Cementing Practices for Salt Wells

Weldon Baker and
Dwight K. Smith
Halliburton Company
Duncan, Oklahoma

ABSTRACT

The cementing of wells for the recovery of salt is similar in many respects to that used for the recovery of oil. This paper reviews the latest techniques and equipment available for these applications.

A wide variety of cementing compositions is also available for use in wells. The blending of salt with cement for down hole applications has been found to produce many desirable properties. Salt in cement improves bonding to water sensitive sands and shales, increases density, functions as a dispersing agent and provides expansion within the set cement. The benefits of salt in cement are described in this presentation.

INTRODUCTION

Cementing operations on salt and evaporite wells utilize many of the precise and complex techniques which have been developed primarily for oil field operations. These techniques have been developed with the experience gained from more than 2, 600, 000 such cementing operations.

The basic principle of casing cementing consists of displacing a cement slurry down the casing so as to fill the annular space to a predetermined point in the well (Fig. 1). This slurry is forced into the annular space between the casing and the wall of the hole and allowed to set. The slurry is formed by mixing water with portland cement or with blends of portland cement and other materials.

The water-cement slurry is mixed with a jet-type mixer. This unit functions by pumping a stream of water through a jet, across the mixer bowl into a discharge line, then into a sump tub from which cement slurry is picked up by the cementing pumps (Fig. 1). The stream of water passing through the bowl pulls cement into the bowl from the hopper above, and as cement enters the stream of water it is thoroughly mixed in the turbulent flow occurring within the discharge pipe. The slurry density which is a measure of the water/cement ratio is controlled by the addition of water into the discharge pipe. Mixers of this type are capable of producing a slurry at a rate of up to 75 cu. ft. per minute. The cementing pumps used for displacement are capable of this rate at low pressure and pumps are also available with pressure limitations in excess of 15, 000 psi.

The most common purposes of cementing the casing are to help: (1) Protect potentially productive zones; (2) Form a seal to prevent contamination of fresh-water zones; (3) Control high pressure gas zones behind the casing; (4) Seal off zones of lost circulation or other troublesome formations to enable additional drilling; (5) Bond casing to formation; (6) Protect casing from corrosive waters, and reduce electrolytic currents; and (7) Protect surface and intermediate casing strings while drilling additional hole.

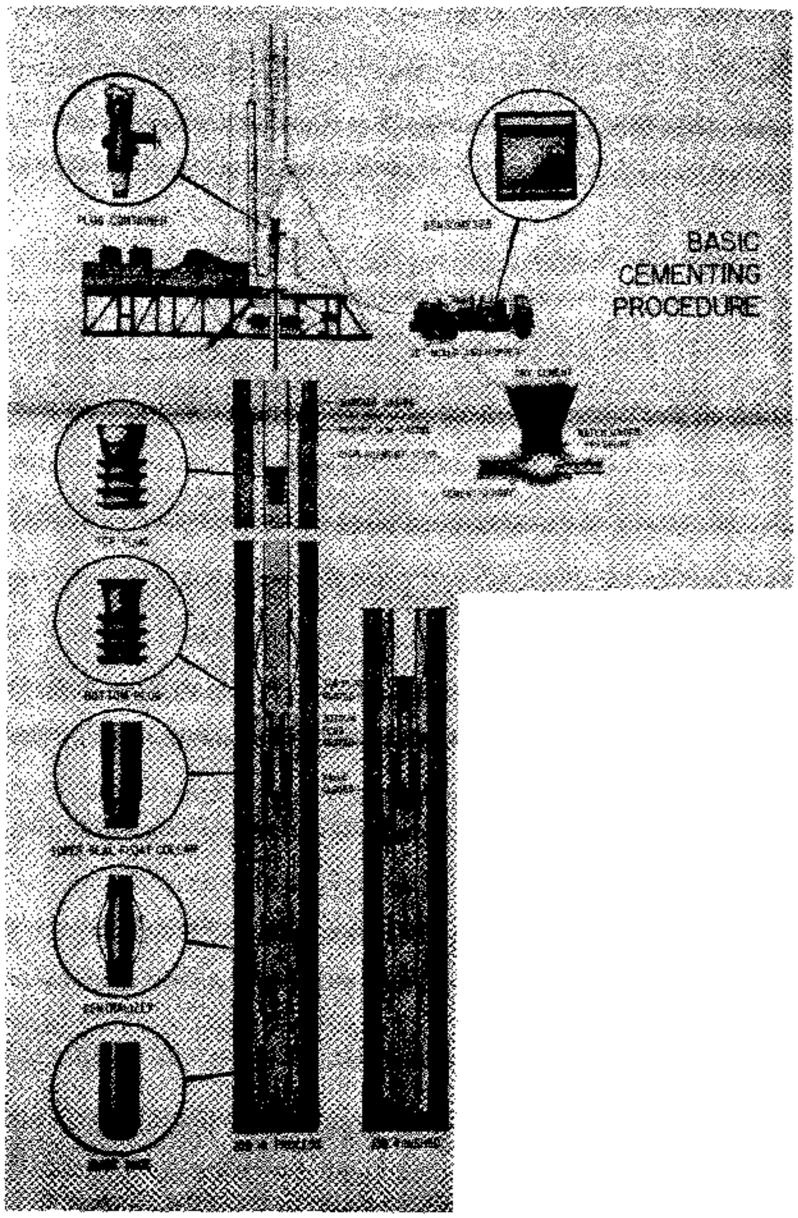

Figure 1

TYPES OF CASING STRINGS

Conductor casing or pipe string (as the name implies) is used to conduct drilling fluid while drilling the relatively shallow surface hole.

Surface casing is set to protect fresh-water zones, to guard against possible cave-in of the shallow surface formations and to provide for initial drilling control.

Intermediate or Protection string is set as a protection against sloughing or heaving formations, high pressure zones, and lost circulation. In air or gas drilling an intermediate string is sometimes necessary to shut off water.

Production or Injection strings are set through or immediately above the evaporite sections. During the useful life of a well the casing continues to keep the hole open and confines the fluids, helping to prevent them from entering other zones or returning to the surface through the annulus. The casing can prevent fluid migration only when it is properly cemented.

CASING CEMENTING

Conductor, surface, and protection strings are usually cemented using the single-stage method. This method is also commonly used on the production string. Single-stage cementing is accomplished by placing one batch of cement through the casing shoe with various types of top and bottom plugs. Different types of heads such as single and double plug containers for continuous cementing procedures are available as well as special adaptations for rotating or reciprocating casing (1).

Multiple-stage cementing uses the two- or three-stage method, making it possible to do a cement job at the bottom through the casing shoe with the second or third cement batch being placed through the stage tool at any predetermined point in the casing. This job can be done as a continuous operation or it is possible to do the bottom job, open the tool and circulate before cementing through the two-stage tool. After the cement job has been completed on the two-stage tool, a special plug closes the outlet ports by operating a built-in sleeve in the tool.

Some of the advantages of two-stage cementing are: (1) Full depth cementing; (2) Cementing off formations at any point; (3) Reducing pump pressure; (4) Minimizing loss of cement slurry to thieving formations by lessening the hydrostatic head.

