KANSAS OIL FIELD BRINES AND THEIR MAGNESIUM CONTENT

By

WALTER H. SCHOEWE

WITH CHEMICAL ANALYSES BY

R. Q. BREWSTER AND
CALVIN VANDER WERF

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ERRATA

p. 46, first word of first paragraph should read "Quantitatively"

p. 60, lines 4 and 5, should read "magnesium chloride + lime + water = magnesium hydroxide + calcium chloride."

p. 62, line 1, should read "$MgCl_2 + 2NaHCO_3 = MgCO_3 + 2NaCl + H_2O + CO_2$"

p. 62, line 4, should read "$MgSO_4 + 2NaHCO_3 = MgCO_3 + Na_2SO_4 + H_2O + CO_2$"

p. 62, 8th line from bottom, should read "$MgO + H_2SiF_6 = MgSiF_6 + H_2O$"

p. 65, description of figure 2, "basic ram materials" should read "basic raw materials"

p. 70, delete 5th line from bottom of page

p. 74, first line under *Zenith oil field,* "stafford" should read "Stafford"

Contents

Illustrations

Tables

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ABSTRACT

This report is a brief study of the Kansas oil field brines, especially as related to their magnesium content. It has been known in a general way that some of the Kansas oil field brines have magnesium content greater than that of sea water from which, in recent years, metallic magnesium is being extracted successfully on a commercial scale. Similarly, metallic magnesium is also being extracted from oil field brines in Michigan. The chief purpose of the investigation was to ascertain the chemical nature of the waste brines, which are now very expensive to dispose of, and to determine whether metallic magnesium, an essential strategic material for war purposes, might not be extracted from these brines. During the summer of 1942 brine samples and other pertinent data were collected from 79 of the major and more important oil fields in the state. The brines were analyzed in the chemical laboratories at the University of Kansas.

On the basis of the analyses, at least six oil-producing formations (Layton, Stalnaker, Kansas City-Lansing, Hoover, Topeka, and Peru pay zones) have an average magnesium content greater than that of ordinary sea water. Certain other formations, such as "chat," Bartlesville, "conglomerate," and Simpson ("Wilcox") formations, yield brines essentially the same in their magnesium content as sea water. The "Mississippi lime," Gorham, Viola, "Hunton," and Arbuckle formations are deficient in this ingredient. The report includes tables giving the complete analyses of the brines studied.

The report includes a brief description of metallic magnesium and its compounds including their occurrences, uses, and derivation from oil field brines. Sources of required processing materials, costs, and prices of magnesium and its coumpounds are briefly outlined.

After discussing the factors controlling the commercial practicability of recovering magnesium from oil field brines, the report concludes with an analysis of Kansas oil fields worthy of consideration for magnesium recovery and recommended for further detailed study. The Kansas oil fields most worthy of consideration on the basis of data on hand are: Burrton field, Reno county; Bornholdt field, McPherson county; Zenith field, Stafford and Reno counties; Welch field, Rice county; Hall-Gurney field, Russell county; and Oxford field, Sumner county.

The present studies indicate that metallic magnesium extraction from oil field brines as a new and specialized industry in Kansas is not feasible. The information at hand does, however, suggest strongly that more detailed study may show the practicability of extracting magnesium from the brines as an auxiliary phase of the oil industry, to the extent of offsetting the high cost of brine disposal. This applies especially to the Burrton oil field in Reno county.

INTRODUCTION

The presence of magnesium in oil field brines and the increasing usefulness of metallic magnesium as an essential strategic material for war purposes have prompted the State Geological Survey of Kansas to investigate the possibility of using the oil field brines of the state as a source of metallic magnesium. It has been known in a general way that some of the Kansas oil field brines have a magnesium content greater than that of sea water from which, in recent years, metallic magnesium has been commercially extracted at Freeport, Texas. Magnesium is also being extracted from oil field brines in Michigan and western Texas (Pawell, 1942, p. 331). Vast amounts of salt water or brine are produced annually along with the oil. At present, the brines are considered only a bothersome and expensive waste, the disposal of which constitutes one of the major problems of the oil operators. Oil field brine disposal is subject to regulations defined by statute. Brines must be disposed of without polluting surface streams, contaminating or mineralizing domestic underground water supplies, damaging soil, or killing vegetation.

Oil field brines in Kansas are disposed of legally in two general ways: (1) impounding it on the lease and (2) injecting the brine into subsurface formations at designated disposal wells. Occasionally, some brine is released directly on the surface, where it either penetrates into the soil, evaporates, or drains off into surface streams.

In any case, the disposal of the brine is bothersome. Furthermore, no mineral matter has as yet been salvaged from it; therefore, its disposal has been an expensive item in the cost of operating an oil lease or oil field. Because Kansas oil field brines contain mineral matter of economic wartime importance, the present investigation was inaugurated as part of the program of the State Geological Survey in the war effort.

The investigation for ascertaining the magnesium content of Kansas oil field brines and the possibility of extracting the mineral for wartime purposes was under the direction of R. C.

Moore, State Geologist, and John C. Frye, Assistant State Geologist. The geological part of the project was assigned to Walter H. Schoewe, staff geologist. The chemical analyses were made by R. Q. Brewster, chemical consultant to the Geological Survey and professor of Chemistry at the University of Kansas, who was assisted by Calvin Vander Werf, assistant professor of Chemistry at the University of Kansas.

Scope of the Survey

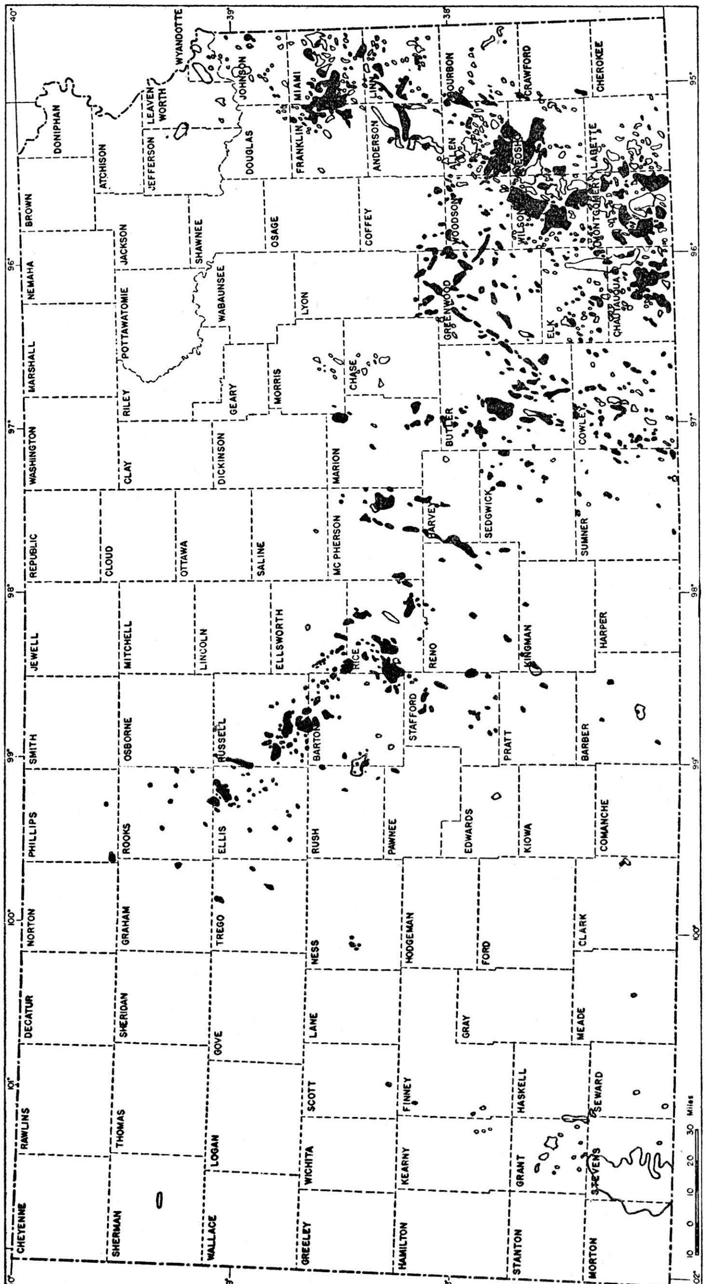
Oil pools investigated.—The present investigation covers the entire oil-producing sections of Kansas (fig. 1). It was impossible, however, because of limited time, to collect brine samples and other pertinent data from every oil pool in the state. Samples of brine were collected from practically all of the major and more important oil pools in western Kansas. Less time and effort were devoted to the eastern oil fields because of their declining production and also because of the greater difficulty in obtaining good and reliable brine samples. In all, 79 oil fields were visited. The names of the oil pools from which samples were obtained are indicated in table 1.

Geologic formations from which samples were obtained.—Brine samples were collected from all of the important oil-bearing formations. Table 2 gives, in chronological sequence, the names of the oil-bearing formations or "pay zones" sampled, together with the number of samples obtained from each.

Method of collecting samples.—Effort was made to collect brine samples representative of the entire oil field. The number of samples collected in any given field depended upon the size of the oil pool and the type of method used in disposing of the salt water. In the smaller fields, one or two samples were normally considered sufficient. In the larger fields, however, effort was made to obtain samples from various parts of the oil pool—from the center and both ends. Where the pool was sufficiently wide, samples were also collected at both sides of the field. Where the field was unusually long, samples were collected approximately every 2 miles along the trend of the field. In cases, however, where the salt water was disposed of in deep disposal wells, one sample was collected at each disposal well, regardless of the length or breadth of the field.

