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**CARBON DIOXIDE FOR THE RECOVERY OF CRUDE OIL
A LITERATURE SEARCH TO JUNE 30, 1979—Final Report**

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The Department of Petroleum Engineering
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Los Angeles, California

U. S. DEPARTMENT OF ENERGY

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**CARBON DIOXIDE FOR THE RECOVERY OF CRUDE OIL
A LITERATURE SEARCH TO JUNE 30, 1979—FINAL REPORT**

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SECTION ONE: EXECUTIVE SUMMARY

SECTION ONE: EXECUTIVE SUMMARY

INDIVIDUAL SUMMARIES AND PERTINENT COMMENTARIES ON EACH OF THE GROUPS OF REFERENCES INTO WHICH THE LITERATURE ON CARBON DIOXIDE FOR THE RECOVERY OF CRUDE OIL HAS BEEN CLASSIFIED ARE PRESENTED IN THE FOLLOWING PAGES. THE MAJOR CLASSIFICATIONS ARE:

- I. PHYSICAL MODELS
- II. LABORATORY STUDIES
- III. FIELD TESTS
- IV. MODELLING
- V. PATENTS
- VI. MISCELLANEOUS

IN ADDITION A SPECIAL SUMMARY THAT REVIEWS AND COMMENTS ON FIELD OPERATIONS, FLUID HANDLING AND CORROSION PROBLEMS FOLLOWS AS SECTION TWO.

BASED ON EXAMINATION OF THE REFERENCES STUDIED, IT APPEARS THAT THE USE OF CARBON DIOXIDE AS A SECONDARY RECOVERY AGENT IS VERY PROMISING, BUT THAT ADDITIONAL STUDY IS REQUIRED TO PROVE CARBON DIOXIDE AS A USEFUL TERTIARY RECOVERY AGENT.

A SECONDARY RECOVERY OPERATION UTILIZING CARBON DIOXIDE, ASSISTED BY A MARKED INCREASE IN RESERVOIR PRESSURE AND EXTENSIVE WORKOVER OPERATIONS, ACHIEVED AN ESTIMATED ADDITIONAL OIL RECOVERY OF 6% AT AN ESTIMATED RATIO OF ONLY 6 MCF/BBL [196].* ANOTHER SECONDARY RECOVERY PROJECT [177] AFTER FIVE YEARS OF OPERATION DISPLAYED A RATIO OF OVER 20 MCF/BBL. BUT, A SIGNIFICANTLY LOWER RATIO IS ANTICIPATED WITHIN THE DECADE. (THE LATTER OPERATION IS MAKING USE OF A RELATIVELY INEXPENSIVE SOURCE OF CARBON DIOXIDE.)

ON THE OTHER HAND, REPORTED CO_2 /OIL RATIOS WELL ABOVE 20 MCF/BBL IN TERTIARY FIELD PILOTS [171, 193, 142] INDICATE THAT PREVIOUS FORECASTS [160, 161, 162, 200] OF CARBON DIOXIDE APPLICABILITY AS A TERTIARY RECOVERY TOOL WERE OVERLY OPTIMISTIC. HOWEVER, AN INTENSIVE STUDY OF SPECIFIC TARGETS TO DELINEATE THE RESIDENCE OF THE RESIDUAL OIL AND THE PROBABLY FLOW PATHS FOR INJECTED CARBON DIOXIDE MAY PROVIDE A FRAME WORK FOR TERTIARY RECOVERY OF OIL BY "CREAMING THE RESERVOIR", VIZ., RECOVERING A SIGNIFICANT PORTION OF THE RESIDUAL OIL AT AN ECONOMIC CARBON DIOXIDE/OIL RATIO, RATHER THAN TRYING TO FLOOD AN ENTIRE RESERVOIR.

A VERY POSITIVE PROGNOSIS EXISTS FOR SECONDARY OR TERTIARY RECOVERY FROM RESERVOIRS HAVING A PRONOUNCED DIP, SUCH AS OCCUR IN SOUTH LOUISIANA AND OFFSHORE [170]. CURRENT REPORTS OF A TEST IN PROGRESS IN SOUTH LOUISIANA [142, 171] ARE VERY PROMISING.

* NUMBERS IN [] REFER TO ABSTRACT NUMBER.

CARBON DIOXIDE APPEARS TO BE CAPABLE OF PRODUCING ADDITIONAL CRUDE OIL EVEN THOUGH MISCIBILITY IS NOT ATTAINED THROUGHOUT THE RESERVOIR [143, 178, 212]. (CERTAINLY, MISCIBILITY CANNOT BE MAINTAINED AS THE PRODUCTION WELL IS APPROACHED, AND THE PRESSURE RAPIDLY DECREASES.) ONE OPERATION, IN A PRIVATE COMMUNICATION, REPORTED THAT EARLY PERFORMANCE FOR CO₂ INJECTION, UNDER NON-MISCIBLE CONDITIONS, IN A 25° API OIL RESERVOIR IS VERY PROMISING. THE FACT THAT MISCIBILITY MAY NOT BE NECESSARY MIGHT SUBSTANTIALLY REDUCE PRESSURE AND CARBON DIOXIDE REQUIREMENTS FOR OIL RECOVERY.

FIELD STUDIES INDICATE STRATIFICATION (PERMEABILITY VARIATION), NOT GRAVITATION INSTABILITY, IS OF MAJOR IMPORTANCE IN CONTROLLING THE ADVANCE OF CARBON DIOXIDE [189, 196]. ON THE OTHER HAND, AN EXTENSIVE NUMERICAL MODELLING EXERCISE [186] OF A FIVE LAYER RESERVOIR INTO WHICH CARBON DIOXIDE WAS INJECTED TO RECOVERY RESIDUAL OIL REVEALED THAT GRAVITATION FORCES DOMINATED THE NATURE OF THE DISPLACEMENT OF THE RESIDUAL OIL. THIS AND OTHER RECENT EXAMPLES [143, 148, 168, 177, 193, 212, 213] INDICATE THAT, WHILE THE BASIC FACTORS GOVERNING OIL RECOVERY BY CARBON DIOXIDE INJECTION HAVE GENERALLY BEEN IDENTIFIED, ACCURATE MODELLING AND PREDICTION OF OIL RECOVERY IS NOT YET POSSIBLE.

IN VIEW OF THE CONTROL EXERCISED OVER CARBON DIOXIDE INJECTION BY SUCH FACTORS AS PERMEABILITY DISTRIBUTION [189, 196], MOLECULAR DIFFUSION [86, 141, S2], VELOCITY [21, 141, S2], WELL SPACING [21, 186, S2], GRAVITY [21, 186], PORE SIZE DISTRIBUTION [21], AND MOBILITY RATIO [29, S2], RESEARCH TOWARDS ELABORATION OF PHASE BEHAVIOR IS BEING OVER EMPHASIZED. AT THIS TIME, MINI-TESTS IN TARGET RESERVOIRS ARE REQUIRED FOR RELIABLE TECHNOLOGICAL EVALUATION IN VIEW OF THE MANY PROBLEMS IN DEVELOPING UNEQUIVOCAL MODELS OF THE DISTRIBUTION OF RESIDUAL OIL, RESERVOIR HETEROGENEITY, AND RECOVERY MECHANISM.

FOR CARBON DIOXIDE TO SUCCEED AS A TERTIARY RECOVERY TOOL, IT APPEARS THAT A FAR GREATER ATTENTION MUST BE PAID TO MOBILITY CONTROL AND THOSE OTHER FACTORS (SUCH AS VELOCITY, FLUID ENTRY, AND DENSITY GRADIENTS WHICH MAY BE AMENABLE TO CONTROL) WHICH INFLUENCE THE UNIFORMITY OF THE ADVANCE OF CARBON DIOXIDE THROUGH THE RESERVOIR. IT WAS THE LACK OF CONTROL OVER THESE FACTORS THAT LED TO THE WIDESPREAD FAILURE OF LPG AND OTHER HYDROCARBON MISCIBLE PROCESSES IN THE PREVIOUS DECADES [212, S22].

THE OVERALL PROGNOSIS FOR SUCCESSFUL, WIDESPREAD IMPLEMENTATION OF CARBON DIOXIDE INJECTION FOR ENHANCED RECOVERY OF CRUDE OIL, FOLLOWING UPON THIS STUDY, WOULD HAVE TO BE RATED FAIR TO GOOD. THE STATE OF THE ART OF CARBON DIOXIDE FLOODING NEEDS TO BE ADVANCED BY OPERATIONAL SUCCESSES AND THE EXPERTISE OBTAINED BY EXPERIENCE WITH SUCH PROJECTS. LABORATORY AND SIMULATION STUDIES MAY WELL SERVE TO PROMOTE SOME FUNDAMENTAL INSIGHT INTO DISPLACEMENT MECHANISMS AND SWEEP EFFICIENCY, BUT THESE ARE LIMITED IN USEFULNESS WITHOUT FIELD CORROBORATION. A SIGNIFICANT EFFORT SHOULD BE PUT ON STUDIES OF MOBILITY CONTROL.

IT IS CONCLUDED FROM THIS SURVEY THAT THE MOST SIGNIFICANT DEFICIENCY IN RESEARCH ON CARBON DIOXIDE FLOODING FOR THE RECOVERY OF CRUDE OIL IS THE PAUCITY OF WELL CONTROLLED AND INTERPRETED FIELD TESTS.

BECAUSE OF THE TIME AND COST OF SUCH FIELD PROGRAMS, A PARTIAL SUBSTITUTE MAY WELL BE THE USE OF RATHER LARGE SCALED PHYSICAL MODELS. BECAUSE OF THE HIGH PRESSURES UNDER WHICH SUCH WORK MUST BE CARRIED OUT, SUCH A SERIES OF STUDIES WOULD BE RELATIVELY EXPENSIVE AND REQUIRE A SIGNIFICANT COMMITMENT. HOWEVER, THEY COULD PROBABLY PROVIDE, IN A RELATIVELY SHORT TIME SPAN, MUCH KNOWLEDGE ON THE INTERACTION OF CARBON DIOXIDE AND CRUDES UNDER DISPLACEMENT CONDITIONS AND AN OPPORTUNITY FOR A FIRMER CALIBRATION AND CONFIRMATION OF NUMERICAL MODELS.

SECTION TWO: INDIVIDUAL SUBJECT SUMMARIES

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I. SUMMARY OF ABSTRACTS ON PHYSICAL PROPERTIES

THE PHYSICAL PROPERTIES OF MIXTURES OF CRUDE OILS AND CARBON DIOXIDE AT RESERVOIR TEMPERATURES AND PRESSURES ARE REPORTED IN ONLY SIX PAPERS. THE PROPERTIES MOST OFTEN REPORTED ARE VISCOSITY AND SOLUBILITY WITH FEWER DATA ON SWELLING, INTERFACIAL TENSION, AND PHASE EQUILIBRIUM RATIOS. ADDITIONAL DATA OF THIS KIND AT AMBIENT TEMPERATURES AND PRESSURES ARE REPORTED IN A LIMITED NUMBER OF REFERENCES.

THE PHYSICAL PROPERTIES OF SIMPLE SYSTEMS OF CARBON DIOXIDE IN BINARY AND TERNARY MIXTURES OF VARIOUS LOW MOLECULAR WEIGHT (LESS THAN 150) HYDROCARBONS ARE REPORTED IN NUMEROUS PAPERS. SUCH PROPERTIES ARE: COMPRESSIBILITY, VISCOSITY, THERMAL CONDUCTIVITY, AND DIFFUSIVITY. THE MAJORITY OF THESE PROPERTIES IS REPORTED FOR THE GASEOUS PHASE.

PHASE BEHAVIOR, INCLUDING SOLID, LIQUID, AND GAS PHASES, IS THE SUBJECT OF MANY OF THESE REFERENCES TO SIMPLE SYSTEMS, PRESSURE AND TEMPERATURE RANGES ARE EXTENSIVE.

SEVERAL PAPERS DESCRIBE PSEUDO-TERNARY PHASE DIAGRAMS USED TO ESTABLISH QUASITHEORETICAL CONDITIONS FOR ATTAINMENT OF MISCIBILITY FOR BOTH CARBON DIOXIDE AND OTHER DRIVE FLUIDS.

THE MOST USEFUL CORRELATION OF SOLUBILITY, SWELLING FACTORS, AND VISCOSITY OF CARBON DIOXIDE AND CRUDE OILS IS PRESENTED IN REFERENCE 51. OTHER SIGNIFICANT REFERENCES ARE THE FOLLOWING: THE MUTUAL SOLUBILITY OF CARBON DIOXIDE IN 261 OTHER MATERIALS IS DESCRIBED IN REFERENCE 14, AND THE DIFFUSION OF CARBON DIOXIDE INTO LIQUIDS OF VARIOUS VISCOSITIES IN REFERENCE 62. REFERENCE 184 SHOWS THAT DESPITE MUCH PREVIOUS WORK, PREDICTIVE METHODS FOR THE PROPERTIES OF CARBON DIOXIDE IN MULTICOMPONENT HYDROCARBON SYSTEMS ARE POOR. REFERENCE 183 SHOWS THAT THE INTERFACIAL TENSION OF CARBON DIOXIDE CRUDE OIL SYSTEMS MAY BE REDUCED BY ONE OR TWO ORDERS OF MAGNITUDE OVER A WIDE BAND RAISING THE POSSIBILITY THAT IF A LOW INTERFACIAL TENSION CONTRIBUTES TO THE EFFECTIVENESS OF CARBON DIOXIDE DISPLACEMENT, IT MAY BE EASIER TO ACHIEVE THAN MISCIBILITY.

THE PHYSICAL PROPERTIES OF CARBON DIOXIDE-CRUDE OIL SYSTEMS MAY BE VERY DIFFICULT TO CORRELATE OR USE FOR THE PREDICTION OF OIL RECOVERY BY CARBON DIOXIDE DISPLACEMENT SINCE A CRITICAL FACTOR IN RESERVOIR PROCESSES WILL BE THE DEGREE OF CONTACT AND ATTAINMENT OF EQUILIBRIUM BETWEEN THE CRUDE AND THE INJECTED FLUIDS. THIS IS EMPHASIZED BY REFERENCE 91 WHICH NOTES THE EFFECT OF CORE LENGTH AND VISCOUS FINGERING ON LABORATORY RESULTS OF MISCIBLE DISPLACEMENT PROCESSES.

II. SUMMARY OF ABSTRACTS ON LABORATORY STUDIES

AN EARLY GROUP OF REFERENCES DESCRIBES LABORATORY WORK ON CARBONATED WATER FLOODS WHICH ATTRACTED MUCH ATTENTION IN THE FIFTIES. THE FIRST PATENT ON CARBON DIOXIDE INJECTION [137] IMPLIED THAT THE CARBON DIOXIDE AND OIL BY INTERACTION BECAME LIKE EACH OTHER IN A PHYSICAL SENSE AND THEREFORE THE DISPLACEMENT OF ONE BY THE OTHER WAS NEAR PERFECT. HIGHER PRESSURE AND PURITY OF CARBON DIOXIDE WAS SHOWN TO IMPROVE DISPLACEMENT. A GROUP OF SUBSEQUENT REFERENCES POINTS TO SUCH FACTORS AS SWELLING AND VISCOSITY REDUCTION AS BEING SIGNIFICANT IN AFFECTING THE DISPLACEMENT OF OIL BY CARBON DIOXIDE.

REFERENCE 20 IS SIGNIFICANT IN THAT IT SHOWS HOW DISPLACEMENT OF OIL CAN BE ACCURATELY ACCOUNTED FOR BY DISPLACEMENT OF OIL BY CARBON DIOXIDE SWOLLEN OIL AND THE DISPLACEMENT OF THE LATTER IN TURN, BY GAS DRIVE.

MUCH SUBSEQUENT AND RECENT WORK ATTEMPTS TO CORRELATE DISPLACEMENT OF OIL BY CARBON DIOXIDE WITH CONCEPTUALIZATION OF PHASE EQUILIBRIA DEVELOPED BY INTERACTION OF DRIVE FLUID WITH RESERVOIR FLUIDS, PARTICULARLY WITH RESPECT TO FORMATION OF MISCIBLE PHASES. REFERENCES DISTINGUISH MECHANISMS FOR DEVELOPMENT OF PHASE EQUILIBRIA INTO CONDENSATION AND VAPORIZATION; IN THE FORMER, COMPONENTS OF RESERVOIR FLUIDS VAPORIZE INTO CARBON DIOXIDE RICH GASEOUS PHASE.

PSUEDO-TERNARY DIAGRAMS REFERRED TO EXTENSIVELY INDICATE POTENTIAL PATHS FOR ATTAINMENT OF MISCIBILITY. REFERENCE 181 SHOWS THAT WHEN TWO IMMISCIBLE PHASES ARE IDENTIFIED IN EQUILIBRIUM STUDIES, A SIGNIFICANT RESIDUAL SATURATION TO CARBON DIOXIDE FLOODING OF CRUDE IS OBSERVED. THE RESIDUAL IS VERY SMALL WHEN ONLY ONE LIQUID PHASE IS DEVELOPED. A NUMBER OF REFERENCES REPORT PHASE EQUILIBRIA STUDIES ON RESERVOIR CRUDE-CARBON DIOXIDE SYSTEMS AND THEN ATTEMPT TO PREDICT RESERVOIR BEHAVIOR WITH SUCH STUDIES, WITH OR WITHOUT CORE DISPLACEMENT EXPERIMENTS. ONE REFERENCE [194] STATES SUCH PHYSICAL OBSERVATIONS ON CARBON DIOXIDE-CRUDE OIL SYSTEMS WERE PLUGGED INTO NUMERICAL SIMULATION ROUTINE FOR SUCH PREDICTION, BUT ABSENCE OF DETAILS ON THE BLACK BOX PREVENTS THE READER FROM JUDGING THE MERITS OF SUCH TECHNIQUES.

THE USE OF LONG, SLIM, SAND-PACKED TUBES TO DETERMINE MISCIBILITY PRESSURE BETWEEN DRIVE FLUID AND CRUDE OIL, WERE FIRST IMPLIED IN REFERENCE 27 IN DISCUSSION OF PHASE EQUILIBRIA AND HYDROCARBON MISCIBLE DISPLACEMENTS. SLIM TUBE EXPERIMENTS DO NOT TAKE INTO ACCOUNT FACTORS WHICH CAN INFLUENCE RESULTS REGARDLESS OF MISCIBILITY: VISCOUS AND GRAVITY STABILITY, DIFFUSION, PORE SIZE, PACK DIAMETER, ETC. REFERENCE 21 IS A CLASSICAL STUDY OF

DISPLACEMENT. THE MOST TELLING STUDY OF THE INFLUENCE OF MOBILITY RATIO WHICH LEADS TO VISCOUS INSTABILITY ON THE DETERIORATION OF SWEEP EFFICIENCY AND OF A SOLVENT SLUG IS REFERENCE 29. THE SIGNIFICANCE OF OTHER FACTORS ON DISPLACEMENT IN A SLIM TUBE RAISES QUESTIONS ABOUT REPORTED MISCIBILITY OF NITROGEN-CRUDE OIL SYSTEMS [202, S12].

A NUMBER OF REFERENCES ADDRESS THE QUESTION OF PROTECTION OF MISCIBLE SLUG DETERIORATION AND MOBILITY CONTROL BY USING BUFFER MATERIALS AND SIMULTANEOUS OR ALTERNATE WATER-GAS INJECTION. ONE OF THE FIRST AND MOST COMPREHENSIVE ANALYSES OF WATER-SOLVENT INJECTION [28] NOTED THAT THE STABILIZING ACTION OF SUCH MIXTURES COULD PROBABLY BE ACHIEVED, IF AT ALL, ONLY AT RATES TOO LOW TO BE ECONOMIC AND FURTHER NOTED ITS USE COULD BE FORESEEN ONLY IN RESERVOIRS WITH HIGH DIP. EXPERIMENTAL RESULTS ON MOBILITY CONTROL ARE CLOUDED BY LACK OF ATTENTION TO PROPER SCALING OF LABORATORY EXPERIMENTS.

THE FIRST MENTION THAT A SIGNIFICANT PROBLEM IN MISCIBLE FLOOD MAY BE THE DIFFICULTY OF CONTACTING RESIDUAL OIL WITH SOLVENT IS IN REFERENCE 71. OTHER EXPERIMENTS [86] SHOWED THAT PROPANE-WATER INJECTION WOULD EVENTUALLY RECOVER ALL RESIDUAL OIL IN LONG CORES, BUT WELL AFTER BREAKTHROUGH OF SOLVENT (TWO TO THREE PORE VOLUMES). RECOVERY IS ATTRIBUTED TO MOLECULAR DIFFUSION AFTER PASSAGE OF SOLVENT FRONT. THE EXPERIMENTS WERE NOT SCALED AND THE AUTHORS ARE FREE TO CONCLUDE THAT RESULTS WOULD BE IMPROVED IN REAL RESERVOIRS.

AN OUTSTANDING CONTRIBUTION ON THE MATTER OF DISPLACEMENT OF CRUDE OIL BY SOLVENTS, INCLUDING CARBON DIOXIDE, IS REFERENCE 141. THE SHORTCOMING IS THAT LITTLE OF THE SYSTEMATIC WORK IS ON TERTIARY RECOVERY (RESIDUAL OIL SATURATION). THE CONCLUSIONS NOTE A PROTECTIVE, SHIELDING ACTION OF WATER ON RESIDUAL SATURATION. VISCOUS FINGERING OF SOLVENT LEAVES MUCH OF RESIDUAL OIL BEHIND WHICH MAY BE ASSIMILATED BY SOLVENT FOLLOWING BREAKTHROUGH AS A RESULT OF DIFFUSION. RATES AND LENGTHS OF THE SYSTEM ARE VERY IMPORTANT IN RECOVERY. IT ALSO CONCLUDES THAT FOR WATER-WET SYSTEMS, THE SIMULTANEOUS INJECTION OF SOLVENT AND WATER LEADS TO TRAPPING OF BOTH SOLVENT AND THE ORIGINAL RESIDUAL OIL SATURATION, THUS IMPLYING THAT SOLVENT-WATER INJECTION, IF USEFUL AT ALL, IS CONFINED TO USE IN OIL WET SYSTEMS ONLY.

SEVERAL UNIQUE WORKS DESERVE NOTING. REFERENCE 42 USED BUCKLEY-LEVERETT ANALYSIS TO DETERMINE BREAKTHROUGH RECOVERY AND THE COURSE OF SUBSEQUENT SOLVENT-OIL PRODUCTION; THE VALIDITY IS RESTRICTED TO QUESTIONABLE SITUATIONS WHEREIN GRAVITY AND DIFFUSION ARE NOT IMPORTANT. REFERENCE 178 PRESENT EXPERIMENTS TO SHOW THAT LOW INTERFACIAL TENSION OF CARBON DIOXIDE-CRUDE OIL SYSTEMS, WHICH CAN BE ACHIEVED MORE READILY THAN MISCIBILITY, CAN BE VERY SIGNIFICANT IN LOWERING RESIDUAL WATER FLOOD OIL SATURATION. REFERENCE 167 CLAIMS A NOVEL USE OF CARBON DIOXIDE INJECTED WITH A LOWER VOLATILITY SOLVENT INTO A SHUT-IN RESERVOIR PRIOR TO STEAM

INJECTION, SUBSEQUENTLY DRAWING PRESSURE DOWN. INJECTION STEAM RESULTS IN STEAM-SOLVENT ACTING TO LOWER VISCOSITY AND CARBON DIOXIDE PROVIDING SOLUTION GAS DRIVE. THE QUESTION OF SOLVENT AND CARBON DIOXIDE DISTRIBUTION IN RESERVOIR AND SOLUTION OF THESE IN THE OIL IS NOT ADDRESSED.

III. SUMMARY OF ABSTRACTS ON FIELD TESTS

A SIGNIFICANT NUMBER OF THE REFERENCES CLASSIFIED UNDER THIS SUBJECT REFERS TO PROCESSES AND TECHNIQUES THAT ARE APPLICABLE TO FIELD OPERATIONS, RATHER THAN REPORTS OF ACTUAL FIELD OPERATIONS. SUCH REFERENCES ARE CROSS CATEGORIZED UNDER PATENTS, LABORATORY STUDIES, ETC. THIS SUMMARY IS CONFINED TO REFERENCES THAT ARE EXCLUSIVELY CONCERNED WITH PERFORMANCE OF FIELD PROJECTS.

SOME EARLY REFERENCES DISCUSS THE USE OF CARBON DIOXIDE AND INERT GASES AS STIMULANTS FOR PRODUCING WELLS [38, 63], AS WELL AS THE TECHNIQUES FOR GENERATING INERT GASES [55].

THE INJECTION OF CARBON DIOXIDE INTO THE NORTH CROSS UNIT (CROSSET, DEVONIAN) IS TRACED IN A SERIES OF PAPERS. THE PROPOSED TEST IS DESCRIBED IN REFERENCE 52 (1966), AND THE PROJECT DESIGN AND INITIAL RESPONSE IN REFERENCE 123 (1974). THE USE OF NUMERICAL SIMULATION TO PREDICT THE PERFORMANCE IS DESCRIBED IN REFERENCE 124 (1974). THE UPDATED RESPONSE AS OF 1975 IS IN REFERENCE 139 AND THE MOST RECENT REVIEW OF PERFORMANCE IS DESCRIBED IN REFERENCE 177 (1977). THIS IS A SECONDARY RECOVERY OPERATION, AND BY 1977, 27.7 BILLION CUBIC FEET OF CARBON DIOXIDE HAD BEEN INJECTED AND 926,000 ADDITIONAL BARRELS OF CRUDE PRODUCED FOR A CO_2 /OIL RATIO OF 30 MCF/BBL. THE OPERATOR EXPECTS THIS TO DECLINE SIGNIFICANTLY AS THE TEST PROCEEDS. CURRENT PERFORMANCE CAN BE FOUND IN CURRENT ISSUES OF ENHANCED RECOVERY FIELD PERFORMANCE (142).

THE INITIAL PROPOSAL TO INJECT CARBON DIOXIDE INTO THE SACROC UNIT OF THE KELLY SNYDER FIELD IS DESCRIBED IN REFERENCE 75 (1969). THE FACILITIES FOR SACROC ARE SUMMARIZED IN REFERENCE 92. A STATUS REPORT FOR 1972 IS IN REFERENCE 104 AND A REPORT THAT THE OPERATION WAS FINANCIALLY SUCCESSFUL IS IN REFERENCE 119, REFERENCE 136 DESCRIBES PROFILE CONTROL OPERATIONS AT SACROC AND REFERENCE 145 PRESENTS A STATUS REPORT AS OF 1976. CORROSION AND OPERATION PROBLEMS ARE DESCRIBED IN REFERENCE 174. THE FINAL RESULTS OF THE TERTIARY PILOT TEST AT SACROC ARE REPORTED IN REFERENCE 193. ABOUT 3% OF THE ORIGINAL OIL IN PLACE WAS RECOVERED AT A CO_2 /OIL RATIO OF 36 MCF/BBL. THE REPORT PROJECTS THAT FULL SCALE OPERATION MIGHT RECOVER 4% TO 6% OF THE OIL AT A RATIO OF 15 TO 20 MCF/BBL.

THE FINAL RESULTS OF THE MAJOR TEST AT SACROC, IN THE PATTERN AREA, WERE INITIATED WELL BEFORE WATER FLOODING HAD BEEN INCREASED AFTER INITIATION OF CARBON DIOXIDE INJECTION. IN ORDER TO ESTIMATE THE ROLE OF CARBON DIOXIDE, NUMEROUS CORRECTIONS WERE REQUIRED TO OFFSET THE EFFECT OF INCREASED PRESSURE AND WATER INFLUX. AN INCREMENTAL RECOVERY OF APPROXIMATELY 6% OF THE ORIGINAL OIL IN PLACE AND A CO_2 /OIL RATIO OF APPROXIMATELY 6 MCF/BBL WAS ESTIMATED FOR THE COMPLETE OPERATION.

THE SIGNIFICANCE OF THE TEST IS FURTHER CLOUDED BY THE CONCLUSION THAT THE CARBON DIOXIDE WAS NOT INJECTED UNDER MISCIBLE CONDITIONS [143] AND THE MARKED REDUCTION IN ESTIMATED ORIGINAL OIL IN PLACE MADE AFTER THE TEST WAS PLANNED.

THE LITTLE CREEK, MISSISSIPPI TEST WAS FIRST DESCRIBED IN THE LITERATURE IN 1974 [114] AND THE FINAL REPORT APPEARED IN 1977 [171]. SIXTY-ONE PERCENT OF THE ESTIMATED 200,000 BARRELS OF OIL IN THE SUBJECT AREA WAS RECOVERED AT A CO_2 /OIL RATIO OF 27.6 MCF/BBL. PLANS FOR A CARBON DIOXIDE TEST AT WASSON ARE DESCRIBED IN REFERENCE 146.

