Early West Texas Drilling and Evaluation Technology

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One of the first gas shows in West Texas was recorded before 1889 at a depth of eighty feet in the Nasworthy water well test some four miles north of San Angelo. The 1200 feet deep Turney well located thirteen miles northeast of Fort Stockton found oil and gas at several depths. It was drilled in 1900. The following year saw another show near Fort Stockton, three shows in Pecos County, a sixty feet deep show in two Concho County water wells, several oil and gas shows in a 282 feet penetration in Pecos County, and oil shows in several holes in El Paso County.

Captain John Pope had introduced cutting-edge drilling technology to West Texas in the month of June 1855. Commissioned by the War Department to test for subsurface water in the area between the Texas Colorado and the Pecos rivers, Captain Pope drilled several wells utilizing the Ruffner solid rod percussion system. His final test in 1858 reached a total depth of 1050 feet. Mr. Brown, who had helped drill the famous Belchar Sugar Refinery well in St. Louis, Missouri, was the civilian superintendent of this project.

Drill-stem testing came into use around 1926, when E.C. and M.O. Johnston invented the retaining valve. A cone shaped packer made from belting material seated on the rim of a pilot-hole. The equalizing valve was added in 1931, and the pressure recorder in 1934.

Resistivity logging was introduced in Europe in 1927; spontaneous potential was discovered in 1931. A gamma-ray log had been run near Kermit by 1937. Neutron logging was described in the early 1940's and quantified by the end of the decade. Microresistivity devices had appeared by 1949.

PARTURITION

The classic reference Texas Oil and Gas Since 1543 (Warner 1939) records that gas was found before 1889 at a depth of eighty feet in the Nasworthy water well located four miles south of San Angelo. The Turney well, thirteen miles northeast of Fort Stockton, in 1900 noted thirteen shows of oil or gas in its 1200 feet. Small amounts of both were produced from the Turney well until 1917. At least five wells found shows of oil or gas in 1901. A 282-foot well six miles southeast of Toyah had shows at 155, 217, 240, and 280 feet. Two water wells six miles from Paint Rock in Concho County encountered oil at less than sixty feet. One or more wells near El Paso recorded a show of oil. A low gravity oil was recovered from about sixty feet in a well about nineteen miles north of Fort Stockton. J.D. Leatherman sold oil for windmill grease from a 170 feet water well drilled fifteen miles northwest of Toyah in 1903. Three more non-commercial shows were drilled near Toyah in 1904, and some gas was found in a twenty-one foot bore northeast of Rustler Spring.

DuPont Powder Company drilled a well with show at 400 feet near the Turney well in 1910. Producers Company had a slight show at 2000 feet in two wells drilled near Toyah in 1911. Calumet and Arizona Copper Company junked a fifty-one foot test, made a five barrel well at 550 feet, and had good shows in a 576 foot well in the Fort Stockton area in 1915. Two tanks of oil were shipped from these Arizona Copper wells in 1922. In 1921 the Grant Number Ten, just forty feet from the Turney well, came in at 1,000 BOPD from ninety-six feet. It soon declined to nothing. Several poor to fair oil wells were drilled in Mitchell County from 1919 to 1923, but West Texas had become known as "The Petroleum Graveyard of the World".

Frank T. Pickrell and Haymon Krupp, operating as Texon Oil and Land Company obtained 431,360 acres of State University lands in several West Texas counties. Nearing the time limit of their drilling contract, they shipped a water well drilling machine to Best. The machine was damaged while removing it from the train, so a location was made beside the railroad tracks and a well spudded there instead of at the planned location. Two non-interested parties were needed to witness the spudding of the well a few hours before the lease was to run out. Fortunately, two men drove up in an automobile and continued to San Angelo to make their affidavits. It is said that Mr. Pickrell had been instructed by some friends in New York to pray to Santa Rita, the Saint of the Impossible. He climbed to the top of the rig and named the well “Santa Rita”, christening it with a blessed rose. Spudded on September 3, 1921, the well blew in from 3028 feet on May 28, 1923. Pickrell drilled some small wells and dry holes until he obtained an initial flow of 1500 BOPD from his Number Nine well. Numbers Ten and Eleven were better than Number Nine, and by 1925 his Number Eighteen well was drilled for an initial production of 9000 BOPD. West Texas was no longer a petroleum graveyard.