By special adaptation, multiple-stage cementing can be extended to three stages. Using this arrangement, it is possible to pump the first stage through the casing shoe and the two subsequent stages at predetermined points by placing two multiple-stage cementers -- a two-stage and a three-stage tool -- in the casing. The first two stages are run as a continuous operation. A bomb-type plug is then used to open the three-stage tool to run the third stage.

It is also possible to pump the first stage through the casing shoe, then open the first tool, circulate, allow the cement to set, and then pump the second stage through the first tool. The second tool is then closed, cement is allowed to set, and the third stage is pumped through the second tool. This arrangement requires special opening and closing plugs and sleeves, but it has been used successfully to solve many special problems (2).

CASING EQUIPMENT AND ACCESSORIES

Attached to the casing are necessary devices such as floating equipment, centralizers, and wall cleaners. This equipment is assembled at the surface.

Floating equipment normally consists of a guide shoe and float collar attached to the bottom of the casing (Figs. 2 and 3). Sometimes two float collars and various combinations of float shoes and collars are run. A guide shoe is a round-nose device placed on bottom of the casing to guide the pipe as it is lowered into the hole. A float collar is placed from one to three joints above the bottom of the pipe to act as a back pressure valve and to reduce the weight of casing on the derrick as it is placed in the well. Various designs are available but all are essentially back pressure valves that allow fluid to be pumped downward through the casing but should not permit fluid movement in the reverse direction. It also helps prevent the backflow of mud or cement into the casing and acts as a stop for the plugs that are used to separate the cement and other fluids inside the casing during the cement job (3).

A modified form of floating equipment permits casing to fill up with drilling mud as it enters the hole; but a back pressure valve or float valve can be brought into action by circulating drilling fluid through the casing or by various other methods. Circulation of fluid activates a mechanism at any chosen point, after which the valve functions in the same manner as in other types of floating equipment. This type of mechanism is generally referred to as automatic fill-up equipment.

Casing centralizers are used to position pipe in the hole to aid in uniformly filling the annular space around the casing with cement. Considerable work has been done to gather data on the proper placing of centralizers and the number of centralizers necessary for various casing loads, depending upon hole size, casing size, and hole deviation.

Wall Scratchers or Cleaners are of various types and designs but all are used to improve the bonding of cement to the formation by removing drilling mud filter cake from the bore of the hole. The two common types of cleaning devices are classified according to the method by which

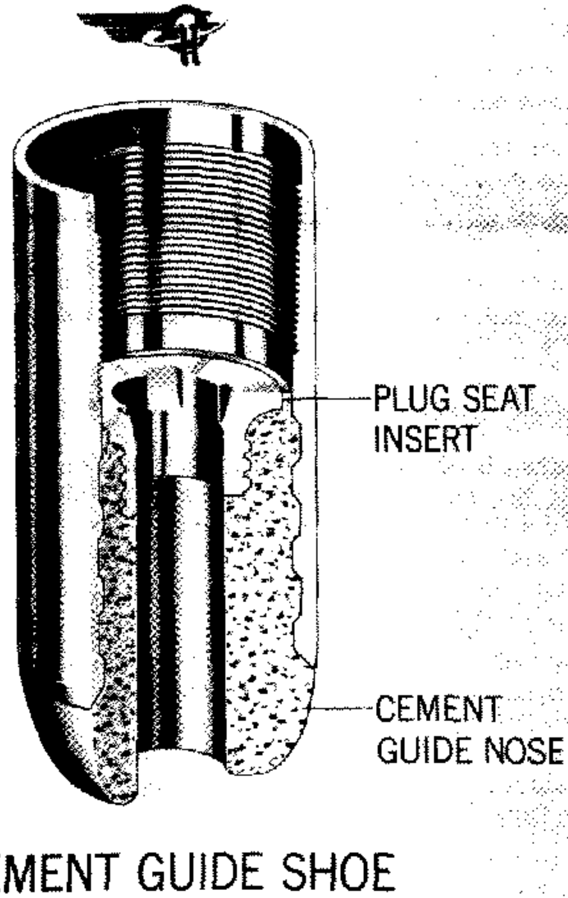

Figure 2. Cement guide shoe serves to guide the casing to be cemented to its proper location and provides a seat for cementing plugs.

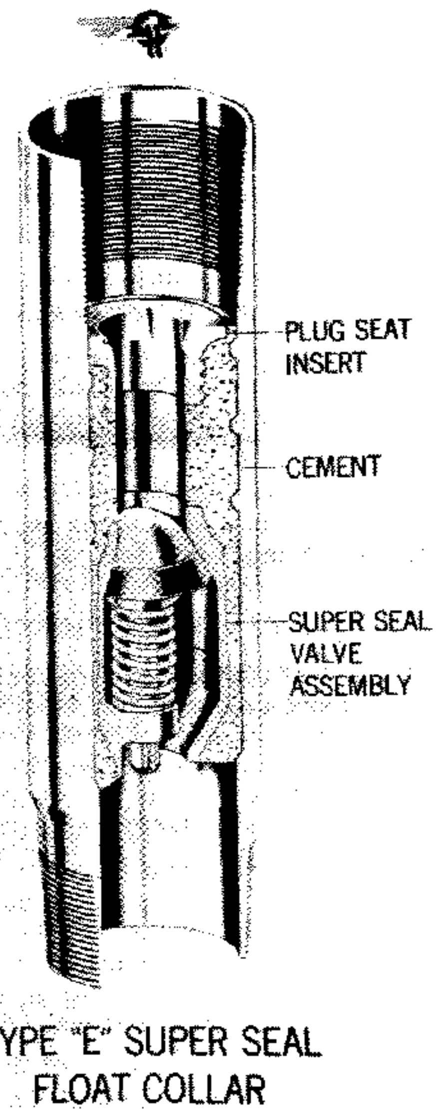

Figure 3. A float collar is basically a back pressure valve that allows fluid to be pumped downward through the casing but does not permit fluid movement in the reverse direction. This helps prevent the back flow of mud or cement into the casing and also acts as a stop for the plugs that are used to separate cement and other fluids inside the casing during the cement job.

they are operated; one is activated by reciprocal motion of the pipe; and the other operates when the pipe is rotated (4).

PLANNING THE CEMENT JOB

Since selection of hole sizes and the casing program are usually determined before drilling is started, plans for cementing the production string may also be made by the well owner before drilling begins (5). Some factors which effect the cement job are:

Mud Qualities. Care should be taken in conditioning mud. This can be a valuable aid in running casing and cementing the well (6). Consideration should be given to the use of a wash or thinner in front of the cement slurry to aid in removal of the circulatable mud.

Selection and Placement of Special Tools. Well logs are a very valuable aid to the selection of locations for Centralizers, Cleaners, etc.

Running Casing. The manner in which casing is run (including selection and location of surface connections) is of great importance during the cement job. Lost circulation problems can be aggravated by lowering the casing string at an excessive rate.

Amount and Type of Material. Varying well conditions make this a very important matter. A hydraulic wellbore analysis is an invaluable aid to the proper selection of the cementing slurry.