SIGNIFICANT WORK HAS BEEN UNDERTAKEN IN PILOT STUDIES IN THE WILLARD UNIT IN WEST TEXAS. AN OFFSET PRODUCER 100 FEET AWAY DID NOT REVEAL ANY ENHANCED PRODUCTION AT THE TIME OF PUBLICATION [172]. CORES TAKEN IN THE WILLARD UNIT FOLLOWING COMPLETION OF CO_2 INJECTION REVEALED VERTICAL DISTRIBUTION OF CARBON DIOXIDE ENTIRELY CONTROLLED BY PERMEABILITY DISTRIBUTION. CARBON DIOXIDE INVASION WAS OBSERVED IN TWO STRATA WHICH STILL CONTAINED SIGNIFICANTLY HIGH OIL SATURATIONS [189]. REFERENCE 190 DESCRIBES THE PROJECTION TO FULL SCALE PERFORMANCE OF THE WILLARD UNIT BASED ON ADJUSTING THE OPERATOR'S RESERVOIR SIMULATOR TO MATCH THE PILOT OBSERVATIONS. TERTIARY OIL IS PRODUCED IN SUCH SIMULATIONS ONLY WHEN AND AFTER CARBON DIOXIDE BREAKS THROUGH TO THE PRODUCING WELL. REFERENCE 191 DESCRIBES THE USE OF NEUTRON LOGGING TO MONITOR THE ARRIVAL OF CARBON DIOXIDE AT OBSERVATION WELLS IN THE WILLARD UNIT, AND REFERENCE 166 DESCRIBES THE USE OF A PRESSURE CORE BARREL TO OBTAIN DEPLETED CORE.

THE WEEK ISLAND SAND GRAVITY STABLE CARBON DIOXIDE INJECTION PROGRAM IS DESCRIBED IN REFERENCE 165 AND EARLY RESULTS ARE IN REFERENCE 201.

A SERIES OF TESTS IN WEST VIRGINIA IS DESCRIBED IN REFERENCES 180, 192, 197, 204, AND 211. PLANNING FOR A TEST IN RANGELY FIELD IN COLORADO IS DESCRIBED IN REFERENCE 194. THE MOST RECENT INTERPRETATIVE REVIEWS OF FIELD PERFORMANCE IF CARBON DIOXIDE PROCESSES ARE IN REFERENCES 173, 206, AND 212.

BECAUSE OF THEIR RELEVANCE, THE REPORTS OF LPG AND ENRICHED GAS FLOODS ARE REFERENCED IN THE SUPPLEMENTARY LISTING; THE LAST SIGNIFICANT REVIEW OF HYDROCARBON MISCIBLE FLOODING OPERATIONS IN THE FIELD IS REFERENCE S22.

IV. SUMMARY OF ABSTRACTS ON MODELLING

PHYSICAL MODEL STUDIES OF THE MISCIBLE DISPLACEMENT PROCESS ARE DESCRIBED IN A HANDFUL OF REFERENCES. THESE DEMONSTRATE THE FUNDAMENTAL PHYSICAL PHENOMENA THAT CONTROL THE MISCIBLE FLOODING PROCESS AND REVEAL THE OBSTACLES THAT MUST BE OVERCOME BY INVENTION, FOR PROGRESS TO BE ACHIEVED.

A SIMPLE MODEL OF RECOVERY AS A RESULT OF CARBON DIOXIDE SOLUBILITY, OIL PHASE SWELLING AND SWOLLEN OIL PHASE DISPLACEMENT BY GAS IN REFERENCE 20, SHOULD BE GIVEN FAR MORE ATTENTION IN VIEW OF PROBLEMS INVOLVED IN ATTAINING MISCIBILITY IN CARBON DIOXIDE INJECTION OPERATIONS.

A CORRELATION OF BREAKTHROUGH RECOVERY AND VOLUMETRIC SWEEP BASED ON BUCKLEY-LEVERETT ANALYSIS AND OBSERVATIONS ON SOLVENT INVASION IN REFERENCE 100 PROVIDE A SIMPLE MEANS FOR ROUGH ESTIMATIONS OF RECOVERY EFFICIENCY UNDER A VARIETY OF OPERATING PRACTICES AND SLUG SIZES.

THE LARGEST GROUP OF REFERENCES DISCUSSES NUMERICAL SIMULATION USING APPROACHES BASED ON COMPOSITIONAL EQUILIBRIA OR MIXING PARAMETERS. THE FUNDAMENTAL PAPER ON THE USE OF MIXING PARAMETERS, DERIVED FROM LABORATORY DATA OR HISTORY MATCHING OPERATION, IS REFERENCE 105, IN WHICH A THREE-PHASE SIMULATOR WAS ADAPTED FOR THE PURPOSE. REFERENCE 186 DESCRIBES THE SAME FOR A FOUR-PHASE SIMULATOR. REFERENCE 540 PRESENTS THE BASIC CONCEPTS FOR A NUMERICAL COMPOSITIONAL SIMULATOR.

FIELD OPERATIONS AT SACROC HAVE BEEN MODELLED WITH A COMPOSITIONAL SIMULATOR [143]; AT WILLARD [190] AND NORTH CROSS [177], MIXING PARAMETER SIMULATORS WERE EMPLOYED. GOOD CORRESPONDENCE IS CLAIMED BETWEEN PERFORMANCE AND SIMULATION UPON HISTORY MATCHING AND PRESUMABLY ADJUSTING RELATIVE PERMEABILITY, MIXING PARAMETERS, AND OBSERVED PERMEABILITY IMPAIRMENT. STRONG EFFECTS OF STRATIFICATION (NON-UNIFORM SATURATION AND PERMEABILITY) ARE REPORTED. WAG RATIOS HAD TO BE INCREASED ACCORDING TO SIMULATION RESULTS TO REDUCE CHANNELING OF CARBON DIOXIDE. THERE IS NO MENTION OF THE EFFECT OF SUCH CHANGES ON OIL DISPLACEMENT AND RECOVERY.

ONE STUDY USES A STREAM TUBE MODEL FOR PROVIDING PERFORMANCE PREDICTION OF ACID GAS IN DISPLACING CRUDE OIL IN A WEST TEXAS RESERVOIR [138]. ANOTHER NUMERICAL STUDY [168] SHOWS HOW DISPERSION AND MIXING ERRORS CAN BE REDUCED, WHILE REFERENCE 154 DEMONSTRATES HOW THE PHASE ENVELOPE AND CRITICAL POINTS CAN BE CALCULATED FOR SUBSEQUENT EQUILIBRIA ATTAINMENT IN MODEL WORK.

A NUMERICAL HISTORY MATCH OF A FIELD CARBON DIOXIDE SOAK OF A VISCOUS OIL RESERVOIR UNDERLAIN BY WATER CONFIRMED THAT THE PROCESS COULD NOT INCREASE ULTIMATE RECOVERY (THEORETICALLY TRUE FOR ANY SOAK PROCESS) BUT ALSO COULD NOT, IN THIS INSTANCE, INCREASE RATE OF RECOVERY [185].

A LABORATORY DISPLACEMENT WAS MODELLED BY SEQUENTIAL EQUILIBRIUM CONTACT STAGES AND EQUATION OF STATE PARAMETERS IN REFERENCE 185. GOOD AGREEMENT WAS CLAIMED BUT THE METHOD IS PROBABLY OF LIMITED UTILITY BECAUSE OF THE REQUIREMENT FOR UNIFORM AND INSTANT ATTAINMENT OF EQUILIBRIUM.

GRAVITATION EFFECTS WERE REVEALED TO DOMINATE DISPLACEMENT OF RESIDUAL OIL IN HYPOTHETICAL SANDSTONES USING A FOUR-PHASE, MIXING PARAMETER SIMULATOR [186]. STRONG OVERRIDE OF CARBON DIOXIDE LIMITED RECOVERY OF RESIDUAL OIL, BUT WATER FOLLOWING CARBON DIOXIDE INCREASED RECOVERY. THIS OCCURRED BECAUSE CARBON DIOXIDE HAD INITIALLY PUSHED OIL DOWN (BELOW THE INTERVAL IN WHICH OVERRIDING OCCURRED) AND THE RESULTING HIGHER SATURATION OF OIL COULD BE DISPLACED BY SUBSEQUENT ENTRY OF WATER. THE PROCESS IS FURTHER IMPROVED BY INJECTION OF CARBON DIOXIDE IN BOTTOM OF RESERVOIR AND WATER IN TOP, THUS FURTHER RESTRICTING GRAVITY SEGREGATION OF CARBON DIOXIDE. THESE RESULTS, BASED ON MIXING IN MACRO-SIZED RESERVOIR CELLS, NEED SOME CONFIRMATION BY PHYSICAL MODEL STUDIES WHICH ATTEMPT TO MODEL MICRO-BEHAVIOR. MODELLING CONFIRMATION BY HISTORY MATCHING IS NOT COMPLETELY SATISFYING IN PROVIDING INSIGHT INTO REQUIRED PROCESS IMPROVEMENT BECAUSE OF POSSIBILITY OF NON-UNIQUE RESULTS. NEVERTHELESS, THE RESULTS WHICH SUGGEST PROFOUND IMPORTANCE OF STRATIFICATION IN SOME INSTANCES, AND GRAVITY IN OTHERS (BOTH OF WHICH SHOULD HAVE BEEN ANTICIPATED FROM KNOWLEDGE OF PHYSICS OF FLUID IN POROUS MEDIA AND WERE DEMONSTRATED IN EARLIER PHYSICAL MODEL STUDIES) ILLUSTRATE THAT MOBILITY CONTROL AND CONTACT OF RESIDUAL OIL BY THE INJECTED CARBON DIOXIDE IS OF DOMINANT IMPORTANCE IN ACHIEVING TECHNOLOGY FOR ENHANCED OIL RECOVERY.

V. SUMMARY OF ABSTRACTS ON PATENTS

SOME 25% OF THE REFERENCES IN THIS STUDY ARE DRAWN FROM THE PATENT LITERATURE. ONE OF THE EARLIEST PATENTS RECOMMENDS HIGH PRESSURE, HIGH PURITY CARBON DIOXIDE INJECTION TO RECOVERY OIL AND IT SUBSTANTIATED CLAIMS WITH LABORATORY STUDIES ON CORES.

THE LARGEST GROUP OF SUBSEQUENT PATENTS IS PRIMARILY CONCERNED WITH VARIOUS SEQUENCES OF SLUGS OF CARBON DIOXIDE, LPG, BUFFER FLUIDS, AND WATER. (IT IS AT TIME DIFFICULT TO UNDERSTAND HOW THE PATENT OFFICE WAS ABLE TO FIND SUFFICIENT NOVELTY IN SUBSEQUENT FILINGS TO JUSTIFY AWARDS.)

A NUMBER OF PATENTS DEALS WITH IN-SITU GENERATION OF CARBON DIOXIDE BY COMBUSTION OR CHEMICAL REACTIONS BETWEEN INJECTED FLUIDS. PATENTS HAVE ALSO BEEN GRANTED FOR RAISING THE PRESSURE OF A RESERVOIR BY INJECTING OIL OR OIL-MISCIBLE SOLVENTS, PRIOR TO THE INJECTION OF CARBON DIOXIDE, FOR INJECTION OF CARBON DIOXIDE AT AN OPTIMUM PRESSURE ABOVE THE BUBBLE POINT, FOR INJECTION OF CARBON DIOXIDE AT A PRESSURE ABOVE THE MINIMUM MISCIBILITY PRESSURE AS DETERMINED FROM SLIM TUBE EXPERIMENTS, AND FOR A SERIES OF SEQUENTIAL SOLVENTS THAT CLAIMS TO OVERCOME THE FACT THAT A SINGLE SOLVENT MIGHT NOT MAKE CONTACT WITH RESIDUAL OIL.

A PATENT HAS BEEN ISSUED TO COVER THE USE OF ADDITIVES TO RAISE THE DENSITY OF CARBON DIOXIDE TO A VALUE JUST LESS THAN THAT OF CRUDE OIL SO AS TO PROMOTE BLANKET SPREADING OF THE CARBON DIOXIDE WHEN INJECTED AT THE TOP OF DIPPING RESERVOIRS, AND THE USE OF SURFACTANT SYSTEMS BEFORE AND AFTER CARBON DIOXIDE INJECTION, HAVE ALSO BEEN PATENTED. ALTERNATING CARBON DIOXIDE-WATER INJECTION HAS BEEN CLAIMED TO INCREASE PERFORMANCE OF MICELLAR-POLYMER FLOODS, AND A PATENT ALSO COVERS THE USE OF CARBON DIOXIDE IN THE OIL WITHIN THE MATRIX, SWELLING IT AND LEADING THEREBY, TO ITS EXPULSION INTO THE FRACTURES.

COMBINATION OF CARBON DIOXIDE WITH SLIGHTLY SOLUBLE GAS HAS BEEN CLAIMED TO BE EFFECTIVE FOR SOAKING WELLS SINCE THE SLIGHTLY SOLUBLE GAS WILL PROVIDE EXPULSIVE ENERGY TO THE LOWERED VISCOSITY CARBON DIOXIDE-CRUDE OIL SOLUTION. CARBON DIOXIDE HAS ALSO BEEN CLAIMED TO BE EFFECTIVE AS A PRECURSOR TO STEAM INJECTION FOR INCREASING THE PERFORMANCE OF STEAM DRIVE.

THE PATENT LITERATURE, IN GENERAL, DOES NOT APPEAR TO PROVIDE A TECHNICALLY SOUND RESOURCE FOR ADVANCING THE STATE OF THE ART OF CARBON DIOXIDE FLOODING. ONE GRANTED CLAIM THAT AN ADDITIONAL BARREL OF OIL CAN BE PRODUCED FOR EVERY 200 TO 250 SCF OF CARBON DIOXIDE INJECTED SUGGESTS THE PATENTS HAVE NOT BEEN REVIEWED BY AWARE AND EXPERT TECHNOLOGISTS.

VI. SUMMARY OF ABSTRACTS ON MISCELLANEOUS REFERENCES

A VERY LARGE NUMBER OF THE REFERENCES LISTED IN THIS CATEGORY IS ALSO REFERENCED UNDER OTHER CATEGORIES; AND STILL ANOTHER SIGNIFICANT GROUP RELATES TRADE PRESS ACCOUNTS OF TOPICAL MATTERS. THE FOLLOWING SUMMARY IS OF THOSE FEW REFERENCES IN THIS CATEGORY WHICH HAVE HISTORICAL SIGNIFICANCE AND ARE NOT INCLUDED IN OTHER CATEGORIES.

OF INTEREST IN THESE REFERENCES IS THE INCREASING ESTIMATES OF CARBON DIOXIDE REQUIREMENTS TO RECOVER AN ADDITIONAL BARREL OF CRUDE. TWO-HUNDRED TO 250 SCF OF CARBON DIOXIDE WERE CLAIMED TO BE SUFFICIENT FOR THE PRODUCTION OF AN ADDITIONAL BARREL OF CRUDE IN 1963 [41]. IN 1976, AN ANALYSIS WAS PRESENTED THAT RAISED THE REQUIREMENT OF 6,000 TO 10,000 SCF [152]. SUBSEQUENT STUDIES BY THE NATIONAL PETROLEUM COUNCIL [162], LEWIN AND ASSOCIATES [161], AND THE OFFICE OF TECHNOLOGICAL ASSESSMENT [200], WHILE NOT PRESENTING SUCH A PARAMETER, PER SE, COULD BE ANALYZED TO REVEAL AN AVERAGE OF ABOUT 5,000 SCF PER ADDITIONAL BARREL OF CRUDE. THE PULLMAN-KELLOGG STUDY [205] FOR CARBON DIOXIDE SUPPLIES IN THE LOS ANGELES BASIN INDICATED REQUIREMENTS OF CARBON DIOXIDE FOR TERTIARY OPERATIONS THAT RANGED TO 15,000 TO 20,000 SCF PER BARREL.

THE PRODUCTION RATES OF CRUDE OIL TO BE ACHIEVED BY CARBON DIOXIDE INJECTION HAVE ALSO BEEN ESTIMATED IN VARIOUS REFERENCES. THE CRITICAL REVIEW APPEARING IN 1976 [152] STATED THAT ADDITIONAL OIL PRODUCTION BY CARBON DIOXIDE PRODUCTION WOULD BE ONLY 175,000 BARRELS A DAY BY THE YEAR 2000; ATTRIBUTING THE RESTRICTION TO BOTH THE LOGISTICS OF SUPPLY AND THE EXCESSIVE QUANTITIES OF CARBON DIOXIDE REQUIRED. THE NATIONAL PETROLEUM COUNCIL, LEWIN & ASSOCIATES AND THE OFFICE OF TECHNOLOGY ASSESSMENT STUDIES WERE IN ACCORD IN PREDICTING THAT THE PRODUCTION RATE IN 1990'S WOULD APPROACH THE ORDER OF ONE MILLION BARRELS A DAY AT WORLD OIL PRICES OF \$10 PER BARREL, THE PRODUCTION WAS NOT EXPECTED TO EXCEED 500,000 BARRELS A DAY BY THE YEAR 2000.

CARBON DIOXIDE WAS REPORTED TO BE THE BEST BET FOR ENHANCED RECOVERY IN OFFSHORE RESERVOIRS IN THE GULF OF MEXICO BECAUSE OF THE PRONOUNCED DIP OF SUCH RESERVOIRS [170]. THE TWO MOST RECENT REVIEWS OF CARBON DIOXIDE FOR ENHANCED OIL RECOVERY ARE REFERENCES 206 AND 212.

SECTION THREE: A SURVEY OF CURRENT OPERATING FIELD PRACTICES AND CORROSION

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I. SUMMARY

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CURRENT CARBON DIOXIDE FLOODS OBTAIN CARBON DIOXIDE FROM NATURAL GAS WELLS, NATURAL GAS OR AMMONIA PLANTS VIA GAS PIPELINES OR IN LIQUID FORM VIA TRUCKS. NEW SOURCES OF CARBON DIOXIDE WILL BE FROM HIGH PURITY CARBON DIOXIDE WELLS. THESE WELLS ARE DIVIDED INTO CATAGORIES ACCORDING TO THEIR BOTTOM HOLE TEMPERATURES; BELOW AND ABOVE 200 F.

A. SOURCE WELLS

1. NATURAL GAS WELLS PRODUCING SOME CARBON DIOXIDE HAVE USUALLY BEEN EQUIPPED WITH CARBON STEEL PIPE. THESE ARE GIVEN BATCH CORROSION INHIBITION EVERY FEW MONTHS. SOME WELLS HAVE "9CR" TUBULARS AND REQUIRE NO CORROSION TREATMENT.

2. NEW HIGH PURITY CARBON DIOXIDE WELLS REQUIRE RESEARCH INTO:

A. HYDRATE TEMPERATURE FOR HIGH PURITY CARBON DIOXIDE.

B. GLYCOL AND CARBON DIOXIDE MIXTURE PROPERTIES.

C. PHASE BEHAVIOR OF CARBON DIOXIDE AND CORROSION INHIBITOR FLUIDS.

D. METALS WHICH WILL BE APPLICABLE IN HIGH TEMPERATURE (150 F) AND NOT SUBJECT TO CHLORIDE CRACKING.

E. ELASTOMERS TO WITHSTAND THE HIGH TEMPERATURE, CARBON DIOXIDE ENVIRONMENT.

F. SEPARATION OF WATER AND CARBON DIOXIDE IN VIEW OF HIGH PRESSURE PHASE BEHAVIOR.

B. INJECTION WELLS

1. INJECTION WELLS FOR CARBON DIOXIDE FLOODS ONLY EXPERIENCE CORROSION WHEN WAG (WATER ALTERNATING WITH GAS) IS PRACTICED SINCE CARBON DIOXIDE ITSELF DOES NOT CONTAIN FREE WATER.

2. CYCLIC GAS AND WATER INJECTION HAS RESULTED IN CORROSION IN (1) THE COMMON METERING LINE AT THE WELLHEAD (2) IN THE INDIVIDUAL GAS AND WATER LINES WHEN SHUT OFF VALVES LEAKED AND (3) ON SOME OF THE "410SS" (STAINLESS STEEL) WELLHEADS. DOWNHOLE TUBULARS, AND PACKERS, HAVE USUALLY BEEN COATED.

3. SATISFACTORY ISOLATION FOR CARBON DIOXIDE AND WATER ARE REQUIRED WHEN PRACTICING WAG OPERATIONS.

C. PRODUCTION WELLS

1. PRODUCTION WELL CORROSION HAS BEEN CONTROLLED BY COATING AND CHEMICAL TREATMENT OTHERWISE A SERIOUS CORROSION PROBLEM COULD OCCUR. SEVERAL OF THE FIELDS VISITED NOTED MINOR CORROSION WITHOUT TREATMENT BUT THIS IS THE EXCEPTION RATHER THAN THE NORM.
2. SCALING TENDENCIES INCREASED DUE TO THE HIGH CARBONATE CONTENT OF PRODUCED AQUEOUS FLUIDS. SCALE INHIBITORS ARE REQUIRED IN MOST FLOODS.
3. DOWNSTREAM OF THE SEPARATION FACILITIES CORROSION IS PREVALENT. THIS IS BELIEVED TO BE DUE TO WEAKER DOWNSTREAM CORROSION CONTROL PRACTICE. COATINGS, LINERS, AND CHEMICAL TREATMENTS ARE ALL USED.
4. THE CORROSION CAUSED BY CARBON DIOXIDE AND HYDROGEN SULFIDE MIXTURES REQUIRES SOME STUDY. MODERATE AMOUNTS OF HYDROGEN SULFIDE (LESS THAN 1 MOL %), APPEAR TO PROVIDE PROTECTION FROM CARBON DIOXIDE CORROSION IN SOME INSTANCES.
5. THE KINETICS OF CARBONATE SCALE FORMATION MAY BE MORE IMPORTANT IN FUTURE FLOODS.

D. PIPELINE

1. PHASE BEHAVIOR OF LIQUID CARBON DIOXIDE IN PIPELINE TRANSMISSION MAY BECOME IMPORTANT AS MORE DIVERSE SOURCES OF CARBON DIOXIDE ARE USED.

II. GENERAL

A REVIEW OF THE ACTIVE AND PROPOSED CARBON DIOXIDE FLOODS IS PRESENTED IN REFERENCE B1. SOME OF THE FACTORS COVERING CORROSION BY CARBON DIOXIDE ARE PRESENTED IN REFERENCES B2 AND B3. ADDITIONAL INFORMATION ON THE EFFECTS OF VELOCITY ON THE CORROSION HAVE BEEN PRESENTED (B5) WITH CORROSION ENGINEERS IN THE VARIOUS COMPANIES USING VARIATIONS OF THIS FORMULA. THE CRITICAL VELOCITY, DEFINED AS THAT WHICH PREVENTS REMOVAL OF SCALE PRODUCTS AND INHIBITOR FILMS, STILL CAN NOT BE DEFINITELY SPECIFIED. USUALLY VELOCITIES OF 50 TO 60 FEET PER SECOND (FPS) ARE FOUND TO BE THE MAXIMUM ALLOWABLE IN FLOWING WELLS. VELOCITIES OF 25 TO 50 FPS IN WELLHEAD PIPING MAY BE LIMITING.

NOTICE SHOULD BE GIVEN TO THE FACT THAT SEVERE CORROSION HAS BEEN NOTED AT A CARBON DIOXIDE PARTIAL PRESSURE OF 4 PSIA IN MANY LOCATIONS. THE OLD RULES PROVIDED FOR CONDENSATE CORROSION ARE NOT VALID FOR MANY CARBON DIOXIDE WELLS. IN ADDITION SOME OF THE WELLS CONTAIN HYDROGEN SULFIDE AND THIS INTRODUCES THE POSSIBILITY OF STRESS CORROSION CRACKING (B4,B6,B7). THE PARTIAL PRESSURE OF HYDROGEN SULFIDE SHOULD BE BELOW 0.05 PSIA. OTHERWISE CARBON AND LOW ALLOY STEELS SHOULD HAVE HARDNESS LESS THAN 23 BHN. IT IS INTERESTING TO NOTE THAT IN SOME CASES SOME HYDROGEN SULFIDE IN THE CARBON DIOXIDE APPEARS TO PROVIDE A PROTECTIVE FILM WHEN 0.5 TO 1% HYDROGEN SULFIDE EXISTS. IT MAY BE THAT THE IRON SULFIDE, SMYTHITE, FORMS RATHER THAN THE MORE COMMON FILM SUBSTANCE, MACHINAWITE.

WEIBE (B8,B9) HAS PRESENTED DATA ON THE WATER CONTENT OF CARBON DIOXIDE AS A FUNCTION OF TEMPERATURE AND PRESSURE. FIGURE 1 SUMMARIZES THIS DATA SHOWING THAT FOR A GIVEN TEMPERATURE AND PRESSURE THE WATER CONTENT HAS A DEFINITE MINIMUM AT A PRESSURE BETWEEN 500 AND 2000 PSI. THUS WHEN REDUCING PRESSURE FROM DOWNHOLE CONDITIONS, FREE WATER MAY OR MAY NOT SEPARATE AND THEREFORE CORROSION MAY OR MAY NOT OCCUR. A PRESSURE - ENTHALPY CHART IS PRESENTED IN FIGURE 2, AND A PRESSURE - TEMPERATURE DIAGRAM IN FIGURE 3. REFERENCE B12 SHOULD BE CONSULTED FOR COMPRESSIBILITY FACTORS IN CARBON DIOXIDE AND CARBON DIOXIDE/METHANE MIXTURES AT HIGH PRESSURES.

III. CORROSION IN CARBON DIOXIDE SOURCE FACILITIES

PULLMAN KELLOGG'S REPORTS (B11, B12) SUMMARIZE THE MAIN SOURCES OF CARBON DIOXIDE IN THE UNITED STATES. THE ACTUAL FIELDS VISITED USED GAS FROM NATURAL WELLS, AN AMMONIA PLANT AND TRUCKED LIQUID CARBON DIOXIDE.

A. CO2 SOURCE WELLS

THE NATURAL SOURCE WELLS FOR CARBON DIOXIDE SHOULD BE DIVIDED ACCORDING TO THEIR TEMPERATURE AND PRESSURE. THEY MAY CONTAIN HYDROGEN SULFIDE AND THIS MUST ALSO BE CONSIDERED IN ANY CATEGORIZATION.

THE CLASSIFICATION OF WELLS IS MADE AS FOLLOWS:

1. NATURAL GAS WELLS WITH UP TO 30% CO2, 170-300 F, 2000-5000 PSIA.

A. CORROSION DOWNHOLE (WITHOUT INHIBITOR OR ALLOY TUBING)

B. CORROSION AT WELLHEAD

C. CORROSION IN FLOWLINE (WITHOUT CHEMICAL OR MATERIAL PROTECTION)

2. HIGH CONTENT (97-99%) CARBON DIOXIDE WELLS 200 F, 2500 PSIA.

A. CORROSION DOWNHOLE (WITHOUT INHIBITOR OR ALLOY TUBING)

B. CORROSION AT WELLHEAD

C. HYDRATE FORMATION AT WELLHEAD

D. WATER AND GAS SEPARATION

E. CORROSION IN FLOWLINE (WITHOUT CHEMICAL OR MATERIAL PROTECTION)

3. HIGH CONTENT (97-99%) CARBON DIOXIDE WELLS 300 F, 12,000 PSIA.

A. SEVERE CORROSION DOWNHOLE (WITHOUT INHIBITION)

B. SPECIAL METALS REQUIRED DOWNHOLE (WHERE CAN'T INHIBIT)

C. CORROSION WELLHEAD (WITHOUT INHIBITION)

D. CORROSION IN FLOWLINE (WITHOUT INHIBITION)

IN THE FIRST CATAGORY ARE THE WEST TEXAS SOURCE WELLS (B23, B24, B25). THE SECOND CATAGORY ARE THE COLORADO WELLS (B10, B26) AND THE THIRD ARE THE MISSISSIPPI WELLS (B27). THE ACTUAL INSTALLATIONS OR PLANNED INSTALLATION AND HOW THESE PROBLEMS ARE HANDLED WILL BE COVERED IN THE FOLLOWING SUBSECTIONS.

B. NATURAL GAS WELLS

- A. PACKED ANNULUS WITH INHIBITOR
- B. COATED TUBING AND INHIBITOR
- C. BARE TUBING AND INHIBITOR
- D. ALLOY, 9 CR, NO INHIBITOR

FOR CORROSION TO OCCUR IN THE GAS WELLS THERE MUST BE WATER PRESENT. THIS MEANS THE DEWPOINT TEMPERATURE ALSO WILL AFFECT THE CORROSION WITH THE MAXIMUM RANGE OCCURRING IN THE RANGE OF 100-200 F REGARDLESS OF THE PARTIAL PRESSURE OF CARBON DIOXIDE IN THE RANGE OF 5 TO 200 PSI (B28) P.R. RHODES (B29) ET AL, HAVE ALSO MENTIONED THAT THE MILL SCALE ON PIPE CAN ENHANCE GALVANIC CORROSION AS COMPARED TO THE DATA MENTIONED IN REFERENCE B2 AND B3 WHICH WAS ON BARE STEEL PIPE.

