ABNORMAL SALT WATER PRESSURES ON THE TEXAS AND LOUISIANA COAST*

Harold Denton

The occurrence of abnormal salt-water flows, as well as abnormal gas pressures, has been more common on the Gulf Coast in the last few years, than at any other time in the history of Gulf Coast drilling. This increase in frequency of abnormal well pressures may be attributed to the present trend of deeper drilling depths. In general, most abnormal pressures on the Gulf Coast occur below depths of 7,500 feet, the exceptions being found in erratic sands on the penetrating type salt domes.

Definition of Abnormal Pressure.—Any bottom hole pressure, regardless of depth, that is greater than the pressure created by a corresponding column of salt water, may be classified as an abnormal pressure. Salt water exerts a pressure head of about .465 pounds per square inch at each foot depth. Average connate water on the Gulf Coast weighs approximately 9 pounds per gallon. The weight of natural Gulf Coast drilling muds vary between 9.4 and 10 pounds per gallon.

From the above data, it is obvious that perhaps many abnormal salt water sands, only slightly above the normal rock pressure, have been penetrated by the bit but have gone unnoticed at the mud discharge line. Especially is this true when weighted muds are used for purposes other than salt water flows. A salt water flow exists when the rock pressure of a water stratum is greater than the effective hydrostatic head of the mud column. The effective

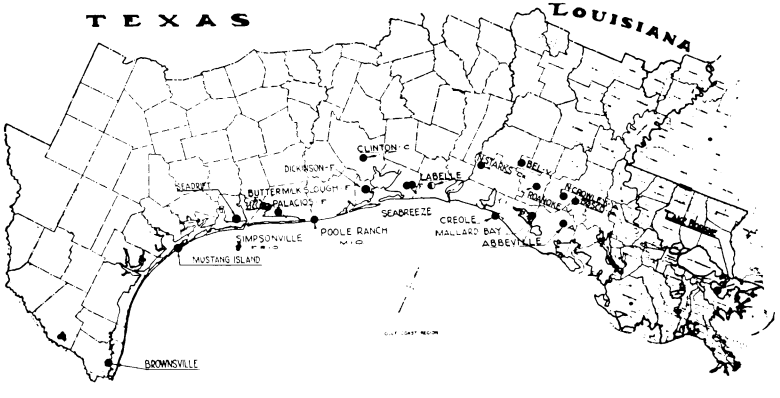
*Special acknowledgment is made to the Sun Oil Company for permission to prepare and present this paper. Assistance, both oral and written, was given by G. E. Cannon, R. W. Wilson, R. E. Dansby, J. Van Der Henst, F. R. Frederick, P. E. Chaney, C. B. Claypool, and Don B. Edwards. This help is sincerely appreciated as is the helpful criticism given by the following: R. W. Pack, C. B. Claypool, C. L. Bartlett, and P. E. Chaney of the Sun Oil Company; T. W. Pew, General Crude Oil Company; and E. W. Louden, Pure Oil Company.

hydrostatic head of the mud column may be less than the theoretical hydrostatic head. Swabbing the hole, when withdrawing the drill pipe, may lower the theoretical hydrostatic head to such an extent that it may permit entrance of an abnormal pressure salt water into the bore hole. The water flows from the porous stratum into the bore hole because of this differential pressure.

If the depth of an abnormal pressure and its magnitude could be known before it was encountered by the bit, the chances of successfully controlling a salt water flow would be materially enchanced. The mud weight could be built up before encountering the high pressure, but on wildcat wells, abnormal pressures cannot be anticipated in advance.

Distribution of Salt Water Flows on the Gulf Coast

Attention is called to the map below of the Texas and Louisiana Gulf Coast showing the geographic distribution,



and in some instances, the geologic age of several known abnormal salt water flows. With the exception of Palacios and Buttermilk Slough, which are abnormal gas pressure areas, all those mapped have encountered abnormal salt water pressures. However, in all cases, gas was associated with the abnormal salt water flows. There has been no attempt to make the abnormal gas pressure list complete.