Mixing Units. A sufficient number and proper type of mixing units, accessory equipment, plugs, and techniques are necessary to provide the best possible cementing job.

Water Supply. An ample supply of suitable water should be available for mixing and displacing. Both rate and quantity should be provided. If any doubt exists as to the suitability of the water for mixing a cement slurry it should be checked prior to cementing operations.

After these factors have been considered and the job has been planned, qualified and experienced personnel are needed to supervise and perform the job. Full cooperation of personnel representing the well owner and the service company will make it possible to plan and successfully execute a much more efficient job.

HYDRAULIC WELLBORE ANALYSIS

The use of high-speed electronic computers makes it possible to perform a complete hydraulic wellbore analysis in a relatively short time if the required information is available (Fig. 4). Within minutes information for a particular well is calculated to determine hydraulic horsepower required for the job, frictional pressure anticipated, circulating pressure, time required for displacement, height of fill-up and/or amount of cement required, wellhead pressure anticipated, estimated bottom hole pressure and other useful advice.

Field tests show that circulatable mud moved ahead of the cement is related to displacement rate, i.e., in plug flow (as illustrated), very little force is exerted on the mud layer and mud removal is poor. As flow rate increases to laminar conditions, fluid velocity is higher and mud removal is improved. Under turbulent conditions, as much as 95 percent of the circulatable mud can be removed by the advancing annular column of slurry. This compares with approximately 60 percent circulatable mud removal achieved with plug flow (Fig. 5).

With greater percentages of displaceable mud removed, the chances of channeling and mud contaminated cement are minimized. More efficient bonding of the cement to both the casing and walls of the borehole should result. The turbulent flow of the slurry not only moves most of the circulatable mud, but may also partially remove the softer layers of the mud filter cake by scouring action.

When critical velocity for turbulent flow is reached, additional surface horsepower is usually unimportant because of energy lost to frictional resistance within the pipe and annulus. A Hydraulic Wellbore Analysis, therefore, determines minimum flow rate and amount of surface horsepower required to reach turbulent flow without wasting unnecessary pumping power. A Hydraulic Wellbore Analysis will also advise against attempting turbulence in a cementing system where well conditions make it impractical. Further, a Hydraulic Wellbore Analysis will recommend special low-friction cements and/or friction reducing additives where the economy of the job can be improved, or where well conditions prohibit turbulent flow without their use.

SUMMARY OF PRACTICES

Practices for good primary cementing as stressed by the drilling industry can be summarized as:

1. Controlled low viscosity muds while cementing.
2. The use of chemical washes preceding the cementing slurry.
3. Two cementing plugs.

[redacted]

SLURRY FLO-PLAN

FOR BACE SALT CO.

WELL NO. 1 BRINY

REQUESTED BY WOOSTER, OHIO

WELL CONDITIONS

✓ DEPTH - 7560 FT.

✓ HOLE SIZE - 6-3/4 IN., WASHED TO 9-3/8 IN.

✓ CASING SIZE - 5-1/2 IN., 15.5 LB/FT.

✓ ANNULAR FILL-UP - TO 5000 FT.

✓ TEMPERATURE - 145 DEG. F.

CONDITIONS CALCULATED FOR TURBULENT FLOW

FLUID 1 - DRILLING MUD
FLUID 2 - POZZOLAN CEMENT + 2 PCT BENTONITE, SALT SATURATED
FLUID 3 - 10 LB/GAL BRINE FOR DISPLACEMENT

FLUID NO.	WT-LBS/GAL	VOL-CU FT/SK	N-PRIME	K-PRIME
✓ 1	10.200	0.000	.670	.00330
✓ 2	14.800	1.370	.560	.01400
✓ 3	10.000	0.000	1.000	.00004

HOLE DIA	ANN-CU FT/FT	CASING I.D.
9.3750	.3143	4.892

ANN. VEL-FT/SEC	FLOW RATE-BPM	PIPE VEL-FT/SEC
3.730	12.7	9.129

FRICTIONAL PRESSURE-PSI/1000 FT.

FLUID NO.	CASING	ANNULUS	CHIKSANS-4 LINES
1	36.	9.	746.
2	55.	15.	1107.
3	30.	6.	684.

WELL-HEAD PRESSURE-MUD CIRCULATING
AT ABOVE PUMPING RATE
344.

DEPTH-TOP PLUG	PRESS-WELLHD	PRESS-BOTTOM HOLE	TIME-MIN.
0.	-1005.	4077.	11.2 TO MIX
500.	-1002.	4077.	12.1
1000.	-1000.	4077.	13.0
1500.	-963.	4088.	13.9
2000.	-800.	4139.	14.9
2500.	-637.	4190.	15.8
3000.	-474.	4241.	16.7
3500.	-310.	4292.	17.6
4000.	-147.	4343.	18.5
4500.	15.	4394.	19.4
5000.	178.	4445.	20.3
5500.	341.	4496.	21.2
6000.	534.	4547.	22.2
6500.	658.	4598.	23.1
7000.	831.	4649.	24.0
7500.	994.	4700.	24.9
7560.	1013.	4706.	25.0

ANN FILL-UP	SACKS
2560.	587.

MAX W-H PRESS	HYD HORSEPOWER
1013.	316.

Figure 4

4. Mechanical aids -- scratchers, centralizers, pipe movement.
5. High displacement rates, or turbulence if possible.
6. Proper selection of materials for well temperature and formation to be cemented.

CEMENTING MATERIALS

Considering the basic fundamentals of good practices, the benefits derived from the use of proper materials should not be overlooked. The normal cementing process for salt wells takes place at relatively low temperatures. The performance of cement under these conditions should:

1. Have sufficient pumpability to allow placement.
2. Develop rapid strength after placement to support the pipe.
3. Provide a good bond to pipe and formation.
4. Protect the pipe from corrosion.

