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An Investigation of Gas Supplies Available to the Cities Service Gas Companies

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Introductory Note

This report contains data prepared at the request of the Kansas Corporation Commission and covers part of an extended investigation of the leaseholds and gas supplies available to the Cities Service Gas Companies.

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Average daily requirement of gas (8-ounce base)
for years ending June 30

1930	186,294 MCF
1931	169,389 MCF
1932	133,681 MCF
1933	133,272 MCF
1934	148,684 MCF
Average	154,264 MCF

A summary of the leaseholds of the Cities Service Gas Companies and of estimated reserves as of June 30, 1934, follows.

Summary of Leaseholds of the Cities Service Gas Companies with statement of estimated reserves as of June 30, 1934, in MCF (8-ounce base)

	Kansas (except Hugoton)	Oklahoma (except Hugoton)	Hugoton field	Texas	Total
(1) Proved operated acreage	6,828.	3,373.33	—	22,229.5	32,430.83
(2) Proved unoperated acreage	—	—	86,857.62	80,829.75 [a]	167,687.37
(3) Probable acreage	—	—	20,500.	2,396.	22,896.
(4) Prospective acreage	516,481.53	256,987.46	—	7,752.75	783,455.74 [b]
Totals	523,309.53	260,360.79	107,357.62	113,208.	1,006,469.94 [c]
(1) Estimated reserves proved operated acreage	10,546,000	13,068,000	—	579,904,913	603,518,913
(2) Estimated reserves proved unoperated acreage	—	—	772,469,712	2,492,066,286 [d]	3,264,535,998
(3) Estimated reserves probable acreage	—	—	91,158,149	41,075,686	132,233,835
Totals	10,546,000	13,068,000	863,627,861	3,113,046,885	4,000,288,746

[a] Includes 8149 acres in "sour gas" proved area, Amarillo field.
[b] Includes 2,234 acres in Missouri.
[c] Does n[illegible] include 2,673,06 acres "dead and unused".

Gas Available from Company Leases

The acreage covered by leases of the Cities Service Gas Companies has been classified by us in four parts, as follows: (1) Proved operated acreage, which is defined to include the area in a lease lying within one-half mile of a producing gas well, provided that in Texas areas in the "sour gas" producing area are excluded. In applying this definition, a square of 640 acres with the producing gas well at its center is laid out and the part of the lease included within this 640-acre tract is regarded as proved operated. (2) Proved unoperated acreage, which is defined to include the area in a lease regarded as proved gas productive but having no producing gas well on the lease or lying more than one-half mile from a producing gas well on the lease. Included in this class but not to be regarded as a source of supply for pipe-line gas without special treating of the gas is acreage in the "sour gas" area of the Amarillo field. This "sour gas" acreage is separately designated in following tabulations. (3) Probable unoperated acreage, which includes those leases or parts of leases that are regarded as likely to be productive of sweet gas but not proved. (4) Prospective unoperated acreage, includes all other acreage which the Companies hold under lease. For convenience and brevity the designation "unoperated" may be omitted in classes 3 and 4.

GAS SUPPLIES AVAILABLE TO THE CITIES SERVICE GAS COMPANIES

Summary of Gas Available from Company Leases and Purchase Contracts

The following table shows totals of estimated gas available daily from Company leases and purchase contracts, as of June 30, 1934.

Summary of Gas Available Daily to the Cities Service Gas Companies (8-ounce base)

State	Gas available daily, MCF		
	Company leases	Purchase contracts	Total
Missouri	—	151.3	151.3
Kansas	13,889	130,768.2	144,657.2
Oklahoma	57,415	361,695.8	419,110.8
Texas	310,361	—	310,361.
	381,665	492,615.3	874,280.3

The peak load for the Companies' distributing system for a 24-hour period in the year ending June 30, 1934, is reported to be 336,600 MCF (8-ounce base), on Feb. 26, 1934. The average daily requirement of gas as indicated by total volume of gas sales reported by the companies for the period from 1930 to 1934, inclusive, are as follows.

Proved operated acreage

The following table shows by states a summary of the operated acreage, producing wells of the Cities Service Gas Companies, total open flow as of June 30, 1934, daily quantity of gas available figured as one-fourth of the open flow, and estimated reserves of acreage classed as proved operated. The quantities of gas are computed on an 8-ounce base.

Summary of Gas Available from Operated Acreage

State	Operated acreage	Producing wells	Acres per well	Total open flow M.C.F.	Gas available daily M.C.F.	Estimated reserves June 30,1934 M.C.F.
Missouri	——	—	——	——	——	——
Kansas	6,828	56	121.9	55,557	13,889	10,546,000
Oklahoma	3,373.33	30	112.4	229,661	57,415	13,068,000
Texas	22,229.5	63	352.8	1,241,447	310,361	579,904,913
Total	32,430.83	149	217.7	1,526,665	381,665	603,518,913

The figures in this table do not include the Hugoton Field because there is no developed Company acreage as yet in this area. The estimated reserve of developed acreage in Texas is based on an original per acre estimated reserve of 34,287,719 M. C. F. on 8-ounce base (33,074,589 M.C.F. on 2-pound base), determined from production-pressure decline data, figured to abandonment pressure of 25 pounds, with subtraction of total production from Company wells on this developed acreage to June 30, 1934, amounting to 182,293,936 M.C.F. This figure for estimated reserves of

developed leaseholds of the Companies in the Amarillo Field is much smaller than 2,217,706,064 M.C.F., which is based on production-pressure decline data for the Companies' wells as given elsewhere in this report. The probable reason for the larger reserve as figured from production-pressure decline is that average acre-yield figures for the field as a whole rather than that for certain more productive parts of the field have been used in making this estimate of the reserves of Cities Service operated acreage. The size of open flow of wells is probably but not necessarily an indication of greater productivity (that is quantity of reserves) of acreage adjacent to the wells, and this indicates that the Cities Service operated acreage in the Amarillo field is above the average in estimated reserves per acre. The figure for reserves as indicated by pressure decline data is believed to represent actual reserves of this part of the field more accurately.

A table showing the distribution of developed leaseholds of the Cities Service Gas Companies as of June 30, 1934, with statement of estimated reserves follows:

Proved Operated Acreage of the Cities Service Gas Companies, with Statement of Total Production and Estimated Reserves by Fields on June 30, 1934 (8-ounce base).

Field	Lease numbers	Proved operated acreage	Abandonment pressure lbs.	Estimated total reserve M.C.F.	Production to June 30, 1934 M.C.F.	Estimated reserve June 30, 1934, M.C.F	Notes
KANSAS							
Butler County							
Augusta	945, 1153, 947, 1145, 1621, and 3583.	926	40	32,492,475	31,792,475	700,000	
El Dorado	1903, 1716, 2095, 1749, 1974, 1992, 1993, 1996, (1713, 1760, 1754, 1758, 2081 and 1755)	4,285	40	19,359,018	17,359,018	2,000,000	Lease Nos. in parentheses, totalling 1845 acres, are also listed as storage leases.
Cowley County							
Cambridge	14774	10	150	401,814	341,814	60,000	
Chase County							
Elmdale	15684 and 15688	320	40	597,396	547,396	50,000	Wells No. 5 and 7 on lease 15684 now practically dead.
Chautauqua County							
Chautauqua	7892, 12938, 2013, 2011, and 2026	563	40	14,943,640	11,943,640	3,000,000	
Elk County							
Shrader	20492	120	40	256,083	86,083	170,000	
Franklin County							
Pomona	15263	244	25	102,305	86,305	16,000	

Field	Lease numbers	Proved operated acreage	Abandonment pressure lbs.	Estimated total reserve M.C.F.	Production to June 30, 1934 M.C.F.	Estimated reserve June 30, 1934, M.C.F.	Notes
Marion County Marion	15765	80	200	1,298,368	498,368	800,000	
Reno County Haury	20180	120	300	4,631,205	881,205	3,750,000	
Johnson County Craig	19567 and 19564	160					
Total Kansas		6,828		74,082,304	63,536,304	10,546,000	
OKLAHOMA							
Osage County Osage	13905	2,480	40	19,559,261	14,659,261	4,900,000	
Creek County Depew	15760	80	100	10,998,029	9,113,029	1,885,000	
Grady County Chickasha	14042	40	80	431,533	351,533	80,000	
Hughes County Veager	16875	53.33	200	1,758,775	1,458,775	300,000	
Misc.	15769	40	100	1,298,219	868,219	430,000	
Kay County Dilworth	13960, 13963, 13966, and 2394	560	40	33,897,041	30,297,041	3,600,000	
Noble County Perry	16825	80	100	2,298,860	438,860	1,860,000	
Nowata County Nowata	19260	40	25	26,427	13,427	13,000	
Total Oklahoma		3,373.33		70,268,145	57,200,145	13,068,000	

Field	Lease numbers	Proved operated acreage	Abandonment pressure lbs.	Estimated total reserve M.C.F.	Production to June 30, 1934 M.C.F.	Estimated reserve June 30, 1934, M.C.F.	Notes
TEXAS							
Gray and Carson Counties							
Amarillo	(See table showing developed leases in Amarillo Field)	22,229.5	25	765,627,621	182,293,936	579,904,913	
Total Kansas, Oklahoma, and Texas		32,430.83		909,978,070	303,030,385	603,518,913	

In the Amarillo field only certain parts of some leases are here classified as "proved operated acreage". The acreage between Company wells less than a mile apart is divided equally between the wells according to distance. The classification of proved operated acreage in this field is indicated by leases in the following table.

Proved operated acreage in the Amarillo Field, by leases, showing portions of certain leases classed as proved unoperated

Lease	Proved operated acreage	Proved unoperated acreage	Total lease acreage	No. wells	Well numbers
6822-Burnett Est.	11,095	51,985[a]	63,880[b]	20	1a to 10a inc.; 16a to 19a inc.; 21a, 22a, 25a, 26a, 27a, 29a.
7323-Burnett Est.	160	160	320	1	13
6823-Burnett Est.	520	400	920	1	11
6835-Burnett Est.	360	1,000	1,360	1	12
7610-Burnett Est.	640	1,920	2,560	1	14
7611-Burnett Est.	240	1,040	1,280	1	15
7681-Burnett Est.	160	160	320	1	24
7053-Fields (½ Int.)	360	280	640	1	1
7754-G. W. Deahl	560	7,920	8,480	2	1, 2
7753-Fuqua	2,560	1,940	5,780[c]	4	1, 2, 3, 4

[a] Includes 320 acres "sour gas" acreage

[b] Includes 320 acres probable and 480 acres prospective

[c] Includes 1,280 acres prospective

Lease	Proved operated acreage	Proved unoperated acreage	Total lease acreage	No. wells	Well numbers
7755-C. E. Deahl	1,400	680	2,080	3	1, 2, 3
7914-Bennett	240	735	975	1	1
7845-Burnett Est.	80		80	1	20
7839-Burnett Est.	80		80	1	23
1776-Lane	320		320	2	1, 2
7338-Dover	160		160	1	1
1729	160		160	1	1
7143-White Deer	160		160	1	1
7188-Noel	160		160	1	1
7130-Crutchfield	160		160	1	1
7916-Poling	162.5		162.5	1	1
7220-Pope	160		160	1	1
7221-Sheridan	160		160	1	1
7066-Hexter	320		320	2	1, 2
7144-Barrett	160		160	1	
7080-Dover	160		160	1	1A
7321-Brown	160		160	1	1
8049-Mongole	160		160	1	1
7142-Case	160		160	1	1
7103-Bell	160		160	1	1
6420-Meers	120		120	1	1
2566-Hughey	160		160	1	1
7219-Holmes	160		160	1	1
2639-Cobb	132		132	1	1
6360-Wall	160		160	1	1
6361-Wall	160		160	1	2
	22,229.5	68,220	92,529.5	63	

A summary of the Companies' operated acreage showing the number of wells, average rock pressure and total open flow, by fields, as of June 30, 1931 (reported by Ralph Davis), and June 30, 1934, is given in the following table. An interesting feature here indicated is the reported increase of average rock pressure and of open flow in certain fields. This is interpreted to be due to withdrawal of gas at a lesser rate than addition of gas to producing parts of the reservoir through advance of edge water which constricts the space occupied by gas and increases gas pressure. For example, in the Dilworth Field, Oklahoma, although open flow shows a decline, the record of production and rock pressure from 1924 to 1934 shows a gradual rise instead of a fall during this period--a "decline curve in reverse". The production-pressure decline curves for the Augusta and El Dorado, Kansas, fields, similarly, show repeated "build-ups" that produce a nearly horizontal curve. Although production of more than 3 billion cubic feet of gas is reported from the El Dorado Field in the period from 1924 to 1934, the average rock pressure in this field was 27 pounds higher in 1934 than in 1924.

