Oil and Gas Production Methods in Montana

Edgar A. Scholz

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OIL AND GAS PRODUCTION METHODS IN MONTANA

by

Edgar A. Scholz

A. Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

Montana School of Mines
Butte, Montana
May, 1941
MONTANA SCHOOL OF MINES LIBRARY
A. Aeroplane view of the Northwest Refinery one mile west of the town of Cut Bank.

B. Aeroplane view of the Glacier Production Company plant located four miles east of Cut Bank on the main line of the Great Northern railway and the oiled highway between Shelby and Cut Bank. North of the highway is the absorption plant, to the south, the 3000 barrel refinery.
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INTRODUCTION

Montana's oil and gas industries aggregate a gross income of over $12,000,000 annually to the state. Oil and gas fields have been thoroughly discussed in literature as to geology, location, production and future possibilities. The specific object of this report has been to compile a comprehensive study of the production methods as they occur.

Information for this paper has been obtained by field work, correspondence with operators, and library research. All areas discussed have been treated as fairly as possible from the data available.

Acknowledgements

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The Montana Power Company and their oil and gas division, the Glacier Production Company have been of invaluable assistance through their engineers A. B. Martin, Mark Hardy, Jr., and Assistant General Manager R. D. Smith. Their advice, advance of information, and contribution of pictures and prints, has greatly increased the accuracy and value of this report.
Acknowledgement is made of the assistance given and information contributed to this work by Clyde Keys, Shelby Division Superintendent, and Cecil W. Smith, Chief Engineer, Montana-Dakota Utilities Company. Permission to use information acquired while in the employ of this company is deeply appreciated.

Mr. Jean F. Gerlough, Superintendent of the Potlach Oil and Refining Company at Shelby, has contributed most of the information on the Kevin-Sunburst-Shelby oil field. This information has been sincerely appreciated.

Other operators throughout the state are thanked for their cooperation and contribution of information aiding in the completion of this report.

GENERALIZED GEOLOGIC AND ECONOMIC HISTORY OF MONTANA

Commercial quantities of oil were first discovered in the Elk Basin field in 1916. The second discovery was at Devils Basin in 1919. Cat Creek, one of the state's important fields, was discovered in 1920. The large Kevin-Sunburst-Shelby field was discovered in 1922. The years 1921-22-23 were "boom years" in Montana oil fields and wildcat wells were drilled everywhere. Since that time the discovery of oil in the Cut Bank Field in 1929 has been the state's most outstanding development.
The aggregate production of the state has held at a high level since 1922 and has averaged an increase since that time though single fields have declined. For a time the Turner Valley field production, which took over Canadian markets, caused a severe slump especially in the Kevin-Sunburst-Sherby field. Today, however, new markets and additional local refineries have provided adequate outlets for all Montana oil.

The natural gas industry in Montana was relatively unimportant until 1928 though natural gas was discovered prior to the discovery of oil. Early operations ignored the natural gas in their search for oil. Between 1928 and 1931 all the major pipe lines had been laid and this important industry began to bring large returns to the operators and comfort and convenience to the consumers.

Development of Montana's oil and gas fields has been characteristic of the industry. Extremely rapid development has followed all discoveries. Dependent upon the success of this drilling program activity continues at a high level or suffers a rapid decline. Eventually all fields settle down to a steady rate of production where development approximately equals the falling off of previously production. The Cut Bank, Kevin-Sunburst-Sherby, and the Pondera fields are Montana's largest producers in the order names. Montana's gas fields in the order of importance of present production are first, Cut Bank, second, Baker-Glendive, and third, the Kevin-Sunburst-Sherby field.
DESCRIPTION OF PRODUCTION METHODS AND EQUIPMENT

ELK BASIN FIELD

Partially in Montana and partially in Wyoming the Elk Basin oil and gas field lies in the extreme south central part of Carbon County, Montana, and the northeastern part of Park County, Wyoming. The part of the field in Montana was the first commercial oil field in this state.

The first well was completed on the Wyoming side in October, 1915, when production was obtained from the First Wall Creek sand of the Frontier formation. Today oil is produced from the First and Second Wall Creek sands.

Gas was discovered in the Cloverly formation of Lower Cretaceous age. This gas had an original rock pressure of 925 pounds and open flows reported to range from 40,000,000 to 75,000,000 feet per day.

Considering both gas and oil, Elk Basin has been and is one of Montana's important fields from an economic point of view. Natural gas of the field has an adequate market in the Billings-Bozeman pipeline system. The oil is a green colored high gravity oil, commanding a good market price. Without production from some new horizon this field will probably continue to decline in importance.

Oil Production

All of the wells drilled in the field were drilled with cable tools except two of the latest which were drilled with rotary rigs. All of the wells must be pumped
and at present procedure is a stripping action. A gas drive is employed to increase oil production. This drive is used mainly in the Second Wall Creek sand. Natural gas is forced into the sands at pressures ranging from forty pounds upward. It was found that pressure was the least at which any well would take the gas. Some wells for reasons unknown would not take the gas into the oil sand. From experience, it was found that shifting the gas drive wells around greatly stepped up oil production. This was believed due to the gas "channeling" through to the wells producing oil.

All of the gas used at present for this purpose is casing-head gas from the oil sands. A pumping or compressor unit was originally installed to strip the wet gas (high test gasoline) from the casing-head gas by compressing and cooling the gas. Now this unit serves a triple purpose; (1) it holds a vacuum on the oil wells, thereby helping to increase their production; (2) it compresses the casing-head gas for the stripping of high test gasoline; and (3) it supplies gas under pressure for the "gas drive". A photograph of the cooling unit of the stripping plant is shown. The building houses the gasoline separators.

The gasoline recovered in the above operation is stored in large tanks which are housed to prevent excessive evaporation. Tank trucks haul the gasoline to the refineries in the surrounding region where it is blended with less volatile cracking-process gasoline.

The oil wells are pumped by central power and wheel
units employing 35 horsepower superior gas fueled internal combustion engines. The pumpjacks, rods, and pump assemblies are standard oil field equipment. A detailed discussion of this equipment will be found under the discussion of the Kevin-Sunburst field, to which the reader is referred.

The Ohio Oil Company and the Stanolind Oil Company operate the entire field on a 40-60 basis respectively sharing in expenses of field operation on that basis. The Ohio Oil Company uses no heat in the "gun-barrels" where the water is separated from the oil. They apply some heat to the storage tanks, finding that in this way they avoid trouble with the precipitation of paraffin in the tanks. The Stanolind Company heats the gunbarrels effecting good water separation, but some difficulty is encountered because of paraffin in the storage tanks. The accompanying photograph (Plate II-A) shows one of the Stanolind Oil Company's oil well units. The tall tank is the gunbarrel, the other tanks are storage tanks; the unit in the foreground is the heating unit for the water circulating system which can be traced by the insulating pipes to the gunbarrel.

The oil is taken from the well gathering lines to the Illinois Pipe Line Company main line pumping station which pumps the oil through a fifteen-mile pipe line to Frannie, a small town on the railroad in Wyoming near the oil field of that name.

The oil recovery methods of Elk Basin are probably
PLATE II

A. View of Stanolind Oil Company oil well showing hot water heating and circulating system in the foreground with gunbarrel and storage tanks in the background.

B. Major main line natural gas dehydration piping preceding the metering and regulating station at Elk Basin. The scene in the distance is a northward view of the basin.

C. "Choke rack" used as a manual control for pressure regulation. Meters and recording pressure gauges may be seen as well as steam pipes for heating the building.

D. Cooling tower and gasoline separation unit of the Elk Basin natural casing head gas "stripping plant".
the most advanced in the state. The high quality of the oil and readily available equipment for the gas drive have undoubtedly been contributing factors in this development. It must be remembered that the factors necessitating such methods also indicate old age of the field.

Natural Gas Production

Since 1923, Elk Basin has supplied gas to Billings, Montana. A typical gas well-head is portrayed in the accompanying photograph, figure 1, page 9. The assembly includes a well pressure gauge, line and well blow-offs, and gate valves as pictured. Toward the top of the picture, a plug valve can be seen on the well blow-off. The writer sees no apparent reason for this type of "tree" other than that it probably is an old installation.

Figure 1.-- Typical gas well head of the Elk Basin field. On the right a recording pressure gauge can be seen. The installation has an excess of expensive gate valves.
Major piping at Elk Basin is featured by above ground installation. The photograph on Plate IIIB, page 8 is looking view of a part of the drip or condensate gathering system just before the gas enters the metering and regulating station.

Gas from the individual wells is not metered, the entire gas being metered through one orifice meter and a check orifice meter. The main line pressure is controlled by Fischer regulators. A remnant of an early type of regulation is shown in an accompanying photograph. C Plate II. It is known as a "pineapple" in gas field parlance. Regulation of pressure may be achieved by closing the main gate valve and opening the valve on the size line desired according to the gas load. This "choke rack" still has a place in manually operated control stations. This device is not used, however, and is being replaced by the modern Fischer regulators mentioned previously.

Gasoline condensate from the main line drips is gathered in tanks by gravity flow. This is similar to the gasoline recovered by the stripping plant. Two calcium chloride dehydrators of the type used in Cut Bank may be seen in the background of picture B Plate II. For a detailed description of these dehydrators, the reader is referred to the discussion under Cut Bank operations on page .

Much of the main gas transmission line to Billings consisting of eight inch screw pipe was reconditioned
Last summer. Leakage at the pipe collars necessitated the reconditioning. The ends of the collars were electrically welded to the pipe in this repair work at considerable expense. However, the job has not proved satisfactory because the welds have numerous pinholes. The writer understands that this line was welded with the pressure on or "alive" as is commonly phrased. Company officials believed the pin holes were due to impurities. It is suggested here that the gas pressure may have been sufficient to hold open a pin hole in the molten metal.

For a more detailed discussion of any particular piece of equipment the reader is referred to the Kevin-Sunburst field report on gas production.

Billings affords an adequate market for all the gas that Elk Basin can produce. At the present rate of withdrawal and decline of the field pressure, the field should last for many years.

Gas production methods at Elk Basin are not particularly modern, probably because the field is quite old, and the old style equipment has proved adequate for production exigencies.
LAKE BASIN

Lying about twenty-five miles west of Billings, the Lake Basin oil and gas field is situated in a region considered structurally favorable. However, production and drilling returns in the field have not been particularly encouraging. Though the field is located upon an anticlinal structure with about 120 feet of closure on a broad structural arch, only six commercial oil wells were found, these in the Kootenai. Commercial quantities of gas were found in the Eagle sandstones at 1,200 feet depth with 300 pounds pressure, and in the Frontier sands at a depth of 3,000 feet and a pressure of 1,000 pounds.