FLOW BEHAVIOR OF NON-NEWTONIAN FLUIDS

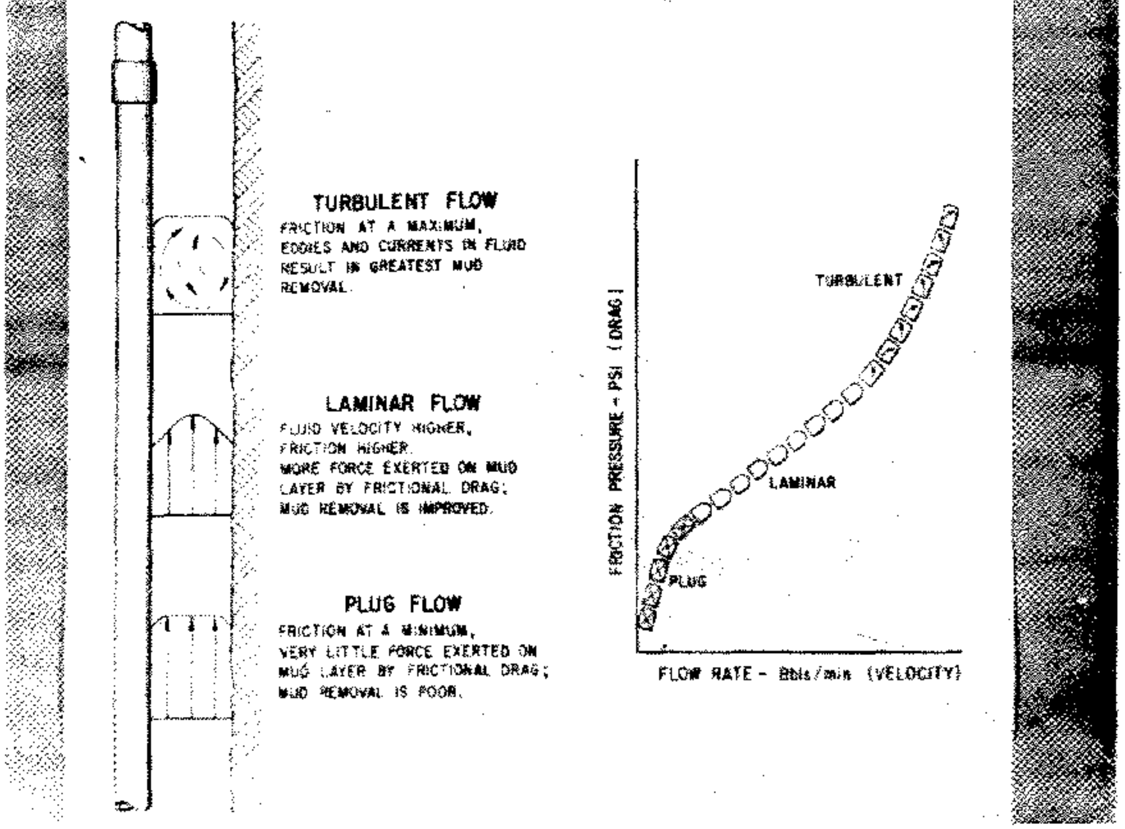

Figure 6

These conditions can be achieved by the proper selection of cements as suggested by the API for down hole temperatures and pressures (7). For most conditions API Class A or B (ASTM Types I or II) or pozzolan type cements are satisfactory for salt well applications since down hole temperatures are usually less than 170°F.

CEMENTING ADMIXTURES

The drilling industry today employs a large number of admixtures to modify cements for certain down hole conditions. The cements designated above are generally very compatible with the additives which are in common usage. Figure 6 lists the wide variety of materials and the application for which they are intended. Of all the cement additives in common usage today, the most versatile appears to be sodium chloride itself. In a cementing slurry for wells salt provides a wide number of benefits and has been recognized as a valuable tool in cementing through fresh-water sensitive shales, clays, bentonitic sands as well as salt formations. Research (8) has disclosed that in addition to inhibiting the action of fresh water on sloughing shales, the salt helps to provide a better bond. Salt acts as a dispersant in most cementing compositions. In the higher concentrations (15 percent and upward by weight of water), salt functions as a retarder, improves flow properties and provides an increase in slurry weight. In lower concentrations (8 percent and less) salt generally acts as an accelerator and provides higher early strength development. In practically all concentrations, salt helps impart rheological properties that allow turbulent flow patterns at lower velocities. Salt is compatible with almost all additives that are used in cementing compositions. Cementing compositions containing salt exhibit a greater degree of expansion than similar compositions mixed with fresh water.

ADDITIVES

APPLICATION	ADDITIVE	TYPES OF CEMENTS	BENEFITS	OTHER CONSIDERATIONS
ACCELERATORS Reduce W.O.C. Time	Calcium Chloride	Pozzolan Cements and API Classes A, B or C Cements	High Early strength	Surface pipe, shallow wells and plugs
	Friction Reducers	---	---	Plugs for whipstocks -- densified cements
RETARDERS Increase Thickening Time	Calcium Lignosulfonate	Pozzolan Cements and API Classes A, B or C Cements	Retard Setting of Slurry	Retarder for moderate temperatures
	Carboxymethyl Hydroxyethyl Cellulose	---	---	Low Water Loss
LIGHT WEIGHT ADDITIVES Decrease Slurry Density	Bentonite	Pozzolan Cements and API Classes A, B or C Cements	Low density -- economical	Filler cement additive -- greater set volume
	Gilsonite	---	Low density -- high strength	Combats lost circulation
	Diatomaceous Earth	---	Low density -- high yield	Combats lost circulation
	Perlite	---	Low density	Combats lost circulation
HEAVY WEIGHT ADDITIVES Increase Slurry Density	Ilmenite	Pozzolan Cements and API Classes A, B or C cements	Combat high pressure	Hard plugs for whipstocks slurries up to 22 lb/gal
	Friction Reducers	---	High slurry weightless water -- low slurry viscosity	Higher strength -- faster setting by reduced water ratios -- Slurries up to 18 lb/gal
LOST CIRCULATION	Gilsonite	Pozzolan Cements and API Classes A, B or C Cements	Combat lost circulation	Light weight slurry -- high fill-up above weak zones -- bridges fractures -- usable in squeeze cementing
	Gypsum Cement	---	Fast setting for plugging lost circulation zones	Plug back, water shutoff and blowouts
	Bentonite Diesel Oil (gunk squeeze)	---	Combat lost circulation, plug fractures, vugs and crevices	Used as spearhead in squeezing fractured zones
LOW FLUID LOSS SLURRIES	Halad[R]-9	Pozzolan Cements and API Classes A, B or C Cements	Reduces slurry dehydration	Reduce flow rate for turbulence in Bentonite cement slurries
	Latex	---	Fluid loss control on squeeze, liner and primary cementing	Good bonding and perforating qualities -- resistant to acid and corrosive fluids
LOW FRICTION CEMENT SLURRIES	CFR-2[TM]	Pozzolan Cements and API Classes A, B or C Cements	Provides turbulence at lower rates -- reduces hydraulic horsepower requirements	Dispersant used in densified cements
	Salt (NaCl)			Bonds to shales, bentonitic sands, and salt zones
	Halad[R]-9	Bentonite Cements (6% and higher)		Provides low fluid loss properties
SPECIAL ADDITIVES	Salt (NaCl)	Pozzolan Cements and API Classes A, B or C Cements	Bonds to salt, shale and bentonitic formations. Improves flow properties	Accelerates in low concentrations -- retards in high concentrations -- more expansion than fresh-water cements -- increases slurry density
	Silica Flour	Pozzolan Cements and API Classes A, B or C Cements	Reduces high temperature strength retrogression in cements	Reduces permeability of set cement -- usable in oil, thermal recovery, steam injection and geothermal steam wells

R -- Registered U.S. Patent Office

TM -- Trademark used by Halliburton

Figure 6

CEMENT FOR SALT FORMATIONS

One of the earlier recorded uses of salt with cement appeared in the completion of wells through the massive salt domes along the Gulf Coast in the 1940's. In the absence of bulk blending facilities, salt on these earlier jobs was added to the mixing water prior to mixing with cement. In the early 1950's dry blending of salt in the cement prior to mixing was initiated in the Williston Basin of North Dakota due to extreme low temperatures in winter operations and has been common practice since that time.