Three notable wells illustrate the dynamic development of West Texas. On October 28, 1926, the eastern Pecos County test of Transcontinental Oil Company blew in at 997 feet and produced at a rate of 135 BOPH. Subsequent deepening to 1150 feet allowed a rated flow of 70,824 BOPD on August 18, 1928,

making its place in history as one of the great wells of the world. Texon Oil and Land Company’s University 1-B at was completed on November 30, 1928 at a depth of 8525 feet, making it the both the deepest producing well and the deepest test at that time. This producer at the end of 1929 was making 2800 BOPD. Gulf Production Company Number 103 McElroy was spudded March 21, 1933 and reached total depth May 5, 1935. It was world’s deepest test at 12,786 feet; an Ellenburger penetration, it was plugged back to a Permian lime for production of 175 BOPD.

CAPTAIN JOHN POPE AND HIS DRILLING MACHINE

State-of-the-art drilling technology came to West Texas long before the search for oil began (Brantly 1961). In January 1855, the War Department instructed Captain John Pope of the Corps of Topographical Engineers to explore for artesian water on the Llano Estacado. The proposed wells would support the planned Pacific Railway venture. Captain Pope, West Point class of 1842, was a native Kentuckian and a Mexican War veteran. After his well-drilling stint, he served in Lincoln's inaugural escort and became a brigadier general of United States Volunteers. He achieved victories at New Madrid and Island #10 and was promoted to major general of volunteers in March 1862. In command of the Army of Virginia he lost the second battle of Bull Run to General Lee. Pope spent the rest of the War Between the States as commander of the Department of the Northwest, where he dealt with the Sioux contumacy. Four years after his retirement in 1886 John Pope was made a major general in the regular army.

Captain Pope's reports are the only surviving account of the day-to-day operations of a drilling rig prior to 1860. He proposed to drill four wells to 600 feet and presented an authorized financial expenditure of $28,532 to the federal government. Costs seem to have stayed under this limit. Mr. Brown was employed as drilling supervisor and brought a crew who had drilled the Belcher Sugar Refinery Well at St. Louis. This well was completed at 2193 feet in 1854 after five years of work.

The first well was spudded in June of 1855 about fifteen miles east of the Pecos River at a latitude of thirty-two degrees. This latitude had been the border of Texas and New Mexico since the Compromise of 1850. The well is located northeast of the present day Red Bluff Reservoir. It reached a total depth of 640 feet in September 1855. Due to cavings the work could not be continued without more pipe; the 500 feet of casing which Pope had brought with him had been used up. Water had risen to 390 feet, but the cavings bridged off the water sand. While waiting for pipe, the party moved west of the Rio Grande and drilled a second well to 293 feet.

Captain Pope returned to the Pecos River and made a new location about five miles east of the first well. He spudded the third test on April 5, 1856, requested a geological survey on April 22, and received the report on May 1 (Shumard 1856). By April 16th, the well had reached a depth of 245 feet, where water was found. The pipe arrived on April 29th and consisted of 1200 feet of three-inch I.D., 3/16th inch wall, nine feet long wrought iron tubing with screw joints. 400 feet of 1 ¼ inch pipe was also included. Drilling resumed until at 450 feet a casing failure occurred three joints off bottom. Recoverable pipe was withdrawn and the rig was skidded on May 20th. By July 20th total depth of the fourth bore was 810 feet. Attrition of the boring rod string caused work to cease on August 26th at a depth of 861 feet.