Summary of Rock Pressures and Open Flow of Wells of the Cities Service Gas Companies, by Fields

Field County	6-30-31			6-30-34		
	No. wells	Average pressure	Total open flow	No. wells	Average pressure	Total open flow
KANSAS		lbs.	M.C.F.		lbs.	M.C.F.
Augusta, Butler	15	88	955	12	80	884
ElDorado, Butler	30	106	3,165	25	100.4	3,768
Cambridge, Cowley	1	230	559	1	241	550
Lips, Chase	4	134	217	3	67	324
Chautauqua Co.	8	319	4,096	6	268	2,523
Shrader, Elk	3	490	5,263	3	494	6,337
Pomona, Franklin	2	130	1,034	1	118	1,140
Centropolis, "	2	378	?	2	403	5,754
Marion County	2	780	4,432	2	630	2,696
Haury, Reno	1	1,195	24,290	1	1,045	26,500
Total Kansas	68		44,011	56		50,476
OKLAHOMA						
Meter No.205, Osage	8	597	39,250	7	203	8,294
Meter No.207, Osage	3	725	2,916	2	307.5	587
Depew, Creek	3	498	92,500	3	415	119,500
Dilworth, Kay	12	233	18,485	11	234	9,141
Chickasha, Grady	1	510	2,724	1	170	2,724
Perry, Noble	2	1,272	31,700	2	1,120	47,100
Nowata County	2		100	2	100	150
Misc., Hughes		450	4,159	1	450	4,159
Yeager, Hughes	2	667	36,000	1	500	17,000
Total Oklahoma	33		227,832	30		208,655

Field County	6-30-31			6-30-34		
	No. wells	Average pressure	Total open flow	No. wells	Average pressure	Total open flow
TEXAS						
Amarillo Field	60	401	1,536,625	63	376	1,127,900
Total, Kansas, Oklahoma and Texas	161		1,808,468	149		1,387,031

Drilling operations since September 1, 1931.--According to records furnished by the Companies only three gas wells have been added to the inventory since September 1, 1931. These are the Hughey No. 1, Poling No. 1 and the Fields No. 1, all in the Amarillo Field, Texas. One-half interest in the Fields No. 1 well is owned by the Cities Service Gas Company.

No dry holes have been drilled by the Cities Service Gas Companies during the period from September 1, 1931, to June 30, 1934.

Unoperated Acreage

Estimate of gas available to the Cities Service Gas Companies from wells drilled by them in future on present acquired leaseholds, calls for consideration of reserves assignable to various classes of unoperated leased acreage. These classes include (2) Proved unoperated acreage, (3) Probable gas-productive acreage, and (4) Prospective gas-productive acreage. The following table shows in summary a classification of the unoperated acreage of the Cities Service Gas Companies with statement of estimated reserves.

Unoperated Acreage of the Cities Service Gas Companies as of June 30, 1934, showing Estimated Reserves

MCF (8-ounce base)

State	Proved unoperated acreage	Estimated reserves	Probable acreage	Estimated reserves	Prospective acreage	Total unoperated acreage	Total estimated reserves
Kansas [a]	———	———	—	———	516,481.53	516,481.53	———
Oklahoma [a]	———	———	—	———	256,987.46	256,987.46	———
Hugoton (Kansas and Oklahoma)	86,857.62	772,469,712	20,500	91,158,149	———	107,357.62	863,627,861
Texas	80,829.75 [1]	2,492,066,286 [2]	2,396	41,075,686	7,752.75	90,978.50	2,533,141,972
Missouri	———	———	—	———	2,234.	2,234.	———
Totals	167,687.37	3,264,535,998	22,896	132,233,835	783,455.74	974,039.11	3,396,769,833

[a] Except Hugoton

[1] Includes 8,149 acres in "sour gas" proved area, Amarillo Field

[2] Does not include reserves from 8,149 acres "sour gas".

No acreage belonging to the Companies in Kansas and Oklahoma, excepting the Hugoton Field, is classed as proved unoperated.

In the Hugoton Field, acreage classed as proved is estimated to have a reserve of 8,893,478 cu. ft. per acre, figured on an 8-ounce base to abandonment pressure of 25 pounds. Acreage in this field classed as probable is estimated to have a reserve of 4,446,739 cu. ft. per acre, figured similarly.

Acreage of the Companies in the Amarillo Field that is classed as proved unoperated includes all leaseholds or parts of leaseholds in the "proven sweet gas area" that are not classed as developed. A small amount of acreage along the south edge of the "proven sweet gas area" is classed as probable. The estimated reserves on this acreage are computed on the basis of average per acre reserves determined from production-pressure decline curves for the Amarillo Field. The original per acre reserve, figured on an 8-ounce base to abandonment pressure of 25 pounds, is estimated to be 34,287,727 M.C.F. for proved acreage and 17,143,859 M.C.F. for probable acreage. No value as to reserves is assigned acreage in the sour gas area or acreage classed as prospective.

Since parts of certain leases in the Amarillo Field are differently classified, a tabulation of these leases showing acreage classed as proved unoperated, probable and prospective is given below.

Classification of Unoperated Acreage of Cities Service Gas Companies in the Amarillo Field

Lease No.	Proved (Sweet)	Proved (Sour)	Probable	Prospective	Total
Moore County					
8024		520			520
8073		320			320
8177		320			320
7981		160			160
8149		160			160
7971		240			240
7982	80	80			160
6901	100	60			160
8168		640			640
6778		160			160
6516		60	100		160
6882	160				160
6852		160			160
6888		160			160
7337		80			80
6812				80	80
6850				160	160
6893				160	160
Hutchinson Co.					
868		320			320
6445		40			40
6450		40			40

Lease No.	Proved (Sweet)	Proved (Sour)	Probable	Prospective	Total
Hutchinson Co.					
874		280			280
7934				320	320
Gray County					
6400		220			220
7087		160			160
2549		160			160
6389		80			80
6356		80			80
6387		40			40
9164		2			2
6342		218			218
9032		80			80
6355		100			100
6354		80			80
6351		160			160
6353		320			320
6359		80			80
6358		129			129
6401		160			160
8305		320			320
6418		120			120
6402		80			80
6369		80			80
6385		40			40
8779	48				48

Lease No.	Proved (Sweet)	Proved (Sour)	Probable	Prospective	Total
Gray County					
2575		160		480	640
8420	160				160
2586			160		160
7271	240				240
8178			320		320
8183			160		160
8189			160		160
8191			160		160
8215			160		160
8195				80	80
8186				160	160
Carson County					
6405	40	40			80
7023	960			960	1920
7169				400	400
7721				160	160
7615				320	320
7719				320	320
7011				320	320
6964				320	320
7343	80		100		180
7034	40		40	240	320
7015	160				160
7057			80	80	160
6984			160		160
6965			160	313.3	473.3
7065			116		116
7017	160				160

Lease No.	Proved (Sweet)	Proved (Sour)	Probable	Prospective	Total
Carson County					
8800	80				80
8797	40		40		80
8799	80				80
7081	640				640
8418	352.75				352.75
9260	320				320
1701A-C		720		160	880
6419		320			320
6425		80			80
6822	51,665	320	320	480	52,785
7323	160				160
6823A-B	400				400
6835	1,000				1,000
7619	1,920				1,920
7611	1,040				1,040
7681	160				160
7754	7,920				7,920
7753	1,940			1,280	3,220
7755	680				680
7914	735				735
7053	280				280
7881	240				240
7015	160				160
7081	640				640
7870	1,120				1,120

Lease No.	Proved (Sweet)	(Sour)	Probable	Prospective	Total
Carson County					
8433				320	320
8737				160	160
8738				320	320
	73,800.75	8,140	1,836	7,593.3	91,370.05

Gas Available from Purchase Contracts

The following tabulation shows in summaries by states and fields data on gas purchase contracts, indicating total open flow of wells and estimating as available daily supply one-fourth of the amount of the open flow. The figures for purchase contract No. 8217 with the Panhandle Eastern Pipeline Company are not included in the totals because this calls for purchase of excess merchantable gas from various fields where gas is gathered and distributed by the Panhandle Company. At times of peak demand it is possible that no gas may be available to the Cities Service Gas Companies under this contract. In any case, this only amounts to 250 MCF daily estimated available delivery.

Summary of Gas Available from Purchase Contracts (2-pound base)

State	Producing wells	Acreage	Total open flow, MCF	Amount of gas available daily, MCF
Missouri	8	80	550	137.5
Kansas	470	45,450	475,233	118,808.3
Oklahoma	227	700,060	1,313,910	328,476.4
Total	605	745,590	1,789,693	447,424.2

Additional available gas from gasoline plant residue contracts is not included above.

A tabulation of data on gas available from purchase contracts classified according to states and fields is given below.

Gas Available from Purchase Contracts

	Acres	Wells	Rock pressure	Total open flow MCF	Amount of gas available daily, MCF
Kansas					
Butler Co.	120	3	110	3,287	821.7
Wilson Co.	1,000	15	PLD	601	150.2
	200	5	PLD	250	62.5
Anderson Co. Welda field	1,880	40	26.4	4,637	1,159.2
Chautauqua Co. Berlin field	2,080	24	158	8,054	2,013.5
Cowley Co. New Salem	1,760	14	107	806	201.5
West Burden	240	3	318	1,469	367.2
Wyandotte Co. Fairfax	200	10	PLD	500	125
Bethel	10,626	114	80	13,932	3,483
Welborn	1,056	5	72	286	71.5
Bonner Springs	1,270	4	110	108	27
Douglas Co.	40	1	138	512	128
Neosho Co.	1,200	10	PLD	1,153	288.2
Elk Denton	880	11	93	1,704	426
Elco	1,360	15	170	4,216	1,054
Heck	240	2	?	269	67.2
Franklin Co. S. Ottawa	5,338	48	68?	1,492	373
Pomona	520	1	160	1,160	290
Gardner	5,000*	469*	PLD	21,300*	5,325*
Labette Co.	3,000	33	PLD	2,933	733.2
	3,600	48		7,299	1,824.7

	Acres	Wells	Rock pressure	Total open flow MCF	Amount of gas available daily, MCF
Montgomery	1,000	20	PLD	1,569	392.2
Reno	2,000	20	PLD	62,000	15,500
Burrton	5,120	17	1,065	353,727	88,431.7
Sumner					
Padgett	160	1	325	2,382	595.5
Chase					
Lips	480	5	82	524	131
Marion	80	1	320	363	90.7
	45,450	470		475,233	118,807.7
Missouri					
Jackson Co.	3,000*	20*	PLD	1,000*	250*
Jackson Co.	80	8	PLD	550	137.5
Oklahoma					
Craig and Nowata	10,000	12	45	750	187.5
Creek					
Depew	460	9	404	112,500	28,125
Garfield					
Garber	160	3	1,500	80,000	20,000
Hughes					
Yeager	240	2	685	40,700	10,175
Logan					
Lovell	80	1	1,360	6,480	1,620
Crescent	160	1	2,475	27,900	6,975
Kay					
Dilworth	80	4	90	3,346	836.5
Noble					
Perry	640	9	1,120	191,500	47,875
Nowata					
Verdigris	2,640	50	PLD	1,000	250
Okfuskee					
Okemah	40	1	500	1,490	372.5
Paden	80	2	1,490	30,894	7,722.5

	Acres	Wells	Rock pressur	Total open flow MCF	Amount of gas available daily, MCF
Weleetka	200	5	1,085	165,900	41,475
Oklahoma					
Oklahoma City	440	11	1,450	560,300	140,075
Osage	684,840	105	201	90,547	22,636.7
Washington					
Bynum	70	12	PLD	603	150.7
	700,130	235		1,314,460	328,613.9
Residue				101,240	?
					447,421.6 Total

* Omitted from totals.