The effects of salt on the properties of oil well cementing slurries was published in 1951 by N. C. Ludwig (9). The fundamental use of salt cement for salt formations at any well depth is to provide a better bond as illustrated in Fig. 7. Here it can be seen that the fresh-water slurry has dissolved a portion of salt at the cement interface resulting in no bonding, while the salt-saturated slurry causes no solution problem and permits contact and bonding of cement to the salt.

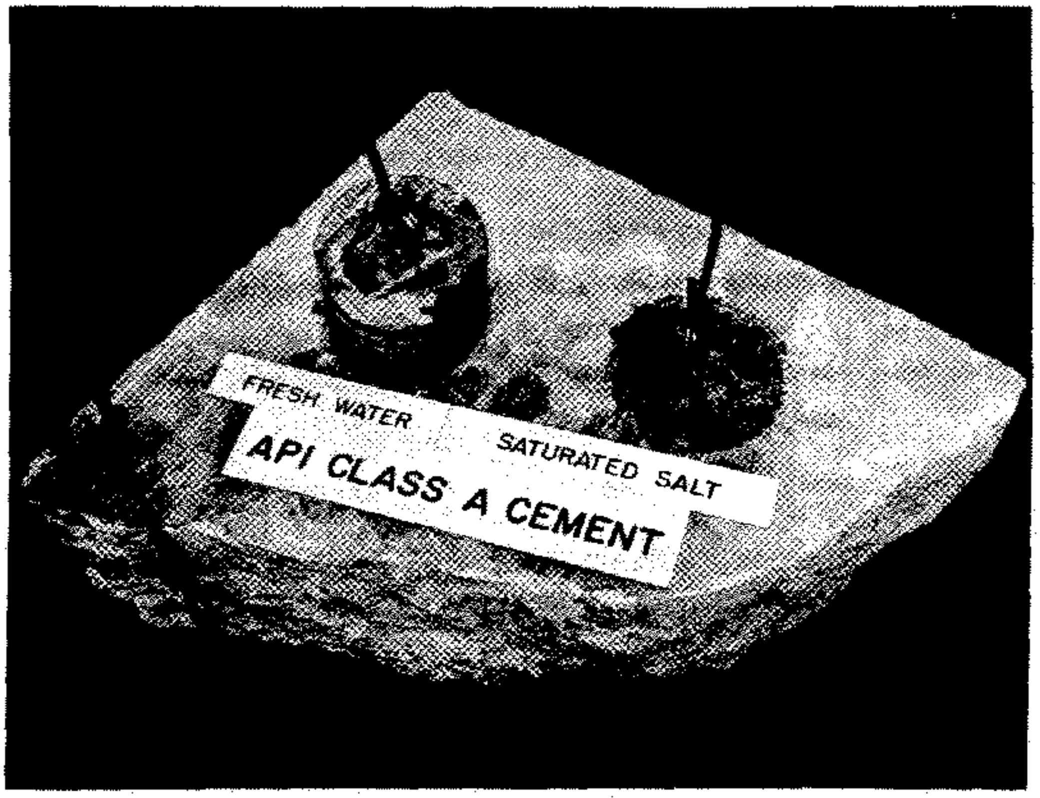

Figure 7

The bonding of salt-saturated pozzolan cement slurries to salt formations has also been demonstrated in some samples recovered from a well in a salt mine after cementing (Fig. 8). This illustrates the excellent bond to the salt after blasting in an area near the bottom of the casing. The compressive strengths of a cement specimen taken from this well was in excess of 5,000 psi.

There have been instances in salt formations where the cement slurry was mixed with less than saturated quantities of salt. This too results in poor bonding as does the use of low water loss materials in fresh-water cement slurries. In slurries using latex or polymers for water loss control there is still sufficient wetting of the formation with the cement filtrate to make it undesirable for cementing salt zones. Normally 3.1 pounds of salt per gallon of water is necessary for saturation in a cement system. Other salt concentrations for shales or sands are noted in Fig. 9.

