. Carothers was given the patent—2130948.

SMITH: They knew they had something good.

LABOVSKY: Yes! It was Dr. E. [Elmer] K. Bolton; he was the guy who decided that polymer 66 was going commercial. The research group made other good polymers, but polymer 66 went full speed ahead from test tube, to semi-works, to pilot plant, to commercial plant in Seaford, Delaware, in five years—1935-1939! It was DuPont's biggest commercial crash program!

SMITH: However, Coffman made the first polyamide fiber in May of 1934.

LABOVSKY: Oh, yes. He also made other polymers, I understand. At that time I was not privy to this stuff. I could only test the polymers they gave me to see whether they were spinnable, the melting point, the textile characteristics—characterize them and all that. It's all recorded in research notebook 2286.

SMITH: Right.

LABOVSKY: I got to be very good at testing, incidentally. Now let me go back and talk about some of the interesting and funny things that happened before polymer 66 was discovered.

I remember my first experiment. I had to remove the polymer from the glass test tube very carefully, because the polymer adhered to the glass. I'd wrap the test tube in a towel and break the test tube with a hammer, open the towel and separate the polymer chips from the glass chips and cotton linters. It was a long and tedious job. With only about an ounce of polymer available, it was very important to get the most of it for testing. Any contamination, cotton linters or very fine glass powder, would plug the hypodermic needle. Therefore, less than half of the precious polymer was available for testing. I'll show you my replica hypodermic needle spinning apparatus to appreciate how important it was to get clean, pure polymer for testing (8).

Even under the best conditions, the spinning lasted for about five minutes. And it took a whole day to clean the apparatus and more than a week to produce another polymer sample for testing.

After several months, I began to question the procedure for getting the polymer out of the test tube. So I went to Dr. Coffman and said, "Look, you gave me this procedure for removing the polymer. It takes a long time, and most of the polymer is wasted, and the remainder is not clean. Why can't I heat the test tube, soften the polymer, and pull it out in a plug?" "No, no! You're going to oxidize the polymer and ruin it! No, no. You follow the procedure I gave you." " Ok, I will. Sorry, Doc."

The next day Dr. Coffman came to me and said, "Joe, let's try that. Take the Bunsen burner, and very gently heat the test tube." I did, and the polymer plug came out 99 percent clean. Simple and fast. Smiling, Don said, "Joe, it's a good idea." He told Dr. Carothers of my suggestion. It felt great to be complimented by them!

From then on, I had a ball, testing polymer samples my way. In all that time all polymer samples I tested did not have the physical properties they were looking for. But sometime in 1935 a polymer sample spun and tested well. That was a pleasant surprise. It's recorded in my notebook 2286. It was polymer 66.

SMITH: Of course, Dr. Berchet first made it in February of 1935. This was the first time they'd made it. Polyamide 66.

LABOVSKY: Sometime in 1935. I don't remember by whom—Dr. Berchet, probably. The proof of the right polymer was, could you spin it? Did it have the desired elongation, tenacity, modules, and melting point? My job was to spin and characterize it and record the data in my

notebook. Polymer 66 met all the objectives. See the remarks made in the notebook on how well it spun and tested.

Early in 1935, before I tested the 66 sample, there was a crisis. There was some kind of a conference going on. I didn't know about what. No more polymer samples were made. I was idle, waiting for somebody to give me something to test. I remember Don Coffman came to me and said, "Joe, we'll all be in conference. It may last several days. I want you to run an experiment for me while I'm gone." "Oh, sure, Don." By that time I knew him well enough to call him Don. "Oh, sure, Don," I said. "What is it?" He went to the sink rack, got a large glass beaker, filled it halfway with water, put it on a tripod and lighted a Bunsen burner under it. He said, "Joe, I'll be gone several days. Now, your job is very important. Boil the water, but keep it always half level." "What kind of experiment is that? It must be something secret," I thought. So for about three days I boiled water in a beaker and refilled it to keep it half level. Mine was not to reason why. . . .

When Don came back, I asked him, "Don, what was the experiment about?" Laughing, he said, "Joe, we were going to be gone for some days, and you had nothing to do. With the Depression on, you may have been laid off. I wanted you kept busy to make sure you didn't wander off."

When that happened to me, John, I thought, "I'd better get out of here. This job is not for me, and it's not going to last very long. For how long can I boil water? I'd better start looking for another job."

Before I came to the Experimental Station, I had applied to DuPont Chambers Works across the Delaware River, and waited to be called. I received a letter from them about an analyst job vacancy, requesting I come for an interview. In the depressed state of mind I was in, the letter was Godsent! "I'll get a real job! This research work is not for me!"

With letter in hand, I went to Dr. Carothers. I said, "Doc, there is a job opening at Chambers Works, and I'd like a day off to go and apply for it." He looked surprised. He said, "I'll let you know tomorrow. I'll let you know tomorrow." That's all he said.

The next day he came to me and said, "Joe, I called the people at Chambers Works, and I'm sorry to tell you the job has been filled already." I was devastated! I hate to say it, John: he lied to me. Sensing my disappointment and the pain in my face, Dr. Carothers said, "Joe, you stick around here," and walked away. I was miserable all day, and for a long time afterwards. "I could have gotten a job with real security, and here I am mucking around with nothing important to do," I thought. Day after day, testing samples and recording data without understanding what those scientists were looking for. I felt, sooner than later, they would do the testing themselves, and I'd be out of a job. "I must find a way out. But there's the Depression. I'd better stick around. A bird in the hand is. . . ."

Despite my pessimism, I noted an air of optimism in Don Coffman. Not being privy to the research group's meetings and discussions, I had no idea what Don was happy about. Later I learned that Dr. Bolton had decided on the 66 polymer, and it was only a matter of perfecting it and developing a manufacturing process. The research job was over, and it was now up to the engineers to finish the job. My pessimism turned to optimism.

From then on, 1935, that's when they finally got the right polyamide. At that time there were exact procedures I had to follow: take the polymer, put it in the cell; attach the hypodermic needle; put the assembly in the hot bath and spin it. I have a picture of the hypodermic needle spinning cell unit (9). I became an expert in spinning nylon in that contraption.

In 1936, to my surprise and happiness, the nature of the research became more practical. The testing I was doing stopped—polymer 66 was it—and my work was less with chemistry and more with machinery and instruments. Right up my alley! "Thanks, Dr. Carothers, for telling me to stick around!"

Starting with 1936, dramatic changes took place. Dr. Carothers began to show moody behavior. He would not show up for days. He became less involved in directing the Research Group—it was my impression, because the basic research of discovering the right polymer was over. Dr. Carothers was no longer interested in the practical work. Dr. Carothers was invited to give a lecture before the prestigious Michael Faraday Society in London, and Dr. George D. Graves took over the research group.