Burrton Field.--In the case of the Burrton Field, in Reno County, Kansas, the size of the field and its importance in relation to supplies of nearby towns, has made desirable a study of prospective future yield of gas from this source.

The most important recent development of new gas supplies available to the Cities Service Gas Companies' transmission line is that in the Burrton Field in Reno County, Kansas. This field is only 10 miles from Hutchinson and 30 miles from Wichita.

The Company's Haury well in the Burrton field was completed in October, 1930, with an initial production of over 23 million cubic feet per day. In addition, the company has made available from this field, under purchase contract, the production from 5,120 acres of leases, which cover more than half of the productive area and three-fourths of the choice gas acreage in the field.

The field is not now fully defined, and the development to date has been directed mainly toward the production of oil. Oil is produced both from the Mississippian (chat) horizon, from which the gas is also produced, and from the deeper Hunton "lime" horizon.

The company lines are connected to 17 wells in the field, six of which are dry gas wells and 11 are combination oil and gas wells.

Production and pressure data, which are tabulated below, indicate a very large amount of gas in the field.

Pressure

Original reservoir pressure	1,180 pounds
Pressure on June 30, 1934	1,065 pounds
Loss	115 pounds

Withdrawals of Gas from the Burrton Field (2 lb. base)

Pipe Line Production to June 30, 1934

Cities Service Co.	3,210,936 MCF
Drillers Gas Co.	686,561
Fuel for wells	900,000
Blown to air	17,000,000
Total withdrawals	21,797,497 MCF

Calculation

Production per lb. loss = $\frac{21,797,497}{115}$ = 189,543 MCF

Original field reserve (2 lb. base) 189,543 M x 1180 = 223,660,740 M

Original reserve to 150 lbs. 189,543 M x 1030 = 195,229,290

Withdrawn to June 30, 1934 21,797,497

Field reserve to 150 lbs. on June 30, 1934 173,431,793 M

Assuming that the company will secure the same proportion of future withdrawals as in the past, the gas available to them under their purchase contracts would be:

$\frac{321}{2179}$ x 173,431,793 = 25,549,153 MCF

Converting to 8 oz. base = 28,121,214 MCF

GAS SUPPLIES AVAILABLE TO THE CITIES SERVICE GAS COMPANIES IN THE AMARILLO FIELD

Production of the Cities Service Gas Companies in the Amarillo Field

The Cities Service Gas Companies began to produce gas in the Amarillo Field in January, 1928. The volume of gas produced by the Cities Service Gas Companies in the Amarillo Field according to years ending June 30, is shown in the following table.

Volume of Gas Produced in Texas by Years ending June 30 (8-ounce base)

Year	Production MCF	Daily average[a] MCF
1928	3,592,533	28,341
1929	20,589,213	72,586
1930	29,068,053	75,028
1931	29,538,813	81,677
1932	30,993,583	83,381
1933	32,788,770	101,292
1934	39,866,274	114,261
Total	186,437,339	

[a] By calendar years.

Open Flow of Company Wells in the Amarillo Field

The open flow from 63 wells reported by the Companies, taken on dates within a short time prior to June 30, 1934, was 1,127,900 MCF on 2-pound base (equals 1,241,446 MCF converted to 8-ounce base), as compared with 1,532,625 MCF (2-pound base) on July 1, 1931, from 60 producing wells.

The peak load of withdrawal from Amarillo wells occurred during February, 1934, when an average of 125,571,036 cubic feet (8-ounce base) were withdrawn daily. This is 10.11 per cent of the open flow on June 30, 1934.

Decline in Rock Pressure with Comparison of Production and Estimate of Future Yield for Leaseholds of the Cities Service Gas Companies in the Amarillo Field

Chart I shows the weighted average rock pressure for three dates covering leases of the Cities Service Gas Companies in the Amarillo Field, plotted against the cumulative production of the leases for these dates. These points define the slope of a decline curve from which estimate of the total available production from the leases, disregarding drainage to or from adjoining acreage, may be derived. This shows a total original reserve of 2,560,000,000 MCF (8 oz. base) for the acreage drained by existing Cities Service Gas Company wells in the Amarillo Field, figuring to zero pressure. Subtracting 182,293,936 MCF produced to date leaves an undeveloped reserve as of June 30, 1934, of 2,377,706,064 MCF. At an abandonment pressure of 25 pounds the original reserve is computed to be 2,400,000,000 MCF and the available reserve as of June 30, 1934, is 2,217,706,064 MCF.

It is pertinent to note here that in comparing the relation of rock pressure decline to production of gas in a field that is reasonably well outlined as to productive area but that is partially and unequally developed, determination of average rock pressure weighted according to area is much more significant than a mathematical average of rock pressures. This id due to the fact that the recorded rock pressures show conditions only at or in the vicinity of the wells measured. If wells are

uniformly spaced over an entire field a mathematical average of their pressures may be accepted as representing average pressure conditions in the reservoir, subject only to correction of unequalized higher pressures in inter-well areas, as discussed elsewhere in this report in treating the subject of reserves of the Amarillo Field. On the other hand, it is clear that a mathematical average of well pressures that are not thus distributed areally may give an entirely erroneous picture of average actual pressures in the reservoir. For instance, the low pressures of 20 wells grouped in one part of a field in which withdrawals are relatively large or in which the reservoir rock is less permeable, when mathematically averaged with the high pressures of 20 wells widely distributed in little developed parts of a field indicate an average rock pressure that is certainly much below the true average pressure in the reservoir as a whole. A weighted average rock pressure takes account of this relation to area of pressure distribution by contouring the measured pressures in a field and in weighting each group of similar pressures according to the productive area over which they prevail. Thus, areas that are as yet little developed and that have relatively high rock pressures are assigned proper weight as against areas that are more heavily drained and that have relatively low pressures.

A map of a part of the Amarillo Field showing Cities Service Gas Companies' leaseholds and indicating by contours the pressure loss from January, 1932, to June, 1934 (Chart 8), is included in this report. The determined weighted average rock

pressure of Company wells as of January 1, 1932, was 412 pounds and as of June 30, 1934, it was 397.5 pounds. This indicates a weighted average decline of 14.5 pounds during this 2.5 year period. A similar determination of weighted average rock pressure of Company wells as of January 1, 1930, gives the figure of 417 pounds.

A mathematical average of rock pressures of Company wells for June 30, 1931, is 395 pounds (as compared with 409 pounds weighted average pressure for this date, determined by interpolation from other figures given), and the mathematical average rock pressure of Company wells for June 30, 1934, is 376 pounds. This indicates a decline of 19 pounds in two years.

The explanation that may be given for the higher value of weighted average rock pressures in this case is that the wells operated by the Company and by other producers in this part of the Amarillo Field have as yet not appreciably affected the pressures, except in certain areas of chief withdrawal of gas. For the same reason, the decline of weighted average rock pressure, which reflects as accurately as possible the actual value and distribution of pressures in the reservoir, is much less than the decline indicated by mathematical average of pressures measured at the wells.

The relation of these figures on pressure decline to estimated future yield may be illustrated by the following computations. (1) Weighted average pressure decline June 30, 1932, to June 30, 1934, amounting to 11.5 pounds (409 pounds, June, 1932, less 397 pounds, June, 1934) is 11.5/384 of the decline

to abandonment pressure of 25 pounds, which amounts to 384 pounds (409 less 25). During this period 72,655,044 MCF were withdrawn from Company wells. Since this production corresponds to a pressure decline of 11.5/384 of the expected total decline, the estimated available reserves of these wells amounts to 72,655,044 times 384/11.5, which equals 2,426,024,574 MCF.

(2) Mathematical average pressure decline from June 30, 1932, to June 30, 1934, amounting to 19 pounds (395 pounds, June, 1932, less 376 pounds, June, 1934) is 19/370 of the decline to abandonment pressure of 25 pounds, which amounts to 370 pounds (395 less 25). The estimated available reserves may be computed on this basis as 72,655,044 times 370/19 which amounts to 1,414,811,672 MCF.

1. Graph showing composite Cumulative Production-Pressure Decline Curve for all wells of the Cities Service Gas Companies in the Amarillo Field.

2. Map of a part of the Amarillo Field, showing Cities Service Gas Companies' leaseholds and pressure loss from January, 1932, to June, 1934 (in pocket).

General Conditions in the Amarillo Field Bearing on Gas Supplies Available to the Cities Service Gas Companies

Present Production Conditions

Records obtained from the books of the Texas Railroad Commission and other sources show that for the first half of the year 1934 a total of 349,700,641 MCF (2-pound base) of natural gas was withdrawn from the Amarillo Field, distributed as follows: 74,189,341 MCF to pipe lines, 81,186,800 MCF to carbon black plants, and 194,324,500 MCF to gasoline stripping plants, field use, etc. The production by years, showing distribution, is given in the following table. These figures are derived in part from records of the Texas Railroad Commission, from Company records and in part from engineers who are most familiar with operations in the field. Especially for later years the figures are reasonably accurate but for some, such as the gas blown to the air during drilling and gas wasted in the early development of the field, the figures given are merely the best available estimate. The data for the years 1926 to 1931 are drawn mainly from Victor Cotner and H. E. Crum (Am. Assoc. Petroleum Geologists, Bull., vol. 17, pp. 892, 899, 1933). The column of the table headed "Blown to Air, etc." includes casinghead and bradenhead gas treated for gasoline and blown to air, casinghead gas not treated and blown to air, gas treated by gasoline stripping plants and blown to air, gas blown to air during drilling in oil and gas wells, and also a relatively small quantity of gas used in the field.

Gas Withdrawals from the Amarillo Field,

by years (2-pound base).

Year	Pipe lines MCF	Carbon black MCF	Blown to air, etc. MCF	Total, MCF
1926*	15,725,533	1,890,000	229,810,000	247,425,533
1927	8,825,598	11,280,000	485,120,000	505,225,598
1928	39,978,176	43,020,000	450,980,000	533,978,176
1929	84,767,509	136,374,000	404,536,000	625,677,509
1930	81,175,878	166,104,000	367,292,000	616,571,878
1931	86,538,708	120,387,000	292,168,000	499,093,708
1932	97,087,290	117,013,553	200,090,480	414,191,323
1933	109,179,977	140,866,141	231,138,425	481,184,543
1934**	74,189,341	81,186,800	194,324,500	349,700,641
Totals	597,468,010	820,121,494	2,855,459,405	4,273,048,909

* Includes previous years
** First six months

That the annual rate of production in the Amarillo Field has varied comparatively little is well shown by the accompanying Chart 5 which indicates "Cumulative Gas Withdrawals from the Amarillo Field". Inspection of this graph emphasizes how closely the reported total withdrawals from the field approximate a straight line curve. The mean annual withdrawal amounts to 502,711,630 MCF (2-pound base). On this chart the quantities of gas run to pipe lines and used for manufacture of carbon black are also shown cumulatively, and it appears that the proportion of total withdrawals used by these has remained approximately constant. From the beginning of production in the Amarillo field, a much larger quantity of gas has been "blown to air" than the combined total of pipe line and carbon black gas. In the early days of Amarillo Field development a huge quantity of gas was blown into the air in order to relieve gas

3. Graph showing cumulative gas withdrawals from the Amarillo Field to 1934, with indication of the amounts taken by pipe lines, used in manufacture of carbon black, and "blown to air".