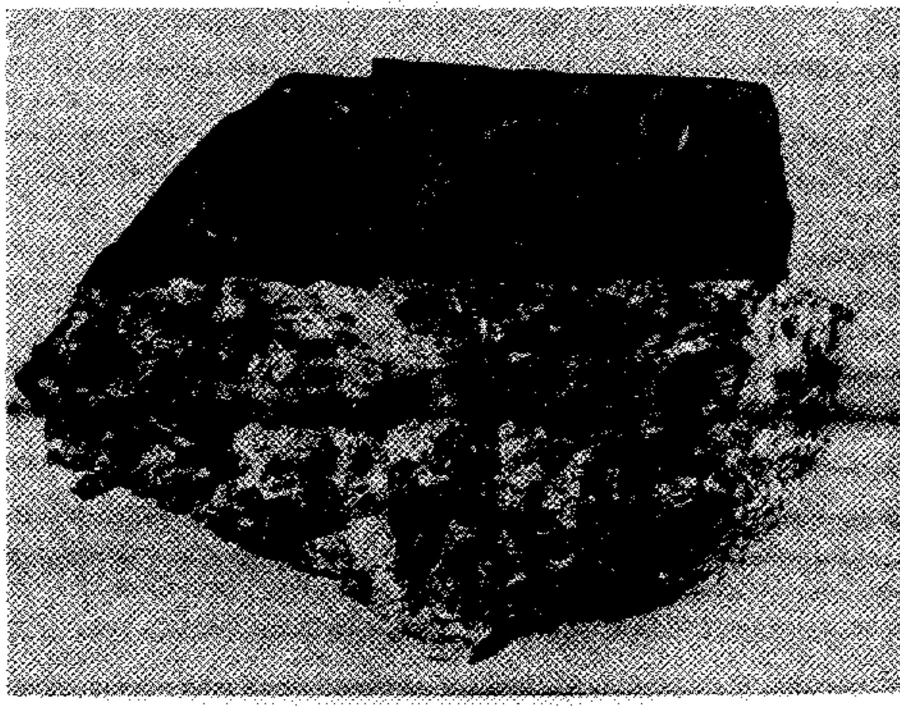

Figure 8

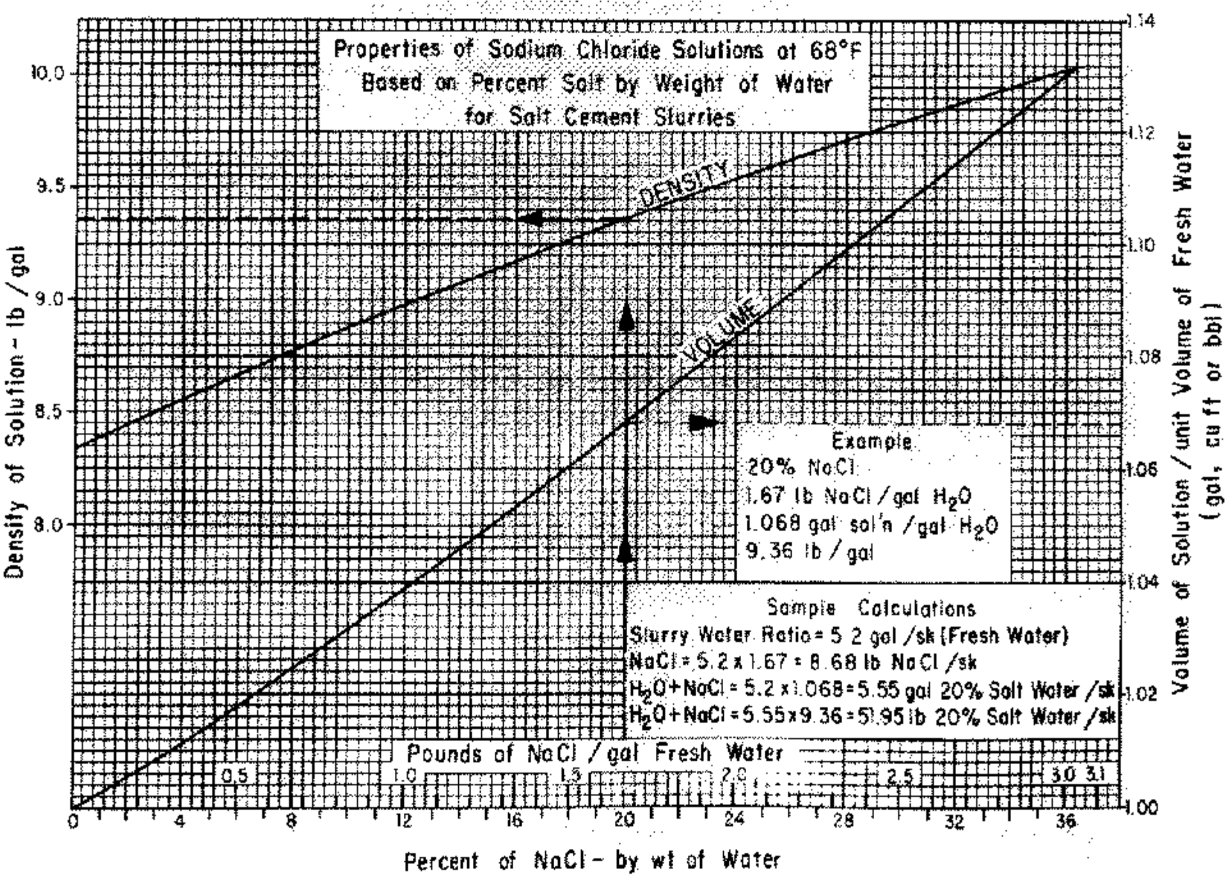

Figure 9

Study and observation of numerous caliper logs extending through salt formations show that circulating fresh-water muds will dissolve or wash out extensive sections in the salt formations. This increases the difficulty and quantity of cement to give a good cementing job. Salt-water muds used in drilling similar salt zones produce nearly gauge size holes. Bond log and microseismogram studies have indicated, similarly, that fresh-water slurries dissolve a portion of the salt, resulting in no bonding between the two, while the salt-saturated slurries permit no salt dissolving and allow excellent contact and bonding of cement and salt.

FOR SLOUGHING SHALES AND WATER SENSITIVE CLAYS (8)

In many instances the principal benefit of salt cement in wells is not from its bonding to salt zones, but rather because of its influence on clay minerals, which represent a predominant portion of shales and exist in various quantities in sands and other producing formations (Fig. 10). Formation brines normally cause these minerals to be present in a flocculated and unexpanded state. Introduction into the system of water-base fluids of low ionic content will often cause deflocculation and expansion of the clays, particularly those water-sensitive ones such as montmorillonite, illite and chlorite. These occurrences can result in permeability damage to "dirty" sand and varying degrees of formation disruption in shales or zones where shales predominate. Formation disruption can be a problem because a flow channel may be created that can affect satisfactory zonal isolation.

While a cement slurry contains lime (calcium hydroxide) saturated water, the extremely low solubility of this chemical results in relatively low ionic content but does contribute to clay flocculation by maintaining a high pH. It is probable that the improvement in formation competency noted with salt cement slurries is due to the influence of both the pH control with lime and the ionic content created by the addition of sodium chloride. We have also found that other inorganic salts in sufficiently high concentration can reduce the amount of deflocculation and formation deterioration -- although, for the most part, neither as effectively nor as economically as sodium chloride,

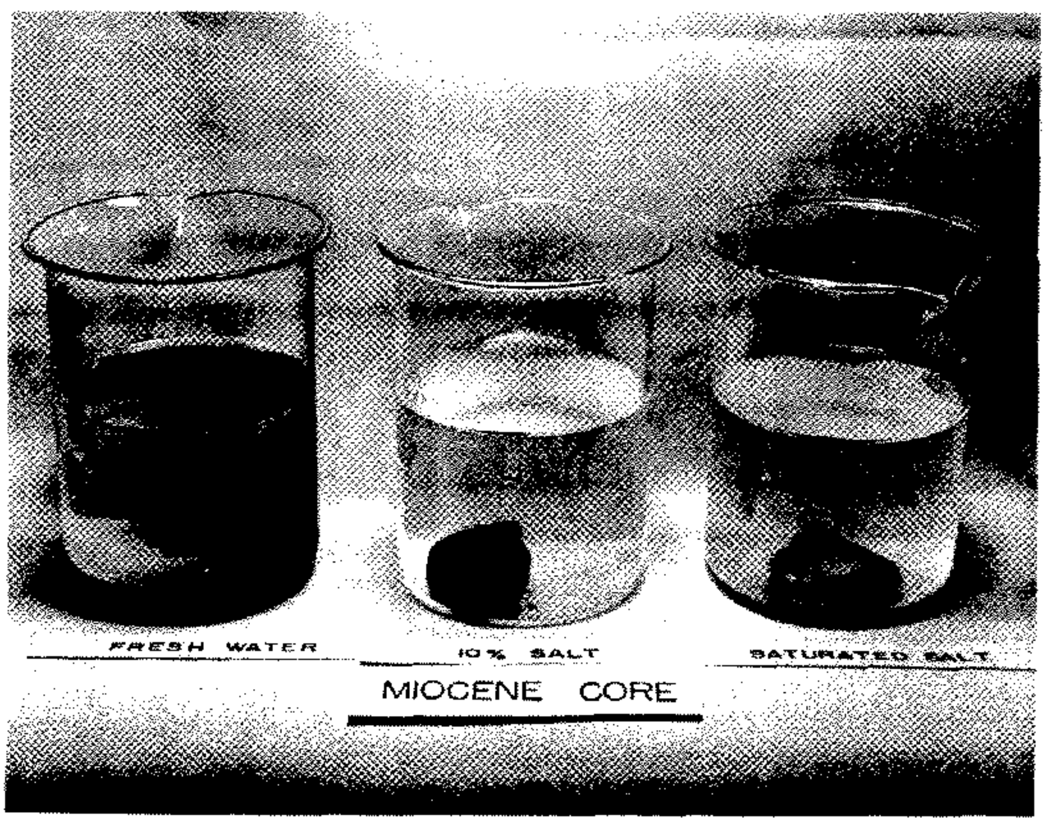

Figure 10

while posing other problems with respect to properties of the cement slurry. An excellent study of clay mineralogy has been published by Moore (10), which, while not concerned with cementing slurries, does describe some of these problems which are encountered with other fluids.