The Pecos River tests employed the Ruffner drilling method. A 3 ½ inch bit connected to a thirty feet long iron rod 1 ¼ inches in diameter. At the top of this stem was a set of drilling jars with an action of sixteen inches. The drilling jars were in those days called “slips”. The jars screwed into oak boring rods that were 1 ¾ inches in diameter and thirty-two feet in length. The rod string was attached to a spring beam by a chain, and the spring pole was activated by a steam engine. A nine feet long copper sand pump attached by a rope to a drum on the engine was used to remove cuttings from the hole. The drill stem was raised and dropped at a rate of fifty-five strokes per minute. Sand pumping was necessary after two and one-half hours of making hole. Pope “carried” casing by means of spring loaded under-reamers 4 ½ inches in diameter. His is the first historical account of “carrying” casing, although the technique was certainly in use before his project.

After a hiatus of more than a year, by May 1, 1858, Pope had resumed drilling and made eighty-one more feet. Caving rock had made it necessary to drive the casing. The iron stem broke and six weeks were needed to fish it. The boiler scaled severely and had to be reworked. A chert stratum cut the wooden rods and bent the iron rods that were run in their place. To get past this layer, Captain Pope ran a string of three inch copper tube. The jars then parted and the copper liner had to be removed. The bottom joint remained in the hole and had to be milled and speared. The jars and stem were recovered, but another fishing job came about further down hole. By August 22nd the boiler had been completely destroyed by the gyp water of the West Texas. The well had reached a total depth of 1050 feet one year and five days before Drake had drilled his sixty-nine feet deep oil well in Pennsylvania.

Captain Pope and Mr. Brown operated in an area located far from supplies and plagued by hostile Indians. Winter operations were often suspended because of fierce northers, and the summer heat must have seemed unbearable to men from the Eastern United States. Nevertheless they drilled thirty-three more feet than the 2400 feet promised in Pope's original proposal, and according to Pope's letters they came in under their authorized financial expenditure.

STANDARD PERCUSSION RIGS AND SPUDDERS

West Texas fields were opened up with both percussion and rotary rigs. In many areas the upper part of the hole might be drilled with a rotary rig and the target formation drilled by cable tools in order to prevent contamination of the producing zone. In other fields with a hard surface lithology, the first part of the hole might be made with the percussion method and the latter section drilled with a rotary rig. The author has drilled in with cable tools as late as 1984, and in 1998 he watched a well at which the spud hole and rat hole were drilled with a spudder. Percussion methods had been supplanted in most parts of the country by the 1940's, but because of the hard lithologies in parts of the Permian Basin they lasted for some years longer.

A detailed account of the construction and operation of the standard rig is given in Oil Production Methods (Paine 1913). The standard rig had been evolved by the 1880's and continued in use well into the 1930's. Its major components from front to back were the boiler, steam engine, band wheel, sand wheel, calf wheel, walking-beam, Sampson post, derrick, and bull wheel.

The boiler provided the steam to drive the engine. Some boilers were wheeled, others skidded. Both water-tube and fire-tube designs were used. For digging the first well in a field, the boilers were fired with wood or coal; after production was obtained, oil or gas was used as fuel. Lack of a good water supply hindered boiler utility in the Permian Basin. Single cylinder sliding valve reversing steam engines of the same design as those used on locomotives drove the standard rig. Displacement was typically ten and one-half by twelve inches. A belt pulley opposite the flywheel supplied power to the band-wheel. The engine was housed in a substantial shed. The driller operated the throttle by a hand line known as the “telegraph cord” and handled the reverse mechanism by means of a one-half inch pipe connected to a handle.