50

Cities Service Gas Company
Amarillo Field Production - Composite All Wells

Rock Pressure Pounds

400
350
300
250
200
150
100
50

Cumulative Production - Pressure Decline

500 1000 1500 2000 2500

Billions of Cubic Feet

(8 oz. base)

pressure and aid production of oil. Much gas was also wasted in bringing in wells. In later years, especially in 1933 and 1934, there has been a rapid increase in the amount of gas used by gasoline stripping plants, and it appears from the chart that this expansion of gas used in stripping takes the place of gas that was wasted in early developments. The chart includes under the designation "Blown to air" some gas that is used in the field.

In June, 1934, average daily withdrawals from the Amarillo Field amounted to 2,057,069 MCF (2-pound base) of which pipe lines used 347,964 MCF, or 16.9 per cent. For the first six months of 1934, average daily withdrawals from the Amarillo Field amounted to 1,921,432 MCF (2-pound base), of which pipe lines used 407,633 MCF, or 21.2 percent. Corresponding figures for 1933 are: Average daily withdrawals 1,318,314 MCF, average daily pipe line runs 299,123 MCF, which is 22.6 per cent of the daily withdrawals.

The annual quantity of natural gas taken by pipe lines from the Amarillo Field has increased from 39,978,176 MCF (2-pound base) in 1928 to an estimated total of 148,378,682 MCF in 1934 (the latter half-year being estimated as equal to the first six months). The increase has been gradual except for relatively rapid increases in 1929 and 1934. The quantity of gas taken by the Cities Service pipe line has shown an increase each year. It appears, however, that the rate of increase of Cities Service pipe line runs is not so great as

that of total pipe line runs. From the year 1928 to 1934 pipe lines have increased their percentages of takes from about 7.5 per cent to slightly over 21 per cent of the total withdrawals from the field, and in spite of an actual considerable increase of pipe line runs from 1932 to 1934 there has been a decline in percentage of total withdrawals from 23.4 per cent in 1932 to 21.2 per cent in 1934 (assuming that the records for the second six months are the same as for the first six months). The percentage of takes by the Cities Service pipe line has increased steadily with exception of a decline in 1934. The conclusion may be drawn that the pipe lines are now taking about the same percentage of the total withdrawals as in recent years and a materially larger percentage than three or four years ago.

In January, 1933, there were 703 gas wells in the Amarillo Field with a combined initial open flow of 18,836,000 MCF per day, or an average of 26.8 million cubic feet per day per well. The open flow of individual wells is reported to range from 2 million cubic feet in a few small wells to more than 100 million cubic feet in some large wells.

The producing area of the Amarillo Field is estimated to include about 1,367,000 acres. The part of the gas producing area in which wells with an initial volume of 10 million cubic feet open flow or larger may be expected consists of approximately 896,500 acres.

According to information supplied by the Texas Railroad Commission as of October 1, 1934, there were 923 gas wells in the Amarillo Field and in addition 2,098 oil wells producing casinghead and bradenhead gas. A classification of these wells with notation of open flow and daily withdrawals is shown in the following table.

Gas Producing Wells in the Amarillo Field as of October 1, 1934, with Statement of Open Flow and Daily Withdrawals

Type of wells	Number	Open flow MCF	Daily withdrawal MCF	Percent daily withdrawal of open flow
Gas wells connected to pipe lines	475	12,540,500	372,961	2.97
Gas wells connected to gasoline plants	328	5,714,350	1,191,211	20.84
Gas wells unconnected (estimated)	120	1,200,000	0	0
Bradenhead wells connected to gasoline plants	65	456,344	93,230	20.42
Casinghead wells connected to gasoline plants	1246	635,516	515,580	81.12
Casinghead wells unconnected, gas blown to air (estimated)	787	92,000	92,000	100.
Used in field for fuel			24,000	
Totals	3,021	20,638,710	2,288,982	11.09

In the period from January 1, 1934, to October 1, 1934, it is reported that new and reconnected gas wells furnishing output to pipe lines number 6 wells, and to gasoline plants 209 wells.

Classification of the volume of open flow from wells as to "sweet" and "sour" gas, as of October 1, 1934, is given in the following table.

Daily Open Flow of Sweet Gas and Sour Gas in the Amarillo Field, as of October 1, 1934, in MCF

	Open flow Sweet gas	Percent of total	Open flow Sour gas	Percent of total
Gas wells connected to pipe lines	12,540,000	100	0	0
Gas wells connected to gasoline plants	2,148,774	37.6	3,565,576	62.4
Gas wells unconnected (estimated)	616,600	51.4	583,400	48.6
Bradenhead wells connected to gasoline plants	96,830	21.2	359,514	78.8
Casinghead wells connected to gasoline plants	396,643	62.4	238,873	37.6
Casinghead wells unconnected (estimated)	32,000	34.7	60,000	65.3
Totals	15,831,347	76.8	4,807,363	23.2

The reported amount of gas daily blown to the air by gasoline plants on June, 1934, was 859,935 MCF. The daily average in July was 896,806 MCF. In September the amount increased to 958,928 MCF and in October to 1,069,838 MCF. A comparison of the quantities of gas daily blown to air by gasoline plants, according to data from the Texas Railroad Commission, shows in September, 1932, an average of 213,282 MCF, in September, 1933, an average of 403,594, and in September, 1934, an average of 958,928 MCF. Additional gas daily blown to the air from unconnected casinghead wells in 1934 amounts to about 92,000 MCF.

Sweet Proven Area and Present Outline of the Producing Area in the Amarillo Field

The Amarillo Field extends from southeastern Wheeler County to the east edge of Hartley County in the Panhandle of Texas, a distance of about 125 miles in a straight line trending east southeast to west northwest. The distance across the field at right angles to this trend ranges from about 10 to 35 miles.

No major changes in the indicated sweet proven area of the Amarillo Field have taken place during the last three years. The most important changes were in Moore County where several sulphur gas wells were completed within the area considered sulphur-free, and one sulphur-free well was completed in the area considered sour. The indicated sulphur line is shifted one to two miles as a result of these completions, but the areas compensate so that there is no important effect on the proved sweet acreage.

The present outline of the producing area is larger than in June, 1931. The most important additions have been made in southeastern Carson County (approximately 9,000 acres) and in southeastern Gray County (approximately 32,000 acres). The total producing area of the field as of July, 1934, is 1,367,748 acres. This area is in close agreement with that indicated on a map showing the west portion of the field furnished by the company, and is also in agreement with a map for the entire field by geologists for the Texoma Natural Gas Company.

The accompanying regional map (Chart 4) indicates the probable northeast extension of the Moore County portion of the field to include a large acreage in Sherman and Hansford counties, to join the Hugoton Field in Texas County, Oklahoma. Geologists are generally in agreement on the probability of this extension, which would add (see dotted area on map) approximately 628,680 acres to the producing area in Texas.

4. Map showing Cities Service pipe lines and main gas fields of Texas, Oklahom, and Kansas, in 1934.

Estimated Reserve of the Amarillo Field

There are two principal methods of computing the estimated reserve of a natural gas field such as Amarillo, both methods being based on the well-known generalization in physics that is called Boyle's law. This law states that the quantity of a gas in a given space is directly proportional to the pressure. One method of applying this law to estimation of reserves in a gas field is to determine as exactly as possible the volume of the reservoir, and when this has been done the amount of gas originally present in the reservoir can be computed readily by multiplying by the observed rock pressure. This is a very unsatisfactory method, at best, because of uncertainties as to thickness of the reservoir and as to the porosity of the reservoir rock. It is employed commonly only when other methods are not possible, as in the early stage of development of a field when production records are unavailable. Application of this method to estimates of reserves in the Amarillo Field have given results ranging from about 12 to 18 trillion MCF. Several geologists who have worked in the Amarillo Field regard 16 trillion MCF as the preferred figure on original reserve of the field.

Another method of computing the reserves in a gas field, also depending on Boyle's law, is the Production-Pressure Decline method which provides for direct plotting of quantities of gas produced against decline in rock pressure resulting from this production. This method is recognized as greatly superior

to the other because it is unnecessary to make assumptions as to the volume of the underground reservoir from which the gas is produced. If sufficient data on production and pressure decline are available a curve can be constructed that involves no subjective element, and it has been demonstrated by experience in many fields that such a curve is the most accurate means of determining the original and the remaining quantities of gas in a given field.

In our study of reserves in the Amarillo Field we now have available records of withdrawals covering a period of several years and records of decline in rock pressure from wells located in practically all parts of the field. Although the records of total withdrawals are not completely satisfactory, since they necessarily include estimates of gas blown to the air in the early period of development and include also some other factors that are not precisely determined, information is sufficient to make desirable an attempt to apply the Production-Pressure Decline method. Records of rock pressure have been taken at intervals on a majority of the wells, especially in the "sweet gas" area, and furnish a reasonably adequate basis for measurement of the decline in rock pressure that accompanies production. It is true that pressure data for parts of the Amarillo Field are very inadequate, but it appears that a much more reliable estimate of reserves, indicating at least the order of magnitude of the true figures, can be had from this type of investigation than from any other.

In deriving figures for decline in rock pressure several features are to be noted. In the first place, as previously noted, it is evident that a mathematical average of all available records of rock pressure for a given data does not express the true average rock pressure in a gas field such as Amarillo, because the wells are not uniformly distributed over the area. Thus, a concentrated group of low-pressure wells in an area of intensive production would be given disproportionate value if averaged mathematically with scattered high-pressure wells in little developed parts of the field. In order to determine more exactly the pressure conditions in the Amarillo Field, a pressure contour map may be constructed which indicates areas of similar pressure conditions. Measurement of the areas between the pressure contours then provides a means of weighting the various pressures according to the area they represent, and from the combined data a weighted average pressure can be derived that expresses more accurately the mean pressure in the entire reservoir.

It is well known to geologists and production engineers that the pressure recorded at a gas well does not represent the actual pressure in the gas reservoir at some distance away from the well. The pressure of areas between wells are higher than in the immediate vicinity of the well bottom, and it is this that causes movement of the gas from the surrounding reservoir into the gas well. The steepness of gradient of the pressure cone surrounding a producing gas well depends mainly on the volume of gas drawn from the well and the permeability of the

reservoir rock. When a well is shut in, as is done before measuring rock pressure, the pressures around the well are gradually equalized, but it is almost certain that excepting wells in extremely permeable reservoir rock and prolonged shut-in periods, the pressure cone surrounding a well does not disappear. Observations in the Amarillo and other fields indicate that pressure gradients of several tens of pounds per mile may exist for considerable periods. Attention is called to this undoubted existence of pressure cones surrounding gas wells and the occurrence of inter-well rock pressures that are higher than pressures recorded at the wells. It is evident that by whatever amount these higher pressures exist, they increase the weighted average pressure as determined from contoured well pressures, and accordingly if no account is taken of the higher inter-well pressures the contouring of well pressures gives results that are somewhat too conservative. In order to show how much difference this factor may make under certain conditions, a study was made of a part of the Burnett Lease in Carson County. The June, 1934, pressures on wells in this area were first contoured and a weighted average rock pressure determined as amounting to 404.28 pounds. Using the same data, the area was contoured again on the assumption that a pressure gradient of 10 pounds per mile extends outward from each well to points where interference by drainage from other wells is encountered. The assumed mean pressure gradient is believed to be conservative. Computation shows that a weighted

average rock pressure of 415.15 pounds exists if pressures are distributed as indicated. The determined loss in pressure according to the first method of contouring is 73.2 per cent greater than that figured according to the second method. In the present study of average rock pressures in the Amarillo Field no account has been taken of the factor of higher inter-well pressures.