GALVANIC COUPLING ACCELERATES CORROSION. THIS IS NOTED ON THE COUPLING OF TWO DIFFERENT METALS OR ON A NON-UNIFORM COMPOSITION OF A SINGLE METAL. THE CLASSIC "RING-WORM CORROSION" ON NON-HEAT TREATED TUBING UPSETS IS A PRIME EXAMPLE OF THIS ATTACK. MESA-TYPE CORROSION ALSO OCCURS UP HOLE WHEN THE CARBON DIOXIDE BEGINS TO DESORB FROM SOLUTION.

IN THE NATURAL GAS WELLS OF WEST TEXAS, SOME OF THE TUBING AND PACKERS ARE UNCOATED WHILE MANY ARE COATED WITH AN EPOXY OR AN EPOXY/PHENOLIC COATING. THESE COATINGS ARE USUALLY LESS THAN 20 MILS THICK AND NEARLY ALWAYS IN THE 5-10 MIL RANGE. IT APPEARS THAT THE THIN COATING IS BETTER THAN THE THICK COATING FOR RESISTING GAS IMPREGNATION OF THE COATING UNDER PRESSURE. WHEN PRESSURE IS RELEASED THE THICK FILM CANNOT RELIEVE THE GAS ACCUMULATED BETWEEN THE FILM AND THE WALL. THIS DIFFERENTIAL PRESSURE CAUSES INTERNAL FRACTURING OF THE COATING AND CAN LEAD TO POPPING OFF (B3) OF THE COATING. THIN FILM COATINGS ARE LESS SUSCEPTIBLE TO THIS DELAY IN DIFFUSION OF THE ACCUMULATED GAS IF THE PRESSURE IS GRADUALLY RELEASED.

THE UNCOATED WELLS AS WELL AS THE COATED WELLS ARE TREATED WITH CORROSION INHIBITOR AS COATING DEFECTS ARE ALWAYS PRESENT. ALSO MOST CORROSIVE MEDIA WILL PERMEATE THE COATING. ADDITIONALLY, WIRE LINE DAMAGE CAN CAUSE COATING FAILURES.

THERE ARE SEVERAL DIFFERING OPINIONS ON WHETHER COATINGS AND INHIBITORS SHOULD BOTH BE USED. THE OPINION AGAINST THIS PRACTICE IS THAT THE COATING PREVENTS THE INHIBITOR FROM ADHERING. THE OPPOSING OPINION IS THAT INHIBITOR COMPENSATES FOR DEFECTS IN COATING. THERE IS ALSO SOME DISCUSSION ON THE CORROSION RESULTING FROM WIRE LINE DAMAGE TO COATINGS. ROBERSON (B30) BELIEVES THE CORROSION FROM CUTS IN THE COATING WILL BE HEALED BY CORROSION PRODUCTS. THE REASON PRESENTED IS THAT INSIDE THE PIPE WITH AN ELECTROLYTE THE CURRENT FLOW IS RESTRICTED TO ABOUT 2 1/2 PIPE DIAMETERS. THUS WITH COATING, THE CATHODE IS LIMITED. ON THE OTHER HAND, SEVERE CORROSION HAS BEEN REPORTED (B31) IN MANY INSTANCES WITH WIRELINE CUTS.

EXPERIENCE OF THE CURRENT STUDY TEAM IS THAT CORROSION INHIBITORS AID IN COATED PIPE. BASED ON THIS EXPERIENCE WIRELINE DAMAGE IS CONSIDERED VERY SERIOUS BECAUSE THE FILM IS UNDERCUT BY CORROSION AND MORE COATING IS LOST. THIS CAN CAUSE PROBLEMS IN SURFACE EQUIPMENT AS WELL AS DOWNHOLE. ALTHOUGH INHIBITOR TREATMENT CAN ASSIST IN REDUCING THE EFFECTS OF WIRE LINE DAMAGE, WIRELINE OPERATION IN COATED TUBING SHOULD BE MINIMIZED.

TO PREVENT THE POPPING OFF OF COATINGS, IT HAS FOUND THAT KILLING THE WELL WITH WATER AND SHUTTING IN FOR THREE DAYS ALLOWS THE GAS TO DIFFUSE FROM THE COATING.

COATING MATERIALS USUALLY SPECIFIED ARE EPOXY, PHENOLIC OR EPOXY/PHENOLIC. INHIBITION IN THESE WELLS IS USUALLY LIMITED TO BATCH TREATMENTS EVERY 3 TO 6 MONTHS (B25). USUALLY THE WELLS ARE TREATED AND SHUT IN FOR 12 TO 16 HOURS. THE INHIBITOR TREATMENT IS USUALLY 10% SOLUTION.

LINERS, WHICH ARE USUALLY 20 TO 30 MILS THICK, ARE BEING CONSIDERED IN SOME OF THE TUBING. THESE USUALLY CONTAIN SOMETHING SIMILAR TO FIBERGLASS FABRIC WHICH MAKES THEM MECHANICALLY STRONGER AND ALSO HAVE 30 MILS GROUT BEHIND THE LINER. ALSO, LESS GAS IMPREGNATION AND PERMEATION OF CORROSIVES OCCUR. GAS PERMEATION DOES OCCUR BUT THE LINER HAS THE STRENGTH TO RESIST COLLAPSE. HOWEVER, UNBONDED LINERS CAN COLLAPSE, DUE TO THE GAS WHICH HAS ACCUMULATED BEHIND THEM, WHENEVER PRESSURE IS ABRUPTLY RELEASED. THE MAJOR LIMITATIONS ARE THEIR TEMPERATURE AND PRESSURE RATINGS WHICH ARE APPROXIMATELY 180 F AND 300 PSI MAXIMUM FOR FIBERGLASS.

THE ALLOY PIPE IS USUALLY A CHROMIUM STEEL. IN REFERENCE B18, 9 CHROMIUM STEEL WAS USED WITH SUCCESS. CORROSION RATES FOR 300 SERIES AUSTENITIC STAINLESS AND THE 410 STAINLESS ARE VERY LOW. HOWEVER, THE 300 SERIES AUSTENITIC STAINLESS STEELS ARE SUSCEPTIBLE TO SULFIDE OR CHLORIDE CRACKING AT TEMPERATURES ABOVE 150 F, AND TYPE 410SS CAN BE SUSCEPTIBLE TO CORROSION CRACKING.

TUBING COUPLING TO PREVENT LEAKING OF THE GAS INTO THE ANNULUS HAS BEEN A PROBLEM. MANY TUBING JOINTS AND ELASTOMERS HAVE BEEN TRIED FOR COATED TUBING. IT APPEARS THAT GOOD SUCCESS HAS BEEN EXPERIENCED USING RYTON, PHILLIP'S POLYPHENYLENE SULFIDE MATERIAL AS AN ELASTOMER WITH CONVENTIONAL JOINTS. THE HYDRIL JOINT WITH UNCOATED TUBING AND OIL IN THE ANNULUS HAS BEEN SUCCESSFUL.

C. LOW PRESSURE, HIGH PERCENTAGE CARBON DIOXIDE WELLS

THE CORROSION CONTROL MIGHT BE CHEMICAL OR MECHANICAL. CHEMICAL TREATMENT WOULD BE CONTINUOUS VIA EITHER AN INHIBITOR FILLED ANNULUS WITH A SPRING LOADED BOTTOM VALVE IN THE PACKER OR BY RUNNING A SMALL TUBING EITHER IN THE ANNULUS OR INSIDE THE TUBING. MECHANICAL CONTROL WOULD BE WITH A FIBERGLASS LINER WITHOUT INHIBITOR ADDITION.

ANOTHER PROBLEM AREA IN THESE WELLS WILL BE CONDENSATION OF WATER AND FORMATION OF HYDRATES (B10,B24,B26). HYDRATE FORMATION MUST BE RESOLVED WITH HEAT, GLYCOL, OR SOME OTHER METHOD. THIS ALSO CAUSES SOME PROBLEMS IN EROSION EFFECTS AND WATER SEPARATION PROBLEMS IN THE SURFACE EQUIPMENT.

D. HIGH PRESSURE, HIGH PERCENTAGE CARBON DIOXIDE WELLS

THESE HIGH TEMPERATURE, HIGH PRESSURE WELLS WILL PROBABLY REQUIRE CONTINUOUS TREATMENT OR SPECIAL ALLOYS. THIS IS A NEW ENVIRONMENT AND WILL REQUIRE ADDITIONAL STUDY. A PHASE BEHAVIOR PROBLEM IS EXPECTED IN CIRCULATING A LIGHT OIL AND INHIBITOR SIMILAR TO THE PHASE BEHAVIOR PROBLEM DOWNHOLE. SIMON (B32) AND STALKUP (B33) HAVE EVALUATED SOME OF THESE PHASE BEHAVIOR PROBLEMS WITH RESERVOIR OIL. THE SAME TYPE OF DATA MUST BE GENERATED FOR THE INHIBITOR PROGRAM.

IT IS FELT A SIMILAR PROGRAM TO THE INHIBITION OF THE DEEP SOUR MISSISSIPPI WELLS WILL BE UTILIZED.

E. OTHER SOURCES

LIQUID CARBON DIOXIDE DELIVERY OR SUPPLY FROM AN AMMONIA PLANT ARE NOT CONSIDERED HERE AS THEY WILL BE DISCUSSED IN RELATION TO SURFACE INJECTION EQUIPMENT.

IV. WELLHEAD OF SOURCE WELLS

INITIALLY SOME INHIBITOR-TREATED CARBON STEEL WELLHEADS WERE USED. THEN THE SWITCH TO TYPE 410 STAINLESS WAS MADE. MOST WELLHEAD VALVES ARE MADE FROM TYPE 410 OR 316 STAINLESS OR AT LEAST THE VALVE TRIM IS 316 STAINLESS.

IN CASES WHERE SALT WATER IS PRESENT (4% OR GREATER BY WEIGHT) THE WELLHEADS MAY BE CONVERTED TO 316 SS BECAUSE OF PITTING CORROSION. HOWEVER, CARE MUST BE TAKEN IN USING THE 300 SERIES STAINLESS BECAUSE CHLORIDE STRESS CORROSION CRACKING CAN OCCUR IF THE TEMPERATURE IS ABOVE 150 TO 180 F.

OTHER ALLOYS SUCH AS INCONEL, ETC. ARE BEING INVESTIGATED FOR VALVE STEMS.

THE WELLHEAD AREA IS ONE OF THE FIRST AREAS WHERE EROSION IS USUALLY A PROBLEM. ON CARBON STEEL, EROSION IS IMPORTANT AS IT REMOVES THE PROTECTION OF THE CORROSION PRODUCT IRON CARBONATE.

V. FLOWLINES

FLOWLINES IN THE PAST HAVE BEEN:

1. BARE STEEL WITH INHIBITION
2. STEEL PIPE WITH LINER OR COATING AND INHIBITION

VELOCITY IN THESE LINES IS PROBABLY AS IMPORTANT AS IT IS IN THE TUBING. BELOW A MINIMUM VELOCITY ENTRAINED WATER CAN SETTLE OUT AND CAUSE CORROSION. ABOVE THE "CRITICAL VELOCITY" EROSION AND CORROSION CAN OCCUR. THE MINIMUM VELOCITY REQUIRED FOR WATER DROP OUT CAN BE ESTIMATED FROM DATA BY WICKS AND FRASER (B33). CHEMICAL INHIBITION IS USUALLY ABOUT 1 PINT/MMSCF. THIS SUPPLEMENTS THE INHIBITOR FROM THE TUBING. CORROSION MONITORING IS USUALLY STARTED AT THE WELLHEAD AND FLOWLINE, AND IS ACCOMPLISHED WITH IRON COUNTS, CORROSION COUPONS, FILM PERSISTENCY METERS, ULTRASONIC THICKNESS TESTS, AND THE HYDROGEN PROBE (B35) OR BY FAILURE ANALYSIS.

VI. FREE WATER SEPARATION (SCRUBBERS)

THE NATURAL GAS WELL STREAMS USUALLY GO TO A NATURAL GAS PLANT. THE HIGH CARBON DIOXIDE WELL WILL ALSO HAVE SEPARATORS TO REMOVE THE FREE WATER. THESE SEPARATORS ARE AGAIN OF THREE TYPES:

1. CARBON STEEL AND INHIBITION
2. ORGANIC LINER AND INHIBITION
3. 304 L STAINLESS CLAD

VII. DEHYDRATION

SOME OF THE NATURAL GAS SOURCE WELLS GO DIRECTLY FROM THE WELLHEAD TO DEHYDRATION EQUIPMENT AND INTO THE PLANT WITHOUT COMPRESSION. IF COMPRESSION IS REQUIRED, THEN DEHYDRATION USUALLY WILL OCCUR AFTER THE THIRD OR FOURTH STAGE OF COMPRESSION. OF COURSE IN SOME INSTANCES, GLYCOL MAY BE INJECTED IN THE FLOW LINE AND RECOVERED AT A MAIN PLANT. USUALLY THE INTERSTAGE PIPING AND GLYCOL UNIT IS 304 STAINLESS OR 304 L CLAD. HOWEVER, MANY UNITS ARE CARBON STEEL WITH INHIBITION ON A CONTINUOUS BASIS. USUALLY THE GLYCOL IS CARBON FILTERED TO REMOVE CONDENSATE AND SOLIDS SO AS TO KEEP THE PURITY HIGH.

THE WATER IS USUALLY SPECIFIED TO BE A MAXIMUM OF ABOUT 50 PPMW OR 123 PPMV. THIS ASSURES NO FURTHER CONDENSATION OF WATER AND HENCE, A LACK OF CORROSION.

VIII. PIPELINE

THE CANYON REEF CARRIER'S PIPELINE IN WEST TEXAS IS THE ONLY EXISTING PIPELINE UTILIZED FOR TRANSPORT OF CARBON DIOXIDE. AS MENTIONED IN THE REFERENCES B13-B16, THE PIPELINE OPERATES AT A PRESSURE IN THE SUPERCRITICAL STATE, ABOVE 1400 PSI WITH A COMPRESSIBILITY FACTOR OF 0.3. OTHER PROPOSED LINES ARE STILL CONSIDERING SUPERCRITICAL VERSUS LOW PRESSURE (LESS THAN 700 PSI) AND LIQUID CARBON DIOXIDE LINES.

SINCE THE PIPELINE IS DRY, THE MAJOR PROBLEM BECOMES ONE OF PHASE SEPARATION AND PRESSURE DROPS.

IX. INJECTION LINES

THE INJECTION SYSTEM WILL DEPEND UPON HOW THE FLOOD WILL BE OPERATED. IT MAY BE A STRAIGHT CARBON DIOXIDE FLOOD OR A COMBINATION WATER ALTERNATING CARBON DIOXIDE FLOOD. ALSO THE SOURCE OF CARBON DIOXIDE MAY BE GAS OR LIQUID.

LIQUID CARBON DIOXIDE WILL REQUIRE PUMPING AND INSULATED INJECTION LINES. THE INJECTION LINES MUST BE EQUIPPED WITH VENTS IN THE EVENT OF A SHUTDOWN. THE VOLUME OF THE CARBON DIOXIDE TRAPPED IN A SHUT IN LINE COULD DEVELOP SUFFICIENT PRESSURE TO BURST THE LINES UNLESS VENTED. THE PUMP MATERIAL MUST ALSO BE ABLE TO OPERATE AT THE LOW TEMPERATURE.

THE MATERIAL FOR THE INJECTION OF THE CARBON DIOXIDE, WHETHER LIQUID OR GAS, CAN BE CARBON STEEL AS NO CORROSION SHOULD OCCUR. IF WATER INJECTION IS ALSO TO BE USED, THEN THE PORTION OF PIPE AT THE WELLHEADS (CONTAINING METER RUN) DOWNSTREAM OF THE BLOCK VALVES MUST HAVE NOT SEALED DURING HIGH PRESSURE INJECTION AND LEAKING OF GAS INTO THE WATER LINE AND VICE VERSA HAS OCCURRED WITH SERIOUS CORROSION. CURRENTLY THE UNUSED VALVES ARE BLIND FLANGED-OFF WHEN ALTERNATING INJECTION. THE METERS ARE MOSTLY TURBINE METERS.

THE WELLHEADS ARE NORMALLY TYPE 410SS OR PREFERABLY 316SS WHEN INJECTING BOTH WATER AND CARBON DIOXIDE AND CARBON STEEL WITH ONLY CARBON DIOXIDE. THE TYPE 316SS RATHER THAN 410SS IS BEING USED BECAUSE OF PITTING CORROSION FROM SALTS IN THE WATER.

THE INJECTION WELL IS USUALLY PACKED OFF AND THE ANNULUS FILLED WITH INHIBITED FLUID. THE CASING PACKER AND THE BOTTOM JOINTS OF TUBING MIGHT BE EXPOSED TO CORROSION OF WATER AND CARBON DIOXIDE SO THE PACKER IS OFTEN COATED. WITH WATER AND CARBON DIOXIDE BEING USED, THE TUBING STRINGS ARE MOSTLY EPOXY OR EPOXY/PHENOLIC COATED. SOME DAMAGE HAS OCCURRED DUE TO MECHANICAL DAMAGE DURING RUNNING AND PULLING. ALSO, LEAKS INTO THE ANNULUS CAN OCCUR WITH SOME TUBING JOINTS AND SEALS. AS PREVIOUSLY MENTIONED, THE PREFERRED NEW COUPLING MATERIAL IS POLYPHENYLENE SULFIDE. COATED CARBON STEEL MIGHT BE SATISFACTORY IN EVEN THE WATER AND CARBON DIOXIDE SINCE IN SWITCHING FROM WATER OR CARBON DIOXIDE THE TUBING WILL NOT BE EXPOSED TO EITHER FLUID FOR A LONG PERIOD OF TIME. HOWEVER, SHUTTING IN A WELL PART WAY THROUGH SWITCHING FLUIDS COULD LEAD TO CORROSION.

ALMOST ALWAYS THE WATER LINE TO THE INJECTION WELLS ARE EITHER CEMENT LINED OR HAVE A FIBERGLASS LINER WHENEVER THE WATER BEING INJECTED IS CORROSIVE. THE CEMENT IS NOT EFFECTIVE IF ANY CARBON DIOXIDE LEAKS INTO THE WATER SYSTEM. CARBON STEEL SHOULD BE SATISFACTORY IF THE WATER IS PROPERLY TREATED AND THE CARBON DIOXIDE DOES NOT LEAK INTO THE STAGNANT WATER LINE.

X. PRODUCTION WELLS

IN MOST CASES THERE HAS BEEN INCREASED CORROSION AFTER CARBON DIOXIDE BREAK THROUGH UNLESS THE PRODUCTION WELLS AND FLOW LINES WERE PREVIOUSLY LINED, COATED ETC., OR A COROSION INHIBITOR PROGRAM WAS IN EFFECT. THUS PRODUCTION CORROSION HAS NOT BEEN SEVERE IF PROPERLY TREATED. THERE ARE A FEW FIELDS WHERE TREATMENT WAS NOT DONE AND NO SEVERE CORROSION WAS NOTED. THE LACK OF CORROSION MAY BE DUE TO THE EXISTING FLOW REGIME AND AN OIL COATING. THERE IS ALSO THE POSSIBILITY THAT THE CORROSION WAS (IS) OCCURRING AT A REDUCED RATE AND HAS NOT YET BEEN NOTICED. ONE FIELD CASE OF SEVERE DOWNHOLE CORROSION FROM CARBON DIOXIDE GAS AND ONE FIELD CASE OF SURFACE CORROSION HAVE BEEN OSERVED WITHOUT ANY CONCURRENT DOWNHOLE CORROSION NOTICED.

ROD PUMP WELLS ARE BATCH TREATED DOWN THE ANNULUS AT LEAST WEEKLY. SUBMERSIBLE PUMPS ARE USUALLY CONTINUOUSLY TREATED. FLOWING WELLS ARE SOMETIMES TREATED WITH A FLUSH TREATMENT.

SCALING HAS NOT BEEN NOTED DOWNHOLE IN MOST INSTANCES. THIS IS PROBABLY DUE TO THE LOW PH. THE SCALE PROBLEM IS MORE PREVALENT IN THE SURFACE EQUIPMENT AFTER THE PRESSURE IS REDUCED AND THE PH INCREASES.

THE PRODUCTION WELLS ARE NEARLY ALL PUMPED OFF TO MAXIMIZE PRODUCTION. THIS CREATES A LOW DOWNHOLE PRESSURE. SINCE THE CARBON DIOXIDE WILL BE LESS SOLUBLE AT LOW PRESSURE, SOME INCREASE IN CORROSION AND SCALING MIGHT BE EXPECTED. HOWEVER, TESTS AT ONE UNIT INDICATED THAT HOLDING A 1600 PSI BACK PRESSURE DID NOT REDUCE THE SCALING OR CORROSION. (WITH A PRODUCTION WELL BOTTOMHOLE PRESSURE OF 600 PSI AND AN INJECTION PRESSURE OF 2000 PSI, THE OIL RECOVERY WOULD BE EXPECTED TO BE REDUCED AS THE CARBON DIOXIDE WOULD LOSE MISCIBILITY SOMEWHERE IN THE RESERVOIR)

IN MOST FIELDS WHERE ALTERNATING SLUGS OF GAS AND WATER ARE USED, FLOWING WELLS CEASE FLOWING WHEN THE WATER REACHES THE PRODUCTION WELLS. WHERE ONLY CARBON DIOXIDE IS INJECTED MANY OF THE WELLS FLOW AS THE GOR (GAS OIL RATIO) INCREASES DUE TO CARBON DIOXIDE BREAKTHROUGH AND INCREASED RESERVOIR PRESSURE.

MONITORING OF PRODUCTION WELL CORROSION REQUIRES THE SAME TECHNIQUES AS USED FOR SOURCE WELLS. WHERE SOME HYDROGEN SULFIDE IS PRODUCED, THE IRON COUNTS MAY NOT BE RELIABLE. ALSO THERE IS MIXED OPINION ON THE OTHER TESTING METHODS. HOWEVER, THE FAILURE ANALYSIS IS THE CHECK ON THE MONITORING METHOD SELECTED.

XI. PRODUCTION FLOWLINES

THE PRODUCTION FLOWLINES CAN BE EXPOSED TO CORROSIVE CONDITIONS DEPENDING UPON THE FLOW REGIME AND THE VELOCITY. CARBON STEEL WAS AND IS USED IN MANY INSTANCES. IN SOME CASES, CONTINUOUS INHIBITION HAS BEEN REQUIRED OR A SWITCH TO COATED LINES, FIBERGLASS LINES OR LINER. SINCE MOST OF THE WELLS ARE ROD PUMPED AND BATCH TREATED, SUFFICIENT INHIBITOR SHOULD CARRY OVER INTO THE FLOWLINE, BUT THIS DOES NOT APPEAR TO BE THE SITUATION WHERE FAILURES HAVE OCCURRED.

THE BEST METHOD APPEARS TO BE COATED PIPE WITH INHIBITOR OR FIBER GLASS PIPE OR LINER. THESE ARE NOT SATISFACTORY AT HIGH PRESSURE OR UNDER PUMPING WITH HYDRAULIC SHOCK. IN LOW WATER CUT AREAS CARBON STEEL PIPE WOULD BE SATISFACTORY WITH OR WITHOUT INHIBITOR.

XII. PRODUCTION MANIFOLD

MOST PRODUCTION MANIFOLDS ARE CARBON STEEL WITH OR WITHOUT CORROSION INHIBITOR DEPENDING UPON THE FIELD. THE VALVES USUALLY ARE EQUIPPED WITH TYPE 316SS TRIM. OFTEN A SCALE INHIBITOR IS INJECTED AT THIS POINT AS WELL AS DOWNHOLE, AND AT THE WELLHEAD.

XIII. SEPARATION EQUIPMENT

SEPARATION EQUIPMENT IS EITHER CARBON STEEL OR CARBON STEEL COATED WITH EPOXY, PHENOLIC, OR GLASSFLAKE REINFORCED POLYESTER LINER. MOST FIELDS OPERATE THESE SEPARATORS AT LOW PRESSURES SO CORROSION SHOULD BE MINIMUM, I.E., A FEW MILS PER YEAR.

HIGH PRESSURE SEPARATORS WILL BE EXPOSED TO MORE CORROSIVE CONDITIONS AND COATING, INHIBITOR, ETC., MAY BE NEEDED.

THE GAS LINE FROM THE SEPARATION EQUIPMENT IS USUALLY STEEL WITH A VOLATILE FILMING AMINE CORROSION INHIBITOR ADDED. ADDITIONAL CORROSION INHIBITION IS REQUIRED AT THE COMPRESSORS.

THE OIL LINE IS SATISFACTORY AS A CARBON STEEL LINE. HOWEVER, IN ANY HEATING VESSELS REQUIRED TO BREAK THE EMULSIONS, CORROSION MAY OCCUR. THE CARBON DIOXIDE DOES APPEAR TO INCREASE THE DIFFICULTY OF BREAKING THE EMULSION.

THE WATER LINE IS EITHER COATED, FIBERGLASS OR PROTECTED WITH A CORROSION INHIBITOR. OFTEN ADDITIONAL SCALE INHIBITOR IS REQUIRED, ESPECIALLY IN FIRED VESSELS.

THIS WATER IS EITHER TREATED FOR REUSE OR IT IS DISPOSED OF AS WASTE WATER. CATHODIC PROTECTION IS SOMETIMES USED TO PROTECT PORTIONS OF THESE VESSELS. UNFORTUNATELY DUE TO MAINTENANCE PROBLEMS CATHODIC PROTECTION IS RARELY USED.

XIV. RECYCLE OF GAS

DEPENDING UPON THE FIELD, THE GAS IS RECYCLED TO A GAS PLANT AND CARBON DIOXIDE PLANT FOR RECOVERY OF THE CARBON DIOXIDE OR IS JUST REINJECTED INTO WELLS WITHOUT GOING TO A GAS PLANT.

WHEN THE GAS IS RECYCLED TO A GAS PLANT AND CARBON DIOXIDE RECOVERY PLANT, IT FIRST MUST BE COMPRESSED. THE OPERATING PROCEDURES ARE SIMILAR TO THOSE DISCUSSED IN PART V AND VI.

MOST OF THE INSTALLATIONS USING CARBON STEEL ADD CHEMICAL AT EVERY STAGE OF COMPRESSION UNTIL DEHYDRATION, AT ABOUT 1 PINT/ MSCF. CHEMICAL INJECTED AT THE SEPARATORS USUALLY CARRIES OVER TO THE FIRST STAGE.

SOME CARBON DIOXIDE RECOVERY PLANTS ARE DISCUSSED IN REFERENCE B11. CURRENTLY OF THE THREE PLANTS IN WEST TEXAS, TWO EMPLOY HOT POTASSIUM CARBONATE UNITS AND ONE MONSANTO'S ETHYLENE AMINE (B17). THESE ARE RECOVERING CARBON DIOXIDE FROM STREAMS CONTAINING 25-30% CARBON DIOXIDE. THE HOT POTASSIUM CARBONATE PLANTS HAVE A PROTECTIVE FILM FROM POTASSIUM PENTAVANADATE. THE AMINE PLANT USES A CORROSION INHIBITOR. IN BOTH SYSTEMS, CORROSION INHIBITORS ARE USED IN THE GAS TO THE GAS PLANT AT 1 PINT/MSCF.

ONE OF THE GAS PLANTS SPENDS ABOUT \$8000/MONTH ON CORROSION INHIBITOR. THESE EXISTING PLANTS DO NOT RECOVER ANY HYDROGEN SULFIDE GAS. SOME OF THE NEW PLANTS WILL HAVE THIS CAPACITY.

XV. CORROSION AND SCALE COSTS

CURRENT FIELD CORROSION AND SCALE CHEMICAL COSTS ARE ABOUT 36 MILS/BL OF PRODUCED LIQUID. CARBON DIOXIDE GAS NOW COSTS (1) ABOUT 30 CENTS/MSCF TO RECOVER FROM PRODUCTION (2) ABOUT 18 CENTS/MSCF TO REINJECT, COMPARED TO ABOUT 50 CENTS TO \$1.00/MSCF TO ACQUIRE AND TRANSMIT FROM NATURAL SOURCES. NEW SOURCES OF CARBON DIOXIDE WILL DIFFER FROM THESE CURRENT COSTS.

XVI. FIELD LOCATIONS

MOST OF THE FIELD LOCATIONS VISITED WERE IN WEST TEXAS.
FIGURE 4 PRESENTS A TYPICAL WEST TEXAS FIELD.

A. FIELD A (FIGURE 5)

THIS FIELD TAKES CARBON DIOXIDE RECOVERED FROM NATURAL GAS WELLS AND TRANSPORTS IT FOR INJECTION. IT ALSO RECOVERS THE CARBON DIOXIDE FOR RECYCLE INJECTION. PRODUCTION IS BY ROD PUMP, FLOWING AND SUBMERSIBLE PUMP. PRODUCED WATER IS RECYCLED WITH MAKEUP FOR REINJECTION.

