

GREENWELL ENGINEERING, INC.

Oil Field Chemical Engineering
10608 ROYAL SPRINGS DRIVE
DALLAS, TEXAS 75229
214/352-0334

February 18, 1985

Mr. Warren Farley
Core Laboratories Australia (QLD.), Ltd.
Brisbane, Australia

Dear Mr. Farley:

The following discussion is concerned with the chemical compatibility of two waters from the Mereenie Fields. The samples furnished were identified as:

1. East Mereenie No. 3 *water bore*
2. West Mereenie No. 4

The first sample proved to be a fresh water, while the second is a brine having ionic strength of 1.17.

The term "compatibility", as applied to waters, appears to be used with various definitions. In order to avoid the implicit pitfalls of this situation, we must state the definition followed herein. This can be done most directly in the negative form of the term: Waters which are "incompatible" will exhibit undesirable chemical reactions when the waters are mixed. "Compatibility" is concerned only with this possibility; it does not address other factors which determine the suitability of a water for injection.

It also is noted that there are two degrees of incompatibility. Some forms of incompatibility are unconditional, while others

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depend upon conditions prevalent when mixing occurs. An example of the former is the precipitation of barium sulfate. If Water A contains more than a certain concentration of barium, and Water B contains more than a certain concentration of sulfate, barium sulfate will precipitate under any and all conditions of mixing. Conditional incompatibility can be illustrated by Water C, which has an appreciable concentration of dissolved iron, and Water D, which has a lower iron concentration. If Water D also contains dissolved oxygen, mixing will result in iron precipitation. If Water D is oxygen-free, precipitation probably will not occur.

Stability of the following elements and compounds requires evaluation in the present case:

1. Calcium sulfate,
2. Calcium carbonate,
3. Strontium sulfate,
4. Iron.

Pacoota Sandstone water, as represented by the enclosed analysis of a sample from West Mereenie No. 4 Well, is at practical saturation with respect to calcium sulfate. The fresh water from East Mereenie No. 3 has low concentrations of calcium and of sulfate ions. When waters are mixed, the resulting waters of intermediate composition should be stable with respect to calcium sulfate. This is shown in Figure I.

Curves in Figure I represent calcium sulfate solubility and calcium sulfate present for all mixtures of fresh and produced waters. The solubility curve lies above the curve for calcium

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sulfate present for the entire range. No precipitation, therefore, is expected to occur.

The fact that produced water is saturated with calcium sulfate at ambient conditions (20°C and one atmosphere pressure) raises the possibility that precipitation could occur without mixing with another water. Solubility of calcium sulfate is sensitive both to temperature and pressure.

Figure II is a curve for calcium sulfate solubility at various temperatures and one atmosphere pressure. Maximum solubility is seen to occur at 35 to 40°C. If temperature of the Pacoota Sandstone is within this range and, if water is saturated in its source formation, precipitation will occur in lifting and handling the water at the surface.

Calcium sulfate solubility increases directly with pressure. Figure III shows quantities of calcium sulfate which would precipitate when waters saturated at a given pressure are reduced to atmospheric pressure.

There is no present evidence that Pacoota Sandstone water is, in fact, saturated with calcium sulfate under reservoir conditions. The sample furnished contained no precipitated sulfates. If the reservoir in question has been produced for any appreciable time, any significant precipitation problems would have been recognized. If the reservoir has not been produced, initial operations should be monitored closely for evidence of calcium sulfate instability.

Both individual waters are stable with respect to calcium

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carbonate. Figure IV presents a plot of Carbonate Index for all mixtures of waters. This curve shows very little variation for the entire range. "Carbonate Index" is a system for determining and expressing carbonate stability on a quantitative basis. It is unique in this respect, as the more familiar indices (Stiff-Davis, Langelier, Ryznar) are qualitative. The mathematical procedure for calculating Carbonate Index involves determining the ion product, $[Ca^{++}][CO_3^{=}]$, based on activities of these ions. This is divided by the solubility product for $CaCO_3$. If the resulting value is greater than 1.00 the water is unstable, and the amount of precipitation which will result can be calculated directly.