Determination of the estimated reserve of the Amarillo Field has been undertaken by two independent studies in which it may be anticipated that the results of the one should check the other.

First calculation. Utilizing all available data, rock pressures in the Amarillo Field as of June, 1934, were contoured and a weighted average rock pressure of 389,3832 pounds was derived for the field. This pressure map is shown in Chart 8. According to the most complete and reliable information obtainable the total withdrawals of gas from the Amarillo Field to the end of June, 1934, amount to 4,273,048,909 MCF (2-pound base). If a decline in mean rock pressure from 430 to 389.38 pounds, or 40.62 pounds, has accompanied this production of 4,273,048,909 MCF, it is apparent that the production per pound of pressure decline amounts to 105,203,970 MCF. Multiplying this figure by 430 we obtain 45,237,707,100 MCF as representing the original reserve of the Amarillo Field. This calculation is expressed graphically on the accompanying Chart 10. The total proved area used in this computation of weighted rock pressure is 1,367,748 acres. Production per acre

per pound decline in pressure is figured at 76,917 cubic feet, and the original reserve per acre amounts to 33,074,589 cubic feet according to this computation.

It may be pointed out that the computed original reserve per acre according to this calculation is an average figure. If account is taken of variation in the productivity of acreage in different parts of the field, this will modify the figures for original reserve per acre in the respective designated classes of acreage but will not affect the total computed original reserve of the field. Let it be assumed that 896,500 acres, which are estimated to yield wells with initial open flow of 10 million cubic feet or more, have twice the original reserve per acre of the remaining 471,248 acres. Given a total production of 4,273,048,909 MCF from the field as a whole to June 30, 1934, and a mean rock pressure decline of 40.62 pounds, the 471,248 acres are computed to yield an average of 1,887,182 MCF per acre and the 896,500 acres twice this amount or 3,774,364 MCF per acre. These figures, divided by 40.62, indicate respectively 46,463 MCF and 92,926 MCF per pound of pressure loss, and multiplying by 430 the amounts of 19,979,128 MCF and 39,958,256 MCF per acre are derived for the original reserve.

19,979,128 x 471,248 =	9,415,124,112 MCF
39,958,256 x 896,500 =	35,822,576,504 MCF
Total	45,237,700,616 MCF

5. Pressure contour map of the Amarillo Field, June, 1934 (in pocket).

Second calculation. Since records for recent years are much better than for the early part of the field's development, study was made of the decline in pressure and the corresponding gas withdrawals during the period from January 1, 1932, to June 30, 1934, amounting to 30 months. For this period a weighted average pressure decline of 10.3068 pounds was determined. The map showing contoured pressure loss for this period is shown in the accompanying Chart 6. The total gas withdrawn in these 30 months is reported to be 1,245,076,507 MCF (2-pound base). Dividing this figure by the pressure loss indicates a production of 120,801,460 MCF per pound of pressure decline, which multiplied by 430 gives 51,944,627,800 MCF for the original reserve of the field. This calculation is graphically represented in the accompanying Chart 7. According to this computation the production per pound per acre amounts to 88,321 cubic feet, and the original reserve per acre 37,978,214 cubic feet. It may be noted that the figure for original reserve of the Amarillo field obtained in the first calculation is 12.9 per cent smaller than that here computed, but it is apparent that both figures are very much larger than the 16 trillion estimate based on figures relating to average porosity and thickness of the reservoir rock. The one Production-Pressure Decline reserve estimate is a little less than three times as great as the 16 trillion figure, and the other is a little more than three times as great. A possible reason for the greater production per pound of pressure decline according to the second

calculation may lie in the elimination to a large extent of the factor of pressure coning around wells since this study takes account only of differences in pressure between two dates, on each of which coning was presumably established. Since, also, the records are more accurate for this period than for the early part of field development, it may be concluded that the second calculation is probably better than the first. In spite of this conclusion as to superiority of the second calculation, we have used the smaller figure of 33,074,589 cu. ft. per acre obtained in the first calculation in making computations of reserves, because this figure is more conservative. Concerning both calculations it may be pointed out that the figures for weighted average pressure necessarily involve consideration of area classed as proved, and if the area so classed is too large it would operate to decrease somewhat the production per pound of pressure decline but to increase the figure for original reserve. It appears, however, that no considerable change tending to reduce the estimated original reserve is likely from this source, and it is to be emphasized that excepting for relatively unimportant possible variation in the contouring of pressures and in the outlining of the proved gas area, which is fairly well agreed, the methods of computing reserves do not involve subjective elements.

6. Map of the Amarillo Field showing pressure loss from January, 1932, to June, 1934 (in pocket).

7. Graph showing estimated gas reserves of the Amarillo Field based on Cumulative Production-Pressure Decline data.

Estimated Life of the Amarillo Field

Estimates of the life of a gas field must be based first on computations of the amount of gas in the ground at a given time and second on estimates of mean annual withdrawals that may be expected. Ordinarily not all of the gas that is calculated to be present in the underground reservoir is figured as available for commercial use because most fields are abandoned before the rock pressure declines to zero. The selected abandonment pressure may therefore affect computations of the life of a field more or less importantly. Finally, it may be noted that the beginning and closing stages in the development history of a typical field invariably show production rates that are much below the peak of production rate and also below the annual average during active operation of the field. Therefore, life during which some gas is produced, stated in years, should exceed the computed life of the field based on figures for annual average production during normal active operation. Also, the period during which it is possible to make withdrawals at an annual rate that is equal to the present rate is somewhat less than the number of years obtained by dividing the determined reserve to abandonment pressure by the amount of present annual withdrawals. This is due to the effect of declining open flow and pressure which require a longer period for withdrawal of a given amount of gas than when open flow and pressure are high.

In the Amarillo Field estimates of original reserves based on cumulative production-pressure decline curves indicate totals ranging from about 45 trillion to 52 trillion cubic feet. These

figures are approximately three times as great as the previously rather generally accepted estimate of 16 trillion cubic feet based on assumed porosity and pay thickness factors. It is apparent that the estimate of reserves is much the most important factor in estimating the life of the Amarillo Field. We believe that the production-pressure decline method of computing the reserves indicates much more accurately the order of magnitude of the reserves than the estimates of volume of the underground reservoir. It is significant that the two independent studies of reserves which we have made using production and pressure decline data are reasonably accordant.

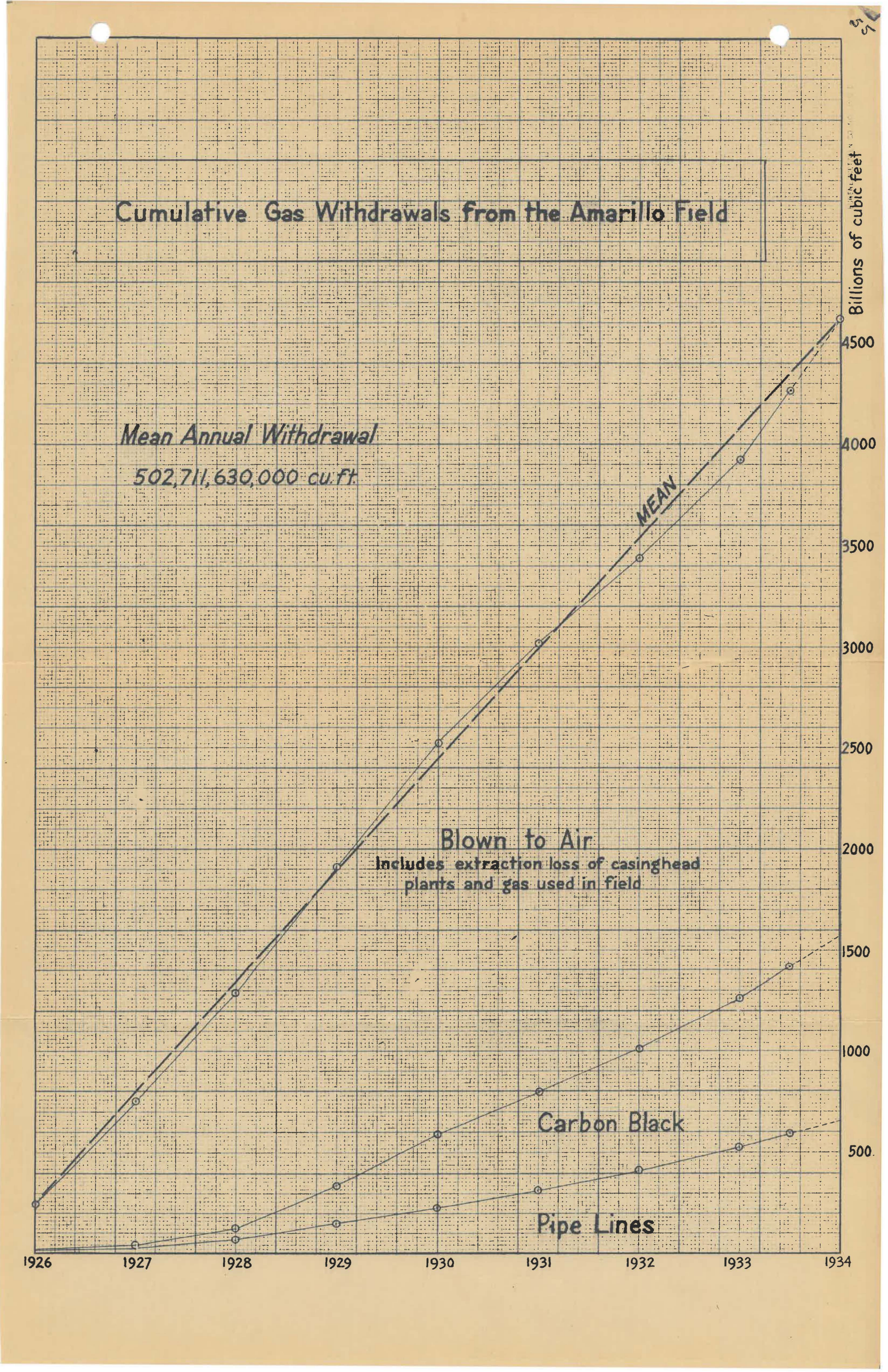
It appears from inspection of records of production that the mean annual withdrawals of gas from the Amarillo Field closely approximate a straight line curve. This means that the proportionally large amount of gas now used for manufacture of carbon black and for gasoline stripping roughly balances the large amounts of gas wasted to the air during early operations of the field. The accompanying Chart 18 shows a projection of this straight line curve which intersects the line for 45 trillion cubic feet at about the year 2010. The graph showing Amarillo Field estimated reserves indicates that with an abandonment pressure of 25 pounds the computed available reserves on the two computed curves are respectively 42.7 trillion and 48.9 trillion cubic feet. Using these figures and assuming that 502 billion cubic feet of gas are annually withdrawn from the field, this indicates that the field would be exhausted in the year 2002 (68 years) or 2016 (82 years).