No gas and only a small amount of oil is now being produced from the field and its disappointing and unprofitable history place it on the sidelines at least until oil and gas are much more scarce than at present.

Oil Production

The oil produced in Lake Basin is raised by the standard rod pumps equipped with ball and cage valves. The oil is 45° Baume and little difficulty has been experienced in separating water from the oil. All production was trucked to Coombe, a railroad station six miles distant.

Since this field has had no important production and is now nearly dormant no attempt has been made to discuss production methods in a thorough manner.
Gas Production

Although there are no pipelines to the Lake Basin gas field, there has been some commercialization of this natural resource. A carbon black plant was erected in 1926 and operated until 1931, at which time by rapid and unlimited withdrawal the gas pressures had been dropped almost to nothing. The plant has produced five million pounds of carbon black in that time.

Since then, the gas pressures have built up again to 160 pounds in the Eagle and 500 pounds in the Frontier. While there is still probably an appreciable quantity of gas in the field, the pressure drop indicates a limited reservoir without sufficient commercial "life" to warrant exploitation under existing conditions.
The Dry Creek field lies in the northern-most end of the Big Horn structural basin, about eight miles east of Red Lodge. Because of obvious domal structure the possibilities of the area were recognized twenty years ago. Present development began with the discovery of gas in the Eagle sandstone by the Ohio Oil Company. More gas was discovered in the Frontier sands with a good flow of oil from the Cloverly, lower most Cretaceous. The Bowman well is the outstanding gas well of the field, producing gas at 1700 pounds pressure in addition to being a good commercial oil well.

A 138-mile pipe line carries gas from Dry Creek to Bozeman and intermediate towns, thereby insuring the field of a good substantial market. The oil is high in quality and brings a premium in price because of its paraffin base. As it now stands, the field should produce profitably for many years. With deeper drilling, new producing zones may be found.

Oil Production Procedure

The oil wells of Dry Creek produce from the first and second Dakota sands at depths in excess of 5,000 feet. Drilling has been done with rotary rigs, the derricks of which have been left over the oil wells. Individual walking-beam and bank-wheel pumping units with
PLATE III

A. Landscape view of the Dry Creek field looking south.

B. McMahon oil well showing the general layout of the pumping equipment. A Superior internal combustion engine, burning casing head gas, transmits power to the walking beam through a belt drive on the bandwheel.

C. Close-up "shot" of the well head of the McMahon well showing the fittings. The gauge is on the casing head gas line and has a pressure reading of 25 pounds.

D. Gunbarrel and storage tanks of the McMahon well.
Superior natural gas burning engines for powering the pumps are standard in the field. The wells are all pumped individually. Gunbarrels and storage tanks are quite large, because of the large volume of production of the wells which yield from 400 barrels per day on the pump to 2400 barrels from the gushers when drilled into the producing zone.

Plate 3 B, page 15, is of the only independent well in the field. The equipment is poorer and the entire installation less orderly than the Ohio Oil Company wells. At the time the pictures were taken, however, the well was pumping satisfactorily, which, in the final analysis, is all that is necessary. The building on the left side of the picture houses the power unit, a Superior engine burning casing head gas. A belt drive transmits the power to the bandwheel which is on the same shaft as the crank which supplies the stroke to the walking beam. This in turn transmits a vertical reciprocating motion to the sucker rods. An average speed is about 20 strokes per minute.

Plate 3 C page 15, shows a closeup view of the McMahon well discussed above. The pump rod, packing box, and oil line take-off are clearly shown. Below the casing-tubing connection, the casing-head gas line can be seen to take-off just above the derrick floor. A pressure gauge appears on this line.
From the well head the oil is pumped to the gunbarrel and storage tanks shown in picture D. Plate three. The highest tank is the gunbarrel which, at the time of the writer's visit, was not being heated. Oil from this well is hauled away by truck.

Most of the wells produce oil through an inner string of pipe called tubing, and gas between the tubing and the casing through what is called the casing head.

Some trouble is experienced with paraffin in the well tubing. To remedy this, solvents are poured down the tubing or between the casing and the tubing depending upon which part has become coated with wax. The Bowman well, Plate IV, clearly shows the two containers in place as installed. Made of welded pipe about two feet long, these tanks are equipped with valves both on the top and the bottom and must be able to stand the full well pressure, in this particular instance 1700 pounds. With the lower valve closed, the upper valve is opened and the solvent liquid poured into the tank. Then the top valve is closed, the lower one opened, and the solvent allowed to run down inside the tubing, or casing, as desired. The pumping rod and packing box also show plainly in this picture. A specially designed "tin pan" somewhat obscures the actual packing box unit. Another pan just below the floor level is also designed to catch oil drippings. The entire unit has a concrete floor, and one is impressed by the immaculate appearance of the entire installation.
There is a concrete cellar around the casing. This cellar is reached by a horizontal entrance, or adit, as it would be termed in mining language.

Oil from the well head goes by pipe line to the gun-barrel and then to the storage tanks. Some heat is applied to the gun barrels when necessary by a hot water circulating system, but the oil-water emulsion separates very easily and the heat required is negligible. The water separated from the oil is drawn off the bottom of the tanks and runs into a sump which keeps the slight amount of oil escaping with the water from spreading over large areas, and it also acts as an emergency oil reservoir in the event of some leakage or trouble. The oil goes from the storage tanks into a field gathering line.

The production methods are standard and simply consist of pumping the oil out of the ground by the use of standard pumps, into conventional gun barrels and storage tanks, and then into pipe lines. The field is comparatively new, the wells are far apart, and areas of practically proven production still remain to be drilled. Therefore, no means of recovery, other than those, have been necessary. At this writing it seems apparent that Dry Creek should produce a considerable quantity of oil even before any additional methods of recovery are tried.

Gas Production Practice

Geology and Economic History

Geology and Economic History:—The Frontier sands of upper Cretaceous age are the gas producing horizons of the
PLATE IV

A. Bowman well, largest gas well in the Dry Creek field and a large oil producer. Note the paraffin solvent tanks and christmas tree assembly.

B. Top view of the regulator setting on the natural gas line of the Bowman well. The pressure reduction is from 1700 pounds to 300 pounds.

C. Front view of the same regulator setting noted above. Entrance to the concrete cellar can be seen under the "No Smoking" sign.

D. Natural gas line of the Bowman well showing pipe bends.
Dry Creek field. Gas occurs with oil in the lower Cretaceous sediments known as the Cloverly (Kootenai). The production zones are at or near the crest of the much faulted domal-shaped anticline, which has a closure of about 1500 feet. Open flow volume of the wells ranges from approximately 2 to 15 million cubic feet per 24 hour period. The smaller wells produce from the Eagle sand at depths of about 2,350 feet. The Frontier sand at 4,450 feet, yields large wells at 1500 pounds rock pressure, and the Cloverly at depths of about 5,400 feet yields large wells at 1700 pounds rock pressure.

Methods of Production and Equipment:—Some of the Dry Creek wells have not been drilled down to the oil producing horizons, so they have the standard type well heads, consisting of well gate, vertical well blow-off, side take-off for the line pipe, with a line gate on the welded right angle take-off. From the well the gas flows through buried pipe drips which are pipe sections of larger size than the line pipe. These contain baffles on which liquid may condense. Because of the larger size of the pipe in the drip, the velocity of the gas is slowed down sufficiently to allow the liquids to drop to the bottom of the drip.

Considerable quantities of naphtha and other light wet gas constituents occur with the natural gas. The drips, described above, catch this high test gasoline, which is then moved to a storage tank sufficiently far off the ground to allow trucks to load the gasoline by gravity.
From the drip the natural gas goes through calcium chloride dehydrators of the same type used at Cut Bank, in fact, they are built to Glacier Production Company specifications. The gas line then passes through a long heated box designed to hold the temperature of the gas above freezing limits. Thence the gas passes through the regulators which reduce well pressure to main line pressure. From this point nothing further occurs to the gas until the regulator and town border metering stations are reached. Then the gas is measured by orifice meters, and the pressure is reduced by regulators to between 50 to 100 pounds. A second stage reduction reduces the pressure to from 10 to 30 pounds depending upon the gas consumption. This pressure is carried throughout the city distribution system.
PLATE V

A. Calcium chloride dehydrators on the natural gas line of the Bowman well. These dehydrators are patterned after those of the Glaciers Production Company at Cut Bank. Fifty pounds of calcium chloride will dehydrate 150,000,000 cubic feet of gas.

B. Typical regulation set-up on a well producing gas only.

C. Casing head gas compressor plant at the Ohio Oil Company camp at Dry Creek. The plant strips gasoline from the natural gas feeding the treated gas to the Bozeman line.
At the individual customer's house there is a final reduction by a low pressure regulator which delivers the gas to the different domestic appliances at four ounces gauge pressure. On the low side of the regulator a positive meter is installed. This measures the gas by a volumetric action upon a leather diaphragm which in turn activates the recording dials.

Comparison of Methods.—The compressor building pictured on Plate V C is situated at the camp of the Ohio Oil Company, the only operators in the Dry Creek field. The building houses three Chicago-Pneumatic 150 horsepower compressors which take casing head gas from the oil horizons and compress it. Then the natural gas is cooled, in a water spray cooling tower, causing the condensation of highly volatile wet gas components. This stripping action is similar to that at Elk Basin, but the plant is more modern. The treated natural gas is fed into the Bozeman main line.

The problems involved in the production of gas at Dry Creek are similar to those of other fields. The first of these, reduction of pressure, is met by the use of conventional regulators of the Globe type. The second is dehydration which is handled by the use of drips and calcium chloride dehydrators of efficient modern design. The last, and minor, is that of heating the gas to prevent freezing; this has been done by heating the gas line in a long insulated box. These methods compare favorably with those of the rest of Montana, though piping and design of equipment does not conform to the most modern practices elsewhere, serving to emphasize the lag in methods used in Montana, on an average as compared to those used in the bigger gas fields.
SOAP CREEK

This field is located in Big Horn County near the Montana-Wyoming state line on an asymmetrical dome on the foothills of the east side of the Big Horn Mountains. Oil was discovered in 1921 at a depth of 1,534 feet and at 1,642 feet in the Tensleep sandstone of Pennsylvanian age. A second well drilled to the lower horizon reported an initial production of 1,500 barrels per day. The production from these and later wells fell off quickly thus discouraging further development of the field. The last production from the field was in 1936 since then there has been no commercial production.