TABLE 1.—*Oil pools from which brine samples were collected*

Pool	County	Samples
Agard	Greenwood	1
Ainsworth	Barton	2
Atherton	Russell	1
Augusta	Butler	2
Augusta, North	Butler	2
Beaumont	Greenwood	2
Bemis	Ellis	2
Bloomer	Ellsworth, Barton	4
Bornholdt	McPherson	3
Browning	Greenwood	1
Burnett	Ellis	1
Burrton	Reno	4
Chase	Rice	4
Cunningham	Pratt	4
Demalorie-Sowder	Greenwood	1
Eastman	Cowley	1
Edwards	Ellsworth	2
Elbing	Butler	4
Eldorado	Butler	6
Eureka	Greenwood	1
Fairport	Russell	2
Fairport-Austin	Russell	1
Fairport-North	Russell	1
Florence	Marion	1
Foxbush	Butler	1
Frog-Hollow	Cowley	1
Garden-Schaffer	Butler	2
Geneseo	Rice	3
Goodrich	Sedgwick	4
Gorham-East	Russell	5
Gorham-West	Russell	2
Graber	McPherson	2
Graham	Cowley	5
Greenvale	Russell	1
Greenwich	Sedgwick	3
Hall-Gurney	Russell	6
Halstead	Harvey	2
Hinchman	Greenwood	1
Hittle	Cowley	2
Johnson	McPherson	1
Keesling	Rice	2
Kraemer	Butler	1
Kraft-Prusa	Barton	4
Lorraine	Ellsworth	2
Madison	Greenwood	2
Miami	Miami	5
New Albany	Elk	1
Oxford	Sumner	5
Padgett	Sumner	1
Peabody	Marion	1
Peace Creek	Reno	1
Potwin	Butler	2
Rainbow-Bend	Sumner	1
Ritz-Canton	McPherson	8
Russell	Russell	2
Sallyards	Greenwood	1
Sedan	Chautauqua	1
Seeley	Greenwood	2
Sellens	Russell	1
Severy	Greenwood	1
Shutts	Ellis	1
Silica	Rice, Barton	5
Sperling	Harvey	1
St. John	Stafford	1
Stafford	Stafford	1
State	Cowley	1
Stoltenberg-Stratman	Ellsworth	3
Trapp	Barton, Russell	4
Trapp, North	Russell	1
Valley Center	Sedgwick	3
Virgil-North	Coffey, Greenwood	2
Virgil-West	Greenwood	1
Voshell	McPherson	2
Welch	Rice	2
Wellington	Sumner	1
Wherry	Rice	2
Wherry-East	Rice	2
Winterscheid	Woodson	2
Zenith	Reno, Stafford	4



Oil Pools

Gas Pools

FIG. 1. Map of Kansas showing location of oil and gas fields. After Raymond P. Keroher.

TABLE 2.—*Producing formations and number of samples collected*

Formation	Samples	Formation	Samples
Tarkio	2	"Basal conglomerate"	4
Topeka	4	"Chat"	18
Hoover	1	"Mississippi lime"	8
Stalnaker	1	"Hunton"	3
Kansas City-Lansing	28	Viola	12
Peru	2	Simpson ("Wilcox")	16
Cherokee, top	1	Arbuckle ("Siliceous lime, dolomite")	51
Bartlesville (New Albany)	14		
Gorham	4		

Quantatively, one quart of brine constituted the normal sample. The brine was collected in glass Mason jars provided with glass covers or tops. Samples were obtained at the wells, usually under the supervision of a farm boss, pumper, or other official. Because of the different methods employed in disposing of the brine waters, the samples were collected from various sources. Some came from the bleeder at the well. Others were obtained at the gun barrel at the siphon, gun barrel gauge, or at the place where the brine coming from the gun barrel siphon emptied into the settling tank, or where the brine, after leaving the siphon, emptied into a pond. In a few cases the valve of the gun barrel had to be opened in order to secure the sample. In oil pools where the salt water was disposed of by means of deep disposal wells, the samples were either collected at the bleeder of the well or at the place where the brine emptied into the settling tank or pit just previous to its entry into the well. In one or two cases, the sample was drawn off from the bottom of the oil storage tank.

The following oil companies and operators cooperated in the project: Aladdin Petroleum Corporation, Amerada Petroleum Corporation, Nate Appleman, Atlantic Refining Company, Aylward Production Company, Barnsdall Oil Company, Bay Petroleum Company, Beardmore Drilling Company, Inc., Beaumont Petroleum Company, H. C. Bennett, Bennett-Wolf, F. Berger, Big Brothers Oil Company, B. B. Blair, Bridgeport Machine Company, British-American Oil Producing Company, Carter Oil Company, Central Supply Company, Cities Service Oil Company, Colorado Petroleum, Inc., Conley and Cooper, Continental Oil Company, Darby Petroleum Company, Deep Rock Oil Corporation, Derby Oil Company, Dickey Oil Company, Drillers Gas Company, El

Dorado Refining Company, Goldstein Company, Gulf Oil Corporation, J. J. Hall, Herndon Drilling Company, Carl Hipple, T. C. Johnson (Estate), Jones-Shelburne, A. Landon, Leader Oil Company, Leader Oil Company-Zephyr Drilling Company, Magnolia Petroleum Company, M. & L. Oil Company, Maxwell Petroleum Company, W. C. McBride, Inc., Ward McGinnis, McPherson Drilling Company, L. R. Mendenhall, Mid-Continent Petroleum Corporation, Mohawk Oil Company, National Refining Company, Ohio Oil Company, OKO Oil and Gas Company, Olson Drilling Company, Oskaloosa Oil and Gas Company, Palmer Oil Company, Phillips Petroleum Company, S. J. Polhamus (Estate), Prunty Production Company, Pryor and Lockhart, Inc., Santa Clara Drilling Company, Shaffer-Howell, E. B. Shawver, Shell Oil Company, Sinclair-Prairie Oil Company, Skelly Oil Company, Snowden and McSweeney, Solar Oil Corporation, L. Spencer, Stanolind Oil and Gas Company, State Training School, Sunray Oil Company, The Texas Company, Tidewater Oil Company, Transwestern Oil Company, White Star Oil, and York State Oil Company.

Acknowledgments.—The present investigation for determining the magnesium content of the State's natural salt water or brines associated with the production of oil would have been impossible without the wholehearted and gracious cooperation of the various oil companies and operators. Although space does not permit the listing of the names of the many farm bosses, pumpers, and other employees of the various oil companies and operators, I wish to express my sincere thanks to them for their courteous and willing aid in helping me to obtain the brine samples and other pertinent data requested. The names of the oil companies and operators cooperating in this project are listed elsewhere in this bulletin. Special gratitude is due to the Cities Service Oil Company for providing me with office space at Oil Hill in the Eldorado district and also for permitting me to study certain data in the files.

I also wish to express my appreciation to Ogden S. Jones, geologist of the Oil Field Section, Division of Sanitation, Kansas State Board of Health, for making it possible for James Nelson, field geologist of the southern district of the same Oil Field Section, to accompany and assist me for several days in the field in collecting the first suite of samples and in obtaining the necessary information relative to them. Thanks are also due Paul Hollands, field geologist for the Great Bend district of the Conservation Division of the Kansas State Corporation Commission, for certain data relative to the project. I wish to express my thanks to John M. Jewett, geologist of the State Geological Survey, who collected five samples from Miami county. Lastly, I thank John C. Frye, Assistant State Geologist, under whose direct supervision the project was carried out, for his interest in the work and for his timely suggestions relative to the writing of this report; R. Q. Brewster for checking chemical data and for his suggestions relative to table 5 through 14; and Dorothea Weingartner for editorial assistance.

MAGNESIUM AND KANSAS OIL FIELD BRINES

Chemistry of Kansas Oil Field Brines

Chemical analyses of Kansas oil field brines show that the brines, irrespective of the oil fields and "pay zones" or horizons from which they come, are essentially alike in the dissolved chemical constituents that they contain, but that they differ materially as to their concentration. The analyses show that of all the dissolved chemical constituents contained in the brines, chloride, sodium, and calcium greatly predominate (table 3). Magnesium is next in importance quantitatively. Other elements present but occurring in much lesser amounts are bromine, iodine, aluminum, iron, and potassium. Magnesium, of all the chemical constituents contained in the brines, is of the greatest importance at the present time. It is the only one which occurs in sufficient amounts to offer possibilities of commercial extraction under present conditions. Other ingredients, such as sodium and calcium, occur in far greater amounts than does magnesium; but, since these substances may be obtained much more readily from other sources, their ex-

Table 3.—*Dissolved chemical constituents of Kansas oil field brines with range in milligrams per liter*

Chemical constituents	Range	Chemical constituents	Range
Total solids	17,880-228,320	Bromide	0- 425
Chloride	10,729-142,547	Iodide	0- 8
Sodium	9,200- 68,700	Sulphate	0- 2,800
Calcium	246- 7,900	Aluminum	0- 781
Magnesium	153- 3,960	Iron	0- 15
Bicarbonate	12- 869		

traction from brines in Kansas is unwarranted and unprofitable. Studies show that certain formations are invariably higher in magnesium content than brines coming from other "pay zones" or oil-producing formations (table 4).

According to the analyses, practically every oil-producing formation in Kansas yields, in some well or wells, brines containing magnesium in amounts greater than is contained in ordinary sea water. However, in most cases the magnesium content is much lower than that of sea water. The highest magnesium bearing

TABLE 4.—*Magnesium content of Kansas oil field brines*

Formation	Magnesium in milligrams per liter		Samples represented
	Range	Average	
Layton		3,960	1
Stalnaker		2,620	1
Kansas City-Lansing	972-3,910	2,525	31
Hoover		2,515	1
Topeka		2,400	1
Peru	1,840-2,610	2,225	2
"Chat"	704-2,460	1,461	19
Bartlesville	461-2,490	1,223	16
"Conglomerate"	750-1,455	1,184	4
Simpson ("Wilcox")	235-2,035	1,033	8
"Mississippi lime"	432-1,857	772	8
Gorham	450-1,030	701	3
Viola	185-1,547	584	14
"Hunton"	153-1,138	523	5
Arbuckle	152-3,110	523	52
Sea Water	1,045 (Jones, 1943, p. 18); 1,279 (Burnett, 1942, Table II); 1,400 (Frye, 1942, p. 105).		

brine is found in the Kansas City-Lansing zone. Not only does this zone produce the highest magnesium salt water, but it does so persistently in all wells and in all oil fields. The Arbuckle limestone, on the other hand, is prevailingly low in magnesium, with an average content less than 500 milligrams per liter. Even this formation, however, occasionally yields a brine high in magnesium. An Arbuckle brine obtained from a well in sec. 24, T. 11 S., R. 18 W., in the Burnett oil field, Ellis county, contained 3,110 milligrams of magnesium per liter.

Not only is there a difference in the magnesium content of the brines of the various oil-producing formations, but there is also a quantitative variation of this ingredient in any one given formation. The magensium concentration varies from one part of a field to another and also among the various oil fields. Variations among fields, as well as complete chemical analyses of the brines, are given in tables 5 through 14.

DESCRIPTION, OCCURRENCE, AND DERIVATION OF METALLIC MAGNESIUM

Description.—Metallic magnesium is a silvery white metal of high tensile strength. It is the lightest of all the known metals that are comparatively little altered under ordinary atmospheric conditions. Its specific gravity is 1.74; its melting point is 633° C.; and its boiling point is 1120° C.

Occurrence.—Magnesium occurs in nature only in the combined state and is one of the most common metals associated with rocks. It constitutes approximately 2.1 percent of the earth's crust, which makes it the eighth most abundant element or sixth most abundant metal.