At the rate of 502 billion cubic feet per year, 16 trillion cubic feet will have been produced by the year 1956 (22 years). Attention may again be directed to the stated qualification of factors entering into this computation. If the figure for estimated reserve is reliable and if gas is extracted at the rate specified, statement of life of the field is very simply indicated by division of the first item by the second. Actually, a variation in the rate of annual withdrawals is to be expected. For purposes of the present study, however, it may be pointed out that if the average annual withdrawals from the Amarillo Field were doubled the expected life of the field would exceed 25 years.

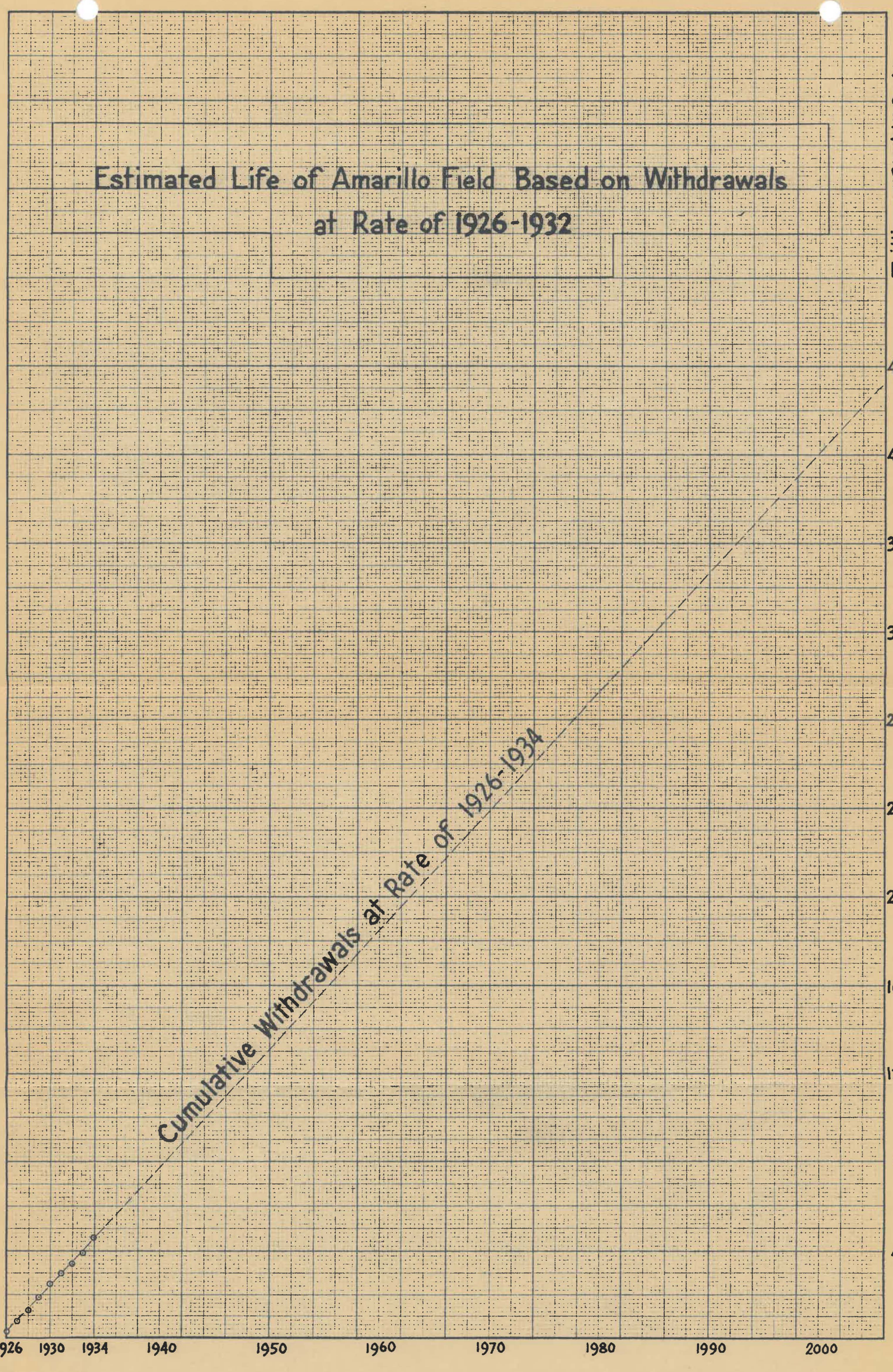
Cumulative Gas Withdrawals from the Amarillo Field

Mean Annual Withdrawal

502,711,630,000 cu. ft.



8. Graph showing estimated life of the Amarillo Field.


Estimated Life of Amarillo Field Based on Withdrawals at Rate of 1926-1932
Trillions of cubic feet
44
40
36
32
28
24
20
16
12
8
4
Cumulative Withdrawals at Rate of 1926-1934
1926
1930
1934
1940
1950
1960
1970
1980
1990
2000

The Price of Gas in the Amarillo Field

The price for gas in the Amarillo Field is so variable as to make a determination of the average or mean price paid impossible.

The price per MCF at the well for all gas processed in casing-head plants is based on the gasoline content and the price of casing-head gasoline. In general the producer (well owner) receives 25 per cent of the value of the gasoline, which in the sweet gas areas will average about one-fourth of a cent per M, and of this one-eighth is paid to the landowner as royalty, amounting to one-thirty second of a cent per MCF.

The price paid by gas pipe line companies, who produce practically all the gas they transport, is variable. In Wheeler County the Lone Star Gas Company pays independent producers and royalty owners 2 cents per M at the well, as does also the Consolidated Gas Utilities Company in this portion of the field.

In Carson, Hutchinson, Moore, and Potter counties a majority of the production taken by the gas pipe line companies from their own wells or wells of their associated companies is at 4 cents per M, based on royalty payments as indicated by division orders on record. This rate (4 cents) is now paid by the Cities Service Company on their Burnett lease, and it continues until 1938 at this rate. The Texoma have a number of division orders now in effect at 3½ cents, to be increased to 4 cents on January 1, 1935, to 4½ cents on January 1, 1940, and to 5 cents on January 1, 1945.

Some early contracts made by the Canadian River Gas Company and the Northern Natural Gas Company applying to royalty in the case of the former company, and to residue gas in the case of the latter, are reported to be on a basis of 6 cents and 8 cents.

In general the pipe-line price for gas can be considered as 2 cents in Wheeler County and 4 cents in the western part of the field.

Per cent of Open Flow that may be Safely Taken

It is agreed by geologists and production engineers familiar with conditions in the Amarillo Field that no damage to wells may be anticipated from the taking of any desired fraction of the daily open flow capacity. This is because of the absence of bottom water in the gas wells.

Regulations Affecting Production

The Railway Commission of Texas has issued orders through the Pampa office which are intended to provide for proper conservation of gas in the Amarillo Field by specification of gas-oil ratio in combination oil and gas wells and by prohibiting blowing of gas to the air except as necessary in drilling in, making open flow measurements and the like. These regulations, however, have been made ineffective by the passage of the so-called ~~sour~~ stripper gas act by the Texas Legislature. This

law permits unrestricted use of gas in the Amarillo Field up to 25 per cent of the open flow of wells for manufacture of gasoline, carbon black or other commercial uses where a light and fuel or pipe-line market is not available. This has led to a large expansion in gas withdrawn, especially for manufacture of gasoline, and includes a considerable quantity of gas taken from the sweet gas area. A large amount of residue gas is blown into the air and no revenue is received therefrom. Such gas is available for purchase.

Acquisition of Leaseholds

There has been very little activity by the gas pipe lines in acquiring additional gas acreage in the Amarillo Field during the last four years. Leases were and are now available at low bonus cost, but the companies have not enlarged their holdings and have been generally inactive, except in some cases where expiring leases were renewed or extended.

A survey was made in July, 1934, for the purpose of determining the distribution of choice sweet gas acreage, with the following results.

Lease holdings in best part of proven sweet gas area of the Amarillo Field, July 31, 1934

(nearest available data)

Gas pipe lines and affiliated companies	565,960 acres	79.18 per cent
Independent producers and oil companies	77,980 acres	10.91 per cent
Unleased	70,740 acres	9.89 per cent
Total	714,680 acres	99.98 per cent

The passage of the stripper law in 1933 had no apparent effect on acquisition of leases or bonuses paid. This was due to the fact that there were already a large number of shut-in wells in the field and a larger number of subsisting leases in the proved area already held by operators without pipe-line outlet and with little prospect of their being drilled before their expiration date. The greatest expense of stripping is in plant and gathering system construction, and, of course, drilling of the wells. Uncertainties concerning the continuation of legal sanction for stripping make the risk too high to encourage new plant construction, and it is doubtful whether an increase in stripping will ever be a factor of importance in the gas lease situation.

Recent lease acquisitions are listed in the following table.

Company acquiring lease	Description	Price per Acre	Map designation
Amarillo Oil Company	All of sec. 15 ex. 71 acres, NW. ¼ SE. ¼ 17, W. ½ SE. ¼ 18, 839 acres, Blk. 3, G. and M. Survey	$2.38	B
Texoma Nat. Gas Company	SE. ¼ NW. ¼ sec. 2, Blk. 4, L. and G. N. 40 acres	12.50	C
Stanley Marsh	N.½ sec. 44, S.½ and NW. ¼ sec. 46, SE.¼ sec. 45, Blk. 4, I. and G. N.	1/	D
Shell Petroleum	N.¼ of SE.¼, S.¼ of NE.¼ sec. 22, Blk. 4, I. and G. N. 80 acres	8.00	E
Texoma Nat. Gas Company	E.½ SW.¼, W.½ SE.¼ sec. 20; NE.¼, NW.¼, and SW.¼ sec. 25; 75 acres in W.½ sec. 21, Blk. 4, I. and G. N. 715 acres.	10.00	F
Lone Star Gas Company	SW.¼ sec. 235, S.½ and W.½ NW.¼ sec. 219, all of sec. 234, N.½ SE.¼ and NW.¼ and N.½ NE. ¼ sec. 233, Blk. B-2, H. and G. N. 1,522 acres.	8.00	G
Phillips Petroleum Co.	NE.¼ sec. 40, Blk. 25, H. and G. N. 160 acres	25.00	H
Texoma Nat. Gas Company	W.½ sec. 174, Blk. B-2, H. and G. N. 320 acres	6.25	I
Texoma Nat. Gas Company	NE.¼, N.½ SE.¼ sec. 189, Blk. B-2, H. and G. N. 240 acres	6.25	J
Phillips Petroleum Co.	N.½ sec. 9, SE.¼ sec. 10, E.½ sec. 12, Blk. 24, H. and G. N. 800 acres.	10.00	K
Texas Company	SW.¼ sec. 39, Blk. 17, H. and G. N. 160 acres.	7.50	L

1/ Reported there was no cash consideration, the lessee agreeing to develop at once.

Texas Company	SW.¼ sec. 59, Blk. 17, H. and G. N. 160 acres	$10.00	M
Texas Company	NE.¼ sec. 42, Blk. 17, H. and G. N. 160 acres	12.50	N
Texas Company	SW.¼ sec. 48, Blk. 13, H. and G. N. 160 acres	10.00	O
North Texas Utilities	SE.¼ and S.½ S.½ NE.¼ sec. 71, NW.¼ sec. 70, Blk. 13, H. and G. N. 360 acres	20.00	P

5716 acres Weighted average cost per acre (oil and gas rights) $9.03

The tracts above which are designated on the map by letters K to P inclusive, in Wheeler County, are recently active in oil development and the consideration paid was largely for the oil prospect. The same is true of the lease designated H above, located in extreme eastern Gray County.

