MECHANIZATION AND LABOR REDUCTION: A HISTORY OF U.S. FLUE-CURED TOBACCO PRODUCTION, 1950 TO 2008

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DEDICATION

This book is dedicated to Alma and Eugene.
They experienced much of what is described here.
They knew what hard work was all about.

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INTRODUCTION

From the earliest days of our country, tobacco and the history of the United States have been intertwined. Accounts of the settlement of Jamestown, VA, credit the production and export of tobacco with saving that early colony by giving it financial resources with which to survive. When John Rolfe and the colonists grew the first crop in 1612, tobacco was already in demand in England with a mild "Spanish" leaf highly valued by London smokers (11). Rolfe found the native tobacco grown by the Indians, *N. rustica*, to be harsh and not well suited for smoking. For that reason the first crop in 1612 was the "Spanish" leaf, *N. tabacum*, with seeds likely imported from Trinidad (11). With demand increasing, tobacco production by the colonists increased, and exports were up to 20,000 pounds by 1617. Production of tobacco continued to flourish, with production levels reaching 130,000,000 pounds shortly after independence was won from England and the 13 colonies formed the United States (8).

The tobacco grown by the early colonists in the fertile soil of tidewater Virginia was probably similar to dark air-cured today. As the colonists moved westward and southward into the Coastal Plain region they took their tobacco commerce with them. The new production areas brought about a positive result for the colonists because the lighter sandy loam soils of the region produced a brighter, sweet-scented tobacco that was in high demand. Thus the first bright tobacco did not result from a special seed or unique curing process but rather the lighter soil of the region (11). To meet demand after the War of 1812 and the greater exposure of the bright tobacco to English soldiers, production expanded into the Piedmont region of Virginia and North Carolina, where the soil was especially suited to growing the bright tobacco.

Development of the flue-cured tobacco industry from the 1800s until 1929 is chronicled in a very detailed book by Nannie May Tilley (50). Her book, along with several other accounts, attributes the discovery of what we know as flue-cured tobacco to an accident on the Slade farm in Caswell County, NC, in 1839. The tobacco barns of that day often used open charcoal fires to keep down humidity and speed up the curing process. A slave, Stephen Slade, fell asleep while tending the fires one evening. When he awakened, the fires were almost out. He hurriedly put extra amounts of charcoal on the fires, and in doing so rapidly raised the temperature in the barn, setting the color of the tobacco and producing a very bright yellow tobacco. Whether this accident was the first "flue-curing" we do not know, for there are additional accounts of related curing developments in that era (11). In 1823, a grower in Louisa County, VA, was reported to have been heating his barn through a stone-lined tunnel from an outside firebox. Also, in the 1828 to 1832 period, Dr. D.G. Tuck of Halifax County, VA, developed and patented a method of curing with flues for the purpose of producing yellow or bright tobacco (8). Whoever discovered the curing process of producing a bright yellow tobacco, other growers recognized its value and strived to adapt curing practices that would allow them to grow and cure the higher valued leaf.

The Civil War brought about several changes for the flue-cured industry (50). Richmond and Danville in Virginia were centers of the industry in that era; the war brought about considerable destruction, with dislocation of industry interests in both cities. Production moved out of the Danville area into the Coastal Plain of North Carolina where tobacco displaced cotton, which was in an economic slump after the war. With a new production area and new farmers, there was a willingness to try improved ways of producing the crop. The use of metal flues in barns to cure the crop became widespread, along with the use of thermometers to measure temperature. As such, metal flues became the first heat exchangers used in curing flue-cured tobacco. The metal flues throughout the barn exhausted the combustion products from the wood burning furnaces to the outside of the barn. Meanwhile, the heat from combustion products inside the flues was transferred through the metal flues to air inside the barn, providing the heat necessary to cure the tobacco. Another change in the 1870s was the harvesting of the tobacco by breaking the leaves off the stalk instead of cutting the whole stalk (50). While it was many years before priming tobacco leaves for harvest became widespread, it did provide for an improved way to harvest and cure tobacco. A suitable way to tie the harvested leaves on a stick with a continuous string was developed by the late 1890s. This innovation helped speed the adaptation of leaf harvesting.

One positive aspect of the Civil War was the exposure of many northern soldiers to the smoking qualities of the milder bright tobacco found in Virginia and North Carolina. While the war caused many disruptions to the industry and an immediate decline in tobacco production, the demand for cigarettes containing the milder-smoking bright tobacco ultimately led to an increased demand for cigarettes containing this tobacco.

Two major events in the late 1800s and early 1900s had a tremendous impact on the ultimate growth of flue-cured tobacco production in the United States (11). First was the invention of the cigarette-making machine by James Bonsack in 1884. With increasing demand for use of tobacco in the form of cigarettes, this invention provided a cost-effective way to meet this rising demand. The Bonsack machine, used by James Duke in his tobacco factories in Durham, NC, played an important role in enabling Duke to consolidate much of the cigarette manufacturing industry into his American Tobacco Company. The second event was the introduction in 1913 of the Camel brand of cigarettes by R.J. Reynolds of Winston-Salem, NC. This was the first cigarette brand to utilize what became known as an American blend of tobaccos, containing flue-cured, burley, and Turkish or Oriental types. The American-blend cigarette gained rapid popularity, especially with its exposure internationally during World War I.

Although there were typical commodity production cycles, the volume of flue-cured tobacco grown in the United States generally increased in the first half of the 1900s, reaching a level of over 1.2 billion pounds in 1950. As this growth occurred, the geographical area where flue-cured tobacco was grown expanded to include what is recognized as the flue-cured belt of south central Virginia, eastern and Piedmont North Carolina, northeastern South Carolina, south Georgia, and north Florida. For these farmers the high value and profit potential of flue-cured tobacco offered an attractive farm enterprise.

Many changes occurred as tobacco production evolved from a few hundred pounds in 1612 at the small Jamestown settlement to over 1 billion pounds of flue-cured leaf on the many farms of the southeastern United States by 1950. However, one thing remained constant: the large amount of labor required to grow the crop. With both leaf quality and per-acre yield important in determining the ultimate profit of any year's crop, intense management was required to assure a profit, and that translated into many man-hours of labor. Westbrook and Hungerford reported 403 man-hours per acre for tobacco production in Georgia in 1920 (51). Ninety hours of the 403 man-hours were spent working with a mule in various operations, with the total effort resulting in a yield of just less than 700 pounds per acre. Splinter and Suggs in a 1959 report indicated that flue-cured tobacco production in North Carolina in 1937 required 408 man-hours per acre, and that number increased to 457 man-hours per acre in 1957 due to increased yields and an associated higher leaf count per acre (44). While the 1957 average was 457 man-hours per acre, there was a lot of variability due to farm size and individual farmer practices. Values ranged from 340 up to 550 man-hours per acre. Four hundred and fifty man-hours per acre seems to be a reasonable value for the labor requirements of the late 1940s, with an average yield of around 1,200 pounds per acre. Thus, it required 22.5 minutes of labor to produce and market one pound of tobacco. Labor requirements were further complicated by the seasonal nature of the crop. Much of the labor need was concentrated into the summer months. Additionally, from a farmer's perspective, it wasn't just the number of man-hours required but also the sheer human drudgery involved in many of the tasks involved in producing the crop. It was just plain hard work!

The most efficient flue-cured tobacco farmers of the early 21st century can produce a crop with as few as 50 man-hours per acre, with the human hand never having to touch a leaf. With yields of up to 3,000 pounds per acre, it could require as little as one minute to produce and market one pound of tobacco. Much of the drudgery in growing the crop has been removed. Describing how this tremendous achievement in labor reduction was accomplished is the purpose of this book. The ingenuity of the human mind coupled with the entrepreneurial spirit of many small businessmen and farmers led to this amazing feat. Naysayers said the crop could never be mechanized and they were proven wrong.

Much of the background for this book resides in the documentation of research done at North Carolina State University and the verbal history of some of the researchers involved. Researchers at other land-grant universities certainly contributed to the overall effort, but the core effort, especially in mechanizing harvesting and curing, was done at North Carolina State University and at several small equipment companies. For those who contributed but who are not mentioned in this book, please accept my apology.

Table 1. Summary of major U.S. flue-cured tobacco federal policy and production productivity changes from the 1950s through 2000s

Production Area	1950s	1960s	1970s	1980s	1990s	2000s
Federal Tobacco Program		Lease and transfer, parity index change		Major quota and price support changes		Quota buyout, program ends
Seedling production	Methyl bromide	Plastic covers		Clipping, undercutting, greenhouses	Widespread greenhouse production	
Field production	Tractors, chemical sucker control, transplanters	Chemical weed and disease control	Mechanical topping			
Harvesting	Mechanical-harvesting research	Prototype commercial mechanical harvesters	Commercial mechanical harvesters		Bulk green-leaf handling systems	
Curing	Bulk-curing research	First commercial bulk curing	Widespread commercial bulk curing, big boxes		Bulk green-leaf handling systems, heat exchangers	
Marketing		Loose-leaf sales			Large bale-marketing package	Contracting

1946 to 1949, HOW IT WAS

As this book is about the improvements in efficiency of flue-cured tobacco production and the resulting reduction in man-hours needed to produce the crop, a starting point or baseline would be very helpful from which to describe or measure improvements. The time period of 1946 to 1949 just after World War II is an ideal baseline from which to start. Coming out of the Great Depression of the 1930s and the focus on winning World War II in the early and mid-1940s, little had changed in tobacco production practices in the 20 years or so leading up to 1950. However, the shift from wartime to peacetime released tremendous energy and creativity into improving the standard of living for the domestic population in the United States. This renewed focus on peacetime productivity had a positive impact on all U.S. agriculture, including tobacco.

Federal Government Policy for Tobacco. Tobacco production, like production of many other commodities, suffered from the difficulty of balancing supply and demand. A typical cycle would go from a short supply and high prices to increased production to the point of oversupply with resulting low prices. The low prices would decrease production until again the supply would drop below demand and the cycle would start over again. From the grower viewpoint, the situation of oversupply and low prices was the most serious portion of the cycle. Over the years, growers had attempted various ways of dealing with the oversupply, from forming cooperatives that collectively control production to more drastic measures such as destroying tobacco at the farm level. All of these measures ultimately failed. The Federal Government stepped in with tobacco supply control and price policy in the 1930s. This tobacco policy would play a major role in the structure and efficiency of tobacco farms over the next 70 years.

The first Federal attempt to control tobacco supply came about with the Agricultural Adjustment Act (AAA) of 1933 (15). Tobacco was designated a "basic" (storable) commodity, and cash payments were made to growers who restricted their production. This Act also established the principal of price parity and a farmer committee system to help administer the program. Unfortunately for the growers involved, the U.S. Supreme Court ruled the 1933 AAA unconstitutional in 1936.

A second federal attempt to control tobacco production came about with the AAA of 1938. To growers' benefit, this Act survived any legal challenges and established the basis of tobacco policy that survived until 2004. Basically, the program guaranteed growers a minimum price for their tobacco if they agreed to limit their production. Details of the program included the establishment of tobacco marketing quotas with penalties for excess production, and also provided for 1) the Secretary of Agriculture to determine and announce quotas in advance of a growing season; 2) a two-thirds majority vote by growers in referendum to approve quotas for upcoming crops; 3) allocation of production poundage quotas to states, counties, and individual farms; and 4) price support of up to 75 percent of parity prices for their tobacco, with the base period of 1919 to 1929 used to establish the parity index for price support calculation (39).

Quotas for the 1938 crop had not been announced by the time the crop needed to be planted, which resulted in excess production for the year and discontent among growers at the marketplace. Because of that, quotas for the 1939 crop were not approved in referendum, and production increased 50 percent over 1938, with the oversupply causing additional discontent in the marketplace. Amendments were made to the 1938 AAA that converted quotas from a poundage to an acreage basis. Also, the parity price base period was changed to 1934 to 1939, resulting in a higher price baseline. With these amendments in hand, the growers approved by referendum the program controls for the 1940 crop, and these controls, with amendments, remained in effect until 2004. Minor changes were made to the program prior to 1950, with the most significant being in the AAA of 1949. This Act made flue-cured price supports mandatory at 90 percent of parity when marketing quotas were in effect.

Another important grower event that took place prior to 1950 was the organization of the Flue-Cured Tobacco Cooperative Stabilization Corporation in 1946. This was a grower cooperative that administered the price support portion of the tobacco program for the United States Department of Agriculture (USDA). Stabilization, as the organization came to be known, would buy a grower's tobacco at auction if the price received by the grower was not above established price support levels. Money to pay for the tobacco was borrowed from the Commodity Credit Corporation of USDA through nonrecourse loans. Stabilization would process and store the grower's tobacco and sell it into the marketplace when demand was strong enough. Revenue from the sale was used to repay the loans to Commodity Credit Corporation. The inventory held by Stabilization was a consideration when the Secretary of Agriculture determined the quotas for an upcoming crop.

Thus, in the 1946 to 1949 time period, growers had a federal program that definitely lessened the risk to them of seasonal price changes while providing a somewhat predictable level of production year to year. The stability this program provided flue-cured farmers contributed significantly to the profitability of the crop and the success of many farmers across the flue-cured tobacco growing region.

Growing the Crop. Before a tobacco crop was started in any year, the farmer had to plan for adequate labor to grow, harvest, and market the crop. In the late 1940s the labor was typically provided by family members, hourly workers, and by sharing labor with neighbors. For farmers with larger operations, the use of tenant farmers who grew the crop on shares with the owner of the farm was a common practice. So, while the 450 man-hours of labor per acre required to grow the crop was quite high, the labor supply was generally adequate by utilizing the combination of family labor, hired labor, shared labor with neighbors, and tenant farmers and their families.

One of the first and most important decisions a tobacco farmer made at the beginning of a crop was which variety of tobacco to grow. In the late 1940s the choices were relatively limited (12). While many different names were given to various "varieties," they were essentially farmer selections or strains of one basic variety, the Orinoco. They had interesting names such as White Stem Orinoco, Cash, Jamaica, Virginia Bright, Bonanza, and Yellow Pryor. A University of Georgia publication of that era listed additional varieties such as Crutcher, Adcock, Warne, Hester, and Gold Leaf (8). Hicks was another of the farmer favorites of the era, and there were many farmer selections of that variety. For farmers who had field disease problems, a few varieties with genetic disease resistance were just coming to market, such as Oxford 1, released in 1943 with some resistance to the fungus disease Black Shank, and Oxford 26, released in 1946 with some resistance to the bacterial disease Granville Wilt. Based primarily on his and his neighbors' experience, a farmer chose a variety that he believed best fit the growing conditions of his farm and gave him the best chance for a profit.

The next task facing the farmer was the production of a good supply of seedlings for transplanting into fields at the correct time. Having adequate, healthy seedlings ready at the right time was critical for a successful crop. Due to the need to get plants into the field early in the growing season and the small size of tobacco seed, approximately 350,000 seeds per ounce, seedlings were grown in seed beds from which they were pulled and transplanted into the field.

In the late 1940s, seedbeds were typically grown on "new ground." A farmer cleared some wooded area at the edge of a field, preferably with southern exposure to get better soil warming. This newly cleared soil was relatively free of soil-borne diseases and had low amounts of weed seeds, giving the grower a better chance of a successful seedbed. To help eliminate any potential weed or disease problems, the farmer burned the newly cleared seedbed by piling brush and small logs on the ground and burning them in an attempt to sterilize the soil to a depth of 3 to 6 inches (12). Another method used to sterilize seedbeds was steaming the soil (9,22). However, this was an expensive and time-consuming process, and most growers did not have the equipment for steam sterilization. During this timeframe, some growers started using a form of chemical weed control by applying a pound of urea and a half pound of cyanamide per square yard of seedbed area, with mixed results (12). Thus, burning brush on the soil remained the most common method used for weed and disease control.

After applying fertilizer to the seedbed site, the farmer was ready for the all-important seeding process. A rule of thumb was to seed a 100-square-yard area to produce enough seedlings to plant an acre of tobacco. This amount of seedbed normally produced excess seedlings but, to be sure the farmer had enough seedlings at the right time, the additional seedbed area was a cheap form of insurance. A seeding rate of 1/8 to 1/6 oz of seed per 100 yard^2 ideally gave a plant density of about 40 plants per square foot, which resulted in a desirable seedling ready for the field in about 90 days (20). With the small size of the seed, farmers typically mixed the seed with sand, ashes, or fertilizer prior to sowing by hand. After seeding, the seedbeds were covered with cotton canvas (cheesecloth) to protect the emerging young plants from cold temperatures. If sufficient rainfall did not occur, the seedbeds were watered to aid seed germination and growth. Also, if the weed control was not successful, the canvas covers were removed so the competing weeds could be removed by hand, which gave the tobacco seedlings a chance to grow. About 19 man-hours per acre were used in producing the tobacco seedlings (44).

With the seedbeds seeded, the farmer now turned his attention to getting the fields ready for transplanting. Tractors were just starting to be a part of farming operations in the tobacco growing region in the late 1940s, so most farms still used horses and mules for soil tillage and cultivation. The farmer used a mule and turning plow to turn over or "break" the topsoil, burying any debris from the previous crop. After breaking, in another pass over the field, the soil was disked or harrowed to smooth and prepare it for running the rows. Using turning plows or opposing disk blade implements, again pulled by mules, a row with a low ridge was established in the field. Rows were typically four feet apart, and often the first application of fertilizer was placed in the row at the time of row formation. To assure uniformity in plant population per acre, the farmer sometimes returned to the field and marked the spacing on each row where a tobacco plant should be placed. This was accomplished by pulling a marking device at right angles to the rows or walking along each row and knocking the top of the ridge off with a weeding hoe at the correct intervals. Plant spacing within each row ranged from 18 to 30 inches, with a typical plant population of 5,000 to 7,000 plants per acre. About 27 man-hours per acre were used in preparing the land for the upcoming transplanting (44).

If a grower did a good job and weather cooperated, his fields were now ready for transplanting, and his seedbeds had produced seedlings of the correct size to go into the field. The labor crew involved in the day's transplanting first went to the seedbeds and pulled by hand the necessary number of plants to be transplanted into the field that day. Much drudgery was involved in this process, and care was taken not to bruise the plants as they were pulled from the seedbeds. Once the plants were pulled from the seedbeds, they were taken to the fields for transplanting. One of several techniques was used to put the plants in the ground. In rare instances there were mechanical transplanters that were pulled by mules to aid in getting the plants into the ground. Another technique that was used, especially after a rainfall when sufficient moisture was in the ground, was to peg the plants into the ground. This normally consisted of one person dropping individual plants along a row at the marked intervals. A second person came along with a wooden peg and made a hole in the ground with the peg, placed the plant into the hole and then packed soil around the plant roots. The most common method of putting plants into the ground in the late 1940s was with the use of a hand transplanter. This device took two people to operate and consisted of two tube-like cylinders that came to a point at the base. One tube was used

Figure 1. A typical conventional plant bed scene where seedlings are being removed by hand for transplanting into a field.

for dropping plants and the other contained a water supply. They were connected by a trigger mechanism. The operator placed the transplanter into the ground at the correct interval while simultaneously the second person dropped a plant into the plant cylinder. The operator then pulled the trigger, releasing the plant into the ground with a measured portion of water. The operator then packed soil around the plant roots by pressing with his foot. This technique was a definite improvement over pegging the plants. In addition to the operator and plant dropper, another person was required to keep the transplanter supplied with water and the dropper with plants. As a whole, the transplanting operation consumed about 30 man-hours per acre (44).

With the tobacco plants in the field, a farmer's attention now turned to assisting Mother Nature in actually growing the crop. The main task was keeping the crop free of grass and weeds, which consumed about 38 man-hours of labor (44). This was accomplished entirely by mechanical means, that is, cultivating with mule-drawn plows and using hand hoes, because there were no herbicides available for tobacco. A crop was cultivated typically three or four times as it grew, with fertilizer being added to the crop at one or two of the cultivations depending on individual farmer practices. Fertilizer was added by hand or with a mechanical distributor attached to the cultivator. Normally, after the first cultivation, the entire crop was weeded by hand with a hoe to control any grass and weeds missed by the cultivation. As the crop grew, the enlarged leaves also helped control grass and weeds by blocking sunlight. Each cultivation added soil to the base of the plants and

Figure 2. Hand transplanter being used to transplant seedling into a field while adding water to seedling at the same time. Notice that one person operates the transplanter while the other drops the plants.

established a ridge for the plants to grow on. The last or "lay by" cultivation pushed a considerable amount of soil around the plant base, assuring a high ridge for the plant to grow on for the rest of the season. This ridge also provided good drainage to move any excess water away from the plants.

As the tobacco plants neared maturity, indicated by flowering, it was time for the last field operations prior to harvest: topping and suckering. Actually, topping and suckering sometimes conflicted with the labor needed for harvesting and put a stress on a farmer's labor supply. The tobacco plant has a terminal bud that, if not removed, will flower and produce seed. Since the farmer is interested in producing leaves, not seeds, the top (terminal bud) is removed, leaving 16 to 20 leaves on the stalk. Topping encourages the plant to direct its growth to producing larger, thicker leaves and thus more per-acre yield, with a higher net return. However, the plant is not so easily fooled. Once the plant is topped, 2 or 3 buds between each leaf axial and the stalk start to rapidly grow and attempt to produce seed. These auxiliary buds, or "suckers," must be removed to keep the plant growth going to the leaves. In the late 1940s all topping and suckering was done by hand and required about 34 man-hours per acre (44).