Dr. Graves took firm charge of the research group. What a change it was! My first assignment under Dr. Graves' regime was a request by Dr. Carothers to prepare charts and graphs for his Michael Faraday Society lecture in London. Dr. Carothers brought me a bunch of data, lots of numbers and notes, and wanted me to prepare tables and graphs, et cetera, for his lecture. He told me quickly what he wanted, and left.

About two or three hours later there were certain questions I had about the numbers, and Dr. Carothers wasn't available. With trepidation, I went to Dr. Graves to figure out what Dr. Carothers wanted. To him it was so obvious, but to me it wasn't. I was not given any kind of a target date for completion.

The next day, Dr. Graves came to me. He said, "Are you done, Joe?" I said, "No. I have to do this and that to finish." He said, "I didn't ask you what you have to do. When are you going to get it done?" Just like that—very curt, like a drill sergeant. I said, "In about a week." "Are you sure?" "Yes." I went right to work on it. Promptly!

The job was done in a couple of days. I took the graphs, et cetera, to Dr. Graves. He looked it over, thanked and complimented me for "a nice job." What a change in his demeanor! He politely asked me lots of questions about my work for Coffman, Flory, and others, and told me from here on I would be working with research and rayon people, and wherever I'm needed.

I thanked him and left feeling good. I had learned that Dr. Graves was a man of action who wanted results now. A month later, he made me foreman of all technicians, with this philosophy: one can't always make hay while the sun shines, but the sun always shines on one who makes hay.

After Carothers went to the Michael Faraday Society lecture and Graves took over, the whole climate changed. The calm and serene academic air that had prevailed under Dr. Carothers' regime changed to a fast pace. Questions: "What happened? Why? When will it be finished?" Questions, demands, impatience. I could sense a feeling of tension and nervousness among the Purity Hall chemists, especially in Dr. Coffman and Dr. Flory. Later Dr. Flory resigned, went to teaching, and won the Nobel Chemistry Prize for polymerization, which would have gone to Dr. Carothers had he lived. Dr. Flory refused a job in nylon manufacturing.

Starting in 1936, experienced textile people were brought in from DuPont rayon plants in Buffalo, Richmond, Waynesboro, and Old Hickory. Also, melt pumps and spinneret spinning were adopted, and other new methods were being tried. There were then two basic and separate groups working: the old research group perfecting the polymer-making process—such as stabilizing the desired molecular weight—and a nucleus manufacturing group to develop the commercial process.

Mr. E. [Ernest] K. Gladding took charge of the manufacturing group. Dr. Preston [George P.] Hoff took charge of the technical group. Mr. A. [Amby] W. Staudt took charge of operations. Almost overnight it seemed to me a revolution took place, and I was in it. Kind of scary, but not as bad as the Communist Revolution. However, just as exciting.

I remember George Graves was just the opposite of Carothers. He was very stern. He wanted things done now and even yesterday! I thought, "What a contrast between the scientific people; between Dr. Graves and Dr. Carothers!" Later on, other people came in: Windy [Winfield W.] Heckert, Don [Donald R.] Hull, Dale Babcock, Cap Wells, J. D. Moore, Bill McGowan. Very smart and very practical men.

Four separate groups were set up to expedite the progress of fiber 66, to go commercial as quickly as possible: first, salt and polymer making; second, spinning of the polymer; third, draw twisting of the spun yarn; fourth, laboratory testing and quality control. And, of course, safety rules were established to handle H.M.D. and molten polymer.

A second set of pragmatic chemists came with Dr. Graves. Engineers came in, and then a slew of rayon department personnel came. That changed the whole climate of Purity Hall. There were two kinds of Ph.D.s, two kinds of people working on nylon 66. The first were the gentlemen, Purity Hall scientists, who discovered nylon—Drs. Carothers, Hill, Berchet, Coffman, Flory, Spanagel. "Ariels," I called them. They were the philosophers. They were the elite academic professors.

The second kind were those who made nylon commercial. Graves, Heckert, Gladding, Hoff, Hull, Bolton, Staudt, [Bill] Wood, et cetera. "Calibans," I called them. The rayon people especially were very conscious of cost. They were now paying the bills, so naturally they wanted to make sure they were getting their money's worth. They had the idea that nylon was another rayon. They were very, very tight-fisted. Oh, gosh! We had a tremendous amount of waste, because nylon was still experimental. The rayon people used to working on penny profit were not used to seeing waste. However, each played their part to make the production of nylon a worldwide success. That's what mattered in the long run!

SMITH: I see.

LABOVSKY: There was also friction between the rayon people and the research people. One day there was even a fisticuffs between a research man and a rayon man—more about it later.

Fortunately for me, I had experience in all those working areas, having worked for Coffman, Flory, Berchet, Peterson, Hill, Spanagel, et cetera. Dr. Graves assigned me where I was needed. I was first their Man Friday and now their Boswell. I got along with the Ariels and the Calibans.

I'd like to say a few words about Dr. Wallace H. Carothers. Much has been written about the life, achievements, and the tragic death of Dr. Carothers. The recent biography of Dr. Carothers is, *Enough for One Life: Wallace Carothers, inventor of nylon,* by Matthew E. Hermes (10). I recommend it to anyone interested in the basic chemistry and history of nylon. However, I strongly disagree with the Hermes biography conclusion that alcoholism drove Dr. Carothers to suicide two days after his forty-first birthday. True, he would frequently imbibe to mask his moods, but he was not the alcoholic depicted in the biography.

In my opinion and the opinion of those who worked with him, Dr. Carothers was not an alcoholic. I never saw him intoxicated, nor did anyone else, at work or socially. Dr. E. W. Spanagel, a Purity Hall research chemist who reported to him, traveled and socialized with him, told me that he never saw Dr. Carothers intoxicated. He was often moody, but never drunk. His moodiness is now characterized as manic-depressive. Alcohol was not the cause of his suicide. I knew and understood Dr. Carothers' persona in a way, I believe, no else did.

I wish to briefly tell of my personal experience and knowledge working for Dr. Carothers. Elsewhere in this oral history of nylon, I have told how Dr. Carothers befriended me, and of our conversations on Russian music and literature. Since these conversations could not always take place during normal working hours, Dr. Carothers would ask me to come in evenings—<u>ostensibly</u> to run some experiments for him, but, I believe, <u>primarily</u> to talk about music and literature. Some evenings our talks lasted beyond midnight and the last trolley leaving for the city of Wilmington. Dr. Carothers would drive me home in his convertible Olds. While our talks were centered, his driving was not.

Dr. Carothers was always very formal, not an easy person to know intimately. Where the other Purity Hall chemists would laugh and joke and sometimes pull pranks in the lab, Dr. Carothers never did; nor did he participate in the levity. His mind was always centered on the problem discussed. He was a different person when discussing music and literature.