A friction belt connected the engine output to the band-wheel. Ten feet in diameter and built of wood, the band-wheel ran on a crankshaft supported by the jack posts. Looking from the floor to the engine house, a five-hole crank was attached to the crankshaft on the left side and a chain sprocket and clutch on the right side. A seven-foot wheel, known as the tug pulley circle, was fixed on the right surface of the band-wheel. The calf-wheel was chain-driven by the clutch and sprocket on the band-wheel. The calf-wheel sat on posts between the band-wheel and the derrick; it had a single toothed wheel and brake drum on the same side. It was used to run casing or tubing, and it operated a traveling block strung to the crown block by seven or nine lines.

Posts on the far side of the derrick floor mounted the bull-wheel. It consisted of two wooden wheels eight feet in diameter joined by a sixteen-inch shaft. The left wheel received power from the band-wheel by means of the bull-rope. The right wheel rim served as the brake drum for the brake-band. The bull-wheel served to raise and lower the drilling line and tools. A friction-powered sand reel was mounted at the band wheel to raise and lower the sand line and bailer or sand pump. The drilling line ran over a single pulley in the crown, and the sand line had a separate pulley at the crown.

Reciprocating action was provided to the tools by the Sampson post and walking-beam. This system was used by early steam pumps to remove the water from British coalmines, was incorporated by paddle-wheel steamboats, and is still used by modern pumping units. The walking-beam is named for its ambulatory movement, and the Sampson post is so called after the Biblical strongman, since it supports a great weight. A pitman connected the walking-beam to the five-hole crank of the band-wheel. The inside or number one hole was reserved for pumping operations. The outside or number five hole was generally used when an extreme jar was necessary to drive casing. Drilling operations were conducted with the three middle holes. The temper screw hung from the head of the walking-beam by an integral tee. Five or six feet long, the coarse-threaded temper screw suspended the drilling line by means of manila-line clamps or wire rope clamps. It allowed the driller to pay out line as he made hole with the tools. When the screw was extended to maximum length, the clamps were shifted.

Drilling line was originally two or two and one-half inch manila rope, which was later replaced by preformed wire rope of smaller diameter. According to the author's father, who began dressing tools at the age of twelve in the year 1924, drillers who came from the Eastern oil fields insisted upon running about one hundred feet of manila line between the tools and the wire line (Cearley 1978). This manila line was called the "snake". Workers who had followed the boom from the East to Texas were thus known as "Pennsylvania Snakes". In drilling ahead, the tools struck bottom on the "crack of the line" something like the action of a bullwhip; the walking beam is already on the way up and a distinct audible jar is heard, thence the name "jarhead" for cable tool workers.

Wood was used for derricks, with oak being preferred. The Lee C. Moore Company introduced steel derricks made of pipe about 1910. Derricks were left on the location when productive wells were found. Bits had a fluted watercourse to facilitate the mixing of cuttings and water. They were attached to a stem, jars, sometimes a sinker bar above the jars, and to a rope socket. Proper twist could not be imparted to the bit with wire line until the invention of the swivel type rope socket. Cable tools were fitted with square shoulders near the tool joints. Great hook-like wrenches were fitted to these squares and a device called a Barrett jack and circle was used to make up and break out the tools. A forge stood on the rig floor and was used to sharpen the bit when it became dull.

It was essential to bail the cuttings from the hole when five to eight feet had been made. Removing a cotter pin from the crank and slipping off the pitman stopped the walking-beam. Since there was no clutch between the band-wheel and the bull-wheel, the bull-rope was slipped on the bull-wheel by hand and the tools were removed from the hole. With the tools banked, the bull-rope was thrown off and the bailer or sand pump was run using the friction-operated sand reel.

The calf wheel was used to run casing. A cellar of eight by ten by twenty feet dug below the floor made this job easier. As in handling modern sucker rods, two sets of elevators (of the thumb-buster type) were used instead of spiders and slips. Casing was not only run normally, i.e. with an annulus, but also carried by under-reaming and driven without under-reaming. It was made up with chain tongs or Crumbies. Perhaps the main reason that the cable tool rig persisted in West Texas was that hole could be made in many fields without carrying casing.