B. FIELD B (FIGURE 6)

THIS FIELD IS SIMILAR TO FIELD A EXCEPT IT DOES NOT ALTERNATE INJECTION OF CO₂ AND WATER. THE PRODUCED GAS IS RECYCLED, BUT IS DIVIDED INTO TWO STREAMS, A HIGHLY CONTAMINATED STREAM (50% CO₂) AND A LOW CONTAMINATED STREAM (2-50% CO₂). THE HIGHLY CONTAMINATED STREAM IS REINJECTED WITH THE 100% CO₂ FROM THE PIPELINE. CORROSION HAS BEEN NOTED IN THE PRODUCTION SERVICE EQUIPMENT. ALL THE CORROSION HAS BEEN CONTROLLED BY A COMBINATION OF COATING AND CORROSION INHIBITOR ADDITION.

C. FIELD C (FIGURE 7)

THIS IS A PILOT AND IT ALTERNATES CO₂ AND WATER INJECTION. HYDROGEN SULFIDE CONTENT IS HIGH. THE INTERSTAGE OF THE COMPRESSORS IS CARBON STEEL AND APPRECIABLE CORROSION HAS BEEN NOTED WITHOUT INHIBITION. IN FACT, THROUGHOUT THE WHOLE PILOT CORROSION MEASURED BY CORROSION COUPONS AVERAGED LESS THAN 2 MPY. SEVERE CORROSION WAS NOTED IN THE CARBON STEEL OF THE INJECTION WELL METERING LOOP UNTIL IT WAS REPLACED WITH TYPE 316SS.

D. FIELD D (FIGURE 8)

THIS SMALL PILOT HAS NOT EXPERIENCED SEVERE CORROSION ALTHOUGH THE PRODUCTION WELLS ARE TREATED WITH INHIBITOR. THE OIL PRODUCTION IN THIS FIELD INCREASED FROM 174 BD TO 820 BD AND WATER DECREASED FROM 20,000 BD TO 100 BD. IT WAS ESTIMATED IT WOULD REQUIRE 600 B/D TO PAY FOR THE CARBON DIOXIDE INJECTION EVEN AT THE VERY LOW CARBON DIOXIDE COSTS OF ABOUT 5.5 CENTS/ MSCF TO PURCHASE AND 35 CENTS TO COMPRESS AND TRANSPORT.

E. FIELD E (FIGURE 9)

THE PERFORMANCE OF THIS FIELD WAS AMAZING AS NO CORROSION WAS NOTED AND ESSENTIALLY NO TREATMENT WAS BEING DONE. THE PRODUCTION WELLS WERE INITIALLY SQUEEZED WITH A SCALE AND CORROSION INHIBITOR BEFORE TREATMENT STARTED. THE OIL IS 17 DEGREES API AND CYCLIC STEAMING WAS DONE BEFORE THE SQUEEZE JOB. THIS SQUEEZE PLUS THE 8 PPM OF CORROSION INHIBITOR AT ONE OF THE TWO SEPARATOR STATIONS IS ALL THE TREATMENT DONE. THE SOURCE GAS IS FROM AN AMMONIA PLANT AND IS DEHYDRATED WITH A CARBON STEEL TOWER WITH NO CORROSION TREATMENT. IT IS FELT SOME AMMONIA CARRY OVER IS LIKELY IN THIS INSTANCE.

NO CORROSION IS OCCURRING DOWNHOLE BUT THIS COULD BE DUE TO THE VARIOUS COMBINATIONS OF OIL, WATER AND GAS. HOWEVER, IT IS NOT DEFINITE BUT IN CONSIDERING THE COMPRESSORS, NO FREE WATER MAY BE FORMING. AT THE SUCTION OF THE COMPRESSOR THE CONDITIONS ARE 50 PSI AND 50 DEGREES F. THE FIRST STAGE DISCHARGE PRESSURE IS 230 PSI WITH A TEMPERATURE OF 260 DEGREES F, WHICH IS REDUCED TO 120 DEGREES F BY THE INTERSTAGE COOLER. IN REVIEWING THE SATURATED WATER CURVE, FIGURE 1, IT CAN BE SEEN THAT IN ALL THE CASES NO FREE WATER WOULD BE FORMED.

WHY SOME CORROSION, DUE TO WATER CONDENSATION, IS NOT OCCURRING IN THE LINES TO THE COMPRESSORS (75 PSI, 130 DEGREES F TO 50 PSI, 50 DEGREES F) MAY BE DUE TO THE HIGH VELOCITY. THE USE OF THE UNDEHYDRATED GAS AS A GAS LIFT WILL RESULT IN CORROSION APPEARING IN THE TUBING CASING ANNULUS EVENTUALLY. CORROSION WILL BEGIN TO OCCUR WHENEVER THE GAS TEMPERATURE AND PRESSURE ARE REDUCED SO THE GAS CONTAINS FREE WATER. THIS SHOULD BE AT THE FLOWLINE CONDITIONS OF 75 PSI AND 130 DEGREES F.

F. FIELD F (FIGURE 10)

THIS PILOT FLOOD USED LIQUID CARBON DIOXIDE. PROBLEMS WERE EXPERIENCED WITH THE POSITIVE DISPLACEMENT PUMP DUE TO LEAKING CARBON DIOXIDE FREEZING AND WEARING OUT SEALS. OTHERWISE, CORROSION PROBLEMS WERE NOT NOTICEABLY INCREASED ABOVE LEVELS EXISTING BEFORE INJECTION OF CARBON DIOXIDE. THIS WAS NOT A LENGTHY PILOT SO THE SEVERE CORROSION MAY NOT HAVE YET OCCURRED.

G. FIELD G (FIGURE 11)

THIS FIELD IS A PLANNED INSTALLATION. IT IS A FIELD WITH CARBON DIOXIDE SOURCE WELLS RATHER THAN NATURAL GAS WELLS. HYDRATES WILL BE A PROBLEM IN THIS INSTALLATION. NOTICE THAT TREATMENT FOR HYDROGEN SULFIDE WILL BE DONE.

H. FIELD H

THIS FIELD WILL USE HIGH TEMPERATURE, HIGH PRESSURE CARBON DIOXIDE SOURCE WELLS. THE TREATMENT FOR CORROSION IS EXPECTED TO BE CONTINUOUS CIRCULATION OF INHIBITORS OR THE USE OF ALLOY TUBULARS DOWNHOLE.

IN ANY EVENT, INITIAL BOTTOM HOLE LINERS HAVE BEEN OF CORROSION RESISTANT MATERIALS. CORROSION CONTROL MEASURED HERE WILL USE MUCH OF THE TECHNOLOGY GAINED FROM DRILLING AND PRODUCING DEEP SOUR GAS WELLS. ONCE PRODUCED, THE GAS WILL BE TRANSMITTED TO THE OIL FIELDS IN MUCH THE SAME MANNER AS OTHER TRANSFER LINES.

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WATER CONTENT OF CARBON DIOXIDE

FIGURE 1

PRESSURE-ENTHALPY CHART

FIGURE 3

TYPICAL WEST TEXAS CARBON DIOXIDE FLOOD

FIGURE 4

FIGURE 5

FIELD B

FIGURE 6

FIELD C

FIGURE 7

FIELD D

FIGURE 8

FIELD E

FIGURE 9

FIGURE 10

FIGURE 11

SECTION FOUR: USER'S GUIDE TO CO₂ LITERATURE SURVEY

The literature study contained herein is arranged in the following manner:

1. Master Reference List of 213 Master References examined. This list is contained in pages 54 through 74 and is arranged chronologically, and then by author.

2. Supplemental Reference List of 60 additional relevant references examined. This list is contained in pages 70 through 74.

3. Abstracts are contained in the next section (pages 1A through 342A) and are arranged in the order of the Master and Supplemental Reference Lists. The abstracts contain a critical review of the cited publication, along with comments, a precis of exhibits, cross-references to other publications reviewed in this study, additional references which will aid in understanding of the matter of the publication, and keyword coding of major topics studied.

4. Additional lists are contained in pages 412 through 504 of sortings of the Master and Supplemental Reference Lists on the basis of

(a) Principal Author (412 through 417)

(b) All Authors (418 through 427)

(c) Chronology (428 through 433)

(d) Affiliation (434 through 441)

(e) Publication (441 through 448)

(f) Six Major Categories

- Physical Properties

- Laboratory Studies

- Field Tests

- Modelling

- Patents

- Miscellaneous

denoting the information contained in the papers
(449 through 459)

(g) Listing of papers according to one hundred detailed subject categories on pages 460 through 504. The detailed subject categories are enumerated on the following page.

SECTION FIVE: SUBJECT CATEGORIES FOR CO₂ LITERATURE STUDY

SUBJECT CATEGORIES FOR CO₂ LITERATURE STUDY

I. PHYSICAL PROPERTIES

1. Theoretical
2. Experimental
3. Correlation
4. Phase Behavior, General
5. Pure Carbon Dioxide
6. Hydrocarbon Components
7. Non-Hydrocarbon Components
8. Binary System
9. Ternary System
10. Multicomponent System
11. Equation of State
12. Effect of Pressure
13. Effect of Temperature
14. Density
15. Swelling
16. Solubility
17. Viscosity
18. Interfacial Tension
19. Refractive Index
20. Equilibrium Ratios
21. Diffusion Coefficients
22. Oil Characterization
23. Miscibility, Undifferentiated
24. Singel Contact Miscibility
25. Multiple Contact Miscibility
26. Dispersion
27. Wettability
28. Emulsions
29. Foams
30. Other

II. LABORATORY STUDIES

31. Procedures and Apparatus
32. Injection Process
33. Secondary Recovery
34. Tertiary Recovery
35. Sandstone
36. Carbonate
37. Mobility Ratio
38. Areal Sweep
39. Instabilities
40. Residual Saturation
41. Miscibility
42. Wettability
43. Oil Characterization
44. Heavy Oil
45. Carbonated Water
46. Flue Gas
47. Additives
48. Impurities
49. Other
- III. FIELD TESTS
50. Sandstone
51. Carbonate
52. Fractured Reservoirs
53. Soak Operation
54. Water Injection
55. Secondary Recovery
56. Tertiary Recovery
57. Miscible Application
58. Immiscible Application
59. Mobility Ratio
60. Areal Sweep
61. Mobility Control
62. Residual Saturations
63. Corrosion
64. Compression
65. Flue Gas
66. Additives
67. Impurities
68. Economics
69. Facilities
70. Operations
71. Other

IV. MODELLING

72. Analytical
73. Buckley-Leverett
74. Finite Element
75. Finite Difference
76. Variational
77. Hele-Shaw
78. Physical Models
79. Slim-Tube Displacements
80. Mixing Zone Models
81. Compositional Models
82. Fractured Reservoirs
83. Screening Criteria
84. Comparison with Lab. Results
85. Comparison with Field Results
86. Other

V. PATENTS

87. U.S. Patent
88. Canadian Patent

VI. MISCELLANEOUS

89. Economics
90. Enriched and High Pressure
91. LPG
92. SNG
93. Source
94. Supply
95. Transportation
96. Separation
97. Chromatographic Effects
98. Alternate Technologies
99. Other

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OIL & GAS J. (MAY 26, 1975) 82-84.
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OF A MISCIBLE FLOOD IN THE BEAR LAKE CARDIUM UNIT,
PEMBINA FIELD, ALBERTA, CANADA", J. PET. TECH. (JUNE, 1975)
672-678.
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BY HIGH-PRESSURE GAS AT BLOCK 31", PET. ENG. (NOV., 1975)
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SYSTEM", A.I.C.H.E. J. (MAY, 1975) V.21, NO.3, 618-620.
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OIL & GAS J. (APR., 1976) 126-127.
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FLOODING - A CASE HISTORY OF THE LEVELLAND UNIT SECONDARY
MISCIBLE PROJECT", PAPER 5826, SPE-AIME 51ST ANN. FALL
MTG., NEW ORLEANS, LA. (OCT., 1976).
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DISPLACEMENT - A CELL-TO-CELL FLASH MODEL STUDY",
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IN BINARY SYSTEM PROPANE - CARBON DIOXIDE", J. CH. & ENG. DATA
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"FUNDAMENTALS OF TERTIARY OIL RECOVERY: PART 2 - LPG MISCIBLE
SLUG PROCESS", PET. ENG. (FEB., 1976) 58-66.
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"FUNDAMENTALS OF TERTIARY OIL RECOVERY: PART 3 - ENRICHED
GAS MISCIBLE SLUG PROCESS", PET. ENG. (MAR., 1976) 84-88.
- S 52. HERBECK, E.F., HEINTZ, R.C. AND HASTINGS, J.R.:
"FUNDAMENTALS OF TERTIARY OIL RECOVERY: PART 4 - HIGH PRESSURE
LEAN GAS MISCIBLE PROCESS", PET. ENG. (APR., 1976) 66-72.

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"DEW POINT STUDY IN THE VAPOR-LIQUID REGION OF THE METHANE -
CARBON DIOXIDE SYSTEM", J. CH. & ENG. DATA (1976) V.21, NO.4,
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PHASE PROPERTIES OF CARBON DIOXIDE - N-BUTANE AND NITROGEN -
HYDROGEN SULFIDE SYSTEMS AT SUBAMBIENT TEMPERATURES",
J. CH. & ENG. DATA (1976) V.21, NO.2, 222-225.
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OIL & GAS J. (SEP. 12, 1977) 54.
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PERFORMANCE ANALYSIS LEADS TO UNDERSTANDING GOLDEN SPIKE'S
MISCIBLE FLOOD", J. PET. TECH. (JULY, 1977) 867-872.
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PET. ENG. (AUG., 1977) 22-26.
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"MISCIBLE DISPLACEMENT WITH NITROGEN", PET. ENG. (NOV., 1977)
26-30.
- S 59. CROW, P.: "PROSPECTS SEEN BRIGHTER FOR U.S. LNG AND SNG",
OIL & GAS J. (JAN. 16, 1978) 23-28.
- S 60. LOFTON, L.K. AND MORSE, R.A.: "THE EFFECTS OF INJECTION
PRESSURE ON CONDENSING GAS DRIVE RECOVERY", PAPER 7472,
SPE-AIME 53RD ANN. FALL MTG., HOUSTON, TX. (OCT., 1978).

SECTION SIX: ABSTRACTS

1. SQUIRES, F.: "APPARATUS FOR AND METHOD OF RECOVERING OIL AND GAS", U.S. PATENT 1,249,232 (DEC. 4, 1917).

ABSTRACT:

----- THIS PATENT RELATES TO THE INJECTION OF "DEOXIDIZED" GAS (FLUE GAS) ALONG WITH HOT WATER TO RECOVER OIL AND GAS. THE RATIONALE FOR THE PATENT IS THAT THE INJECTED GAS WILL CARRY ALONG OIL TO PRODUCING WELLS. THE HOT WATER IS INJECTED TO AGITATE AND HEAT THE OIL SO THAT THE INJECTED GAS MAY MORE EASILY CARRY IT.

COMMENTS:

----- IN THIS EARLY PATENT, MANY OF THE ADVANTAGES TO BE GAINED FROM INERT GAS INJECTION PROCESSES ARE DEFINED.

EXHIBITS:

----- 2 FIGURES

KEYWORDS:

FIELD SECONDARY RECOVERY
FLUE GAS FIELD APPLICATIONS

WATER INJECTION
FIELD IMMISCIBLE APPLICATION
U.S. PATENT

2. WAITZ, C.A.: "METHOD OF OPERATING OIL WELLS", U.S. PATENT
1,295,243 (FEB. 25, 1919).

ABSTRACT:

----- THIS PATENT INVOLVES INJECTING NATURAL GAS AT
HIGH PRESSURES AS A FLOODING AGENT. THE BASIC CONCEPTS OF BOTH
SOAK AND DRIVE OPERATIONS ARE COVERED, AS WELL AS THE NECESSITY
OF INJECTION WELL CLEANUP PRIOR TO COMMENCING OPERATIONS.

COMMENTS:

----- THIS PATENT IS ONLY OF HISTORICAL INTEREST.

EXHIBITS:

----- 2 FIGURES

KEYWORDS:

OTHER FIELD INFORMATION

SOAK OPERATION
U.S. PATENT

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3. BEECHER, C.E. AND PARKHURST, I.P.: "EFFECT OF DISSOLVED GAS UPON THE VISCOSITY AND SURFACE TENSION OF CRUDE OIL", TRANS., AIME (1926) V.G-26, 51-69.

ABSTRACT:

----- THIS IS ONE OF THE EARLIER PAPERS DEALING WITH PROPERTIES OF OIL AND GASES. DATA PRESENTED INCLUDE SOLUBILITY, VISCOSITY, AND SURFACE TENSION OF CRUDE OIL WITH DISSOLVED NATURAL GAS, CARBON DIOXIDE, HYDROGEN, AND AIR. IT WAS FOUND THAT CO₂ SOLUBILITY AT A GIVEN PRESSURE IS TWO TO FOUR TIMES THAT OF NATURAL GAS, AND MORE THAN TEN TIMES THAT OF AIR OR HYDROGEN. CONCERNING THE OILS TESTED, IT WAS FOUND THAT FOR CONSTANT AMOUNTS OF GAS IN SOLUTION, THE VISCOSITY DATA FOR HYDROGEN AND THE TWO NATURAL GASES USED WERE ESSENTIALLY IDENTICAL, AND THE DATA FOR CO₂ SHOWED ADDITIONAL VISCOSITY DECREASES BY ABOUT 20%. VISCOSITY DATA FOR OIL WITH DISSOLVED AIR WERE ERRATIC BECAUSE OF OXIDATION. SURFACE TENSION DATA WITH CO₂ WERE NOT REPORTED.

COMMENTS:

----- THIS IS ONE OF THE EARLIEST PAPERS DOCUMENTING THE EFFECTS OF CARBON DIOXIDE ON CRUDE OIL, AND IT IS ONE OF ONLY A FEW PAPERS WHERE THE EFFECTS OF CARBON DIOXIDE CAN BE COMPARED TO A NUMBER OF OTHER GASES.

EXHIBITS:

----- 2 TABLES, 10 FIGURES, INCLUDING COMPOSITION DATA AND EXPERIMENTAL RESULTS.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
NON-HYDROCARBON COMPONENTS
EFFECTS OF TEMPERATURE
VISCOSITY

HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
SOLUBILITY
INTERFACIAL TENSION

4. STRAIGHT, H.R.: "PROCESS FOR INCREASING THE PRODUCTION OF OIL
WELLS", U.S. PATENT 1,978,655 (OCT. 30, 1934).

ABSTRACT:

----- THIS PATENT INVOLVES THE INJECTION OF GAS TO DRIVE
OIL FOR PRODUCTION. THE PURPOSES IDENTIFIED FOR THE GAS ARE
VISCOSITY REDUCTION AND DRIVE ENERGY. IN ORDER TO PREVENT
CORROSION, AIR IS COMBUSTED IN THE PRESENCE OF STEAM AND EXCESS
NATURAL GAS TO FORM WATER GAS (CARBON MONOXIDE AND HYDROGEN) AND
CARBON DIOXIDE, WHICH IS THEN INJECTED.

COMMENTS:

----- THE DIFFICULTIES THAT WOULD BE ENCOUNTERED WITH
HANDLING WATER GAS IN THE FIELD PROBABLY PRECLUDE APPLICATION,
UNLESS CARBON MONOXIDE HAS ADDITIONAL BENEFITS OVER CARBON DIOXIDE
THAT ARE NOT APPARENT.

KEYWORDS:

FLUE GAS FIELD APPLICATIONS
U.S. PATENT

FIELD SECONDARY RECOVERY
OTHER FIELD INFORMATION
ALTERNATE TECHNOLOGIES

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5. OLDS, R.H., REAMER, H.H., SAGE, B.H. AND LACEY, W.N.:
"PHASE EQUILIBRIA IN HYDROCARBON SYSTEMS: THE N-BUTANE -
CARBON DIOXIDE SYSTEM", IND. & ENG. CH. (MAR., 1949)
V.41, NO.3, 475-482.

ABSTRACT:

----- THE VOLUMETRIC BEHAVIOR OF FIVE MIXTURES OF
N-BUTANE AND CARBON DIOXIDE WAS INVESTIGATED AT PRESSURES UP TO
10000 PSIA AND TEMPERATURES FROM 100 TO 460 F. THE EXPERIMENTAL
RESULTS ARE PRESENTED IN TABULAR AND GRAPHICAL FORM. THE
COMPOSITIONS OF COEXISTING LIQUID AND GAS PHASES WERE DETERMINED.
DATA PRESENTED INCLUDE DEW POINTS, BUBBLE POINTS, CRITICAL POINTS,
CRICONDENTHERMS AND CRICONDENBARS, AND COMPRESSIBILITY FACTORS.

COMMENTS:

----- THIS PAPER CONTAINS AN ESSENTIALLY COMPLETE
ANALYSIS OF THE N-BUTANE - CARBON DIOXIDE SYSTEM; IT WOULD BE
EDUCATIONAL TO COMPARE THE VARIOUS PROPOSED EQUATIONS OF STATE
WITH THIS KNOWN SYSTEM.

EXHIBITS:

----- 4 TABLES, 5 FIGURES, INCLUDING EXPERIMENTAL DATA.

ADDITIONAL REFERENCES:

- 1. POETTMANN AND KATZ: IND. & ENG.
CH. (1944) V.36, 282.
2. SAGE AND LACEY: TRANS., AIME (1940) V.136, 136.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
EFFECTS OF PRESSURE
OTHER PHYSICAL PROPERTIES

BINARY SYSTEMS
EFFECTS OF TEMPERATURE
LAB. PROCEDURES AND APPARATUS

6. MARTIN, J.W.: "ADDITIONAL OIL PRODUCTION THROUGH FLOODING WITH CARBONATED WATER", PROD. MO. (JULY, 1951) 18-22.

ABSTRACT:

----- THIS PAPER DESCRIBES LABORATORY AND FIELD TESTS OF THE CARBONATED WATERFLOOD PROCESS. THE PROPERTIES WHICH ARE IDENTIFIED AS INFLUENCING THE RECOVERY OF OIL WITH CARBONATED WATERFLOODING ARE: DEGREE OF CARBONATION, TEMPERATURE, PRESSURE, NATURE OF THE CRUDE OIL, ADDITIVES, AND WETTING AGENTS.

TWO FIELD TESTS IN WATERFLOODED SANDS ARE DESCRIBED. THE MAJOR DIFFERENCES BETWEEN THE TERTIARY CARBONATED WATERFLOOD AND THE SECONDARY WATERFLOOD PERFORMANCE INCLUDE INCREASED INJECTIVITY BY A FACTOR OF TWO, INCREASED NATURAL GAS PRODUCTION (FROM 25 TO 300 SCF/BBL), PRODUCTION OF ORGANIC ACIDS, AND INCREASED RECOVERY. NO CORROSION, PLUGGING, OR ALTERATION OF THE OIL WAS SEEN AS A RESULT OF CARBONATED WATERFLOODING.

COMMENTS:

----- THIS PAPER IS MORE A MEDIUM FOR PROMOTION THAN THE REPORTING OF TECHNICAL RESULTS.

EXHIBITS:

----- 4 FIGURES

CROSS REFERENCES:

7. MARTIN: PROD. MO. (MAY, 1951 B) 13.

KEYWORDS:

WETTABILITY (LAB. EXP.)
ADDITIVES (LAB. EXP.)
WATER INJECTION

CARBONATED WATER (LAB. EXP.)
SANDSTONE FIELD
FIELD TERTIARY RECOVERY

7. MARTIN, J.W.: "THE USE OF CARBON DIOXIDE IN INCREASING THE RECOVERY OF OIL", PROD. MO. (MAY, 1951) 13-15.

ABSTRACT:

----- THIS ARTICLE IS ESSENTIALLY NO DIFFERENT THAN THE PRECEEDING ARTICLE, EXCEPT THAT SLIGHTLY MORE DETAIL IS GIVEN CONCERNING FIELD OPERATIONS.

COMMENTS:

----- THIS PAPER IS MORE A MEDIUM FOR PROMOTION THAN THE REPORTING OF TECHNICAL RESULTS.

CROSS REFERENCES:

- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.

KEYWORDS:

CARBONATED WATER (LAB. EXP.)
SANDSTONE FIELD
FIELD TERTIARY RECOVERY

WETTABILITY (LAB. EXP.)
ADDITIVES (LAB. EXP.)
WATER INJECTION
OPERATIONS

8. POETTMANN, F.H.: "VAPORIZATION CHARACTERISTICS OF CARBON DIOXIDE IN A NATURAL GAS-CRUDE OIL SYSTEM", TRANS., AIME (1951) V.192, 141-144.

ABSTRACT:

----- THIS PAPER REPORTS EQUILIBRIUM VAPORIZATION RATIOS FOR A MIXTURE OF LEAGUE CITY (TEXAS) GAS, BILLINGS FIELD (OKLAHOMA) CRUDE OIL, AND CARBON DIOXIDE (UP TO 12 MOLE %). ALL MEASUREMENTS WERE PERFORMED AT CONSTANT TOTAL COMPOSITION. NO SIGNIFICANT VARIATION WAS SHOWN IN THE EQUILIBRIUM RATIOS OF THE HYDROCARBONS OR THE CARBON DIOXIDE ITSELF WITHIN THE LIMITS OF THE EXPERIMENT. CARBON DIOXIDE WAS FOUND TO BE MORE SOLUBLE IN CRUDE OIL THAN IN DISTILLATE.

COMMENTS:

----- BECAUSE OF THE LIMITED RANGE OF CARBON DIOXIDE CONCENTRATIONS EXAMINED AND THE PRESENCE OF MORE RECENT AND COMPREHENSIVE WORK, THIS PAPER IS OF MARGINAL INTEREST TODAY.

EXHIBITS:

----- 3 TABLES, 8 FIGURES

ADDITIONAL REFERENCES:

- 1. POETTMANN AND KATZ:
IND. & ENG. CH. (1945) V.37, 847.
2. POETTMANN AND KATZ: IND. & ENG. CH. (1946) V.38, 530.

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.

KEYWORDS:

MULTICOMPONENT SYSTEMS
EFFECTS OF TEMPERATURE
EXPERIMENTAL PHYSICAL PROPERTIES
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

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9. SAXON, J., JR., BRESTON, J.N. AND MACFARLANE, R.M.:
"LABORATORY TESTS WITH CARBON DIOXIDE AND CARBONATED
WATER AS FLOODING MEDIUMS", PROD. MO. (NOV., 1951) 8-14.

ABSTRACT:

----- THIS IS ONE OF THE EARLIER PAPERS ON LABORATORY
RECOVERIES FROM CO₂ AND CARBONATED WATER FLOODS. THE TESTS WERE
DESIGNED TO DETERMINE WHETHER ANY DIFFERENCE EXISTS BETWEEN
RECOVERIES WITH WATERFLOOD, CARBONATED WATERFLOOD, CO₂ GAS FLOOD
OR LIQUID CO₂ FLOOD.

THE RESULTS SHOWED ONLY MINOR DIFFERENCES BETWEEN WATERFLOOD
AND CARBONATED WATERFLOOD OR CO₂ GAS FLOOD, WHILE SLIGHTLY MORE
OIL WAS RECOVERED WITH A LIQUID CO₂ DRIVE.

COMMENTS:

----- THE AUTHORS' CAUTION THAT THE TEST RESULTS
PRESENTED IN THIS PAPER WERE PRELIMINARY PROBABLY EXPLAINS WHY
THEY DIFFER FROM THE REST OF THE LITERATURE.

EXHIBITS:

----- 5 FIGURES, 3 TABLES

CROSS REFERENCES:

- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
7. MARTIN: PROD. MO. (MAY, 1951 B) 13.

KEYWORDS:

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)

10. BRESTON, J.N. AND MACFARLANE, R.M.: "THE EFFECT OF A NUMBER OF VARIABLES ON OIL RECOVERY FROM CORES WHEN FLOODED WITH CARBONATED WATER AND LIQUID CO₂", PROD. MO. (NOV., 1952) 36-45.

ABSTRACT:

----- THIS IS A SUMMARY ARTICLE DEALING WITH THE VARIABLES INFLUENCING CARBONATED WATERFLOOD RECOVERY. THE CONCLUSIONS REACHED INCLUDE:

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1. ROCK TYPE - MINOR EFFECT
 2. AGE OF CORE SAMPLES - OLD CORES [WHICH ARE PROBABLY MORE OIL-WET] SHOW POORER RESPONSE.
 3. PREVIOUS FLOODING DOES NOT APPEAR TO AFFECT FINAL RESIDUAL OIL SATURATION.
 4. INITIAL OIL SATURATION AND RESIDUAL OIL SATURATION MAY BE RELATED [THIS MAY DENOTE NO MORE THAN A RELATIONSHIP BETWEEN RESIDUAL OIL SATURATION AND IRREDUCIBLE WATER SATURATION].
 5. HIGHER RECOVERIES ARE OBTAINED FOR MORE PERMEABLE ROCK.
 6. POROSITY AND FRACTIONAL RECOVERY ARE UNCORRELATED.
 7. PRESSURE GRADIENT HAD ONLY A MINOR EFFECT ON OIL RECOVERY.
 8. OIL RECOVERY DID INCREASE WITH INCREASED CARBON DIOXIDE CONCENTRATION IN WATER.

COMMENTS:

----- THE CONCLUSIONS OF THIS STUDY ARE BASED ON A SMALL NUMBER OF EXPERIMENTS AND SERVE ONLY AS INDICATORS FOR CARBONATED WATERFLOODING.