When the tobacco plants started to produce the flowers, a topping crew went through the field and broke out the flowers. Any early sucker growth was eliminated at time of topping. As workers went through the field and touched each plant, often they would also use the opportunity to perform insect control by removing by hand and killing any of the commonly found tobacco hornworms that were on the plant. After topping and the resulting rapid growth of suckers, a work crew was needed on a weekly basis to walk through the field and remove the newly formed 2- to 4-inch suckers by hand. If not removed, suckers could rapidly grow to a foot or more in length. When this suckering labor demand conflicted with harvesting, harvesting took priority. So, with the tobacco plants topped, suckered, and nearly completely grown, it was time for the harvesting process to begin.

Harvesting and Curing. As the tobacco plant matures, its leaves gradually ripen from the bottom of the stalk to the top. For the varieties used by farmers in the late 1940s, the rate of ripening was 2 to 4 leaves per week. Ripening was indicated by a leaf color change from a dark green to a soft or pale yellow. The color change was easily detected by the human eye, and the person harvesting the tobacco decided on a stalk-by-stalk basis which leaves to harvest. A field was harvested weekly, so the entire harvesting process took 5 to 7 weeks. In certain parts of the U.S. flue-cured growing area, harvesting of the leaves was also referred to as priming or cropping. The harvesting, barning, and curing process was the most labor-intensive part of the tobacco production cycle, requiring about 145 man-hours per acre over the 5- to 7-week period (44).

A harvesting crew consisted of 2 to 4 men and a mule that pulled a sled or "slide truck" through the field to collect and transport the harvested leaves. Each harvester or primer was responsible for harvesting the leaves from one row as he went through the field. Sometimes a primer harvested the leaves from 2 rows at a time by rotating between two adjacent rows to pull the leaves. However, the extra motion required was especially tiring and usually not as efficient as priming 1 row at a time. As a primer broke the leaves from the stalk, he placed them under his arm until he could carry no more. He then took the arm load and placed it in the sled and returned to priming more leaves. A well-trained mule responded to verbal commands and advanced down the row keeping up with the primers. Once the sled was loaded, a person guided the mule to the curing barn where another labor crew prepared the leaves to go into the barn.

Harvesting the leaves from the field was one of the most physically demanding and unpleasant tasks in the whole production cycle. The primer was required to walk down each row in a stooped position to reach the leaves. This was especially difficult when harvesting the very bottom leaves—the first priming—for it required one to put his head at almost ground level to see the leaves. Since harvesting took place mostly in July and August, it was also a very hot task. It was not unusual for a primer to stay wet practically all day, in the morning from the dew on the leaves and later in the day from perspiration.

When the loaded sled arrived at the curing barn, it was unloaded and the leaves were placed on a table to be strung onto sticks ready for curing. A barn crew unit consisted of 2 handers and 1 stringer. Depending on how rapidly

Figure 3. Hand-harvesting leaves at the first harvest from the bottom of the plant.

the leaves were coming in from the field, there would be 2 or 3 stringing units for a total of 6 to 9 people putting leaves on the stick. Typically, a hander put 2 to 4 leaves together to form a “hand,” which was given to the stringer. The stringer looped the hand of leaves onto a stick with cotton twine and pulled them tight so the leaves would not fall off the stick. This action was repeated until the length of the stick was filled with hands of leaves, normally about 90 to 100 leaves per stick. Then the full stick was placed onto a pile or hung in racks until enough sticks were strung to fill a barn.

When enough tobacco had been harvested to fill a barn, normally late in the afternoon, the harvesting crew came in to help the barn crew finish up and then get the sticks hung in the barn for curing. Although some masonry barns existed, most barns of the day were wood frame, with dimensions of 16×16 ft^2 or 16×20 ft with a height of 18 to 20 ft. The barn interior was divided into 4 or 5 rooms, each 4 ft wide with 6 or 7 vertical tiers about 2 ft apart. Two men climbed into the barn, one above the other, to hang the sticks. A crew then formed a line and passed the sticks from the pile or rack, one by one, up into the barn to be hung on the tier poles. Depending on size of the tobacco and the barn, a barn held between 400 and 600 sticks. With the barn uniformly loaded with sticks of tobacco, the farmer was now ready for the all-important curing process.

Curing of tobacco, as opposed to straight drying, was and still is part science and part art. While drying is a straightforward removal of water, tobacco curing is a controlled moisture removal to bring about desired color and biochemical changes in the leaf. Proper curing captures the inherent

Figure 4. Leaves are being strung on a stick using cotton string in preparation for hanging in a barn for curing.

quality aspects of the leaf. Because net income for the farmer depended on both per-acre yield and leaf quality, this was a critical part of the production cycle. The curing atmosphere or schedule used in the late 1940s is very similar to the one used today and will be discussed in more detail later in the book. The curing schedule consisted of 3 parts: leaf coloring, leaf color setting and drying, and stem drying. The curing atmosphere was controlled by elementary but generally effective means. A dry bulb thermometer was used for temperature control, and natural ventilation was used to control humidity. A low temperature and high humidity was needed for yellowing, with the temperature increasing and humidity decreasing during color setting and leaf drying. A higher temperature with low humidity was needed to finish the stem drying. A typical cure required from 5 to 7 days to complete.

From a labor and drudgery viewpoint, the type of fuel used to generate heat for the curing process was a very important consideration. Prior to World War II wood was the predominant curing fuel for tobacco; however, with the greater availability of petroleum products and electricity on the farm after the war, farmers started shifting away from wood. Mr. Bill Long, of what later became Long Manufacturing Company in Tarboro, NC, was one of the first suppliers to offer oil burners for tobacco curing with the Buckeye brand in the early 1940s (W. Denton, personal communication). During World War II he also developed the Silent Flame brand, which became very

Figure 5. Tobacco leaves on sticks are being hung in a barn prior to curing.

popular with tobacco growers. A survey reported by Hassler showed that in North Carolina in 1947 about one half, or 127,000 of 252,000, barns still cured with wood (19). Of the remainder, 104,000 used oil and 20,000 used coal.

For farmers who still used wood, curing tobacco was an especially arduous process. In the winter, prior to the next crop, trees had to be cut and hauled to the curing barn, where the wood was split and stacked to dry prior to the curing season. When the curing season arrived, the person in charge of curing practically lived at the curing barn. Since temperature was so important in the curing process, wood loading of the furnace was critical to maintaining the correct temperature. Especially during the leaf and stem drying stages, when a higher temperature was required, the wood furnace had to be stoked with additional wood every 2 or 3 hr, which allowed the curer little time for restful sleep. It is easy to see why farmers were shifting to oil as a fuel of choice. Even though it was more expensive than wood, oil required much less total labor (no wood cutting and hauling) and better control of temperature through flow regulators that allowed the curer an opportunity to get more sleep at night.

With a cure complete, the cured leaf had to be removed from the barn to allow refilling the barn for the next cure. A barn went through 5 to 8 curing cycles per growing season. To remove cured leaf from the barn without breaking or crumbling, the moisture content of the leaf had to be increased from the near bone-dry condition at the end of curing. This was accomplished by opening the barn doors and ventilators to allow moist night air to enter the barn and bring the tobacco into order, or "case," as it was commonly described. With the leaves in good order, emptying the barn was just the reverse of filling it. Two men climbed up into the barn and removed the sticks of cured leaf, usually 2 sticks at a time, and passed them out of the barn where they were piled onto a farm wagon or truck to be transported to a storage building or "pack house." This was an especially unpleasant task when removing lower-stalk-position harvests, such as the first priming, because some sand from the field was still on the cured leaves and easily fell off the leaves and down the back or into the eyes of the men in the barn. Once at the pack house, the sticks of cured tobacco were unloaded and placed into piles to await market preparation. Often this tobacco was repacked several times for aeration and removal of any damaged leaves.

Grading and Marketing. The final part of the production cycle for the farmer was preparing the tobacco for market and getting the tobacco sold. At about 116 man-hours per acre, the labor requirements for this portion of the crop cycle were almost as demanding as harvesting and curing (44). However, the labor requirements here were not as physically demanding as harvesting and curing. Having a paycheck on the horizon also made this task a little more pleasant for the farmer.

Most farms had a dedicated building, called a "strip room," where leaves were stripped from the stick and prepared for market. Normally it would be a one-room building of varying size with an earthen pit dug beneath the floor that contained wooden racks to hold sticks of cured tobacco. The moist air in the pit was used to bring the tobacco into order so the leaves could be handled without crumbling.

The market preparation step started with removal of the tobacco from the pack house. Tobacco was loaded onto a farm wagon or truck and taken to the strip room and unloaded into the pit. This was done late in a day so the tobacco would come into order overnight and be ready for grading the next day. The sticks of tobacco were taken out of the pit and piled in the strip room. Then the stringing process was reversed and the leaves taken off the stick by "pulling" the leaves from the cotton string that held the leaves on the stick. The individual leaves were then put in piles for the all-important grading process.

Grading was another part of the crop cycle where farmers had their own individualized way of doing things that they believed added value to the final product before going to market. Within a single harvest or stalk position, grading was done to separate the leaves based primarily on color. A skilled farm worker who knew how to make the needed color distinctions in grading was a valued person. Typically there would be 3 separate grades, although some farmers made up to 5 or even more. There was the main grade, which consisted of the majority of the leaves and had a relatively uniform yellow or orange color. The other 2 grades were for leaves that did not match the predominant color. One was a darker brown, or "trash," representing leaves that yellowed too long during curing and were oxidized. The other grade was "green," or leaves harvested slightly unripe that did not yellow enough during the curing process, resulting in a light green color. Farmers who made more than 3 grades split the main grade into different, more uniform shades of yellow or orange.

The grader took a pile of leaves, inspected each leaf individually, decided which grade it should go into, and placed the leaf on the grading table designated for that grade. Another person then took a handful of leaves from a grade and tied them into a hand by using a folded leaf to wrap around the butt or stem end of 40 to 50 leaves. This was a very artful process, with each person having a unique way of tying the hand that was nearly as identifiable as the person's signature. Care was taken to choose a tie leaf that was of high quality, for it would be very visible to buyers when the tobacco was placed on the auction floor. After the hands were tied they were packed down, each grade separately, and pressed with a board to smooth out the leaves and give the tobacco a neat appearance. When all of the tobacco from a particular barn or harvest was graded, tied, and packed down, it was then again placed on sticks that had been smoothed. Each individual hand was put on a stick, with a full stick containing 20 to 25 hands. The sticks of tied tobacco were then loaded onto a truck or wagon for transport to market.

The farmer delivered his tobacco to a warehouse where it was later sold at a public auction. The warehouse normally was owned and operated by an independent businessman, although there were a few warehouses operated by grower cooperatives. In return for providing a place to sell his crop, the farmer paid the warehouseman certain fees plus a percentage commission on the value of the tobacco sold. As the farmer delivered tobacco to the warehouse, it was removed from the sticks and neatly packed in piles on wooden baskets, with each pile weighing up to 300 pounds. The piles of tobacco were then placed in rows within the warehouse for sale. On the day of the sale, the tobacco was inspected by graders from the USDA. As provided by the federal tobacco program, the USDA inspectors placed a USDA grade, which carried a corresponding price support level, on the tobacco. At the auction sale, representatives of buying interests, including tobacco manufacturers and leaf suppliers, bid on the piles of tobacco. The auction was lead by an auctioneer hired by the warehouseman. In a rapid and colorful process, the auctioneer indicated which buyer was the highest bidder for each pile of tobacco. If the bid price was above the federal price support level, the buyer owned the tobacco. If the bid price was at or below the federal price support level, the tobacco was taken in by Stabilization, processed, stored, and sold at a later date. The warehouseman then wrote the farmer a check for his net proceeds. The crop year had now come full circle.

Closing Comments on How It Was. From this description it is hoped that one can get a sense of the tremendous amount of labor required to produce and market tobacco and the demanding physical and repetitive nature of this labor. A report by Giles estimated that growing and marketing an acre of tobacco involved 240,000 leaf handlings plus an additional 29,000 stick handlings (13). Giles summed it up nicely when he said "from this, one can better appreciate the disagreeable and time consuming job of producing tobacco and can better understand why hand labor is listed as one of the chief objections to farming as a profession." It was just plain hard work!

1950 TO 1969, DEVELOPING TECHNOLOGY

Federal Government Policy for Tobacco. During the 1950s and 1960s, the federal tobacco program continued to provide a relatively stable production base and market for U.S. flue-cured tobacco producers. Marketing levels averaged around 1.1 to 1.2 billion pounds within a range of 1.0 to 1.4 billion pounds, and market prices increased from 55 cents to 72 cents per pound over the 2 decades. However, there were several changes made to the program, some of which affected the efficiency of producing the crop (15).

Faced with price supports increasing more rapidly than world market prices, a continuing issue with the program, the 1960 price support level was frozen at the 1959 level. Additionally, the formula for future crops was changed to reflect a moving 3-year average of the Parity Index compared to 1959 instead of the 90 percent parity level as passed by Congress in 1949. The net effect was to slow, for a few years, the rate of price support increases for future crops and to make U.S. tobacco more competitive in the world marketplace.

Beginning with the 1962 crop, a grower within a county could lease and transfer quota from a farm in the county to his own farm instead of having to grow the tobacco on the farm to which the quota was assigned. This policy change allowed, for the first time, a grower to consolidate onto one farm enough production to begin realizing some benefit from the economies of scale. A reduction in production costs was also realized by not having to move equipment and labor from farm to farm, allowing the farmer to stay focused on one geographical location.

The increasing per-acre yields resulting from better varieties and cultural practices were making the acreage production control portion of the tobacco program less effective. Thus, in 1965 the acreage control of production was changed to a combination acreage/poundage control system that allowed a grower to sell only so many pounds, which were to be produced on a specified number of acres. This change was made to better control the pounds sold and to encourage production of tobacco that was in demand.

A simple change in marketing policy in 1968 was a defining point in labor reduction that opened the door for acceptance of mechanical harvesting, which will be discussed in more detail later. The change was the acceptance of loose-leaf marketing. Loose leaves, not tied in bundles, had been the historical method of marketing in the Georgia-Florida belt of the production area. In 1968, loose leaf marketing was extended to all belts of the production area, resulting in a tremendous reduction in farm labor for the farmer. So, while no major revisions of the tobacco program were made during this time period, changes were made that aided in the reduction of labor requirements and encouraged the development of mechanization.

Growing the Crop. The labor situation for tobacco farmers began to change during the 1950s and 1960s. With more off-farm employment opportunities becoming available, some tenant farmers and their families sought other employment where skill and education levels allowed options. Children of farmers were less likely than previous generations to stay on the farm when they became adults. Family size also began to decrease. Thus, the tobacco farmer was facing pressure to reduce labor requirements or find other sources of labor for the farming operation.

Significant changes came about in this time period relative to the varieties available to be grown and how the seedlings of these varieties were produced. Developments in these two areas helped farmers meet some of their reduced labor needs. These changes both increased the per-acre yield and reduced the amount of labor required to get the seedlings into the field.

As late as 1954, the varieties grown by farmers were still localized, and any one variety made up a very small percentage of production. It was estimated that as many as 70 cultivars were still being grown that year (4). The situation was about to change. Dr. Hoyt Rogers, of Coker Seed Company, bred and released a new variety in 1955, Coker 139, that immediately changed the seed business. The variety increased per-acre yield by 30%, and within 2 years, 50% of the flue-cured acreage was planted with this one variety (4). However, this variety had physical, chemical, and smoke flavor properties undesirable to the buying interest, and much of this production went into Stabilization stocks. The USDA declared this and similar varieties, such as Coker 316, as “discount” varieties with reduced price supports, and plantings of these varieties diminished quickly. Coker 139 was an important milestone, however, for its enhanced yield potential led to its being used extensively in breeding programs by university and private plant breeders alike.

Other significant varieties that became available to growers in this time period were Coker 298, Coker 258, Coker 254, and Coker 347. From Speight Seed Farms came Speight G-28, developed by Mark Grimsley, which became popular in the late 1960s. From the breeding program at North Carolina State University came NC 2326, a very high-quality variety especially desired by export customers. The Oxford Tobacco Research Station increased the number of multiple resistant varieties in 1953 by releasing Dixie Bright 101, which had some resistance to both Black Shank and Granville Wilt. The variety NC 95, released in 1961, was the first variety to carry some resistance to Granville Wilt, Black Shank, Fusarium Wilt, and Root Knot Nematodes.

Another notable development in the seed industry was the establishment of a Minimum Standards Program to assure the quality of future varieties (3). An outgrowth of the poor end-user quality of the discount varieties in the mid 1950s, this action was a joint, voluntary effort of public and private plant breeders, the USDA, state departments of agriculture, land grant universities, tobacco leaf suppliers, and tobacco manufacturers. The foundation of this program was laid at the 1958 Tobacco Workers Conference at Athens, GA. Later, an MS thesis at North Carolina State University examined 6 widely different varieties of the 1956 to 1960 era. These varieties were evaluated for 49 chemical and physical properties in cooperation with 7 buying companies. Data from this research provided the basis for the Minimum Standards Program. Field trials began in 1963, and the first varieties that met the minimum standards were released in 1964. Thus, growers in this time period had a choice of varieties that increased per-acre yield and a program that assured that future varieties would meet yield, quality, and disease-resistance standards valued by growers and buyers alike.

With varieties available to the farmer vastly improved, the method of transplant production was also ripe for efficiency improvements. One of the earliest and most dramatic improvements came in the area of weed and disease control. This improvement was the practical sterilization of the plant bed top soil by fumigation with methyl bromide, which started being used in the early 1950s (20). This was a giant leap in weed control that, if properly applied, eliminated hand pulling of weeds in the plant bed. Fumigation with methyl bromide was also effective in controlling nematodes and any insects in the top 6 inches of the soil. This practice also eliminated the need to clear new ground for plant beds each year since good seedbed locations in the edge of fields could be used more than once. To fumigate with methyl bromide required the farmer to cover the seedbed with a material, usually plastic, that would hold the vaporized gas and allow it to penetrate the soil.

Using plastic covers on the plant bed brought about another change. As in the 1940s, the plant bed needed to be covered after seeding to protect the young plants after they germinated and were in early growth stages. For a number of years this continued to be done predominately with cotton cheesecloth covers. However, since they already had plastic covers, some growers started using the plastic covers after seeding, which created a generally warmer environment for the emerging plants. If coupled with good plant bed practices, the use of plastic covers resulted in better seed germination and more rapid growth of plants. Seedlings ready for the field could be produced in about 65 days in North Carolina using plastic covers compared with about 90 days with cotton cheesecloth covers (20). Greater management of the plant beds was required when plastic covers were used because the temperature under the plastic could easily get high enough to kill the tender plants. Because of this fact it was recommended that the plastic be perforated when the seed bed was sowed and removed completely when outside temperature reached 85°F or higher. The use of these plant production advances increased the chance that the farmer would have weed-free and disease-free seedlings ready to go into the field at the right time with less labor and drudgery.

Land preparation was another area where tremendous labor reductions were achieved. The use of mules rapidly gave way to tractors in the 1950s, and the use of mules in tobacco production practically disappeared by the late 1960s. Tractor-drawn turning plows and disks could rapidly prepare many acres of land for subsequent operations. The bedding of rows prior to transplanting was also done with tractors pulling disk bedders. Initially this was usually done one row at a time, but as more powerful tractors were used, 2-row and 4-row bedding became possible by the late 1960s. Again, this was a tremendous saving of labor and drudgery.

The transplanting operation also afforded some improvements in labor efficiency in the 1950s and 1960s; however, the improvements were not as dramatic as in some other areas. Even though the plant beds were now generally weed-free and more uniform in seedling size due to the use of methyl bromide and plastic covers, the seedlings still had to be pulled by hand. This was still a very time-consuming and backbreaking task. However, improvements were made in getting the tobacco plants transplanted into the field. With the advent of tractors, mechanical transplanters that had been mule drawn were adapted to be pulled by tractors. The more simple designs provided a place for the workers to ride such that they placed the plants by hand directly into an opened furrow made by the transplanter. The transplanter also added water to the freshly placed plant, and a wheel pressed soil around the plant roots. More advanced designs had mechanical fingers into which plants were placed by the workers and the fingers rotated and placed the plants into the soil. Either version required 2 workers per row to be able to place the plants into the transplanter at a reasonable rate. Most early models of these machines were 1-row, but later models were 2-row, and by the late 1960s, 4-row models were being used.

Various companies began manufacturing and marketing transplanters so that farmers did have some choices when it came to purchasing these machines. Powell Manufacturing Company, formed by 3 brothers in Wilson, NC, after World War II and incorporated in 1951, manufactured mechanical transplanters for tobacco farmers in eastern North Carolina. The business was successful, and its market expanded into most of the flue-cured and burley growing areas. In a 1956 research report, Splinter and Suggs reported on studies of 3 brands of transplanters: Lee, Holland, and Powell (42). The Lee machine involved direct hand placement of plants into the soil while the Powell and Holland brands utilized mechanical fingers to place the plants into the soil. Since these types of machines could be used to transplant other plants such as vegetables, they became quite common in tobacco-growing operations.