Often Dr. Carothers would ask me to deliver envelopes to Miss Sweetman. I assumed they were patent applications or matters pertaining to work. Miss Sweetman, Helen, was a lovely young 24-year-old chemist working at the Experimental Station Patent Office. Later I learned Dr. Carothers was courting Miss Helen Sweetman, and the envelopes I delivered were not always about patents. Helen told me this later. Dr. Carothers and Miss Sweetman were married February 21, 1936. On April 29, 1937, Dr. Carothers committed suicide. Mrs. Carothers was then three months with child. Their daughter Jane was born November 26, 1937. The photographs of Helen and Jane were taken by me in 1996 when they came to see my nylon museum (11).

On April 15, 1937, exactly two weeks before Dr. Carothers committed suicide, an ominous incident occurred which greatly worried me. In retrospect, I wish I had told someone, perhaps Dr. Graves, my boss.

This was the incident. Dr. Carothers, as often before, asked me to come in and set up some experiment. I did. Afterwards, I went to his office expecting, as usual, a discussion on a musical or literary subject. Instead, he asked me to sit at a table behind his desk and sign or witness a pile of papers. Without another word, Dr. Carothers sat at his desk with his back to me. There was complete silence, which was most unusual. It had never happened before.

After a while, to break the silence, I stopped signing and said, facetiously, “Doc, I don’t know what I’m signing. It might be my death warrant.” Dr. Carothers spun around in his chair and shouted at me, “Damn it, read it, <u>read</u> <u>it</u>,” and walked out. I was stunned. It was so unlike him. He was always so polite and formal with me. I sensed something on his mind was troubling him. Perhaps I should have reported this unusual behavior.

I completed signing the papers and went to the laboratory. Dr. Carothers was dismantling the apparatus I set up. I told him I was finished and asked him if he wanted me to do something else. He answered, “No. Goodnight, Joe.” I answered, “Goodnight, Doc,” and left to catch the trolley home.

I did not see or hear from Dr. Carothers for two weeks, until the morning of April 29th. On the way to work on the trolley, reading the *Philadelphia Record* newspaper, on the front page I was shocked to read the heading, “Noted Chemist’s Poison Suicide.”

Thus ended the saga of the life of a genius chemist, a sure candidate for the Nobel Prize for chemistry, Dr. Wallace H. Carothers, the inventor of nylon: the word and the product that revolutionized the textile industry, created the plastic industry. Nylon, one of the great inventions and commercial achievements of the twentieth century.

To perpetuate his historic achievements and his memory, I have donated all my early nylon artifacts, photographs, reports, and memorabilia to the Chemical Heritage Foundation, 315 Chestnut Street, Philadelphia, Pennsylvania (12). I have asked Mrs. Helen S. Carothers and Jane Carothers Wylen, widow and daughter, respectively, to contribute their nylon artifacts to the Chemical Heritage Foundation. In October 1997, Chemical Heritage Foundation will set up an extensive nylon exhibition in memory of Dr. Carothers.

Dr. Herman Mark noted that Dr. Carothers was a brilliant scientist and accomplished more in less than twelve years than most do in a lifetime. In 1974, the Nobel Prize for polymer chemistry was awarded to Dr. Paul J. Flory, who reported to Dr. Carothers. In his acceptance speech, Dr. Flory remarked the prize would have been Dr. Carothers'. *Sic transit gloria mundi*.

Oh well, to return to the nylon story, once the rayon department chemists and engineers started coming in, we escalated production from test tubes to autoclaves: two pounds, fifty pounds, two hundred fifty pounds. Glassware wasn't suitable, so new alloys were explored. Iron was poison: it discolored the polymer. Silver was the only metal that did not poison or contaminate the nylon. Too expensive! But we had a silver-lined autoclave made. Nylon polymer needed to be made under pressure to prevent the loss of diamine—Dr. Spanagel's discovery—to stabilize the molecular weight. A very important discovery! Thus, stainless steel autoclaves were designed to withstand the high pressure and temperature.

To go into a little bit of detail, I will talk about nylon intermediates. There were many intermediates that produced polyamide synthetic fibers, but none met the requirements of melting point, tenacity, modulus, et cetera, necessary to match silk properties.

In 1934, Dr. Don Coffman, to whom I reported, made the first polyamide polymer—9-aminocaproic acid—that sparked research in polyamides. Then followed many other polyamide polymers, until the polymer was made by Dr. Berchet in 1935. It was made from adipic acid and hexamethylene diamine. It was called 66 polymer because each ingredient had six carbons. It also became the secret code: fiber 66. It had all the physical characteristics of silk, and more! Dr. Bolton made the important decision to go all out to commercialize it, because the basic intermediates could be made from benzene, a cheap and plentiful material.

The manufacture of the ingredients to produce nylon salt is another fascinating story for someone else to tell. This very important operation took place at DuPont's Belle, West Virginia Plant. There they made adipic acid and hexamethylene diamine, the basic ingredients for nylon salt for polymerization to nylon polymer, without which none of our work at the Experimental Station could have taken place. They did a superb job!

When it came to making nylon polymer, it was exciting and quite a challenge to scale up from one ounce to one pound, two pounds, fifty pounds, two hundred fifty pounds, and eventually to two thousand pounds. From a glass test tube, to a silver-lined autoclave, and finally to a stainless steel autoclave. What problems on the way, and smart people to solve them!

The first important step was going from dry nylon salt to salt in a water solution. Polymerizing from dry nylon salt in one- to five-pound batches was no problem. Going to fifty pounds was a serious problem—poor heat transfer. Mr. Crawford Greenewalt came up with a simple solution to a major problem. He said, "Make a water-salt solution." This was a simple but tremendous idea. Instead of using a mechanical stirrer to get the heat transfer, the water did it. We didn't need mechanical stirrers because the boiling water did the stirring and the heat transfer at the same time.

The next steps were going from electric heating to Dowtherm heating, and to almost pure nitrogen gas blanketing: 99.99 percent O_2 free. Then we went on a frantic search for a stabilizer to control the molecular weight. Acetic acid was discovered, thanks to Wes Peterson! Then we faced problems from the loss of amine during polymerization, affecting the molecular weight. Thanks to Ed Spanagel's suggestion to use autoclave pressure, two hundred fifty pounds per square inch autoclave pressure became the standard for making polymer.

Next we went from chipping nylon ribbon by hand to automatic chipping, or cutting at autoclave extrusion. There was company pressure to go commercial, and fun at the same time to get there. Finally, the operation moved from the laboratory to semi-works to the pilot plant in 1938. By the end of 1939, Seaford! And being a participant and witness to it all was sheer pleasure! Here are photos showing the evolution of the process (13).

SMITH: That's great.

LABOVSKY: To go back for a minute, we started making fifty-pound batches in a semi-works operation. Then came new engineering department-designed machinery, and spinning technology exploded. From a hypodermic needle, to the first gas spinner; the second gas spinner; the first pump spinner; the second pump spinner; and then, finally, the spinner that froze the design for the pilot plant and the commercial plant at Seaford—the Number 3 Spinning Machine.