Internal-combustion engines had been introduced to percussion drilling by 1918, but steam power lasted many years until its disappearance around 1954 (Brantly 1961). Wood was replaced by steel in standard rigs, and the spudder replaced the standard rig itself. Spudders utilize a reciprocating arm; the drilling line runs from the spooling drum under a sheave on the spudding arm and thence over the crown pulley to the tools. This superior design eventually prevailed.

THE ROTARY RIG

The basic design of the rotary rig had been achieved before the opening of the Permian Basin. Like the standard rig, the rotary had to be torn down and rebuilt at the next location. In 1934, the first unitized rig was deployed, putting an end to the practice of completely constructing the draw works, known then as the "casing drum" on each wellsite. The rotary rig was driven by steam; the steam mud pump mandated greater boiler capacity than was necessary for a standard rig of the same hoisting capacity. Steam pumps were simple and efficient. There was no gear end. The power end applied energy by the pump rods directly to the fluid end.

Although the square kelly was invented in 1844, its high manufacturing cost made the grip ring the industry standard during the first one-third of the twentieth century. The grip ring made a compression fit to the drill pipe and had to be continually loosened and tightened by the roughnecks in order to allow the pipe to drill ahead.

Modern Web Wilson tongs had replaced chain tongs and rope-and-pole grips by the end of the 1920's. Side door elevators displaced the "thumb-buster" type. The Foster friction cathead did away with the live catheads of the early rotary rigs. These live catheads took many lives, as did the first rotary tables. Early rotary tables were chain driven by the draw works, with the rotary clutch attached to the table itself. When tripping, the rotary chain turned all the time. A board was inserted between the upper and lower chain to keep the floor hands out of it. A belt guard later replaced this board. Unit rigs provided for a rotary clutch integral to the draw works. Brake bands were replaced by brake blocks, which grip the brake drums evenly all the way around. Jaw clutches gave way to friction and later air clutches.

Steam power was replaced by internal combustion as the power of stock engines increased and portability became more important to the drilling contractor. Although diesel power plants were introduced in 1937, natural gas engines continued in use for thirty more years partly because fuel in the form of lease gas was free.

Drill pipe evolved from line pipe to pipe with square shouldered tool joints to pipe with bottlenecked tool joints. An important consideration for the geologist is the fact that until the year 1934 in the Permian Basin, drill pipe was run in compression. Only one or two drill collars were used, and the drill pipe supplied the rest of the weight necessary to achieve maximum rate of penetration. An average run for a string of drill pipe under these conditions was 20,000 feet. Crooked hole is almost a certainty with drill pipe in compression. This is verified by modern shallow holes drilled with a pulldown. A mapping geologist should suspect both formation tops and bottom-hole location on any well drilled by a rotary before 1934 in West Texas. In 1934, a contractor from California moved into the region and began drilling with eight or ten drill collars, as was the practice in California. Area drilling contractors immediately saw the advantage of this system and copied it. The life of a string of drill pipe jumped from 20,000 feet to more than 100,000 feet. Straighter holes became more common. A considerable drill pipe surcharge was dropped from drilling contracts.

Except for the change to diesel and diesel electric power, few changes have been made in the basic West Texas drilling rig since 1940. Some drillers are running the same rig their grandfather broke out on. The great improvements since 1940 have been made in bits, portability, well control, and mud systems.

WELL CONTROL EQUIPMENT

"Development of Mechanical Control Equipment Used to Prevent Blowouts" (Works 1937) gives a comprehensive history of surface equipment. The earliest attempt at well control was the gate valve used on both standard and rotary rigs. By 1937 some 10,000 patents had been granted covering some aspect of well control, with the first patent issued in 1882. Several systems stand out.

The Decker preventer of 1900 incorporated two screw operated compression rams, a pipe-centering mechanism, and a single relief outlet. The Savoie blowout preventer of 1911 was a hinged lead-seal tool that was forced into the bell-nipple by the weight of the drill pipe. Lip-type packing for cylindrical rams was invented in 1922. The widely used Hosmer preventer, similar to a modern stripping bowl, replaced the Savoie device.