The voluntary surrender of numerous leases in the sweet gas area in Moore County is thought to have an important bearing on the availability of leases in this county, and to some extent in the entire field. These surrendered leases were in some cases near large gas wells and were very desirable from a gas production standpoint, yet the owners voluntarily relinquished them rather than pay $1.00 per acre annual rental. Some of the leases could have been held by rental payments until 1940. More than 7,000 acres have been voluntarily released in the proved sweet gas area of Moore County, some by the major gas pipe line companies. Many of these leases were acquired during 1929-30 at prices of $10 to $40 per acre, and their voluntary relinquishment at this time is an indication of the trend during recent years.

Partial List of Leases Voluntarily Surrendered

Moore County

Company	Description	Acres
Canadian River Gas Co.	SW.¼ sec. 74, N.½ NW.¼ sec. 233, S.½ SW.¼ sec. 233, NW.¼ sec. 228, Blk. 44, H. and T. C.	480
Gulf Production Company	S.½ sec. 72, S.½ sec. 73, Blk. 44, H. and T. C.	640
Empire Gas and Fuel Co.	E.½, N.½ NW.¼ sec. 153, N.½ E.½ SE.¼ sec. 142, SW.¼, W.½ SE.¼ sec. 100, SW.¼ sec. 70, Blk. 44, H. and T. C.	1200
Shamrock Oil and Gas Co.	W.½ sec. 7, S.½ and NE.¼ sec. 51, N.½ sec. 100, E.½ SW.¼ sec. 228, Blk. 44, H. and T. C. R. R.	1200
Shamrock Oil and Gas Co.	NW.¼ sec. 9, NW.¼ sec. 13, W.½ sec. 32, Blk. P. Mc, E. L. and R. R. R.	640
Shamrock Oil and Gas Co.	SW.¼ sec. 5, W.½ NW.¼ and E.½ NE.¼ sec. 7, Blk. 2, G. and M.	320
Prairie and Texoma	N.½ sec. 8, J. Poitevent	320

The most important transaction of blocked leases was the purchase by the Phillips Petroleum Company of the J. L. Williams ranch in Hutchinson and Moore counties on December 14, 1933. This tract is designated on the accompanying map as A, is outlined in red, and consists of 6628½ acres. The consideration paid for the oil and gas rights, after deducting the value of a producing well, was $11.46 per acre. This tract is located near the oil fields and it is estimated more than half of the consideration paid attaches to the oil rights. It is also in

good gas territory, approximately two-thirds of the tract being in the sweet gas area. Three sweet gas wells have been drilled within one-half mile of the tract, one having been completed with an initial volume of 80 million cubic feet per day.

GAS SUPPLIES AVAILABLE TO THE CITIES SERVICE GAS COMPANIES IN THE HUGOTON FIELD

Development by the Cities Service Gas Companies in the Hugoton Field

Leaseholds Acquired by the Companies in the Hugoton Field

The leaseholds acquired by the Companies in the Hugoton Field are as follows:

	Proved	Probable	Total
Texas County, Oklahoma	79,475.4	18,260	97,735.4
Stevens County, Kansas	7,382.22	2,240	9,622.22
	86,857,62	20,500	107,357.62

These leases are all in what might be termed proved area, the so-called probable acreage being located near the indicated border of the field and in areas where the yields are expected to be less than average.

The Cities Service leaseholds in the Hugoton Field are not readily available as a reserve as they are 90 miles removed from the present Cities Service line to the Amarillo Field. This line of 20 inch diameter and a daily capacity of 125 million cubic feet has been operating at or near capacity for eighteen months. This line has a supply in the Amarillo Field which is definitely adequate for a period of more than twenty years at full-line capacity. Therefore, the reserves contained in the Companies' 107,357.62 acres in Hugoton are not available to

their markets, even with the construction of a 90-mile pipe line, except in so far as they would displace the presently used supplies at Amarillo. In this light it appears that the Hugoton reserves will only be made available to the Companies' lines at Wichita, Kansas, or Dilworth, Oklahoma, a distance of more than 200 miles.

Development of Companies' Leases in the Hugoton Field

The Companies' leases in Hugoton have had no development. Some of the leases are within a mile of producing wells, and most of them are in the areas between producing wells, but none are offset to production. No drainage of the leases has been effected, nor is any threatened at this time.

General Conditions in the Hugoton Field Bearing on Gas Supplies Available to the Cities Service Companies

Present Production Conditions

Production from the Hugoton Field now amounts to about 1,151,000 MCF per month (2-pound base), or a daily average for the first six months of 1934 amounting to 40,164 MCF per day.

Production of Gas from Hugoton Field, Kansas and Oklahoma, in MCF (2-pound base).

	Cimarron	Argus-Western	Panhandle	Lamar
1928	65,187			
1929	174,593			
1930	228,596		75[illegible],570	
1931	249,884	2,430,577	1,843,763	203,902
1932	243,384	7,812,505	2,713,319	341,766
1933	173,367	12,062,240	3,946,501	347,412
1934*	84,604	5,168,924	1,976,299	183,540
	1,219,615	27,474,246	11,237,452	1,076,620

* Six months.

At the present time there are 151 wells in the field, of which number 14 are not connected to pipe lines. All of the gas produced is transported by pipe lines for use as fuel in nearby cities and in part in distant cities through the lines of the Panhandle Eastern and Northern Gas companies. There are no carbon black plants or gasoline stripping plants in the

field, although a permit has been issued by the Oklahoma Corporation Commission for construction of a carbon black plant near Guymon, Oklahoma. The Argus Gas Company, with which the Western Production Company is now merged, a subsidiary of the Northern Gas and Pipe Line Company, has 90 wells in the field. The Texas Interstate Pipe Line Company, a subsidiary of the Panhandle Eastern Pipe Line Company, has 35 wells, of which 13 furnish gas in the Argus pipe lines. Three wells in the northern part of the field furnish gas for a line to Lamar, Colorado, and four wells are connected to a line of the Liberal Pipe Line Company which supplies Liberal, Kansas.

It is estimated that 1,833,000 MCF of gas has been withdrawn from the Hugoton Field for use as fuel during drilling of wells and blown to the air during drilling in of wells.

Change of Outline in Proven Gas Area in Hugoton Field

There has been only one important change in the indicated producing area at Hugoton since the first hearing in 1931. This change is due to the completion of a gas well in the center of the SW. ¼ sec. 16, T. 25 S., R. 34 W., in December, 1932. This well, known as Brown No. 1, had an initial open flow of 5½ million cubic feet and the producing horizon and pressure were the same as in wells in the Hugoton Field. This new well is 12 miles southwest of Garden City and about 32 miles north of the nearest producing well in the Hugoton Field, the Trees et al. No. 1 Warner in the center of the SE. ¼ sec. 29, T. 30 S., R. 34 W., in the southwestern part of Haskell County.

The Brown well in Finney County is considered as extending the Hugoton Field approximately 30 miles to the northeast, and thus enlarging the proved area by approximately 12 townships or 276,480 acres.

Estimated Reserve of the Hugoton Field

The development of the Hugoton Field is yet too little advanced to give data necessary for reliable estimates of reserves. Drilling and production up to the present time are concentrated in a relatively small part of the field, and the records on this development contain inaccuracies and are incomplete. It is certain that the area that will yield commercial gas wells is vastly greater than the area now partly developed, but there is room for much doubt as to exact location of the boundaries of gas-productive territory. Estimates of reserves are necessarily based in large part on conclusions as to the quantity of gas-productive acreage. Hence, the indefiniteness of the outlines of the field introduces corresponding possible variation in estimates of reserves.

Reservoir volume method. The method of estimating reserves that bases computation on figures for volume of the underground gas reservoir and on measured mean rock pressures is little more than a scientific guess because it is impossible to secure satisfactory reliable data concerning the thickness and porosity of the reservoir throughout the field, or for that matter, even in part of the field. This method has been employed by us and by others, however. Using 45 feet as etsimated average thickness of the pay and a mean porosity of 20 per cent, we made an estimate in 1931 (Report to Kansas Corporation Commission) showing 10,859,508 MCF per acre original reserve in the Hugoton field, computed on a 2-pound base. At

that time the proved area was regarded as containing 651,000 acres, and accordingly a total original reserve of 7,069,539,708 MCF was derived for the field. This may be compared with the estimate of Cotner and Crum (Am. Assoc. Petroleum Geologists, Bull., vol. 17, p. 903, 1933), who use factors of 50 feet for average thickness of pay and 12 per cent for porosity and estimate a reserve of 8,000 MCF per acre. For the area of 388,000 acres that is regarded by them as proved, this gives an original reserve of 3,124,000,000 MCF, and for an additional 678,000 acres classed as probable gas-bearing territory this acre-yield figure would indicate 5,424,000,000 MCF, making a total of 8,548,000,000 MCF. Although these estimates are roughly accordant, they are not at all satisfactory.

Production-Pressure Decline Method. The method of calculating reserves by plotting production of gas against decline in rock pressure is much more accurate than the method of attempting to determine the volume of the gas reservoir. Effort to apply the production-pressure decline method to the Hugoton Field encounters chief difficulty in the lack of reliable records of original rock pressures, and determination of decline in rock pressure properly weighted according to area. Total recorded production, also, amounts to less than 39,000,000 MCF and this with added estimated quantity of 1,833,000 MCF blown to air is an insufficient amount to determine satisfactorily the pitch of the decline curve. Three calculations that were made give results as follows.

(1) First calculation. The original rock pressure was assumed to be 440 pounds, as commonly accepted for this field. Ten out of 35 wells drilled by the Texas Interstate Pipe Line Company have reported initial rock pressures of 440 pounds, the other 25 wells having lower reported initial pressures. The highest initial rock pressure of 90 wells drilled by the Argus Pipe Line Company is 438 pounds, and this pressure is recorded in only two wells. A weighted average rock pressure as of June, 1934, was determined for the developed part of the field near Hugoton, comprising an outlined area of 249,600 acres. In making this determination pressures were contoured on the basis of a gradient of 10 pounds per mile increasing outward from wells (see map). This pressure gradient is based on the observed rate of pressure change between the Trees well in the NW. ¼ sec. 2, T. 35 S., R. 39 W., which has been shut in since completion, and a neighboring well a mile to the south, produced at an average rate. Pressures on both wells were available. The indicated pressure cone gradients seem conservative and in an area of such widely scattered wells and limited production it is reasonably certain that territory with practically virgin pressures lie between some of the producing wells. The weighted average rock pressure for June 30, 1934, thus determined for 249,600 acres of the Hugoton Field is 431.66 pounds. This figure subtracted from 440 pounds indicates an average pressure loss of 8.34 pounds. Total withdrawals of gas in this area, 40,544,698 MCF, divided by 8.34 indicates a production of 4,859,726 MCF per pound of pressure decline. Dividing

the last figure by 249,600 and multiplying by 440 indicates an original reserve per acre of 8,566,800 cu. ft. (2-pound base). Converting this figure to 8-ounce base, the indicated acre reserve is 9,429,230 cu. ft. The per acre reserve to an abandonment pressure of 25 pounds amounts to 8,893,478 cu. ft. (8-ounce base).

(2) Second calculation. Although the reported average initial rock pressure of 90 wells of the Argus Pipe Line Company is 430.87 pounds, a mean of the pressures on these wells measured by engineers for Brokaw, Dixon, Garner and McKee in November, 1931, is 437.4 pounds. An average of the initial rock pressure of 35 wells of the Texas Interstate Pipe Line Company is 436.5. Making calculations as in the first case, but using an assumed initial rock pressure of 438 pounds, the indicated original reserve per acre in this part of the Hugoton Field is 10,780 MCF (2-pound base).