I would like to discuss spinning nylon a little more. We started spinning nylon through a hypodermic needle. Here is a photograph of the spinning machine, circa 1935, a simple contraption (9). That's all there was to it, but a revolutionary invention. It was four feet long

and perched on a laboratory bench, very simple. But the problems to commercialize it, as I was saying, were enormous!

All natural fibers—silk, cotton, wool, linen, et cetera—are produced by Mother Nature under normal atmospheric pressures and temperatures. Even rayon, made from wood, cellulose, or cotton, is spun or extruded at about room temperature.

Here comes nylon, an all-chemical, man-made, silk-like fiber that must be spun from a molten mass at a temperature of around six hundred degrees Fahrenheit! Furthermore, the spun fiber had to be uniform in size—denier—and cooled to room temperature in seconds, at speeds from two thousand to over three thousand feet per minute. Wow! But it was done!

Then, in 1936, there was another crisis. We had the polymer, but we could not melt spin it. All the experience of making yarn—say, rayon or acetate rayon—was solution spinning or dry spinning. I remember Coffman dissolving the polymer in phenol, making a solution, trying to spin it like rayon. That was a mess. It was dangerous. It didn't work. Nylon demanded a revolutionary technology!

Melt spinning seemed impossible. The polymer temperature had to be approximately three hundred degrees Celsius and about two hundred eighty-five degrees Celsius to spin it, but there was no uniformity in the yarn, using nitrogen gas pressure to precisely meter the melt to the spinneret.

However, top management decided to go with melt spinning. The die was cast—it was for us to cross the Rubicon. The only pumps available at that time were rayon pumps. Rayon pumps in the nylon melt failed in about a half hour. The gears virtually melted away. The melt pressure and temperature were very high, and all the pump gear teeth wore out! The alloys that were used for rayon just weren't good enough for nylon. Melt spinning was impossible. Furthermore, the high temperature created gas bubbles in the nylon melt. We learned we had to get the gas bubbles in solution and the pack pressure had to be four to five thousand pounds per square inch to do it! This high pressure and high temperature against the pump gears completely destroyed the rayon pump.

In spite of all the impossible problems with melt spinning, management said, "It's going to be melt spinning, period." So the metallurgists went to work, found the right alloy—Ohio Air-die—and melt spinning was a brilliant success.

Here is the sequence: A special stainless steel alloy was invented for a pump to withstand six hundred degrees Fahrenheit temperature and a pack pressure of over five thousand pounds per square inch; next, an air chimney blowing air across the emerging hot filaments cooled them to room temperature in seconds; and finally, a steam chimney immediately humidified the filaments and kept them from sliding off the bobbin rotating at the high speed, over thirty-five hundred feet per minute!

It took about three years to do it. By 1938 we had a prototype spinning machine—Number 3—to start construction of the pilot plant. Donald R. Hull, a wonderful engineer—practical and very, very versatile—was chosen to go to Europe with Spinning Machine Number 3 to demonstrate the nylon invention. He had just gotten married. DuPont sent him, Number 3 Machine, and his lovely bride Blanche on their honeymoon to Europe to demonstrate the nylon process to obtain European patents. After all, nylon did have romantic and happy times!

I remember vividly Spinning Machine Number 3. As I was helping to pack it for Europe, Crawford Greenewalt came to me and said, "Joe, are your papers in order so you can go overseas?" Wow, I would go and be Don's assistant! He would be negotiating, and I would run the machine. "Oh, yes, yes," I answered. I came home and I told my parents, "I think I'm going to Europe on a job!" They were excited. They told their friends, "Joe is going to Europe. DuPont is sending him to Europe." Then I waited and waited to go. Don Hull and his bride, Blanche, went to Europe in July 1938 with the Number 3 Machine, and nobody told me why I was left behind. I was too embarrassed to go to Mr. Greenewalt and ask why, "What happened?"

Number 3 Spinning Machine was a honey to operate at eight hundred to one thousand feet per minute, but that was not an efficient commercial speed. But when we went over one thousand feet per minute, the yarn slid off the bobbin—a very serious problem! The objective was to go over twenty five hundred feet per minute, commercial speed.

SMITH: That's incredible.

LABOVSKY: Once again, a great discovery was made, and the problem was solved! In melt spinning, the yarn comes out very dry. At low speed the yarn picks up ambient moisture, just enough to stabilize it, and the yarn would stay on the bobbin. As we went to higher speeds, there was not enough time for the yarn to pick up equilibrium moisture from the air and get stabilized before winding up on the bobbin.

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LABOVSKY: As I said, at the higher speeds, the yarn did not pick up the equilibrium moisture from the air, swell up, and slide off the bobbin. We tried all kinds of tricks to keep the yarn from sliding off: shellac, paste, glue, et cetera. Nothing helped. Dr. Dale [F.] Babcock—did you ever hear of him? He came along and solved the problem!

SMITH: I've heard the name.

LABOVSKY: He was a great guy. Smart, and really a fun guy to work with. He came into the semi-works where Number 3 Spinning Machine was operating, saw the mess of sliding yarn, and said, "Joe, do you know what I think's wrong? That yarn is too thirsty. It needs a drink." I said, "Okay." He took a long piece of rubber tubing, hooked it up to a steam line, and shot the steam to the yarn as it came out of the spinneret. Presto! Eureka! The yarn did not slide off the bobbin! Thus, the steam chimney was invented and we went to windup speeds as high as thirty-three hundred feet per minute.

SMITH: That's just incredible!

LABOVSKY: That was it. Very simple. Immediately we started building steam chimneys. The filaments came out of the spinneret, went through the steam chimney, picked up its equilibrium moisture, and stayed on the bobbin. It was perfect. I'll tell you, that was a tremendous discovery! Thanks to the astute thinking of Dale Babcock. Dale also discovered the draw pin for draw-twisters to obtain uniform yarn. Later, Dale was transferred to the Manhattan Project to work on the atomic bomb with other smart DuPont people, under the supervision of Crawford Greenewalt.

We had many other problems with nylon, but there was always somebody who came to the rescue. It was amazing how quickly problems were solved by the astute people working on nylon.

SMITH: Different people.

LABOVSKY: Different smart people.

As I said before, the problem with nylon was getting stable molecular weight. Without a stabilizer, the nylon polymer would continue to polymerize in spinning, increasing the molecular weight so high it became unspinnable.

SMITH: What a mess.

LABOVSKY: Yes, what a mess. We were making half-polymerized polymer, hoping and thinking that by the time the melt came out of the spinneret, it would polymerize just right. It

didn't work. That's when we started looking for a polymer stabilizer. Wes Peterson came along and found that acetic acid was, of many others tested, the stabilizer. We could hardly wait to produce HAc-stabilized polymer. By God, that was it! Another crucial moment in nylon was overcome and nylon was full speed to commercial production.