Strontium sulfate is a more sparingly soluble compound than calcium sulfate. Pacoota Sandstone water was found to contain 22.5 mg/l of strontium, which low value should ensure freedom from problems of strontium sulfate precipitation. Figure V contains curves for strontium sulfate solubility and for concentrations present at various ratios of mixing. The curves are widely separated, with solubility greatly exceeding the concentrations present for all possible mixtures.

Concentrations of iron dissolved in both waters are quite limited. Both waters are slightly acidic, and the individual pH values are not widely separated. Iron precipitation should not occur, when the waters are kept free of oxygen.

It will be noted that undissolved solids associated with fresh water were quite rich in iron. In the analysis process, this iron was put into acid solution only with difficulty, indicating that it originated as an iron-bearing mineral and not as iron

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precipitated from the water.

It is concluded that waters can be mixed without hazard of "incompatibility". Whether mixed or separate use of waters is more advantageous is not necessarily determined by this consideration alone. Relative volumes of the two waters, changes in these volumes with time, undissolved solids content of the individual waters, bacterial activity in the waters, oil content of produced water are among the factors which will affect this choice.

Thank you for this opportunity to be of service. I will be pleased to assist with flow scheme design of systems and specification of operating procedures, should your client require.

Yours very truly,



H. E. Greenwell, P. Eng.

HEG:cg

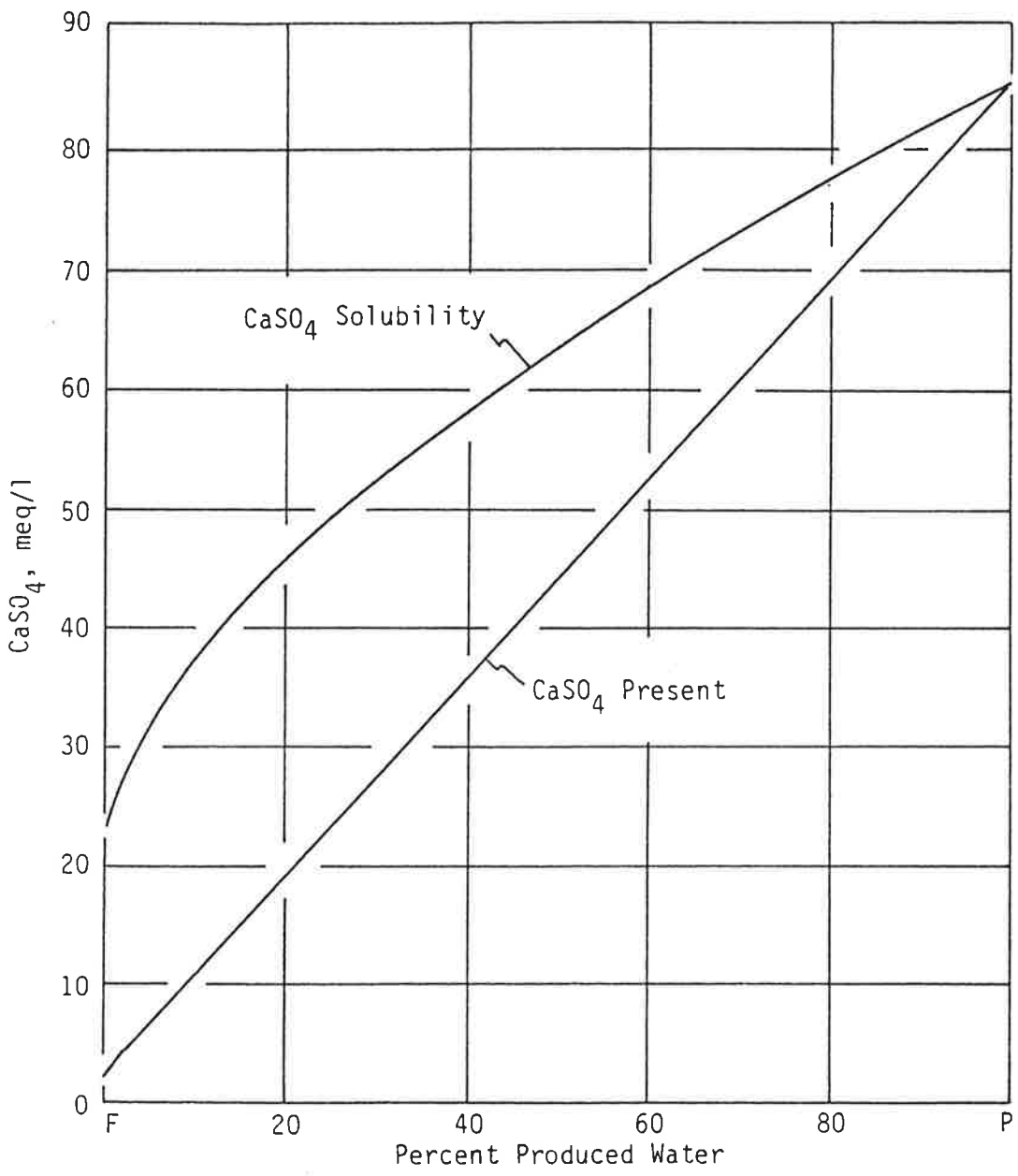


FIGURE I

Calcium Sulfate Stability in Mixtures
of Fresh and Produced Water

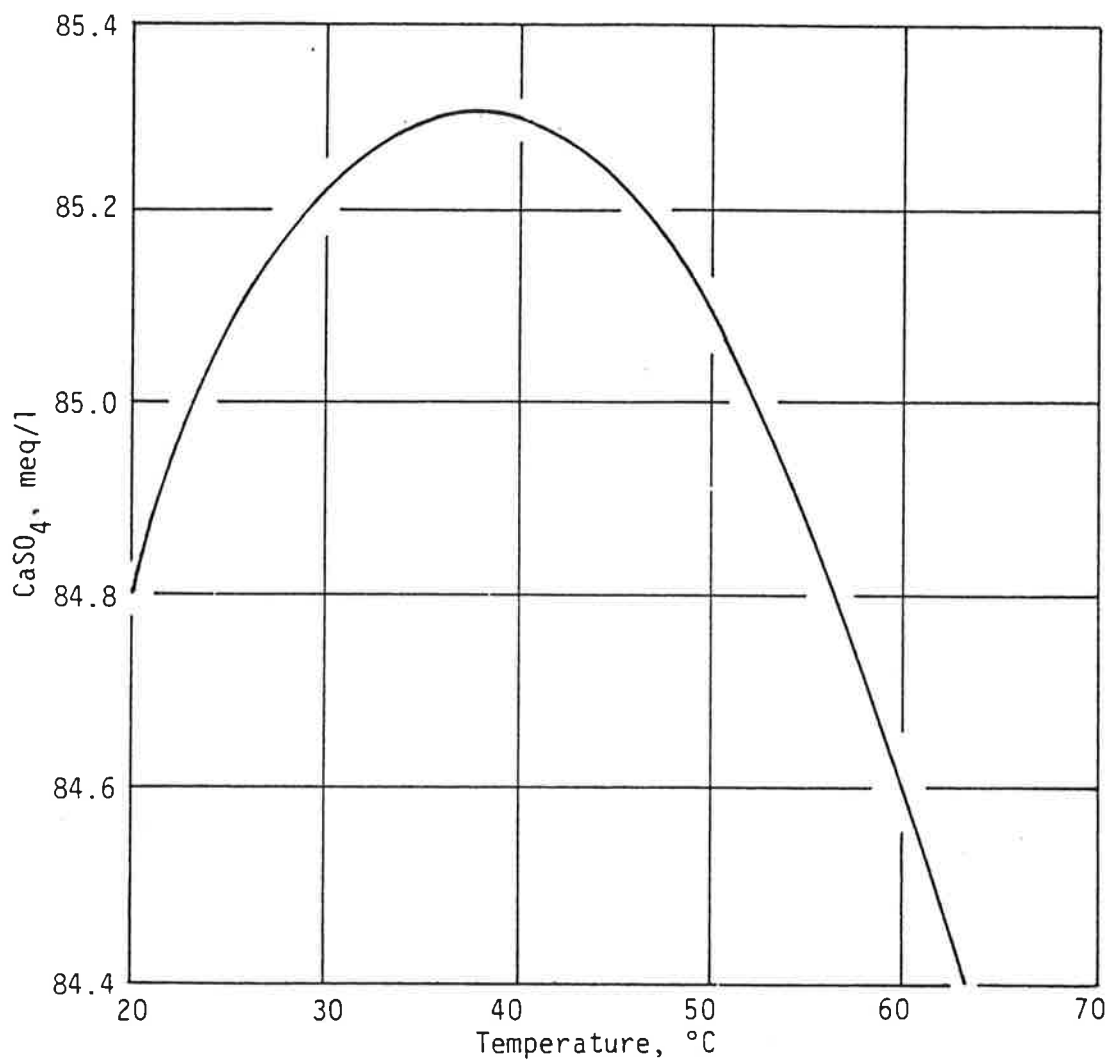


FIGURE II

Variation of CaSO₄ Solubility with Temperature
Pressure = 1 atm.