The first daily blowout prevention drill was held in Louisiana in 1925, but this practice has yet to reach certain parts of West Texas. Steam activated rams were used at Hobbs in 1928. That year also saw the fabrication of self-centering pipe rams. A rudimentary rotating head had been used by 1929. Remote control was used for insertion of a packer-type preventer in 1931, and by 1934 a steam operated turbine closing wheel with remote operation was in service.

Kelly cocks and safety joints were available in 1937, and mud crosses were in general use. Variable chokes were being advocated as essential to proper well relief, but modern well control training, procedures, and equipment were some distance down the road.

DRILL-STEM TESTING

E.C. and M.O. Johnston developed the first commercial test tools in 1926. They built a retaining valve from a railroad boxcar spring and a poppet valve and ran it with a cone-shaped packer made of drive belt material. Metal straps welded to the outside of the tool kept the valve from opening when running it in the hole. When the drill pipe sat on bottom, the straps collapsed and allowed the retaining valve to open. Picking up on the drill pipe let the spring close the valve; fluid was recovered in the drill pipe. This simple system required the drilling of a pilot hole called the “rat hole”. The packer seated on the shoulder of the smaller diameter hole. The short anchor did not touch bottom; weight was borne by the cone-shaped packer. This packer was dressed with belting material because it was thought that it would unseat more easily. Rat hole packers were still widely used as late as 1939 (O’Neill 1940) even though more sophisticated methods were available.

By 1928, the Johnstons had replaced the metal straps with a trip valve run above the retaining valve. Dropping a metal bar down the drill pipe activated the trip valve after the packer had been seated. An equalizing valve was tested by 1931; this valve let pressure above and below the packer reach the same level so that the tool could be unseated. Johnstons bought a pressure recorder and installed it in the anchor in 1933. Soon two pressure recorders were used so as to detect tool plugging. An adjustable flow bean was utilized later in the 1930’s and a reverse circulating tool appeared in the 1940’s. Improvements in rubber manufacture and in mud systems led to the dominance of straight-wall packers with which an anchor supported the drill string weight rather than a pilot hole shoulder. Testing was only accepted as a safe practice in the middle 1940's, partly because mud systems were not far enough advanced to accommodate the drill-stem test procedure.

SAMPLES AND CORING

The percussion drilling system allowed very effective examination of the rock cuttings. Temper screws were five to six feet in length, but the stretch of the drilling line allowed five to eight feet of hole to be made before running the bailer or sand pump. The cuttings dumped from the bailer were thus free from contamination by upper lithology. In dry holes, oil or gas would enter the borehole freely, as there was no hydrostatic impediment. When it was thought necessary to examine a section more closely, the "chip-coring" method was utilized. The driller would cut one foot of hole and bail. The largest cuttings were then scrutinized as being indicative of the last rock drilled. A record of rig activity combined with a description of the cuttings recovered was called a log as early as 1913 (Paine 1913).

The evaluation of rotary cuttings was not so simple. Although the M.T. Chapman rotary patent of 1887 discussed mud, and B. Andrew, Sr. of Louisiana had drilled with mud by 1889, early mud properties were extremely poor by modern standards (Brantly 1961). In 1921 a Louisianan named Stroud weighted mud with iron oxide; by 1926 he had received a patent which covered barite as a weight material. Drillers weighed a gallon bucket of drilling fluid with a spring scale; from this test came the term "pounds per gallon". Various methods of measuring viscosity were standardized into the Marsh funnel test. The filter press and sand content tests were introduced in 1936. Starch was used as an additive in 1941, and lime in 1944. Little was known about such properties as gel strength and plastic viscosity. Sample quality must have been poor.