Beginning in the early to mid-1960s, research at North Carolina State University was conducted on completely automating the transplanting operation. As part of the overall effort to reduce labor input and improve crop uniformity, Dr. W.E. Splinter, Dr. C.W. Suggs and Dr. B. Huang undertook the task. The concept was to produce transplants in rectangular trays, with the plants in defined rows and columns with a plant in each cell. A tray of plants was then placed on a specially designed transplanter. The tractor-drawn machine advanced a plant-holding cell over an opening such that a plant fell through a chute and into an opened furrow in the ground. Once in the ground, a press wheel firmed the soil around the plant. As the machine went through the field, a mechanism advanced the tray cells over the opening so that a plant fell to the ground at the desired interval. Considerable effort was devoted to this project; however, the concept proved very difficult to put into practice. The main difficulties were in producing uniform seedlings with 100 percent of the cells filled with plants and in the mechanical reliability of the transplanter.

Grass and weed control in the growing crop was another area where labor reductions were achieved during this period. The most significant event was again the replacement of the mule with the tractor. Cultivation of tobacco with a tractor was much more efficient than using a mule for the same job. The ability of the farmer to do a really good job with tractor cultivation was greatly aided by the development of the offset 1-row tractor. Models such as the Farmall Super A and Farmall 140 from International Harvester and the Ford 541 became staples of any tobacco-farming operation, especially from the mid-1950s through the 1960s. In addition to cultivation for weed control, the use of these tractors made other tasks such as building a row ridge, fertilizer application, and the spraying of insecticides much more time efficient.

Chemical weed control also came into its own during this time period, primarily in the mid- and late 1960s. Some of the first research on the potential of using herbicides on tobacco was conducted by Robert Wilson beginning in 1949 (52). The studies were continued in 1950 and 1951 in collaboration with Dr. Glenn Klingman of the Agronomy Department at North Carolina State University, and their results were presented to the Southern Weed Conference in 1952 at a meeting in Atlanta, GA. Dr. Klingman continued with basic research in chemical weed control. As a result of his evaluations, Diphenamid (Enide), Tillam, and Dacthal were labeled for use on flue-cured tobacco in 1963 (27). While more effective herbicides were developed by chemical companies in later years, these early herbicides demonstrated that it was possible to reduce hoeing by hand and, at the same time, reduce the number of tractor cultivations needed to control grass and weeds.

Another area of efficiency gain and cost reduction was in the use of higher analysis fertilizers. During much of this period, the fertilizer commonly used was 3-9-9 at the rate of 2,000 pounds per acre. This analysis fertilizer had about 50% filler, which provided no benefit to the farmer. North Carolina State tobacco extension specialist S.N. Hawks, Jr., and Dr. W.K. Collins led an on-farm educational program to demonstrate the benefit of higher-analysis fertilizers. Using fertilizers such as 6-18-18 with limited filler at the rate of 1,000 pounds per acre gave the same quality and yield as 2,000 pounds of 3-9-9. The change to higher-analysis fertilizer by farmers took about 10 years due to the resistance of the fertilizer industry. However, this change ultimately lowered labor, transportation, and handling costs for farmers due to the reduced weight of fertilizer needed to produce the crop.

The other major productivity improvement related to growing the crop in the 1950s and 1960s was in chemical sucker control. With the tremendous labor requirement for hand removal of suckers and the conflict of this labor requirement with labor needs for harvesting, researchers worked for many years to find a way to control sucker growth chemically. A 1952 research report by Robert Wilson contained a summary of a sucker control seminar held on the North Carolina State University campus (53). Dr. W.G. Woltz reviewed the benefits of best practices in sucker control and stated that they provided a 30% increase in value per acre. Dr. H.T. Scofield reviewed the history of attempted chemical control, with most of the earlier work focused on the use of oils to damage or kill the emerging suckers. In his book, S.N. Hawks, Jr., discussed some of the earlier uses of oils to control suckers (20). Mineral oil emulsions were found to work best and were used by applying oil to the top of a plant after the flower had been removed. The oil ran down the stalk, contacted the suckers at the leaf axils, and controlled the suckers by burning the tender leaf tissue. However, there were considerable problems with this method. If the oil contacted the desirable leaf tissue it also caused damage. Weather conditions and oil concentrations also greatly affected the end result. It was common for the oils to damage the leaf axils, causing leaves to fall off the stalk and in some instances kill the entire stalk. While oil emulsions were used in the early and mid-1950s, they quickly gave way to what became a grower standard, the plant-growth regulator maleic hydrazide.

The use of maleic hydrazide (MH) to control suckers had become widespread by the mid-1950s. With the advantage of being a systemic material, MH could be sprayed on the leaves of a plant, where it was absorbed and translocated to all parts of the plant, including all of the suckers. MH limited sucker growth by stopping cell division within the leaves. One disadvantage of MH was that if it was applied too early, before leaves had their normal number of cells, it would stunt the growth of the upper tip leaves, reducing both yield and quality. This problem was solved by incorporating the use of contact sucker control materials, such as fatty alcohols, prior to using MH. This research was pioneered by Dr. Bill Collins at North Carolina State University in the early 1960s and gained widespread use by growers by the mid- to late 1960s. The fatty alcohols, at a 4 to 5% percent concentration, killed young suckers upon contact with them without damaging more mature leaves. The development of improved spraying equipment for use with tractors made the use of fatty alcohols both practical and effective. The practice allowed farmers to kill early suckers with the fatty alcohols, top the plants at an early flower stage, and follow with an application of MH, resulting in good sucker control until harvest was complete. This sucker control practice allowed better development of the tip leaves and resulted in improved yield and quality over the use of MH alone. Another significant implication of this advancement in sucker control was that it helped pave the way for mechanical harvesting in the immediately following years.

Harvesting and Curing. The 1950s and 1960s can clearly be called the golden era of technology development as far as flue-cured harvesting and curing are concerned. During the 1950s, the foundation was laid for revolutionary changes in how tobacco was harvested and cured. During the 1960s, this technology was refined to the point of adoption by some flue-cured growers. However, at the beginning of the decade of the 1950s, one would not have anticipated the major changes that were coming. At North Carolina State University there were two research projects in the then Agricultural Engineering Department focused on mechanical aspects of tobacco production and the improvement of curing.

A project headed by Robert Wilson was concerned with engineering studies in tobacco production (52). Some of his work has been previously mentioned. He was focused mainly on improving weed control techniques through investigation of the potential of chemical weed control along with improving cultivation techniques. He investigated the use of rotary hoes and other implements in cultivating tobacco. His work was published in an experiment station bulletin in 1956 (55). His other line of investigation focused on using oils for sucker control, and he was heavily involved with efforts to develop a hand-operated device that would both top the plant and also correctly apply the sucker control oil. Both lines of investigation were timely and held the potential of reducing labor but were not directly related to mechanically harvesting tobacco leaves.

A similar situation existed with curing. Here the project—curing and grading of bright-leaf tobacco—was a little broader, involving the USDA, the Agricultural Engineering and Agronomy Departments, and the North Carolina Department of Agriculture. Project personnel included Mr. J.M. Carr, Mr. R.W. Gupton, Dr. F.J. Hassler, Mr. H.B. Puckett, Mr. N.W. Weldon, and Dr. J.A. Weybrew. The focus of this work was of a more fundamental nature in better understanding the curing process and would have some application in later curing developments (17). It was established that removal of up to 30% of initial moisture by drying actually helped the yellowing process. A maximum yellowing temperature was established at around 105°F. Other research involved studying the browning reaction, which they found to have a maximum rate at 135°F, and some practical research on design and use of a bituminous coal stoker furnace as a heat source for curing. Yet, there was little in this project work that foretold the major shifts in curing that were on the horizon.

The defining moment in flue-cured tobacco mechanization came in 1953 when Dr. G.W. Giles, then department head of Agricultural Engineering, published a treatise that called for action on mechanizing harvesting and other operations of flue-cured tobacco production (13). He pointed out that while tobacco provided a very high gross return per acre, the net return was low due to high labor requirements. When put on a return per labor hour basis, the labor for tobacco production was returning less per hour than other crops being grown in North Carolina at the time. He pointed out the progress that was being made through tractor use, new cultivation techniques, and new sucker-control practices. He also pointed out the lack of progress in harvesting and barning, which were consuming 165 of the estimated 480 man-hours per acre to produce the crop. Progress had to be made in these areas to maintain tobacco production as a viable enterprise in the southern United States. Giles was one of the first to point out that foreign countries such as China, India, and others in Africa and South America had abundant supplies of cheap labor and had the potential to supply the world needs for flue-cured tobacco. His solution to the labor problem was a major research initiative focused on mechanization. He stated,

> "The research for this long range approach should be carried out on harvesting, curing, grading and marketing and should be well integrated. This is justified when one recognizes that curing methods and procedures influence the harvesting and the grading. For example, the curing process determines the quality, the degree of ripeness of leaf and the manner in which the leaf is handled and presented for curing. It is conceivable that a curing process may be devised whereby more of the leaves can be harvested and handled at the same time. In somewhat similar manner, the curing process determines the extent of grading and the manner in which the leaf is handled for grading. It is conceivable that knowing what leaf to prime and what curing environment is required that fewer grades will emerge from the curing process thus simplifying the grading and marketing and making possible improvements in practice (13)."

The call to action had been made, and now it was up to researchers to deliver the needed technology.

Mechanical harvesting research started late in the 1953 growing season following the Giles treatise in May of that year. Robert Wilson remained as project leader of the research and he was joined in late summer by a young graduate student Charles W. Suggs. Charlie Suggs, as he was better known, came to the Agricultural Engineering Department to pursue a master's degree following his former job as superintendent of the Lower Coastal Plains Research Station near Greenville, NC. (The station was later moved to a location near Kinston, NC.) Suggs continued his graduate studies and later received the first Ph.D. degree from the then Agricultural Engineering Department at North Carolina State University. One of his timely accomplishments as a research station superintendent was the demonstration of being able to produce a tobacco crop without mules, but instead relying solely on tractors (C. Suggs, personal communication). Since it was late in the growing season when Suggs joined the research project, little was accomplished that first year. However, several mechanical means were tried for removing leaves from the stalk (54). While no conclusions were made, it was demonstrated that mechanical devices could remove the leaves from the stalk by striking the leaf stem where it attached to the stalk without causing any significant leaf damage.

The project was expanded in 1954 to include a machine frame that was attached to a high-clearance tractor so that various leaf-removal devices could be tested in the field (54). No efforts were made to collect the leaves but rather just to evaluate various designs of defoliators. An objective was to remove ripe leaves from both sides of a row and also in line with the row in a single pass through the field. Some success was achieved, with two devices showing the most promise. One was described as an echelon mounted finger bar unit. The operation of the unit was described as follows: "the finger bar unit is made up of three bars with rubber fingers mounted on the bars. The bars move with a roulette motion so that when in operation the removal

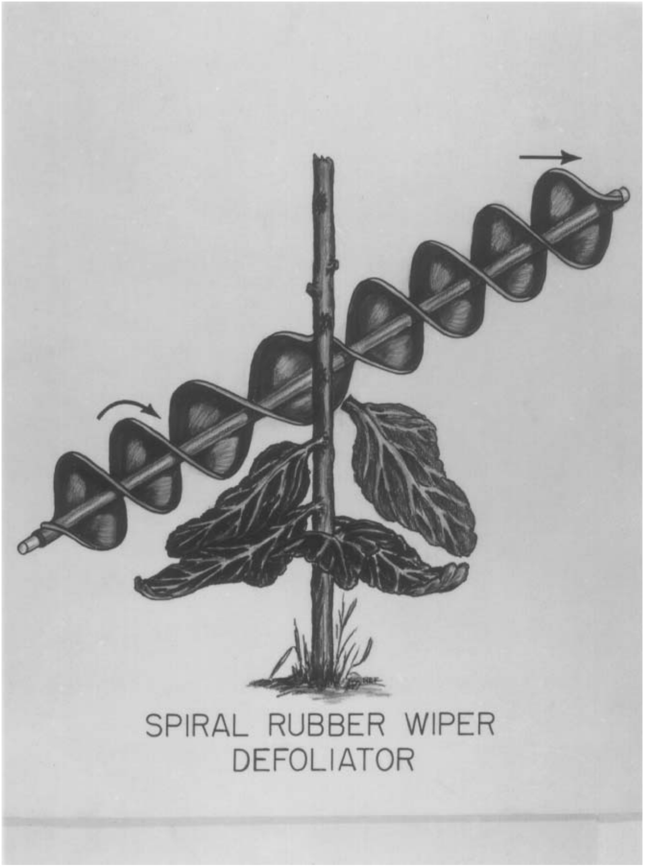

Figure 6. Diagram of early version of spiral rubber defoliator used to remove leaves from the stalk with a mechanical harvester.

portions have a downward action along the stalk with the fingers remaining horizontal and pointed out into the row at all times"(54). The other unit was two spiral defoliators, one on each side of the row. The spiral defoliators, made of hard rubber, rotated on each side of the row, with the rotating motion striking the leaves at their base where attached to the stalk, knocking them off the stalk. Both units were angled upward as they went down the row, with the front part about 15 inches higher than the rear. These results were somewhat encouraging and were coupled with some personnel changes on the project. Dr. William E. "Bill" Splinter joined the faculty in July of 1954 and Robert Wilson left the university in the fall of that year to join Powell Manufacturing Company.

As the 1955 crop year began, Bill Splinter was now project leader, with Charlie Suggs still assisting as a graduate student. They took a much broader vision of the whole mechanical harvesting issue. They realized that to be successful they needed a uniform crop to harvest and thus looked at the

Figure 7. Graduate student Charlie Suggs operating an early prototype of the mechanical harvester developed by North Carolina State University.

integration of various crop operations. Their 1955 project work included 17 subprojects (42). It is informative to look at some of these. Some of the preharvesting studies included germination studies on tobacco seed, growth rate of seedlings in different environments, seedling size and fertilizer placement impact on plant growth, and the efficiency of transplanter operation relative to missing plants. The project also was the first to look at mechanically topping tobacco plants by using rotating saw blades to cut out the flower head. Their investigations were intended to integrate mechanical topping with application of either emulsion oil or MH to achieve chemical sucker control, thus eliminating hand labor in the topping and sucker control operations. It was several years before mechanical topping became a reality, but they made the first try. Other parts of the project were focused on evaluating and improving the defoliating work that had been done to date. Design improvements were made to the spiral defoliator by increasing its width to 8 inches and relocating its bearings. This design worked very well for the bottom and middle leaves but at the top of the plant the stalk was pushed down and often broke. The task of moving the tobacco after it was broken off the stalk was also attempted for the first time in 1955. A collection belt carried the leaves to the rear of the machine, where they were elevated to the top of the machine by pressing the leaves gently between two belts traveling in a vertical direction. This concept proved usable, although many refinements

Figure 8. North Carolina State University prototype mechanical harvester with early belt conveyor design.

were needed. The balance of the project work was spent on evaluating the operation of the machine relative to ground speed, defoliator speed, leaf loss, and leaf damage. Many advances were made during 1955 and they laid the basis for the 1956 project work.

In 1956 the project was largely a continuation of what was started in 1955, with a focus on evaluating the leaf-removal technology relative to leaf loss (43). Some of the preharvest studies on efforts to produce a uniform crop were also continued. Another year's effort was devoted to mechanical topping, which demonstrated the effectiveness of mechanically removing the top. A cutter bar was used that year for actually cutting the top. The cutting mechanism worked very well, the main difficulty being discarding the top once it had been cut. With MH becoming widely used as a sucker control material, efforts to apply emulsion oils for sucker control were discontinued after the 1956 crop. To get a jump start on evaluating modifications between the 1955 and 1956 crop years, the experimental harvester was taken to the farm of D.P. Blake near Homestead, FL, in February 1956. Some mechanical defects were found on the defoliator units that were able to be corrected by the summer. The leaf elevator belts worked very well with the exception of difficulty in keeping the belts aligned, which was corrected with a slight design change. Overall, the mid-winter tests accelerated what could be accomplished in the summer of 1956. Much evaluation was done in the summer of 1956 on the operation of the harvester and on reducing the leaf loss, both what was missed by the defoliators and remained on the stalk and what was dropped by the conveyors. Leaf loss remained in the 9 to 10% range, which was considered too high for commercial acceptance.

Project work in 1957 and 1958 focused on comparing the operating effectiveness of the two defoliators, spiral rubber and echelon fingers. Also in 1958 a bin was mounted on the rear of the harvester to collect the harvested leaves. The bin also was tried as a container for bulk curing (development of bulk curing will be discussed later) to demonstrate a totally integrated harvesting and curing system. A report by Splinter and Suggs in 1959 summarized much of the work that had been done on mechanical harvesting to that date (44). Two defoliator devices had been developed that were suitable for further refinement by commercial manufacturers. A conveying system had been developed that could transport and elevate the leaves to a bin for transport without excessive leaf damage. It was believed the field losses were still too high but could be reduced by refinement of the current harvester. Relative to the main objective of labor reduction in tobacco harvesting, tremendous strides had been achieved. Based on results of experiments through 1958, it was estimated that a 2-man crew using a 1-row harvester traveling at 2 mi/hr could harvest and barn tobacco at a rate of 15 man-hours per acre compared to the then-required 165 man-hours per acre—quite an achievement.

While the basic technology had been developed for mechanical harvesting, refinement into a commercially acceptable machine for farmer use was still to come. Additionally, the acceptance of the final product by leaf buyers and tobacco manufacturers was far from a foregone conclusion in a tradition-bound industry. Splinter and Suggs indicated the difficulty in their 1959 report (44) when they stated, "The acceptance of mechanical harvesting as described here must depend on the accompanying acceptance of curing in bulk and, to achieve full realization of labor reduction, modification of the marketing system to loose leaf or perhaps baled leaf sales." Still, great strides had been made in only five years, from 1953 to 1958.

Interest in manufacturing and marketing a commercial version of the mechanical harvester increased as the machine technology became more defined. Powell Manufacturing Company, which was now located in Bennettsville, SC, built the first commercial prototype in 1961. This was followed by Harrington Manufacturing Company of Lewiston, NC, with a prototype of its Roanoke brand. Early field trials showed that there was still much development needed before the machines were ready for grower purchase and use. In 1965 Splinter and Suggs reported on 3 years of evaluation of the 1-row Powell machine at several locations (46). Machine reliability was an early issue that limited collection of reliable operational data. Even with the mechanical problems, the machine showed promise. During both 1963 and 1964, the machine was able to harvest 2 barns full of tobacco while covering 6 acres of land, even though it required 12 hr because of machine breakdowns.

It appeared that a ground speed of 2.0 mi/hr for lower stalk positions increasing to 2.5 to 3.0 mi/hr at upper stalk positions was realistic. Leaf loss was being reduced and was approaching a more acceptable 5% level. These evaluations identified a potential problem, which was material handling of the harvested leaves. The harvester was designed to allow filling of racks for bulk curing at the rear of the machine, where the leaves had been elevated to a temporary bin. It became evident that when the harvester was working efficiently, the leaves were being harvested more quickly than they could be racked, thus limiting machine capacity. Nonuniformity of the loaded racks also occurred, and this was causing curing problems.

While assisting the commercial manufacturers in evaluating their designs, Splinter and Suggs continued to refine their technology. For example, in 1961 Suggs designed a tractor-mounted defoliator that, when placed on a 1-row offset tractor, provided a more economical approach to mechanical harvesting. To use this model, every third row in the field had to be skipped to allow room for the tractor, and this was prohibited at the time by the federal acreage/poundage control system. They also restarted work on development of a mechanical topper in 1963. A continuing issue with this work was how to get the plant flower cut without damaging the tip leaves of the plant.

Considerable effort was also spent on trying to align the harvested leaves so that the leaf butts were pointing in the same direction. While the harvester was designed to be compatible with the emerging bulk curing, it was believed that leaf alignment would allow quicker adoption of the harvester if it was compatible with the current stick-barning system and hand-tied marketing. Gravity drops from different conveyor designs and the use of fans were tried, but only with limited success. It appeared that success of the harvester would depend on acceptance of nonaligned loose-leaf marketing, as Splinter had earlier stated.

During the mid- to late 1960s, much effort was placed on evaluating commercial versions of the North Carolina State mechanical harvester. One problem that continued to plague the machines was the difficulty in cleanly removing the top leaves. It had been shown clearly that the spiral rubber defoliator worked well on the lower-stalk-position leaves and was acceptable for mid-stalk leaves. The echelon defoliator also was effective for mid-stalk leaves. However, neither worked well on the removal of upper stalk leaves. The upper stalk was mechanically weaker than the lower parts of the stalk and often broke when the spiral defoliator was used. Often times, if sucker control was less than excellent, suckers were present at the top of the stalk, which made the echelon defoliator ineffective. Splinter and Suggs had developed a knife defoliator in the late 1950s and later reported on its effectiveness, which seemed to solve the problem of removing the tip leaves (45).