Common magnesium-bearing minerals include magnesite, $MgCO_3$; dolomite, $CaMg(CO_3)_2$; olivine, $2(MgFe)OSiO_2$; serpentine, $H_4Mg_3Si_2O_9$; epsomite (epsom salt), $MgSO_4.7H_2O$; brucite, and the Stassfurth salts of commercial importance— carnallite $KMgCl_3.6H_2O$; kainite, $MgSO_4.KCl.3H_2O$; kieserite, $MgSO_4.H_2O$;and schoenite, $K_2SO_4.MgSO_4.6H_2O$. In addition, other magnesium minerals are asbestos, meerschaum, spinel, tourmaline, chrondrodite, pyrope, biotite, phlogopite, chlorite, talc, sepiolite, garnierite, bradleyite, and some of the pyroxenes and amphiboles. Magnesium is also found in mineral waters, sea bitterns, sea water, and oil field brines.

Derivation, general.—At the present time metallic magnesium is derived from the following minerals: magnesite, dolomite, epsomite, olivine, and serpentine. It is also obtained from chemically produced magnesia, or magnesium oxide in its various forms, magnesium chloride, magnesium sulphate, magnesium hydroxide, and magnesium silicofluoride. Today it is also extracted from ordinary sea water, bitterns, saline deposits, and oil field brines.

Derivation of metallic magnesium from oil field brines.—Natural brines contain sodium chloride, calcium chloride, magnesium chloride, bromine, and other chemical constituents. The first step in obtaining metal magnesium, Mg, is to treat the brine with calcium hydroxide (calcined limestone or quicklime, CaO, or with calcined dolomite, CaO and MgO). As a result, magnesium hydroxide, Mg $(OH)_2$, and calcium chloride, $CaCl_2$, are formed. The magnesium hydroxide is then dissolved in hydrocloric acid, HCl, to form magnesium chloride, $MgCl_2$, from which metallic magnesium and gaseous chlorine are derived by electrolysis. According to Gann (1930, p. 694), at the Dow Chemical Company's plant at Midland, Michigan, the bromine is first removed from the brine after which the brine is treated with a magnesium hydrate slurry to precipitate iron and any other impurities contained therein. After the sodium chloride has been removed by crystallization, the magnesium and calcium chlorides in the rotary-filter mother liquor are separated from each other by fractional crystallization, with addition of chlorine during the process. The purified magnesium chloride solution is concentrated further by crystallization. The crystals are melted in their water of crystallization, the fused mass flaked, and then air-dried until an almost anhydrous magnesium chloride, $MgCl_2$, is produced. The magnesium chloride is then electrolyzed in a sodium chloride bath. The process is continuous, and the metal, which is of high purity, is periodically dipped from the rectangular cast-steel pots in which electrolysis occurs and cast into ingots of various sizes.

Although metallic magnesium is the end product sought, it may not be desirable, feasible, or practicable to extract the metal from the oil field brines at each recovery plant established. It may prove to be more advantageous merely to produce magnesium hydroxide, $Mg(OH)_2$, dry it, and ship it elsewhere to be further processed. On the other hand, it may be desirable to further process the magnesium hydroxide to some specific magnesium product, such as "caustic," "calcined," or "dead-burned" magnesia, and then dispose of the product. Or the process may be carried on to completion until metallic magnesium is obtained. In the following pages a brief description is given concerning the processing of the more important magnesium compounds.

Magnesium hydroxide, $Mg(OH)_2$.—Regardless of what magnesium substance is desired at any oil field brine recovery plant, the first step consists in converting the contained magnesium chloride into magnesium hydroxide. This may be done by treating the magnesium chloride of the brine either with calcined limestone (quicklime, CaO), or with calcined dolomite, or with

TABLE 5.—*Kansas City-Lansing brine data with chemical analyses*

Pool	County	Location Sec.	T.	R.	Brine (bbls. day)	Depth to horizon	Disposal method	Sp. Gr. (60° F.)	Sample number
Severy	Greenwood	17	28	11E	60	1225	Pond	1.098	164
Madison	do.	5	23	11E	—	1060	—	—	†
do.	do.	15	22	11E	—	1310	—	—	†
Teeter	do.	16	23	9E	—	1515	—	—	†
do.	do.	16	23	9E	—	1915	—	—	†
Eldorado	Butler	21	25	5E	—	1743	—	—	†
do.	do.	29	25	5E	—	1970	—	—	†
Augusta	do.	35	27	4E	little	2300	Pond	1.121	131
do.	do.	17	28	4E	—	2060	—	—	†
do.	do.	29	28	4E	—	2140	—	—	†
North Augusta	do.	11	27	4E	80	2200	Pond	1.106	130
Elbing	do.	17	23	4E	20	2160	Pond	1.110	122
Graham	Cowley	10	33	3E	40	2500	Pond	1.150	139
Hillsboro	Marion	20	20	2E	—	1980	—	—	†
Goodrich	Sedgwick	15	25	1E	20	2626	Pond	1.150	30
Silica	Rice	27	19	10W	30	3200	Pond	1.108	57
Bloomer	Ellsworth	31	17	10W	30-40	3070	Pond	1.100	66
Kraft-Prusa	Barton	17	16	11W	50	—	Pond	1.097	73
Cunningham	Pratt	35	27	11W	20	3450	Pond	1.158	174
do.	do.	25	27	11W	little	3450	Pond	1.150	176
do.	do.	24	27	11W	little	3450	Pond	1.159	175
Greenvale	Russell	4	15	12W	—	3100	Pond	1.088	105
Hall-Gurney	do.	31	14	13W	5	2950	Pond	1.114	92
do.	do.	26	14	13W	8-30%	2800	Pond	1.072	94
do.	do.	22	14	14W	32	2950	Pond	1.112	97
Gorham, East	do.	2	14	15W	—	3050	Deep well	1.040	78
Gorham, West	do.	4	14	15W	150	3050	Pond	1.040	81
Fairport-Austin	do.	31	12	15W	75	3000	Pond	1.075	83
Fairport	do.	30	12	15W	little	3000	Pond	1.095	84
do.	do.	8	12	15W	5-10	3025	Pond	1.100	85
Fairport North	do.	32	11	15W	30	3000	Pond	1.095	86

TABLE 6.—*Bartlesville brine data with chemical analyses*

Shambaugh	Greenwood	15	23	13E	700	1565	Deep well	1.040	155
Seeley	do.	32	22	11E	1000	2000	Pond	1.045	160
Madison	do.	14	22	11E	2	1900	Pond	1.052	156
do.	do.	14	22	11E	—	1900	—	—	†
do.	do.	12	22	11E	50	1800	Pond	1.060	157
Demalorie-Sowder	do.	12	22	10E	2	2000	Pond	1.063	158
Browning	do.	30	22	10E	30	2300	Pond	1.068	159
Teeter	do.	16	23	9E	—	2540	—	—	†
Sallyards	do.	1	26	8E	little	2400	Deep well	1.079	167
Eastman	Butler	6	31	6E	85	2850	Pond	1.100	133
Garden-Schaffer	do.	6	27	6E	100	2750	Pond	1.102	126
Frog-Hollow	Cowley	20	32	5E	50	3000	Pond	1.140	134
Fox-Bush	Butler	26	28	5E	100	2800	Pond	1.095	132
Haverhill	do.	27	27	5E	—	2774	—	—	†
Augusta	do.	16	28	4E	400	2550	Pond	1.030	117
Rainbow-Bend	Sumner	21	33	3E	100	3200	Pond	1.141	141

All chemical analyses in milligrams per liter. To convert to parts per million, divide by specific gravity of the brine. * denotes a concentration of less than 1 milligram per liter; ‡ denotes a concentration of less than 25 milligrams per liter; † denotes analyses supplied by private companies; all other analyses were made by R. Q. Brewster and Calvin Vander Werf at the University of Kansas.

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
164	2208	47600	6550	93905	‡	102	60	15	‡	*	150400
†	1351	33812	3443	63333	76	109	—	—	—	12	103700
†	1585	34366	3838	65333	67	113	—	—	—	12	106500
†	1785	40773	4739	78330	68	109	—	—	—	94	128200
†	1593	41852	5382	80330	70	106	—	—	—	84	131400
†	2540	55690	8203	107783	41	48	—	—	—	42	174400
†	3550	51483	14927	116032	50	130	—	—	—	—	186800
131	3410	53500	9050	131328	‡	72	105	5	210	*	197700
†	2974	58491	9533	115764	36	38	—	—	—	67	186900
†	2774	63020	8585	122500	128	38	—	—	—	17	199700
130	2670	55200	8040	101534	150	108	50	8	320	*	177100
122	2262	55100	7200	107479	50	84	60	5	‡	*	172200
139	2940	77000	12480	145105	‡	12	100	3	‡	*	237600
†	2569	53564	6050	103000	‡	71	—	—	—	53	168000
30	3910	71380	10900	145860	‡	33	375	2	895	2	233400
57	3492	52420	8085	109806	‡	82	130	*	864	*	174900
66	2705	49290	8965	98040	‡	113	155	*	461	*	161300
73	2690	42860	9610	92540	50	90	200	15	464	3	148200
174	3351	75600	14000	156749	‡	48	110	15	166	1	250000
176	2441	67400	16000	145855	175	*	115	10	84	80	232200
175	2810	75000	14730	156203	75	6	105	15	360	16	249300
105	2685	41500	8440	89300	‡	110	30	*	93	2	142200
92	3075	55300	11100	117825	200	48	70	10	51	1	187700
94	2420	38400	7000	80970	100	120	110	*	‡	*	129100
97	3240	53300	11200	117733	50	36	145	5	50	1	185800
78	1015	16940	2540	34130	275	96	30	3	64	20	55000
81	972	17590	2560	34590	400	448	25	*	‡	*	56600
83	2200	34620	6420	73030	250	48	40	10	138	64	115200
84	2580	44675	9300	96660	75	48	95	5	402	2	152600
85	2240	50760	5670	94940	600	84	125	3	68	*	154200
86	2760	43870	8620	92980	100	66	60	2	255	3	148700
155	712	19900	1980	32059	50	232	25	2	‡	*	55000
160	703	21675	2660	41172	‡	168	20	2	‡	*	66400
156	900	25150	3065	49223	‡	180	40	2	‡	*	78600
†	632	28629	3694	52830	491	88	—	—	—	13	87200
157	1078	28800	3660	56876	‡	84	20	2	‡	*	90500
158	1093	29750	4400	61051	‡	6	75	2	81	62	96500
159	1122	33150	4415	63875	100	54	60	5	129	10	102900
†	863	26715	3316	50000	14	61	—	—	—	99	81700
167	1187	34400	6160	77890	50	72	20	8	48	5	119800
133	1330	52000	5600	98098	‡	54	40	5	190	3	157300
126	1564	51100	7460	100184	75	96	150	3	87	1	160700
134	2060	46000	14680	165494	50	18	60	*	230	8	228600
132	1910	47400	6820	92396	400	36	20	2	293	3	149300
†	1464	47095	7100	90000	33	84	—	—	—	36	146500
117	461	11900	1830	23659	750	210	110	*	‡	*	38900
141	2490	69600	12120	141167	50	12	130	2	302	7	225900