As the field produces no oil now the production methods are not important and are not discussed here.
CAT CREEK

Geology and Economic History:—This field lies in the central part of Montana in Petroleum and Garfield counties. Winnett, county seat of Petroleum county, on a branch line of the Chicago, Milwaukee, and St. Paul Railroad is the nearest shipping point being fifteen miles west of the field.

In 1920 oil was discovered in a sandstone named the Second Cat Creek sand. This production was ten barrels per day at a depth of 1,000 feet. Other wells drilled were dry or encountered large flows of water on this structure, the Mosby Dome. In 1921 the Frantz Oil Company struck a well which drilled itself in as a 2,500 barrel well. This greatly stimulated activity on this structure known as the West Dome, which is three and one-half miles west of the discovery well. Drilling activity has waned steadily since 1922 when 214 wells were completed, 141 being producers. Development activity is now at a standstill and production from the field declining. At the peak of production in 1922, 2,333,000 barrels of oil were produced. Present production is approximately 225,000 barrels per year.

The Colorado shale has been exposed on the crest of the Cat Creek anticline. Local domes on this structure have trapped the oil. The major production is from the First Cat Creek sand of uppermost Kootenai age at the base of the Colorado 800 feet below the surface. The Second Cat Creek sand produces from the Kootenai 160 to 235 feet stratigraphically lower. A third sand carries a small amount of heavy oil.
Oil Production

Methods and Equipment:—Oil is produced from the wells in this field by standard bail and cage type pumps with equipped ordinary sucker rods and pump jacks. Most of the wells are pumped by central power bandwheel units. From the well head oil flows to 160 barrels where the water is usually effectively separated by a cold "cut". A hot water circulating system applies the small amount of heat needed in cold weather. The high gravity Baume oil (50°) flows to storage tanks after which a pipeline conducts it to Winnett, the railroad shipping point fifteen miles distant.

Comparison of Methods:—Production practices are the conventional accepted methods. The high quality of the oil makes the possibilities of a water or gas drive intriguing but there is no available natural gas. Water could be obtained from the First and Second Cat Creek sands on the flank of the structure.
KEVIN--SUNBURST--SHELBY OIL AND GAS FIELD

Geology and Economic History.--Second in importance only to Cut Bank, the Kevin-Sunburst-Shelby oil and gas field, discovered in 1921-22, has an excellent record of continuous production. The name of the field locates it rather well as it begins one-half mile north of Shelby and extends northward twenty-two miles roughly to the vicinity of Sunburst and northwestward five miles beyond Kevin. The area has been logically divided into a northern portion now containing over eighty square miles and producing both gas and oil, and a southern district producing gas only, with the above fifty square miles of productive area. Most of the gas to date has been produced from the southern area. The gas producing region is mostly south of the crest of the Sunburst dome, the structural feature at least partially responsible for the accumulation of gas and oil on this elevated section of the broad Sweet-grass arch. The northern oil and gas territory lies on the north and west slope of the Sunburst dome, which it may be stated, has a closure of 700 feet.

The area within the last closing contour of the Sunburst dome would be approximated by a circle thirty miles in diameter. The major part of the gas is produced from the Sunburst sand, a local term for a sandstone number in the lower Kootenai formation, at depths of about 1,200 feet. Wells in the northern part of the field have open flows of from 1,000,000 to 3,000,000 cubic feet per day,
while in the southern area, where only gas is produced, the daily open flow averaged from 5,000,000 to 10,000,000 cubic feet initial capacity at 360 pounds rock pressure.

At the far northern end of the field, in a three to four square mile area, oil in commercial quantities was discovered in 1922-23. It was from this pool that the name "Sunburst" was obtained for the producing sand of the lower Kootenai.

The major oil production of the field is from the upper porous, leached, and dolomitized part of the Madison limestone which bears the local name of "Ellis sand". Many dry holes were drilled and the size of the commercial wells varied between wide limits. Acidization of the limestone has made producing wells of almost all those drilled in the proven area, and has greatly increased production from individual wells and from the field as a whole. Production from individual wells has been as high as 3,000 barrels per day.

This field has been a consistent producer of both gas and oil. Since acidization has proved so successful in reviving old wells with waning production the oil operators have a pleasant future in a probable long life of the present producing area. With the aid of acidization the proven regions may be considerably extended. Natural gas operators perhaps do not face as bright an outlook though the rate of decline of the field is slow and an extension of pipe lines into the oil area would provide
resources of gas not yet used to beyond a minor extent. Natural gas production will continue to be a major industry of the region for many years.

Oil Production

Methods and Equipment.—Most of the wells have been drilled with cable tools. The use of rotary rigs has been limited and the results not encouraging because the pressure of the mud in the hole has either caused the production zone to be missed entirely or its porosity impaired by what is termed a "mudding up" of the sand. Since the wells are seldom much over 1500 feet deep the shorter time required to "set up" a cable tool rig gives the latter another advantage. Furthermore, initial cost of the rotary rig is considerably more expensive than that of the cable, tool rig. A final factor and one of importance is the preference of men operating the fields, the most of whom are cable tool operators.

The cable tool rigs used in the field are either standard derricks of wood, or occasionally of steel, or the single-mast-type spudders. The power used for drilling is generally supplied by gasoline or natural gas portable four or six cylinder internal combustion engines. The well is spudded in and drilled with a large size bit, usually ten inches in diameter down to solid formations. Then a corresponding large size surface string of casing is run. This prevents caving of the loose surface material. A smaller bit is then used, about seven inches across the
PLATE VI

A. International Refinery at Sunburst as seen looking south along the paved road from the town to the refinery. A large bank of cooling towers can be seen at the left of the picture. A water pond lies just beyond the towers.

B. General view of a part of the Kevin-Sunburst-Shelby oil field looking northeastward. A portable well clean-out machine looms in the foreground, while in the background West Butte, the western-most member of the Sweetgrass Hills, can be perceived.
face, and drilling continued. In some parts of the field a water sand is encountered which necessitates the running of an additional string of casing which is set with packers below the water sand, thus sealing it off from the hole so that drilling can proceed. The well is then drilled down to the producing horizon with a smaller bit and casing set above the sand.

In most of the region water is not encountered so only one string of casing, the production string of casing, is run down. Pipe used is usually seven-inch outside diameter, six and five-eights inches inside diameter, lap-weld casing in twenty foot lengths, having a weight of twenty pounds per foot, with medium length or long collars, and with both ends threaded ten threads to the inch. Sometimes lighter pipe is used, this usually being seamless casing having a weight of seventeen pounds per foot.

If a standard rig is being used, three joints of casing are screwed together being lifted upward on the drilling cable. These three lengths of casing are then lowered into the hole and held by clamps. Three more joints are made up and screwed onto those in the hole, and the casing lowered and clamped again. This process is repeated until the entire desired footage of casing has been run in the hole.

After running the full string of casing, it is usually advisable to cement in the bottom of the hole with
fifteen or twenty sacks of oil well cement, making an absolutely tight shut-off between the producing horizon and the formations above it. In outlining the procedure followed, the cement is lowered to the bottom of the well in the bailer. After all the cement is lowered, water is often added above the cement in order to put sufficient pressure on the cement to force some of it around and back of the casing. After the cement has hardened the well is drilled through the cement and into the producing horizon, effecting a completion of the well. However, many wells are drilled in without cementing the casing. This is of necessity true if it is anticipated that the producing sand might be shot with nitroglycerin, in which case the pipe would have to be lifted several hundred feet to escape damage from the shot.

In the event of a flowing or "gusher" well is expected, a casing control head is screwed to the top of the casing at the level of the drilling rig floor. The design of the casing control head is similar to that of a large plug valve. When it is open the full inside diameter of the casing is exposed so that drilling may continue through the control head. The interior of the control head is bored out in tapered cylindrical form into which the plug or valve is inserted. The valve is open at one end permitting horizontal escape of oil or gas through an opening in the side of the unit. This opening is connected by pipeline to the oil storage tanks. The opposite end
of the plug is reduced in diameter to form a stem which extends through a stuffing box. A half turn of this stem either opens or closes the control head as far as vertical flow is concerned.

Flowing wells clean themselves, the bottom-hole pressure being sufficient to lift the full column of oil to the top of the casing.

The oil is diverted by the control head into a pipeline and thence into the tanks. A further control of the well is obtained by restricting the size of opening through the pipeline which delivers the oil from the well. Restricting the flow in this manner is known as "beaning" or "choking". This is often done to create a back pressure on the well as uncontrolled flow is likely to cause the well to "drill" itself into water, if water is present anywhere near the oil sand.

When a well ceases to flow through the casing of its own pressure, it often may be made to continue flowing by the insertion of a string of small tubing, to the bottom of which is attached a tubing-wall packer. Thus the well which had insufficient pressure left to lift the oil through the casing, will have ample pressure to flow the oil through the smaller tubing where the pressure is diverted to the tubing. This is brought about by the tubing packer which is designed to plug off the open space existing between the outer wall of the tubing and the inside wall of the casing. The packer is screwed into
the tubing near the bottom of the well, the packer hav-
ing a bore through its center the same size as the tubing. There are many different makes of packer and also different materials are used in construction. Probably the most common material used is rubber, the outer diameter of the rubber being slightly less than the inside diameter of the casing, and designed so that the weight of the tubing when it is set on bottom will expand the diameter of the packer and provide a tight fit against the inside of the casing.

An attempt was once made to flow Kevin wells by the air-lift method where there was not pressure enough for the well to flow by itself. This attempt resulted in failure because of the corrosive action on tubing, casing and other metal parts. It would appear that introduction of air into the wells supplied the oxygen necessary to form a dilute sulphuric acid action when combined with hydrogen sulphide gas escaping with the oil. At any rate, tubing was completely destroyed in a short time and the project of installing air compressors and flowing the wells by air instead of gas had to be abandoned.

Most wells in Kevin field are small and the oil has to be recovered by pumping. The initial step in getting a well ready for pumping is to bail all mud, casings, sand, etc., from the bottom of the hole and to thoroughly wash the oil sand with water to remove anything which might impede the flow of oil into the well.
when the tools are lowered into the well but closes when being lifted out again. Thus the swab will drop easily through the column of oil, but when it is lifted the valve closes and the whole fluid column is lifted creating a strong suction which opens up the channels in the oil sand and increases the flow of oil into the hole. Swabbing is also resorted to when paraffin and other matter is present in such quantity as to make pumping by ordinary methods impractical. This latter condition does not exist in the Kevin field.

In tubing a well preparatory to putting it on the pump, the first pipe used is the anchor which is to rest on the bottom of the hole. This usually consists of from five to twenty feet of extra tubing or in extreme cases, several joints of tubing where caving conditions are bad.