Field evaluation of the Powell machine continued in 1967 on the Graham Howard farm near Angier, NC. (47). One objective was to confirm operating capacities observed in earlier studies now that mechanical reliability was improving. The 1967 study confirmed the overall operational parameters for

Figure 9. Picture from a Powell Manufacturing Company ad from about 1968 showing their prototype mechanical harvester and commercial bulk curing barn.

a 1-row machine that were established in the 1963 and 1964 trials. The 1-row machine could operate at 2.5 mi/hr and had a capacity of 0.75 acres per hour, allowing for 10% downtime with a 6% leaf loss. With ripe tobacco, the machine could harvest enough tobacco to fill a bulk barn in a little over 3 hr, giving it a daily capacity of about 3 barns per day. For a 5- man crew, this calculated to about 20 man-hours per acre to harvest and barn the tobacco. This was a tremendous improvement over hand harvest and conventional stick barning.

Through special arrangements, the tobacco from the 1967 study was purchased by R.J. Reynolds along with hand-harvested tobacco from the same farm. Of the 6 stalk position harvests, the hand-harvested tobacco brought a higher price for 4 stalk positions, with the hand and machine harvested tobacco being roughly equal for the remaining 2 harvests. On average, the machine-harvested tobacco sold for 8 cents per pound less than the hand harvested. It appeared that uniform loading of the bulk curing racks on the harvester continued to be a problem, which led to nonuniform curing of the leaf.

During the summer of 1967 there were also evaluations of the Harrington Roanoke machine. The Harrington machine use confirmed the superiority of cutter bar knives for removing the upper leaves. Spiral rubber defoliators of different rubber hardness were evaluated. Tests showed that there was a wide range of rubber hardness that gave satisfactory leaf removal with the spiral defoliator. Tests showed that a long (22 inch) rubber spiral did a better job on the Harrington machine than a short (16 inch) one. An informative result of these tests was that the Harrington machine, which had a different elevator design, had lower leaf loss in the elevating conveyor than either the Powell or North Carolina State machines. This clearly demonstrated that there was room for improvement in reducing field losses from conveying by looking at alternative conveyor designs.

The year 1968 proved to be an eventful one for the potential commercialization of mechanical harvesting of flue-cured tobacco. For several years, farmers and their political leadership had been working with USDA to gain acceptance of loose-leaf marketing for all belts as it was accepted in the Georgia-Florida belt. As a result of these actions, there were trials for expanding loose-leaf marketing to the other belts in the mid-1960s. The trials were a big success for the farmers and they marketed about 72% of the 1967 crop in loose-leaf form. Based on this result, marketing restraints were lifted, and the entire 1968 crop could be marketed loose leaf. Under the federal tobacco program, any growers who wanted to could still market hand-tied tobacco and receive a price support 3 cents per pound higher than untied leaf; however, nearly all farmers marketed their tobacco loose leaf in 1968 because of labor savings and convenience. Thus, a major hurdle to the acceptance of mechanical harvesting, the lack of acceptance of loose leaf marketing, was now removed.

Additional industry evaluation of mechanically harvested tobacco was also made in 1968. With the potential of mechanical harvesting becoming accepted by growers, more information was needed on how tobacco so produced handled in leaf processing plants relative to conventionally produced tobacco. Universal Leaf Tobacco Company, in cooperation with a farmer in eastern North Carolina and the North Carolina Agricultural Experiment Station, conducted tests on tobacco from about 80 acres. The objective of the tests was to gain a comparison of machine-harvested and bulk-cured leaf with hand harvested and conventionally cured leaf in a typical farm situation. Evaluation criteria were the grade established by USDA, the corresponding market price for each grade, and the processing yield. Results showed no significant differences in grade, price, or processing yield for the two methods of harvesting and curing and established more confidence in acceptance of machine-harvested leaf by leaf purchasers.

There remained one additional hurdle to successfully marketing mechanically harvested tobacco and that was leaf alignment. With modern processing equipment such as whole-leaf threshers, leaf alignment was no longer needed by leaf buyers and processors. However, leaf alignment was still a part of grading standards for USDA grading and the resulting price support level. In 1969 Rupert Watkins, extension tobacco specialist at North Carolina State University, who also owned a farm in Johnston County, NC, decided to see what would happen if machine-harvested, bulk-cured, unaligned leaves were placed on the market in loose-leaf form. Seven acres of his tobacco, which yielded about 14,000 pounds, were used for the experiment. Efforts were made to minimize variables in how the tobacco was grown, harvested, and cured except for the machine versus hand harvesting and the accompanying unaligned versus aligned leaves. The cured leaf was prepared for market in a way to maintain the leaf alignment that existed at curing. The hand-harvested tobacco was aligned with all leaf butts pointing in the same direction, while the machine-harvested tobacco had randomly oriented leaves. The tobacco was taken to market, and no one at the marketplace was aware of the experiment except Watkins (C. Suggs, personal communication). Harvests 1 and 2 were sold in Fairmont, NC; harvests 3 and 4 were sold in Valdosta, GA, and harvests 5 and 6 were sold in Smithfield, NC. At the time of sale the USDA graders appeared somewhat perplexed by the randomly oriented leaves but did put USDA grades on the tobacco, which were comparable to the aligned leaves (C. Suggs, personal communication). At the auctions, all of the tobacco sold well with no significance difference in the sales price based upon harvesting method and leaf alignment. While this was only one test from one farm, it did show that nonaligned leaves could be accepted by the buying companies.

As the 1960s came to an end, most of the development work for mechanical harvesting had been completed and commercialization of the technology was near. Great strides had been made since Dr. G.W. Giles' call to action in 1953. As a side note, Dr. Bill Splinter left the mechanical harvesting project in mid-1968 to accept a position at the University of Nebraska, and Dr. Charlie Suggs took over leadership of the project.

In organizing the content of this book, it was debated in what order to describe the development of mechanical harvesting and bulk curing. A consideration was to describe the developments concurrently since much of the fundamental research for both technologies was accomplished in the mid- and late 1950s. Ultimately it was decided to describe the two developments in the chronology of the crop: harvesting followed by curing. The true benefit of this technology was the synergy between mechanical harvesting and bulk curing that resulted in greatly reduced labor requirements. Bulk curing was actually commercialized earlier than mechanical harvesting and could have been a stand-alone technology, since it was compatible with hand harvesting. The success of mechanical harvesting, however, was dependent on bulk handling of the harvested leaves in both the curing and marketing operations.

The curing research project at North Carolina State University continued to be lead by Dr. Pat Hassler. The project team was joined in 1954 by a young graduate student, William H. Johnson, who had finished his Bachelor of Science degree in Agricultural Engineering in the spring of that year. Dr. Hassler had encouraged him to go to graduate school and he agreed, joining Dr. Hassler and others at the Oxford Tobacco Research station for curing studies during the summer of 1954. Bill Johnson, as he was better known, along with Wiley H. Henson, a USDA employee, was pursuing a master's degree, and both were in the process of determining research topics that would be appropriate for fulfilling their degree requirements. Bill Johnson continued his education and received the second Ph.D. degree from the Agricultural Engineering Department at North Carolina State University. Wiley Henson continued his graduate studies at North Carolina State University and also received a Ph.D. in Agricultural Engineering.

Hassler had begun to do some basic research into better understanding the dynamics of the flue-curing process (18). His work had included leaf temperature measurements and observations related to sponging, or the oxidative browning process, that can occur during curing. One of his observations was that the enzymes involved in the oxidative browning could be inactivated in about 1 second at 212°F leaf temperature. Based on some of these findings it is believed that Hassler was thinking about the possibility of a rapid leaf-drying process, perhaps using infrared energy, as a replacement for the conventional curing process (W.H. Johnson, personal communication).

In fact, by 1954 Hassler and Pucket had built an infrared dryer for yellowed tobacco leaves. The dryer consisted of 2 pre-heating rollers, a continuous chain conveyor, and several banks of infrared lamps with associated controls. Since leaf midribs or stems interfered with uniform heat treatment, only the lamina portion of leaves was treated. In operation, yellowed leaves without midribs were introduced singly into 2 counter-rotating, electrically heated rollers, which elevated the leaf temperature to about 212°F. The heated rollers inactivated the browning enzymes and stabilized leaf color. The leaves then were conveyed beneath infrared lamps to dry the leaves without scorching before they exited the dryer.

To further develop this concept, they needed a more labor-efficient way to yellow the leaves relative to the conventional curing process, and they needed leaves with the stems removed. These needs led to the research topics for both Henson and Johnson. Wiley Henson took on the task of trying to yellow the leaves in a pile (21). Bill Johnson took on the task of removing the stems from the green and yellowed leaves and determining the sensitivity to bruising and the effect of bruising on chemical and physical properties of the leaf (25,24). Some of this research began in the summer of 1954, but it was the summer of 1955 before these two projects were fully implemented.

Wiley Henson had some success with yellowing the harvested tobacco leaves in a pile. He found that with time, there was a temperature rise within the pile of green leaves caused by leaf respiration, which gives off heat. The heat of respiration was sufficient to yellow the tobacco in bulk without any supplemental heat; however, the tobacco had to be hand turned to prevent excessive temperature buildup within the pile. He found that temperatures in the center of the pile would rise to as high as 129°F and cause damage to the tobacco. His solution for removing the excess heat was to aerate the tobacco with a fan. A small chamber about 24 inches high was constructed in which the leaves were laid flat in a horizontal direction, with the butts of the leaves facing each other and subject to a low-pressure air supply inside the chamber. The top of the chamber held the leaves in place and forced the airflow to move horizontally through the leaves. Air for the test was supplied by a small fan near the bottom of the chamber. Tests were conducted with both intermittent and continuous airflow, and both proved successful in allowing the tobacco to yellow without overheating. Observations also showed that the tobacco was losing weight during the aeration, with about 27% being lost with continuous aeration.

Hassler, Johnson, and Henson met frequently to review experimental progress as these studies were ongoing during the summer of 1955. One such meeting, which took place at Elmo's restaurant in Oxford, NC, turned out to be a very eventful one (W.H. Johnson, personal communication). While reviewing results of their studies and noting that some drying was taking place during the aeration of bulk yellowing tobacco, Hassler posed the question as to whether it would be possible to both yellow and dry the tobacco in bulk and thus complete the cure. Much discussion took place on how to dry the leaves, especially with them lying horizontally on each other. Results had shown that moisture removal during aeration of pile yellowing was not uniform, with higher moisture loss for tobacco higher in the pile. As tobacco wilted, it compressed more at the bottom due to the weight of the tobacco above it. This vertical density difference resulted in nonuniform air flow and moisture loss for different heights in the pile.

Bill Johnson suggested that drying would be more uniform if the leaves were in a vertical position, as this would eliminate problems associated with vertical density differences. He further suggested that if the butts of the leaves were pointing down, they would help support the leaves as they dried. This could be accomplished by placing the leaves horizontally on a board within a curing bin, then quickly rotating or flipping the board 90° to a vertical position so that the butts were pointed down.

Based on this discussion, it was agreed to proceed with curing tests having leaves positioned vertically; however, the harvest season was well underway, and much work had to be done quickly. Johnson, Henson, and other project personnel went to work to construct a small curing unit about 4 ft wide, 4 ft high, and 8 ft long. The curing unit was a simple design, like a rectangular box, having an open top, a removable end wall, and a perforated floor of expanded sheet metal about 15 inches from the bottom. Heat and air flow were provided by electrical heat elements and a fan in a side duct at the bottom of the unit.

Loading tobacco into the curing unit was difficult and required several people to accomplish. Tobacco leaves were placed on a board making a layer several inches high. The board was then rotated 90° so the butts were facing down and resting on the perforated floor. While the first board held the tobacco in place, a second board was loaded, rotated, and placed into the curing unit with the tobacco pressing against the first board. The first board was then removed, and the procedure was repeated until the curing unit was

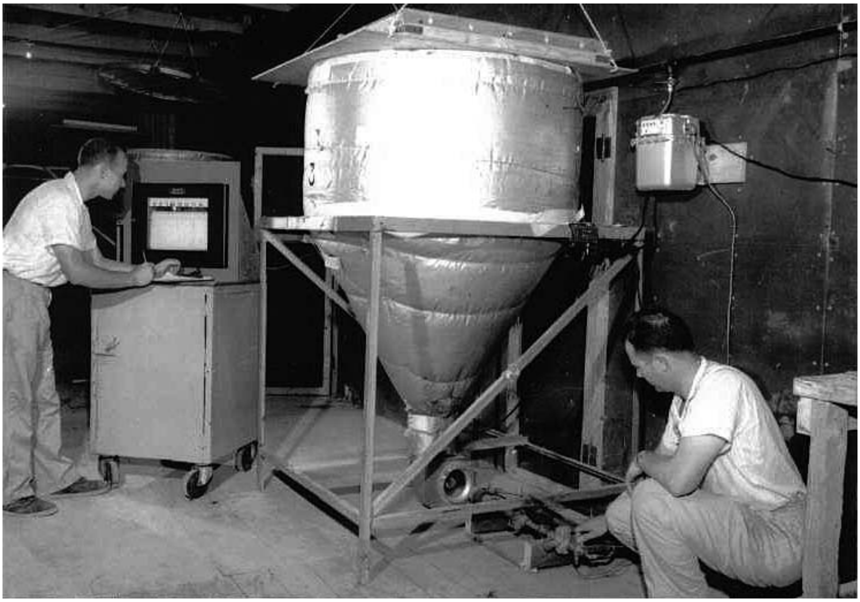

Figure 10. Graduate students Bill Johnson and Wiley Henson conducting laboratory bulk-curing experiments in 1956.

filled. The removable end wall was installed on the open end of the curing unit, and the first curing test of tobacco in bulk was begun.

Since the curing unit had no air recirculation, it was necessary to run the fan intermittently to avoid overdrying during yellowing. The fan was run continuously during leaf and stem drying. A tarp was placed over the top of the open bin to help in control of airflow and exit air temperature from the unit. Heat supply to the curing unit was provided by manual adjustment of the voltage supply to the heating element. The first experiment was only partially successful, with the tobacco slumping down and not completely drying, but it showed enough promise to continue. A second cure was made in which 3 long steel rods were pushed lengthwise through the end wall, through the tobacco, and through the opposite end wall to support the leaves during curing. This technique improved results, but much remained for this curing method to become a practical innovation. However, the concept of both yellowing and drying the tobacco in bulk using forced ventilation of heated air to replace the conventional natural convection curing process had been born.

During the fall of 1955, Bill Johnson was appointed Research Instructor effective January 1, 1956, and in this capacity, Hassler made him responsible for much of the development work on bulk curing. In the winter of 1955/56, bulk curing research was also conducted at the same location in Homestead, FL, as the mechanical harvesting research. Based on the trials at Homestead, a plan of work was established for the 1956 curing season in an attempt to further develop the concept of bulk curing. A curing chamber design was chosen that consisted of a conical plenum with a cylindrical section on top of that to hold the tobacco (26). The two sections were separated by mesh wire on which the tobacco leaves were placed. A cylindrical shape for the curing chamber was chosen, believing it would provide more uniform air distribution within the leaves. The unit was heated by a jet-type gas burner with a fan to force the heated air through the tobacco from the bottom of the cylinder to the top. To load the unit, it was tilted sideways and the tobacco leaves were placed by hand into the cylinder butt ends first. After loading, the unit was positioned upright, and several support rods were inserted. A loaded unit held about 200 pounds of uncured tobacco. Some trials were conducted using leaves that had been cut into about one-half-inch strips. A curing schedule was used that involved no added heat during yellowing to utilize the heat of respiration, drying at 130°F for 8 to 15 hr followed by drying at 170°F until the leaf was completely dry.

Results of the 1956 experiments showed that much work remained to be done. The loading technique gave a nonuniform density that resulted in uneven airflow and uneven curing results. Yellowing environment also was relatively nonuniform with on-off fan operation. The rapid increase in temperature for drying caused some leaf discoloration. With no recirculation of heated air, energy requirements were quite high relative to conventional curing. Even with these observations there were some encouraging aspects of the tests. One test reversed the direction of air flow over the leaves, with the butt end up and the air flowing from tip to butt of the leaves. This direction of air flow seemed more uniform and gave the additional advantage of drying in the same direction as yellowing, tip to butt, which gave better color in the cured leaves. There were sections of the curing chamber where packing density and curing conditions were more favorable and good-looking cured leaf was obtained. However, in general, the bulk-cured tobacco was inferior to the conventionally cured experimental control tobacco. Further improvements were needed before bulk curing could be considered a replacement for the conventional stick curing process.

In the winter of 1956/57, plans were made to improve on the previous year's results by focusing on a better way to load bulk tobacco into a chamber and by improving the curing schedule, while including recirculation of the heated air for energy efficiency (26). The rack Johnson designed that winter to hold the leaves served as the basis for rack design as bulk curing later became commercialized. The rack, used in conjunction with a loading form, provided a new loading method that enabled faster, easier bulking with greater uniformity of tobacco in the racks. The loading rack consisted of 2 members constructed of 2 inch by 4 inch by 48 inch wood. One member had a series of 3/8-inch metal rods spaced at 6-inch intervals. The member without rods was placed in the bottom of a loading form that was similar to a box with an open top and front. Tobacco was then placed horizontally in the loading form to a given height, with butts pressing against the back of the loading form. The second member of the rack, with rods, was now pressed

Figure 11. Experimental bulk-curing chamber using new rack design to hold leaves for curing at Oxford Tobacco Research Station in 1957.

downward from the top of the loading form, piercing the tobacco with the rods. The two rack members were now connected, thereby clamping the tobacco in a 16 inch by 48 inch rectangle. The filled rack, holding about 80 pounds of green tobacco, could then be lifted from the loading form, rotated 90°, and placed on rails in the curing chamber with the butts pointed upward.

For the 1957 bulk-curing trials, small curing chambers at the Oxford Tobacco Research Station were chosen. The existing 6 chambers held 2 bulk racks each and allowed for several replications of the experiment. The curing chambers provided several important features: forced air movement, air recirculation with damper control of inlet/exhaust air, and thermostats to control air temperature. In addition, a steam supply provided a positive method for bringing cured leaves into order or case. Six tests (cures) were conducted with control samples cured in small conventional barns for comparison.

A curing schedule similar to what was being used for conventional curing was chosen. This schedule consisted of yellowing at 95 to 100°F with high humidity, elevating temperature slowly up to 135°F with reduced humidity for leaf drying, and increasing temperature with low humidity up to 160 to 170°F for stem (midrib) drying. The bulk curing trials that summer went very well, with greatly improved results compared to the 1956 work. With controlled recirculation of the heated air, bulk curing actually was more energy

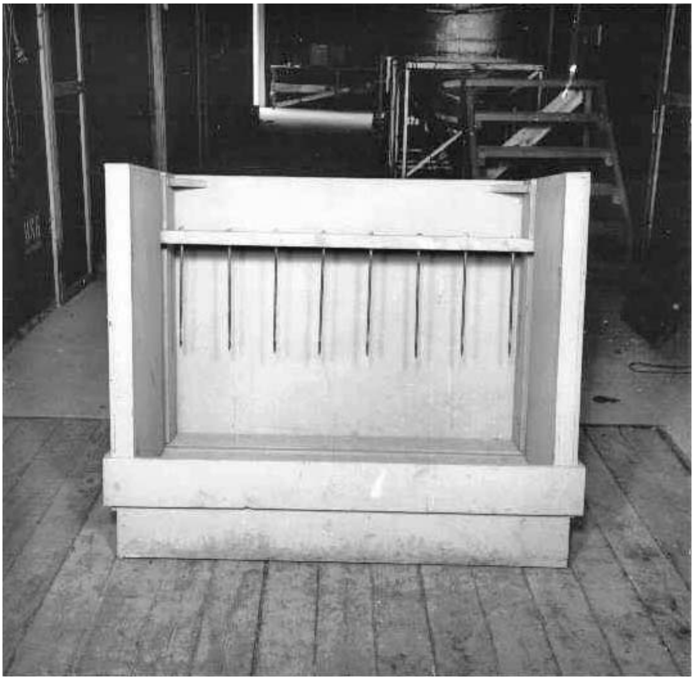

Figure 12. Loading platform and bulk rack to hold leaves designed by Bill Johnson and first used in 1957 experiments.

efficient than conventional curing with its natural convection and no recirculation. Tobacco from the 1957 bulk-curing trials was evaluated relative to the conventionally cured experimental control by several domestic tobacco manufacturers and found to be no different. The concept of bulk curing flue-cured tobacco had been proven.

The next step in the evolution of bulk curing was to get the process out of the laboratory and into practical use. To help accomplish this task Johnson and Henson, working cooperatively, designed and constructed a pilot bulk-curing barn for the 1958 curing season at the Oxford Tobacco Research Station (26). Laboratory findings and techniques of the 1957 curing season were incorporated into the bulk barn design and rack-loading method. The barn had 2 rooms, with 2 tiers per room. The rack design was improved, and each rack now held about 120 pounds of uncured or green tobacco. To fill the pilot barn required 28 bulk racks, which was equivalent to about 330 sticks of conventionally harvested tobacco. A temperature and humidity curing schedule similar to conventional curing was again used. Thermostatically controlled heated air for the cure was provided by a heat exchanger, and a fan forced the air through the tightly packed tobacco at 15 to 30 ft/min. Humidity was controlled by manually adjusting an intake/exhaust damper located in the recirculating air stream.