TABLE 7.—*"Conglomerate" brine data with chemical analyses*

Pool	County	Location Sec.	T.	R.	Brine (bbls. day)	Depth to horizon	Disposal method	Sp. Gr. (60° F.)	Sample number
Wherry	Rice	6	21	7W	little	3400	Pond	1.070	24
do.	do.	12	21	7W	40	3469	Pond	1.090	15
do.	do.	16	21	7W	20	3400	Pond	1.066	23
do.	do.	21	21	7W	—	—	Pond	1.080	16

TABLE 8.—*"Chat" brine data with chemical analyses*

Greenwich	Sedgwick	14	26	2E	4000	2850	Deep well	1.072	37
Goodrich	do.	21	25	1E	600	3000	Pond	1.075	29
Wellington	Sumner	4	32	1W	20	3690	Pond	1.143	147
Ritz-Canton	McPherson	19	19	1W	300	2900	Pond	1.079	44
do.	do.	29	19	1W	80	2960	Pond	1.071	41
do.	do.	25	19	2W	360	2970	Deep well	1.075	42
do.	do.	36	19	2W	120	3000	Pond	1.068	43
Halstead	Harvey	2	23	2W	3000	3000	Deep well	1.070	2
do.	do.	12	23	2W	—	2980	Pond	1.070	1
Johnson	McPherson	30	19	3W	60-70	3100	Pond	1.087	48
Burrton	Reno	15	24	4W	4000	3400	Deep well	1.115	8
do.	do.	10	24	4W	—	—	Pond	1.128	9
do.	do.	23	23	4W	—	—	Deep well	1.110	10
do.	do.	1	23	4W	—	3500	Pond	1.119	11
Bornholdt	McPherson	31	20	5W	—	3333	Deep well	1.098	12
do.	do.	29	20	5W	550	3350	Deep well	1.090	13
do.	do.	18	20	5W	300	—	Pond	1.085	14
Welch	Rice	3	21	6W	1700	3410	Deep well	1.105	6
do.	do.	2	21	6W	1000	2350	Deep well	1.100	7

TABLE 9.—*Mississippi lime brine data with chemical analyses*

Stephenson	Woodson	7	24	14E	25	1700	Pond	1.037	152
Winterschied	do.	29	23	14E	12	1700	Pond	1.050	153
Hinchman	Greenwood	20	24	13E	200	1600	Pond	1.036	150
Blackwell	do.	10	24	13E	100	1659	Pond	1.033	151
Virgil-North	Coffey	14	23	13E	25	1700	Pond	1.025	154
Virgil	Greenwood	11	24	12E	200	1750	Deep well	1.037	168
Eureka	do.	36	25	10E	20	2000	Pond	1.050	163
Beaumont	do.	25	27	8E	30	2510	Pond	1.091	165

TABLE 10.—*Hunton brine data with chemical analyses*

Peabody	Marion	15	22	4E	6097	2510	Pond	1.015	124
Elbing	Butler	20	23	4E	3748	2370	Pond	1.020	120
Graber	McPherson	20	21	1W	1200	3300	Deep well	1.044	38
do.	do.	32	21	1W	—	3300	Deep well	1.075	39
Sperling	Harvey	13	22	2W	60	3305	Deep well	1.031	3

All chemical analyses in milligrams per liter. To convert to parts per million, divide by specific gravity of the brine. * denotes a concentration of less than 1 milligram per liter; ‡ denotes a concentration of less than 25 milligrams per liter; † denotes analyses supplied by private companies; all other analyses were made by R. Q. Brewster and Calvin Vander Werf at the University of Kansas.

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
24	1190	34830	5100	66951	‡	74	175	*	33	4	108400
15	1455	46600	6050	89412	‡	27	425	*	440	10	144700
23	750	34520	5330	65570	‡	84	270	*	57	6	106700
16	1340	40170	5700	67630	‡	120	385	*	294	*	125600

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
37	1192	36420	4260	69000	‡	86	10	8	223	*	111200
29	1110	36020	4050	62588	‡	90	200	2	220	*	109200
147	1950	66500	13480	137652	2200	30	190	2	781	15	222800
44	704	40560	4070	72578	50	73	45	2	‡	*	117960
41	1182	37270	3940	69010	‡	59	170	*	130	*	111760
42	1101	37470	3980	69560	‡	89	70	3	113	10	112160
43	859	35380	3624	64610	‡	64	58	*	121	*	104720
2	794	34770	3350	61700	‡	130	150	*	142	2	101250
1	980	33110	3480	63310	‡	122	110	2	‡	*	101400
48	1491	43980	5720	83450	‡	40	50	*	38	*	134720
8	2180	66652	9200	129015	‡	60	247	*	525	1	207880
9	2460	75264	10600	143862	‡	84	110	*	‡	*	232380
10	2140	58720	8620	113200	‡	48	395	*	‡	*	183220
11	2270	67370	9510	128240	50	94	130	*	‡	*	207620
12	1510	57942	7370	109290	40	46	310	*	335	3	176850
13	1630	46400	7040	89316	‡	33	420	*	‡	*	146840
14	1410	38900	6100	91140	‡	40	90	*	208	4	137880
6	1230	53568	7800	103324	‡	40	150	*	540	8	166660
7	1560	51197	7450	101420	‡	46	100	*	900	7	162680

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
152	514	16500	2340	32107	125	264	20	*	49	1	51900
153	458	24200	1890	43105	‡	104	10	2	20	11	69800
150	641	16700	1765	29415	450	342	*	2	58	1	50000
151	600	15050	1630	28484	550	396	10	*	‡	*	46700
154	432	11050	1117	20677	150	444	10	*	‡	*	33900
168	700	16700	2180	32441	‡	254	5	*	‡	*	52300
163	971	22500	2830	43673	‡	246	20	*	‡	*	70200
165	1857	44550	6780	89009	175	96	10	3	‡	*	142500

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
124	153	5760	710	10982	225	330	*	*	‡	*	18200
120	320	8500	990	16195	725	300	10	*	‡	*	27000
38	751	21090	2327	40090	‡	96	*	*	133	3	64300
39	1138	36590	4149	68430	‡	67	*	2	182	*	110600
3	253	14150	1260	25000	100	120	65	*	‡	*	41300

TABLE 11.—*Viola brine data with chemical analyses*

Pool	County	Location Sec.	T.	R.	Brine (bbls. day)	Depth to horizon	Disposal method	Sp. Gr. (60° F.)	Sample number
Garden-Schaffer	Butler	4	27	6E	400	3100	Pond	1.031	127
Eldorado	do.	4	26	5E	15	2650	Pond	1.048	108
do.	do.	17	26	5E	Much	2600	Pond	1.040	112
Florence	Marion	18	21	5E	—	2300	Pond	1.017	125
Elbing	Butler	17	23	4E	—	2350	—	—	†
do.	do.	17	23	4E	150	2400	Pond	1.018	123
Greenwich	Sedgwick	14	26	2E	4000	3100	Deep well	1.020	36
Hillsboro	Marion	28	20	2E	—	3037	—	—	†
Ritz-Canton	McPherson	20	19	1W	**	3000	Deep well	1.030	40
do.	do.	17	19	1W	800	3387	Pond	1.030	46
do.	do.	11	19	2W	35	3300	Pond	1.020	45
Peace Creek	Reno	22	23	10W	—	—	Pond	1.035	22
Cunningham	Pratt	12	28	11W	20	4250	Pond	1.095	177
Stafford	Stafford	15	24	12W	—	3800	—	1.065	20

** Several hundred.

TABLE 12.—*Simpson (Wilcox) brine data with chemical analyses*

Padgett	Sumner	26	34	2E	30	3500	Pond	1.140	140
Greenwich	Sedgwick	15	26	2E	300	3000	Deep well	1.020	35
Valley Center	do.	1	26	1E	140	3390	Deep well	1.040	32
Ritz-Canton	McPherson	21	19	1W	75	3440	Pond	1.015	47
Zenith	Reno	7	24	10W	—	3607	Pond	1.055	17
do.	Stafford	14	24	11W	—	—	Deep well	1.065	21
do.	do.	15	24	11W	200	3600	Pond	1.075	18
do.	do.	23	24	11W	—	3600	Pond	1.050	19

TABLE 13.—*Arbuckle brine data with chemical analyses*

Beaumont	Greenwood	25	27	8E	100	2750	Pond	1.045	166
Eldorado	Butler	5	26	5E	400	2450	Deep well	1.028	109
do.	do.	15	25	5E	—	2500	—	—	†
Hittle	Cowley	28	31	4E	—	3300	Pond	1.043	115
State	do.	15	32	4E	300	—	Pond	1.055	114
Graham	do.	9	33	3E	375	3500	Pond	1.067	136
do.	do.	10	33	3E	400	3500	Pond	1.064	137
do.	do.	10	33	3E	800	3500	Pond	1.073	138
Voshell	McPherson	9	21	3W	350	3395	Pond	1.028	5
Lorraine	Ellsworth	23	17	3W	500-1000	3260	Deep well	1.024	62
Geneseo	Rice	19	18	7W	—	—	Deep well	1.018	26
do.	do.	6	19	7W	—	—	Pond	1.014	25
do.	do.	12	18	8W	—	—	Pond	1.025	27
Edwards	Ellsworth	27	17	8W	240	3200	Pond	1.033	60
do.	do.	33	17	8W	150-200	3250	Deep well	1.024	59
Lorraine	Ellsworth	11	17	9W	—	3216	—	—	†
do.	do.	23	17	9W	Much	3200	Pond	1.024	61
Chase	Rice		19	9W	800-1000	3250	Deep well	1.020	54

All chemical analyses in milligrams per liter. To convert to parts per million, divide by specific gravity of the brine. * denotes a concentration of less than 1 milligram per liter; ‡ denotes a concentration of less than 25 milligrams per liter; † denotes analyses supplied by private companies; all other analyses were made by R. Q. Brewster and Calvin Vander Werf at the University of Kansas.