Texas Gulf Coast.—In Texas, several cases of abnormal salt water flows have been found in the Frio sands at

depths below 8,000 feet. In general these Frio salt water flows have been encountered in a zone approximately 25 miles in width parallel to the Texas Gulf Coast from Brownsville to Sabine Pass. However, most Frio tests drilled below 8,000 feet in the above area, have not encountered abnormal pressure salt water sands. It has been impossible to correlate definitely abnormal pressure areas, though zones in which abnormal pressures may be expected can be mapped.

An interesting abnormal salt water pressure was found in a deep test in the Clinton Field, Harris County, Texas. This abnormal pressure was encountered in the Cookfield section below 8,500 feet. When the mud weight was allowed to get as low as 16 pounds per gallon, salt water would enter the hole; mud weights above 17 pounds per gallon would go back into the formation. It was impossible to keep a good filter cake on the wall of the hole because of the constant intrusion of salt water. At times this well made slugs of clear salt water. On the Poole ranch in southwest Matagorda County, a salt water flow was encountered in the Miocene below 7,000 feet.

Louisiana Gulf Coast.—In the southern portion of Louisiana, most of the high pressure salt water flows have been encountered between 9,400 and 12,000 feet. This zone of deep gas-salt flows, approximately 70 miles wide, parallels the Louisiana Gulf Coast. In the northern half of this zone most of the abnormal pressures are found in the Vicksburg or Alazan formations. In the southern half, several cases of abnormal water pressures are found at the top of the Oligocene.

A prolific Vicksburg salt water flow is found at Bel, Allen Parish, Louisiana, at a depth of about 7,750 feet. Up to 1938, this well which has been flowing since May, 1936, has produced about seven millions barrels of salt water. At North Starks, Calcasieu Parish, Louisiana, an abnormal salt water pressure was encountered in the Crockett formation at 9,480 feet. The sub-surface pressure at 9,480 was estimated to be above 7,400 pounds per square inch or 2,990

pounds above the normal. At 15 pound per gallon mud would not keep the salt water from entering the hole, yet a 15.5 pound mud would go back into the formation.

Bottom Hole Pressures of Abnormal Salt Water Flows

Salt water flows are usually encountered in an uncased hole while it is being drilled. Hence, production methods of determining bottom hole pressures by a bottom hole pressure bomb, or by a measurement of shut-in pressures, obviously cannot be used in an open hole.

The method used to compute botton hole pressures on the listed abnormal salt water flows is based on the principle of the U-tube. It is assumed that the maximum hydrostatic head of mud, which failed to prevent flow from the formation into the well bore, will be less than the rock pressure of the salt water stratum. This method is not altogether accurate, as it usually records bottom hole pressure values lower than they actually exist.

Abnormal Gas Pressures

Actual gauge measurements have been recorded on a few abnormal gas pressure wells on the Gulf Coast. The world's highest gauged surface pressure on an oil and gas well was recorded on a well in this area. When testing a sand at 9,250 feet, the tubing pressure on Sun Oil Company's Bayshore Farms No. 1, Palacios, Texas, was gauged at 6,300 pounds per square inch. It is estimated that the bottom hole pressure at 9,250 feet was about 7,950 pounds per square inch or about 3,654 pounds above normal.

Tubing pressures of 5,500 pounds per square inch have been gauged on gas-distillate wells in both the LaBelle Field, Jefferson County and the Buttermilk Slough Field, Matagorda County, Texas.

Theoretical Consideration

The fact that most abnormal pressures occur below a depth of 7,500 feet, supports the theory that overburden is a factor in producing abnormal pressures. A plausible explanation of excessive pressures is that below some depth, the strata cannot support the weight of the overburden

and are undergoing compaction. It appears that abnormal-pressure sands containing gas or fluid must be in poor communication with sands that are continuous to an outcrop either by lenticularity, or by being isolated by faulting against impervious beds.

Several abnormal salt water flows are found on known oil producing structures that are probable deep seated salt domes. This type of structure is characterized by graben and horst faults cutting the major structure into different fault segments. These segments may form independent oil, gas, or water traps, when pervious sands are faulted against impervious shale beds. Sands can lose communication with other sand bodies by block faulting.