EXHIBITS:

----- TOTAL OF 10 TABLES, 34 FIGURES

CROSS REFERENCES:

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6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
 7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
 9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
WETTABILITY (LAB. EXP.)

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES

11. JOHNSON, W.E., MACFARLANE, R.M. AND BRESTON, J.N.: "CHANGES IN PHYSICAL PROPERTIES OF BRADFORD CRUDE OIL WHEN CONTACTED WITH CARBON DIOXIDE AND CARBONATED WATER", PROD. MO. (NOV., 1952) 16-22.

ABSTRACT:

----- THE EFFECTS OF CARBON DIOXIDE AND CARBONATED WATER ON VARIOUS PROPERTIES OF BRADFORD CRUDE OIL WERE TESTED. AMONG THE PROPERTIES TESTED WERE SWELLING, SOLUBILITY, AND INTERFACIAL TENSION. THE PRESSURE AT WHICH A LIQUID CARBON DIOXIDE PHASE WAS FORMED WAS THE SAME FOR CONTACT OF THE OIL WITH CARBON DIOXIDE OR WITH CARBONATED WATER. MARKED VISCOSITY AND INTERFACIAL TENSION DECREASES WERE ALSO NOTED.

COMMENTS:

----- THE USEFULNESS OF THIS PAPER TODAY IS IN THE DETAILED DESCRIPTION OF EXPERIMENTAL APPARATUS AND PROCEDURES.

EXHIBITS:

----- 12 FIGURES, INCLUDING EXPERIMENTAL APPARATUS.

KEYWORDS:

OIL SWELLING
VISCOSITY

EXPERIMENTAL PHYSICAL PROPERTIES
SOLUBILITY
INTERFACIAL TENSION

12. MACFARLANE, R.M., BRESTON, J.N. AND NEIL, D.C.: "OIL RECOVERY FROM CORES WHEN FLOODED WITH CARBONATED WATER AND LIQUID CO₂", PROD. MO. (NOV., 1952) 23-35.

ABSTRACT:

----- THIS PAPER DESCRIBES LABORATORY STUDIES OF THE FACTORS AFFECTING TERTIARY CARBONATED WATERFLOODING OR LIQUID CO₂ FLOODING. THE RESULTS INDICATE THAT AFTER MANY PORE VOLUMES THROUGHPUT, SIGNIFICANT TERTIARY OIL RECOVERY MIGHT BE OBTAINED. ADDITIONAL OIL WAS PRODUCED ON BLOWDOWN AFTER FLOODOUT.

COMMENTS:

----- 1. AT 65 F, LITTLE OR NO OIL RECOVERY WAS OBSERVED, WHILE AT 75 F GOOD OIL RECOVERY WAS OBTAINED. THE AUTHORS FEEL THAT THIS COULD BE DUE TO THE LOW MOBILITY OF THE OIL SINCE IT WAS NEAR THE PARAFFIN PRECIPITATION TEMPERATURE. IF TRUE, THIS MIGHT BE AN IMPORTANT CHARACTERIZING FACTOR FOR CO₂ FLOODING.

2. ADDITION OF A WETTING AGENT RESULTED IN ADDITIONAL 1 TO 1.5% OIL RECOVERY; THIS MAY IDENTIFY A BASIS FOR FUTURE STUDIES.

EXHIBITS:

----- TOTAL OF 8 TABLES, 27 FIGURES

KEYWORDS:

LAB. PROCEDURES AND APPARATUS
TERTIARY RECOVERY (LAB. EXP.)
WETTABILITY (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)

LABORATORY INJECTION PROCESS
RESIDUAL SATURATION (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
ADDITIVES (LAB. EXP.)

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13. WHORTON, L.P., BROWNSCOMBE, E.R. AND DYES, A.B.: "METHOD FOR PRODUCING OIL BY MEANS OF CARBON DIOXIDE", U.S. PATENT 2,623,596 (DEC. 30, 1952).

ABSTRACT:

----- THIS INVENTION RELATES TO THE PRODUCTION OF OIL BY CARBON DIOXIDE FLOODING. THE RECOMMENDED SLUG SIZE IS 10 TO 100% OF A PURE VOLUME, WITH PRESSURES IN EXCESS OF 1000 PSIA AND COMPOSITION BEING 50% OR MORE CARBON DIOXIDE.

THE RESULTS OF FIVE LABORATORY EXPERIMENTS ARE PRESENTED. IN SUMMARY, THESE INDICATE THAT ESSENTIALLY TOTAL RECOVERY IS OBTAINED WITH PURE CARBON DIOXIDE, AND THAT ULTIMATE RECOVERY INCREASES WITH CONCENTRATION OF CO2 IN THE INJECTED GAS.

COMMENTS:

----- THIS IS A KEY PATENT ON THE USE OF CARBON DIOXIDE AS A RECOVERY AGENT AND SHOULD BE STUDIED BY ALL PERSONS INTERESTED IN THE ART.

EXHIBITS:

----- 3 FIGURES

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)

LABORATORY INJECTION PROCESS
RESIDUAL SATURATION (LAB. EXP.)
U.S. PATENT

14. FRANCIS, A.W.: "TERNARY SYSTEMS OF LIQUID CARBON DIOXIDE",
J. PH. CH. (DEC., 1954) V.58, 1099-1114.

ABSTRACT:

----- MUTUAL SOLUBILITIES OF LIQUID CARBON DIOXIDE WITH
EACH OF 261 OTHER SUBSTANCES ARE REPORTED. NEARLY HALF OF THESE
ARE MISCIBLE WITH CARBON DIOXIDE. SOME RELATIONS TO STRUCTURE ARE
NOTED.

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TERNARY GRAPHS FOR 464 SYSTEMS INVOLVING LIQUID CARBON DIOXIDE
ARE PRESENTED. SEVERAL OF THESE ARE OF NOVEL TYPES, INCLUDING 21
SYSTEMS WITH THREE SEPARATE BINODAL CURVES AND 38 SHOWING A BINODAL
BAND ACROSS TWO SIDES OF THE TRIANGLE WITH A SEPARATE BINODAL CURVE
ON THE THIRD SIDE. TWENTY-NINE SYSTEMS HAD THREE LIQUID PHASES.

COMMENTS:

----- 1. THIS IS A VERY IMPORTANT PAPER ON THE PHASE
BEHAVIOR OF CO₂ AND SHOULD BE STUDIED BY ALL PERSONS INTERESTED
IN SAME.

2. FROM TABLE 11 OF THIS PAPER, THE MISCIBILITIES OF MANY
SUBSTANCES WITH CO₂ MAY BE PREDICTED.

EXHIBITS:

----- 3 TABLES, 269 FIGURES COVERING 464 TERNARY SYSTEMS.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
BINARY SYSTEMS
DENSITY

GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
TERNARY SYSTEMS
SOLUBILITY

15. MELDRUM, A.H. AND NIELSEN, R.F.: "A STUDY OF THREE-PHASE EQUILIBRIA FOR CARBON DIOXIDE - HYDROCARBON MIXTURES", PROD. MO. (AUG., 1955) 22.

ABSTRACT:

----- THIS PAPER REPORTS THE RESULTS OF EXPERIMENTAL INVESTIGATIONS OF THE TERNARY SYSTEMS CARBON DIOXIDE - PROPANE - N-HEXADECANE, CARBON DIOXIDE - N-DECANE - N-HEXADECANE, CARBON DIOXIDE - PROPANE - STRIPPED BRADFORD CRUDE OIL, AND CARBON DIOXIDE - N-DECANE - STRIPPED BRADFORD CRUDE OIL. THE MEASUREMENTS WERE TAKEN NEAR AND BELOW THE CRITICAL POINT OF CARBON DIOXIDE (1070 PSIA AND 88 F). LIQUID-LIQUID DISTRIBUTION COEFFICIENTS AND VAPORIZATION EQUILIBRIUM CONSTANTS WERE CALCULATED DIRECTLY FROM THE EXPERIMENTAL DATA.

THE LIQUID-LIQUID DISTRIBUTION COEFFICIENTS ARE DEFINED AS THE RATIO BETWEEN MOLE FRACTIONS OF A GIVEN COMPONENT IN THE TWO LIQUID PHASES. THESE COEFFICIENTS WERE FOUND TO BE LINEARLY CORRELATED WITH HYDROCARBON MOLECULAR WEIGHT. IT WAS FOUND THAT A SIMILAR LINEAR (FIRST ORDER) CORRECTION TO RAULT'S LAW INVOLVING MOLE FRACTION CARBON DIOXIDE ACCURATELY PREDICTED EQUILIBRIUM RATIOS FOR CARBON DIOXIDE CONCENTRATIONS UP TO 30 MOLE %.

COMMENTS:

----- 1. ONE OF THE KEY RESULTS OF THIS PAPER IS THAT EQUILIBRIUM RATIOS DEPEND ON CARBON DIOXIDE CONCENTRATION IN THE LIQUID PHASE, REGARDLESS OF OTHER HYDROCARBONS PRESENT.

2. THE SIMPLIFIED METHOD FOR CORRELATING MULTIPLE LIQUID PHASES SHOULD PROVE USEFUL IN ANALYZING OTHER RESULTS.

EXHIBITS:

----- 2 TABLES, 14 FIGURES, INCLUDING EXPERIMENTAL DATA.

ADDITIONAL REFERENCES:

- 1. REAMER, SAGE, AND LACEY: FUND. RES. ON THE OCCURRENCE AND RECOVERY OF PETROLEUM (1952) 64-69.
2. POETTMANN AND KATZ: IND. & ENG. CH. (1945) V.37, 847-853.
3. LARA: M.S. THESIS, PA. STATE U. (1943).
4. STEWART: M.S. THESIS, PA. STATE U. (1953).
5. STEWART AND NIELSEN: PROD. MO. (JAN., 1954) V.15, NO.3, 27-3

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
EQUILIBRIUM RATIOS
OTHER PHYSICAL PROPERTIES

THEORETICAL PHYSICAL PROPERTIES
CORRELATIONS
TERNARY SYSTEMS
SOLUBILITY
MISCIBILITY, UNDIFFERENTIATED
LAB. PROCEDURES AND APPARATUS

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16. WHORTON, L.P. AND BROWNSCOMBE, E.R.: "METHOD OF RECOVERING DESIRABLE PETROLEUM HYDROCARBON FRACTIONS FROM PRODUCING OIL RESERVOIRS", U.S. PATENT 2,724,437 (NOV. 22, 1955).

ABSTRACT:

----- THIS INVENTION RELATES TO THE USE OF HIGH PRESSURE (3000 TO 6000 PSIA) NATURAL GAS AS A DRIVING AGENT. TWO FACTORS ARE IMPORTANT IN UNDERSTANDING THIS PATENT. FIRST, AT THE HIGH PRESSURES USED, THE VISCOSITY OF THE DISPLACING PHASE BECOMES CLOSER TO THAT OF THE DISPLACED OIL, IMPROVING MOBILITY RATIO; DATA PRESENTED INDICATE INCREASED RECOVERY WITH INCREASING PRESSURE. THE SECOND KEY FACTOR TO THIS INVENTION IS THE REQUIREMENT THAT IT BE IMPLEMENTED BEFORE A FLOWING FREE GAS SATURATION IS CREATED, TO AVOID FRONTAL INSTABILITIES AND CHANNELING.

COMMENTS:

----- THIS PATENT HAS LITTLE RELAVENCE TODAY.

EXHIBITS:

----- 3 FIGURES

CROSS REFERENCES:

- 17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
S 1. BAYS: U.S. PATENT 2,135,319 (NOV. 1, 1938).

KEYWORDS:

LABORATORY INJECTION PROCESS
AREAL SWEEP (LAB. EXP.)
OTHER LABORATORY STUDIES

MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
U.S. PATENT

17. WHORTON, L.P. AND BROWNSCOMBE, E.R.: "METHOD OF RECOVERING DESIRABLE PETROLEUM HYDROCARBON FRACTIONS FROM PRODUCING OIL RESERVOIRS", U.S. PATENT 2,724,438 (NOV. 22, 1955).

ABSTRACT:

----- THIS PATENT INVOLVES USING A MISCIBLE DISPLACEMENT TO EFFECT ALMOST PERFECT DISPLACEMENT OF OIL. THE PATENT DISTINGUISHES BETWEEN (HIGH PRESSURE) IMMISCIBLE DISPLACEMENT (SUCH AS THAT COVERED BY THE PREVIOUS REFERENCE), TRULY MISCIBLE PROCESSES AND MISCIBLE FRONT PROCESSES. TRULY MISCIBLE PROCESSES REQUIRE PRESSURES ABOVE THE CRICONDENBAR TO EFFECT DISPLACEMENT; FOR THE MISCIBLE FRONT PROCESS, AN INTERMEDIATE ZONE IS SHOWN TO BE CREATED IN LONG CORES AT MUCH LOWER PRESSURES, WHICH INTERMEDIATE ZONE YIELDS MISCIBLE DISPLACEMENT BY VIRTUE OF ITS BEING MISCIBLE BOTH IN RESERVOIR OIL AND IN THE DISPLACING PHASE.

COMMENTS:

----- 1. THIS PATENT HAS SHAPED THE PROGRESS OF THE INDUSTRY TO THE EXTENT THAT DEVELOPMENT TODAY NORMALLY INVOLVES A "MISCIBLE FRONT" PROCESS. THE PATENT IS REQUIRED READING FOR ALL PERSONS INTERESTED IN THE ART.

2. THIS PATENT ALSO MARKS THE INTRODUCTION OF THE PSEUDO-TERNARY DIAGRAM TO THE OIL INDUSTRY.

EXHIBITS:

----- 10 FIGURES

CROSS REFERENCES:

- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
S 1. BAYS: U.S. PATENT 2,135,319 (NOV. 1, 1938).

KEYWORDS:

MISCIBILITY (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS

LABORATORY INJECTION PROCESS
OTHER LABORATORY STUDIES
U.S. PATENT

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18. HAVERFIELD, F.B.: "SEPARATING CO2-PETROLEUM MIXTURES",
U.S. PATENT 2,729,291 (JAN. 3, 1956).

ABSTRACT:

----- THIS IS AN EARLY PATENT DEALING WITH THE SEPARATION
OF CARBON DIOXIDE - CRUDE OIL MIXTURES AT WALDEN, COLORADO . THE
BASIC PROCESS DESCRIBED IN THE PATENT INVOLVES HEATING THE PRODUCED
FLUID STREAM TO DECREASE THE CO2 CONCENTRATION IN THE LIQUID PHASE
TO A VALUE THAT, UPON SUBSEQUENT COOLING AND DEPRESSING, WILL NOT
REMOVE A LARGE PROPORTION OF THE HYDROCARBONS TO THE GAS PHASE,
THE PROCESS APPARENTLY WAS IMPLEMENTED IN THE FIELD.

COMMENTS:

----- THIS PATENT, EXCEPT FOR ENGINEERING DATA FOR
WALDEN FIELD, IS OF MINOR INTEREST.

EXHIBITS:

----- 2 FIGURES

KEYWORDS:

OTHER FIELD INFORMATION
CO2 SOURCE

FIELD ECONOMICS
U.S. PATENT
SEPARATION

19. RZASA, M.J. AND TERWILLIGER, P.L.: "RECOVERY OF OIL FROM RESERVOIRS", U.S. PATENT 2,822,872 (FEB. 11, 1958).

ABSTRACT:

----- THIS PATENT RELATES TO USING AN INTERMEDIATE SLUG BETWEEN AN LPG (MISCIBLE) SLUG AND DRIVE FLUID (HERE, SPECIFICALLY GAS). SEVERAL ADVANTAGES ARE CLAIMED. FIRST, BECAUSE THE INTERMEDIATE SLUG (PREDOMINANTLY METHANE OR CO2) IS MISCIBLE IN THE LPG, VERY EFFICIENT DISPLACEMENT OF THE LPG IS OBTAINED. SECONDLY, LOWER OPERATING PRESSURES MAY BE USED SINCE THE LPG TRANSITION ZONE MAY BE MADE NARROWER (LESS LOSS AND BETTER DISPLACEMENT). FINALLY, IF A "NON-EXPLOSIVE" GAS SUCH AS CO2 IS USED FOR THE INTERMEDIATE SLUG, THEN THE DRIVE FLUID MAY BE AIR RATHER THAN NATURAL GAS, ETC.

COMMENTS:

----- THIS PATENT IS OF LITTLE USE TODAY.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).

KEYWORDS:

U.S. PATENT

LPG

20. BEESON, D.M. AND ORTLOFF, G.D.: "LABORATORY INVESTIGATION OF THE WATER-DRIVEN CARBON DIOXIDE PROCESS FOR OIL RECOVERY", TRANS., AIME (1959) V.216, 338-391.

ABSTRACT:

----- THIS PAPER PRESENTS LABORATORY RESULTS OF EXPERIMENTS ON THE WATER-DRIVEN CARBON DIOXIDE PROCESS. TWO OILS WERE TESTED - A LIGHT 38 API, 6 CP OIL AND A HEAVY 400 CP OIL. THE EXPERIMENTAL RESULTS INDICATE THAT WATER PROPELLED CARBON DIOXIDE BANKS SUBSTANTIALLY INCREASE OIL RECOVERY OVER THAT OBTAINABLE BY WATERFLOOD, THAT RECOVERY DURING A CARBON DIOXIDE BANK FLOOD CAN BE CLOSELY PREDICTED FROM PHASE BEHAVIOR AND WATERFLOODING DATA, AND THAT ADDITIONAL OIL IS RECOVERED BY DEPRESSURING AFTER FLOODING.

COMMENTS:

----- THE EXCELLENT AGREEMENT OBTAINED BETWEEN PREDICTION AND EXPERIMENTAL RECOVERIES INDICATES THAT A GOOD METHOD HAS BEEN OBTAINED FOR PREDICTING RECOVERIES, EVEN WHEN (FOR THE LIGHT OIL) A MISCIBLE PROCESS WAS PROBABLY ATTAINED. THE PREDICTION METHOD INVOLVES A NORMAL WATERFLOOD DISPLACEMENT METHOD WITH THE VISCOSITY RATIO BEING THAT OF CO₂ SATURATED OIL DISPLACING VIRGIN OIL, AND THE RESIDUAL OIL BEING CO₂ SWELLED. PRESUMABLY, CONVENTIONAL SOLUTION GAS DRIVE METHODS MAY BE USED TO PREDICT THE BLOWDOWN RECOVERY.

EXHIBITS:

----- 3 TABLES, 3 FIGURES

CROSS REFERENCES:

- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
HEAVY OIL (LAB. EXP.)
COMPARISONS WITH LAB. RESULTS

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
OTHER LABORATORY STUDIES
OTHER MODELLING

21. BLACKWELL, R.J., RAYNE, J.R. AND TERRY, W.M.: "FACTORS INFLUENCING THE EFFICIENCY OF MISCIBLE DISPLACEMENT", TRANS., AIME (1959) V.216, 1-8.

ABSTRACT:

----- THIS PAPER DETAILS EXPERIMENTS CONCERNING THE MICROSCOPIC AND MACROSCOPIC ASPECTS OF MISCIBLE DISPLACEMENT. MIXING ON THE MICROSCOPIC LEVEL WAS STUDIED IN SAND PACKED TUBES; IT WAS FOUND THAT MOLECULAR DIFFUSION IS THE DOMINANT MIXING MECHANISM FOR RESERVOIR CONDITIONS OF RATE, LENGTH, AND PORE SIZES. MACROSCOPIC CHANNELING WAS STUDIED IN RESERVOIR MODELS SCALED BY VISCOUS, GRAVITATIONAL, AND DIFFUSIONAL FORCES. THE FORMATION OF CHANNELS WAS DUE TO VISCOUS FINGERING, GRAVITY SEGREGATION, AND VARIATIONS IN PERMEABILITY. IT WAS FOUND THAT FINGERS WILL FORM AND GROW, EVEN IN HOMOGENEOUS RESERVOIRS, AT ADVERSE MOBILITY RATIOS. AT SUFFICIENTLY LOW RATES, CHANNELING WAS ELIMINATED BY GRAVITY SEGREGATION IN TILTED RESERVOIRS.

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COMMENTS:

----- THIS IS ONE OF THE BASIC PAPERS ON THE FACTORS GOVERNING MISCIBLE DISPLACEMENT, BUT SOME OF THE MORE RECENT STUDIES ARE MORE IMPORTANT TO AN UNDERSTANDING OF THE ART.

EXHIBITS:

----- 3 TABLES, 10 FIGURES ILLUSTRATING THE EFFECTS OF MODEL SIZE, RATE, MOBILITY RATIO, GRAVITY SEGREGATION, AND STRATIFICATION ON RECOVERY.

CROSS REFERENCES:

- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.

KEYWORDS:

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
OTHER LABORATORY STUDIES
SLIM-TUBE DISPLACEMENTS
COMPARISONS WITH LAB. RESULTS

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
PHYSICAL MODELS
MIXING ZONE MODELS
OTHER MODELLING

22. HOLM, L.W.: "CARBON DIOXIDE SOLVENT FLOODING FOR INCREASED OIL RECOVERY", TRANS., AIME (1959) V.216, 225-231.

ABSTRACT:

----- THIS PAPER PRESENTS RESULTS FROM LABORATORY FLOODING EXPERIMENTS IN LINEAR SYSTEMS DESIGNED SPECIFICALLY TO EVALUATE RECOVERIES WITH SUPERCRITICAL CARBON DIOXIDE AND TO EXAMINE RESULTS IN CARBONATE RESERVOIRS. VARIABLES INCLUDE TYPE OF POROUS MEDIUM, PORE GEOMETRY, CORE LENGTH, AND FLOODING PRESSURE. OIL RECOVERIES RANGING FROM 60 TO 80% OF THE ORIGINAL OIL IN PLACE WERE OBTAINED BY CO₂ - CARBONATED WATERFLOODS AT PRESSURES BETWEEN 900 AND 1800 PSI, COMPARED WITH SOLUTION GAS DRIVE AND WATERFLOOD RECOVERIES OF 30 TO 45%, FOR BOTH THE SANDSTONE AND IRREGULAR POROSITY CARBONATE CORES. RECOVERIES OF 6 TO 15% OF THE ORIGINAL OIL IN PLACE WERE OBTAINED DURING BLOWDOWN.

COMMENTS:

- 1. MISCIBLE FLOODING RECOVERED ONLY A FEW PERCENT MORE OIL BY DOUBLING THE OPERATING PRESSURE. WHETHER OR NOT THIS CAN BE JUSTIFIED SHOULD BE CLOSELY EXAMINED.
2. WHEN THE CO₂ SLUG IS FOLLOWED BY PLAIN WATER INSTEAD OF CARBONATED WATER, POORER RECOVERIES OCCURRED ON BOTH THE FLOOD AND BLOWDOWN CYCLES.
3. LONG CORES ARE REQUIRED TO PROPERLY MODEL BLOWDOWN RECOVERIES.
4. CO₂ - CARBONATED WATERFLOODING INCREASES THE PERMEABILITY OF CARBONATE ROCKS.
5. NEITHER THE PRESENCE OF METHANE (UP TO 15% BY VOLUME) IN THE CO₂ SLUG NOR HIGH GAS SATURATION APPRECIABLY REDUCE THE EFFICIENCY OF THE CO₂ - CARBONATED WATERFLOOD PROCESS.

EXHIBITS:

----- 6 TABLES, 6 FIGURES

ADDITIONAL REFERENCES:

----- POETTMANN AND KATZ:
IND. & ENG. CH. (1945) V.37, 847.

CROSS REFERENCES:

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6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)

KEYWORDS:

EFFECTS OF PRESSURE
SOLUBILITY
LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)

EFFECTS OF TEMPERATURE
LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
CARBONATE (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
OTHER LABORATORY STUDIES

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23. LINDAUER, R.L., JR.: "RECOVERY OF HYDROCARBONS FROM SUBTERRANEAN RESERVOIRS", U.S. PATENT 2,885,003 (MAY 5, 1959).

ABSTRACT:

----- THIS PATENT RELATES TO USE OF MISCIBLE FLUIDS TO AUGMENT PRIMARY RECOVERY PROCESSES. THE PATENT IS ADDRESSED TO THOSE RESERVOIRS WITH A GAS CAP DRIVE AND/OR AN EDGE/BOTTOM WATER DRIVE. THE THRUST OF THE INVENTION IS TO INJECT A SUBSTANCE MISCIBLE WITH THE RESERVOIR OIL AND INTERMEDIATE IN DENSITY BETWEEN THE NATURAL DISPLACING FLUID (GAS OR WATER) AND THE OIL TO FORM A BUFFER ZONE THAT ASSISTS THE RECOVERY OF OIL. SUBSTANCES SUGGESTED INCLUDE CO₂ FOR GAS CAP DRIVE OR ALCOHOL FOR WATER DRIVE. THE BASIC PURPOSES OF THIS BUFFER ZONE ARE TO HELP STABILIZE THE GAS-OIL OR WATER-OIL CONTACT AND TO EFFECT BETTER DISPLACEMENT OF THE OIL (LESS RESIDUAL SATURATION).

COMMENTS:

----- THIS PATENT MAY PROVE USEFUL IN EXTENDING THE RANGE OF APPLICATION OF MISCIBLE PROCESSES. ALSO, THE USE OF NATURAL DRIVE ENERGIES IN CONJUNCTION WITH SUPPLEMENTAL INJECTION (CO₂ MISCIBLE DRIVE) MAY ALLOW MORE TECHNICALLY AND ECONOMICALLY VIABLE APPLICATION IN SOME RESERVOIRS.

EXHIBITS:

----- 2 TABLES, 3 FIGURES

KEYWORDS:

FIELD MISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
U.S. PATENT

FIELD AREAL SWEEP
OTHER FIELD INFORMATION
ALTERNATE TECHNOLOGIES

24. MARTIN, J.W.: "METHOD OF RECOVERY OF OIL BY INJECTION OF HYDROCARBON SOLUTION OF CARBON DIOXIDE INTO OIL STRUCTURE", U.S. PATENT 2,875,830 (MAR. 3, 1959).

ABSTRACT:

----- THIS PATENT INVOLVES A VARIANT OF THE CARBON DIOXIDE/LPG DRIVE PROCESS WHEREIN CARBON DIOXIDE AND LIGHT HYDROCARBONS (LPG, BENZENE, ETC.) ARE INJECTED SIMULTANEOUSLY. THE CARBON DIOXIDE IS BASICALLY CONSIDERED TO BE AN ADDITIVE FOR THE LIGHT HYDROCARBON (DEFINED AS HAVING A BOILING POINT LESS THAN 350 C). THE CO2 REDUCES VISCOSITY AND SURFACE TENSION AND SWELLS THE LIGHT HYDROCARBON TO EFFECT A BETTER DISPLACEMENT OVERALL.

COMMENTS:

----- IT IS NOT CLEAR THAT ANY MATERIAL IMPROVEMENT IN RECOVERY OVER THAT OBTAINED FROM CO2 OR LPG FLOODING WOULD RESULT FROM APPLICATION OF THIS PATENT.

CROSS REFERENCES:

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1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
 4. STRAIGHT: U.S. PATENT 1,978,655 (OCT. 30, 1934).
 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).

KEYWORDS:

FIELD SECONDARY RECOVERY
OTHER FIELD INFORMATION

WATER INJECTION
FIELD MISCIBLE APPLICATION
U.S. PATENT

25. MARTIN, J.W.: "PROCESS OF RECOVERING OIL FROM OIL FIELDS INVOLVING THE USE OF CRITICALLY CARBONATED WATER", U.S. PATENT 2,875,833 (MAR. 3, 1959).

ABSTRACT:

----- THIS PATENT IS ONE FOR CARBONATED WATERFLOODING OF OIL RESERVOIRS. THE BASIC IMPETUS OF THE INVENTION IS THE USE OF "CRITICALLY" CARBONATED WATER; CRITICAL HERE MEANING HAVING SUFFICIENT CONCENTRATION OF CARBON DIOXIDE SO AS TO NEUTRALIZE ALKALINE SUBSTANCES IN THE FORMATION. THIS CONCENTRATION LEVEL IS 20% OR SO.

COMMENTS:

----- ALL THAT THIS PATENT REALLY SAYS IS THAT FOR CO2 CONCENTRATIONS LESS THAN 20% IN INJECTED WATER, NO GAIN IN RECOVERY OVER CONVENTIONAL WATERFLOODING MAY BE EXPECTED AS A RESULT OF CARBONATED WATERFLOODING.

EXHIBITS:

----- 7 FIGURES

CROSS REFERENCES:

- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
4. STRAIGHT: U.S. PATENT 1,978,655 (OCT. 30, 1934).
13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).

KEYWORDS:

OTHER LABORATORY STUDIES

CARBONATED WATER (LAB. EXP.)
U.S. PATENT

26. MARTIN, J.W., HESSEL, F.A., HAMMER, I.P. AND RUST, J.B.:
"GASEOUS HYDROCARBON AND CARBON DIOXIDE SOLUTIONS IN
HYDROCARBONS", U.S. PATENT 2,875,832 (MAR. 3, 1959).