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
127	516	13200	1800	25720	700	264	*	*	‡	*	42200
108	1170	22500	3140	44656	375	24	15	*	‡	*	71900
112	864	18600	2640	36715	500	396	5	*	‡	*	59700
125	228	5670	616	10729	325	312	*	*	‡	*	17900
†	371	5399	909	10000	1178	301	—	—	—	24	18100
123	248	6600	870	12766	300	246	10	*	‡	*	21000
36	204	7800	755	14320	‡	501	*	*	‡	*	23600
†	271	5284	597	10000	15	79	—	—	—	—	16400
40	404	11980	1803	22990	75	233	15	*	‡	*	37400
46	353	11980	1619	22520	65	175	10	*	‡	*	36700
45	185	9280	1191	17111	55	322	15	*	‡	*	28200
22	640	16720	1670	30918	‡	650	15	*	65	*	50700
177	1547	46500	7900	83852	175	12	90	8	110	6	140200
20	1140	30100	5540	60500	‡	210	65	*	91	*	97600
140	2035	68500	14400	142547	300	18	105	3	407	5	228300
35	288	8360	789	15990	90	530	*	*	‡	*	26000
32	628	17830	1900	32965	90	250	80	*	‡	*	53600
47	235	5560	892	10874	80	184	*	*	‡	*	17700
17	1150	26170	4150	51533	‡	230	45	*	‡	*	83300
21	1450	31290	5260	63860	‡	204	75	*	350	1	102700
18	1515	36080	5900	71000	‡	72	345	*	‡	*	114900
19	985	20745	3220	29410	‡	335	70	*	47	1	76400
166	674	19000	3050	38034	325	312	5	*	‡	*	61400
109	408	10000	1635	20153	650	264	10	*	‡	*	33100
†	313	11054	1398	19330	1357	322	—	—	—	25	33700
115	519	15440	2070	30000	450	606	35	*	‡	*	49100
114	835	24650	3720	48706	700	294	15	*	‡	*	78900
136	1050	30900	4130	59558	400	252	30	*	‡	*	96300
137	1263	29200	4130	57142	400	270	15	*	‡	*	92400
138	1263	34450	5170	67655	750	252	20	*	‡	*	109600
5	380	12378	1550	22963	50	404	55	*	‡	*	37800
62	366	10320	1430	19350	275	522	15	*	‡	*	32300
26	320	7150	1260	14220	—	245	10	*	‡	*	23200
25	237	6990	835	12832	—	576	10	*	‡	*	21500
27	340	10430	1760	20280	—	505	5	*	‡	*	33300
60	505	13440	2205	25970	350	427	10	*	‡	*	43000
59	246	8460	1562	16413	400	512	5	*	‡	*	27200
†	152	6260	400	10660	35	476	—	—	—	1	18000
61	188	6120	657	11070	—	632	20	*	‡	*	18700
54	209	7360	647	14370	—	579	5	*	‡	*	21800

TABLE 13.—*Arbuckle brine data with chemical analyses, continued*

Pool	County	Location Sec.	T.	R.	Brine (bbls. day)	Depth to horizon	Disposal method	Sp. Gr. (60° F.)	Sample number
Chase	Rice	21	19	9W	385	3250	Deep well	1.017	53
do.	do.	5	20	9W	1500	3250	Deep well	1.020	52
do.	do.	18	20	9W	360	3380	Pond	1.020	51
do.	do.	19	20	9W	—	3384	—	—	†
Keesling	do.	10	20	9W	100	3230	Pond	1.020	49
do.	do.	16	20	9W	900	3260	Pond	1.018	50
Silica	do.	33	19	10W	1224	3300	Deep-well	1.022	56
do.	do.	34	19	10W	—	3297	Pond	1.022	58
Stoltenberg	Ellsworth	1	17	10W	3000	3270	Pond	1.026	63
Bloomer	do.	31	17	10W	100	3240	Pond	1.020	65
do.	do.	33	17	10W	6	3800	Pond	1.024	71
do.	do.	36	17	11W	50	3280	Pond	1.031	67
Silica	Barton	1	20	11W	900	3200	Deep well	1.020	55
do.	do.	12	20	11W	900	3300	Deep well	1.020	64
Kraft-Prusa	do.	17	16	11W	240	—	Pond	1.020	72
do.	do.	33	16	11W	115	3350	Pond	1.020	70
Hall-Gurney	Russell	24	14	13W	120	3200	Pond	1.027	95
St. Johns	Stafford	28	24	13W	15	4200	Pond	1.035	178
Ainsworth	Barton	33	16	13W	200	3400	Deep well	1.022	103
do.	do.	26	18	13W	—	3380	Pond	1.022	102
Trapp	do.	8	16	13W	30%	3300	Pond	1.028	101
do.	do.	29	15	13W	300	3300	Pond	1.032	99
Sellens	Russell	26	15	13W	350	3300	Deep well	1.029	100
Russell	do.	27	13	14W	100	3290	Deep well	1.024	75
do.	do.	33	13	14W	70	3290	Pond	1.022	106
Ochs	Russell	24	15	14W	—	3350	—	—	†
Trapp	do.	25	15	14W	100	3325	Pond	1.033	98
do.	do.	36	15	14W	—	3400	Pond	1.028	104
Atherton	do.	30	13	14W	100	3200	Deep well	1.023	107
North Trapp	do.	8	13	15W	300	3000	Pond	1.032	96
Beemis	Ellis	12	11	17W	130	3350	Deep well	1.045	87
do.	do.	14	11	17W	80	3396	Pond	1.044	88
Shutts	do.	5	12	17W	150	3600	Pond	1.037	90
Burnett	do.	24	11	18W	little	3150	Pond	1.115	89

TABLE 14.—*Topeka, Hoover, Stalnaker, Layton, Peru, Gorham, and New Albany brine data with chemical analyses*

Topeka	Oxford	Sumner	14	32	2E	75	1300	Deep well	1.140	145
Hoover	do.	do.	14	32	2E	75	1700	Deep well	1.140	146
Stalnaker	do.	do.	14	32	2E	870	2100	Deep well	1.155	142
Layton	do.	do.	14	32	2E	100	2400	Deep well	1.158	144
Peru	Sedan	Chautauqua	12	33	10E	50	1400	Pond	1.090	148
Peru	Hittle	Cowley	24	31	4E	little	2400	Pond	1.135	116
Gorham	Hall-Gurney	Russell	31	14	13W	30-40%	3300	Pond	1.024	93
Gorham	Gorham, East	do.	2	14	15W	—	3250	Deep well	1.045	77
Gorham	do.	do.	11	14	15W	Much	3257	Pond	1.028	82
New Albany	New Albany	Elk	3	29	13E	25	550	Creek	1.055	149

All chemical analyses in milligrams per liter. To convert to parts per million, divide by specific gravity of the brine. * denotes a concentration of less than 1 milligram per liter; ‡ denotes a concentration of less than 25 milligrams per liter; † denotes analyses supplied by private companies; all other analyses were made by R. Q. Brewster and Calvin Vander Werf at the University of Kansas.

Sample number	Magnesium (Mg)	Sodium (Na)	Calcium (Ca)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)	Bromide (Br)	Iodide (I)	Aluminum (Al)	Iron (Fe)	Total solids
53	288	7520	994	14090	—	507	5	*	‡	*	23400
52	299	7540	1304	14650	75	411	5	*	‡	*	24300
51	227	6660	860	12310	70	510	5	*	‡	*	20600
†	167	6484	917	11000	1340	351	—	—	—	—	20200
49	273	8910	788	15830	55	577	5	*	‡	*	26400
50	229	7000	761	12700	—	507	—	*	‡	*	21200
56	317	8690	1258	16550	80	344	—	*	‡	*	27200
58	301	8180	1078	15280	500	519	5	*	‡	*	25400
63	526	8750	2062	18820	625	394	25	*	‡	*	31200
65	281	7710	1190	14494	475	489	—	*	‡	*	24600
71	445	7780	1370	15380	675	264	10	*	‡	*	26000
67	649	14100	2360	27500	550	581	30	*	‡	*	44800
55	287	7900	1041	14916	—	181	—	*	‡	*	24300
64	338	7980	1203	15030	525	497	25	*	‡	*	25600
72	310	6330	1180	12515	—	696	10	*	‡	*	21300
70	296	6950	1270	13365	525	605	10	*	‡	*	23000
95	600	10900	2095	23031	650	269	15	*	‡	*	37600
178	500	10230	2335	32207	2200	378	*	*	‡	*	47900
103	399	7790	1580	16537	450	444	*	*	‡	*	27200
102	340	8550	1595	17616	625	474	*	*	‡	*	29200
101	460	10850	1550	20360	250	690	*	*	‡	*	34200
99	618	13050	2370	27042	180	660	*	*	‡	*	43900
100	618	11840	2260	26270	300	312	*	*	‡	*	41600
75	316	8750	715	15550	250	498	5	*	‡	*	26100
106	479	8800	1910	19060	300	532	—	*	—	*	31100
†	425	12106	2142	22000	2227	501	—	—	—	31	39500
98	585	15050	2575	25763	160	588	*	*	‡	*	44700
104	545	12100	1690	23870	275	720	*	*	‡	*	39200
107	420	7400	1780	16449	325	786	*	*	‡	*	27200
96	708	12380	2470	26383	150	692	17	*	‡	*	42800
87	804	18400	3120	37430	125	294	35	*	107	5	60500
88	766	17720	2660	35410	135	402	20	*	‡	*	57100
90	615	15550	2500	31110	700	324	*	*	‡	*	50800
89	3110	52000	10990	112670	75	144	77	*	248	6	179300

145	2400	65000	9410	127530	2100	72	180	4	220	4	206900
146	2515	67500	9415	131874	1400	36	280	2	290	8	213300
142	2620	71100	11100	141072	‡	24	120	2	710	12	226800
144	3960	75000	11820	152162	‡	72	180	2	321	3	243500
148	1840	40500	6910	82962	‡	54	90	4	115	5	132500
116	2610	68700	11300	138884	50	24	*	*	371	5	221900
93	450	10950	1150	19452	275	513	10	*	‡	*	32800
77	1030	17060	3960	35950	625	750	10	*	‡	*	59300
82	624	8300	1370	17075	50	841	5	*	‡	*	28400
149	1750	26800	2880	51164	50	186	30	8	170	2	83000

both. The chemical reactions represented by the first two processes are shown in the following equations:

1. $MgCl_2 + CaO + H_2O = Mg(OH)_2 + CaCl_2$.
   magnesium chloride + lime + magnesia + water = magnesium hydroxide + calcium chloride.

2. $MgCl_2 + CaO + MgO + 2H_2O = 2Mg(OH)_2 + CaCl_2$
   magnesium chloride + lime + magnesia + water = magnesium hydroxide + calcium chloride

The magnesium hydroxide, $Mg(OH)_2$, is an amorphous substance that is more than twice as heavy as metallic magnesium. It may be shipped to other plants for further processing or it may be further treated at the recovery plant, as outlined in the following pages.

Magnesium oxide or magnesia, MgO.—The basic magnesium hydroxide when calcined or dehydrated is converted into magnesium oxide, MgO, which is a white powder, very soft and light. Commercially it is known as magnesia. This chemical substance may be had on the market in various forms which depend upon the temperatures at which the magnesium hydroxide was calcined (table 15).