Since the information obtained from rotary cuttings was unreliable, cores had to be taken. Although diamond drill rotary coring was used in the mining industry in the nineteenth century, it was not adopted by the oil industry for many decades. One early oil well coring system used a bottom-hole joint of ordinary drill pipe whose end was serrated. After the sufficient footage had been cut, extra weight was applied which collapsed the teeth. This was known as "burning in the core" and served both to separate and retain the core. This is similar in principle to a fishing catch known as the "poor-boy basket". Another early coring method used a piece of drill pipe with one or more slots cut at an angle from the vertical. Chilled shot was used to abrade the rock. Wedging the core to the inside of the pipe with dropped shot provided retention. By 1930 more than twenty types of coring devices were in use, some of them of the modern type. After the introduction of double barrel rotary core drills, a percussion coring system was developed for standard cable tool rigs. Wireline side-wall samplers had been used in Southwest Texas by 1936.

Sample lag time was not properly understood until 1940, if then. Up until this time, it was thought, for example, that rock drilled at 3100 feet might arrive at the surface before rock drilled at 3000 feet. By dropping materials such as oats, aquarium gravel, and gasoline simultaneously, J.T. Hayward discounted this theory (Hayward 1941). Still, his paper speaks of "lead time" in which bottom-hole samples would surface before calculated pump displacement of the annulus.

This "lead time" was considered in some situations to be as much as fifty percent. These were known as "fast holes". Those holes in which samples lagged calculated displacement were known as "slow holes". Poor mud qualities and washouts easily explain these "slow holes". They are unfortunately still around today.

Fluorescence was not recognized as an oil indicator until between 1933 and 1936. Before that period, cuttings oil was tested by sight, taste, and smell; it was extracted by solvents including photosensitive acetone. Hot-wire gas detection, or mudlogging, came into use during the period 1937-1942. The drilling-rate recorder, or geolograph, was invented in 1937 and manufactured commercially in 1943. It replaced the five-foot stick, which had previously been used to record drilling time. Five-foot times were used since there was no reliable method to apply continuous weight-on-bit. One-foot times were considered too unreliable to record.

ELECTRICAL LOGGING

From 1927 to 1931 electrical resistivity was measured point by point (Leonardon 1961). In 1932 the spontaneous potential curve was introduced, and by the end of the year continuous logging of S.P. and one resistivity curve was available from a three-conductor wireline. Four cables were used in 1938 and six cables by 1941; a single pass array with S.P., one short, and one normal resistivity curve was then possible. California saw a demonstration of Electrical Survey in 1929, and surveys were run in the Gulf Coast and Kansas-Oklahoma in 1930. Electrical Survey was slow to take off in the Permian Basin; by 1935 only thirty wells had been logged in the region (Deussen 1935). The limitations of Electrical Survey were soon recognized (Zaba 1940). By 1941 Archie had expounded the principle of water saturation.

Caliper logging was available in the 1930's, and temperature surveys run at the rate of 2000 feet per hour were used in 1935 (Gillingham 1938). The open hole temperature log was utilized to set the production-casing shoe below the oil-gas contact. The J.D. Walton B-8 and Colby C-22 in Kermit Field were the first two wells in the world in which a continuous gamma-ray survey was conducted. These logs were run in late 1937, and employed Geiger-Mueller tubes. Neutron-neutron logging was described and used in 1941, but supplied only a qualitative record for some years thereafter. Although private sonic velocity logs were used as early as 1949, they were not commercially available until 1954.

The focused Electrical Survey came into use in October 1950. Induction logging was first employed commercially in 1946; it had been developed from a land mine detection system used in World War II. Originally designed for holes containing oil-based muds, its advantages were readily apparent. The Microlog appeared in 1948. Saltwater Electrical Surveys and Micrologs were introduced in 1950. The Limestone Device was a system whose general application was limited to West Texas. It measured a short lateral Ri to Rm ratio as an indication of porosity (Hilchie 1979). Its use spanned a short period from 1945 to the early 1950's.

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