ABSTRACT:

----- THIS PATENT RELATES TO THE USE OF CO2 AS AN
ADDITIVE FOR GAS DRIVE PROCESSES. THE PATENT INVOKES LABORATORY
DATA TO INDICATE THAT SOME CO2 WILL INCREASE THE AMOUNT OF METHANE
OR ETHANE IN SOLUTION. THIS KEEPS VOLUME FACTOR HIGH AND VISCOSITY
LOW AND HELPS REDUCE FREE GAS PRODUCTION DURING GAS DRIVE.

COMMENTS:

----- THIS PATENT IS OF MINOR CONCERN TODAY.

EXHIBITS:

----- 3 TABLES, 6 FIGURES

CROSS REFERENCES:

- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).

KEYWORDS:

LABORATORY INJECTION PROCESS
OTHER LABORATORY STUDIES

SECONDARY RECOVERY (LAB. EXP.)
U.S. PATENT

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27. BENHAM, A.L., DOWDEN, W.E. AND KUNZMAN, W.J.: "MISCIBLE FLUID DISPLACEMENT - PREDICTION OF MISCIBILITY", TRANS., AIME (1960) V.219, 229-237.

ABSTRACT:

----- THE MECHANISM INVOLVED IN CREATING A MISCIBLE FLUID DISPLACEMENT OF TYPICAL RESERVOIR FLUIDS THROUGH POROUS MEDIA BY LIGHT HYDROCARBON MIXTURES USUALLY INVOLVES A NUMBER OF MIXING AND SEPARATION STAGES IN THE CONTACT AREA. THIS MECHANISM HAS BEEN ILLUSTRATED ON TERNARY DIAGRAMS FOR MISCIBLE DISPLACEMENT OF RESERVOIR FLUID BY RICH HYDROCARBON GASES.

A METHOD IS PRESENTED FOR CALCULATING THE CONDITIONS FOR MISCIBLE DISPLACEMENT. BASICALLY THREE STEPS ARE INVOLVED. FIRST, A PSEUDO-TERNARY DIAGRAM IS CONSTRUCTED FOR THE TEMPERATURE AND PRESSURE OF INTEREST. THEN, THE CRITICAL POINT IS MARKED ON THE DIAGRAM. FINALLY, A TANGENT LINE TO THE TWO PHASE ENVELOPE IS DRAWN THROUGH THE CRITICAL POINT TO THE POINT OF ZERO HEAVY COMPONENTS CONCENTRATION. THIS POINT IS THE LEANEST MIXTURE FOR WHICH MISCIBILITY MAY BE OBTAINED. IT IS FOUND THAT MISCIBILITY IS FAVORED BY INCREASED PRESSURES, DECREASED TEMPERATURE, LIGHT RESERVOIR FLUIDS AND LIGHT HYDROCARBON-DISPLACING FLUIDS RICH IN THE HEAVIER COMPONENTS.

IN CONSTRUCTING THE PSEUDO-TERNARY DIAGRAM, THE AUTHORS SUGGEST THAT THE INTERMEDIATE FRACTION (C2,C3 AND C4) SHOULD HAVE CHARACTER EQUAL TO THAT OF THE INJECTION MIXTURE, WHILE THE HEAVY FRACTION (C5+) SHOULD HAVE A CHARACTER EQUAL TO THAT OF THE RESERVOIR FLUID. IN USING THIS METHOD FOR ENRICHED GAS OR LPG FLOODING, A SIMPLIFICATION MAY ALSO BE OBTAINED SUFFICIENT FOR ENGINEERING ACCURACY BY ELIMINATING STEP TWO (DETERMINATION OF THE CRITICAL POINT) ABOVE, AND SIMPLY DRAWING THE TANGENT LINE FOR THE TWO-PHASE ENVELOPE FOR CONSTANT PERCENTAGE INTERMEDIATES.

A CORRELATION WAS DEVELOPED AND CHECKED EXPERIMENTALLY FOR MISCIBILITY. THE CORRELATION IS ON THE BASIS OF TEMPERATURE, PRESSURE, MOLECULAR WEIGHT OF HEAVY FRACTION OF RESERVOIR FLUID, MOLECULAR WEIGHT OF INTERMEDIATE FRACTION OF DISPLACING FLUID, AND MOLE PERCENT METHANE IN THE DISPLACING FLUID.

COMMENTS:

- 1. THE SAME BASIC METHOD FOR DETERMINATION OF (FIRST CONTACT) MISCIBILITY IS APPLICABLE TO CO₂.
2. THE USE OF PENTANE AS THE CUTOFF FOR THE HEAVY FRACTION RATHER THAN HEPTANES IS USED IN THIS PAPER. IT MAY BE THAT THIS WOULD BE MORE APPLICABLE FOR CO₂ MISCIBILITY DETERMINATION ALSO.
3. THIS PAPER IS IMPORTANT TO ANYONE DESIRING AN UNDERSTANDING OF THE ART.

EXHIBITS:

----- 5 TABLES, 18 FIGURES, INCLUDING TERNARY AND PSEUDO-TERNARY DIAGRAMS AND CORRELATION.

ADDITIONAL REFERENCES:

----- KOCH AND HUTCHINSON:
TRANS., AIME (1958) V.213, 7.

CROSS REFERENCES:

16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).

17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).

S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 1

S 6. WILSON: TRANS., AIME (1960) 223.

S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.

KEYWORDS:

CORRELATIONS
TERNARY SYSTEMS
FIRST CONTACT MISCIBILITY
ENRICHED AND HIGH PRESSURE GAS
EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
MISCIBILITY (LAB. EXP.)
LPG

28. BLACKWELL, R.J., TERRY, W.M., RAYNE, J.R., LINDLEY, D.C. AND HENDERSON, J.R.: "RECOVERY OF OIL BY DISPLACEMENTS WITH WATER-SOLVENT MIXTURES", TRANS., AIME (1960) V.219, 293-300.

ABSTRACT:

----- THIS PAPER PRESENTS THE RESULTS OF A LABORATORY INVESTIGATION OF THE EFFICIENCY OF WATER-SOLVENT MIXTURES IN RECOVERY OF OIL. THESE MIXTURES MAY HAVE THE HIGH DISPLACEMENT EFFICIENCIES CHARACTERISTIC OF SOLVENT FLOODS AND THE HIGH SWEEP EFFICIENCIES CHARACTERISTIC OF WATERFLOODS.

EXPERIMENTS ON THE USE OF WATER-SOLVENT MIXTURES FOR THE RECOVERY OF OIL WERE CONDUCTED TO FIND THE GENERAL APPLICABILITY OF THE PROCESS. THESE STUDIES DEMONSTRATED THAT, IN FLOWING THROUGH SANDS, WATER AND SOLVENT SEGREGATED INTO A SOLVENT LAYER ON THE TOP AND A WATER LAYER ON THE BOTTOM RATHER THAN FLOWING AS A UNIFORM MIXTURE. CALCULATIONS BASED ON SIMULTANEOUS FLOW OF WATER AND SOLVENT IN LAYERS WERE USED TO PREDICT THE EFFECTIVE MOBILITY OF THE MIXTURE AND THE OPTIMUM OPERATION OF THE PROCESS IN STEEPLY DRIPPING HOMOGENEOUS RESERVOIRS. AS MOST RESERVOIRS ARE NOT SUITED FOR THE OPERATION OF THE PROCESS UNDER IDEAL CONDITIONS, EXPERIMENTAL STUDIES WERE UNDERTAKEN WITH SAND PACK MODELS SCALED TO REPRESENT MORE REALISTIC RESERVOIRS. THESE STUDIES INCLUDED THE EFFECTS ON RECOVERY OF RATE OF INJECTION, OIL VISCOSITY, PERMEABILITY VARIATION, AND WATER-SOLVENT RATIO. FOR THE RANGE OF CONDITIONS STUDIED, HIGHER RECOVERIES WERE OBTAINED WITH WATER-SOLVENT MIXTURES THAN WITH WATER OR PRACTICAL VOLUMES OF SOLVENT ALONE.

COMMENTS:

----- 1. BASED ON THIS PAPER, THE IMPORTANT FACTORS FOR SCALING LABORATORY MODELS ARE SIMILAR GEOMETRY, BOUNDARY AND INITIAL CONDITIONS, SAME RELATIVE PERMEABILITY AND CAPILLARY PRESSURE CURVES, SAME VISCOSITY RATIOS, SAME RATIO OF VISCOUS TO GRAVITATIONAL FORCES, SAME IMPORTANCE OF MICROSCOPIC MIXING, AND SAME RATIO OF GRAVITY TO CAPILLARY FORCES.

2. AS SHOWN IN THE PAPER, THE CONDITIONS UNDER WHICH A STABLE DISPLACEMENT OF SOLVENT IS OBTAINED ARE FREQUENTLY AT TOO LOW A RATE TO BE ECONOMIC AND MAY NOT EXIST AT ALL.

EXHIBITS:

----- 2 TABLES, 9 FIGURES

ADDITIONAL REFERENCES:

----- DYES, CAUDLE, AND ERICKSON :
TRANS., AIME (1954) V.201, 81.

CROSS REFERENCES:

- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
PHYSICAL MODELS

SECONDARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
MISCIBILITY (LAB. EXP.)
OTHER LABORATORY STUDIES
COMPARISONS WITH LAB. RESULTS

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29. HABERMANN, B.: "THE EFFICIENCY OF MISCIBLE DISPLACEMENT AS A FUNCTION OF MOBILITY RATIO", TRANS., AIME (1960) V.219, 264-272.

ABSTRACT:

----- ARTIFICIALLY CONSOLIDATED SAND MODELS REPRESENTING ONE-QUARTER OF A FIVE-SPOT WERE DEVELOPED AND USED TO STUDY FACTORS AFFECTING MISCIBLE DISPLACEMENT. SWEEP EFFICIENCY AT BREAKTHROUGH, SIZE OF THE MIXING ZONE BETWEEN TWO MISCIBLE FLUIDS AND AREAL SWEEP AT BREAKTHROUGH WERE DETERMINED FOR THE HIGH MOBILITY RATIOS ENCOUNTERED IN ACTUAL RESERVOIRS. QUANTITATIVE RELATIONSHIPS BETWEEN THE DEGREE OF VISCOUS FINGERING AND MOBILITY RATIO WERE OBTAINED BY MEASURING THE LENGTH OF THE FLUID INTERFACE.

VISCOUS FINGERING IN HOMOGENEOUS POROUS MEDIA CAN BE QUANTITATIVELY CORRELATED WITH MOBILITY RATIO. THE SIZE OF THE MIXING ZONE BETWEEN MISCIBLE FLUIDS INCREASES WITH AN INCREASE IN MOBILITY RATIO. WHERE VISCOUS FINGERS ARE FORMED, THE SLUG IS UNEVENLY DISTRIBUTED ALONG THE FRONT, AND THE MIXING ZONE MUST BE DESCRIBED IN TWO DIMENSIONS.

LABORATORY TWO DIMENSIONAL FLOW EXPERIMENTS PRESENTED IN THIS PAPER AND SUPPORTED BY FIELD EVIDENCE INDICATE THAT AT HIGH MOBILITY RATIOS, A MISCIBLE SLUG CONTAINING AS MUCH AS 10% OF A PORE VOLUME WILL DETERIORATE AFTER A SMALL FRACTION OF THE RESERVOIR HAS BEEN SWEEPED. FOR THIS REASON, AN ENRICHED GAS DRIVE MAY APPROACH AN ORDINARY GAS DRIVE AS THE DISPLACEMENT PROGRESSES.

COMMENTS:

- 1. THE CARE TAKEN IN OBTAINING THE DATA IN THIS PAPER MAKE IT THE BEST SINGLE PAPER IN THE LITERATURE FOR THE PREDICTION OF AREAL SWEEP AS A FUNCTION OF MOBILITY RATIO.
2. AN UNDERSTANDING OF THIS PAPER IS REQUIRED FOR ANYONE WISHING TO BECOME SKILLED IN THE ART OF MISCIBLE FLOODING.

EXHIBITS:

----- 3 TABLES, 11 FIGURES INCLUDING LABORATORY RESULTS.

CROSS REFERENCES:

- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

LABORATORY INJECTION PROCESS
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
OTHER LABORATORY STUDIES
FIELD MOBILITY RATIO
PHYSICAL MODELS
ENRICHED AND HIGH PRESSURE GAS

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION
OTHER MODELLING
LPG

30. HICKOK, C.W., CHRISTENSEN, R.J. AND RAMSAY, H.J., JR.:
"PROGRESS REVIEW OF THE K&S CARBONATED WATERFLOOD PROJECT",
J. PET. TECH. (DEC., 1960) 20-24.

ABSTRACT:

----- THIS PAPER IS A PROGRESS REPORT OUTLINING ACCOMPLISHMENTS AND DIFFICULTIES AT THE K&S PROJECT NEAR BARTLESVILLE, OKLAHOMA. THE PROJECT HAS 35 INJECTION WELLS AND 24 PRODUCTION WELLS ARRANGED IN REGULAR 10 ACRE FIVE SPOT PATTERNS. CARBONATED WATERFLOODING WAS STARTED IN EARLY 1958.

THE BARTLESVILLE SAND IS BEING FLOODED. IT IS AT A DEPTH OF 1250 FEET AND HAS A NET THICKNESS OF 60 FEET. IT IS A UNIFORM, FINE GRAINED SANDSTONE WITH 56 MD PERMEABILITY AND 18% POROSITY, AND HAD AN AVERAGE OIL SATURATION AT THE START OF FLOODING OF ABOUT 30%. THE OIL IS 33 API AND HAS A VISCOSITY OF 6.4 CP AT 100 F.

THE FIELD WAS DISCOVERED IN 1905 AND PRODUCED 440 MBBL UNDER PRIMARY DEPLETION THROUGH 1934. FROM 1934 THROUGH 1951 THE LEASES WERE NON-PRODUCTIVE. IN 1951, A SMALL WATERFLOOD WAS INITIATED WHICH RECOVERED 74 MBBL THROUGH 1957.

THE WATER SOURCE IS THE ARBUCKLE LIME AT A DEPTH OF 2550 FEET. CARBON DIOXIDE IS BEING PRODUCED FROM FLUE GAS, WITH EXTRACTION BY THE MEA ABSORPTION PROCESS. THE PRODUCING WELLS WERE SHOT WITH NITROGLYCERINE, AND THE INJECTION WELLS ARE ALL PERFORATED COMPLETIONS. LATE IN 1959, 17 OF THE PRODUCING WELLS WERE FRACTURE TREATED WHICH GREATLY INCREASED WATER PRODUCTION. DURING 1959, THE PROJECT PRODUCED 560 MBBL, MORE THAN THAT PRODUCED DURING THE ENTIRE PRIMARY PERIOD.

COMMENTS:

----- 1. THE AREAS WHICH WERE PREVIOUSLY WATERFLOODED HAVE PRODUCED CONSIDERABLE OIL AS A RESULT OF THE CARBONATED WATERFLOOD.

2. INJECTIVITY INCREASED BY A FACTOR OF TWO TO FOUR IN THE CARBONATED WATERFLOOD WELLS OVER THAT SEEN IN ADJACENT CONVENTIONAL WATERFLOOD INJECTORS.

3. THE FRACTURE TREATING OF PRODUCING WELLS WAS ALMOST CERTAINLY AN UNECONOMIC VENTURE.

EXHIBITS:

----- 2 TABLES, 5 FIGURES INCLUDING RESERVOIR AND PRODUCTION DATA.

KEYWORDS:

SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FACILITIES

WATER INJECTION
FIELD TERTIARY RECOVERY
FLUE GAS FIELD APPLICATIONS
OPERATIONS

31. HOLM, L.W.: "A COMPARISON OF PROPANE AND CARBON DIOXIDE SOLVENT FLOODING PROCESSES", A.I.C.H.E. J. (JUNE, 1961) V.7, NO.2, 179-184.

ABSTRACT:

----- A LABORATORY INVESTIGATION WAS CONDUCTED ON OIL DISPLACEMENT IN POROUS MEDIA BY THE USE OF EITHER A SLUG OF PROPANE FOLLOWED BY GAS OR A SLUG OF CARBON DIOXIDE FOLLOWED BY WATER. A COMPARISON WAS MADE OF THE EFFICIENCY OF THESE TWO SOLVENT FLOODING PROCESSES. THE RESULTS OF THE EXPERIMENTS SHOW THE EFFECT OF THE TYPE OF POROUS MEDIUM, PORE GEOMETRY, LENGTH TO WIDTH RATIO, FLUID VISCOSITIES, AND MISCIBILITY. RECOVERIES OF 60 TO 80% OF THE ORIGINAL OIL IN PLACE WERE OBTAINED WITH SLUG SIZES OF 10 TO 30% OF A HYDROCARBON PORE VOLUME, WITH LESS SOLVENT BEING REQUIRED PROPORTIONATELY AS THE FLOOD PATH INCREASES.

REGARDLESS OF THE FLOODING PROCESS USED, LESS OIL WAS RECOVERED FROM THE IRREGULAR DOLOMITE CONES THAN WAS PRODUCED FROM THE UNIFORM SANDSTONE CONES. THE ADDITIONAL OIL RECOVERED OVER WATERFLOODING FROM THE IRREGULAR POROSITY ROCK BY EITHER SOLVENT PROCESS WAS ACHIEVED EARLY IN THE LIFE OF THE FLOODS AS COMPARED TO THAT OBTAINED ON THE UNIFORM SANDSTONE. LESS TOTAL FLUID INJECTION WAS REQUIRED FOR THE CARBON DIOXIDE - CARBONATED WATERFLOOD TO OBTAIN INCREASED OIL RECOVERY THAN WAS NEEDED FOR THE PROPANE-METHANE PROCESS. OVERALL, CARBON DIOXIDE - CARBONATED WATERFLOODING PERFORMED BETTER IN THAT IT RECOVERED MORE OIL IN A SHORTER TIME THAN DID PROPANE-GAS FLOOD.

COMMENTS:

----- THIS PAPER PRESENTS AN EXCELLENT EXPERIMENTAL COMPARISON BETWEEN CARBON DIOXIDE AND LPG FLOODING, TO THE DETRIMENT OF LPG FLOODING.

EXHIBITS:

----- 2 TABLES, 11 FIGURES INCLUDING EXPERIMENTAL RESULTS

CROSS REFERENCES:

- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
MISCIBILITY (LAB. EXP.)

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
CARBONATE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES

32. KENNEDY, J.T. AND THODOS, G.: "THE TRANSPORT PROPERTIES OF CARBON DIOXIDE", A.I.C.H.E. J. (DEC., 1961) V.7, NO.4, 625-631.

ABSTRACT:

----- THIS PAPER PRESENTS A LITERATURE REVIEW OF EXPERIMENTAL VISCOSITY, THERMAL CONDUCTIVITY AND SELF-DIFFUSIVITY DATA. THE DATA WERE USED TO DEVELOP REDUCED STATE CORRELATIONS FOR TRANSPORT PROPERTIES FOR CO₂ OR OTHER NON-POLAR COMPOUNDS HAVING A CRITICAL COMPRESSIBILITY FACTOR OF 0.275. THE RESIDUAL PROPERTIES APPROACH WAS USED TO ESTABLISH THE TRANSPORT PROPERTIES IN THE HIGH PRESSURE AND LIQUID STATE REGIONS. THE RESIDUAL QUANTITIES REPRESENT THE DIFFERENCE BETWEEN THE VALUE OF A PROPERTY AT ANY PRESSURE AND TEMPERATURE, AND THE VALUE AT ATMOSPHERIC PRESSURE AND THE SAME TEMPERATURE.

CORRELATIONS EXTEND FROM THE SATURATED VAPOR AND LIQUID STATES TO TEMPERATURES OF 5500 F (REDUCED TEMPERATURE OF 10) AND PRESSURES TO 54000 PSI (REDUCED PRESSURE OF 50). COMPARISONS BETWEEN THE VALUES RESULTING FROM THESE CORRELATIONS AND EXPERIMENTAL VALUES INDICATE A MEAN ERROR OF 2% FOR VISCOSITY, 1.4% FOR THERMAL CONDUCTIVITY, AND 6% FOR SELF-DIFFUSIVITY.

COMMENTS:

----- 1. THE RESIDUAL PROPERTIES APPROACH YIELDS GOOD VALUES FOR PROPERTIES EVEN NEAR THE CRITICAL POINT; THUS, THIS PAPER PRESENTS ESSENTIALLY A COMPLETE TREATMENT OF THE TRANSPORT PROPERTIES OF PURE CO₂.

2. THE INFORMATION CONTAINED IN THIS PAPER MAY BE OF USE FOR DESIGN OF SEPARATION, TRANSPORTATION, OR OTHER CO₂ HANDLING FACILITIES.

EXHIBITS:

----- 10 FIGURES INCLUDING THE CORRELATIONS.

ADDITIONAL REFERENCES:

----- THERE ARE SIXTY-FOUR ADDITIONAL REFERENCES LISTED IN THIS PAPER DEALING WITH THE VARIOUS PROPERTIES CORRELATED.

KEYWORDS:

CORRELATIONS
PURE CARBON DIOXIDE BEHAVIOR
EFFECTS OF TEMPERATURE
DIFFUSION COEFFICIENTS

EXPERIMENTAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
EFFECTS OF PRESSURE
VISCOSITY
OTHER PHYSICAL PROPERTIES

33. SLOBOD, R.L. AND KOCH, H.A., JR.: "MISCIBLE SLUG FOLLOWED BY GAS AND WATER", U.S. PATENT 2,968,350 (JAN. 17, 1961).

ABSTRACT:

----- THIS PATENT RELATES TO THE USE OF A MISCIBLE SLUG DRIVEN BY GAS, WITH WATER AS THE FINAL DRIVING FLUID. THE SIZE OF THE MISCIBLE SLUG SHOULD BE BETWEEN 0.01 AND 5% OF A HYDROCARBON PORE VOLUME. THE SLUG MAY BE A MIXTURE OF ETHANE, PROPANE, AND BUTANE OR MAY BE COMPRISED OF SEPARATE SLUGS OF EACH OF THESE FLUIDS, AND SHOULD BE MISCIBLE WITH BOTH THE RESERVOIR OIL AND THE DISPLACING GAS. THE AMOUNT OF GAS FOLLOWING THE MISCIBLE SLUG SHOULD BE SUFFICIENT TO LEAVE A RESIDUAL GAS PHASE THROUGHOUT THE ENTIRE RESERVOIR AFTER FINAL WATERFLOODING.

LABORATORY EXPERIMENTS INDICATE THIS PROCESS WORKS BETTER THAN EITHER A CONVENTIONAL WATERFLOOD OR A TOTALLY GAS DRIVEN MISCIBLE SLUG. THE RATIONALE FOR THIS INVENTION IS THAT THE GAS SLUG BECOMES TRAPPED BY THE FOLLOW UP WATER AND HENCE WILL NOT CHANNEL THROUGH THE MISCIBLE SLUG TO THE PRODUCING WELLS.

COMMENTS:

----- 1. THIS PATENT IS JUST ANOTHER VARIANT OF THE "BUFFER" TECHNIQUE FOR MISCIBLE FLOODING.

2. X-RAY SHADOWGRAPH RESULTS ARE USED AS THE BASIS FOR THE CLAIMS OF THIS PATENT; A PHYSICAL MODEL STUDY UNDER THE SAME CONDITIONS MIGHT DEVELOP USEFUL INFORMATION.

EXHIBITS:

----- 5 FIGURES

CROSS REFERENCES:

13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).

KEYWORDS:

LABORATORY INJECTION PROCESS
MISCIBILITY (LAB. EXP.)
U.S. PATENT

AREAL SWEEP (LAB. EXP.)
OTHER LABORATORY STUDIES
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34. STONE, H.L.: "METHOD OF INCREASING OIL RECOVERY", U.S. PATENT 2,994,373 (AUG. 1, 1961).

ABSTRACT:

----- THIS PATENT RELATES TO A METHOD WHEREBY ENRICHED GAS OR LIQUEFIED PETROLEUM GAS IS INJECTED INTO ONE WELL AND AN "INERT" GAS SUCH AS CO₂ OR NITROGEN IS INJECTED INTO A SECOND WELL. THE WELLS ARE LOCATED AND INJECTION RATES ARE BALANCED SO AS TO HAVE THE FRONTS FROM EACH OF THE INJECTION WELLS REACH THE PRODUCING WELL AT THE SAME TIME. THE RATIONALE FOR THE PATENT IS TO DIMINISH OR ELIMINATE RESERVOIR PRESSURE DECLINE DURING THE DISPLACEMENT.

COMMENTS:

----- THE BASIC PURPOSE OF THIS PATENT APPEARS TO BE A REDUCTION IN THE AMOUNT OF MISCIBLE FLUID NEEDED; BECAUSE STEADY-STATE PRESSURE CONDITIONS ARE QUICKLY OBTAINED IN A FILLED UP RESERVOIR, NO PARTICULAR ADVANTAGE IS GAINED BY USING THIS PROCESS.

EXHIBITS:

----- 2 FIGURES

CROSS REFERENCES:

23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).

KEYWORDS:

FIELD SECONDARY RECOVERY
OTHER FIELD INFORMATION
ENRICHED AND HIGH PRESSURE GAS

FIELD MISCIBLE APPLICATION
U.S. PATENT
LPG

35. HOLM, L.W.: "OIL RECOVERY PROCESS", U.S. PATENT 3,065,790
(NOV. 27, 1962).

ABSTRACT:

----- THIS INVENTION RELATES TO THE USE OF CARBON DIOXIDE AS AN OIL RECOVERY AGENT IN VUGGY LIMESTONE RESERVOIRS. THERE ARE TWO SPECIFIC EMBODIMENTS TO THIS PATENT: FIRST THAT CARBONATED WATER SHOULD BE USED TO DISPLACE THE CO₂, AND SECOND, THAT A BLOWDOWN CYCLE IS NECESSARY AFTER WATER PRODUCTION.

EXPERIMENTAL RESULTS ARE PRESENTED COMPARING THE PROCESS OF THIS PATENT AND THE WHORTON, ET AL, PROCESS. USING THE WHORTON PROCESS, WHICH DOES NOT INCLUDE THE BLOWDOWN CYCLE, RECOVERY EFFICIENCY OF ABOUT 70% WAS OBTAINED. WITH THE BLOWDOWN CYCLE INCLUDED, 95+% RECOVERIES WERE OBTAINED. FURTHERMORE, IT WAS FOUND THAT ONCE BLOWDOWN HAS PROCEEDED TO ABOUT 500 PSI, REINITIATION OF CARBONATED WATERFLOODING WILL RECOVER THE REMAINING OIL FASTER, SINCE OIL RECOVERY BY DEPLETION IN THE LOW PRESSURE RANGE IS A VERY SLOW AND INEFFICIENT PROCESS. OVERALL, THIRTY OR MORE PERCENT OF THE OIL IN PLACE WAS RECOVERED BY BLOWDOWN.

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COMMENTS:

----- 1. LABORATORY RESULTS PRESENTED IN THIS PATENT INDICATE THAT THE AMOUNT OF OIL RECOVERED DURING THE BLOWDOWN PHASE WILL GENERALLY BE MUCH HIGHER FOR VUGGY, IRREGULAR POROSITY LIMESTONES THAN FOR UNIFORM POROSITY SANDSTONES.

2. REINITIATION OF WATERFLOOD DURING THE DEPLETION (BLOWDOWN) CYCLE MAY BE A USEFUL METHOD IN SANDSTONE RESERVOIRS AS WELL.

3. THE LABORATORY RESULTS PRESENTED ON CARBONATE ROCKS ARE EXCELLENT, AND ALSO CONTAIN WATERFLOOD RECOVERIES FOR REFERENCE.

EXHIBITS:

----- 2 TABLES, 1 FIGURE INCLUDING EXPERIMENTAL RESULTS.

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
OTHER LABORATORY STUDIES

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
CARBONATE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)
U.S. PATENT

36. HOLM, L.W. AND CSASZAR, A.K.: "OIL RECOVERY BY SOLVENTS MUTUALLY SOLUBLE IN OIL AND WATER", SOC. PET. ENG. J. (JUNE, 1962) 129-144.

ABSTRACT:

----- A SERIES OF LABORATORY EXPERIMENTS WAS CONDUCTED IN WHICH OIL WAS DISPLACED FROM A POROUS MEDIUM BY WATER - DRIVEN SLUGS OF ALCOHOLS OR SIMILAR SOLVENTS. THE SOLVENTS USED WERE SOLUBLE TO SOME DEGREE IN BOTH OIL AND WATER AND COVERED THE RANGE OF SOLUBILITIES FROM COMPLETE SOLUBILITY IN OIL TO COMPLETE SOLUBILITY IN WATER. THE DISPLACEMENT EXPERIMENTS WERE CONDUCTED ON CONSOLIDATED CORES AND UNCONSOLIDATED SAND PACKS RANGING IN LENGTH FROM ONE TO 30 FEET AND WERE SATURATED WITH BRINE AND CRUDE OR REFINED OILS.