Numerous strike faults of regional importance are found on the Gulf Coast that are downthrown downdip from the regional dip. These strike faults probably account for some of the abnormal pressures occurring in the Gulf Coast area.

The compressibility of water is negligible. Hence, a high pressure water flow with a fairly large volume has either an abnormal pressure gas sand associated with it in the same reservoir, or compaction is instantaneous with the abnormal flow. It seems doubtful that compaction is instantaneous with the withdrawal of a fluid from an abnormal pressure stratum. A more logical explanation is that an abnormal gas pressure is present in the same reservoir of most large-volume abnormal salt water flows. Hence, both abnormal gas pressure and abnormal salt water flows are perhaps directly related to some type of geologic trap.

Conclusions

A salt water flow should be stopped immediately by increasing the weight of the mud so that the hydrostatic head of the mud column will be greater than the rock pressure of the salt water stratum.

The abnormal pressures cannot definitely be correlated on the Gulf Coast. Only zones in which abnormal

TABLE I
ABNORMAL SALT WATER FLOWS—TEXAS GULF COAST

LOCATION	Depth Salt Water Flow	Formation	Weight Mud When Hit	Max. Mud Weight	REMARKS
LaBelle, Jefferson County	9,370	Frio	15.8	16.4	Lost mud formation at 16.4. 9⅝" casing set through Miocene sands.
Seabreeze, Chambers County	8,761 to 8,795	Frio	9.8	14.	Only surface casing set. Miocene sands open. Stuck pipe 9 days after flow at 8,375 feet. Abandoned.
Seabreeze, Chambers County	8,797 to 8,803	Frio	13.4	15.9	9⅝" casing set at 8,487'. Casing permitted carrying 15.9 mud. Well completed as oil well in upper Frio sand.
Willow Slough, Chambers County	9,019 to 9,055	Frio	10.0	11.3	Well temporarily abandoned 9,055. Reworked and completed in upper Frio sand.
Willow Slough, Chambers County	9,617 to 9,637	Frio	9.7	12.2	Only surface casing in hole. Lost 12.2 mud in hole. Unable to ream back to bottom. Well abandoned.
Simpsonville, Matagorda County	9,700	Frio	13.2	13.8	Salt water broke in hole after making trip at 9,777'. Chloride went from 1,600 to 4,750 parts per million.
Poole Ranch, Brazoria County	7,509	Miocene			Well blew out with drill stem out of hole. Flowed 9⅝ inch stream 170° salt water to crown block. Well bridged. Plugged and abandoned. T. D. 7,509'.
Clinton, Harris County	8,591	Cockfield		17.	Above 17# circulation was lost. Below 16# salt water would enter hole. At times well made slugs clear salt water.
Seadrift, Calhoun County	8,500	Frio	14.	16.	Silicate mud used on this hole.
Dickinson, Galveston County	8,850 to 9,000	Frio	13.0	15.	13.8 to 14.5 pound mud would not prevent salt water from entering hole.
Brownsville, Cameron County	6,150			11.5	
Brownsville, Cameron County	8,450			15.	Salt water would enter hole if weight got as low as 14.5 pound per gallon.
Mustang Island, East of Corpus Christi	7,732			13.	Salt water would flow into well bore with 13 pound mud in hole. Well abandoned.
North Kenedy County	9,400			14.5	Salt water would flow into well bore with 14.5 pound mud in hole. Well abandoned.