Directly above the anchor is installed a perforated joint of tubing usually three to five feet in length with small round or slotted perforations to permit the oil to enter the pump. Above this perforated joint is set the pump.

The pump consists of an outside cylinder or "working barrel" the same diameter as the tubing and from five to ten feet in length and with the inside or bore working barrel is set a lower or standing valve of the ball and cage type. Above the lower valve is installed
PLATE VII

A. Standard pump-jack over a producing oil well in the Kevin-Sunburst field. The pull-rods may be traced back to the tank farm about one-fourth mile distant. A central-power pumping unit operates a series of wells in the vicinity.

B. Pump-jack shown near at hand. Note the method whereby the horizontal action of the pull-rods is translated to the desired vertical reciprocating action.
a leather-cupped plunger which is connected with the top of the well by means of sucker rods. Above the plunger, in the working barrel is another ball and cage valve known as the upper or traveling valve. Operation of the pump is as follows. At the bottom of the down stroke of the plunger both lower and upper valves are closed. With the beginning of the up stroke, the upper or traveling valve remains closed due to the weight of oil on top of it. The lower or standing valve opens because of the oil and gas pressure beneath it and because of the vacuum caused by lifting the plunger withing the working barrel. The plunger has reached its highest position, the working barrel is full of oil and both valves close momentarily. When the down stroke of the plunger begins, the lower valve remains closed while the upper valve is forced open and the oil passes through it and up into the tubing above the pump on each successive stroke of the pump until the tubing is all full and the oil is then forced through the flow line into the tanks at the surface.

The tubing naturally extends from top to bottom of the well inside the casing. It usually is two inches in diameter although two and one-half, three, and even four inch tubing are sometimes used where large volumes of fluid are to be lifted, and especially in wells making a great deal of water and only a small percentage of oil. Tubing is of steel, comes in twenty-foot lengths and weighs from four to four and one-half pounds to the
foot. Pipe threads are eleven and one-half to the inch. Where larger tubing than two-inch is used, the working barrel and pump are of correspondingly larger sizes.

The pump plunger is actuated by means of steel sucker rods five-eighths inch in diameter, twenty-five feet to a joint. The bottom rod is connected or screwed into the pump plunger and all other rods are screwed to this one and lowered into the hole. At the head of the well, a casing head is screwed to the top of the casing. In this casing is a stuffing box through which a polished rod is inserted and connected with the top of the sucker rods. The polished rod in turn is connected with whatever device which may be employed for lifting the sucker rods and placing the pump in operation.

The equipment or device used for lifting the sucker rods depend upon the amount and kind of fluid to be lifted and upon other conditions which might require some special method of pumping. If a well is making a large amount of oil, it usually is pumped off the beam of the drilling rig, power being supplied through the band-wheel which is belt-driven from a twenty-five or thirty-five horsepower gas engine. This method permits giving the pump a longer and faster stroke than is ordinarily employed, and pumping off an individual engine both speed and length of stroke may be readily changed or adjusted. Such a rig usually is pumped with about a thirty-six inch stroke at the rate of about twenty-five strokes a minute.

Plate 8A, page 47 illustrates one of these units.
Where large amounts of water are to be handled along with the oil, a similar method is employed for pumping except that large oval gears are attached to the band-wheel by means of which a much longer stroke may be transmitted to the pump. Larger tubing and pump equipment are used on a well of this kind. Tubing may be as large as four inches in diameter and the stroke of the pump as long as sixty inches. Such an outfit will lift as high as 1,500 barrels of fluid a day from a depth of 1,500 feet.

If the oil well is small and there is no other pumping power nearby to which it may be attached, small individual pumping units may be installed temporarily or until such time as the well may be connected with some central pumping power.

Most wells are pumped by central powers from which pull-rod lines are strung radially outward to the wells and connected with pump jacks set up over the wells, see Plate 7, page 38. If not to exceed four or five wells are to be pumped, geared powers are used. There are a number of different types of geared powers. One in common use is an underpull power. A single eccentric giving a sixteen-inch stroke is carried on a vertical spindle which is cast integral with the base. A large bevel gear is bolted to the eccentric hub and is driven by a pinion on a horizontal shaft. This pinion is carried between two bearings, one on the upper end of the spindle and the other on a pedestal attached to the base. The belt pulley
is mounted on this pinion shaft. The power is belt driven by a ten or fifteen horsepower gas engine.

Where a larger number of wells are to be pumped, the band-wheel power is employed. It comes in a number of different sizes designed to pump anywhere from five to thirty wells off the one power. A common size is the eighteen foot band-wheel. This wheel, eighteen feet in diameter, is of steel with a fifteen inch face and has two eccentrics each delivering an eighteen inch stroke. The eccentrics are carried on large bearings on a vertical spindle which is cast integral with the base. The hub is direct connected to the eccentrics. It revolves about the spindle and supports the structural steel band to which the power from the engine is conveyed. Full rods are connected to the eccentrics and extend radially outward to the wells. A twelve inch belt 130 feet in length connects the band-wheel with a thirty-five or forty horsepower gas engine. A galvanized iron building from twenty-four to thirty feet wide and seventy feet long houses the band-wheel power. The pump rods lines may be hooked on or off at will at the power house.

- Full-rods extending from the power house to the well are of steel from five-eights to seven-eights of an inch in diameter and are in twenty-five foot lengths. The ends of the rods are reinforced and have a head at each end. Rods are connected together by grip couplings. The rod line is held off the ground by means of oak rod carriers which are inserted on the top of posts made from
iron pipe cut to proper length according to the terrain and driven into the ground. In some cases old drilling line is used to pull the wells in place of pull rods.

Most wells are lifted by pump jacks set up over the well as shown in Plate 7, page 38. The jack is a device which transmits the horizontal reciprocating motion given by the central power to the vertical reciprocating motion required to move the sucker rods up and down and thus operate the pump in the well. There are many types of jack. It consists of an L-shaped steel frame at the top of which is connected a horizontal steel beam which is attached at the other end to the polish rod at the well head. This beam is actuated by means of a steel post extending from the beam down to a triangular steel frame mounted on a bearing or saddle at the base of the jack. The top or apex of this triangular frame is connected with the pull rods from the power house. When the triangle is pulled by the power, it tips downward on the side towards the power and is forced upward on the side nearest the well. The action may be likened to that of a teeter-totter board. Thus when the pull is exerted by the power the jack is forced upward on the side nearest the well. This lifts the beam and raises the plunger in the pump. At the end of the up-stroke, the weight of the sucker rods and the fluid in the well force the plunger to drop to the bottom of the working barrel again and
the operation is repeated at each successive stroke or pull of the jack from the power house. Pumping is usually at from fifteen to twenty strokes to the minute with about an eighteen inch stroke, although both the length and number of strokes may vary according to local conditions.

Oil from the wells is pumped through two inch pipe lines which are known as "flow lines" or "lead lines" to a battery of tanks where the oil is conditioned for marketing. These lines are buried at a depth of four and one-half feet to prevent freezing in winter time where the oil contains water, and that includes practically the entire field. The line pipe used is quite similar to tubing, but not quite so heavy. It comes in twenty-foot lengths, is threaded with eleven and one-half threads to the inch, and weighs approximately four pounds to the foot.

When the oil contains considerable water, it is first pumped into a tank known as a "gun-barrel". This tank is usually made by removing the top and bottom from two 250-barrel stock tanks. The gun-barrel is fitted with a well made of large diameter pipe, perhaps twelve to twenty inches in diameter, which extends from top to bottom of the gun-barrel, with the lower part perforated so that the fluid may escape into the bottom of the tank. The fluid pumped from the well is introduced into the top of the well in the gun-barrel, thence to the bottom of the
tank where separation of oil from water is made by gravity, the oil rising to the top of the gun-barrel and the water remaining at the bottom. As pumping continues, the water is drawn off at the bottom of the tank.

Steam coils are installed in the bottom of the gun-barrel. A forty to fifty horsepower steam boiler supplies steam for these coils and heats the fluid in the bottom of the gun-barrel which facilitates and hastens the separation of oil and water. Heating tends to break up the oil-water emulsions. Where large quantities of water are handled with the oil, usually two gun-barrels are employed. The first one removes a large percentage of the water with a cold "cut". The "over" flow goes to the second gun-barrel which is heated and water is further eliminated there down to less than two percent. The overflow from this gun-barrel goes to the stock tanks, where the balance of the water is drained off as soon as it settles to the bottom.

Where emulsions cannot be broken up by heating the fluid, chemical reagents are employed for this purpose. The one most commonly used is known as "Tret-o-lite". A small quantity of this is injected into the gun-barrel by a small feed pump as the oil comes into the gun-barrel and brings ready separation of oil-water emulsions.

Oil is in condition to run to the pipe line when it contains less than one-half of one percent water or basic sediments. It is tested by the gauger employed by the
pipeline company. A sample is taken from the bottom of the tank by a device known as an "oil thief". The sample is then ground out in graduated glass tubes inserted in a centrifuge. Action of the centrifuge separates any remaining impurities in the oil into the bottom of the glass tube where the amount may be read in fractions of a percent. Stock tanks are "strapped" or measured one percent short by volume to compensate for losses. In other words the average tank of 200 barrels sold actually measured 202 barrels.

When oil is accepted for delivery to the pipeline, it is released from a connection one foot above the tank and introduced into a steam pump which forces the oil into the pipe line and thence to the pipe line terminal at the refinery. If ordinary pump pressures are insufficient to force the oil through the line, the pipe-line company installs booster pumps at intervals to handle the extra load.

Pipe-line sizes vary from three to four inch gathering lines on the leases, to six inch, eight inch, and even ten inch lines according to the load to be handled and the distance from the refinery. Lateral lines are usually of common threaded pipe screwed together and laid below the frost line. Trunk lines of larger heavier pipe are mostly plain end pipe which is welded together when laid, although considerable six inch threaded pipe is used.
PLATE VIII

A. Oil well pumping unit in the Kevin-Sunburst field. A longer, and adjustable stroke can be imparted to the pump from this arrangement. A natural gas burning engine supplies the power by a belt drive to the band-wheel to which the crank-arm supplying the motion to pitman and, hence, the walking beam, is keyed.

B. View of make-shift spudder rig setting up in the gas field about six miles north of Shelby.
Both old and new wells which produce from the Madison are amendable to acid treatment. About 500 gallons of dilute hydrochloric acid are pumped down the well and forced out into the porous limestone. The acid reacts readily and greatly enlarges the pore space in the bottom of the hole thus making it much easier for the oil to flow to the pump.