IT WAS FOUND THAT ALL OF THE OIL PRESENT COULD BE MISCIBLY DISPLACED BY INJECTING A SLUG OF MUTUAL SOLVENT AND DRIVING IT WITH WATER. THE OIL RECOVERY EFFICIENCY WAS DEPENDENT ON THE RELATIVE SOLUBILITIES OF THE SOLVENT IN OIL AND WATER AND THE FLOODING LENGTH. FOR COMPLETE OIL RECOVERY FROM CONES, A SMALLER AMOUNT OF PREFERENTIALLY OIL SOLUBLE SOLVENT WAS REQUIRED, COMPARED TO THE AMOUNT OF PREFERENTIALLY WATER SOLUBLE SOLVENT NEEDED. THE REQUIRED SLUG SIZE VARIED INVERSELY WITH THE FLOODING LENGTH RAISED TO THE TWO-THIRDS POWER.

WATER-DRIVEN DUAL SOLVENT COMBINATIONS (AN OIL-SOLUBLE SOLVENT SLUG FOLLOWED BY A WATER-SOLUBLE SOLVENT SLUG) WERE FOUND TO EFFECT COMPLETE OIL RECOVERY WITH LESS TOTAL SOLVENT THAN ANY SINGLE SOLVENT USED. IN THE DUAL-SOLVENT DISPLACEMENT EXPERIMENTS, THE SLUG SIZE REQUIRED VARIED INVERSELY WITH FLOODING LENGTH TO THE ONE-HALF POWER.

BASED ON THE EXPERIMENTAL RESULTS, A THEORY WAS DEVELOPED TO DESCRIBE THE DISPLACEMENT OF OIL AND WATER BY MUTUAL SOLVENTS, AND SIMPLIFIED EQUATIONS ARE PRESENTED TO PREDICT THE PRODUCTION HISTORY IN A LINEAR SYSTEM. THESE EQUATIONS TAKE INTO ACCOUNT THE PROPERTIES OF THE SOLVENTS AND THE POROUS MEDIUM USING A MATERIAL BALANCE APPROACH.

COMMENTS:

----- 1. THE RESULTS PRESENTED IN THIS PAPER INDICATE THAT SOLVENT FLOODING AFTER WATERFLOODING WOULD NOT BE AN ECONOMIC PROCESS. THIS WOULD NOT NECESSARILY BE TRUE OF CO₂ FLOODING.

2. IN THE DISCUSSION, RESULTS OF EXPERIMENTS WITH CORES UP TO 100 FEET IN LENGTH ARE PRESENTED; THESE RESULTS INDICATE THAT THE POWER LAW EXTRAPOLATION FOR SLUG SIZING IS APPLICABLE. IT MAY BE POSSIBLE TO ESTABLISH A SIMILAR POWER LAW FORMULA FOR OPTIMUM CO₂ SLUG SIZING.

3. WHEN INSUFFICIENT SOLVENT WAS INJECTED TO EFFECT MISCIBILITY THROUGHOUT THE ENTIRE LENGTH OF THE CORE, THE RECOVERY MECHANISM REVERTED TO AN IMMISCIBLE DISPLACEMENT, BUT THE OIL THAT HAD BEEN MOBILIZED UP TO THAT TIME WAS RECOVERED.

EXHIBITS:

----- 5 TABLES, 20 FIGURES INCLUDING EXPERIMENTAL RESULTS
AND CORRELATIONS.

ADDITIONAL REFERENCES:

----- TABOR, KAMATH, AND REED:
SOC. PET. ENG J. (SEP 1961) 195.

CROSS REFERENCES:

S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.

KEYWORDS:

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES

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37. BOND, D.C. AND HOLM, L.W.: "IMPROVED FLOODING METHOD FOR THE RECOVERY OF PETROLEUM", U.S. PATENT 3,072,185 (JAN. 8, 1963).

ABSTRACT:

----- THIS INVENTION RELATES TO THE RECOVERY OF RESIDUAL OIL FROM PARTIALLY DEPLETED RESERVOIRS. IT IS CONCERNED WITH IMPROVING THE RECOVERY OF OIL FROM LIMESTONE RESERVOIRS BEYOND THAT OBTAINABLE WITH WATERFLOODING OR GAS INJECTION.

THE INVENTION INVOLVES USING COMBUSTION TO GENERATE BETWEEN 500 AND 33500 STANDARD CUBIC FEET OF CARBON DIOXIDE PER BARREL OF OIL IN PLACE. THE COMBUSTION IS THEN TERMINATED AND WATER IS INJECTED TO BUILD UP PRESSURE TO BETWEEN 700 AND 2500 PSI. FLOODING WITH WATER IS CONTINUED TO WATER BREAKTHROUGH AND PRODUCTION IS THEN CARRIED OUT UNDER DEPLETION OPERATIONS. THE DEPLETION STAGE MAY BE REPLACED BY RENEWED WATER INJECTION IN A FASHION SIMILAR TO THAT DESCRIBED IN HOLM (1962A). BETWEEN 80 AND 90% OF THE RESIDUAL OIL MAY BE RECOVERED USING THIS INVENTION.

COMMENTS:

----- THIS PATENT IS ACTUALLY AN EXTENSION OF HOLM'S 1962 PATENT WHEREIN CARBON DIOXIDE IS CREATED BY COMBUSTION RATHER THAN INJECTION.

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES

LABORATORY INJECTION PROCESS
CARBONATE (LAB. EXP.)
FLUE GAS (LAB. EXP.)
U.S. PATENT

38. CRAWFORD, H.R., NEILL, G.H., BUCY, R.J. AND CRAWFORD, P.B.:
"CARBON DIOXIDE - A MULTIPURPOSE ADDITIVE FOR EFFECTIVE
WELL STIMULATION", J. PET. TECH. (MAR., 1963) 237-242.

ABSTRACT:

----- THIS PAPER PRESENTS PHYSICAL AND CHEMICAL PROPERTIES
OF CARBON DIOXIDE WHICH FORM THE THEORETICAL BASIS FOR ITS USE AS
A WELL STIMULATION ADDITIVE. THE MEANS OF APPLICATION OF CO2 IN
FRACTURING AND ACIDIZING TREATMENTS ARE DESCRIBED, AND A METHOD
FOR SIZING TREATMENTS IS GIVEN.

SOME OF THE ADVANTAGES WHICH CAN BE EXPECTED FROM THE USE OF
CO2 AS AN ADDITIVE FOR WELL STIMULATION INCLUDE ELIMINATION OF
SWABBING, RAPID CLEANUP, PREVENTION OF WATER OR EMULSION BLOCKS,
RETARDATION OF ACID REACTION WITH THE FORMATION, PREVENTION OF
CLAY SWELLING, PREVENTION OF PRECIPITATION OF IRON AND ALUMINUM
HYDROXIDES, INCREASED PERMEABILITY. SEVERAL FIELD RESULTS AT
VARYING DEPTHS, INJECTION RATES AND PRODUCTION RATES ARE PRESENTED.
IN NEARLY ALL CASES, TREATING FLUIDS FLOWED TO THE SURFACE WITHOUT
SWABBING.

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COMMENTS:

----- 1. THE USE OF CARBON DIOXIDE OR NITROGEN AS AN
ADDITIVE FOR WELL STIMULATION IS NOW A COMMON PRACTICE.
2. THIS PAPER PRESENTS A SUMMARY OF CORRELATIONS THROUGH
1963 OF THE BASIC PHYSICAL AND CHEMICAL PROPERTIES OF CARBON DIOXIDE.

EXHIBITS:

----- 16 FIGURES INCLUDING DESIGN CHARTS.

ADDITIONAL REFERENCES:

----- REAMER, OLDS, SAGE AND LACEY:
IND. & ENG. CH. (1944) V.36, 88.

CROSS REFERENCES:

20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
22. HOLM: TRANS., AIME (1959) 225.

KEYWORDS:

OTHER FIELD INFORMATION

MISCELLANEOUS DATA

39. DOTTS, W.M., JR. AND STEVENS, W.E.: "METHOD FOR HIGH PRESSURE SELECTIVE ABSORPTION OF GASES", U.S. PATENT 3,097,917 (JULY 16, 1963).

ABSTRACT:

----- THIS INVENTION RELATES TO A METHOD FOR TREATING A GAS TO CHANGE THE CONCENTRATION OF A COMPONENT. THE METHOD INVOLVES CONTACTING THE GAS COUNTERCURRENTLY AT HIGH PRESSURE WITH AN ABSORBING LIQUID HAVING A PREFERENTIAL CAPACITY FOR THE COMPONENT TO BE SEPARATED. THE TREATING "VESSEL" IS A SEALED WELLBORE.

THE METHOD TAKES ADVANTAGE OF THE FACT THAT DEEP HOLES CAN BE USED TO OBTAIN A LONG CONTACT TIME AND LARGE VOLUME FOR TREATMENT. USING A WELLBORE, HIGH TREATMENT PRESSURES AND LONG CONTACT LENGTHS CAN BE OBTAINED WITHOUT ELABORATE SUPPORTING STRUCTURES OR LARGE AREA REQUIREMENTS.

SAMPLE ECONOMICS PRESENTED IN THE PATENT INDICATE THAT THE INVESTMENT FOR TREATMENT WITH THIS METHOD WOULD BE ABOUT ONE-EIGHTH OF THE INVESTMENT OF CONVENTIONAL FACILITIES TO PURIFY 25 MM SCFD OF 15% HYDROGEN SULFIDE GAS; OPERATING COSTS WOULD BE CUT 80% USING THE INVENTION.

THE METHOD IS SAID TO BE APPLICABLE FOR THE REMOVAL OF HYDROGEN SULFIDE ACIDIC CONSTITUENTS OR WATER VAPOR FROM NATURAL GAS, REMOVAL OF CARBON DIOXIDE FROM FLUE GAS, OR TREATMENT OF AIR TO SEPARATE NITROGEN AND OXYGEN.

COMMENTS

----- THIS PATENT MAY PROVIDE A USEFUL METHOD FOR SEPARATION OF CARBON DIOXIDE FROM FLUE GAS OR PRODUCED GAS STREAMS.

EXHIBITS:

----- 1 TABLE, 7 FIGURES INCLUDING SAMPLE ECONOMICS.

KEYWORDS:

U.S. PATENT

SEPARATION

40. HOLM, L.W.: "CO2 REQUIREMENTS IN CO2 SLUG AND CARBONATED WATER OIL RECOVERY PROCESSES", PROD. MO. (SEP., 1963) 6-28.

ABSTRACT:

----- THIS PATENT RELATES TO A METHOD OF OBTAINING CARBON DIOXIDE FROM FLUE GAS. THE CARBON DIOXIDE MAY THEN BE INJECTED. THE BASIC CONCEPT OF THE PATENT IS TO UTILIZE THE HIGH SOLUBILITY OF CARBON DIOXIDE IN OIL (OR GASOLINE, KEROSENE, ETC); BECAUSE NITROGEN (THE OTHER MAJOR COMPONENT OF FLUE GAS) IS VIRTUALLY INSOLUBLE IN OIL, THE OIL ACTS AS AN ABSORBENT FOR CO2. THE CO2 MAY THEN BE FLASHED FROM THE OIL BY HEATING OR DEPRESSURING OR THE CO2-OIL MIXTURE, A FLUID WHICH SHOULD BE MISCIBLE WITH RESERVOIR OIL, MAY BE INJECTED TO INITIATE A MISCIBLE DISPLACEMENT.

COMMENTS:

----- 1. THE ECONOMICS CONCERNING THE USE OF OIL AS A SEPARATION ABSORBENT FOR CO2 WOULD NEED TO BE EXAMINED BEFORE THIS PATENT COULD BE APPLIED; IT IS DOUBTFUL THAT THEY WILL BE ANY BETTER THAN CONVENTIONAL METHODS.

2. INJECTING THE CO2-OIL MIXTURE BEFORE CO2 ALONE IS INJECTED WOULD GIVE ESSENTIALLY IMMEDIATE MISCIBILITY; A NUMBER OF OTHER PATENTS ALSO SUGGEST METHODS OF ACHIEVING THIS.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

- 11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
22. HOLM: TRANS., AIME (1959) 225.
31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.

KEYWORDS:

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
CARBONATE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)

SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
LABORATORY INSTABILITIES
MISCIBILITY (LAB. EXP.)
HEAVY OIL (LAB. EXP.)
OTHER LABORATORY STUDIES

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41. HOLM, L.W.: "SECONDARY RECOVERY OF PETROLEUM", U.S. PATENT 3,075,918 (JAN. 29, 1963).

ABSTRACT:

----- THIS PAPER PRESENTS LABORATORY RESULTS ON THE CONDITIONS UNDER WHICH CO₂ SHOULD BE EFFECTIVE AS AN OIL RECOVERY AGENT, THE IMPROVEMENT IN OIL RECOVERY OVER A WATERFLOOD THAT CAN BE EXPECTED FROM FLOODING WITH CO₂ AND THE AMOUNT OF CO₂ REQUIRED TO OBTAIN THIS IMPROVEMENT. INCLUDED IS A COMPARISON BETWEEN A WATER DRIVEN CO₂ SLUG AND CARBONATED WATERFLOOD.

RESULTS INDICATE THAT A 50 TO 100% INCREASE IN OIL RECOVERY OVER WATERFLOODING MAY BE OBTAINED WITH CO₂. THE AMOUNT OF CO₂ REQUIRED TO OBTAIN THIS IMPROVEMENT IS 200 TO 250 SCF CO₂ PER BARREL OF OIL IN PLACE OR ABOUT 5% OF A PORE VOLUME. FOR HEAVY OIL-RESERVOIRS, AS LITTLE AS 2% OF A PORE VOLUME MAY BE SUFFICIENT, WHILE FOR WATERED OUT RESERVOIRS, ABOUT 7% OF A PORE VOLUME MAY BE NECESSARY. THE PROCESS APPEARS TO YIELD SIMILAR RECOVERIES FOR IRREGULAR POROSITY, HETEROGENEOUS ROCK AS FOR UNIFORM SANDSTONES, IN CONTRAST TO WATERFLOOD BEHAVIOR. FINALLY, AT SIMILAR VOLUMES OF TOTAL CO₂ INJECTION, THE CARBONATED WATERFLOOD PROCESS YIELDED OIL RECOVERIES ONLY 75 TO 80% OF THOSE OBTAINED WITH THE WATER-DRIVEN CO₂ SLUG.

COMMENTS:

- 1. THIS PAPER SUMMARIZES THE STATE OF THE ART IN 1963; HOWEVER, IT IS NOT OF CRUCIAL IMPORTANCE TODAY.
2. THE LABORATORY RESULTS EXAMINED IN THIS PAPER WERE IN THE MAIN REPORTED IN THE REFERENCES.

EXHIBITS:

----- 1 TABLE, 11 FIGURES

CROSS REFERENCES:

- 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)

KEYWORDS:

FLUE GAS FIELD APPLICATIONS
CO₂ SOURCE

U.S. PATENT
SEPARATION

42. KOVAL, E.J.: "A METHOD FOR PREDICTING THE PERFORMANCE OF UNSTABLE MISCIBLE DISPLACEMENT IN HETEROGENEOUS MEDIA", TRANS., AIME (1963) V.228, 145-154.

ABSTRACT:

----- PRACTICAL MISCIBLE DISPLACEMENT PROCESSES ARE CHARACTERIZED BY FINGERING OF THE SOLVENT INTO THE OIL. THIS FINGERING PROCESS IS BROUGHT ON BY VISCOSITY DIFFERENCES, AND CAN BE ACCENTUATED BY CHANNELING, PERMEABILITY HETEROGENEITY, AND LONGITUDINAL DISPERSION.

A SIMPLE BUCKLEY-LEVERETT APPROACH WAS USED TO GENERATE EQUATIONS GOVERNING FRACTION FLOW OF MISCIBLE FLUIDS. THIS METHOD PREDICTS RECOVERY AND SOLVENT CUT AS A FUNCTION OF PORE VOLUMES OF SOLVENT INJECTED. THE KEY ASSUMPTIONS OF THE METHOD ARE: LINEAR SYSTEM, MISCIBILITY, NO GRAVITY EFFECTS, AND HIGH FLOODING RATES TO MINIMIZE SMALL RATE EFFECTS AND DIFFUSION. EXPERIMENTAL DATA ARE INCLUDED AND SHOW EXCELLENT AGREEMENT WITH THEORY FOR A WIDE VARIETY OF SANDSTONE CORES AND VISCOSITY RATIOS.

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COMMENTS:

- 1. THE SIMPLE MODEL PRESENTED HERE SHOULD BE GENERALIZED TO MULTIPLE BANKS AND OTHER FLOODING GEOMETRIES.
2. NEGLECT OF GRAVITATIONAL FORCES MAY BE A SEVERE DRAWBACK FOR THIS METHOD.

EXHIBITS:

----- 2 TABLES, 20 FIGURES INCLUDING LABORATORY RESULTS.

ADDITIONAL REFERENCES:

----- BUCKLEY AND LEVERETT:
TRANS., AIME (1942) V.146, 107.

CROSS REFERENCES:

- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
29. HABERMANN: TRANS., AIME (1960) 264.

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
OTHER LABORATORY STUDIES
BUCKLEY-LEVERETT MODELLING
COMPARISONS WITH LAB. RESULTS

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
ANALYTICAL MODELLING
MIXING ZONE MODELS
OTHER MODELLING

43. MENZIE, D.E. AND NIELSEN, R.F.: "A STUDY OF THE VAPORIZATION OF CRUDE OIL BY CARBON DIOXIDE REPRESSURING", TRANS., AIME (1963) V.228, 1247-1252.

ABSTRACT:

----- THE OBJECT OF THIS STUDY WAS TO DETERMINE WHETHER CRUDE OIL COULD BE PRODUCED BY VAPORIZATION USING CARBON DIOXIDE REPRESSURING. THE PROCESS MIGHT HAVE APPLICATION TO HIGHLY FRACTURED RESERVOIRS WHERE MOST OF THE OIL IS CONTAINED IN TIGHT MATRIX. LABORATORY EXPERIMENTS INDICATE THAT CARBON DIOXIDE - OIL EQUILIBRIUM IS TYPICALLY REACHED IN ABOUT FOUR DAYS.

COMMENTS:

----- 1. THE KEY RESULT OF THIS PAPER IS THAT CO₂ - OIL EQUILIBRIUM (BY MICROSCOPIC DIFFUSION OR WHATEVER PROCESS) IS REACHED RAPIDLY ON A RESERVOIR TIME SCALE; THE QUESTION ARISES THEN, IS CO₂ - OIL EQUILIBRIUM REACHED IN AN EXPERIMENTAL TIME SCALE?

2. THE SUGGESTION BY THE AUTHORS THAT CO₂ VAPORIZATION OF OIL CAN TECHNICALLY RECOVER OIL FROM TIGHT MATRIX NEEDS FURTHER VERIFICATION.

CROSS REFERENCES:

- 8. POETTMANN: TRANS., AIME (1951) 141.
13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.

KEYWORDS:

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)

LABORATORY INJECTION PROCESS
OTHER LABORATORY STUDIES

44. REAMER, H.H. AND SAGE, B.H.: "PHASE EQUILIBRIA IN HYDROCARBON SYSTEMS. VOLUMETRIC AND PHASE BEHAVIOR OF THE N-DECANE - CO₂ SYSTEM", J. CH. & ENG. DATA (OCT., 1963) 508-513.

ABSTRACT:

----- THIS PAPER REPORTS EXPERIMENTAL MEASUREMENTS OF THE VOLUMETRIC AND PHASE BEHAVIOR OF THE BINARY SYSTEM N-DECANE-CO₂. THE DATA PRESENTED ARE FOR PRESSURES UP TO 10,000 PSI, TEMPERATURES BETWEEN 40 AND 460 F, COVERING THE ENTIRE RANGE OF COMPOSITION.

COMMENTS:

----- THIS IS ONE OF A LARGE NUMBER OF PAPERS ON BINARY CO₂-HYDROCARBON SYSTEMS.

EXHIBITS:

----- 2 TABLES, 5 FIGURES

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.

KEYWORDS:

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
OTHER PHYSICAL PROPERTIES

HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS
LAB. PROCEDURES AND APPARATUS

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45. WELKER, J.R. AND DUNLOP, D.D.: "PHYSICAL PROPERTIES OF CARBONATED OILS", TRANS., AIME (AUG., 1963) 873-876.

ABSTRACT:

----- THIS PAPER PRESENTS SOLUBILITY, SWELLING, AND VISCOSITY MEASUREMENTS FOR 11 CRUDE OILS SATURATED WITH CARBON DIOXIDE. IT WAS FOUND THAT SOLUBILITY IS APPROXIMATELY A QUADRATIC FUNCTION OF SATURATION PRESSURE, SWELLING FACTOR IS APPROXIMATELY LINEAR WITH SOLUBILITY, AND THAT VISCOSITY MAY BE RELATED TO SATURATION PRESSURE. GRAPHICAL CORRELATIONS ARE PRESENTED.

COMMENTS:

----- 1. THE CORRELATION PRESENTED FOR VISCOSITY IS APPLICABLE ONLY AT 80 F; THE CORRELATIONS FOR SOLUBILITY AND SWELLING FACTOR DO NOT INCLUDE THE EFFECT OF API GRAVITY EXCEPT AT 80 F; HENCE THIS PAPER HAS LIMITED APPLICABILITY.

EXHIBITS:

----- 1 TABLE, 9 FIGURES

CROSS REFERENCES:

- 3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.

KEYWORDS:

MULTICOMPONENT SYSTEMS
EFFECTS OF TEMPERATURE
SOLUBILITY

CORRELATIONS
EFFECTS OF PRESSURE
OIL SWELLING
VISCOSITY

46. WEST, R.C., ORTLOFF, G.D. AND BEESON, D.M.: "SECONDARY RECOVERY OF PETROLEUM", U.S. PATENT 3,084,743 (APR. 9, 1963).

ABSTRACT:

----- THIS PATENT INVOLVES THE INJECTION OF A SLUG OF CARBON DIOXIDE (5 TO 25% OF A PORE VOLUME) AT PRESSURES BETWEEN 1000 AND 4000 PSI. THE SLUG IS DRIVEN BY WATER. AFTER A HIGH WATER-OIL RATIO IS REACHED (ABOUT 25 TO 1) A BLOWDOWN CYCLE IS TAKEN.

LABORATORY RESULTS ARE PRESENTED THAT INDICATE THAT THE RECOVERY FROM CO2 FLOOD AND BLOWDOWN ARE NOT AFFECTED BY THE LENGTH OF THE CORE OR THE FLOOD PRODUCTION OR INJECTION RATES; THUS, BLOWDOWN RECOVERIES SHOULD BE REALIZABLE IN THE FIELD.

COMMENTS:

----- THIS PATENT IS THE BASIC PATENT ON THE RECOGNITION THAT ADDITIONAL RECOVERY CAN BE OBTAINED BY BLOWDOWN.

EXHIBITS:

----- 4 TABLES, 1 FIGURE INCLUDING EXPERIMENTAL RESULTS.

CROSS REFERENCES:

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- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
 - 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
 - 25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
 - 26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
OTHER LABORATORY STUDIES

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
U.S. PATENT

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47. MUIRBROOK, N.K.: "EXPERIMENTAL AND THERMODYNAMIC STUDY OF THE HIGH-PRESSURE VAPOR-LIQUID EQUILIBRIA FOR THE NITROGEN-OXYGEN-CARBON DIOXIDE SYSTEM", PH.D. DISSERTATION, U. CA., BERKELEY (1964).

ABSTRACT:

----- AN EXPERIMENTAL STUDY IS DESCRIBED FOR VAPOR-LIQUID PHASE COMPOSITIONS, MOLAL VOLUMES, AND PRESSURES AT 0 C FOR THE N₂-O₂-CO₂ TERNARY AND BINARY SYSTEMS N₂-CO₂ AND O₂-CO₂. THE O₂-N₂ BINARY LIQUID PHASE DOES NOT EXIST AT 0 C. FUGACITIES, K-FACTORS, AND ACTIVITY COEFFICIENTS ARE DERIVED BY THERMODYNAMIC ANALYSES OF THE DATA, USING THE MODIFIED REDLICH-KWONG EQUATION OF STATE FOR VAPOR FUGACITIES. PREDICTION OF TERNARY BEHAVIOR FROM BINARY DATA WAS GENERALLY SUCCESSFUL. A NOVEL EQUILIBRIUM CELL SAMPLING AND MIXING SYSTEM IS DESCRIBED. THE BIBLIOGRAPHY CONTAINS 21 REFERENCES TO THERMODYNAMIC AND EXPERIMENTAL TOPICS.

COMMENTS:

----- THE AUTHOR SUGGESTS THAT DIFFERENTIAL VOLATILITY OF N₂ AND O₂ IN LIQUID CO₂ MIGHT BE USED TO DESIGN A PROCESS FOR SEPARATING O₂ FROM AIR (VOLATILITY OF N₂ IS ABOUT 1.1 TO 1.2 TIMES VOLATILITY OF O₂). ALTHOUGH A SCHEMATIC FLOW SHEET IS GIVEN, NO PROCESS CALCULATIONS WERE MADE, AND THE FINAL REMOVAL OF CO₂ FROM THE PRODUCT N₂ AND O₂ STREAMS IS GLOSSED OVER, AS THE AUTHOR STATES. A POSSIBLE EOR APPLICATION WOULD BE THE ENRICHMENT OF OF FLUE GAS IN CO₂ BY FRACTIONAL DISTILLATION - SUFFICIENT DATA ARE GIVEN TO ALLOW A FEASIBILITY STUDY TO BE MADE.

EXHIBITS:

----- 14 TABLES PLUS 16 PAGES OF COMPUTER PRINTOUTS OF CALCULATED DATA, 25 FIGURES.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES	THEORETICAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR	CORRELATIONS
BINARY SYSTEMS	NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE	EQUATIONS OF STATE
SOLUBILITY	DENSITY
LAB. PROCEDURES AND APPARATUS	EQUILIBRIUM RATIOS
SEPARATION	CO ₂ SUPPLY
	MISCELLANEOUS DATA

48. BUXTON, T.S.: "THE PREDICTION OF THE COMPRESSIBILITY FACTORS FOR LEAN NATURAL GAS - CARBON DIOXIDE MIXTURES AT HIGH PRESSURE", PH.D. DISSERTATION, U. OK., NORMAN, OK. (1965).

ABSTRACT:

----- COMPRESSIBILITY FACTORS WERE DETERMINED EXPERIMENTALLY ON FIVE MIXTURES CONTAINING CH₄, CO₂, AND C₂H₆ OR C₃H₈ AT 100, 130, AND 160 F AND PRESSURES UP TO 7026 PSIA. THESE DATA WERE THEN USED TO INVESTIGATE PARAMETER COMBINING RULES USED IN EXTENSION OF THE THEORY OF CORRESPONDING STATES FROM PURE COMPONENTS TO MIXTURES. PARTICULARLY EMPHASIZED ARE VARIOUS "THIRD PARAMETERS" PROPOSED BY OTHER INVESTIGATORS TO CHARACTERIZE DEPARTURES FROM CLASSICAL CORRESPONDING STATES TREATMENT. THE FOLLOWING CONCLUSIONS ARE SUPPORTED FOR THE MIXTURES STUDIED:

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1. A MACROSCOPIC "THIRD PARAMETER" (E.G., CRITICAL COMPRESSIBILITY FACTOR) IS MORE PRACTICAL THAN MOLECULAR PARAMETERS.
2. VARIOUS "THIRD PARAMETERS" ARE ALMOST LINEARLY RELATED, SO THAT THE CHOICE OF A PARTICULAR ONE IS ARBITRARY.
3. PITZER'S ACCENTRIC FACTOR CAN BE USED FOR MIXTURES, PROVIDED THAT PSEUDO-CRITICAL CONSTANTS CAN BE PROPERLY DETERMINED.
4. MIXING RULES FOR PSEUDO-CRITICAL CONSTANTS MUST BE TESTED EXPERIMENTALLY ON TYPICAL MIXTURES CONTAINING THE COMPONENTS OF INTEREST.

COMMENTS:

----- NOT DIRECTLY APPLICABLE TO EOR APPLICATIONS OF CO₂, BUT USEFUL DATA AND THERMODYNAMIC ANALYSES FOR PROPERTIES OF MIXTURES CONTAINING CO₂.

EXHIBITS:

----- 13 TABLES, 31 FIGURES

ADDITIONAL REFERENCES:

----- BIBLIOGRAPHY OF 68 REFERENCES, NOT DIRECTLY APPLICABLE TO EOR WITH CO₂.

KEYWORDS:

THEORETICAL PHYSICAL PROPERTIES
CORRELATIONS
NON-HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
EFFECTS OF PRESSURE
LAB. PROCEDURES AND APPARATUS

49. LEWIS, W.K.: "PETROLEUM RECOVERY WITH INERT GASES",
U.S. PATENT 3,193,006 (JULY 6, 1965).

ABSTRACT:

----- THIS PATENT RELATES TO USING OR CREATING A GAS
CAP/MISCIBLE GAS DRIVE BY INJECTING CO₂ INTO THE OIL ZONE AND
NITROGEN INTO A PRE-EXISTING OR CREATED GAS CAP, WITH THE
ASSOCIATED DRIVE ENERGIES AND ADVANTAGES OF EACH.