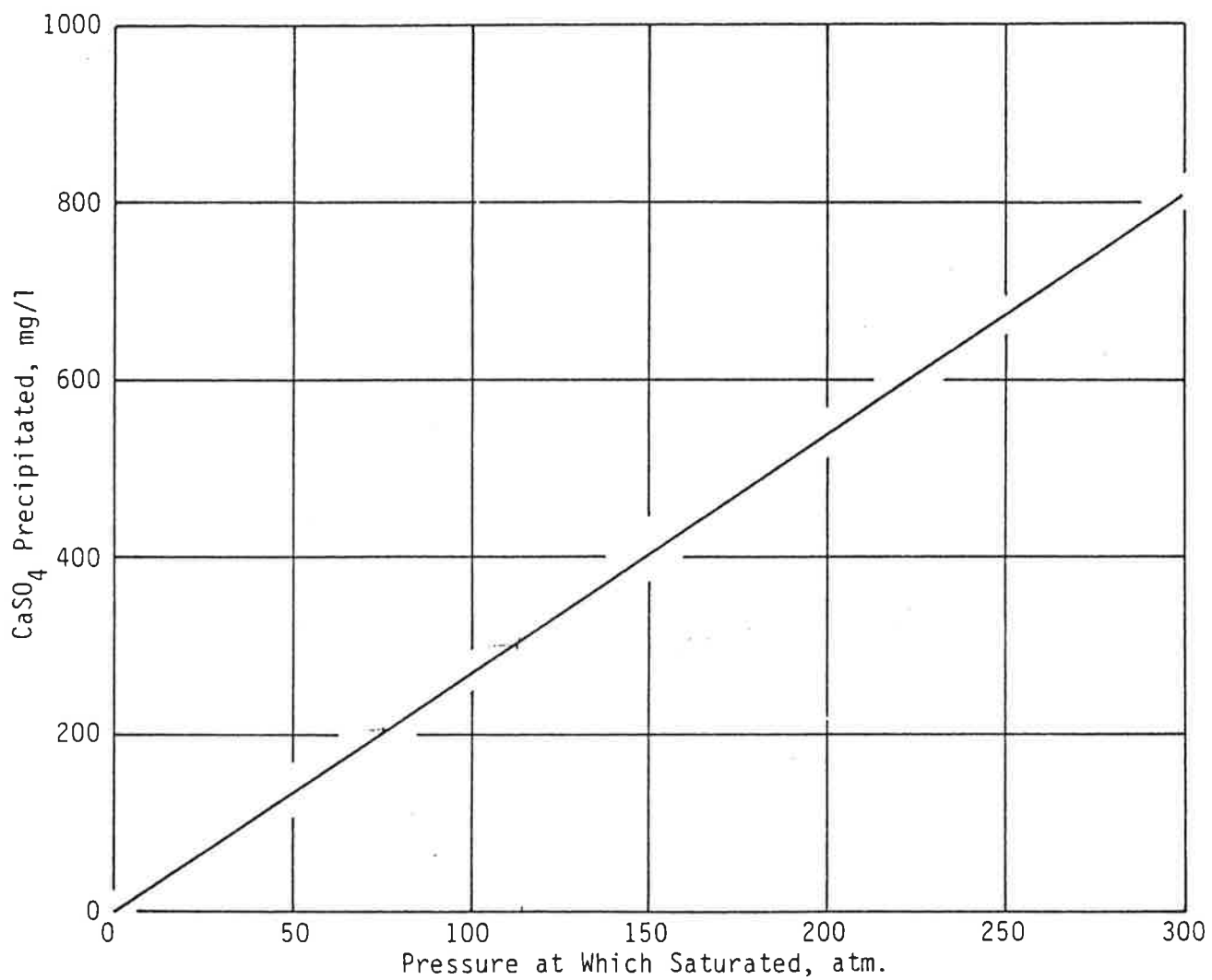


FIGURE III

CaSO₄ Precipitation when Pressure is Reduced to One Atmosphere

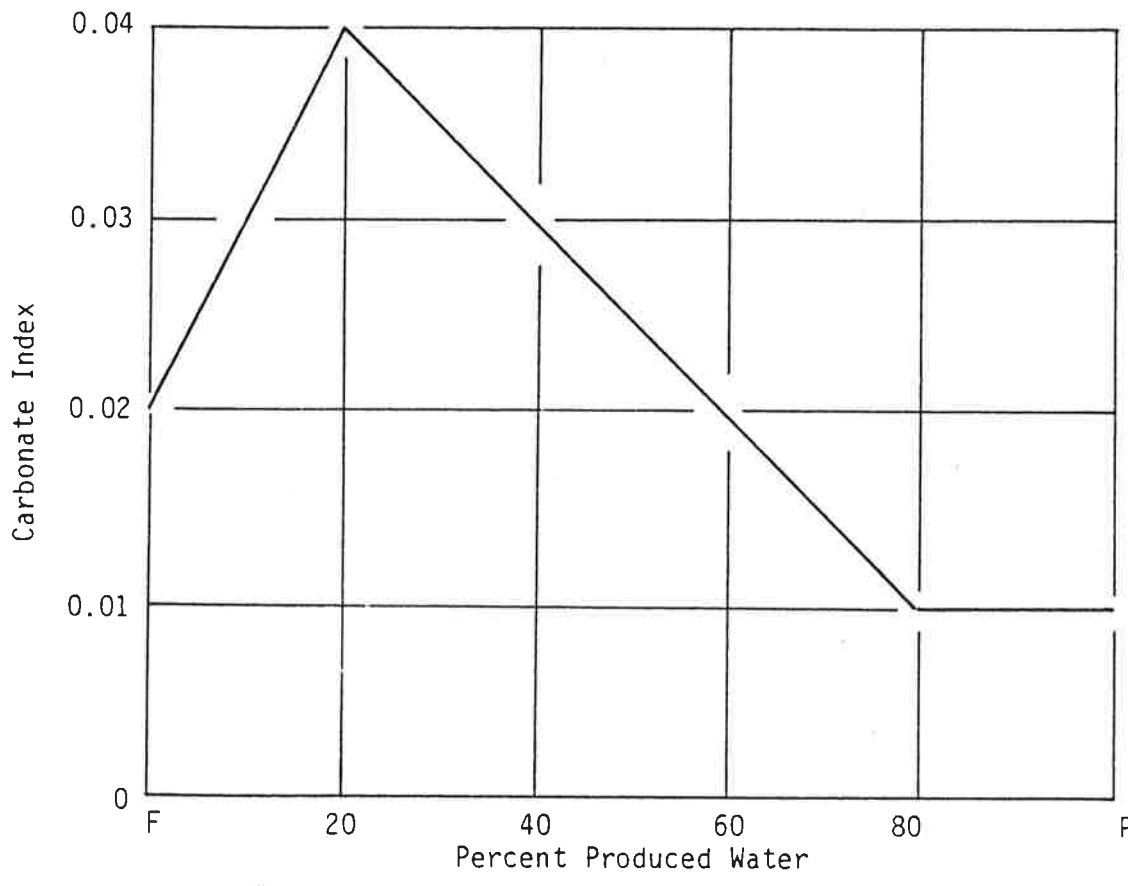


FIGURE IV

Carbonate Stability in Mixtures of Fresh and Produced Waters

NOTE: Carbonate Index = 1.00 corresponds to equilibrium saturation. Indices greater than 1.00 provide a quantitative indication of carbonate precipitation.