SMITH: Yes.

LABOVSKY: Here are some photos showing nylon machines from the hypodermic needle to the commercial plant, Seaford, Delaware (14).

SMITH: I see.

LABOVSKY: Now I'd like to talk about cold drawing or stretching nylon yarn. In the beginning, with the hypodermic needle, nylon was spun at around one hundred feet per minute, and drawn or stretched three to four times the length—at the same time. As spinning increased to commercial speeds, three thousand feet per minute and over, it became necessary to separate drawing from spinning, to obtain good uniformity—denier—and good commercial productivity. To accomplish that, the spun thread was pre-twisted to hold the bundle of individual filaments together; the thread drawn or stretched between two rolls running at different speeds, then through a traveler ring to add a slight twist; and finally collected on a pirn. The machine was called a draw-twister. Dr. Dale Babcock's agate draw pin was the icing on nylon quality.

By 1938, a commercial draw-twister was ready for the pilot plant and, with a few improvements, for the Seaford plant. To really appreciate the steps taken to design the machine, see the series of photos.

I'd like to take a minute to talk about nylon testing and quality control.

SMITH: Okay.

LABOVSKY: To manufacture nylon is really not very hard, but to manufacture it with consistent quality is hard. In the beginning, when polymers were made in one-ounce test tubes, the only important test was, did it spin? As the batch quantity of the polymer increased, it was critical to control the molecular weight, the polymerization cycle, to know what went on—and off—in the autoclave.

Dr. Paul J. Flory was given the job to develop tests for nylon. I was assigned to work for Dr. Flory to run molecular weight determinations. Dr. Flory was a chemist's chemist. He and Dr. Carothers would be in a corner of the lab discussing the test data and planning modification of the chemistry for the next batch. Dr. Carothers, I believed, had better rapport with Dr. Flory than with the other chemists.

Following were the basic tests to characterize a polymer: molecular weight, intrinsic viscosity, moisture, color, melt viscosity. Parameter standards were set for each test, and from that the correct polymerization cycles were established—e.g., stabilizer or HAc, autoclave pressure, autoclave temperatures, holding cycle, reducing cycle pressures, et cetera.

Polymer 66, to be consistent in quality, had to meet tight standards in order to be spinnable and produce a quality yarn consistently. Also, at Belle, West Virginia, quality control standards were set for the nylon salt—very important for a quality polymer, yarn, and subsequently uniform dyeing.

In 1938, we started licensing Italy, France, and the British to make 66 nylon. The Germans, we learned, had their own nylon 6—caprolactam. Perlon was their trade name, based on Dr. Carothers' experiments.

When DuPont learned the Germans had a caprolactam polymer—nylon 6—they quickly had Belle make a two thousand-pound batch for us to spin at the pilot plant. It spun okay but gave off a great cloud of monomer. The pilot plant was in a thick fog! The 6 yarn tested well but it did not have the good physical properties of 66 yarn. Also, the melt temperature was about ten degrees Fahrenheit lower, but the dyeing property was better.

Later in 1938, with the clouds of war coming on, military people started visiting us. We would show them the pilot plant operation. DuPont had nylon fiber to replace silk for parachutes, and nylon for tire cord, and so on. Higher-ranking military people started coming, and top DuPont executives—Greenewalt, Bolton, [Arthur P.] Tanberg—would show them around the pilot plant, showing "silk" coming out of the spinneret. The pressure was on to get the show on the road—to get nylon in commercial production.

At the nylon plant we started working shift work, around the clock. Things invariably went wrong, and at the end of the shift we were exhausted. In the morning, when the executives started coming in—well-rested, well-dressed, ties and all—housekeeping became very important. Everything had to be ship-shape—rayon philosophy—before the brass came in, in spite of how tough a night we had had, fighting the problems. Housekeeping had to be perfect!

I remember the one time we worked all night long, everything went wrong. We couldn't get anything spinning till morning. Naturally the place looked bad. The rayon guy, Amby Staudt, came in. The shift supervisor was Mike McCall, a real rough and tough former football player and coach at Salesianum High School. Amby was supervisor of the pilot plant. He

would always come in 7:30 a.m. sharp to inspect. He was the real rayon man. That morning the place looked terrible. He said, "Mike, this place looks like a shit house." Mike exploded. He grabbed Amby by the coat, lifted him off the floor, and said, "You son of a bitch! Don't you dare say that to me!" He was almost speechless with rage. I ran over to Mike yelling, "Mike! Mike! Don't, don't! Please, please!" He dropped Amby. There would have been blood on the floor. There were many other such scuffles. This was the worst. There were lots of human and inhuman stories in the making of nylon.

A spinning unit was made up of a stainless steel 75-pound block, a Dowtherm heated melt grid, and metering pumps. In about six hours, the nylon chips would bridge the grid and reduce the melt pool needed for spinning. Then it became necessary to change units, a very tedious and nasty job. The cleaning was done in a bath of hot sulfuric and nitric acid, a messy and dangerous job. But that's the way it had to be done in the pilot plant. We had one very serious accident. The hot acid container tipped over and covered the operator, Schmitty. Afterwards, cleaning was done by burning off the polymer—dry cleaning.

When a spinning problem occurred several hours before 8:00 a.m., there was no time to change units and do housekeeping at the same time. So we all learned how to cheat on the graveyard shifts: shut off the pumps, let the melt pool build up at the same time, do our housekeeping, and start the pumps running by 7:30 a.m. When all the brass came in, we were spinning nice nylon and the area was ship-shape clean. We were complimented for a job well done!

Unfortunately, after about two hours, the units ran out of melt, all spinning stopped, and the day shift had the nasty, dirty, dangerous job of cleaning units and getting spinning started again. So what! We all did it! Management got wise to us and put a stop to it. But by that time, grid melt capacity was improved, and we were able to schedule units for cleaning. Until then, everybody was happy!

SMITH: Yes.

LABOVSKY: In retrospect, every problem had a solution: one, polymer 66; two, stainless steel for autoclaves; three, two hundred fifty pounds-per-square-inch pressure to stop loss of amine; four, acetic acid stabilizer; five, live steam on the yarn to make high-speed spinning possible; six, a draw pin between rolls to produce quality nylon yarn; seven, metering pumps; et cetera, et cetera. There were hundreds of problems, and somebody always came up with the solution. The making of nylon was a gold mine of opportunities. I am happy to say, the sun shined on me while I made hay. See my haystack.

SMITH: Right.

LABOVSKY: The first commercial nylon plant was in Seaford, Delaware. December 15, 1939 was the starting date of the Seaford plant. Chuck [Charles L.] du Pont was the plant manager. Coincidentally, December 12 was the date I came to America.

SMITH: Did you go to Seaford?

LABOVSKY: Yes, I went to Seaford. Instead of going into production, I was sent as a quality control technical person. I was sent as a troubleshooter, to spot and correct production problems. A most interesting, exciting, and challenging assignment!