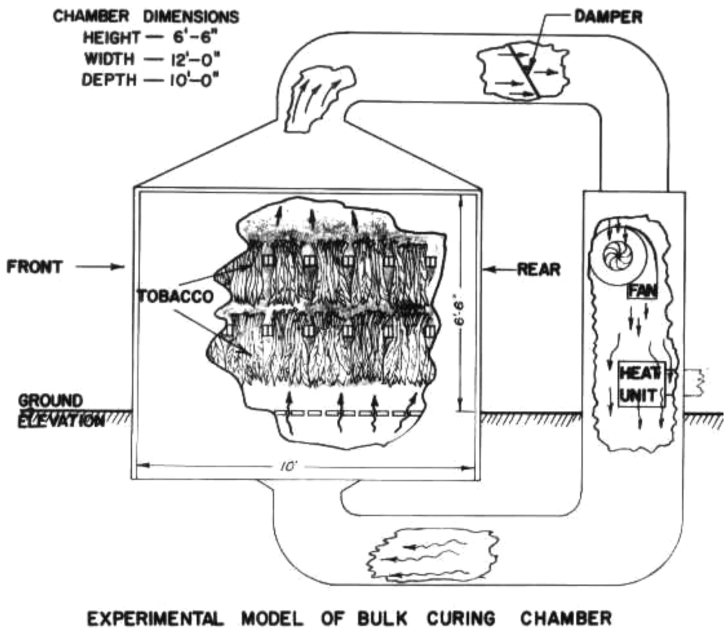

Figure 13. Drawing of first large-scale bulk-curing barn used at Oxford Tobacco Research Station in 1958.

The entire space needed for the bulk barn was estimated to be only one sixth of that required for curing an equal volume of tobacco conventionally. The pilot operation was quite successful that year, creating considerable publicity and interest among farmers. Comparisons with conventionally cured tobacco were again favorable. Based on USDA grading of the tobacco, the bulk-cured leaf had a slightly higher quality than the conventionally cured. Bulk-cured leaf sold on the auction market also brought favorable prices. A cooperating tobacco manufacturer again found the bulk-cured leaf suitable for use in manufactured products. Bulk curing had been successfully scaled up in a pilot operation and now was ready for commercialization.

As bulk curing awaited commercial acceptance, it offered the farmer several important advantages when compared to conventional curing. First, since an indirect heat source (heat exchanger) was used to provide energy for curing, it was a safer process with much less a chance of fire than conventional barns. Bulk barns were much more compact than conventional barns and were a real space saver around the farmstead. With forced air circulation through the tobacco and control of temperature and humidity, the entire curing process was better controlled with an opportunity for higher quality cures. Recirculation of heated air made bulk curing more energy efficient. On the all-important labor issue, bulk curing offered considerable labor savings in the materials handling related to getting the tobacco into and out of the barn. Some estimates indicated that as much as three fourths of the materials-handling labor could be eliminated (26). Of course the downside of bulk curing was that the farmer had to purchase a new barn to replace a good one currently in use. Additionally, there was practically no alternative use for the no-longer-needed conventional barn. Thus, the farmer had to be convinced that labor savings and convenience were enough to justify the capital investment needed to purchase a new barn.

It was also important that bulk curing was compatible with the established method of hand harvesting the tobacco. This fact allowed a farmer to transition to bulk curing and capture its labor savings without disrupting other aspects of his farming operation. However, the potentially biggest advantage of the bulk curing process was that it made mechanical harvesting practical at the farm level. By providing the ability to handle and cure harvested leaves in bulk, this curing process opened the door to complete mechanization of the flue-cured harvesting and curing operations.

The road to commercial use of bulk curing at the farm level took an interesting and unexpected turn in 1959. Alkon, a company from New Jersey, approached the Agricultural Engineering department at North Carolina State University about the feasibility of manufacturing and marketing conventional curing barns made primarily out of metal. Hassler, Johnson, and others in the department met with Alkon representatives to discuss the concept. While acknowledging that metal conventional barns were a possibility, they introduced Alkon to the bulk-curing research that had been done and to the future potential for bulk curing. Alkon was encouraged to begin production of metal bulk-curing barns instead of conventional barns. After some deliberation, Alkon decided to build a metal barn for bulk curing and asked North Carolina State University to design a commercial version for their consideration and assist in its farm application. They wanted to have a barn on a farm to test during the 1960 curing season. Hassler agreed and asked Bill Johnson if he would design a commercial version of the 1958 pilot barn. Johnson designed the first commercial bulk barn, enlarged over the pilot barn from 2 to 3 rooms each having 2 tiers that were considerably longer than the pilot barn. Alkon decided to provide all-metal racks that could be fabricated more easily. The barn had a capacity of 94 metal racks, or about 9,000 to 11,000 pounds of uncured tobacco.

The plans were sent to Alkon and the company fabricated all of the barn components. Stone Brothers Farm in Robeson County, NC, was the recipient of the first barn components. Since Alkon wanted North Carolina State University to assist in assembling and operating the barn that year, Bill Johnson and Wiley Henson were assigned to the task. With help from farm labor, Johnson and Henson assembled the component parts and got the barn ready for operation. Thus, the first commercial use of bulk curing took place on the Stone Brothers Farm in an Alkon barn during the summer of 1960 (7). Results from that first curing season were also positive. The new curing method received lots of publicity and interest from other tobacco farmers.

Based on the success of the 1960 season, Alkon manufactured and sold about 35 barns for the 1961 crop year, with the barns being placed on farms

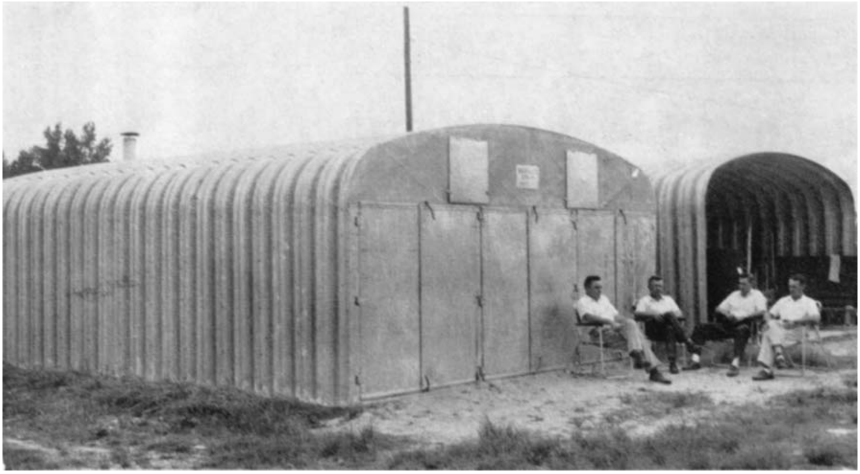

Figure 14. First commercial bulk-curing barn operated at the Stone Brothers' farm near Rowland, NC, in 1960.

from Florida to Virginia (6). Other manufacturers became interested in the market for this new product and soon followed with their own models of bulk-curing barns. Companies such as Powell, Harrington (Roanoke brand), and Long were quickly into the market, with Powell reportedly making barns as early as 1961. Other familiar names such as Bulk ToBac, from Gas Fired Products in Charlotte, NC, and Taylor Manufacturing from Elizabethtown, NC, were soon in the market. Taylor Manufacturing converted some of its peanut-drying equipment to make it applicable for bulk curing in 1965/66 (R. Taylor, personal communication). They were all joined later by numerous smaller companies so that, by the late 1960s, farmers had many suppliers of bulk barns from which to choose. Interest at the farm level also quickened. The number of bulk barns sold to farmers in North Carolina increased from around 40 in 1961 to 775 in 1967, with an additional 500 plus being added in 1968 and 1969 (30,31,32). So, at the end of the 1960s, bulk curing had become an accepted practice at the farm level and in the marketplace, which made implementation of mechanical harvesting an easier task than it would have been otherwise.

There is one other interesting aspect of bulk curing that should be discussed and that is patents. Surprisingly, the original bulk curing process developed by Johnson, Hassler, and Henson never received a valid patent. After successful completion of the pilot bulk curing operation in the summer of 1958, Johnson approached Hassler about the possibility of patenting the process (W.H. Johnson, personal communication). Johnson believed that the technology had been reduced to practice and that it was different enough from conventional curing that it could be patented. Hassler indicated that he did not believe that a patent should be pursued. His view was that, whatever might get covered in a patent, companies could patent around it and the effort would be basically futile. Based on this decision it was decided to make all of the development work public, and Johnson presented a paper on bulk curing development at the summer meeting of the American Society of Agricultural Engineers in June of 1959 at Cornell University. This paper was published about a year later in the ASAE journal, *Agricultural Engineering* (26). Then along came Alkon and their interest in manufacturing and marketing metal bulk curing barns in 1959. They questioned if there was a patent for the process since they were interested in some protection before they started manufacturing. At that time Hassler revealed that there was no patent on the process, but that he had made a patent disclosure to the university patent committee in 1955. The patent committee returned the disclosure to him with an indication that they did not believe that seeking a patent on the process was justified.

With this information revealed, Hassler offered to sell his patent disclosure information to Alkon for one dollar if they wanted to pursue a patent. Alkon took him up on the offer and filed a patent application dated June 13, 1960, with Hassler being the named inventor for the process. A patent, number 3,110,326, was issued on November 12, 1963, with Hassler as the inventor. Since Alkon had sold their bulk barn business along with the patent rights to Powell Manufacturing Company, the patent rights were assigned to the parent company of Powell. Shortly thereafter, Long Manufacturing Company challenged the patent, and there began a legal proceeding over the patent rights to the process. Many of those involved in the process development, including Johnson, were deposed (W.H. Johnson, personal communication).

Ultimately the judge in the case ruled that the Hassler patent was invalid due to prior disclosure, and the prior disclosure cited was the Johnson paper presented in 1959 and published in 1960 (26). So, ironically, the original curing process that changed how flue-cured was handled and cured wound up with no patent coverage.

While much of the focus in the harvesting, barning, and curing operations during the 1950s and 1960s was in the development of mechanical harvesting and bulk curing, that was not all that was happening. The entrepreneurial spirit of the U.S. tobacco grower and small equipment manufacturers was alive and well during this time period and contributed to many labor-saving and drudgery-reducing devices. Any discussion of harvesting, barning, and curing would be incomplete without taking a look at some of these machines and systems.

In 1952 George Watson of Watson Seed Farm near Rocky Mount, NC, and Bill Long of Long Manufacturing Company went to the midwest to observe some of the equipment used in detasseling corn (W. Denton, personal communication). At the end of this visit, they ordered two of the self propelled corn detasseling machines that they observed. Watson used his machine in his seed production operation, while Long used his machine as a prototype for building a self-propelled, riding tobacco harvester. After some development work and field testing, Long introduced his Silent Flame brand

Figure 15. A harvesting aid typically used in the 1950s and 1960s that reduced drudgery in harvesting.

riding tobacco harvester in September 1954. An ad placed in the September 7, 1954, Raleigh *News and Observer* encouraged growers to come see the first public demonstration of this machine at Watson Farms in Rocky Mount, NC. The machine was advertised to have a capacity of 800 to 1,000 sticks a day and would be available to farmers for the 1955 crop year.

Other manufacturers made similar machines, both self-propelled and tractor pulled. A typical machine had seats for 4 primers who rode through the field on the harvester breaking off the ripe leaves rather than walking. After the leaves were broken off, they were placed in a conveyor that carried them to the looper on a platform above the tobacco plants. This platform was usually covered to provide shade for the workers. The looper took the leaves off the conveyor and strung or looped them onto the stick. A full stick was placed by another worker on a pile or in a rack to be later hung in the curing barn. Some of the simpler tractor-pulled units had the looper and primers on the same level. These machines needed a skip row in the field so that the tractor pulling the machine could get into the field without destroying the tobacco. Nearly all of the self-propelled units were high-clearance machines that could be used in solid-planted fields.

Splinter and Suggs evaluated several of these machines during the 1955 growing season (42). The machines evaluated included the Long Silent Flame, a Roanoke-Holliday machine, as well as ones manufactured by Powell, Shaver, and Bell. The top capacity of any of them was rated at about 600 sticks a day using a driver, 4 primers, and 2 loopers.

During the 1956 growing season, an economic study was made comparing the use of self-propelled tobacco harvesters on 48 farms to hand harvesting on 48 other farms, all located in Wilson County, NC (10). The study showed that there were some labor savings from using the harvester compared to walking and hand harvesting, about one-fifth of the labor costs. Thus, if a farmer owned a self-propelled harvester, it made sense to use it. However, when the costs of purchasing and operating the machine were considered, the economics became less clear. Labor rates had to be unusually high, or the life expectancy of the machine had to extend well beyond the assumed 5 years, for the economics to be attractive. So, basically it was a neutral situation as far as cost savings were concerned. Since several thousand of these machines were sold, there had to be some attraction to the farmer, and there was. The physical endurance needed to prime the leaves all day was reduced by riding, and this expanded the labor pool for the task. Older, younger, and female workers could now be used for this demanding task. With the labor savings, however small, often a farmer could put together a labor crew from family labor or with a minimum of outside labor. So, with some reduction in the drudgery involved in harvesting and with easier management of the required labor, the riding harvesters were attractive to some growers. This was especially true in eastern North Carolina where the flatter topography was more accommodating to the high center of gravity, self-propelled machines.

Another labor-saving device that became popular during this time period was the automatic tying or sewing machine. The first of these machines appeared around 1961 and rapidly gained favor with tobacco farmers during the 1960s (2). The machine replaced the handing and stringing operations of preparing the tobacco for a conventional barn. The machine, powered by an electric motor, consisted of a conveyor belt to which a sewing head similar to a sewing machine was attached. A layer of tobacco leaves was placed on the conveyor belt, then a stick was positioned near the butt end of the leaves, and a second layer of leaves was placed on top of the stick. The conveyor belt carried the leaves under the sewing head, which sewed cotton twine through the leaf butts, thereby holding the leaves on the stick. The loaded stick was then taken off the conveyor and hung directly into the curing barn. The popularity of these machines is indicated by the approximately 5,000 that were in use for the 1967 growing season (30). They extended the usefulness of conventional barns by reducing the barning labor by about one half.

A Virginia Tech study in the late 1960s evaluated these sewing machines as well as other devices in reducing harvesting, barning, and marketing costs (40). The study showed nearly a two-thirds reduction in labor needed to get tobacco on the stick using the sewing machines, compared with hand stringing. Additionally, there was a small amount of labor saved when the tobacco was removed from the stick compared to hand-strung sticks. It is interesting to note that the most efficient method studied for harvesting and barning was hand harvesting coupled with bulk curing. Of course this was before the introduction of mechanical harvesting, but the study illustrated the

Figure 16. An auction scene for tobacco marketing in loose-leaf form on burlap sheets.

compatibility of bulk curing with a conventional, hand-harvesting system. The use of sewing machines, riding harvesters, and other labor- and drudgery-saving devices for harvesting and barning did much to make life for tobacco farmers a little easier in the 1960s, while they waited for implementation of mechanical harvesting coupled with bulk curing.

Marketing. Much of what happened in the marketing area has already been mentioned earlier in this chapter. The most significant event was the shift from hand-tied to loose-leaf sales. As previously noted, there was political pressure from farmers, their organizations, and their political leadership for the USDA to change marketing regulations to allow farmers in all belts to market in loose-leaf form as had been done in the Georgia-Florida belt for many years. Small trials of loose-leaf marketing in the other belts were allowed in the mid-1960s, starting with marketing of the downstalk primings and lugs grades. In 1967 this was expanded to allow the first 95 hr of marketing time in each belt to be loose-leaf sales. This action resulted in about 72% of the entire crop being sold loose leaf. Starting with the 1968 crop, all of the tobacco could be marketed in loose-leaf form if the farmer so chose. Marketing in hand-tied form was still allowed for a few more years, and any tobacco sold in this form carried an extra 3 cents per pound price support level. Very few farmers still hand tied their tobacco, and starting in 1968, practically the entire crop was sold loose leaf. In addition to the obvious labor savings for the farmer, loose-leaf sales removed one of the last remaining obstacles to the practical application of mechanical harvesting.

The privately owned auction warehouse system continued to be the basis for marketing tobacco in this time period, and it continued to function relatively well. As with any system that brings buyers and sellers together, there were points of disagreement on how the system was operated. Mr. Roy Bennett, then a state extension tobacco specialist for North Carolina State University, summarized many of these ongoing topics in 1964 (2). Many of these issues received attention from the various industry sectors but would remain unresolved for years. Some were of little consequence, while others, such as USDA grading of tobacco from mixed stalk positions or grade groups, would go on to pose a serious issue.

When the marketing form shifted to loose leaves, a different marketing container was needed. The one chosen was what was being used in the Georgia-Florida belt, which was a large, about 8 ft^2, burlap sheet. The tobacco was placed in the middle of the sheet and the corners were then tied to contain the tobacco. The sheets offered the advantages of being inexpensive, light weight, easy to transport, and flexible enough to easily conform to the shape of the tobacco. However, the sheets did little to protect the tobacco, other than just contain it. Initially, warehousemen placed the sheets onto baskets as they had done with hand-tied bundles, and thus had 2 containers for each pile of tobacco. Eventually, they moved away from this practice and started flooring the tobacco contained only by the burlap sheet, which raised material-handling issues since the sheets did not have the solid form of the baskets. A USDA agricultural engineer in the Biological and Agricultural Engineering Department at North Carolina State University, Al Graves, started research projects on materials handling at the auction markets in the late 1960s in an effort to improve marketing efficiency for all sectors of the industry (14). These efforts continued for a number of years and resulted in more efficient handling of sheets at the warehouse level.

Closing Comments on the 1950s and 1960s. No other time period was as eventful in developing labor-saving technology for flue-cured tobacco production as the 1950s and 1960s. While the centerpiece of these developments was mechanical harvesting and bulk curing, other developments were very significant. These include widespread use of tractors for land preparation and cultivation, methyl bromide and plastic covers in transplant production, better disease-resistant varieties, mechanical transplanters, soil fumigants, herbicides, insecticides, maleic hydrazide and fatty alcohols for sucker control, and tractor-mounted sprayers to accurately apply these materials. These technological developments, along with regulatory changes to allow loose-leaf marketing, all contributed to a large reduction in the amount of labor required to produce an acre of tobacco. Charlie Suggs estimated that labor requirements for the 1971 crop had been reduced to 246 man-hours per acre (49). This was 2 years past 1969, but was reflective of labor requirements that year since mechanical harvesting was almost nil in 1971. This represented almost a 50% reduction compared to the late 1940s. Given the increased per-acre yield, the labor reduction was even more dramatic on a per-pound of cured leaf basis. It truly was the golden era of technology development in flue-cured tobacco production.

1970 TO 1986, ADOPTION AND REFINEMENT

Federal Government Policy for Tobacco. Entering the 1970s, the federal tobacco program continued to function well, and few would have expected the turbulent times that were awaiting the program in the early and mid-1980s. In 1970, marketings of flue-cured were 1.18 billion pounds, with a price support level of $0.67 per pound and a market average price of $0.72 per pound. Quotas, and resulting marketings, had an upward trend peaking in 1975 at a little over 1.4 billion pounds. In that year the price support level increased to $0.93 per pound, which pushed the market average up to $1.00 per pound. The economic atmosphere created by these conditions was positive, and tobacco farmers looked to upgrade their operations and increased adoption of labor-saving technology.

However, the high inflation rate that plagued the general economy in the 1970s had a negative impact on the tobacco program. High inflation increased average price support levels, which in turn drove up market prices. By 1982 the average price support level had jumped to $1.699 per pound, with a corresponding market average of $1.785 per pound, a very large increase over the levels of even 1975. Demand responded to these rapidly increasing prices with marketings dropping to 994 million pounds by 1982. Even as demand and marketings for U.S.-grown flue-cured tobacco decreased, the total supply increased from 1.6 billion pounds in 1975 to 2.1 billion pounds in 1982. Much of this increase came from increased inventories of unsold leaf held by the grower's cooperative, Stabilization. Stabilization's inventories were at their highest level in 13 years, and much of it was overpriced relative to world market conditions (15). Also, producers in international markets started to take advantage of the rapidly increasing prices in the United States. Competing countries such as Brazil and Zimbabwe found a receptive market in the United States for their less expensive, although lower quality leaf, especially grades from priming and lug stalk positions. Imports of foreign-grown flue-cured tobacco increased from 24 million pounds in 1975 to 103 million pounds in 1982 (16). The export market for unmanufactured U.S. flue-cured tobacco was also decreasing in this time period, dropping from 391 million pounds in 1975 to 348 million pounds in 1982.

As the operational aspects of the program deteriorated, the political support for the program also came into question. The tobacco program was in permanent legislation and, as such, escaped the 5-year renewal process that most farm programs had to undergo. However, when debate for the 1980 farm bill began, the tobacco program was dragged into the political discussions. Many legislators from non–tobacco-producing states seriously questioned whether the tobacco program should continue, even though its operational history to date had shown minimal costs to the government. In a compromise to gain support for continuing the tobacco program, legislators from the tobacco-producing states committed to having the tobacco program operate at no net cost to the taxpayers except for normal administrative costs.