Field performance of salt cement for the past 12 years has not produced any recognizable formation damage to productive formations. The advantages derived from salt cement for shales and swelling clays have far overbalanced any possible detrimental effects.

SQUEEZE CEMENTING USING SALT SLURRIES

In some instances, squeeze cementing results also can be improved when formations to be squeezed contain significant quantities of shale or clay. Formation characteristics may include "dirty" sands, limestones or dolomites, interfaces between shale and other formations, or shale streaks which may exist in the perforated section being squeezed. Benefits from salt cement under these conditions are apparently attributable to the minimization of shale deterioration when cement contacts the formation, thereby allowing the formation to remain relatively stable and withstand the squeeze pressure.

Inhibition of water reaction with some shales can be obtained with a lower concentration of salt than that required for saturation. Several areas use only sufficient salt to provide 10 to 18 percent in solution in the slurry and achieve excellent results. At these concentrations there is no significant retardation of 24-hour compressive strength, although the pumping time with 18 to saturated cementing slurries will be longer. In other areas where the more expansive clay minerals such as montmorillonite (bentonite) are present in the formations, salt saturation of the mixing water may be required.

POTASH CEMENT SLURRIES

Cementing of wells for storage, or mining of water soluble salts other than sodium chloride, has been cited by Maier, Pollock and Hemilick (11). The use of potassium carbonate to saturate the cementing slurry provides much better bonding in potash deposits than sodium chloride as illustrated in the bonding tests in Fig. 11. The cementing program on these wells has been performed in two separate stages by the use of a DV tool placed above the potash deposits. The lower stage was cemented with the potash saturated cement slurry and allowed to set while the upper stage was cemented with conventional cement with thinners to obtain turbulence. Table I shows the effect of sodium and potassium salts on the strengths of cement at 140°F. after various periods of curing. At lower temperatures strength developments would be slower and longer setting time between stages would be required. This practice could be applied to other types of salts for better bonding but each should be tested prior to field usage.

EXPANSION OF SALT CEMENT

Introduction of commercial expanding cements for construction application has prompted research on the use of admixtures to promote cement expansion to improve down hole bonding. While

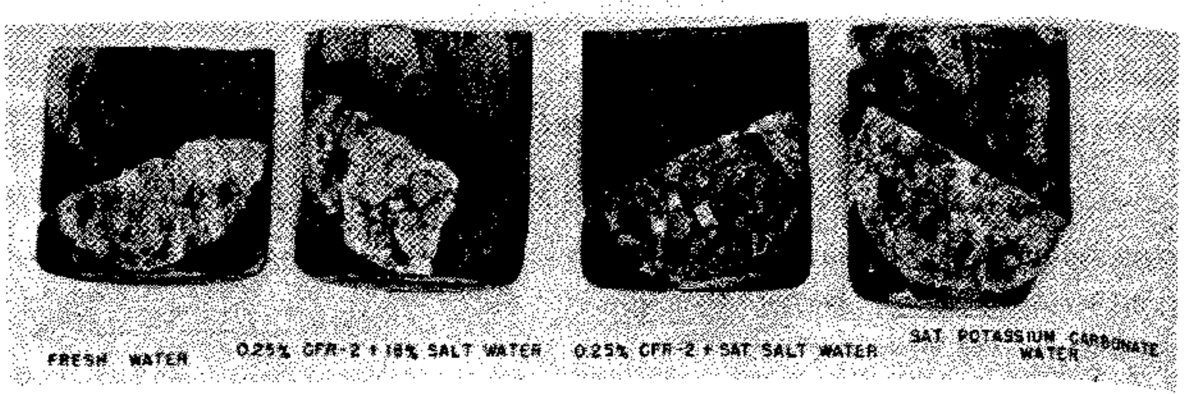

Figure 11

TABLE I

COMPRESSIVE STRENGTH

140°F.
Portland Type Cement
Water -- 4.85 Gals/Sack

Curing Time Hours	Fresh Water	Salt Saturated 3.1 #/Gal NaCl	Salt Saturated 3.0 #/Gal NaCl 2.8 #/Gal KCl
12	2,470	1,580	1,500
24	4,875	1,680	2,085
48	5,760	1,660	2,100

the effects of salt cement on clay minerals have been widely stressed the secondary benefit of expansion in the set cement has not been generally recognized. The chemistry of salt crystal growth as a source of expansion has recently been reported by W.C. Hansen (12).

Data on 1 × 1 × 10 inch bars (Fig. 12) indicates that salt added to cement functions as a very good substitute for the more expensive expanding type of cement for use in wells. It should be noted that salt does not expand as rapidly at early stages of curing yet this expansion appears to be much greater after the cement sets for several days. A simplified demonstration of salt-saturated Portland Cement expansion is illustrated in a glass container in Fig. 13. The expansion of the salt slurry in this instance usually occurs after about 48 hours or less at room temperature and is sufficient to crack the container. This slurry was mixed with 5.2 gallons of water and sealed to