Comparison of Methods.—Oil production methods are good. The wells are produced at reasonable rates in order to insure long life. Voluntary proration assures an equitable rate of production for all operators. Acidization has thus far been so successful in bringing the wells back to normal production that no other method have been necessary. Summarizing, methods are good sound practical procedure and most operators cooperate fully.

Gas Production

The gas wells of the Kevin-Sunburst-Shelby field have been drilled with cable tools and casing run as described above under oil production. The casing is generally six and five-eights inch inside diameter pipe. At the surface of the ground the casing is generally swedged to four inch size though many wells have six inch swedges and six inch well head gates rather than the smaller cheaper four inch gate valve.
PLATE IX

A. Christmas tree of the Sunburst-Hewson No. 1, a good commercial well producing gas for the Great Falls line.

B. A second Kevin-Sunburst- Shelby gas well christmas tree. The pipe and gates are all six-inch, the well line riser is two-inch pipe, the gathering line itself is of four-inch pipe Dresser coupled. (Note the streaks caused by a heavy snow driving across the camera field.)
Above the gate the pipe is swaged to four, three, or two-inch size. A T-connection of either welded or cast construction is next in the assembly. A bull plug with a one-inch plug valve blow-off finishes the assembly.

Beginning the well line, a one-foot long nipple of appropriate size is screwed in the T-connection. A gate or plug valve is next in this sequence. A two-foot nipple follows, then an elbow, then a short nipple which connects with a riser from the well by the use of a union.

Fifty feet from the well along the gathering line a small drip is located. This drip consists of a six foot section of ten or twelve-inch pipe with closed ends. Six or eight inches from one end of the large pipe stub pieces of gathering line are welded to each side of the large section after holes the size of gathering line have been cut diametrically opposing one another. The appearance of this section completed is that of a T with the large pipe forming the leg of the letter and the gathering line the horizontal member. Near the other end of the pipe a two-inch pipe about five feet long is welded into the large pipe after it is projected through a hole in the top of the pipe down to within an inch of the bottom or other side of the pipe. A plug valve on the top of this blow-off completes the drip.

The drip is connected into the well line by Dresser couplings with the large pipe slanting downward away from the line at an angle of approximately twenty-five degrees.
PLATE X

A. Typical meter house and meter run in the Shelby field. All meter runs are of four-inch pipe and all meters have pipe connections. The meter house is of paneled galvanized iron and is bought ready-made for assembly.

B. Meter house and meter run of the Sunburst-Hewson No. 1.
thus forming the trap for condensates which are both gasoline and water in this field.

Forty feet further along the line is the meter setting. Risers in the well-line bring the meter run above ground. Meter runs are twenty foot sections of four inch pipe with orifice flanges in the center. The meters used are Westcott orifice meters using L-10 charts. Pipe connections to the meters are used. That is, the pressure taps are located on the top side of the pipe, four pipe diameters upstream and sixteen pipe diameters downstream from the orifice.

The well gathering line continues to the main gathering line where a gate valve is located on the well line. The flow of gas is then continued uninterrupted until it reaches the compressor stations. There are two small units boosting gas from isolated series of wells. A large compressor plant equipped with 150-horsepower Ingersoll-Rand units boosts gas to Great Falls. The intake pressure on these compressors is approximately 150 pounds and the delivery pressure near 225 pounds. These figures vary considerable with the gas load. In the summer the compressor plant is completely shut down as well pressures are sufficient to feed the line.

An ethylene glycol dehydration plant removes the water from the gas on the delivery side of the compressors. This unit is self-contained and regenerative. The gas contacts the ethylene glycol in bubble towers. As the
ethylene glycol becomes saturated it is drawn off and the water removed in boiler heating units. A high pressure pump then forces the renewal solution back to the bubble towers. This unit is automatic and is noted for its effectiveness and cheapness of operation.

Except for occasional main line gate valves the flow of gas continues uninterruptedly through the twelve inch Dresser-coupled line to Great Falls.

At the town border the gas is metered by Westcott orifice meters. Regulators cut the pressure from 200 pounds to the city distribution pressure of ten pounds. The gas then flows through individual consumer's low pressure regulators which reduce the pressure to four ounce gauge. A positive meter records the flow going to the various domestic appliances.

A small compressor plant with three fifty-horsepower Superior natural gas-burning compressors boosts the pressure of the gas going to Conrad, Choteau, and Valier. The field pressure of about 150 pounds is boosted to 200 pounds on the delivery side of the unit. This plant is not operated during the summer months of the year.

Zinc electrodes have been placed 300 to 600 feet from the main line in those sections where corrosion is particularly bad. The electrode is connected with the pipe by insulated copper wire. The zinc is more active than the iron and reverses the current flow in the region making the iron negative. Zinc will protect twenty times
its own area of steel.

Comparison of Methods.—The methods used in this field are good in general, but are conservative. Only definitely proven methods are adopted. The sound conservative basis on which this field is operated probably makes it the most cheaply operated in the state.
PONDERA

Lying ten miles southwest of Conrad, this field was developed as a result of the discovery of some oil and about 3,500,000 cubic feet of gas daily production from the upper part of the Madison at a depth of 2,060 feet, in 1927. The field covers over 4,000 acres on the western flank of the southern part of the Sweetgrass arch.

Many commercial oil wells have been drilled in the field and a number of wells have produced both gas and oil. The oil is a mixed base oil and has considerable sulphur. At this writing oil productions is falling steadily and to date no attempts have been made to recover additional oil from the strata of the large number of subcommercial wells, other than acidation. The gas in the field has never been used except for local field activities and it appears that the quantity available does not warrant much expensive development.

The field has been third in importance in Montana until the last several years with over 5,650,000 barrels of oil total production. The field continues to decline in importance despite the benefits or stimulus of acidation.

Oil Production

Methods and Equipment:—Present production of oil in the Pondera field may be classed as a stripping operation. The wells are being pumped to recover all the oil possible. Some wells making only one barrel per day are produced intermittently.
The usual array of equipment may be found here. A string of two inch tubing and pump cylinders are run down the hole. The well head is standard equipment as are the pump sucker rods and packing box preventing escape of the oil around the rod. Three types of pumping units are in service in the field: electric powered individual units, natural gas motor powered individual units, and central power units with pump-jacks over the individual wells.

From the well the oil goes by pipe line to water separation tanks where heat is applied when necessary, and thence to storage tanks. From the storage tanks the oil is pumped through a pipe line to Conrad where it has been intermittently refined and shipped elsewhere, generally to Great Falls.

A detailed description of all types of equipment used in the Pondera field may be found by referring to the discussion of oil production in the Kevin-Sunburst field.

The writer believes that a "water" or "gas drive" might be used profitably in the field. No known attempt to do this has been made.

Gas Production

Since there has been no commercial production of gas in the field no study of methods has been attempted. It is possible that a market might be developed by selling gas to the Montana-Dakota Utilities Company whose Choteau main line runs within one-half mile of the field.
BANNATYNE FIELD

Geology and Economic History:--Located twenty-two miles south of Conrad and twenty-five miles southeast of the Fondera field. The structure lies on gently rolling prairie nine miles from Collins, the nearest railroad station, on the west side of the Sweetgrass arch on a small dome with fifty feet of closure.

Oil was discovered in 1927 by the Genom Oil Company which obtained a thirty barrel well in a "stray" sand occurring at the base of the Ellis formation (Jurassic) after a show of oil was increased by shooting with nitroglycerin. By the end of 1929 and spring of 1930 thirty-four commercial wells had been drilled. However, at the end of 1930 only five wells were producing with a total of seventy-five barrels per day. At present there is no commercial production from the field. Therefore, production methods are believed to be of minor importance at this time and are not included in this discussion.
SWEETGRASS HILLS

Geology and Economic History:—Thirty miles north and east of Shelby and five miles south of the Canadian border in north central Montana, the Sweetgrass Hills region consists of five small laccolithic mountains rising to 2,000 feet above the associated surrounding structures of the plain. Numerous dikes and sills complicate the geologic features which are buried under glacial drift of the Wisconsin Period.

Drilling in the area began in 1915 with the completion of the Montana-Canadian Pritchard No. 1. Four miles north of the International Boundary in Dead Horse Coulee, Alberta the Rogers Imperial well was completed in the same year. This well had an initial twenty-four hour open flow of 54,000,000 cubic feet at a pressure in excess of 700 pounds. Half of this production was from the upper part of the Madison at 1,050 pounds pressure, but this had so much sulphur content that the well was plugged back to the upper producing horizon, a sandstone in the lower Kootenai. The Whitlash dome has seen the greatest development in the region occupying an area of twenty-five square miles just northwest of East Butte.

The lower Colorado formation known as the Blackleaf member is the most important gas-producing horizon in the area. Ranging from 850 to 1,000 feet in
thickness the formation contains four to six or more sandstones lenticularly interspaced with black shales. Three of these sands are important producers and are located at 1,200, 1,420, and 1,520 feet stratigraphically below the top of the Colorado.

Underlying the Colorado is the Kootenai series of sandstones and shales. This formation has an average thickness of 500 feet and has two lower sandstones of importance. Gas was found in them at Whitlash and some oil on the Pritchard, Flat Coulee, and Bears Den structures.

Open flows of gas vary from 500,000 to 15,000,000 cubic feet per day in the Blackleaf sandstones. Pressures are below average for the depths of between 1,137 feet to 2,038 feet, ranging from 275 to 330 pounds. From lower horizons the State No. 1 had a reported pressure of 900 pounds and the Wallace No. 1 a pressure of 710 pounds. This would seem to indicate that there has been no leakage from lower strata as pressures are normal of depth.

Oil was discovered in a lower Colorado sandstone in the Whitlash field at a depth of 1700 feet. This well, drilled in 1932-33, obtained an initial flow of 100 barrels of 50° Baume oil. Four oil wells have produced oil in commercial quantities since that time.

The Flat Coulee field, six miles north of East Butte and four miles east of Whitlash field was completed in 1928 with a reported production of twelve to fifteen barrels per day of 31° Baume oil from the lower Kootenai. This well was deepened to the Ellis-Madison contact where
terrific gas pressures encountered wrecked the casing, thus causing loss of the hole. A second well drilled in 1935 obtained 50 to 150 barrels per day production from the Baskoo sand (lower Kootenai).

In 1929 an initial production of from 50 to 100 barrels of 39° Baume paraffin base oil was obtained in a well on the Bears Den structure. A second well also yielded commercial production.

Four gas wells capable of commercial production were found. Dry holes have discouraged further prospecting.