In July 1982, the "No-Net-Cost Tobacco Program" was signed into law as mandated by the 1981 Agriculture and Food Act. The legislation provided that beginning with the 1982 crop, as a condition of receiving price supports, a tobacco producer had to contribute to a no-net-cost fund or account to assure that the program would operate at no net cost to the government. The no-net-cost fee was set at 3 cents a pound in 1982 and increased to 7 cents a pound for the 1983 and 1984 crops. Also included in this legislation was, for the first time, the ability for a quota holder to sell quota separate from the land, subject to certain restrictions. It also required that non-farming entities, such as utilities and corporations, that owned quota as a result of past land acquisitions sell that quota to active farmers within a specified time period. Along with ending the ability of tobacco farmers to rent or lease quota in the fall of a year after the crop was grown, these measures were aimed at attempting to get the quota into the hands of active tobacco farmers and away from passive quota holders. As the supply of quota decreased, the rental rates paid by active farmers to quota holders became quite high, causing tension between nongrowing quota holders and active farmers.

While addressing some issues, the 1982 legislation did not solve the program's problems, and additional measures were taken. In July 1983, legislation (P. L. 98-53) was signed into law that froze the 1983 price support level at the 1982 level. Later that same year additional legislation (P. L. 98-180) was passed that froze the 1984 price supports at the 1982 level and gave the USDA some discretion in future price support increases and price support levels on individual grades of flue-cured tobacco having low market demand. To further encourage the sale of quota from passive holders to active tobacco farmers, the legislation also abolished lease and transfer of quota beginning in 1987. At that time a quota holder could either grow the tobacco on the farm to which the quota was assigned, rent it to another farmer who had to grow it on the farm to which the quota was assigned, or sell the quota to another active tobacco farmer with certain restrictions. Further, the law required the forfeiture of quota from any farm where the tobacco had not been planted 2 of the previous 3 years.

From the flurry of legislative activity relative to the tobacco program, one can see that the condition of the tobacco program and the economic state of tobacco farmers was not good in late 1984. Then things got worse. With Stabilization inventories still high and growing, the no-net-cost fee was determined to be 25 cents per pound for 1985, high enough to practically eliminate any profit from growing the crop, and the whole program was about to collapse under its own weight. Thus, beginning in early 1985 an initiative led by Senators Jesse Helms of North Carolina and Wendell Ford of Kentucky began to craft legislation to again put the tobacco program on solid footing. Concerned parties, including farm organizations, tobacco manufacturers, and leaf suppliers, were all brought into the process of developing the legislative plan. After months of negotiation, agreement was reached in late June of 1985 on how to modify the program. Now the problem was how to get this plan passed by Congress and signed into law. The tobacco provisions, along with some from the dairy industry, were placed in the Omnibus Budget Reconciliation Act of 1985 that was signed into law in April 1986. Administrative changes were made relative to the 1985 crop to help the crop sell in the marketplace, and the program changes became effective with the 1986 crop. These changes were extensive and were intended to make the tobacco program more responsive to future market conditions. The changes for flue-cured tobacco included:

- Lowering the price support level for 1986 to $1.438 per pound. Future price support increases would be based on changes in market average prices and cost of production. The USDA retained some discretion in applying the formula-determined increase.
- Quotas were to be set by a new formula, which included the amount of tobacco the domestic tobacco manufacturers intended to buy out of the upcoming crop, plus an estimate of the amount of tobacco that would be in demand by export customers. To help assure accurate buying intentions, domestic manufacturers had to purchase 90% of their stated buying intention or face a financial penalty.
- The producers and purchasers of flue-cured tobacco would pay the same no-net-cost fee to cover any future program loss.
- Four participating domestic manufacturers, Philip Morris USA, R.J. Reynolds, Brown and Williamson, and Lorillard agreed to purchase the excessive inventories of Stabilization at discounted prices.

With these changes in place starting with the 1986 crop, it was hoped that renewed stability could replace uncertainty in the tobacco-growing sector. Uncertainty over the future of the federal tobacco program did have a negative impact on the movement to mechanize tobacco-farming operations. After a positive beginning in the 1970s, this uncertainty, especially in the early 1980s, brought adoption of mechanization to a virtual standstill. Growers were reluctant to make additional investments in their operations until the future of the federal tobacco program became clearer. With the 1986 changes they now had a chance to again focus on improving their farming operations instead of merely surviving until the next crop year.

Growing the Crop. The actual growing of the crop in the 1970s and early 1980s did not see the dramatic changes, such as the introduction of chemical sucker control, that occurred in the 1950s. However, significant opportunity remained to refine and improve production methods, such as the adoption of integrated pest-management practices. Studies by agronomists on transplant loss and replanting, along with simulated hail damage, demonstrated the significant ability of the tobacco plant to compensate for field loss. Tobacco plants could have noticeable chewing insect damage without any loss of yield and quality. As a result, the number of applications of insecticides could be greatly reduced without negatively impacting gross returns, while reducing labor and material costs.

The use of tractors in land preparation and cultivation was nearly 100% by now, and larger and more efficient tractors were being used. Many farming operations were utilizing 4-row equipment in land preparation and transplanting, squeezing some efficiency into these operations. Where 4-row equipment was not practical in some of the more hilly areas of the Piedmont, at least 2-row equipment was in use.

Variety development was very healthy in this time period, and growers had a wide selection of varieties to meet the needs of their individual farming situations. Three dominant private seed companies, Coker, Speight, and McNair, which was purchased by Northrup King in 1979, were very productive (4). Dr. Hoytt Rogers, instrumental in the release of Coker 139, retired from Coker Seed Company and was replaced by Dr. Carol Miller. Dr. Miller's contributions to variety development included Coker 176, released in 1971. This was one of the first tobacco mosaic virus–resistant varieties that also had acceptable quality. He also released Coker 371-Gold in 1986, a high Black Shank resistant variety. While neither of these two varieties achieved a dominant share of the market, they both were planted by many growers and were an important source of germplasm for future variety development. At the family-owned Speight Seed Farms, Mark Grimsley was the plant breeder responsible for 2 important varieties. Both Speight G-28, released in 1968, and Speight G-70, released in 1978, were widely planted by growers and accepted by the buying companies. At McNair Seed Company, Bill Early was the plant breeder in this time period. He was responsible for two important varieties, one of which became a legend in tobacco circles. McNair 944, released in 1972, became popular with growers partly because it was relatively easy to cure. The other variety was the legendary K 326. This variety produced yields above other available varieties and was also relatively easy to cure. However, its most appealing trait to growers was its ability to ripen and remain in the field several weeks without significant deterioration of intrinsic quality. This trait allowed growers to spread out the harvest season and get more use of their curing barns, thus reducing overhead costs. This variety became so popular that it was grown on 50% of U.S. flue-cured tobacco acreage for 15 years and was planted widely internationally (4).

Public sector tobacco breeding was very active also; however, much of this effort was directed to more basic research on breeding techniques and germplasm development. Active programs were conducted at Clemson University, Virginia Tech, North Carolina State University, and the USDA station in Oxford, NC. A very high-quality variety, NC 82, developed by Dr. Richard Gwyn at the USDA, was released in 1978 and achieved some popularity with growers. Dr. Robert Terrill of Virginia Tech was responsible for developing germplasm that was resistant to tobacco cyst nematodes, a particular problem in the southern Virginia area. The breeding techniques and germplasm development of these programs came to fruition in the 1990s, especially through the work of Dr. Earl Wernsman at North Carolina State University.

The result of these improved varieties for growers was better quality, improved plant disease resistance, and increased yield. While all of these traits helped improve grower profitability, the increased yield improved productivity as well by allowing more pounds to be produced on a given acreage. From 1954 to 1981, about one-third of the improved yield was attributed to improved genetics, with the remainder resulting from better cultural practices such as fertilization and sucker control (5). Yield improvements since 1981 have continued, with varieties such as K 326 and others to come in the 1990s.

Improvement in seedling production also continued in the 1970s and early 1980s. Seedling production under perforated plastic covers started in the 1960s and continued to spread. By the late 1970s, about two thirds of all seedlings were grown this way (35). The percentage rapidly increased such that by 1983, nearly 90% of seedlings were grown under plastic (36). As mentioned earlier, the use of plastic covers allowed better germination of seed and made possible a lower seeding rate. Also, the seedlings grew at a more rapid rate than under cotton covers, assuring that the transplants were ready to go into the field at the desired time. An additional production practice, clipping, was introduced to seedling production in the early 1980s from Zimbabwe. The practice typically used a rotary mower blade to clip off the upper leaf parts of the growing plant, while carefully avoiding the growing bud of the plant. This had the effect of slowing plant growth, thereby allowing smaller plants in the seedbed to catch up with larger plants. The result was a larger percentage of usable plants per unit area of plant bed grown. An additional benefit was sturdier plants having a higher survival rate in the field. However, careful sanitation and management were needed to prevent the spread of foliar diseases, especially tobacco mosaic virus, since the cutter blade came into contact with nearly every plant in the seedbed and could easily spread disease. Where uniform plant growth had been achieved, an additional practice, undercutting, was introduced that reduced the required labor to pull plants. A blade attached to a tractor was pulled several inches below the soil surface to loosen the plant roots. This allowed pulling of plants by the handful, greatly speeding up the task of getting plants out of the seedbed and ready for transplanting. Thus, by utilizing clipping and undercutting, a grower could greatly reduce the labor and drudgery needed to pull seedling from the seedbed.

The process of getting the transplants into the field changed little from that used in the 1960s. As with land preparation, more multi-row equipment was used, with larger farms using 4-row transplanters and most other operations using at least a 2-row transplanter. The transplanting operation evolved as some other field tasks were combined with transplanting. Compatible insecticides were often incorporated into the transplant water that was applied to the plant roots. Additionally, some growers used this pass through the field to accurately place a first application of fertilizer around the plant. Those growers using herbicides sprayed over the top of the young plants also used the transplanting pass through the field to make this application. So, while the transplanting task still required a tractor driver along with 2 plant droppers per row transplanted, the pass through the field was used to include other tasks where possible, which improved overall efficiency in growing the crop.

Going into the 1970s there was still only limited use of herbicides. Available herbicides included trade names such as Enide, Paarlan, and Tillam, which provided control of grasses, but not broad leaf weeds. Thus, some cultivation was still needed. Also, the soil-incorporated products, Paarlan and Tillam, had to be incorporated precisely, or some stunting of early season plant growth would occur. In spite of these limitations, herbicide use became more widespread as the decade advanced, and their use contributed to improved efficiency by reducing the number of cultivations needed for the crop. Weekly cultivations were no longer needed. Herbicides were especially valuable in wet growing seasons, when it was difficult to get cultivation equipment into the field to destroy early season grass growth.

One field operation that did see significant change in the 1970s was topping. The early work by Suggs and Splinter on mechanical topping that started in 1955 finally came to practical application with the arrival of commercial machines around 1970. It seems that developmental work on mechanical toppers was being conducted at several locations in the late 1960s and early 1970s. Prototypes were being developed in Tifton, GA (G. Atkins, personal communication). An article in the May 1969 issue of *Flue-Cured Tobacco Farmer* magazine described the efforts of two brothers in Elm City, NC, who made their own machine capable of topping two acres per hour. They used a reel to pull the plant flower into a cutter-bar mechanism to actually remove the top. The apparatus was powered by a small gasoline engine. The machine developed at Tifton seemed to be the basis of the most widely adapted mechanism for removing the flower heads. It consisted of a fan that blew air downward to push the tip leaves down and away from the cutter head. A rotary blade then cut the flower head off and pushed the cut top off of the plant into the plant row below. This technique was quickly commercialized by a number of companies. Some of them, including Powell Manufacturing, Harrington Manufacturing, and Vann Industries of Clinton, NC, were advertising their machines in the May 1971 issue of *Flue-Cured Tobacco Farmer* magazine. Advertised capacities ranged from 8 to 24 acres per day for one of the machines.

The use of this topping technology began to be used by a considerable number of growers, but it had to be combined with careful crop management to be successful. If suckers were allowed to grow prior to topping, hand labor was still required to remove them prior to chemical application in order to get effective sucker control. Also, the air deflection device was not 100% effective, and some of the tip leaves were clipped when the top was removed. Even with these shortcomings, the device offered the potential of significant labor savings. Its use put even more pressure on good sucker control practices. The techniques pioneered in the 1960s by Dr. Bill Collins and others to use fatty alcohols to control early sucker growth became even more significant. If this technique was used properly to control early sucker growth, then mechanical topping followed by application of maleic hydrazide offered the potential of achieving sucker control and topping with minimal hand labor—a major achievement indeed.

Harvesting and Curing. The 1971 crop was an eventful one in tobacco mechanization history. Rupert Watkins (33), an extension tobacco specialist with North Carolina State University, described it in this manner: "After 18 years of research by college engineers and several years of research and support by machinery manufacturers and tobacco companies, the first successful, unsubsidized, full scale farm operations using the tobacco combine were recorded in 1971." Four farms in North Carolina used the machines to harvest their entire crop. The size of the operations handled by 1 machine ranged from 18 to 35 acres. The tobacco was cured in bulk barns in random leaf form and was presented at the auction market in the same manner. There was no discrimination against the tobacco by either the USDA graders or the buying interests, with both parties fully aware of the history of the tobacco. Obviously, the commercial acceptance of tobacco handled by mechanical harvesters was a key component in the overall success of mechanical harvesters at the farm level.

The equipment manufacturers geared up to supply an increasing demand in 1972. The January 1972 issue of *Flue-Cured Tobacco Farmer* magazine carried an article on the 3 companies that had machines to market in 1972. Powell Manufacturing advertised its Powell "66" machine with a stated capacity of 0.75 to 1 acre per hour. Depending on how the machine was equipped, it sold for $12,000 to $14,500 that year. They were sold on an order-only basis and were equipped with a spiral leaf remover for the bottom and middle stalk positions, and a cutter-bar header for upper stalk leaves. Harrington Manufacturing Company offered its "Roanoke Automatic Tobacco Primer" for a price of $13,500. The third machine on the market was the Hawk Automatic Primer made by Eagle Machine Company of London, ON, Canada. They planned to have 40 to 50 machines available for 1972 at a price of $14,500. The Hawk machine was advertised as having the ability to keep the leaves partly aligned as they were removed from the stalk, which made it more compatible with growers who still used stick barns and automatic stringing machines. However, the more complicated design of the Hawk machine led to more mechanical problems in the field than either the Powell or Harrington machines in the 1971 operations.

With the increased quotas and marketings during the early to mid-1970s, the atmosphere was conducive to investment in mechanical harvesters and bulk barns, and that is what farmers did. The increasing acceptance of mechanical harvesters was documented by Rupert Watkins in his portion of the annual *Tobacco Information* publication made available to tobacco farmers through the Agricultural Extension Service. For the 1972 crop, 39 of the machines were sold to Carolina farmers, with 27 of them in North Carolina. The machines were used to harvest the entire crop on farms with acreages ranging from 18 to 60 acres.

Machine capacity was found to vary considerably due to field layout, which greatly influenced the amount of time spent in turning the machine around at the end of rows and the time needed to load and unload containers for carrying the harvested tobacco to the curing barns. In general the operating speed of the machine in the field was found to be faster than most assumptions during development, which increased field capacity. Most capacity assumptions had been based on an operating speed of 2 to 3 mi/hr. Experience showed that a well-organized operation could operate the machine at 3 to 4 mi/hr on average, and at some of the mid-stalk leaf positions, speeds of up to 5 mi/hr could be maintained. For a 1-row machine, this resulted in harvest rates of around 1.5 acres per hour or a total field capacity of 50 to 60 acres.

Economists were helping growers make the decisions of whether it was economical to switch from how they were currently operating their farms to a fully mechanized machine-harvest and bulk-curing system. While labor availability and quality, along with the farmer's management ability, entered into the decision, it basically came down to comparing the value of labor saved to the annual fixed costs of the new investment in the harvester and, if needed, bulk barns. Average farm operations were shown to save 180 man-hours per acre when comparing mechanical harvesting and bulk curing with conventional hand harvesting and stringing on sticks (34). This comparison included labor involved in harvesting, barning, curing, and market preparation. For very efficient conventional operations, the advantage for mechanical harvesting and bulk curing decreased to about 100 man-hours per acre. Lesser savings were achieved when mechanical harvesting and bulk curing were compared with systems that included harvesting aids and tying machines.

Whatever the decision base, farmers were switching to mechanical harvesters and bulk curing in increasing numbers. For the 1973 crop, approximately 300 mechanical harvesters were on North Carolina tobacco farms, and the number jumped to 1,750 in 1975, 2,628 in 1977, and 3,413 in 1979. Many of these purchases were for farms where bulk curing had not been used before; thus, the conversion from conventional to bulk curing was accelerated by the machine purchase. Bulk barn sales had been going at a rate of 500 to 800 barns a year in the mid- to late 1960s. For the 1973 crop, there were 3,987 bulk barns sold, bringing the total in North Carolina to 8,771, which was enough to cure about 12% of that year's crop. The total number of bulk barns and the percent of the crop cured in them jumped to 23,531 and 30% in 1975, 32,485 and 52% in 1977, and 38,381 and 62% in 1979. A later report by the North Carolina Tobacco Foundation showed that in North Carolina an estimated 56% of the crop was machine harvested and 70% was bulk cured by the early 1980s (37).

With widespread acceptance of mechanical harvesting and bulk curing, competition among equipment manufacturers increased in the 1970s, providing growers with additional options in equipment selection. Taylor Manufacturing Company entered the mechanical harvesting arena by offering 1-row, and later 2-row, tractor-pulled mechanical harvesters in the 1972 to 1975 time frame (R. Taylor, personal communication). The tractor-pulled units were a less expensive alternative to the standard self-propelled units. Taylor later followed in the late 1970s with its own version of a self-propelled tobacco combine. Powell introduced a 2-row version of its mechanical harvester in 1975, which was followed shortly by a similar model from Harrington Manufacturing Company. While doubling the harvesting capacity, the 2-row unit typically sold for about one and one-half times the cost of a 1-row unit. Growers now had choices that allowed them to match the capacity and cost of a harvesting system with what was needed for their individual farm.

The most radical harvesting concept came out of Clemson University and its Pee Dee Research and Education Center in Florence, SC. Under the direction of station superintendent Dr. John Pitner, engineer Dr. John Alphin, and agronomist Dr. Bob Currin, a once-over harvesting system was developed (1). Their concept varied transplanting date, fertilization, and harvesting date to produce a low-profile plant with about 8 to 12 leaves that was harvested all at once. Theoretically, the harvested leaves of tobacco grown this way would have the physical, chemical, and smoke flavor of tobacco from the various stalk positions grown and harvested conventionally. By altering the transplanting date, fertilization, and harvesting date you could grow any stalk position or grade of tobacco desired.

From a harvesting and materials-handling viewpoint, this was a very efficient system; however, per-acre yields were reduced significantly. Development work began in 1967 and was field tested in 1967 and 1968. The harvester was a 1-row unit with a different leaf-removal mechanism. A chain-like belt was constructed with numerous openings that moved over and down the low profile stalks as the tractor-mounted harvester moved forward through the field, breaking the leaves off the stalk from top to bottom. A very high rate of harvest was achieved. Early tests showed a harvest rate of 150 pounds of uncured leaf per minute, which was enough to fill 3 or 4 barns in a 10-hr day. Development work continued for several more years, and a commercial version of the harvester was placed on the market in 1974 by Long Manufacturing Company. This harvester did not gain widespread acceptance because tobacco grown, harvested, and cured under this system did not meet buyer requirements. Tobacco produced under this system had characteristics of upper-stalk leaves from conventionally produced tobacco and did not provide the variety of grades needed by buyers (28,29).

The once-over harvester did get some use as a last-over harvester to harvest the top leaves from conventionally grown tobacco. Due to its high capacity, some growers used the machine to harvest more leaves per plant in the last harvest than they normally would, whether harvested by hand or using the multi-pass harvesters. This action contributed to a trend that had already begun, which was to reduce the number of harvests. As a way to reduce costs, some growers were starting to make as few as 3 or even 2 harvests instead of the traditional 5 or 6 harvests. This production practice put these growers at odds with the buying interests. By mixing stalk positions at harvest, these growers were unable to provide the range of individual grades that the buying interests needed, which, along with high prices, reduced market demand for U.S. leaf.

This situation was further complicated by the USDA grading system and the application of this system by individual graders. The grading system, with corresponding price support levels, was based primarily on where the leaves originated on the stalk. Leaf color and uniformity were other grade factors, but stalk position was primary. Mixed tobacco from various stalk positions caused difficulty in determining which grade to apply because there were no provisions for grades of mixed-stalk-position tobacco. Graders would typically place a grade on mixed tobacco that corresponded to the most prevalent stalk position present. Since the majority of the leaves had characteristics from the top of the stalk, graders would place a leaf or "B" grade on these mixed piles of tobacco, which also carried the highest price support level. Growers were, therefore, able to sell tobacco from priming, lug, and cutter stalk positions at leaf stalk position prices. Thus, the grading system and its application encouraged growers to produce mixed stalk position tobacco, which was in less demand by buyers than well-graded tobacco. Eventually, mixed grades with lower price support levels were developed by the USDA, but graders rarely used them. The mixing of stalk positions became more of an issue in the 1980s and 1990s, which was not resolved until contracting replaced the auction markets around the year 2000. The lack of grades desired by buyers, along with high prices, contributed to reductions in U.S. quotas and production in later years.