After the plant started, my job was full-time troubleshooting. I wrote the first manual on troubleshooting, *Probable Causes of Spinning Problems* (15). It's now in the archives of Chemical Heritage Foundation.

Before, every time they had a problem, they'd call Joe, day and night! The manual reduced the calls greatly.

SMITH: You were there for the start-up procedures, then.

LABOVSKY: Yes, I was there for the start-up. Even before the start-up. During every step of construction: we followed it right up to plant start-up. According to official records, the plant started on December 15, 1939. Actually, it started on the 12th of December. You see, we knew when the plant officially opened, there would be a lot of dignitaries and officials. We had to make sure that things were running well, so we started spinning on the 12th of December. We started operations three days early—a dress rehearsal, so to speak—to make sure nothing went wrong on opening night. We got everything going before they cut the ribbon. Everything was well prepared, well staged, to make sure. We couldn't go and start the pumps with all those visitors staring. You know, Murphy's Law.

SMITH: How did it go?

LABOVSKY: Real good! There were eight T-8 spinning machines, one hundred sixty spinning positions. The total production capacity was four million pounds a year. Nothing went wrong when Harwood K. Strange, shift supervisor and my technician when I was supervisor at the pilot plant, started the pumps on the first position on Spinning Machine 1. Watching him were

DuPont executives, military men, government officials, and university guests, among them Dr. Conant, president of Harvard University and friend of the late Dr. Carothers. While there were smiles and applause from the honored guests, there was much nervousness among us operating folks, lest something go wrong. It didn't then, but it did when we started up the full machine the next day!

Nylon is a fickle fiber. Sometimes it comes out of the spinneret in drips and drops instead of continuous filaments, or the spinneret orifices get plugged, or the pack leaks, or the pump gears break, et cetera, et cetera. But none of the above troubles happened on December 15, 1939. What a joyous sigh of relief it was!

Nylon went commercial ten years from 1930, the time Dr. Julian Hill pulled from a test tube the first fiber-forming polymer—it was polyester—and five years after Dr. Bolton chose the polymer 66 in 1935.

For me, the opening of the Seaford nylon plant was a solemn and emotional experience. To be a witness to the invention of a revolutionary fiber, a participant from the test tube to the nylon commercial plant, was a dream hard to believe. And to have worked for Dr. Carothers, the inventor of nylon, and Dr. Paul Flory, the Nobel Laureate, was a great honor and privilege. All of that happening in fifteen years of my coming to America is something for me to reminisce and enjoy in the twilight of my years and to the end of my life.

It was then being said then that nylon was made from coal, air, and water. "Not so," said Dr. George D. Graves in a speech before the plant opened (16). The secret ingredients of nylon were vision, genius, and faith: the vision of DuPont management to go into fundamental or pure research; the genius of Dr. Carothers' mind; the faith DuPont had in Purity Hall chemists, engineers, et cetera, to risk twenty-seven million dollars in a project that gave a new word and a new product to the world—nylon.

Later, as I said, I was assigned to work in the plant process control area to write operating instructions and inspection standards—standard practice—and be the process troubleshooter. Then, in October 1941, I was transferred to DuPont's second nylon plant at Martinsville, Virginia, as standard practice or quality control supervisor. Then came Pearl Harbor, December 7, 1941. That's another interesting story to be told at another time.

SMITH: Yes.

LABOVSKY: You see, drawing spun nylon became a problem. Spinning was right, but in drawing, breaking of filaments was a serious problem. You couldn't draw the yarn direct off the spin bobbin. We had to pre-twist the yarn to hold the filaments together. If there was a weak

filament in the bobbin, the other filaments would hold it together. There would be a broken filament in the bundle, but the break wouldn't cause interruption in drawing.

The drawn yarn wasn't uniform. The yarn had nubs in it, resulting in ugly specks in the stocking when dyed.

Once again, Dr. Dale Babcock solved the problem: an agate drawpin between the draw rolls. Thus the nubs were ironed out by the pin. The quality of the spun yarn improved, and we could draw the yarn direct from the spin bobbin, eliminating the expensive pre-twisting operation. The pre-twister machines were converted to draw-twisters at a very substantial cost reduction.

John, in your book, *Science and Corporate Strategy*, you mentioned that one of the big problems was finding a size for nylon (17). Dr. Spanagel was the hero in solving this very serious problem. The Seaford plant was being finished, with a large area for sizing machines, but no suitable size was available. Without it, nylon yarn was not commercial—a very critical problem!

SMITH: That's right.

LABOVSKY: Dr. Spanagel was the guy who, contrary to all the theories about sizes, formulated the correct size for nylon yarn.

DuPont had a German specialist making sizes and finishes for rayon and acetate yarns. His name was Papa [H. H.] Freund.

SMITH: He was a consultant, wasn't he?

LABOVSKY: Yes, he was a consultant, good at making rayon sizes and finishes. But nylon was so different, out of his field. He could not come up with a size for nylon.

Dr. Spanagel was assigned the job of producing a size for nylon. I was then at the Seaford plant. We made a lot of yarn for testing. The sizes were always improvised—good enough to make testing hose, but not commercial. A big problem!

Papa Freund couldn't come up with a suitable size in months of experimentation. Spanagel did! When I asked Ed about it recently, how he did it, he said, "Aw, hell! They were using the old ideas about old yarns. I said, 'The hell with it!' They kept telling me, 'No, you can't do this; you can't do that.'" Contrary to all the science of sizing, Dr. Spanagel came up

with the right size just in time. That was a tremendous achievement. That was nothing to Dr. Spanagel—like Julius Caesar: "*Vini, vidi, vici*."

Have you talked to Dr. Spanagel? He will be ninety-two years old on July 25. He is sharp, alert, and very interesting when he starts reminiscing about nylon days. I suggest you take his oral history (18). He will tell you how DuPont lost the nylon 6 patent—caprolactam—and other interesting tidbits about working with Dr. Carothers.

As I said before, a spin unit block had two pumps: a booster and a meter. They eliminated the booster pump. They redesigned the pumps into squeeze pumps, a very ingenious idea. Each pump worked both as booster and meter pump. That doubled production, from four million pounds to eight million pounds a year, at a very small cost!

SMITH: That's just incredible.

LABOVSKY: Incidentally, it was Dr. W. W. Heckert's invention.

SMITH: That was Windy Heckert?

LABOVSKY: Yes, Windy Heckert came up with the idea of doubling production at Seaford. It all happened in less than a year from the plant start-up!

SMITH: That's incredible.

LABOVSKY: These are the kinds of incredible things that happened on the way to making nylon a big success.

[END OF TAPE, SIDE 4]

LABOVSKY: There were many other interesting problems when we opened the Seaford plant. We were hiring people—operators, technicians, yarn inspectors, et cetera. All kinds of non-technical people.

SMITH: You were hiring people from southern Delaware?