An important quantity of gas has been and will be produced from the Sweetgrass Hills area. The oil occurrence has been of minor commercial importance on the small structures which surround the laccolithic intrusives.

Oil Production

Methods and Equipment:—The oil wells must be pumped in order to produce them. The pumps are standard ball and cage equipment and the wells are generally individually powered. Paraffin accumulates on the tubing and to remove it live steam is passed down the tubing and up the casing around it or vice versa as desired. At Whitlash the oil flows to gunbarrels where the water separates from the oil at ordinary temperatures. In the winter, however, some heat is applied through heating coils connected with a steam boiler. The oil then flows to storage tanks.
There is a good demand for Whitlash oil because of its minor sulphur content and high gravity Baumé. It is burned directly in tractors and stationary engines, and farmers over wide areas buy the unrefined oil at a premium price and haul it themselves as fast as it can be produced. The demand is so great that orders are several months ahead of production.

Comparison of Methods:—The methods employed are standard for wells necessitating pumping. No attempt has been made to increase production other than acidification of the limy Baskoo sands at Flat Coulee with no success.

Gas Production

Methods and Equipment:—Practices in this field show the effect of guidance of the Montana-Dakota Utilities Company who contract, operate, and produce all gas originally developed by the Western Natural Gas Company, former owners of this field.

A variation in well heads is noted. Since there are several commercial gas horizons in the field, all with different pressure, they must be cased off from one another. Therefore one or two sands must be produced through Braden head assemblies. Fifty feet out along the gathering line drips similar to those of the Kevin-Sunburst field are installed. Choke racks cut down the
pressure of high pressure wells to the normal line pressure of 150 pounds, approximately. The gas is then metered through Westcott orifice meters arranged similarly to those in the Shelby field.

The gas flows to the main line where gate valves are located on the well lines. Once in the main line the gas is metered again by the same type orifice meters as outlined above. Thence the flow of gas continues thirty-five miles through a Dresser-coupled ten inch pipe line with twenty foot joints to the Montana-Dakota Utilities compressor plant at Telstod, fourteen miles east of Shelby. The compressor boost the pressure to 200 to 250 pounds for its uninterrupted flow to Great Falls.

Comparison of Methods:—The actual methods of producing the gas compare favorably to the average of the state. In drilling the wells some poor practice has been encountered. Casing has either not been cemented in above the producing horizons or an ineffective job has been done for some of the wells leak gas up around the casing for considerable distances. Then too, high and low pressure gas producing sands have not been separated with the result that the high pressure is dissipated by feeding gas into the low pressure horizon. A third faulty practice has been the setting of casing several hundred feet above the producing sand leaving enough open hole so that caving will damage and has damaged, the productive capacity of some wells.
BORDER-RED COULEE

Extending into Canada, this field lies in the northwestern corner of Toole County about six miles west of Sweetgrass and forty miles northwest of Shelby.

Gas and oil were discovered in 1929 by a well 281 feet north of the border. This well had an initial production of 60 barrels of oil and 3,500,000 cubic feet of gas per day. The oil occurred in the lower part of the Kootenai formation and the gas in an upper Kootenai sand equivalent to or slightly higher than the type Sunburst sand.

Taking the field as a unit, it has probably not been a profitable investment because of the large number of dry holes drilled and the very rapid decline of the producing wells. There has not been a single well completion in the field, since 1934, this fact alone speaking more eloquently than any other data available.

Oil Production

Petroleum production in this field has declined to a stripping action with a total of about twelve wells pumping less than seven barrels per day each.

The pumps and pump jacks are similar to those found in the Kevin-Sunburst field. The power is supplied by natural gas burning engines which operate gear-driven band-wheel units of relatively small size. The oil pumped from the well is delivered to 500 barrel gun barrels where heat is applied by hot water circulation systems or the heavier duty "dutch ovens". After a water
separation the oil goes to storage tanks. When the tank is full, it is "gauged" to determine the quantity of oil present. When this has been done, the oil is inducted into a pipe line running to a 600 barrel per day refinery located at Sweetgrass. Large storage tanks reserve the oil for use as needed.

Comparison of Methods:—Again the oldest method of recovery of oil is the only method practiced. It may be that attempts made toward effecting a greater recovery would be too expensive for the probable results obtainable.

Gas Production

Natural gas was found in fifteen wells with an average pressure of 390 pounds per square inch, and an open flow capacity of 2,000,000 cubic feet per day. A pipe line was constructed to Sweetgrass and some gas delivered to the town. Later the line was converted to an oil line. Some gas is used in the field itself, but the operation is relatively so unimportant, and since no attempt is made to apply modern methods to this production, it is not discussed in this report.
PLATE XI

A. Glacier Production Company absorption plant and refinery as it appears when viewed from the south.

B. Internal combustion engine powered pump operating in the area south of the town of Cut Bank. The eastern fringe of the Rocky Mountains can be dimly seen against the horizon, about forty-five miles away.
Geology and Economic History.-- Ranking first in the yearly production of gas and oil in Montana since 1936, this field, discovered in 1986, constitutes a narrow band thirty miles long running north and south through the town of Cut Bank. The field averaging about four miles in width, lies on the west flank of the Sweetgrass arch. Wells in the field are spudded in glacial drift and pierce successively 200 feet of Upper Cretaceous Two Medicine formation, 200 feet of Eagle (Virgelle) sandstone, the Colorado formation about 1,850 feet thick, and 400 to 600 feet of Kootenai interbedded sandstones and shales in reaching the producing horizon. The gas and oil sands are roughly the same horizon with the gas occurring higher up on the flank of the Sweetgrass arch. Down dip from the gas, oil occurs, and wells still further down dip have encountered water.

The occurrence of oil and gas is largely due to stratigraphic features since it is a lensing of sands or at least of porosity up dip which has trapped the hydrocarbons. Considerable variation in volume seems to be due to variation in porosity of the sands.

A few oil wells have yielded as high as 1,000 barrels per day the oil flowing from the wells, but the average production per well in the field is about thirty-five barrels a day, the oil being brought to the surface by pumping.

Gas wells exhibit similar variable capacities, initial daily open flows ranging between 1,000,000 to 37,000,000 cubic
PLATE XII

A. Standard steel rig (derrick) as used in the Cut Bank field.

B. Conventional style pump-jack lifting the oil from one of the Texas Company's wells.
feet at about 700 pounds rock pressure. Since 1935, Cut Bank has exceeded all other fields in Montana in yearly production.

The Cut Bank field is the newest important oil and gas development in the state and today produces more gas and more oil than any of the other fields in the state. Both gas and oil operations have been highly profitable in the past and should continue similarly in the future.

Oil Production

Methods and Equipment.—The wells of the Cut Bank area are drilled to a maximum depth of about 2950 feet. Most of the early wells were drilled with cable tools. Many newer holes have been drilled with rotary rigs and cored in the producing Kootenai sandstone. The majority of the wells have been and still are being drilled with churn drills. The use of rotary rigs is, however, becoming more and more prevalent.

The casing is run similarly to that in the Kevin-Sun-burst field. Only the producing string of casing is needed in wells drilled with rotary rigs because the pressure of the drilling mud is sufficient to seal off flows of water, and, incidentally, stray flows of gas which might be encountered. With cable tools heavy flows of water would have to be cased off with an extra string of casing. Most of the strata in Cut Bank are dry enough to make this unnecessary.

Generally speaking, the oil wells of this field must be pumped. Five wells, however, are produced by natural flowing.
PLATE XIII

A. Typical well drilling operation in the Cut Bank field.

B. Central-power pumping unit in the oil-field north of Cut Bank. This unit is a belt driven geared eccentric type of central power wheel. The engine is a 35 HP. semi-automatic type. Its flywheels are approximately five feet in diameter.
The rate of flow is controlled by "flow beans", which restrict the opening in the well line. Those wells where pumping is necessary, employ essentially the same equipment and methods employed elsewhere in Montana.

The pump jacks are identical to those of other fields. Power is derived from individual units using Waukesha or Ford V-8 motors. Large numbers of wells are pumped by central power bandwheel units, usually Oilwell Supply Company or Superior equipment. A complete pump adapted for use in the field costs about $1,100.00.

Pumps must be serviced in the field approximately once every thirty days some needing attentions often and some not so often.

If the casing or tubing become choked with paraffin hot oil may be poured into the well, scrapers maybe used, or an electric current sufficient to heat the pipe may be tried. The latter method is new and, at this writing, little used.

The oil is pumped to gun barrels where the oil-water emulsion is broken down by the application of heat and the water drained off the bottom of the tank. The gun barrels are tall 500-barrel or larger tanks. Approximately half of the tank is filled with water with the upper half containing the oil. The oil from the well flows over the top of the tank and down a stand pipe which may extend nearly to the bottom of the tank with perforations below the water level through the oil can escape to filter upward. The
PLATE XIV

A. Texas Company well, pumping unit, gunbarrel, and storage tank in Montana's most productive oil field.

B. Loading racks of the Glacier Production Company along the Great Northern railroad. These racks are located directly back of the absorption plant.
A. "Skidding" a rig (derrick). Where no rough terrain is encountered this is the accepted method of moving rigs within the field.

B. Pulling the "sucker-rods" in an oil well. On a field average the producing wells must be serviced once each 30 days. Some wells require much less attention.
heat is supplied to the tanks in several ways. Steam coils situated inside the tanks are heated by a forty horsepower boiler. Large-size hot water heaters circulate the water through heating coils. "Dutch ovens" are boilers which circulate the water through copper coils inside the gun-barrel. Sometimes these units are directly beneath the gun-barrel, a dangerous and highly unsatisfactory practice.

When the oil-water emulsion is heated to between 85 and 90°F, separation is effected. Where excess water occurs the temperature may be raised to 105°F. The Glacier Production Company uses large hot water heaters for the above task rating them as 350,000 B.T.U. heaters.

The de-watered oil reaches the storage tanks which may or may not be insulated. Asbestos and vermiculite are the insulating materials used.

Once oil has reached the storage tanks it has four possible major destinations. It may reach the International one mile west of Cut Bank, or the Glacier Production Co. refinery at Sunburst, the Northwest Refinery four miles east of Cut Banks by pipe line. The fourth major destination is by large tank trucks to the Home Oil and Refinery Company at Great Falls.

Comparison of Methods.—Cut Bank oil operators are alert, and in the aggregate production practices are good. There has been contemplation of trying some means of forcing more oil from the strata than can normally be recovered. To date conditions are much too good to necessitate any such action though a gas or water drive would probably be successful.
PLATE XVI

A. Oil well three miles north of Cut Bank. The pump has been "frozen" at the height of its stroke by the camera. The pump is driven by ten horsepower Waukesha motor burning casing head gas from the well being pumped.