TABLE 15.—*Forms of magnesium oxide or magnesia and the temperatures at which they are formed*

Product	Temperature (degrees C.)
"Caustic" magnesia	700-1,200
"Dead-burned" or sintered magnesia	1,400-1,560 (in presence of iron) 1,400-1,600 (absence of impurities)
Artificial periclase	1,700 and above
Magnesia brick	1,700 and above

The products in table 15 are also called "caustic" and "calcined magnesite." The chemical reaction involved in the formation of magnesium oxide from magnesium hydroxide is represented by the following chemical equation:

$Mg(OH)_2 + heat = MgO + H_2O$.
magnesium hydroxide + heat = magnesia + water

Magnesium chloride, $MgCl_2$.—Although magnesium is present in the brine chiefly in the form of the chloride; nevertheless, in order to obtain it, it is necessary first to convert the magnesium chloride into either the hydroxide or oxide as mentioned above and then precipitate magnesium chloride by dissolving the hydroxide or oxide in hydrocloric acid. The chemical reactions are as follows:

$$Mg(OH)_2 + 2HCl = MgCl_2 + 2H_2O$$

magnesium hydroxide + hydrochloric acid = magnesium chloride + water

Magnesium chloride is the substance from which metallic magnesium is derived by electrolysis.

Magnesium chloride may be had commercially in the form of a hydrous crystalline salt, $MgCl_2.6H_2O$, as a partially dehydrated flaky material, and also in the anhydrous state.

Magnesium sulphate, $MgSO_4$.—Magnesium hydroxide or magnesium oxide treated with sulphuric acid results in the formation of magnesium sulphate, according to the following chemical reactions:

$$Mg(OH)_2 + H_2SO_4 = MgSO_4 + 2H_2O$$

magnesium hydroxide + sulphuric acid = magnesium sulphate + water

$$MgO + H_2SO_4 = MgSO_4 + H_2O$$

magnesium oxide + sulphuric acid = magnesium sulphate + water

Magnesium sulphate is found in salt beds and in a number of hydrous varieties, chief of which is Epsom salt, $MgSO_4.7H_2O$. Epsom salt is a soft, highly soluble, colorless to white mineral having a bitter salty taste. It occurs commonly as granular, fibrous, or earthy masses. Kieserite, $MgSO_4.H_2O$, kainite, $MgSO_4.KCl.3H_2O$, and schoenite, $K_2SO_4.MgSO_4.6H_2O$, are other hydrous magnesium sulphate salts of commercial importance. These are associated with the world-famous Stassfurt salt deposits in Germany.

Magnesium carbonate, $MgCO_3$.—Magnesium carbonate, $MgCO_3$, which occurs in nature in the form of the mineral magnesite, is produced chemically by treating magnesium chloride or magnesium sulphate with sodium bicarbonate.

$MgCl_2 + 2NaHCO_8 = MgCO_3 + 2NACl + H_2O + CO_2$
magnesium chloride + sodium bicarbonate = magnesium carbonate
+ sodium chloride + water + carbon dioxide

$MgSO_4 + 2NaHCO_3 = MgCO_3 + Na2SO_4 + H_2O + CO_2$
magnesium sulphate + sodium bicarbonate = magnesium carbonate
+ sodium sulphate + water + carbon dioxide

Magnesium carbonate is an infusible, glassy to earthy substance, colorless to white, yellow, brown, or blackish. It is brittle and breaks with a conchoidal fracture. In the form of the mineral, it usually occurs as a granular, compact, or unglazed porcelain-like earthy mass.

Magnesium silicate, $2H_2Mg_3\ Si_4O_{12}$.—Magnesium chloride or magnesium sulphate when treated with sodium silicate yields magnesium silicate, a substance in composition similar to that of the mineral talc, $H_2Mg_3Si_4O_{12}$. This substance is useful in various ways as indicated elsewhere in this report.

$6MgCl_2 + 8Na_2SiO_3 + 4H_2O = 2H_2Mg_3Si_4O_{12} + 12NaCl + 4NaOH$

magnesium chloride + sodium silicate + water = magnesium silicate
+ sodium chloride + sodium hydroxide

$6MgSO_4 + 8Na_2SiO_3 + 4H_2O = 2H_2Mg_3Si_4O_{12} + 6Na_2SO_4 + 4NaOH$

magnesium sulphate + sodium silicate + water = magnesium silicate
+ sodium sulphate + sodium hydroxide

Magnesium silicofluoride, $MgSiF_6$.—Magnesium hydroxide or magnesium oxide treated with hydrosilicofluoric acid yields a water soluble, white, crystalline powder known as magnesium silicofluoride.

$Mg(OH)_2 + H_2SiF_6 = MgSiF_6 + 2H_2O$
magnesium hydroxide + hydrosilicofluoride = magnesium silicofluoride
+ water

$MgO + H_2SiF_6 = MgSiF_5 + H_2O$
magnesium oxide + hydrosilicofluoride = magnesium silicofluoride
+ water

Uses of Metallic Magnesium and its Compounds

Metallic magnesium, Mg.—Metallic magnesium has been used largely as a deoxidizing and desulphurizing agent in the manufacture of alloys, especially aluminum. It is used in making castings for aircraft parts, such as crankcases, pistons, oil-pans, bearings, and control levers. It is used in the manufacture of motion picture machines, field glasses, microscopes, and surveying and other scientific instruments. Magnesium is an important ingredient in incendiary bombs, military flares, flashlight powders, pyrotechnics, tracer bullets, and shells. It is used in the making of optical mirrors, electric batteries, and numerous other articles.

Magnesium oxide or magnesia, MgO.—Magnesium oxide or magnesia has been used extensively in making refractories and magnesia cements. It is also important in the manufacture of crucibles, furnace linings, and insulating and fireproofing compounds. Magnesia is an ingredient in face powder and toilet preparations, as well as in paints and varnishes. It is used in medicine and it is found in mineral waters.

Magnesium chloride $MgCl_2$.—Magnesium chloride is the substance from which, by electrolysis, metallic magnesium is derived. It is used in making hydrochloric acid, magnesia cements, stucco, flooring and fire-extinguishing compounds, and ceramic materials. It is also an ingredient in medicine. It has many other uses.

Magnesium sulphate, $MgSO_4$.—Like magnesium chloride, magnesium sulphate is used in ceramics, dyeing, and medicine. It is used in manufacturing printing ink, frosted paper, matches, motion picture snow, and explosives. It is used in fertilizers, tanning, sizing paper, and fireproofing and waterproofing textiles.

Magnesium carbonate, $MgCO_3$.—Magnesium carbonate is used largely in making refractories and, in general, fire-resisting materials. It goes into the making of cosmetics, tooth-paste, varnishes, paints, printing ink, fertilizers, linoleum, oilcloth, and many other substances. It is also used in medicine.

Magnesium silicate, $2H_2Mg_3Si_4O_{12}$.—Magnesium silicate is used in paints, lacquers, and varnishes, in ceramics, refractories, rubber compounding, and as an oil-bleaching agent.

Magnesium silicofluoride, $MgSiF_6$.—Magnesium silicofluoride is used in ceramics. It is also an ingredient in insecticides. It is employed in hardening and waterproofing concrete.

Sources of Required Processing Materials

Calcined limestone (quicklime), or calcined dolomite, and fuel are the basic raw materials needed in the extraction of magnesium compounds from oil field brines. The practicability of magnesium extraction is, therefore, directly related to the availability of these basic raw materials or to the cost of the substance to the producer at the processing plant. Fortunately, limestone, including chalk, is abundant in Kansas and, in most cases, is close to the oil fields (fig. 2). Dolomite, which could be used instead of limestone, is available in limited quantities in Rice, Reno, and Kingman counties, where the Stone Corral dolomite crops out, and in Clark county where the Day Creek dolomite occurs.

At the present time there are no lime kilns operating in the state, although in former years lime kilns were not uncommon. Calcined limestone or quicklime is manufactured, however, in connection with the making of Portland cement at six plants now operating in Kansas. The Portland cement plants are located mainly in eastern Kansas, not too distant from the oil fields, at Bonner Springs, Wyandotte county; Iola and Humboldt, Allen county; Chanute, Neosho county; Fredonia, Wilson county; and Independence, Montgomery county (fig. 3). It is conceivable and not unreasonable that quicklime plants might easily be established in the chalk area of western Kansas close to the important oil fields of that part of the state.

Sufficient cheap fuel in the form of natural gas or fuel oil is available in most of the oil fields, or is within easy reach. In eastern Kansas, sufficient coal resources are at hand to replace the gas or oil for fuel if necessary. Apparently there is no necessity for shipping in from great distances the required processing materials, and certainly there is no need for shipping from outside of the state.

Costs

It is impossible to calculate the actual cost involved in establishing a plant designed to process the oil field brines for magnesium. In general, the cost of the brine should not be charged against the recovery of the magnesium when the brine is a waste product pumped up with the oil and when the extraction plant is operated in connection with oil production. The only legitimate cost involved, so far as the brine is concerned, is for pipe lines to be used in transporting the brine from a number of leases to a central recovery plant. In cases where brine is specifically produced as a raw material and is not related to oil production, the cost of drill-

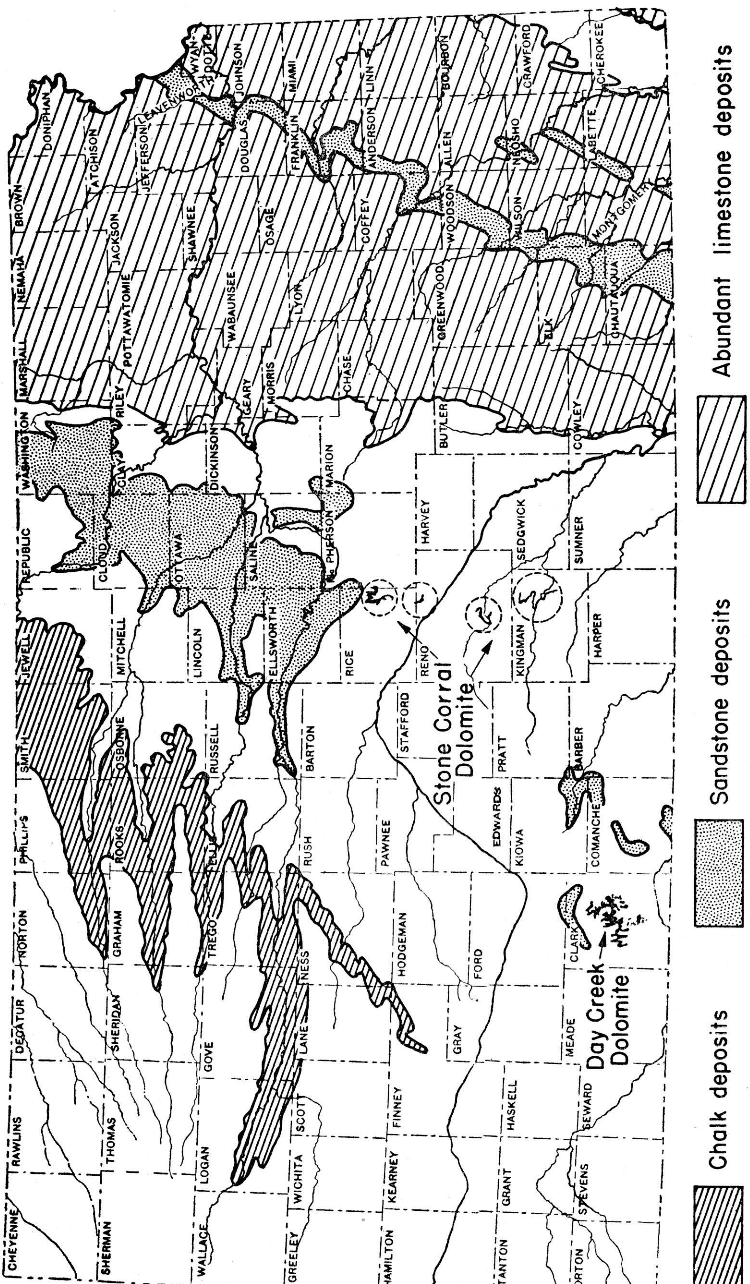


FIG. 2. Map of Kansas showing location of areas of abundant limestone, chalk, and dolomite, basic raw materials needed in magnesium recovery from brines. After J. M. Jewett.