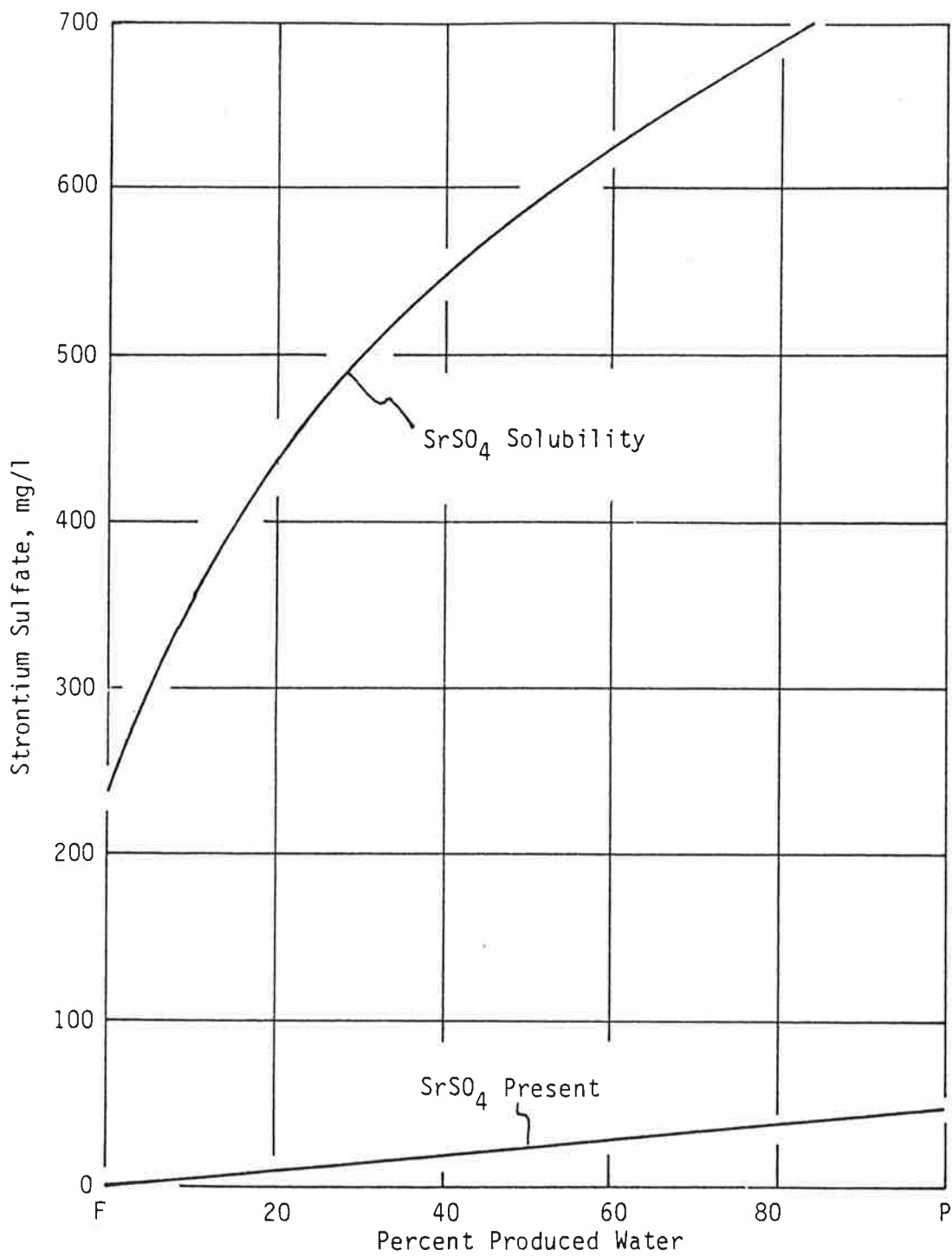


FIGURE V

Strontium Sulfate Stability in Mixtures
of Fresh and Produced Waters

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WATER ANALYSIS

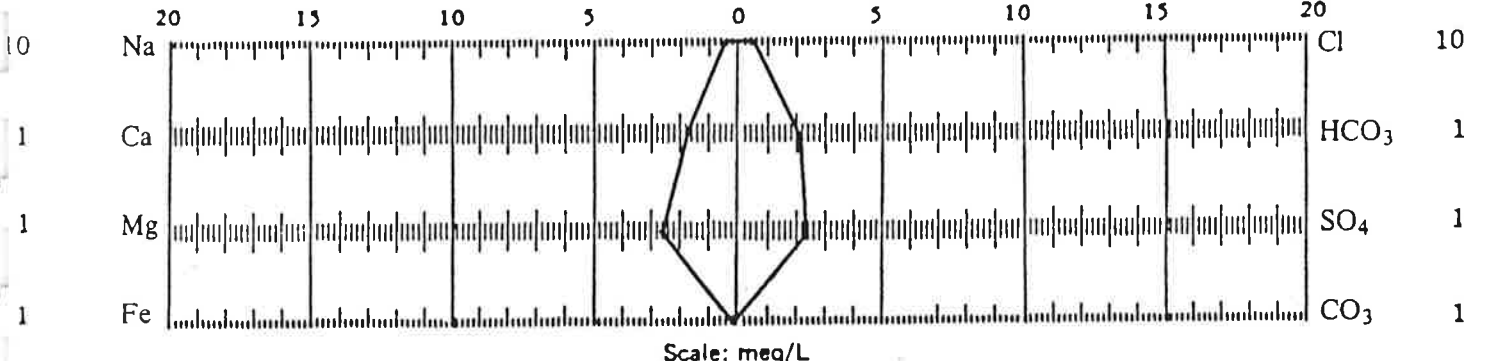
File DCL 856015

Company Oilmin N.L. Well Name E. Mereenie No. 3 Sample No. EM-3
 Formation _____ Depth _____ Sampled From Bore Water
 Location _____ Field Mereenie County _____ State Australia
 Date Sampled _____ Date Analyzed January 30-31, 1985 Analyst R.A. Law

Total Dissolved Solids 564 mg/L calculated Sp. Gr. 0.9976 @ 74.5 °F
 Resistivity 11.13 ohm-meters @ 74.5 °F measured 0.9984 @ 20 °C (68°F)
 Conductivity 898 µmhos/cm 74.5°F Total Sulfide _____

pH 6.86 @ 72 °F Hydrogen Sulfide Absent

Constituents	meq/L	mg/L	Constituents	meq/L	mg/L
Sodium	<u>4.49</u>	<u>103</u>	Chloride	<u>4.46</u>	<u>158</u>
Calcium	<u>1.66</u>	<u>33.2</u>	Bicarbonate	<u>2.08</u>	<u>127</u>
Magnesium	<u>2.62</u>	<u>31.9</u>	*Sulfate	<u>2.27</u>	<u>109</u>
Iron	<u>0.04</u>	<u>1.16</u>	Carbonate	<u>0.0</u>	<u>0.0</u>
*Barium	<u>0.0</u>	<u>0.0</u>	Hydroxide	<u>0.0</u>	<u>0.0</u>



Sodium value above is calculated
 Sodium by analysis 109 mg/l Na
 Potassium by analysis 16.5 mg/l K
 Strontium by analysis 0.11 mg/l Sr

* Gravimetric Analysis

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Oilmin N.L.
Brisbane, Australia

Job No. DCL 856015

SUSPENDED SOLIDS

E. Mereenie No. 3 Bore Water

Material brick red in color - readily settleable

Total dried solids used	79.4 mgs	100.00%
Organic, solvent soluble	0.2 mgs	0.25%
Loss on ignition @ 550°C	4.8 mgs	6.04%
Acid soluble portion, HCl	22.5 mgs	28.34%
Iron as Fe ₂ O ₃	21.05 mgs	26.51%
Calcium as CaCO ₃	0.10 mgs	0.13%
Magnesium as MgCO ₃	1.35 mgs	1.70%
Sulfate	absent	absent
Insoluble residue	51.9 mgs	65.37%

NOTE: All red color was consumed after treatment with acid leaving white granular siliceous residue.