B. Gunbarrel and storage tanks of well described in (A).

C. Taking the temperature of the gas and oil produced by this well, one of the few producing both.

D. Preparing to run a string of small tubing in a gas well for the purpose of installing a "stage lift". This apparatus removes water from the well.
Gas Production

Methods and Equipment.—In 1931, gas production from Cut Bank field began on a large scale with the completion of large lines to Butte, Helena, and Anaconda.

Wells have in the main been drilled with cable tools. Casing has been run in the conventional manner and all wells cemented to insure a tight seal between the casing and the formations above the gas sand. This is important because the 700 pound rock pressure would otherwise work up around the outside of the casing. A typical well head is shown on page 76, Plate 17. The same well head is shown after the installation of a calcium chloride dehydrator, which also shown in Plate 17, page 76. The calcium chloride dehydrators, though not an absolutely original development of the Glacier Production Company, owe their present efficiency and design to this company. A print of this design has been incorporated with this report through their courtesy. The reader is referred to Plate 20, page 96. Under ordinary operating conditions in the field, fifty pounds of calcium chloride will dehydrate 150,000,000 cubic feet of gas. All of the wells operated by the Glacier Production Company are equipped with these dehydrators.

The dehydration of gas is of vital importance because of the danger of the line freezing full of ice in the winter months. A series of hydrates of the volatile "wet gas" hydrocarbons forms at temperatures as high as 58°F. It is these hydrates which make "freeze-ups" particularly dangerous and the removal of the water a paramount importance.
PLATE XVII

A. Bottom-hole pressure gauge and auxiliary equipment as developed by the Glacier Production Company.

B. Second view of the same apparatus. By the use of the bottom-hole pressure gauge and an accurate measure of the gas flowing through the well line the open flow capacity of the well can be computed without the loss of gas, as is the case when the fifteen minute blow-down test is used. The apparatus pictured is a recent development.

C. Early christmas tree and calcium chloride dehydrator in the Cut Bank field.

D. Same well as (C) with revamped well head. Newer design.
In this connection a few of the wells which make some water have been equipped with "stage lifts". These consist of a string of small size tubing run in the well with "kick-off" valves located at intervals in the tubing. The location of these valves must be calculated from the gas pressure and the amount of liquid to be lifted. The lifted liquid must flow through the calcium chloride dehydrators.

From the dehydrators the gas flows to the metering stations located near the main trunk line. The meters used are Westcott meters using flange pressure connections. The major and minor piping of the measuring station are shown on Plate 21, page 97, and Plate 22, page 98, respectively.

Field regulator stations reduce the well pressure to the main line pressure. These stations receive gas from a group of wells in order to operate more efficiently and economically. Heat is applied to the gas before it passes through the regulators in order to prevent the freezing due to expansion of the gas. This heat is applied by water jackets around the pipe these jackets being heated with gas.

From the regulator stations the gas flows through an "absorption plant" clearly portrayed on the frontal piece of this report. The natural gas contains in excess of one pint of "wet gas" constituents per 1,000 cubic feet. This is recovered from the dry gas in the plant and used for blending purposes with other gasoline.

The natural gas flows uninterrupted from the absorption plant to the town borders where, after being metered by Westcott
A. Running a string of small size tubing with appropriately spaced "kick-off" valves for a stage lift. The tubing is being run against a gas pressure of 700 pounds without losing any gas. Rubber packing through which the small pipe is forced forms the effective pressure seal.

B. Close-up shot of the well head showing clamp and chain arrangement for forcing the tubing down the hole against the high gas pressure.

PLATE XVIII
orifice meters, the gas is reduced to 50 to 100 pounds pressure in the first stage reduction. Second stage regulators reduce the pressure to the city distribution pressures of from ten to thirty pounds. A final reduction of pressure is made by individual consumer's units to four ounces gauge pressure, following which a positive meter records the cubic feet of gas used.

At the Butte town border a "stand-by" plant has been erected by the Montana Power Company. This plant stores under pressure a sufficient quantity of the highly volatile "wet gas" removed from the gas at Cut Bank to run the system for from 48 to 72 hours. The gas is vaporized and mixed with air the concentration of gas in relation to air being kept well above that of an explosive mixture. This plant insures the company against any failures of service which might ordinarily appear.

Gas well flows are tested by the use of bottom hole gauges for the pressure and manometers measuring the flow of gas through the well line. This method is very good since no gas is wasted as has been the case in the Shelby area.

Electrolytic corrosion surveys have been made on all Montana Power Company pipe lines and cathodic protection o units installed. These units protect ten to thirteen miles of pipe. Where the power line is available copper oxide rectifiers are used to supply the direct current necessary In other regions wind or natural gas powered generators supply the current. The plus pole of the generator is connected to a ground bed of old scrap iron buried about 300
A. Spring load diaphragm type first stage regulator. This is a town border regulator used by the Montana Power Company to reduce main line pressures to between fifty and one hundred pounds.

B. Pilot operated spring loaded second stage regulator as used by the Montana Power Company to reduce pressures of first stage regulation to ten to thirty pounds, the city distribution system pressure.

C. Second stage regulator of another design.

D. Special meter run and manometer for testing the flow of gas wells in conjunction with bottom-hole pressure tests.
to 600 feet from the pipe in a favorable location for low ground resistance. The pipe is then connected to the other pole of the system thus being given the necessary negative charge assuring protection. When the pipe carries a current intensity of twenty microamperes per square inch and three-tenths volt current differential between soil and pipe it is adequately protected.

Comparison of Methods.—The production methods of the Cut Bank field are the best in Montana and equal those of any field outside the state. The Glacier Production Company has a very busy and productive natural gas research department under the direction of Mark Hardy, Jr.
HAVRE

Gas was discovered in the Havre field in 1914, though the first commercial well was not completed until 1915. Following this twenty-six more wells were completed with a wide range of flows reported at from one to fifteen million cubic feet per day. These wells obtained production in the Eagle formation. An area two miles northeast of the city found good flows of gas in the Eagle at depths ranging from 947 to 1,145 feet and pressures of from 400 to 540 pounds. Heavy flows of water both above and below the gas sand were reported to have been improperly sealed off and water drowned the gas flows forcing abandonment of the field. Six miles east of Havre an 8,000,000 cubic foot open flow well at 100 pounds pressure was found at a depth of 420 feet in a sandstone of what appears to be the Judith River formation. No further development has been carried on in this area. The wells discussed above do not all fall in the area specified as the Havre field. They are, however, included here in recognition of the close correlation of occurrences and location. The original field lies at the Havre town border on an elongated antelinal dome trending N70°W. Considerable faulting has affected gas distribution, most of the production being from the area north of the faults.

Since the fields are dead or dormant no attempt has been made to go into production methods. The value of such a discussion would be mainly historical, and, it is believed, of little value.
BOWES FIELD

This gas producing area lies about 20 miles south-east of Havre and seven miles south of Chinook. Four wells were drilled in 1926 ranging from 7,000,000 to 30,000,000 initial 24-hour open-flow. Pipe-lines were laid to Havre and Chinook in 1926. Three more wells were drilled in 1929. The production horizon is the upper part of the Eagle ranging in depth from 653 to 1,078 feet with rock pressures of 250 to 300 pounds.

This field is operated by the Montana Gas Corporation with which the writer is somewhat familiar. No field trip was made to the area, but from all information obtainable by correspondence the conditions are as will be outlined below.

Production Methods

The casing is set five to twenty-five feet above the sand and the well drilled "in". At the surface the casing is reduced to four-inch size by a swedge nipple which terminates at a height of approximately three feet above the ground. Here a four inch gate valve is screwed on the nipple and the gas flow closed off. Above the gate valve a four-inch nipple one foot long equipped with a two, three, or four-inch T-connection for the gathering line take-off and a collar on the upper threads. Then a bull plug made of four inch pipe which has been swedged to a one-inch blow-
off generally equipped with a plug valve. A gate valve is screwed on the T-connection, a four-inch nipple two foot long screws into the downstream side of the gate, an ell comes next in the assemblage allowing the line to connect with the main line of underground pipe by means of a pipe union. The gas travels about fifty feet along the gathering line through a condensate drip or water trap. Fifty feet further down the line a metering run with an orifice meter built by the Foxboro Company constitutes the measuring equipment for the well, and the last important feature of the well-line until the main gathering line is reached. At this point a gate valve is located on the well-line. The gas flow continues uninterrupted to the city border stations where the gas is again measured with Foxboro orifice meters and the pressure reduced to between five and twenty-five pounds, which is the city distribution system pressure.

It is here noted that the methods employed, type of meters, dehydrators, and piping could probably be modernized. To date the company has felt that the expense involved would not be warranted in view of present generally satisfactory operations.
BOWDOIN-SACO

This area is located between Malta and Hinsdale and is the furthest east that northern Montana's gas producing zones are known to occur. Over 60 miles across, the Bowdoin dome, with a closure of 700 feet and a proven area of 50,000 acres is among Montana's largest gas fields so far as areal extent is concerned. Though well pressures are only 200 pounds and open flows average three-fourths to one million feet per day, the great area of the reservoir may place Bowdoin among the foremost fields from a quantitative view as well.

Gas was discovered in the area in 1931 at a depth of 740 feet. Intensive drilling in the area began in 1929 when twenty-five wells were drilled to depths of from 700 to 1200 feet all getting some gas. These wells were contracted and were drilled with cable tools. Pipe lines were laid to Glasgow and Malta in 1930 with an extension line to Glasgow in 1935, and a further extension in 1940 to tie in the Baker-Glendive lines.

It is probable that Bowdoin will have a long life with a large aggregate production.

Production Practice

Early wells drilled in the field were drilled with cable tools. Later wells have been drilled with light rotary rigs. The summer of 1940 initiated a spurt of drilling activity in the field with a goal of thirty wells set. At this writing only part of this number of wells have been completed. They are being drilled with
a light portable rotary rig mounted on the bed of a truck, the small portable unit manufactured by the Brauer Machine and Supply Company of Oklahoma City, Oklahoma. Some difficulties were encountered in the drilling operation, but these were mainly overcome and wells are completed with great rapidity.

Casing in these wells is set just above the producing zone, a sandy horizon 445 feet from the top of the Colorado. Pressures of the wells are near 200 pounds and open flows approximately 1,000,000 feet per day.