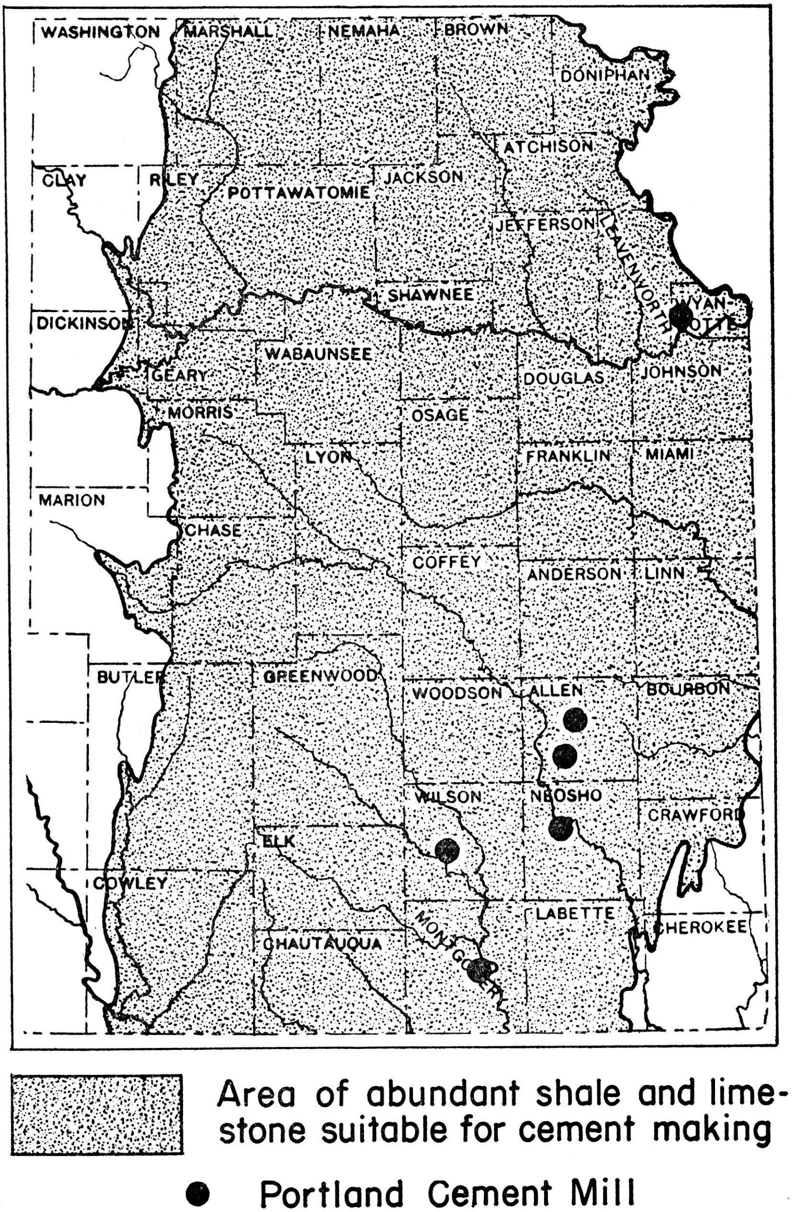


FIG. 3. Map of eastern Kansas showing location of Portland cement mills, possible sources for calcined limestone needed in the recovery of magnesium from brines. After J. M. Jewett.

ing both brine well and disposal well, as well as producing and disposing of the brine, will necessarily have to be charged against the cost of recovering the magnesium. Burwell (1942) summarized the cost of a brine-treating plant as follows:

A. Cost of construction of the brine-treating and magnesium recovery plant.
B. Amortization of equipment and buildings.
C. Cost of brine (if produced or purchased for extraction only).
D. Cost of power, water, and fuel.
E. Cost of labor.
F. Overhead.

Other items involved are the cost of the quicklime or calcined dolomite—costs that are variable with location of the recovery plant and source of raw materials.

Prices of Magnesium and Its Compounds

In 1942, metallic magnesium sold at 22½ cents per pound, or at 450 dollars per ton. The price of other magnesium compounds in 1942, according to Burwell, are listed in table 16.

TABLE 16.—*Prices per ton of magnesium compounds in 1942*

Magnesium oxide, powdered	$ 58.75
Magnesium oxide, U. S. P. light	400.00
Magnesium oxide, heavy	500.00
Magnesium chloride, flake, 97% $MgCl_2.6H_2O$	32.00
Magnesium chloride, anhydrous	260.00
Magnesium sulphate, technical	36.00
Magnesium sulphate, U. S. P.	40.00
Magnesium carbonate, precipitated, technical	125.00
Magnesium carbonate, precipitated, U. S. P.	180.00
Magnesium silicofluoride, technical	400.00

Factors Affecting Magnesium Recovery from Oil Field Brines

The commercial practicability of recovering magnesium from oil field brines, aside from the cost of erecting and maintaining a recovery plant, is dependent upon several factors: (1) the magnesium content of the brine, (2) the amount of brine produced per well, (3) the total number of wells producing brine in the field, (4) the number of days per year the wells are producing, (5) the presence or absence of deep disposal wells, (6) the selling price of the recovered magnesium or its compounds, and (7) special chemical characteristics of the brine that would either inhibit or aid magnesium recovery.

At present, magnesium is being profitably extracted from ordinary sea water which has a magnesium content varying from 1,040 to approximately 1,400 milligrams per liter. Many of the Kansas oil field brines (tables 5 to 14) not only have a magnesium content equal to that of ocean water, but some of them have a much greater content, in some cases as much as double or triple the amount. So far as the magnesium content is concerned, many of the Kansas oil field brines qualify for magnesium recovery.

Important as the magnesium content of a brine may be, it is, nevertheless, of little value for commercial magnesium recovery unless sufficient brine is produced. This relationship of high magnesium content to volume of brine produced is well illustrated by the brines coming from the Kansas City-Lansing formations. Brines produced from this pay zone have practically the highest magnesium content of any of the Kansas oil field brines (table 4). Analyses of the samples collected (table 5) show a magnesium content varying from 972 to 3,910 milligrams per liter, with an average of 2,525 milligrams. So far as the magnesium content is concerned, the Kansas City-Lansing brines are very favorable for magnesium extraction. The amount of brine produced from wells drilled into this formation, however, is insignificant. Many of them produce practically no brine and most yield less than 20 barrels per day. In a few cases some of the wells furnish from 60 to 150 barrels of brine per day. Such wells, however, are exceptional. Table 17 has been prepared to show the minimum number of barrels of brine required to produce 2,000 pounds of metallic magnesium (or 6,840 pounds of magnesium chloride) from brines containing from 1,000 to 3,500 milligrams of magnesium per liter.

The number of barrels of brine required to furnish 2,000 pounds of metallic magnesium varies inversely with the milligrams per liter magnesium content of the brine. In other words it takes a smaller number of barrels of brine to produce a given amount of metallic magnesium from a high magnesium brine that it does from one low in that constituent.

Since a large amount of brine is necessary to insure the success of a recovery plant, and since chloride and other constituents are not removed, it follows that provision must be at hand for the disposal of the brine after the magnesium has been extracted. The most satisfactory means of disposing of the processed brine is by means of deep disposal wells. In many of the Kansas oil fields, deep disposal wells are now in existence; especially is this true in the oil fields of western Kansas. In such cases there would be practically no added cost in disposing of the waste brine.

The selling price of magnesium or its compounds is another factor to be considered in establishing a magnesium recovery plant. The many uses to which magnesium and its compounds are adaptable, together with the growing demand for these substances, are certain to insure a fair selling price, not only during the war emergency but also in the future. Prices of magnesium and its compounds for 1942 are listed on page 67 of this report. It should be recognized that magnesium recovery from Kansas oil field brines is not on a competitive basis with larger establishments erected solely for the purpose of securing magnesium or its compounds. It is probable that Kansas oil field brines can never yield magnesium as more than a by-product of oil production. Such a by-product industry might pay the cost of brine disposal although showing little or no profit in itself. As an illustration, during the past five years, more than 6,863,100 barrels of brine having a magnesium content of 3,199 milligrams per liter have passed through a single disposal system in the Burrton oil field in Reno county. One barrel of such brine contains 1.123 pounds of metallic magnesium. On that basis, 7,707,261.3 pounds, or 3,853.6 tons, of metallic magnesium were returned to the underground strata during a five-year period. On the basis of the 1942 price, this amount of magensium has a value of $1,734,120.

Possible Magnesium Recovery Plants in Kansas Oil Fields

High magnesium content, a large volume of brine, and the existence of deep disposal wells make several oil fields in Kansas worthy of study for possible establishment of magnesium recovery plants. Only those oil fields that theoretically could yield 1,000 tons of metallic magnesium annually are considered. The oil fields most worthy of consideration on the basis of the data at hand are: Burrton field, Reno county; Bornholdt field, McPherson county; Zenith field, Stafford and Reno counties; Welch field, Rice county; Hall-Gurney field, Russell county; and Oxford field, Sumner county. Data pertaining to these fields are summarized in table 18.