The success of mechanical harvesting became well established in the 1970s. As is often the case in mechanizing a task previously done by human hands, once the high labor-limiting task, in this case hand harvest, is eliminated, another task in the system emerges and becomes a limiting bottleneck. In the harvesting, barning, and curing of flue-cured tobacco, the limiting factor now became the materials handling required to transport the machine-harvested tobacco to the curing barn, rack the leaves, and place the racks into the barn. In many situations it required 6 people, 2 to transport and 4 to rack, to keep up with the supply of leaves from 1 mechanical harvester. The solution to this problem was the big box-curing container.

The genesis of the box-curing container actually was the original bulk-curing research done by Johnson in 1955 and 1956 (25). At that time he experimented with curing tobacco in cut strip form by cutting the leaves into rectangular pieces before curing. Since the cut leaves did not have much structural strength, a box was needed to contain them for the curing process. Johnson continued research of cut-strip curing in comparison with whole leaves with the 1970 crop, in which much larger boxes and cages were used to hold the tobacco (48). In that same time frame, Suggs was looking for a way to break the materials-handling bottleneck with the mechanical harvester, and starting curing whole leaves in boxes placed inside the curing barns. One change here was that the curing boxes were filled on the harvester as the leaves came off conveyor belts, and thus the curing box became the transport container for getting the tobacco from the field to the barn. This was a very efficient method. However, it was found that the key to successful curing in boxes was uniform loading of the box to assure uniform air flow through the tobacco. When the boxes were filled on the harvester, the transport to the barn often resulted in settling and uneven distribution of tobacco in the box. Some farmers were successful in harvester loading of boxes, but many chose to wait and load them at the curing barn to assure uniform density in the box to help assure a successful cure.

The development work on curing in big boxes quickly accelerated. Rupert Watkins reported on work at the Central Crops Research Station, Clayton, NC, where he successfully cured leaves in big boxes with a screen partition in the middle of the box to support leaves in the upper part of the box during filling (49). Suggs continued his work on harvester loading of the boxes. Taylor Manufacturing Company reportedly sold some commercial boxes for the 1972 growing season (R. Taylor, personal communication). Various size boxes were used for curing, with most of the manufactured ones being metal, with some wooden ones made on the farm. Barn manufacturers started manufacturing barns that were compatible with boxes soon thereafter and, by the 1975 growing season, big-box curing was being widely adopted by growers.

The determining factor in successful curing with big boxes continued to be uniform loading with a relatively high density of tobacco to assure even airflow through the tobacco during curing. Many growers had some early problems in curing with boxes due to lack of experience with them and the need to load them uniformly. This was especially true of tobacco from the lower stalk positions. These difficulties slowed the growth of box barns, but this was a temporary situation. As growers learned how to properly load the boxes, the labor-saving aspects of curing with boxes made them a popular choice. The uncertainty that accompanied the tobacco program issues in the early to mid-1980s also slowed the conversion to boxes from racks and had a negative impact on tobacco equipment manufacturers in general. However, by the late 1980s and into the 1990s, the manufacture of box barns was a contributing factor to the economic survival of some equipment manufacturers.

Marketing. No significant changes occurred in the 1970s and early 1980s in how tobacco was marketed, certainly nothing that would compare with the shift to loose-leaf sales that came about in 1968. However, the shift to loose-leaf sales did have an impact on markets in subsequent years. Since loose-leaf sales allowed the farmer to prepare tobacco for market much faster than hand tying it, tobacco reached the marketplace at a faster rate than in days prior to loose-leaf sales. The faster rate of marketing, coupled with the larger crops of the early 1970s, led to an overwhelming of the marketing system. Long lines formed outside warehouses as farmers waited to get their tobacco onto the auction floors. Sales volume was larger than the buyers' processing plants could handle, resulting in suspension of sales for days at a time when the storage and shipping facilities downstream from the auctions became completely filled. All of this resulted in much frustration for everyone involved, especially the farmers, who were anxious to get their tobacco sold before buyers' orders were filled. Additionally, the timing of sales was critical for many farmers who depended on the cash flow to repay debt that had been incurred to produce the crop.

Eventually a solution was found—the grower designation program. Beginning with the 1974 crop, as a condition for receiving price supports, each farmer had to designate a warehouse located within 100 miles of the county seat in which the farm was located at which he intended to market his tobacco. This simple action provided the needed information to allocate the sets of graders and buyers more efficiently and also established the sales volume such that the flow of tobacco did not exceed the ability of the system to handle it.

The shift to loose-leaf sales and the issues it generated also led to some research into how to market flue-cured tobacco more efficiently while maintaining the auction system. The work, begun by Al Graves in the late 1960s, continued as he worked with warehousemen to put in place more efficient materials-handling systems for tobacco in burlap sheets at the warehouses. His work also led to an expanded research project involving Dr. Robert Sowell and other faculty members plus a cross section of the flue-cured marketing industry. Prior to the 1971 marketing season, a steering subcommittee was formed, which included representatives of buyers, the packaging industry, warehousemen, farmers, Stabilization, and the USDA along with the North Carolina State University researchers (41). One of the main objectives of the research was to determine if an improved package for loose-leaf sales could be found that could replace the burlap sheet. After a series of meetings, a decision was made to try collapsible plywood boxes for the 1971 season. Growers were found to participate in the study, and ultimately tobacco in 141 boxes was sold at auction that season. They were about 32 ft^3 in volume and held on average 360 pounds of tobacco each, about twice the average weight of tobacco in sheets. The boxes were then shipped to processing plants to see how they would hold up in the current handling system.

Evaluation of the 1971 project found two major problems with the boxes. First was the expense of the box, especially when compared to the burlap sheet. This concern included not only the initial expense but also the expense of shipping the heavy box among the processing plants, warehouses, and farms. There also would be maintenance and repair expenses that would have to be borne by someone. The other concern was the inability of graders and buyers to examine tobacco that was in the bottom of the box. While this concern was secondary to the expense issue, it was a considerable concern for some. Ultimately the research group decided that the collapsible box was not a suitable replacement for the burlap sheet.

Going into the 1972 marketing season, there was strong interest from the steering subcommittee in evaluating another alternative marketing package, the bale (41). Bales were being used to market flue-cured tobacco in other markets such as Canada and Zimbabwe, and it was felt that bales could work in the United States. Several sizes of bales were tried ranging from about 70 to 200 pounds each. Different bale densities were used, mostly in the 15 to 20 pounds per cubic foot range. Shipping and handling of the bales showed that those at 15 pounds per cubic foot density were not stable when stacked on top of one another. The lower bale compressed and the piles of bales fell over, posing safety issues. Even some of the bales at 20 pounds per cubic foot density showed additional compression when stacked on pallets for shipping.

It was concluded that densities higher than 20 pounds per cubic foot would be needed in order to palletize the bales with stability, and this required a level of on-farm equipment that many believed was not practical. The subcommittee also concluded that the use of a packaging size smaller than the average sheet weight was not practical, since it would run counter to the current farm trend of going to a larger scale in other tobacco operations such as harvesting and curing. The subcommittee gave up on the bale. Thus, the burlap sheet remained the marketing package for the next 25 years. The flue-cured bale in the early 1970s was a concept ahead of its time.

1987 TO 2008, AN END AND A BEGINNING

Federal Government Policy for Tobacco. Changes in the tobacco program, beginning with the 1986 crop, proved to be helpful for the industry as a whole. The flue-cured tobacco quota for the 1986 crop was 728 million pounds; after a small drop in 1987, it increased to around 900 million pounds by the late 1980s and continued near that level into the early 1990s. These quota levels provided some renewed sense of stability, and investment in equipment and productivity picked up from the levels of the early to mid-1980s. However, the inventories of Stabilization were again increasing, and now these inventories had a negative impact on quotas due to their specific inclusion in how future quotas were calculated.

This situation again led to a politically driven short-term solution. Senators Helms of North Carolina and Ford of Kentucky once again called the manufacturing and grower interests together to try and find a solution. It was more difficult this time than in the 1985 situation because there was little incentive for the manufacturers to purchase the excessive Stabilization inventories. The manufacturers already had adequate inventories, and only the no-net-cost money that had been collected was available to discount the overpriced stocks of Stabilization. Ultimately, an agreement was reached where the major domestic manufacturers agreed to purchase the excess inventory of Stabilization over time. This action took that large negative factor out of quota calculations for a few years.

One aspect of the agreement was to convene an advisory committee of industry participants, primarily the buyers, including leaf suppliers, and the growers to review and recommend any additional changes to make the tobacco program more effective. The advisory committee met during the winter and early spring of 1995 under the guidance of Senator Ford's office and the USDA. A report was issued in May of that year. The report contained a number of detailed recommendations relative to operation of the tobacco program that would have improved its responsiveness to the marketplace. The main issue remained the relative noncompetitive price of U. S. tobacco compared to the world market. The grower leadership, especially Stabilization, strongly resisted making any changes to the program that would make U.S. tobacco more competitive in the world marketplace. As a result, the last chance to put the Federal Tobacco Program on a sound footing was lost.

The mid-1990s provided U.S. growers with a unique opportunity to regain market share in world flue-cured tobacco production. The just-concluded agreement with U.S. manufacturers removed Stabilization inventories as a burden in the quota formula calculation, paving the way for quota increases. At the same time, cigarette exports from the United States were increasing significantly, providing a new demand factor for domestic tobacco. This situation was coupled with a tight supply for high-quality flue-cured tobacco on a worldwide basis, which made U.S. tobacco more attractive from a value viewpoint than it normally would have been. A move at that time by U.S. growers to make their tobacco more competitive in world markets by reducing prices stood an excellent chance of resulting in increased market share of world production for U.S. growers. However, as stated previously, no action was taken and the opportunity passed, with much of the increased demand being met by increased production in Brazil.

This situation was followed by the Master Settlement Agreement in 1998 between the major cigarette manufacturers and the states Attorneys General to resolve outstanding litigation between the parties. This agreement led to significantly increased domestic cigarette prices with a resulting decline in consumption and decline in demand for U.S. tobacco. At the same time, the previously increasing cigarette exports began declining, and raw tobacco exports also continued to decline. The result of all of this was a rapid decline in demand for U.S. flue-cured tobacco, which manifested itself in smaller quotas and marketings. By 2004 the production level had dropped to around 500 million pounds and was likely to fall below that level. At this level of production the volume of tobacco was insufficient to sustain all of the growers, and numerous growers were exiting the business, with others having to make difficult decisions about the future. The call for a quota buyout became widespread.

The subject of a possible buyout of the quota and price support system had been a topic of conversation for several years. Those who did not want a government commodity program involving tobacco saw this as a way to get the government out of tobacco policy. Growers increasingly saw a buyout as a way to get their equity out of the system and to provide them an opportunity to produce tobacco in a free-market situation. After much political maneuvering, on October 24, 2004, the President signed into law legislation that provided for a buyout of the Federal Tobacco Program. Funding for the buyout was provided by tobacco manufacturers and importers based on their domestic market share. Funding totaled $10.1 billion, with $9.6 billion going to growers and quota owners to be paid over a 10-year period, and $0.5 billion being used to dispose of stocks being held by the USDA and grower cooperatives. Over the 10-year buyout period, quota owners would receive $7 for each pound of quota owned for the 2002 market year. Growers would receive $3 for the average of each pound of tobacco grown in 2002, 2003, and 2004. If a grower did not grow in all three of those years, there would be partial payment for the years in which he grew the tobacco. Beginning with the 2005 crop, quotas and price supports were nonexistent and growers operated in an open marketplace. Thus, the Federal Tobacco Program that began in 1938 no longer existed after the 2004 crop.

Growing the Crop. The structure of tobacco farming continued to evolve during the late 1980s into the early 2000s. Many of the larger operations became family partnerships or corporations, although some single ownership continued to thrive. As the quota stabilized and increased some in the late 1980s and 1990s, investment in mechanization and other productivity improvement picked up. Labor for many operations consisted of family members, full-time hired labor, and part-time help, much of which was provided by migrant workers.

In the area of land preparation there were few changes in this time period, with the exception of the continuing shift to larger equipment. Most growers now were using 4-row equipment to prepare rows for transplanting, with some of the larger farms even beginning to use 8-row units. Some of the smaller farms, especially in the Piedmont of North Carolina and Virginia, where the land was more rolling and less friendly to large equipment, still used 2-row equipment. Where mechanical harvesters were the dominant method of harvesting the crop, most growers would solid-plant a field, leaving out skip rows as needed to get reel irrigation equipment into the field. Growers who still depended on hand harvest still left out every fifth or ninth row to allow room to get tractor-drawn equipment into the field without damaging the tobacco.

Growers continued to have a good flow of new and improved varieties during this time period; however, the source for new variety development primarily shifted from the private to the public sector (4). Northrup King, which had acquired McNair Seed Company in 1979, acquired Coker Pedigreed Seed Company and its breeding program in 1988, then abruptly terminated its entire tobacco breeding program in 1989. Northrup King continued to sell its popular varieties, which had about 80% marketshare in the United States, until 1995, when Mr. Marion Hawkins purchased controlling interest in Northrup King's tobacco germplasm. He formed Gold Leaf Seed Company in Hartsville, SC, to market these varieties and others, and this company continues to be a significant factor in the supply of flue-cured tobacco seed in 2008.

A new participant in flue-cured tobacco variety development arrived in 1996 with the formation of ProfiGen, a subsidiary of U.S. Smokeless Tobacco, Inc. ProfiGen acquired R.G. Seeds, formed by Dr. Richard Gwynn when he retired from the USDA in 1987, and F.W. Rickard Seeds of Winchester, KY, traditionally a burley seed company. With Dr. Gwynn as their flue-cured plant breeder, Profigen became active in flue-cured variety development and became a supplier of certain flue-cured varieties. Although they remained active in seed production and marketing, ProfiGen discontinued its U.S. flue-cured tobacco breeding program in 2007.

Speight Seed Farms has remained active in variety development. A new participant, Cross Creek Seeds, has entered the business. Both of these companies have some plant breeding resources, but rely more on their seed production and marketing components. Thus, while there continues to be adequate commercial interests in producing and marketing flue-cured varieties, there has been a significant reduction in the resources available for variety development in the private sector.

From the early 1990s onward, the burden of flue-cured variety development has been carried primarily by the public sector. Clemson and Virginia Tech continue to have some involvement in this area, but most of the variety development activity has been and continues to be done at North Carolina

State University. Dr. Earl Wernsman has released several varieties that have gained commercial success, including NC 55, NC 71, and NC 72. NC 71, a flue-cured hybrid released in 1997, is the first variety to consistently out-yield K 326. This variety also has good curing characteristics and has taken market share from K 326, the dominant variety for many years. Additionally, Dr. Wernsman developed NC 196, another high-yielding, good-quality variety, made available for planting in the 2007 crop year. Dr. Wernsman retired from North Carolina State University but continued to work part time in variety development. North Carolina State University continues to devote considerable resources to flue-cured variety development, and Dr. Ramsey Lewis and others continue to work in this area.

During this time period, production practices that changed considerably were seedling production and transplanting. Even though much progress had been made in traditional plant bed production of seedlings through the use of clipping and undercutting, plant beds still carried a degree of uncertainty in the farmer's ability to have healthy seedlings ready to go to the field when needed. Also, there was the continuing need for labor to pull seedlings from the plant bed prior to getting them into the field. The advancement in this area was greenhouse production of tobacco seedlings.

Traditional greenhouses with overhead watering systems had been around for a long time, and some tobacco producers had tried using them to produce seedlings. However, the high initial costs of purchasing such a greenhouse, along with the high upkeep and operating costs, were strong deterrents to growers trying this approach to seedling production. This situation started to change when Speedling Incorporated, a major supplier of vegetable transplants from Florida, introduced a plug and transfer system for tobacco seedling production in the mid-1980s. The Speedling system involved the company supplying tobacco growers with young tobacco seedlings in trays. To reach a sufficient size for transplanting, the young plants needed to be transferred from the trays supplied by Speedling into trays with larger cells, thus the transfer part of the system. Once the seedlings were in the larger cell trays, the trays were floated in a greenhouse structure containing a heated water bed. The trays had an opening at the bottom of each cell that allowed water from the bed to wick up into the soil medium in the trays and keep the plants watered. Nutrients could be added to the plants through the water, and thus, the greenhouse structure did not need an overhead watering system. This type of greenhouse structure was less costly than traditional ones and was also cheaper to maintain and operate. While this system had its advantages over traditional greenhouses in producing seedlings, the high labor requirements to transfer the plants to larger cell trays was a big drawback in gaining acceptance by growers.

This problem was solved with the development of a direct-seeding method for putting tobacco seed directly into the larger cell trays (W.D. Smith, personal communication). Carolina Greenhouses located near Kinston, NC, had a partnership with Speedling to develop and market the plug and transfer system. Seeing the limitation of the plug and transfer system, they encouraged North Carolina State University through the Agronomy Department to develop a direct seeding system for float greenhouse production of tobacco seedlings. Beginning around 1986 or 1987, cooperative work began in this area. Large cell trays were filled with a soil medium that had the capacity to wick water from a water bed into the cell. In each cell of the tray a single tobacco seed was placed. To accomplish this feat, raw tobacco seeds were coated with a substance that was water soluble that made each single seed large enough to physically handle. After the coated seed was placed into the soil medium of the tray cell, the tray was floated on the water in the greenhouse. Moisture wicked into the soil medium and dissolved the seed coat while providing the moisture needed to germinate the seed. This research proved successful, and the float system, coupled with direct seeding of the trays, provided growers with a viable option for producing tobacco seedlings. Acceptance by growers was rapid, with float greenhouse production of transplants making up 35% of production in 1992 and 70% in 1996. By the year 2000, practically all of the tobacco seedlings grown in North Carolina were produced in float greenhouses.

Even though additional investment was required to get into greenhouse production of seedlings, there were considerable advantages for the farmer compared to the old plant bed method of growing seedlings. First there was a net labor reduction. No labor was required to pull plants from the plant bed, and the labor required for seeding and floating trays was comparable to or less than that needed to prepare and seed plant beds. Perhaps the biggest advantage for growers was improved management control of the entire seedling production and transplanting operations. The time from seeding until ready for transplanting was very predictable in the controlled climate of the greenhouse. Clipping was adapted to the greenhouse so that seedlings could be held for several weeks before transplanting. When it was time to transplant, all the grower had to do was remove the trays from the greenhouse and take them to the field. If, for some reason, all the transplants were not needed that day, the only requirement to preserve them was to refloat them in the greenhouse. Ultimately, the grower got better quality and more uniform seedlings that yielded positive results for him all during the growing season. Uniformity of transplants resulted in a more uniform crop relative to growth and ripening, which made plants much more accommodating to mechanical topping and mechanical harvesting. All in all, the shift to float greenhouse production of tobacco seedlings was well worth it for growers, both from an economic and a management standpoint.

An additional advantage of greenhouse transplants was labor reduction in the actual transplanting operation. The key to this labor reduction was the compatibility of the seedlings grown in the tray cells with the carousel type transplanter. This type of transplanter placed the seedling into the ground using the force of gravity, which was made possible by the weight of the root system and surrounding soil medium of each plant. As with other transplanters, the carousel type opened the row for plant placement but, instead of having mechanical fingers place the plant into the soil, it just opened a container holding a plant and let gravity pull the plant into the row. The weight of the root mass relative to the total plant weight was such that the plant traveled quickly to the ground and landed upright just prior to the press wheel packing soil around it. This type of transplanter typically has a magazine of 5 or 6 containers, each of which can be loaded with a plant awaiting transplanting. This feature of the carousel transplanter, along with the ease of removing individual plants from the trays, required only 1 person per row to keep the transplanter operating, as opposed to 2 needed for mechanical finger transplanters, and thus the labor savings.

During this timeframe, there were no other major changes in how the crop was grown; however, there continued to be refinements in several areas of crop production. In the area of herbicides, the effectiveness of products was an improvement over what was available to the grower in previous years. By using labeled combinations of herbicides such as Command, Devrinol, Poast, Prowl, Sparatan, and Tillam, a grower could achieve almost complete control of grass and weeds. Most growers continued to cultivate the crop for other reasons, such as fertilizer application and shaping of the row bed to better accommodate mechanical harvesting and runoff of excess water; however, the need for cultivation to control grass and weeds was greatly diminished.

Another area of crop production that saw refinement in this time period was the area of chemical sucker control. The introduction of MH as an effective chemical sucker control agent in the mid-1950s was a revolutionary change in how growers managed sucker growth after topping. The introduction of fatty alcohols, used in conjunction with MH in the 1960s and 1970s, made chemical control more effective and extended the time period for effective control of suckers. However, additional improvement was needed. With the development of varieties such as K 326, which would hold in the field longer without significant quality or yield reduction, coupled with growers' desire to extend the harvest season to gain more efficient use of harvesting equipment and barns, new techniques were needed to extend the length of sucker control. This technique arrived with a new type of chemical sucker control material, commonly known as a contact-local systemic, of which Prime+ was one of the commercial brands. To be effective, these materials had to come into direct contact with the sucker and provided good control as long as suckers did not exceed about 1 inch in length. Thus, spray equipment, such as that used with the contact fatty alcohols, was needed to apply Prime+ or other such materials. By using contact fatty alcohols, followed by a combination of MH and Prime+ at labeled rates, growers could now achieve season-long sucker control and reduce objectionable levels of MH residues.