(3) Third calculation. Substitution of 436.5 pounds as the figure for the original rock pressure gives the computed original reserve of 13,253 MCF per acre (2-pound base).

The first of the calculations reported is the most conservative, but it is not, as a consequence, more reliable. If this figure is used the following tabulation of estimated reserves in the Hugoton Field is obtained.

Estimated Original Reserves in the Hugoton Field

Proved		
Kansas	981,120 acres	8,725,569,135 MCF
Oklahoma	302,080 acres	2,686,541,834 MCF
	Total	11,412,110,969 MCF
Probable		
Kansas	275,000 acres	1,222,853,225 MCF
Oklahoma	496,640 acres	2,220,842,845 MCF
	Total	3,443,696,070 MCF
Total		14,855,807,030 MCF

Many geologists regard the territory lying between the southern part of the Hugoton Field and the northwestern extremity of the Amarillo Field, as now outlined, as probable gas-producing territory. This area is structurally high and the geologic conditions are similar to those in the Hugoton Field. The recent drilling of a 100-million cubic foot gas well by the Phillips Company (SE. cor. sec. 179, Blk. 3 T, T and No RR) in northeastern Moore County near the northwest border of the Amarillo Field "boundary" strengthens this conclusion. If an area of 628,679 acres in Texas between the Amarillo and Hugoton fields, here classed as probable gas-producing territory, is calculated to have an acre-yield of 8,556.8 MCF, this amounts to 5,385,767,257 MCF.

9. Map of developed part of the Hugoton gas field showing rock pressures, June, 1934. (In pocket)

Price of Gas in the Hugoton Field

The prevailing price for gas in the Hugoton Field is 5 cents per M at the well, 2 pound base, 60° F., assuming 14.4 pounds as atmospheric pressure. This price is based on the payments for royalty gas by Argus Gas Company and Texas Interstate. These companies produce over 95 per cent of the gas now taken from the field.

Per Cent of Open Flow Safely Taken

The Argus Gas Company owns 90 wells in the Hugoton Field and their wells are all opened into the line and produce according to their ability to put gas into the line against the working pressure. However, the company has made tests on various wells from which they conclude that any volume up to 100 per cent of capacity can safely be taken from Hugoton wells without danger of coning water or otherwise damaging the well.

Regulations Affecting Production

There are no regulations affecting the production of gas from Hugoton wells at this time.

Acquisition of Leaseholds

The Cities Service Gas Companies have recently been active in the acquisition of leaseholds in the Texas County, Oklahoma, portion of the Hugoton Field. The terms of these leases will permit the company to validate or perpetuate leaseholds under nine sections with the drilling of one well. No other important lease acquisitions have taken place in this portion of the Hugoton Field.

In the northeastern part of the Hugoton Field a block of 35,000 to 40,000 acres has recently been acquired by individuals from Pittsburgh, Pennsylvania (leases taken in the name of Alden W. Foster). The consideration paid to the landowners was $60 per quarter section or 37½ cents per acre. This block is reported to cover an area including parts of Stevens, Seward, Haskell and Grant counties, Kansas.

The supply of proved leases in the Hugoton Field exceeds the demand by so wide a margin that the proved area is more than half open or unleased. The Argus Gas Company alone has surrendered leases on 375,000 acres, most of it in the proved area. They have retained about 75,000 acres, on which they now have 90 producing wells.

With more than half of the proved acreage open and with no active demand for leases, it is possible to secure leases in almost any part of the field for 50 cents per acre, with a similar annual rental payment.

GAS SUPPLIES AVAILABLE TO THE CITIES SERVICE GAS COMPANIES FROM FIELDS IN KANSAS, OKLAHOMA, AND MISSOURI (EXCEPT HUGOTON)

Wells Drilled by Cities Service Gas Companies

The Cities Service Gas Companies have drilled no wells on their leases in Kansas, Oklahoma, and Missouri during the period from June, 1931, to June, 1934.

Production of Gas from Companies' Wells

Production from Cities Service Gas Companies' wells in Kansas, Oklahoma, and Missouri for the twelve-month periods ending as shown are here tabulated.

Production in MCF, 8-ounce base

	June, 1931	June, 1932	June, 1933	June, 1934	Totals
Oklahoma	2,079,456	1,438,836	1,414,417	990,123	5,922,832
Kansas	1,045,974	724,109	602,595	636,182	3,008,860
Missouri	9,148	7,475	1,092		17,715
	3,134,578	2,170,420	2,018,104	1,626,305	8,949,407

During the last three years the rate of withdrawal from the Companies' wells in Kansas, Oklahoma, and Missouri has been reduced by one-half, while during this period the rate of withdrawal from the Companies' Amarillo wells has been increased by one-third. The producing wells in Missouri have been abandoned, and all leaseholds in Missouri have been relinquished.

Open Flow of Companies' Wells in Kansas and Oklahoma

The open flow of the Companies' wells in Kansas and Oklahoma on June 30, 1934, is reported as 259,131,000 cu. ft. per day (2-pound base) from 86 wells. In July, 1931, the open flow of these wells (including Missouri) totalled 258,837,000 cu. ft. per day from 136 wells. It is therefore noted that, although no new wells have been drilled, the open flow on June 30, 1934, from the Companies' producing wells outside of Amarillo is slightly more than from the same wells on June 30, 1931, though 50 more wells were producing at the earlier date. This unusual condition can only be explained by the fact that withdrawals have been diminished to a point where the pressure and open flow in the wells are gradually building up, probably due to advance of edge water in the producing horizons.

The Per cent of Open Flow Safely Taken

The per cent of open flow safely taken from wells owned by the Cities Service Gas Companies in Kansas and Oklahoma is generally considered from 20 to 25 per cent. Using 25 per cent, the withdrawal available from the Companies' 86 wells in Kansas and Oklahoma is 71,304 MCF daily.

Estimated Future Supplies

Reserves from the Companies' operated leaseholds in Kansas and Oklahoma are relatively unimportant, and their possibilities for future development practically exhausted. The reserves in these leases were calculated as 33,424,000 MCF (8-ounce base) on July 1, 1931. Since then 5,819,529 MCF have been withdrawn. The present reserves are estimated as the difference between these amounts, or 27,604,500 MCF.

Amarillo Field Estimated Reserves

POUNDS

400

350

300

250

200

150

100

50

For enlargement of this part of graph see at right.

Cumulative Production - Pressure Decline on basis of 120,801,460 MCF per pound pressure loss

Same on basis of 105,203,970 MCF per pound pressure loss

4 8 12 16 20 24 28 32 36 40 44 48 52 60

TRILLIONS OF CUBIC FEET

LBS.

430

420

410

400

390

380

Production to June 30, 1934, 4,273,048,909 MCF

Weighted Av Pressure Loss to 6/30/34 40.6168 lbs

Production 1/1/32 to 6/30/34 - 1,245,076,507 MCF

Weighted Average Pressure Loss Jan. 1, 1932 to June 30, 1934 - 10.3068 lbs

389.38

Weighted Average Pressure, June 30, 1934

1 2 3 4 5

TRILLIONS OF CUBIC FEET

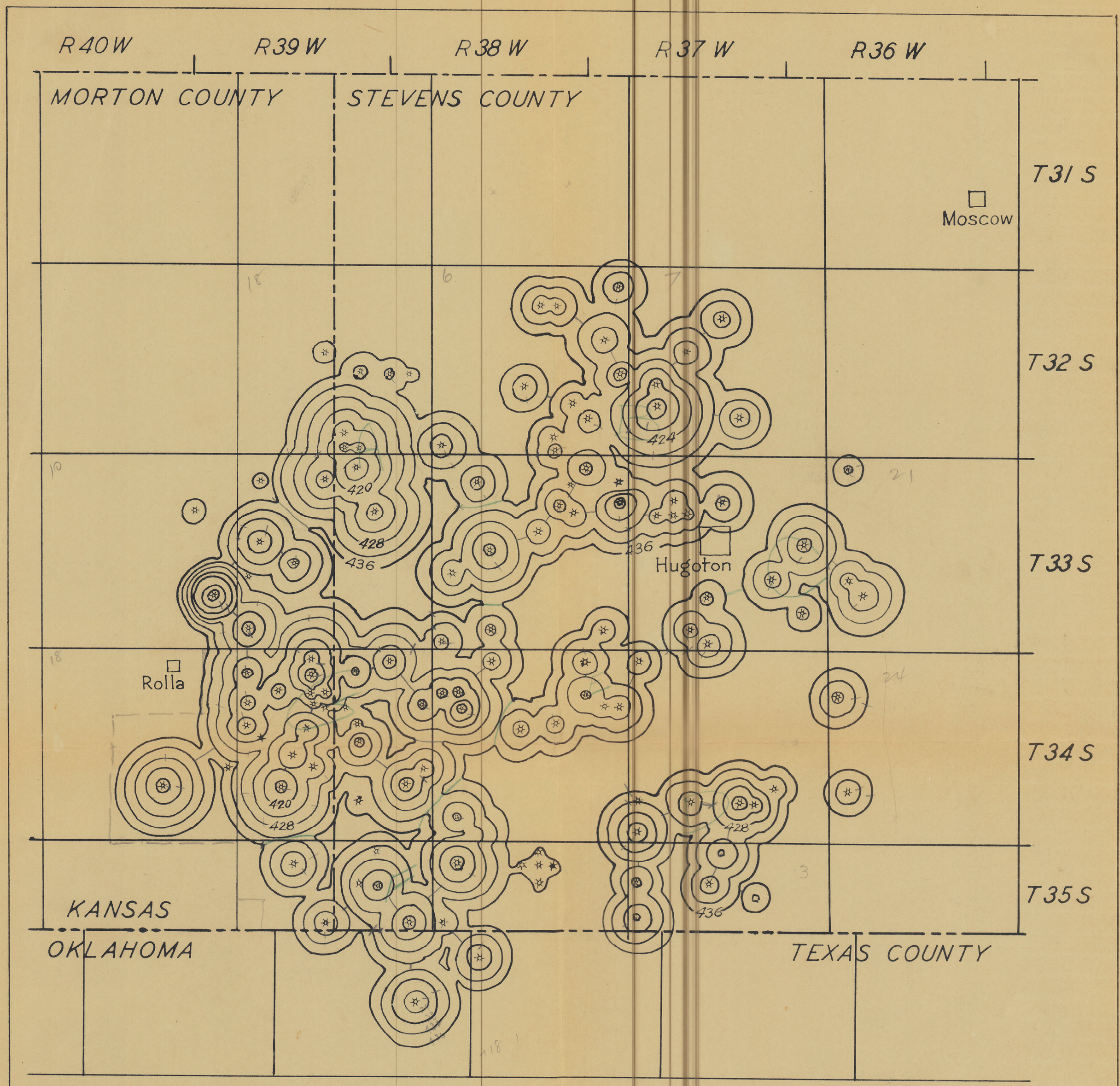
INDEX

AMARILLO FIELD

SHOWING

CONTOURS ON PRESSURE LOSS

JAN. 1932 TO JUNE 1934



MAP OF DEVELOPED PART OF HUGOTON GAS FIELD SHOWING ROCK PRESSURES – JUNE, 1934

Contour interval 4 pounds

KANSAS

OKLAHOMA

TEXAS

Hugoton Field

Burrton Field

Probable gas-producing area

Amarillo Field

Map showing Cities Service Pipe Lines and Main Gas Fields - 1934

HUTCHINSON

CARSON | GRAY

PRESSURE LOSS MAP

JAN. 1932 TO JUNE 1934

SHOWING

PART OF AMARILLO FIELD

C. S. GAS CO. LEASEHOLDS

PRESSURE CONTOURS
IN THE
AMARILLO FIELD
JUNE 1934