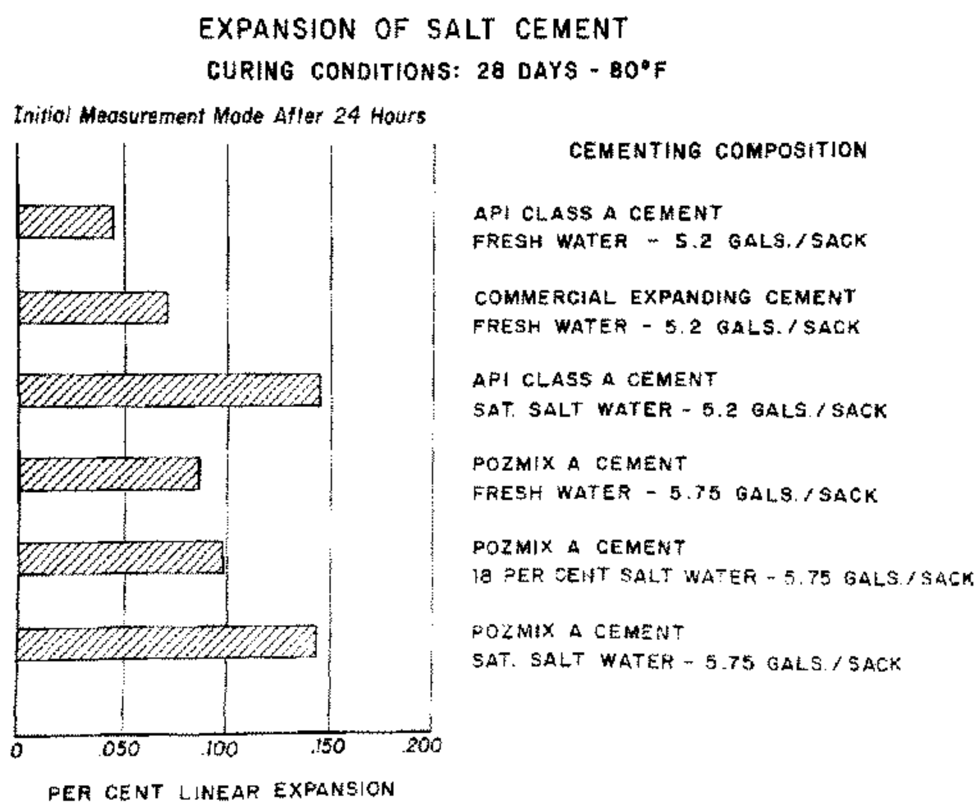

Figure 12

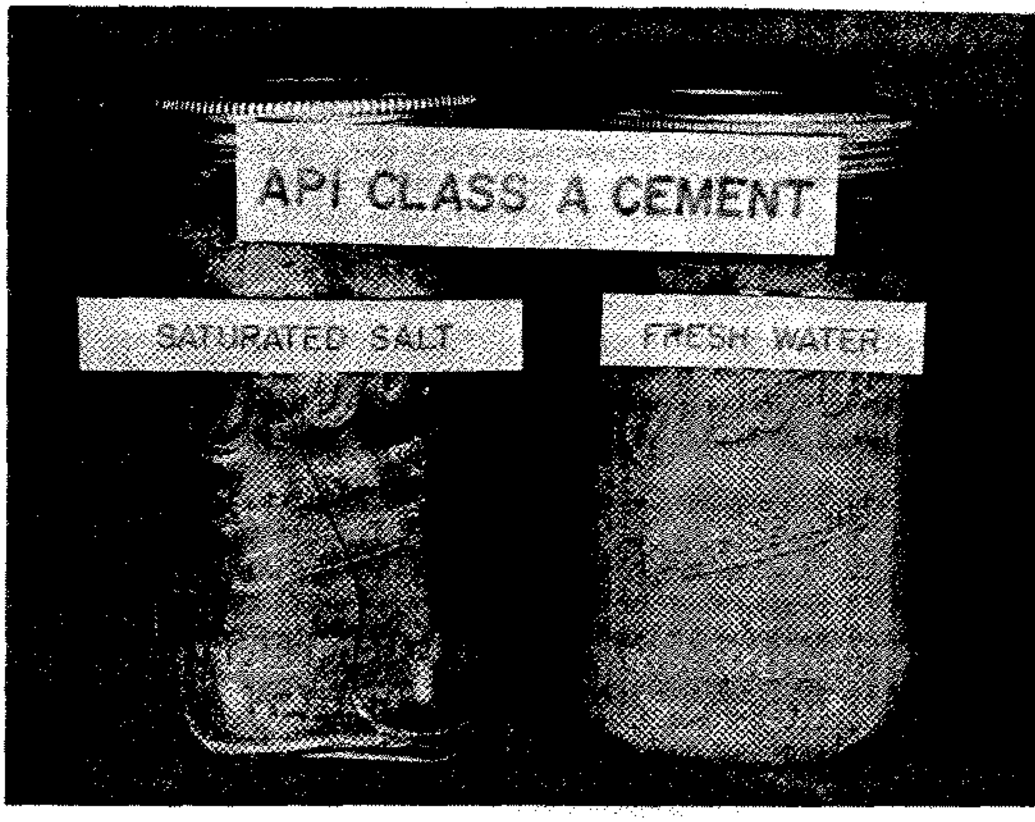

Figure 13

prevent drying of the cement which would not occur under down hole conditions. The difference in the two specimens is the salt addition. In most instances saturation is much better than with lesser quantities of salt. Table II illustrates expansion in micro inches per inch of another test series of Pozzolan Cement with salt utilizing strain gauges. The test data under down hole pressures have been found to produce a similar expansion trend.

TABLE II

Expansion Data -- Mass Cement
Temperature -- 110°F.
MEASUREMENTS MADE WITH STRAIN GAUGES
FROM TIME SLURRY INITIALLY PREPARED
Micro Inches Per Inch

Curing Time Days	Commercial Expanding Cement		Pozzolan A Cement, 2% Gel	
	Fresh Water	Salt Sat.	Fresh Water	Salt Sat.
1	820	670	510	150
2	873	784	551	220
4	960	923	660	305
6	1,160	1,195	930	480
10	1,230	1,245	985	870
14	1,525	1,590	1,260	1,500
18	1,580	1,665	1,305	1,730
20	1,770	1,870	1,410	2,065
46	1,970	2,125	1,715	2,890

CONCLUSIONS

Techniques, equipment and materials for cementing wells have advanced to a highly scienti operation. While these developments have been basically for the oil industry they are also appli-cable for the down hole recovery of salt or evaporite minerals. Emphasis on good practices is a essential part of a successful operation in combination with good cementing materials. The use o salt as an additive in cementing wells has also become a widely accepted practice. The dispersin and acceleration effects of salt in cement at low temperatures and the retardation properties at elevated temperatures fit a wide range of well conditions. The more recent recognition of expan-sion and improvements in bonding of salt cementing compositions to salt, shale and fresh-water sensitive formations has stimulated its usages in wells.

ACKNOWLEDGMENT

The authors wish to thank the Halliburton Company for permission to publish these data, an those in the laboratory and field organizations who assisted in its preparation.

REFERENCES

1. Francis M. Anderson, "Modern Oil Well Cementing Operations," California Oil World, p. 43, August 1953.
2. Phil Montgomery, "Multiple Stage Cementing Uses Two- and Three-Stage Methods," World Oil, vol. 139, no. 7, p. 76, December 1954.
3. William D. Owsley, "Improved Casing Cementing Achieved by Adoption of Materials and Prac-tices Readily Available Today," Oil and Gas Journal, vol. 48, no. 32, p. 76, December 15, 1949.
4. Phil Montgomery, "Equipment Materials, Tools for Cementing Deep Wells," The Petroleum Engineer, vol. 25, p. B-40, January 1953.
5. Waldo L. Grossman, "Primary Cementing of Casing in Rotary Drilled Wells," World Oil, vol. 132, no. 5, p. 153, April 1951.
6. Francis M. Anderson, "The Effect of Mud-Treating Chemicals on Oil Well Cements," Oil and Gas Journal, vol. 51, no. 21, p. 283, September 29, 1952.
7. API Standards 10A "Specifications for Oil-Well Cements," 11th Edition -- 1965.
8. Knox A. Slagle, Dwight K. Smith, "Salt Cement for Shale and Bentonitic Sands," Journal of Petroleum Technology, vol. 15, p. 187, February 1963.
9. N.C. Ludwig, "Effects of Sodium Chloride on Setting Properties of Oil Well Cements," Oil and Gas Journal, vol. 50, n 3, p. 125, May 24, 1951.
10. John E. Moore, "Clay Mineralogy Problems in Oil Recovery," Petroleum Engineer, vol. 32, parts 1 and 2, p. B-40 and B-78, February, March 1960.
11. L.F. Maier, R.W. Pollock, and W.H. Heimlick, "Cementing the Casing of Underground Stor-age Caverns in Saskatchewan," American Gas Association Transmission Conference, Van-couver British Columbia, May 4-5, 1964.
12. W.C. Hansen, "Crystal Growth as a Source of Expansion in Portland-Cement Concrete," Sixty-Sixth ASTM Meeting -- Atlantic City, New Jersey, June 1963.