Production Methods

This field is being produced by the Montana-Dakota Utilities Company, which is also the chief operator in the Kevin-Sunburst field. Production practices are similar to those outlined in detail for the Kevin-Sunburst field.

Gas comes from the producing sand up the casing, through single well heads and into the well gathering line. A drip is installed about fifty feet away from the well along the line to catch any excess moisture brought out of the well by the gas. This drip has a blow-off where the water may be blown from the drip as often as the operators find necessary.

Approximately forty feet further out along the gathering line a meter installation is made. In this field the well lines run straight through, and the meter house and setting are sunk in the ground accordingly. Orifice flanges are screwed to the ends of
threaded pipe ranging from two to four inches in diameter. These flanges are built so that, once installed, the bolts may be removed and set screws turned in to hold the flanges apart in order that orifice discs may be changed. These flanges are gasketed to prevent leakage. In addition, each flange is tapped for one-fourth inch pipe connection one inch back from the orifice disc.

A saddle of the correct size to fit the pipe is next clamped in place along side the flanges, and leveled with the aid of set screws. The meter, (Westcott orifice meters with twenty-four hour clocks) is attached to this base and the pressure connections, valves, and fittings made with one-fourth inch pipe.

The meter houses are generally six by eight foot corrugated iron houses though some wooden structures have been built.

Gas from the wells flows uninterrupted from the meters through the field lines to Saco where a compressor or "booster" plant increases the pressure sufficient to force gas to the town border stations at pressures of from 100 to 200 pounds depending upon the load. The compressor engines are internal combustion units whose pumping capacity is regulated by adding or taking off a complete unit as may be necessitated.

At the Glasgow town border straightening vanes have been installed in the pipe to prevent a turbulent flow of gas from reaching the orifice meter. Vanes are
of many designs some of which are folded sheet steel forming a honeycomb unit of a size just small enough to insert in the pipe. The other important type is made up of a group of small thin-walled pipe welded together to form a resultant unit similar to that made of sheet steel.

Regulators are installed in the same building as the orifice meter reducing the pressure to that of the city mains. A complete duplicate set of equipment including meters and regulators has been installed at all town border stations. In event something should go wrong with the operating meter or regulators, or if the orifice was too large or too small to record the flow efficiently on the meter chart, the flow may be switched to the other "run".

In the last few years a study of pipeline corrosion has been made on the Bowdoin system and zinc electrodes have been installed at the "hot spots", or points of greatest corrosion. The zinc electrode is buried from 300 to 600 feet from the line at a point where the resistivity of the soil is low, and connected to the line by copper wire. The zinc must have an area ratio of one part to 20 parts of steel. This ratio is the basis for calculating the amount or area of zinc necessary to protect any given length of line. Since zinc is more active chemically than is iron the zinc becomes the positively charged pole and the pipe assumes a negative
charge of a zinc-iron-soil-electrolyte battery. In the area where the pipe carries a negative charge the positively charged iron ions will not leave the pipe, in fact, are actually attracted to it. At periodic intervals the zinc electrodes must be taken up and cleaned.

Comparison of Methods:—Operators in the Bowdoin field have been slow to adopt new production methods. However, in the last four years, they have begun a steady improvement program. This program has resulted in studies of pipe corrosion, methods of dehydration, and de-watering of wells, which will undoubtedly continue to bring about many advantages, of new developments and modern practices.
Geology and Economic History.--This field lies near the Montana-North Dakota line, the structure beginning several miles southwest of Glendive and continuing through Baker into North Dakota for an over all length of approximately 100 miles. In 1915, gas was discovered near Glendive. Since that time, gas has been discovered along the structure for a distance of approximately seventy miles. Production is from equivalents of the Judith River and Eagle formations consisting of shales and sandy shales. Two producing gas horizons are found, the upper one being found at depths of 700-1,100 feet, and the lower one between 1,300 and 1,500 feet. A great variation in the open flow of wells occurs with commercial producers ranging from one to twenty-eight million feet per day at pressures averaging 200 pounds in the Judith River and 420 pounds in the Eagle.

Production is not continuous along the Cedar Creek structure, being found on a series of smaller domes along the large anticline.

In 1936, the Montana-Dakota Utilities Company began three deep test wells near Baker. One of these wells found oil between 6,500 and 6,800 feet in what was believed to be upper Madison. Unofficial reports placed this flow of oil at several hundred barrels per day. Acidation brought in a 6,000 barrel gusher which turned
to water after three days due perhaps to a coning of the oil-water contact.

A second well, completed in 1937, found the producing upper Madison at 6750 feet and obtained an official production of 400 barrels per day. No additional deep wells have been drilled.

The Cedar Creek anticline has furnished gas in large quantities and some oil to a desolate semi-desert region badly in need of the stimulus offered by a thriving business enterprise.

Natural gas is marketed through much of eastern Montana, in North Dakota, and southward in the Black Hills region and other parts of South Dakota. A carbon black plant operated most of the time from 1918 to 1930 burning about 105,000,000 cubic feet of gas per month. This plant pulled down some of the well pressures in the Baker area to as low as 30 pounds. In excess of 5,000,000,000 cubic feet of gas are now produced from this area per year.

The oil production is very minor, but may be developed further in the future.

A profitable history has been written for the Baker-Glendive field with the forecast of a long and profitable future looming before the area. Recent developments do not warrant much further extension of pipe lines for new markets.
Oil Production

The oil production of the region at present has been deemed too small to warrant discussion. Future deep well production may greatly alter this situation. It may be stated that the deep test wells were drilled with rotary rigs and complete cores taken.

Gas Production

The natural gas production methods and equipment used in Montana's eastern-most gas field is similar to those of the Bowdoin field. This is mainly because the Montana-Dakota Utilities Company is practically the sole operator in both fields.

An important difference occurs in casing the wells. An outer string of casing is set just above the first producing sand. Then the well is deepened below this sand to the second or Eagle zone of production where a second smaller size string of casing is set just above the sand. In this way the sands are properly separated preventing the high pressure gas from flowing into the low pressure strata. Usually only one of these sands is produced at a time though both are connected to the line, the first from the Braden head and the second from the inner string of casing.

From the well head the gas flows underground fifty feet to a drip made of large size pipe and of a length sufficient to support about sixty gallons of water and gasoline. The drip is blown free of water and gasoline
as often as experience finds it necessary. Approximately fifty feet further along the line the orifice meter measuring the production of the well is installed. The meter settings in this field are similar to those in the Bowdoin field. The well gathering line runs straight through the meter house at the normal depth underground of approximately thirty inches. Orifice flanges are screwed on opposing ends of the pipe, the proper size orifice disc installed sharp side pointing upstream, and the flanges bolted together. One inch on either side of orifice disc the flanges are tapped for one-fourth inch pipe connections for connection to the meter.

A saddle is clamped to the pipe and the orifice meter attached to that. The meters are connected to the flange pressure taps with one-fourth inch pipe. Many of the meters are of the old type requiring square root of the extensions read on the chart in order to correctly compute the flow.

After passing the meter the gas continues in the well line to its intersection with the main field gathering line. A gate valve on the well line near the junction of the two lines completes the equipment of the field. An occasional large size drip may be placed in a low spot where liquids might gather, but these are not found beyond the vicinity of the field except below compressor stations and near town borders.
Two large compressor plants are within the area, one at Cabin Creek, and the other at Baker. These compressors have a suction pressure of 50 to 150 pounds and delivery pressure of approximately 250 pounds depending somewhat on the line load.

From the field areas four main pipe lines transmit the gas to markets in many Montana, North Dakota, and South Dakota towns. These lines include a twelve inch line southward to Bell Fourche, Deadwood, Lead, and Rapid City with a six inch branch eastward to Marmarth and Bowman; an eight inch line stretches northward to Glendive, Sidney, and Williston; an eight inch line extends westward to Miles City, with a branch to Terry; and a twelve inch line east to Dickinson and Bismark, with a branch line to Wibaux.

At the town borders the gas is metered by orifice meters after which the pressure is reduced to city main pressure by regulators in two stages. From the city mains the gas flows to the individual consumer's lines through a small low pressure regulator which cuts the pressure to four ounces gauge. A positive meter records the number of cubic feet used.

Comparison of Methods.—Many practices used in this field are lagging behind approved modern methods. This is probably due to the presence of much serviceable old style equipment.
HARDIN

The Hardin gas field lies about one and one-half miles northwest of the town of that name on the bench lands bordering the Big Horn River. Gas was discovered in 1913, but the small amount created no great interest until the civic leaders of Hardin decided to drill additional wells and develop volume adequate for the use of the city.

Production is found at a depth of 725 feet in the Frontier formation. The uppermost sediment in the field is the Niobrara series. The rock pressure is 137 pounds and the 24 hour open flow capacity, of individual wells ranges from 30,000 to 160,000 cubic feet.

Specific technical data on this field has not been obtained though production methods are simple. Gas flows from the well into the line passing through drips similar to those of the Kevin-Sunburst field. Less than two miles of main line carry the gas to the town border, where it is reduced by first and second stage high pressure regulators to the city distribution line pressure. Individual low pressure regulators at points of consumption make the final reduction to four ounces gauge pressure.
SUMMARY

Montana's oil and gas fields are typical of similar fields outside the state. Larger operations have used some methods that hav not been applicable to the smaller scale operations in this state. There has been less waste and mismanagement of fields in Montana than in areas of larger production.

The production of gas in Montana has resulted in many changes and advances in equipment and design, since operations in this latitude must cope with the added hazard of severe winter temperature conditions. The Glacier Production Company, particularly, has improved much of their equipment and has designed and built a great deal of new apparatus aiding im more efficient and reliable natural gas service. In this respect, Montana's production equipment is in many ways more advanced than most regions elsewhere.
BIBLIOGRAPHY

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NOTE:
-E INDICATES ELECTRIC WELD; PREFIXED NUMBER SIGNIFIES PASSES TO BE MADE.
-REFER TO SPECIFICATION SHEET FOR EXPLANATION OF LETTERS AND NUMBERS.

1939
BUBBLE TOWER DEHYDRATOR
FOR
GAS WELLS

MAY 18, 1939
SCALE AS NOTED

THE MONTANA POWER CO.
GAS ENGINEERING DEPT.
BUTTE, MONTANA

OWN & TR. BY E. S.
WELL MEASURING STATION
MAJOR PIPING
JUNE 20, 1940
SCALE 3"=1'-0"

NOTE: REFER TO SPECIFICATION SHEET FOR EXPLANATION OF LETTERS AND NUMBERS.

GLACIER PRODUCTION CO.
GAS ENGINEERING DEPT.
BUTTE, MONTANA