LABOVSKY: Yes, southern Delaware, and Maryland, and Virginia peninsula.

SMITH: They were from the counties?

LABOVSKY: Yes. And I'll tell you, the people we hired were intelligent people, but some were illiterate! Many of them couldn't read or write!

SMITH: That's just incredible.

LABOVSKY: That was an interesting problem. Operators had to read identification of various types of yarns and deniers. We had to make sure they didn't mix them.

SMITH: That's right.

LABOVSKY: To make sure they didn't mix them, production was identified with farm symbols. Cows, horses, haystacks, wagons, shovels, et cetera, et cetera, but not mules—they looked like horses—potential mixes. Thus cows stayed with cows, horses with horses, et cetera, et cetera.

SMITH: That's really amazing! [laughter]

LABOVSKY: Necessity is the mother of invention. Nothing to it; a very practical thing to do. In fact, we had less mix-ups and less problems with this system than trying to read the number identification on a disk or tape. [laughter]

Let me tell you something funny. Chuck du Pont was the first plant manager, a very nice fellow. Another duPonter was Paul du Pont, a very good engineer, but also a playboy. He designed the spin pack. He was made supervisor in charge of maintenance of spinning pumps. When pumps came off the machines, they were cleaned and checked before being put back into service. That was Paul du Pont's job. But instead of maintaining used pumps to be ready for service, Paul was always using new pumps. No problem: he had plenty of new pumps.

Everything was going well, until one day we ran into a very serious crisis. Pure nitrogen gas—99.999 percent free of O_2—was used to blanket the nylon melt in the spinning units. It was absolutely imperative that every new N_2 cylinder be tested for O_2 content before it was put on line. The Philadelphia producers of N_2 gas knew the importance and never sent us a bad lot of nitrogen gas. However, the plant, to make sure the N_2 was okay, always tested it. It was an absolute rule.

One weekend the testing apparatus broke down, and the process control supervisor, Bill Tyson, decided to put a new trailer of N_2 on line without testing. Well, Murphy's Law worked. For the first time the N_2 was bad, and the shit hit the fan! The spinning operation stopped.

SMITH: Oh, no!

LABOVSKY: I tell you, oh my. Oh, God. The high O_2 content in the nitrogen oxidized the nylon, and we had to shut down spinning!

There are twenty positions to a machine, two pumps to a position, and eight machines—20 times 2, times 8, equals 320. That's 160 positions and 320 pumps! We had to shut down the plant, clean up all the positions, and change all the pumps—320 of them. Paul du Pont, instead of maintaining used pumps and putting them in service, always installed new pumps. That was very smart, he thought. Why take a chance with a used pump? He knew a new pump was always good—guaranteed quality spinning.

At that time, quality and productivity were important, so he had a great idea—only new pumps went into the operation. It worked beautifully for about six months, until suddenly we had a very serious crisis: we needed 320 pumps at once, and he didn't have them. It took three days to get the plant back in production! All hell broke loose. Would you believe it, Paul was fired. [laughter] A du Ponter fired! What happened to Bill Tyson? He was chewed out royally and never given more responsibility.

SMITH: I can imagine!

LABOVSKY: Paul du Pont had a good idea for the plant start-up—use new pumps to insure high quality yarn. But he should have cleared it with technical for permission and made provision in case of any emergency. He didn't do either. duPonter or no duPonter, he was fired to set an example for others: get permission before changing production procedures.

We went into commercial production under the direction of experienced men like E. K. Gladding, Pres Hoff and Laird Stabler. They were smart, disciplined production people. They

didn't know the details of nylon, but they knew production. No alibis, no excuses! They were good for nylon because they didn't tolerate any kind of loose thinking: no research thinking in production. Once you develop a production procedure or process, you've got to stick to it; otherwise, you don't have quality uniformity, no control. God help you if you change a standard practice procedure without authorization! That taught me a lot in my transition from research to production and quality control: no deviation once a procedure is established. If you have an idea, write it up! I wrote up over a thousand (15).

Let me tell you something interesting about the ideas and the World War II. I was transferred to the second nylon plant in Martinsville, Virginia, as standard practice supervisor. We could not draw bright nylon yarn without excessive broken filaments and high waste. I solved the problem, for which I received a War Production Award Commendation (19).

SMITH: What year was that?

LABOVSKY: The year was 1941, October 1941. I remember, almost two months later was Pearl Harbor, December 7th. I was in Martinsville during the war. I tried to enlist in the Air Corps, but DuPont would not release me because nylon was a critical war material. I received seven deferments. Honestly, I really wanted to fly a fighter plane. I used to fly a Piper Cub.

I was always in quality control. I knew enough about manufacturing but never got a manufacturing job. I was always used as a technical man. Jim [James] Beleza was the technical superintendent. He was once a rayon man—a very, very dynamic person. He was made manufacturing superintendent. He sent for me one day. "Joe," he said, "why the hell aren't you in manufacturing? You know enough about it." I answered, "Nobody asked me. Well, tell me where you want me, and I'll go." So he put me in charge of manufacturing-process control, where we made up high-pressure packs for spinning, inspected spinnerets, and controlled denier. I was made supervisor of spinnerets, pack room, and the denier control area.

Process control was under the manufacturing budget, but under the aegis of technical. So, in 1948, I was in manufacturing, but under technical control. DuPont was making a hell of a lot of money from nylon. In fact, the nylon demand was so great, John, that before an order would be filled, the customer had to send a check for it. Money in advance before shipment. Therefore, it was very important to produce the maximum amount of high quality nylon with the minimum amount of waste. Jim Beleza thought I would help to do it.

SMITH: That's amazing.

LABOVSKY: The demand was so great. We had to make sure customers who wanted nylon had the money to pay for it. That's the way it was. Even Burlington Mills would send a check for a hundred thousand dollars to fill an order. It was not DuPont greed. The demand was so great, fly-by-night companies sprung up. Everybody wanted nylon. There was not enough production to fill demand. Only reliable, bona fide customers were given priority. Anyway, in 1948, I was in charge of making spinneret packs. Precisely made spinneret packs greatly reduced spinning interruptions, thus insuring the maximum productivity.

SMITH: Spinnerets in what?

LABOVSKY: Spinneret packs. Spinnerets were made up in a pack. Sand was the filter medium. In a stainless steel cylinder, various gradations of sand were placed. Underneath was a fine-mesh stainless steel screen to hold the sand, and then a spinneret. The spinneret pack assembly went into a spinning melt block. The pack assembly built up a pressure of five thousand pounds per square inch, to put gas bubbles in melt solution, to insure continuous filaments out of the spinneret.

The spinneret was the most expensive and critical component of the pack assembly. A spinneret cost anywhere from twenty-five dollars to one hundred dollars, depending on the number of orifices. At that time the practice was to reject spinnerets with the slightest damage. Only new spinnerets were used to ensure no problems. It reminded me of Paul du Pont playing safe by using only new pumps!