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WATER ANALYSIS

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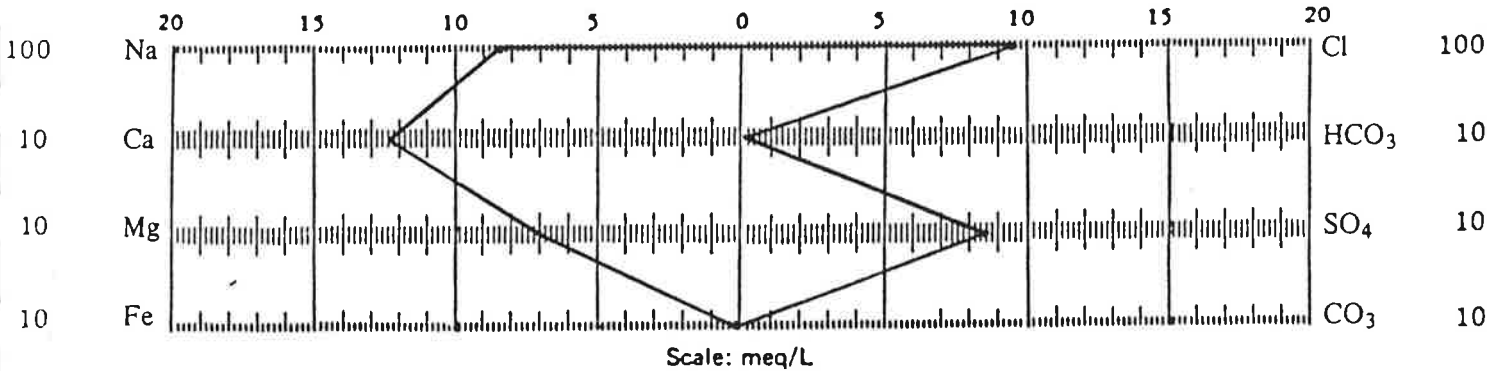
Company Oilmin N.L. Well Name W. Mereenie No. 4 Sample No. WM-4
Formation Pacoota Sandstone Depth _____ Sampled From Formation Water DST No. 1
Location _____ Field Mereenie County _____ State Australia
Date Sampled _____ Date Analyzed January 30-31, 1985 Analyst R.A. Law

Total Dissolved Solids 60458 mg/L calculated Sp. Gr. 1.0410 @ 75.0 °F
Resistivity 0.1222 ohm-meters @ 75.0 °F measured 1.0419 @ 20 °C (68 °F)

Total Sulfide _____

pH 6.42 @ 72 °F Hydrogen Sulfide Absent

Constituents	meq/L	mg/L	Constituents	meq/L	mg/L
Sodium	<u>842.45</u>	<u>19368</u>	Chloride	<u>949.52</u>	<u>33659</u>
Calcium	<u>122.65</u>	<u>2458</u>	Bicarbonate	<u>0.79</u>	<u>48.5</u>
Magnesium	<u>70.0</u>	<u>851</u>	*Sulfate	<u>84.80</u>	<u>4073</u>
Iron	<u>0.01</u>	<u>0.23</u>	Carbonate	<u>0.0</u>	<u>0.0</u>
*Barium	<u>0.0</u>	<u>0.0</u>	Hydroxide	<u>0.0</u>	<u>0.0</u>



Sodium value above is calculated
Sodium by analysis 19250 mg/l Na
Potassium by analysis 2025 mg/l K
Strontium by analysis 22.5 mg/l Sr

* Gravimetric Analysis

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