Harvesting & Curing

Harvesting and curing also continued to see refinements during this time period; however, the changes were not nearly as dramatic as those in the earlier decades. The most notable change was the development of green-leaf, bulk-handling systems in the late 1990s. With the high harvesting capacity of 2-row mechanical harvesters, getting the harvested tobacco to the curing barns and loaded into barns in a timely manner became a bottleneck. The limited capacity of trailers carried on the rear of harvesters required frequent changing of trailers, with the associated downtime for the harvester. When trailers arrived at the curing barn, they had to be unloaded and the tobacco placed into curing boxes or racks for curing. Much of this activity was accomplished by hand labor. As previously discussed, the filling of curing boxes was sometimes accomplished directly on the harvester. However, the capacity of the boxes was typically smaller than the trailers, requiring more frequent downtime for box exchange. Additionally, there was the issue of settling and uneven distribution of tobacco as it was transported to the curing barn, often resulting in curing problems resulting from uneven air flow.

The solution for growers who used box curing systems was the green-leaf handling system. Interestingly, this concept was demonstrated at the research level by Dr. Bill Johnson more than 20 years previously, in the mid-1970s (23). Johnson's system consisted of a modified Roanoke mechanical harvester with a live bottom bin at the rear of the machine. When the bin was full of harvested leaves, the live bottom was used to unload the tobacco into a transport trailer that also had a live bottom. The trailer was used to transport the tobacco to the curing barn where the live bottom was used to unload the tobacco onto a conveyer for transport and loading of the curing box. While the scale was relatively small, about 1,000 pounds per trailer, the concept was the same as the 1990s system.

The commercial system of the 1990s consisted of 3 parts and allowed bulk transporting of harvested tobacco and precise loading of curing boxes, with minimal hand labor involved. The first component was a large container on the harvester with a live bottom, which is just a motor-driven belt. Typically, these containers were about twice the size of the previously used trailers, which resulted in less downtime for the harvesters when unloading. When a container was full, the harvester operator activated the belt bottom and unloaded the tobacco into a larger trailer or truck that also had a live bottom. The typical transport trailer held several discharges from the harvester before needing to take the tobacco to the barn for unloading. When a trailer-load of harvested leaves was taken to the curing barn, it was unloaded into the third component of the system, the box-loading component. The box-loading component consisted of a series of belt conveyors that fed the leaves into the curing box that rested on an electronic scale. The belts moved at sequentially faster speeds and placed an evenly metered amount of tobacco into the curing boxes, while the scales assured that each box had the same amount of tobacco. The result was an evenly loaded curing box, with each box in the curing barn having the same density, and all of this was accomplished with minimal hand labor. Curing boxes loaded this way also greatly aided the grower in getting a uniform, high-quality cure from each barn due to the even flow of forced air.

While not directly related to increased efficiency or labor reduction, another development related to curing was the increased use of heat exchangers in bulk-curing barns. This action was driven by an understanding of what caused the formation of tobacco-specific nitrosamines (TSNAs) in flue-cured tobacco. TSNAs are chemical compounds that have been identified as part of the risk components in tobacco usage. Thus, when the formation mechanism was discovered, the industry took quick action to prevent their formation in subsequent crops.

In the late 1990s, Star Scientific Company filed and received several patents on the production of low-TSNA tobacco. The basis of their early patents was the completion of the curing process by drying the tobacco by microwave energy instead of using heated air. In that same time period, Dr. David Peele, with R.J. Reynolds, published a paper that revealed that the cause of TSNA formation was the reaction of nitric oxides in the curing environment with the natural alkaloids in tobacco (38). Thus, it was not the microwave drying of the tobacco itself that resulted in low TSNAs, but rather the absence of nitric oxides in the curing environment. Since nearly all of the nitric oxides in the curing environment came from the incomplete combustion of LP or natural gas being burned as a fuel source, installation of heat exchangers to vent the combustion products away from the curing environment resulted in low-TSNA tobacco. The first bulk-curing barns from the 1960s used heat exchangers to keep the byproducts from combustion of fuel oil being burned away from the tobacco, due to odor and deposition issues. It is ironic that low-TSNA tobacco was being produced from these barns even though no one was aware of it. Samples of cured leaf from some of the old heat exchanger barns were tested during the 2000 curing season to confirm the findings of Peele. Only when growers changed to direct-fired curing systems for energy efficiency during the oil crises of the 1970s and 1980s did the potential for higher TSNAs return to flue-cured tobacco. This change to direct-fired and more energy-efficient curing was made possible by the availability and relative costs of cleaner-burning LP and natural gas compared to fuel oil.

Once the knowledge of how to reduce the formation of TSNAs in flue-cured tobacco became known in 1999, the industry moved quickly to address the issue. R.J. Reynolds started contracting directly with growers in 2000 to acquire low-TSNA tobacco. Reynolds provided the heat exchangers for the curing barns on a cost-sharing basis with the growers. Brown and Williamson started contracting through Star Scientific to acquire low-TSNA tobacco. The rest of the industry, led by Philip Morris USA and Stabilization, established a fund to assist growers with the cost of converting curing barns to the use of heat exchangers. The cost-sharing program started with the 2000 crop, and all conversions had to be completed by June 30, 2001, prior to curing the 2001 crop. As a condition of price support, all tobacco for the 2001 and future crops had to be cured in barns equipped with heat exchangers. Heat exchangers for curing barns also became a basic requirement of all contracts when the industry went to direct contracting with growers. Although this issue did not involve production efficiency, growers and buyers demonstrated that change could occur quickly when it was needed.

Marketing

One area that did see significant change was the area of marketing. Like many changes that occur, the effort by Al Graves and others in the late 1960s and early 1970s to market flue-cured tobacco in large bales was ahead of its time. However, by the mid- and late 1990s, the mood of the industry was shifting. The declining quota and resulting reduced marketings had created an excess of warehouse selling space. Warehousemen were reluctant to consolidate or leave the business. This situation created additional inefficiency, as purchasers had to travel considerable distances for the opportunity to purchase relatively small quantities of tobacco. Also, an improved marketing package was sorely needed. While the burlap sheet was inexpensive to purchase and transport, a package had long been sought that would better protect the tobacco from spillage and other losses. The time was right for the shift to large bales as a marketing package for flue-cured tobacco.

The first marketing experiment with large bales, encouraged by Stabilization, occurred during the 1996 marketing season when 5 growers in eastern North Carolina agreed to produce some bales for evaluation. The experimental bale size was a 44-inch cube with a target weight of around 800 pounds. Plans also were to produce some half bales. Unfortunately, Hurricane Fran hit eastern North Carolina in early September of that year, destroying most of the tobacco that remained in the field at that time. This reduced the amount of tobacco for the experiment and also distorted market conditions such that it was impossible to get much helpful feedback from the industry on the acceptability of bales. However, enough interest was generated to expand the experiment for the 1997 crop.

Industry-wide meetings were held during the winter of 1996/97 with a consensus to continue the baling experiment for the 1997 crop. Funds were raised, primarily from the buying companies, to purchase experimental balers for use by growers. The funds, administered by the North Carolina Tobacco Foundation, Inc., were used to support building of at least 10 experimental balers that would be distributed for use by growers throughout the flue-cured growing area. Taylor Manufacturing Company won the contract to build the balers based on a design by Dr. Mike Boyette of North Carolina State University. To assure equitable access to growers, one baler was placed in each district of Stabilization. Instruction for their use and allocation of balers to growers was coordinated by the respective state university extension services. The USDA's Agricultural Marketing Service graded the tobacco as experimental to guarantee that the baled tobacco would receive price support. The bales had a dimension of 42 inches by 42 inches by 40 inches, a targeted weight of 735 pounds, and a tolerance of plus or minus 50 pounds. In general, the baling experiment of 1997 was a success, with over 5 million pounds of tobacco marketed in this manner. Buying interests supported the bale package in the marketplace by paying a premium of around 5 cents per pound for tobacco marketed in bales.

Going into the 1998 crop there was generally enthusiasm for shifting to the large bale as the marketing package for flue-cured tobacco, although there remained opposition to shifting away from burlap sheets. Since 1 bale contained the tobacco weight of about 3 burlap sheets, a shift to bales would require only about one-third of the auction floor space needed for sheets. This fact placed further pressure on the auction warehousemen to consolidate or get out of the business, and generally warehousemen opposed the shift to bales. Buying interests generally favored the shift to bales, since it provided a more efficient and secure package with which to purchase and transport the tobacco. An accompanying program to use unique and tamper-proof bale tags to identify the original seller of the tobacco also improved the accountability and traceability of tobacco in the auction process.

Growers in general were neutral about the shift to bales in the early stages. They saw this change as requiring additional capital investment to purchase another piece of equipment. However, some of the grower leadership saw baling in a broader context. Specifically, Mr. Charlie Harvey, then Executive Vice President of the Tobacco Growers Association of North Carolina, saw additional opportunities for tobacco farmers. One was the obvious chance to improve operational efficiency at the farm level. Another, which was less obvious, was the opportunity to improve relationships between growers and buyers. The increased security and integrity offered by the bale package assured buyers that they were getting the quality they saw on the auction floor. Coupled with the identity tags, buyers also could see the quality delivered by individual farmers. These factors did improve the relationship between tobacco growers and buyers and lessened the influence of the warehouse system. In a way, baling was a catalyst that helped pave the way for acceptance of contracting by both growers and buyers.

When individual farmers saw the time and labor efficiency the bales provided at the farm level, they too became strong supporters of the shift to bales. The farmers' attitude change was aided by a virtual explosion in the number of suppliers of balers. These suppliers offered balers with a wide range of price and complexity. Low-capacity balers powered by a farm tractor were available for a few hundred dollars. High-capacity balers with independent power systems ranged in price up to around $30,000. The net effect was a shift to large bales as the marketing package for flue-cured tobacco, with nearly the entire crop being sold in bales by the 2000 crop year.

The controversy over the shift from burlap sheets to large bales had not quite subsided when an even more dramatic change relative to marketing emerged, a change from the traditional auction system to direct contracting between grower and buyer. The potential for this change was driven by two emerging situations. First was the continuing decline in the size of U.S. crops. The historical advantage of the auction market was the ability of a buyer to go into the marketplace and pick, choose, and purchase the grades he desired to buy from the available supply. As the crop sizes continued to decline, the supply of available grades of tobacco also declined. This made it more difficult for a buyer to find the volume of grades needed, especially for buyers of large volumes of any particular grade. The second driving force was the need to acquire tobaccos with low TSNAs. All manufacturers saw the need to acquire tobacco with low TSNAs, but since this was a quality trait that could not be visually detected, the auction system did not lend itself to easily verifying the TSNA level of tobacco before purchase. The mandate to use heat exchangers for the 2001 crop aided the auction market situation, but the shift to contracting had already begun.

The first significant shift to direct contracting began with the formation of United Tobacco Company. In late 1997, a group of large tobacco producers in eastern North Carolina, along with several former executives from the leaf-supplier sector of the industry, came together to form this company. The growers involved contracted their tobacco directly to the company to supply mainly export customers. While this caused a ripple in the industry, the 1998 season went by with a focus still on the auction process for selling tobacco. However, the crop size continued to shrink, with marketings in 1999 dropping to 654 million pounds. The knowledge of how to produce low-TSNA tobacco became widely known in late 1999. This knowledge, coupled with a crop size drop to around 550 million pounds in 2000, increased the pressure on the auction process. R.J. Reynolds was the first major domestic manufacturer to shift to contracting, purchasing much of their 2000 crop requirements through direct contracts with growers, using low-TSNA tobacco as a rationale. Also in 2000, Brown and Williamson acquired a portion of their needs through Star Scientific, which contracted with growers for low-TSNA tobacco. Philip Morris USA also used contracting with flue-cured growers to acquire some low-TSNA tobacco during 2000. However, the auction process was still the primary method of selling tobacco for the 2000 crop.

The major shift to contracting began with the 2001 crop, which was also around 550 million pounds in size. The indication for this change was when Philip Morris USA started a pilot contracting program in 2000 for burley tobacco, which had had even more severe supply issues than flue-cured. Philip Morris USA expanded its contracting to flue-cured in 2001. For the 2001 crop, nearly all purchasers of U.S. flue-cured tobacco participated in contract purchasing from growers either directly, through their own system, or indirectly through the systems of leaf suppliers. Even with the continuing option of selling at auction, by the 2004 crop year, growers were selling about 80% of the crop through direct contracting with buyers.

The shift from the auction process to direct contracting was highly controversial for a tradition-bound industry like the tobacco industry. Even though direct contracting was being used as the method of selling for many other agricultural products, the shift to direct contracting in tobacco brought out many emotions. Generally, the large buyers and growers were in favor of contracting because it cut out middlemen and provided the potential for cost savings for both buyers and growers. The change was generally opposed by auction warehousemen because it would put many of them out of business. However, some of the more successful warehousemen became receiving station agents for delivery of contracted tobacco for the large buyers. Contracting was also strongly opposed by the grower cooperatives, as they saw it as an additional threat to continuation of the Federal Tobacco Program, the basic reason the cooperatives existed. Ultimately, the shift to direct contracting in the early 2000s was a blessing to growers, for when the tobacco program was bought out, starting with the 2005 crop, the method of direct contracting was already established. Thus, the uncertainty of how growers would sell their tobacco without the price support program and the auction process had already been removed. Just as importantly, the combination of the bale-marketing package and direct contracting with buyers provided growers with significant savings in man-hours and costs in producing the crop.

Summary. The time period from the mid-1980s to 2008 did not contain the dramatic changes in labor improvements of some of the earlier time periods; however, significant changes did occur. Primary among the changes was the shift from plant-bed to greenhouse production of tobacco seedlings with the accompanying labor and managerial savings. Also significant was the change from burlap sheets to the large bale as a more efficient marketing package for flue-cured tobacco. However, the most significant changes in the industry during this time period were of a policy nature. The change from auction markets to direct contracting was a large change for a tradition-bound industry; however, the elimination of the Federal Tobacco Program through the quota buyout, ending nearly 70 years of federal regulation of tobacco production, was by far the biggest change that occurred.

2008, HOW IT IS

In his research reports in 1973, Dr. Charlie Suggs estimated that at some future date the amount of labor required to produce an acre of tobacco would be reduced to 35 man- hours (49). In 2008 the most efficient tobacco producer is not far from that target. Dr. Gary Bullen, a North Carolina State University agricultural economist reports that the most efficient growers in eastern North Carolina are near 50 man-hours per acre, with the most efficient 10% of growers in the 50 to 70 man-hours per acre range (G. Bullen, personal communication). That is a tremendous improvement in efficiency and productivity from the 450 to 500 man hours required in the late 1940s, just after World War II. Results are even more dramatic when compared on a per-pound basis. The 22.5 minutes required to produce and market a pound of tobacco in the late 1940s has been reduced to 1 min (or slightly more depending on yield) for the most efficient farmers in 2008.

What does a modern tobacco farm look like in 2008? Obviously, it is very mechanized and managed by a farmer who has great organizational and coordination skills. The latest in technology is used at all steps of the production cycle.

The production cycle begins the year before in planning the best rotation with other crops and the physical location of the fields relative to curing barns and available irrigation water. The crop year begins with production of the seedlings. The seedlings are grown in a float greenhouse system with the seedling trays seeded directly with coated seed. The variety or varieties selected have the combination of yield, quality, and disease resistance that best fits the farmer's individual fields being used that year.

Seedling growth is closely monitored and controlled through fertilization, with the plants being clipped frequently to assure maximum uniformity and survivability when taken to the field. Typically the seedlings are ready for the field in 60 to 65 days after seeding.

Field preparation, of course, is all done with tractors. When the fields are disked, soil-incorporated insecticides and herbicides are applied as needed. Next, the row beds are prepared and, if chisel plows are used, they are just ahead of the row formers. Any fumigants being used are injected into the row bed as it is being formed. As the time for transplanting nears, the row beds may be opened and reformed to allow any residual fumigant to escape and to freshen the soil surface, thereby destroying any grass that may have started to grow. Just prior to transplanting, the row ridge is leveled and any soil surface herbicides to be used are applied then or just after transplanting.

When the transplanting operation is ready to begin, the plant trays are removed from the greenhouse and taken to the field. Carousel-type transplanters are used, with 1 person per row needed to supply plants to the transplanter in either a 4- or 8-row machine.

When the plants have started growing, they are cultivated and fertilized with tractor-drawn equipment, again typically in a 4-row operation.

Figure 17. A mature field of flue-cured tobacco that has been topped and the lower leaves harvested.

Cultivation is not often needed for grass or weed control but rather for precise fertilizer application and row-bed formation. At the last cultivation, called lay by, a high bed is formed around the base of the plant to make the plant more accessible to the mechanical harvester soon to follow, as well as to provide for good drainage. At this time the crop is closely scouted for any insects, and insecticides are applied only when there is economic justification.

Several weeks after lay by, the chemical sucker control program begins. This program includes 2 or 3 applications of a contact fatty alcohol material followed by MH and Prime+ either in a tank mix or as sequential treatments. Topping occurs when the plant flowers are at an early button stage with just a few flowers showing. Mechanical topping is used, which benefits from the use of uniform greenhouse seedlings since most of the plants will flower at nearly the same time. Minimal hand labor is required to clean up any missed tops or suckers. Effective sucker control is extremely important, so that sucker growth will neither interfere with mechanical harvesting nor provide a "food" source for insects.

When the tobacco has ripened and is ready for harvest, the leaves are mechanically primed by a mechanical harvester. A 2-row harvester is used, having an annual capacity of about 100 acres. A spiral defoliator is used on the bottom and middle stalk positions, with cutter bars used for the top stalk positions. The harvester is equipped with a live bottom storage container on the rear of the machine as part of a green-leaf handling system, to be able to

Figure 18. Mechanical topper cutting flower heads from (topping) tobacco plants.

Figure 19. Modern 2-row mechanical harvester with live bottom collection bin entering a field.

Figure 20. Modern bulk-curing barn complex with large shelter joining units and providing protection from weather for loading and unloading operations.

quickly off-load the tobacco when the container is full. Once the container is full, the leaves are off-loaded into a live bottom trailer for transport to the curing barns.

At the barns, the leaves are off-loaded onto the third component of the green-leaf handling system, the box loader. There the curing boxes are evenly filled and weighed to assure equal weight in each curing box. Once filled, the curing box is loaded into the curing barn. Each barn, depending on its size, holds 8 or 10 curing boxes for each cure. The curing environment is computer controlled using dry bulb and wet bulb sensors as indicators for temperature and humidity to regulate the furnace firing and air recirculation. The cure is complete in approximately 7 days. After a brief reordering cycle to get the moisture content back up to 14 or 15% for handling without breakage, the curing boxes are removed and taken to the baling operation. There the curing boxes are mechanically unloaded and the tobacco inspected for quality, with any undesirable leaves or nontobacco materials removed before baling. Then the tobacco is mechanically fed into the baler to form the approximately 735-pound bale into the desired 42- by 42- by 40-inch shape. Once formed, the bale is either placed in short-term storage on the farm or loaded directly onto a truck for delivery to the contractor's receiving station for sale.

All of this production is accomplished with only 50 to 70 man-hours per acre, resulting on average in about a 2,500-pound per-acre yield. Only a little over 1 min of labor is required to produce each pound of tobacco. Yes, the

American tobacco farmer has come a long way in the last 60 years. Much of the manual labor and drudgery has been removed from producing the crop. However, to be successful as a modern tobacco farmer requires passion, great management skills, and the art that only comes with experience.

LEGACY

As with numerous other agricultural crops, many people said that the harvest and curing of flue-cured tobacco could never be mechanized. They were proven wrong. Through the determination, ingenuity, creativity, and engineering skill of numerous researchers and entrepreneurs, the crop was successfully mechanized. The modern American tobacco farmer owes a huge debt of gratitude to individuals such as Dr. Bill Johnson, Dr. Pat Hassler, and Dr. Wiley Henson with bulk curing and Dr. Charlie Suggs, Dr. Bill Splinter, and Mr. Robert Wilson with mechanical harvesting. In more recent times, Dr. Mike Boyette has kept the flame of innovation alive through developments in baling, electronic curing controls, and energy efficiency.

All of these individuals and many more in the tobacco agri-business sector not mentioned here leave a rich legacy. Not only has labor and drudgery been removed from tobacco production, but the entire quality of life has been improved for the tobacco farmer and others needed to grow the crop. A huge supply of labor, not now needed, has been released to be more productive in other sectors of society. All of these productivity gains have allowed tobacco farming to remain in the United States and has preserved the culture of this part of American agriculture. Because of these individuals, today's American tobacco farmer has the tools that allow him to predictably and consistently produce tobacco that maintains U.S. quality superiority in the world market and provides a good value for customers worldwide.

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