TABLE 17.—*Number of barrels of brine required to produce 2,000 pounds of metallic magnesium*

Mg. (milligrams per liter)	Barrels	Mg. (milligrams per liter)	Barrels
1,000	5,700	2,300	2,478
1,100	5,181	2,400	2,372
1,200	4,755	2,500	2,278
1,300	4,381	2,600	2,191
1,400	4,065	2,700	2,110
1,500	3,802	2,800	2,033
1,600	3,559	2,900	1,967
1,700	3,350	3,000	1,900
1,800	3,165	3,100	1,838
1,900	3,000	3,200	1.781
2,000	2,850	3,300	1,727
2,100	2,714	3,400	1,676
2,200	2,587	3,500	1,629

The calculated tonnage of metallic magnesium given in table 18 is only of relative and comparative value and is based upon two assumptions. In computing the total amount of brine produced in any given field during the year, it was assumed that the wells were pumped daily and at the same rate throughout the period. The amount of brine is, therefore, a variable factor and can be computed accurately only from actual pumping data. The amount of brine in barrels per year in the table is accordingly too high. In ascertaining the amount of metallic magnesium in a barrel of brine, as well as the potential yield, the specific gravity of the brine was taken as 1. On the basis of the chemical analyses, of the brine was taken as 1. On the bisis of the chemical analyses, the specific gravity ranged from 1.014 to 1.159. If the latter variable specific gravities had been used instead of 1, the metallic magnesium content per barrel would be higher than those indicated in the table. Consequently, the theoretical yield of metallic mag-

Table 18.—*Summary of data pertaining to Kansas oil fields worthy of further study for the possible establishment of magnesium recovery plants*

Field	County	Horizon	Producing wells	Theoretical brine production per year (barrels)	Disposal wells	Average Mg. content (milligrams per liter)	Average metallic Mg. content (per barrel)	Theoretical yield (tons)	
								Metallic Mg.	Anhydrous $MgCl_2$
Burrton	Reno	"Chat"	335	550,420,000	14	2,263	0.773	212,737.3	858,655.2
Bornholdt	McPherson	"Chat"	150	23,118,750	2	1,516	0.526	6,080.2	24,043.5
Zenith	Stafford Reno	Simpson Viola	301	21,973,000		1,275	0.448	4,922.0	19,336.7
Welch	Rice	"Chat"	24	11,826,000	1	1,395	0.492	2,909.2	11,471.2
Oxford	Sumner	Topeka Hoover Stalnaker Layton	19	4,401,900	1	2,874	1.000	2,200.9	8,759.7
Hall-Gurney	Russell	Kansas City- Lansing	396	2,168,100		2,912	1.010	1,094.8	4,368.7

nesium would have been increased correspondingly. It must also be pointed out that not all of the metallic magnesium as given in the table can be extracted from the brine in the recovery process.

Burrton oil field.—The Burrton oil field is chiefly in Reno county east of Hutchinson in T. 22, 23, and 24 S., R. 4 W. The pool extends into Harvey county in T. 23 S., R. 3 W. Production is mainly from the Mississippian "chat" and from the "Hunton." Four brine samples were collected, each one of which showed on analysis a magnesium content of over 2,000 milligrams per liter (table 8). The brine originated in the "chat" at a depth varying between 3,300 and 3,400 feet. Data relative to the amount of brine produced were obtained from only one well, the Sinclair-Prairie well in sec. 15, T. 24 S., R. 4 W. This well is reported to yield 4,000 barrels of brine per day. Should the other "chat" wells, 335 in number, produce an equal volume of brine, the field would produce yearly 550,420,000 barrels of brine, exclusive of the salt water yielded by the 72 "Hunton" wells in the field. On the basis that the magnesium content of the 550,420,000 barrels of brine is the same as the average of the four samples collected and analyzed (2,263 milligrams per liter) and that each barrel of brine contains 0.773 pounds of metallic magnesium (table 19), the Burrton "chat" well brines capable of being produced during the year would contain 21,273.7 tons of metallic magnesium. At the 1942 price, 21,273.7 tons of metallic magnesium are worth $9,573,165. At the present time, there are 14 disposal wells now in use in the Burrton field (table 20) with two disposal associations operating. The North Burrton Disposal Association, operated by the Sinclair-Prairie Company, takes care of much of the brine in the north part of the field; whereas, the South Burrton Disposal Association, operated by the Sinclair-Prairie and Barnsdall companies, disposes of the brines in the south end of the field. The disposal wells are distributed in twelve different sections, six in T. 23 S. and six in T. 24 S.

The available data suggest that the Burrton oil field offers the best possibilities for magnesium recovery of any field studied. The other oil fields studied are listed, however, because further study may reveal the practicability of using their brines for magnesium recovery, at least to the extent of offsetting the cost of present brine disposal. Any fields theoretically capable of producing ap-

TABLE 19.—*Metallic and other magnesium content of one barrel of brine (42 gal.)*

Mg. (milligrams per liter)	Metallic Mg. (lbs.)	$MgCl_2$ (Anhydrous) (lbs.)	$Mg(OH)_2$ (lbs.)	MgO (lbs.)
1,000	0.351	1.39	0.848	0.582
1,100	0.386	1.52	0.926	0.640
1,200	0.421	1.66	1.010	0.698
1,300	0.456	1.80	1.094	0.756
1,400	0.492	1.94	1.180	0.816
1,500	0.526	2.08	1.262	0.873
1,600	0.562	2.22	1.348	0.932
1,700	0.597	2.36	1.432	0.932
1,800	0.632	2.50	1.516	0.991
1,900	0.667	2.64	1.600	1.049
2,000	0.702	2.78	1.684	1,107
2,100	0.737	2.92	1.768	1.165
2,200	0.773	3.05	1.855	1.223
2,300	0.807	3.19	1.936	1.283
2,400	0.843	3.33	2.023	1.339
2,500	0.878	3.47	2.107	1.457
2,600	0.913	3.61	2.191	1.515
2,700	0.948	3.75	2.275	1.573
2,800	0.984	3.86	2.361	1.633
2,900	1.017	4.02	2.440	1.688
3,000	1.053	4.16	2.527	1.747
3,100	1.088	4.30	2.611	1.806
3,200	1.123	4.43	2.695	1.864
3,300	1.158	4.57	2.779	1.922
3,400	1.193	4.75	2.863	1.980
3,500	1.228	4.85	2.947	2.038

proximately 1,000 tons of metallic magnesium annually are considered.

The Bornholdt oil field.—The Bornholdt oil field is in McPherson and Rice counties. The major part of the field is in T. 20 S., R. 5 W., McPherson county. In 1941, there were 150 wells in the field, all producing from the "chat" at a depth of around 3,340 feet. Three brine samples were collected from this field (table 8). The average magnesium content of the brines analyzed is 1,517 milligrams per liter, somewhat higher than average sea water. Data as to the amount of brine produced were obtained from two of the wells. The average volume produced was 425 barrels per day. At that rate the 150 wells in the field would produce annually

TABLE 20.—*Disposal wells now in use in the Burrton oil field*

Company or operator	Location	
Lloyd, Frost, and Study	SE	2-23-4W.
Ledo and Wilcox	W½ SW NW	12-23-4W.
Barnsdall	NW SE SE	11-23-4W.
Sinclair Prairie	SE NE SE	14-23-4W.
North Burrton Disposal Association (Sinclair-Prairie)	NW NW NE	14-23-4W.
	NE NE SE	23-23-4W.
	NE NE SW	26-23-4W.
	NW NW SE	26-23-4W.
Skelly	S½ SW NW	2-24-4W.
Gulf	NW SE NW	3-24-W.
South Burrton Disposal Association (Sinclair-Prairie)	C NE NW	15-24-4W.
Texas	NW NW SE	17-24-4W.
South Burrton Disposal Association (Barnsdall)	NW SW	20-24-4W.
Nadel and Gussman	NW NE NW	30-24-4W.

23,118,750 barrels of brine. Since one barrel of brine having a magnesium content of 1,500 milligrams per liter (table 19) contains 0.526 pounds of metallic magnesium, the total potential volume of brine capable of being produced per year would contain 6,080.2 tons of metallic magnesium having a value of $2,736,090, based on the 1942 prices. There are at least two disposal wells in the field, one in sec. 25, T. 20 S., R. 6 W., and one in sec. 29, T. 20 S., R. 5 W.

Zenith oil field.—The Zenith oil field is in stafford and Reno counties and had, in 1941, 301 producing wells. Production is mainly in the Mississippian Misener formation and Viola limestone of Ordovician age. Four samples of brine were collected, one in Reno county and three in Stafford county (table 12). According to information received, production was from the Simpson formation at a depth of approximately 3,600 feet. Analyses showed that the brines had an average magnesium content of 1,275 milligrams per liter, or approximately the same as that of ordinary sea water. Two hundred barrels of brine were produced per day from the one well on which data were obtained (table 12). Should all the wells in the field produce at the rate of 200 barrels of brine per day, a total of 21,973,000 barrels of brine would be produced during the year. Even at the low magnesium content of this brine, it contains 4,922 tons of metallic magnesium which, on the 1942 basis of prices, would be worth $2,214,900. Four well-distributed disposal wells in the field now provide for disposal of much of the brine produced.

Welch oil field.—The Welch oil field is in Rice county. The 24 wells producing from the "chat" are theoretically capable of producing 11,826,000 barrels of brine annually. This volume of brine, on the basis of analyses (table 8), contains 2,909.2 tons of metallic magnesium. In 1942, 2,909 tons of metallic magnesium were valued at $1,309,050. At least one deep disposal well is located in the field.

Hall-Gurney oil field.—The Hall-Gurney oil field is in Russell county. In 1941, 396 wells were producing from the Kansas City-Lansing rocks. On the basis of three samples collected (table 5), the brine contains, on the average, 2,912 milligrams of magnesium per liter. In spite of the low production of brine per well per day, the calculated total brine production for the year amounts to 2,168,100 barrels. This volume of brine, because of the high metallic magnesium content per barrel (table 19), contains 1,094.8 tons of metallic magnesium, worth approximately half a million dollars.

Oxford oil field.—The Oxford oil field is in secs. 14 and 23, T. 32 S., R. 2 E., Sumner county. In 1941, 13 wells were producing from the Stalnaker formation, 6 from the Layton, and 21 from the Arbuckle. Four brine samples were collected, one each from the Topeka, Hoover, Stalnaker, and Layton pay zones (table 14). The samples came from the Amerada Petroleum Corporation wells, all of which were located in an area less than 10 acres in extent. The analyses showed an average magnesium content of 2,874 milligrams per liter. All of the non-Arbuckle wells in the field, if pumped daily, would produce, per year, 4,401,900 barrels of brine containing 2,200.9 tons of metallic magnesium worth approximately one million dollars. The volume of brine and, therefore, the metallic magnesium content could be increased materially if all or part of these wells penetrated all four of the pay zones, a possibility suggested by the offset wells from which some of the samples were collected. All of the brine of the sampled wells is returned into subsurface strata by means of a deep disposal well.

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