I did not like what I saw. We were throwing away a lot of good spinnerets. I developed special tools and a technique to repair damaged spinnerets to meet all the specs of new spinnerets.

I showed engineering how to repair damaged spinnerets and put them back in service. Not interested. "Check with works technical." I did. Not interested. I had a pow-wow meeting with Technical and Engineering. "No, no, Joe. We don't want to fool around with junk spinnerets. Throw them away. We can afford new ones." Nylon money was pouring in, and they didn't want to use repaired spinnerets. I was also warned, "Don't you ever dare use them!" Of course, I wouldn't have! I knew the rules of production and obeyed them. But I was not happy to see repairable spinnerets thrown away.

There was no problem buying spinnerets, and money to pay for them was easy to get. So, I went to the plant manager, Don [W. D.] Hartford, and said, "Don, I am teed off about us not repairing spinnerets. Could I have your permission to repair them on my own time? Maybe there'll be a rainy day and we'll need them." He said, "Permission granted."

On Sundays I would come in and collect all the damaged spinnerets. For two years I repaired damaged spinnerets and stored them in a five-drawer file cabinet, all classified and put away for a rainy day. And the rainy day came in 1950!

The Korean War! In 1950, all hell broke loose. Don Hartford came to me, asking, "have you still got the procedure for repairing spinnerets?" "Yes." The Korean War created a scarcity of stainless steel. This time nylon no longer had the priority of World War II, and we could not get stainless steel easily. What we could get was at a high cost.

I used to repair about one hundred spinnerets a week, sometimes more. I did it for about two and a half years and had over ten thousand spinnerets ready for production. I became a war hero, fighting my kind of war!

Not only the Martinsville plant—where I was—the Seaford plant, the Chattanooga plant, had the same spinneret shortage problem. Thus, the Martinsville plant became the center for repairing spinnerets for all plants—not only nylon, also polyester and rayon. And, in time, the Martinsville plant started to manufacture new spinnerets for all plants.

For that, I got a nice promotion and later a three part A bonus.

SMITH: Yes.

LABOVSKY: You get a straight A bonus for inventing or discovering something important. You get a three-part A bonus for really hitting the jackpot! My invention saved the company millions of dollars, but the proudest moment was the compliment I got from Mr. Hartford for my stubbornness in not giving up the idea of salvaging spinnerets. Mr. Hartford was one of the kindest and wisest managers I worked for. He gave me these words of wisdom: "A good manager never gets or gives ulcers."

SMITH: My goodness.

LABOVSKY: You had to be mum about salary, B bonus, A bonus, and especially about a three-part A bonus. Now that I'm retired, I can talk about it!

Going back to the invention and production of nylon, I experienced happy and tragic events. The most painful was seeing two men die. They violated a strict safety rule. Still, their unnecessary deaths will always be on my mind.

SMITH: Certainly.

LABOVSKY: During the war we had a lot of women working in the plant. Wearing of rings, wristwatches, and jewelry was strictly forbidden. People violated the safety rules and, as a result, lost fingers, and some were blinded.

DuPont has the highest reputation for safety, and the best no-injury record in the industry. The Martinsville plant went for five years with no lost-time injuries. Yet people, through violation of safety rules, lost life and limb.

With all the fun and excitement of being a witness and participant in the invention of nylon, the human tragedies pained me a lot.

Well, I don't think I have any more to tell now. Thank you for listening.

SMITH: Well, I'd like to thank you very much for spending this time with me.

LABOVSKY: You're welcome.

[END OF TAPE, SIDE 5]

[END OF INTERVIEW]

EPILOGUE

Philosophically, the revolutionary discovery of nylon occurred several years before Dr. Wallace H. Carothers came to DuPont.

It occurred when Dr. Charles M. A. Stine, the son of a Lutheran minister, conceived the revolutionary idea of exploring uncharted fields in chemistry. He had the foresight and courage to convince DuPont to spend money for basic and fundamental research—pure science. A radical departure for DuPont from their research policy of improving existing products.

Fortunately, Dr. Stine had the support and the vision of Mr. Lammot du Pont, then the president of DuPont. The fortuitous combination of a dreamer and a believer was the right chemistry for Dr. Carothers to create nylon.

ADDENDUM

Joseph Labovsky now lives in Wilmington, Delaware.

He was married to the late Edith Busch Labovsky for forty-five years. He has three children: Michelle [Micki] Labovsky Edelsohn, Stephen Labovsky, and Lora Labovsky Meyer; and three grandsons: Andrew Edelsohn, Robert Edelsohn, and Gifford Meyer.

NOTES

1. Photograph of Joseph Labovsky at Babi Yar, 1991. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

2. See "Karta Pobytu," in Chemical Heritage Foundation Oral History Research File #0148.

3. See copy of photo on "Karta Pobytu," in Chemical Heritage Foundation Oral History Research File #0148.

4. Leo Tolstoy, *War and Peace, a novel* (New York: Mead Dodd, 1930).

5. Fyodor Dostoyevsky, *Crime and Punishment* (New York: Macmillan, 1927).

6. Fyodor Dostoyevsky, *The Brothers Karamazov* (New York: E. P. Dutton, 1927).

7. Leo Tolstoy, *Anna Karenina* (New York: Mead Dodd and Co., 1928).

8. Replica hypodermic needle spinning apparatus by Joseph Labovsky. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

9. Picture of the hypodermic needle spinning unit in notebook titled, "History of Nylon Process Machinery, etc., 1930-1938." Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

10. Matthew E. Hermes, *Enough for One Life: Wallace Carothers, inventor of nylon* (Washington, D.C.: American Chemical Society and the Chemical Heritage Foundation, 1996).

11. Two photographs of Helen and Jane Carothers in front of Labovsky's nylon museum, taken by Joseph Labovsky. See notebook, "Joseph Labovsky," Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

12. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

13. Photos showing the evolution of the nylon development process. See notebooks, "Joseph Labovsky," "Photographs 1946-April 9, 1947," and "History of Nylon Process Machinery, etc., 1930-1938." Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

14. Photos showing nylon spinning machines from the hypodermic needle to the commercial plant, Seaford, Delaware. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

15. Joseph Labovsky, *Probable Causes of Spinning Problems*. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

16. George D. Graves, speech at opening of Seaford nylon plant, December 15, 1939. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

17. David A. Hounshell and John K. Smith, *Science and Corporate Strategy: DuPont R&D, 1902-1980* (New York: Cambridge University Press, 1988).

18. Edgar W. Spanagel, interview by John J. Smith at Wilmington, Delaware, 9 May 1997 (Philadelphia: Chemical Heritage Foundation, Oral History Transcript #0158).

19. War Production Board Commendation presented to Joseph Labovsky. Wallace Carothers Memorial Archives, Chemical Heritage Foundation, Philadelphia, PA.

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