TABLE II
ABNORMAL SALT WATER FLOWS—LOUISIANA GULF COAST

LOCATION	Depth Salt Water Flow	Formation	Weight Mud When Hit	Max. Mud Weight	REMARKS
North Starks, Northwest Calcasieu Parish	9,445 to 9,480	Crockett	13.5	15.5	Only surface casing set 2,000 feet. Chloride content mud went from 670 to 8,240 parts per million. Lost circulation 15.5 lb. mud.
Bosco Field, South St. Landry Parish	10,210	Alazan		16.1	Well abandoned shortly after encountering salt water flow.
Roanoke Field, Jeff. Davis Parish	10,750	Vicksburg		16.1	7″ casing set 9,750′. Stuck drill pipe after salt water flow at 10,750 feet.
Abbeville, Vermilion Parish	11,909	Alazan	15.2		Blew out 11,909′. Flowed 15,000 bbls. salt water daily. Plugged back and perforated 7,884 to 7,890. Completed as oil well. 7⅝″ casing set 11,342.
North Crowley, Acadia Parish	10,602	Alazan	15.9	16.4	7¾″ casing set 9,500′. 16.4 lb. mud evidently killed flow.
Mallard Bay, Cameron Parish	10,146	Oligocene Discorbis	14.2		While circulating no evidence of salt water flow. When pump was shut down, mud flowed out discharge line indicating that if drill pipe were pulled a blow out would occur. Lost returns. Cemented drill pipe in hole and shot drill pipe off above cement plug.
Mallard Bay, Cameron Parish	9,445	Top Olig.	10.		2,000 feet surface casing set. Drill pipe was pulled up to 2,000′ prior to placing abd. plug. Well blew full nine-inch stream salt water with very little gas. Shut in pressure about 425 pounds.
Creole, Southern Cameron Parish	10,112	Top Oligocene			Heavy mud pumped into hole cut from 4 to 8 pounds per gallon by salt water dilution.
Creole, Southern Cameron Parish	9,394	Miocene Discorbis			The shut in pressure caused by an abnormal salt water flow reached a maximum of 1,250 pounds.
Lake Borgne, St. Bernard Parish	10,600		15.	15.6	Lost circulation with 15.6 pound mud. Set casing at 10,528′. Small amount of gas was associated with salt water flow. Used sodium silicate mud on this test. Sodium silicate mud was successful.
Bel Allen Parish	7,750	Vicksburg			Well has been flowing salt water since May, 1926

TABLE III

LOCATION	Depth of Flow	Normal Pressure At That Depth	Est. Actual Pressure	Est. Pressure Above Normal	Mud Wt. Water Would Enter Hole	Hydrostatic Head Per Ft., P. S. I. of Mud That Permitted Flow
Clinton, Texas	8,591'	4,000#	7,155#	3,155#	16 #	.833
Seabreeze, Texas	8,795'	4,092#	5,949#	1,875#	13 #	.676
Seabreeze, Texas	8,803'	4,095#	6,864#	2,769#	15 #	.780
Willow Slough, Texas	9,055'	4,210#	5,342#	1,132#	11.2#	.590
LaBelle, Texas	9,370'	4,371#	7,661#	3,290#	15.8#	.818
North Starks, La.	9,480'	4,408#	7,394#	2,986#	15 #	.780
Williow Slough, La.	9,637'	4,482#	6,015#	1,533#	12 #	.624
Simpsonville, La.	9,700'	5,510#	6,693#	2,183#	13.2#	.69
Mallard Bay, La.	10,146'	4,720#	7,410#	2,690#	14.1#	.73
Bosco, La.	10,210'	4,747#	7,964#	3,217#	15 #	.78
Lake Borgne, La.	10,600'	5,929#	8,374#	3,445#	15.2#	.79
North Crowley, La.	10,602'	4,930#	8,819#	3,890#	16 #	.832
Roanoke, La.	10,750'	5.000#	8,600#	8,600#	15.5#	.80
Abbeville, La.	11,909'	5,533#	9,282#	3,749#	15 #	.78

The depths and pressures of several abnormal pressure Gulf Coast salt water flows. The further the pressure points are to the right of the normal pressure gradient the greater is the magnitude of abnormality.

pressures may be expected can be mapped. Most of these zones occur below depths of 7,500 feet. In southern Louisiana abnormal pressures are more likely to be found at depths between 9,400 and 12,000 feet.

Salt water flows are probably related to some type of geological trap.

REFERENCES

G. E. Cannon and R. C. Craze: "Abnormal Pressures and Pressure Variations With Depth of Petroleum Reservoirs." *Petroleum Development and Technology* A. I. M. E. 1938, pp. 31-38.

Preston E. Chaney: "A Review of Recent Advances in Drilling-Mud Control." Paper presented at the 23rd National Meeting American Petroleum Institute, Chicago, November 10, 1942.