THE CARBON DIOXIDE AND NITROGEN ARE OBTAINED FROM NATURAL
GAS AND AIR USING A FE₂O₃ - FE₃O₄ TECHNIQUE. THE METHOD INVOLVES
REACTING (FOR EXAMPLE) METHANE WITH FE₂O₃ TO OBTAIN CARBON DIOXIDE
WATER, AND FE₃O₄. THE CARBON DIOXIDE IS USED FOR INJECTION. THE
FE₃O₄ IS RECLAIMED BY REACTION WITH THE OXYGEN IN AIR TO OBTAIN
FE₂O₃ AND AN ESSENTIALLY PURE STREAM OF NITROGEN FOR INJECTION.

COMMENTS:

----- ONE STANDARD CUBIC FOOT OF CARBON DIOXIDE IS
CREATED BY THIS PROCESS FOR EACH STANDARD CUBIC FOOT OF METHANE
USED; THIS WAS ATTRACTIVE WHEN NATURAL GAS WAS BEING VENTED OR
FLARED, BUT WOULD PROBABLY BE UNECONOMIC TODAY.

EXHIBITS:

----- 1 FIGURE

ADDITIONAL REFERENCES:

- 1. LEWIS AND GILLILAND:
U.S. PATENT 2,665,971 (1954).
2. LINDLEY: U.S. PATENT 3,064,729 (NOV. 20, 1962).

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
18. HAVERFIELD: U.S. PATENT 2,729,291 (JAN. 3, 1956).
23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).
25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
34. STONE: U.S. PATENT 2,944,373 (AUG. 1, 1961).

KEYWORDS:

OTHER FIELD INFORMATION
CO₂ SOURCE
ALTERNATE TECHNOLOGIES

U.S. PATENT
SEPARATION
MISCELLANEOUS DATA

50. SHARP, L.G.: "METHODS OF RECOVERING OIL BY IN-SITU PRODUCED CARBON DIOXIDE", U.S. PATENT 3,174,543 (MAR. 23, 1965).

ABSTRACT:

----- THIS PATENT INVOLVES INJECTING OXYGEN (AT LEAST 66% BY VOLUME) TO PRODUCE CARBON DIOXIDE, AND THEN DRIVING THE RESERVOIR OIL AND CARBON DIOXIDE TO A PRODUCING WELL. A SECOND PART OF THE PATENT DESCRIBES A COMBUSTION SOAK OPERATION, WHEREIN AIR IS INJECTED AND THE WELL IS HEATED TO INITIATE COMBUSTION. AFTER THE COMBUSTION HAS PROCEEDED THROUGH ABOUT 10% OF A PORE VOLUME, THE WELL IS BACKFLOWED UNTIL TRACE QUANTITIES OF REFORMED OIL ARE PRODUCED. THIS OIL HAS BEEN CRACKED BY THE TEMPERATURE IN THE BURNED ZONE. COMBUSTION IS THEN REINITIATED TO GENERATE CO2 IN-SITU. AFTER SUFFICIENT CO2 IS GENERATED, THE COMBUSTION IS HALTED, AND THE OIL AND CARBON DIOXIDE ARE DRIVEN TO THE PRODUCING WELL.

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COMMENTS:

----- 1. AS A METHOD OF GENERATING CO2, THIS PATENT MIGHT PROVE USEFUL IN THE ABSENCE OF A SUITABLE SOURCE; HOWEVER, OTHER METHODS MAY BE MORE ATTRACTIVE ECONOMICALLY.

2. THE CARBON DIOXIDE GENERATED BY COMBUSTION OR LOW TEMPERATURE OXIDATION OF CRUDE OIL MAY BE IMPORTANT TO RECOVERY BY COMBUSTION OR AIR INJECTION.

CROSS REFERENCES:

37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).

KEYWORDS:

OTHER LABORATORY STUDIES
FIELD SECONDARY RECOVERY
CO2 SOURCE

LABORATORY INJECTION PROCESS
SOAK OPERATION
U.S. PATENT
ALTERNATE TECHNOLOGIES

51. SIMON, R. AND GRAUE, D.J.: "GENERALIZED CORRELATIONS FOR PREDICTING SOLUBILITY, SWELLING AND VISCOSITY BEHAVIOR OF CO₂ - CRUDE OIL SYSTEMS", TRANS., AIME (1965) V.234, 102-106.

ABSTRACT:

----- THIS PAPER PRESENTS CORRELATIONS FOR PREDICTING THE SOLUBILITY, SWELLING, AND VISCOSITY BEHAVIOR OF CO₂ - CRUDE OIL SYSTEMS. THE CORRELATIONS WERE DEVELOPED FROM EXPERIMENTAL DATA OBTAINED BY THE AUTHORS. THE DATA ARE ALSO PRESENTED,

DATA WERE DETERMINED BY MEASURING THE PROPERTIES OF MIXTURES OF CO₂ AND NINE DIFFERENT OILS. EXPERIMENTAL CONDITIONS COVERED A RANGE OF 100 TO 250 F AND PRESSURES UP TO 2300 PSIA. PROPERTIES PREDICTED BY THE CORRELATIONS HAVE AVERAGE DEVIATIONS OF 2% FOR SOLUBILITY, 0.5% FOR SWELLING AND 12% FOR VISCOSITY. THE MAXIMUM DEVIATIONS OBSERVED WERE 6.8% FOR SOLUBILITY, 2.6% FOR SWELLING, AND 28% FOR VISCOSITY.

COMMENTS:

----- 1. THE CORRELATIONS CONTAINED WITHIN THIS PAPER ARE SOME OF THE BEST AVAILABLE FOR ENGINEERING PURPOSES.

2. THE DATA PRESENTED INDICATE THAT CO₂ SATURATED OILS CAN HAVE HIGHER DENSITIES THAN THE VIRGIN OIL.

EXHIBITS:

----- 2 TABLES, 7 FIGURES, INCLUDING ORIGINAL RESULTS AND CORRELATIONS IN GRAPHICAL FORM.

ADDITIONAL REFERENCES:

----- POETTMAN AND KATZ:
IND. & ENG. CH. (1946) V.38, 530.

CROSS REFERENCES:

- 8. POETTMANN: TRANS., AIME (1951) 141.
11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
22. HOLM: TRANS., AIME (1959) 225.
38. CRAWFORD, NEILL, BUCY, CRAWFORD: J. PET. TECH. (MAR., 1963) 237.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
45. WELKER, DUNLOP: TRANS., AIME (1963) 873.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF TEMPERATURE
OIL SWELLING
VISCOSITY

CORRELATIONS
EFFECTS OF PRESSURE
DENSITY
SOLUBILITY
OIL PROPERTIES CHARACTERIZATION

52. ANDN.: "SHELL PLANS BIG CO2 MISCIBLE DRIVE", OIL & GAS J.
(APR. 18, 1966) 60-61.

ABSTRACT:

----- THIS ARTICLE DESCRIBES THE PROPOSED CO2 FLOOD IN
THE CROSSETT (DEVONIAN) FIELD IN TEXAS. THE PROPOSED SLUG SIZE
IS 15% OF A PORE VOLUME. THE SOURCE FOR CO2 IS THE BROWN-BUSSETT
FIELD, WHERE 40% OF THE PRODUCED GAS IS CO2.

LABORATORY STUDIES HAVE BEEN CONDUCTED AND INDICATE THAT MORE
OIL WILL BE RECOVERED BY CARBON DIOXIDE FLOODING THAN BY
WATERFLOODING. NO PILOT WILL BE RUN SINCE THE COST OF A PIPELINE
WON'T COST MUCH MORE THAN TRUCKING CO2 FOR A PILOT WOULD COST.

COMMENTS:

----- ONE OF THE PURPOSES FOR CO2 FLOODING HERE MAY BE
THE INCREASED ALLOWABLES THAT WERE REQUESTED.

EXHIBITS:

----- 1 FIGURE

KEYWORDS:

FIELD SECONDARY RECOVERY
OTHER FIELD INFORMATION

WATER INJECTION
FIELD MISCIBLE APPLICATION
CO2 SOURCE

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53. BRIGHAM, W.E., DEW, J.N. AND REED, P.W.: "RECOVERY PROCESS FOR PRODUCING PETROLEUM", U.S. PATENT 3,249,157 (MAY 3, 1966).

ABSTRACT:

----- THIS PATENT DESCRIBES THE INJECTION OF ALTERNATE SLUGS OF CO₂ OR LPG AND WATER. THE PATENT STARTS WITH A DESCRIPTION OF METHODS FOR SIZING RELATIVE AMOUNTS OF MISCIBLE AND IMMISCIBLE FLUID TO BE INJECTED; IT IS FOUND THAT THE THEORETICAL MIXTURE SHOULD BE APPROXIMATELY 1 PART MISCIBLE FLUID TO 10 PARTS IMMISCIBLE FLUID. LABORATORY EXPERIMENTS, HOWEVER, INDICATE THAT A RATIO FROM 1 TO 1 UP TO 10 TO 1 IS MORE EFFICIENT. A FIELD TEST OF LPG FLOODING WHEREIN LPG AND WATER WERE INJECTED IN ALTERNATE SLUGS IS ALSO DESCRIBED; NO BREAKTHROUGH WAS OBSERVED AFTER 2 YEARS OF INJECTION, WHEREAS THE ORIGINAL PILOT WITH A SLUG HAVING BEEN INJECTED WITHOUT BREAKING IT UP WITH SLUGS OF WATER HAD BREAKTHROUGH IN 12 MONTHS.

COMMENTS:

----- 1. THE OPTIMAL SIZE FOR EACH SLUG OF MISCIBLE FLUID IS LESS THAN 2%, AND NORMALLY BETWEEN 0.05 AND 0.15%.

2. THE OPTIMUM RATIO BETWEEN THE SIZES OF THE ALTERNATE MISCIBLE AND IMMISCIBLE SLUGS IS BETWEEN 3 TO 2 AND 9 TO 1.

EXHIBITS:

----- 1 TABLE, 3 FIGURES

KEYWORDS:

LABORATORY INJECTION PROCESS
RESIDUAL SATURATION (LAB. EXP.)
SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FIELD AREAL SWEEP
FIELD RESIDUAL SATURATIONS

CARBONATE (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
WATER INJECTION
FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
U.S. PATENT

54. CONNALLY, C., JR., ELFRINK, E.B. AND SHARP, L.G.: "SECONDARY RECOVERY OF OIL FROM A SUBTERRANEAN FORMATION", U.S. PATENT 3,262,498 (JULY 26, 1966).

ABSTRACT:

----- THIS PATENT RELATES TO USING A COMBINATION OF CARBON DIOXIDE AND LPG FLOODING. THE BASIC PROCESS INVOLVES INJECTING A SLUG OF CO2 FOLLOWED BY A SLUG OF LPG, ALL OF WHICH IS PUSHED THROUGH THE RESERVOIR BY AN AQUEOUS DRIVE FLUID.

THE BASIC RATIONALE FOR THIS INVENTION IS TO PROVIDE A GRADUAL CHANGE IN PROPERTIES FROM THE VIRGIN OIL TO LPG, WITH THE CO2 SLUG BEING ESSENTIALLY TOTALLY DISSOLVED.

COMMENTS:

----- THIS PATENT IS BASICALLY FOR A VARIANT OF LPG FLOODING AND THE PROCESS DESCRIBED WOULD PROBABLY NOT BE ECONOMICALLY VIABLE TODAY.

CROSS REFERENCES:

- 19. RZASA, TERWILLIGER: U.S. PATENT 2,822,872 (FEB. 11, 1958).
26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C
34. STONE: U.S. PATENT 2,944,373 (AUG. 1, 1961).
46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).

KEYWORDS:

FIELD MISCIBLE APPLICATION
U.S. PATENT

OTHER FIELD INFORMATION
LPG

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55. DAVISON, K.: "INERT GAS GENERATORS STIMULATE VISCOUS OIL FLOW", PET. EQUIP. (MAR.-APR., 1966) 6-8.

ABSTRACT:

----- THIS ARTICLE DESCRIBES THE EQUIPMENT AND OPERATION OF FLUE GAS GENERATORS. THE BASIC STOICHIOMETRY FOR GENERATION OF THE GAS WORKS BEST WITH AN AIR FUEL RATIO OF 9.5 TO 1 FOR NATURAL GAS BURNING OR 24 TO 1 FOR BURNING PROPANE. WITH THESE CONCENTRATIONS THE RESULTING FLUE GAS IS 88% NITROGEN AND 12% CO₂. TO GENERATE ONE MCF OF FLUE GAS, 114 CUFT OF NATURAL GAS OR 45 CUFT (1.28 GAL) OF PROPANE ARE REQUIRED.

COMMENTS:

----- THIS ARTICLE SUCCINCTLY DESCRIBES AN INERT GAS GENERATOR.

EXHIBITS:

----- 5 FIGURES

KEYWORDS:

FLUE GAS FIELD APPLICATIONS
OPERATIONS

FACILITIES
OTHER FIELD INFORMATION

56. DEWITT, K.J. AND THODOS, G.: "VISCOSITIES OF BINARY MIXTURES IN THE DENSE GASEOUS STATE: THE METHANE - CARBON DIOXIDE SYSTEM", CAN. J. CH. ENG. (JUNE, 1966) 148-151.

ABSTRACT:

----- THIS PAPER REPORTS VISCOSITY MEASUREMENTS FOR THREE BINARY MIXTURES OF METHANE AND CARBON DIOXIDE AT TEMPERATURES FROM 50 TO 200 C (100 TO 400 F) AND PRESSURES RANGING UP TO 10000 PSI. MEASUREMENTS WERE MADE WITH AN UNSTEADY STATE CAPILLARY VISCOMETER.

THE DATA WERE FIT WITH A RESIDUAL VISCOSITY CORRELATION. IT WAS FOUND THAT THE VISCOSITY IS A BASE VALUE PLUS A CORRECTION TERM. THE CORRECTION TERM IS OF THE FORM OF THE SQUARE ROOT OF MOLECULAR WEIGHT TIMES THE CRITICAL PRESSURE TO THE TWO-THIRDS POWER DIVIDED BY THE SIXTH ROOT OF TEMPERATURE, ALL TIMES BY A FUNCTION OF REDUCED DENSITY. THE CORRELATION PREDICTS VISCOSITY WITH AN AVERAGE ERROR OF 2% AND A MAXIMUM ERROR OF 5.4%, OVER THE ENTIRE RANGE OF DATA GATHERED.

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COMMENTS:

----- THE CORRELATION TECHNIQUE FOR VISCOSITY OF GAS MIXTURES PRESENTED HERE SHOULD BE APPLICABLE TO OTHER SYSTEMS AS WELL.

EXHIBITS:

----- 1 TABLE, 4 FIGURES, INCLUDING EXPERIMENTAL RESULTS.

ADDITIONAL REFERENCES:

- 1. STIEL AND THODOS:
A.I.CH.E. J. (1967) V.10, 275.
2. REAMER, OLDS, SAGE AND LACE: IND. ENG. CH. (1944) V.36, 88.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
VISCOSITY

CORRELATIONS
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
LAB. PROCEDURES AND APPARATUS

57. GILMORE, T.F. AND COMINGS, E.W.: "THERMAL CONDUCTIVITY OF BINARY MIXTURES OF CARBON DIOXIDE, NITROGEN, AND ETHANE AT HIGH PRESSURES: COMPARISON WITH CORRELATION AND THEORY", A.I.C.H.E. J. (NOV., 1966) V.12, NO.6, 1172-1178.

ABSTRACT:

----- THE THERMAL CONDUCTIVITY OF NITROGEN, ETHANE, AND BINARY MIXTURES OF CARBON DIOXIDE, NITROGEN, AND ETHANE WERE DETERMINED AT 75 C (170 F) FOR PRESSURES UP TO 3000 ATM (45000 PSI). THE EXPERIMENTAL DATA ARE SAID TO BE ACCURATE TO WITHIN 3%.

THE ENSKOG (HARD SPHERE) MODEL HAD ERRORS OF AS MUCH AS 75%, PRESUMABLY AT VERY HIGH PRESSURES AND PROBABLY BECAUSE IT DOES NOT INCLUDE MOLECULAR ATTRACTION. THE SEMI-EMPIRICAL LINDSAY-BROMLEY CORRELATION HAD ERRORS AS HIGH AS 30%, WHILE A MOLE BASIS HARMONIC MEAN HAD A MAXIMUM ERROR OF 25%. IN ALL CASES, THE GREATEST ERRORS OCCURRED NEAR THE CRITICAL DENSITY.

COMMENTS:

----- IT DOES NOT APPEAR THAT ANY CORRELATION TESTED ACCURATELY PREDICTS THERMAL CONDUCTIVITY NEAR THE CRITICAL POINT; THIS MAY BE TRUE OF OTHER PROPERTIES AS WELL.

EXHIBITS:

----- 2 TABLES, 5 FIGURES, INCLUDING EXPERIMENTAL RESULTS.

ADDITIONAL REFERENCES:

----- 1. HIRSCHFELDER, CURTISS AND BIRD:
MOLECULAR THEORY OF GASES AND LIQUIDS (1954).
2. REID AND SHERWOOD: PROPERTIES OF GASES AND LIQUIDS (1958).

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
BINARY SYSTEMS
OTHER PHYSICAL PROPERTIES
THEORETICAL PHYSICAL PROPERTIES
CORRELATIONS
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
LAB. PROCEDURES AND APPARATUS

58. JOFFE, J. AND ZUDKEVITCH, D.: "FUGACITY COEFFICIENTS IN GAS MIXTURES CONTAINING LIGHT HYDROCARBONS AND CARBON DIOXIDE", I & EC FUND. (NOV., 1966) V.5, NO.4, 455-462.

ABSTRACT:

----- MIXTURES OF CARBON DIOXIDE AND HYDROCARBON GASES HAVE UNUSUAL PVT BEHAVIOR ATTRIBUTED TO INTERACTION EFFECTS BETWEEN THE CARBON DIOXIDE AND HYDROCARBONS. AFTER REVIEWING METHODS FOR TAKING THESE EFFECTS INTO ACCOUNT, A METHOD WAS DEVELOPED FOR INTRODUCING INTERACTION COEFFICIENTS (DERIVED FROM THOSE OF THE VIRIAL EQUATION) INTO THE REDLICH-KWONG EQUATION OF STATE. THE PROCEDURE IS CONVENIENT FOR COMPUTER APPLICATIONS AND IS VALID OVER A MUCH WIDER PRESSURE RANGE THAN THE VIRIAL EQUATION.

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COMMENTS:

----- THE MODIFIED REDLICH-KWONG EQUATION APPEARS TO BE ACCURATE FOR PREDICTION OF EQUILIBRIUM RATIOS AND COMPRESSIBILITY FACTORS FOR TEMPERATURES FROM 40 TO 250 F AND PRESSURES OF 1500 PSIA OR MORE.

EXHIBITS:

----- 6 TABLES , 4 FIGURES

ADDITIONAL REFERENCES:

- 1. CHAO AND SEADER:
A.I.C.H.E. J. (1961) V.7, 598
2. REDLICH AND KWONG: CHEM. REVS. (1949) V.44, 233.

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.

KEYWORDS:

HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
EQUILIBRIUM RATIOS

CORRELATIONS
BINARY SYSTEMS
EFFECTS OF PRESSURE
DENSITY
OTHER PHYSICAL PROPERTIES

59. MURPHREE, E.V. AND OGORZALY, H.J.: "METHODS OF RECOVERY OF OIL", U.S. PATENT 3,256,933 (JUNE 21, 1966).

ABSTRACT:

----- THIS PATENT RELATES TO THE INJECTION OF LIQUIFIED PETROLEUM GAS OR PROPANE TO RECOVER OIL. THE PROPANE IS MISCIBLE WITH RESERVOIR OIL AND WILL TEND TO BECOME SATURATED WITH OIL AND CARRY IT TO THE PRODUCING WELLS. IT IS STATED THAT IT SHOULD RESULT IN A LIQUID PHASE FOR BEST OIL RECOVERY.

ONE OF THE VARIANTS DESCRIBED HERE IS TO REMOVE THE PROPANE OIL MIXTURE AT OR NEAR ITS FRONT AND RECLAIM THE PROPANE FROM THE OIL FOR REINJECTION AHEAD OF THE DRIVE FLUID FRONT TO PROVIDE A GOOD METHOD FOR EXTENDING THE PROCESS INTO PREVIOUSLY UNDEVELOPED PARTS OF A FIELD.

COMMENTS:

----- THIS IS ONE OF THE BASIC PATENTS FOR THE CO2 OR LPG DRIVE PROCESS.

EXHIBITS:

----- 2 FIGURES

CROSS REFERENCES:

4. STRAIGHT: U.S. PATENT 1,978,655 (OCT. 30, 1934).
S 1. BAYS: U.S. PATENT 2,135,319 (NOV. 1, 1938).

KEYWORDS:

FIELD AREAL SWEEP
OTHER FIELD INFORMATION
ENRICHED AND HIGH PRESSURE GAS

FIELD SECONDARY RECOVERY
FIELD RESIDUAL SATURATIONS
U.S. PATENT
LPG

60. BOSTON, W.G.: "SECONDARY RECOVERY OF OIL BY PARTIALLY MISCIBLE PHASE DISPLACEMENT", U.S. PATENT 3,346,046 (OCT. 10, 1967).

ABSTRACT:

----- THIS PATENT PRESENTS A METHOD FOR INJECTING AN UNDERSATURATED OIL INTO A RESERVOIR WITH A FREE GAS PHASE. THE INJECTED OIL SHOULD BE MISCIBLE WITH THE OIL IN THE FORMATION. THIS LIQUID IS INJECTED IN A QUANTITY SUFFICIENT TO PREVENT FLOW OF INJECTED CARBON DIOXIDE OR ENRICHED GAS THROUGH PASSAGES IN THE FORMATION OCCUPIED BY FREE GAS AT THE START OF INJECTION. BECAUSE THE INJECTED HYDROCARBON LIQUID (WHICH MAY BE CRUDE OIL, LIQUIFIED PETROLEUM GAS, NAPHTHA, OR KEROSENE) IS UNDERSATURATED, IT WILL TAKE INTO SOLUTION FREE GAS, AND HENCE REDUCE OR PREVENT CHANNELING OF INJECTED CO2.

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COMMENTS:

----- IT WOULD APPEAR THAT USE OF A LESS EXPENSIVE LIQUID (I.E., WATER) TO ACHIEVE FILLUP WOULD BE ADVISABLE.

EXHIBITS:

----- 1 TABLE

CROSS REFERENCES:

- 19. RZASA, TERWILLIGER: U.S. PATENT 2,822,872 (FEB. 11, 1958).
33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).
59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)

LABORATORY INJECTION PROCESS
LABORATORY INSTABILITIES
U.S. PATENT

61. BUXTON, T.S. AND CAMPBELL, J.M.: "COMPRESSIBILITY FACTORS FOR LEAN NATURAL GAS-CARBON DIOXIDE MIXTURES AT HIGH PRESSURES", SOC. PET. ENG. J. (MAR., 1967) 80-86.

ABSTRACT:

----- THIS STUDY INDICATES THAT THE PSEUDOCRITICAL CONSTANT CORRELATION OF STEWART, BURKHARDT, AND VOO IS BETTER FOR THE PREDICTION OF THOSE CONSTANTS THAN KAY'S RULE. FOR HYDROCARBON - CARBON DIOXIDE SYSTEMS, A CORRECTION IS REQUIRED, WHICH IS BASED ON PITZER'S ACENTRIC FACTOR.

TO TEST THE PROPOSED CALCULATION TECHNIQUE, COMPRESSIBILITY FACTORS FOR FIVE MIXTURES OF METHANE, CARBON DIOXIDE AND EITHER ETHANE OR PROPANE WERE EXPERIMENTALLY DETERMINED AT 100, 130, AND 160 F FOR PRESSURES UP TO 7000 PSIG. THE PREDICTED AND EXPERIMENTAL COMPRESSIBILITY FACTORS FOR THESE FIVE MIXTURES HAD AN AVERAGE ABSOLUTE DEVIATION OF 0.55%, WITH A MAXIMUM DEVIATION OF -2.27%.

COMMENTS:

- 1. FOR COMPARISON, THE CORRELATION OF CARR, KOBAYASHI, AND BURROWS FOR CORRECTION OF PSEUDOCRITICAL CONSTANTS WAS APPLIED TO THE BROWN, ET AL Z FACTOR CHART; AN AVERAGE ERROR OF ABOUT 6% WAS SEEN.
2. THE ACENTRIC FACTOR CORRECTION REDUCES THE ERROR INCURRED IN USING THE STEWART, BURKHARDT, AND VOO CORRELATION FROM ABOUT 0.92% TO 0.55%.

EXHIBITS:

----- 4 TABLES, 3 FIGURES

KEYWORDS:

THEORETICAL PHYSICAL PROPERTIES
CORRELATIONS
BINARY SYSTEMS
MULTICOMPONENT SYSTEMS
EFFECTS OF PRESSURE

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE

62. DAVIES, G.A., PONTER, A.B. AND CRAINE, K.: "THE DIFFUSION OF CARBON DIOXIDE IN ORGANIC LIQUIDS", CAN. J. CH. ENG. (DEC., 1967) V.45, 372-376.

ABSTRACT:

----- METHODS OF PREDICTING GAS-LIQUID DIFFUSION COEFFICIENTS ARE REVIEWED. A STUDY WAS MADE ON THE DIFFUSION OF CARBON DIOXIDE INTO A RANGE OF ORGANIC LIQUIDS AND HYDROCARBON MIXTURES OVER A SIXTY FOLD RANGE OF SOLVENT VISCOSITY. ALL AVAILABLE MODELS FOR PREDICTING DIFFUSION COEFFICIENTS WERE TESTED. IT WAS FOUND THAT THE DATA PRESENTED ARE BEST FITTED BY ARNOLD'S EQUATION, WHICH ASSUMES ALL COLLISIONS ARE BINARY AND THAT INTERMOLECULAR FORCES ARE NEGLIGIBLE, BUT INCLUDES "ASSOCIATION FACTORS" TO CORRECT FOR DEVIATIONS. THIS AFFORDS A RELIABLE METHOD FOR CORRELATING GAS-LIQUID DIFFUSION DATA.

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COMMENTS:

----- THE IMPLICATIONS OF THIS STUDY ARE THAT THE DIFFUSION COEFFICIENT IS INVERSELY PROPORTIONAL TO THE SQUARE ROOT OF LIQUID VISCOSITY, RATHER THAN THE LIQUID VISCOSITY.

EXHIBITS:

----- 3 TABLES, 5 FIGURES

KEYWORDS:

THEORETICAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS

EXPERIMENTAL PHYSICAL PROPERTIES
DIFFUSION COEFFICIENTS

63. DAVISON, K.: "INERT GAS BOOSTS RECOVERY FROM HEAVY OIL RESERVOIRS", WORLD OIL (MAR., 1967) 98-105.

ABSTRACT:

----- THIS ARTICLE DESCRIBES FIELD TESTS OF FLUE GAS SOAK OPERATIONS. IT WAS FOUND THAT FIVE FOLD INCREASES IN PRODUCTION RATE OCCURRED AFTER INJECTION OF 200 MMCF OF COMBUSTION EXHAUST (87% N₂ AND 13% CO₂) ON A 27 WELL LEASE, THE INCREMENTAL OIL-GAS RATIO WAS 85BBL/MMSCF (12000 SCF/BBL).

LABORATORY AND CORRELATION RESULTS ARE PRESENTED WHICH INDICATE THAT THE VISCOSITY REDUCTION ASSOCIATED WITH CO₂ SOLUTION IN OIL IS ESSENTIALLY SIMILAR TO THAT ACHIEVED WITH HEATING, WITH A ONE DEGREE F INCREASE IN TEMPERATURE CORRESPONDING TO 4 PSI INCREASE IN CO₂ SATURATION PRESSURE. HEAVY OILS RESPONDED BEST TO THE TREATMENT.

COMMENTS:

----- 1. FLUE GAS SOAK OPERATIONS WITH INCREMENTAL INCREASES OF THE MAGNITUDE SHOWN HERE WOULD CERTAINLY BE ECONOMIC TODAY.

2. THE COMPARISON BETWEEN VISCOSITY REDUCTION FROM CO₂ AND HEAT IS A USEFUL RULE OF THUMB BUT IS FOR COMPARING STEAM AND FLUE GAS SOAKS.

EXHIBITS:

----- 4 FIGURES, INCLUDING COMPARISON BETWEEN CO₂ AND HEAT AS A VISCOSITY REDUCTION MECHANISM.

CROSS REFERENCES:

- 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
51. SIMON, GRAUE: TRANS., AIME (1965) 102.

KEYWORDS:

SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FIELD ECONOMICS
OPERATIONS

SOAK OPERATION
FLUE GAS FIELD APPLICATIONS
FACILITIES
OTHER FIELD INFORMATION

64. GILCHRIST, R.E.: "FLUID DRIVE PRODUCTION OF OIL", U.S. PATENT 3,344,857 (OCT. 3, 1967).

ABSTRACT:

----- THIS INVENTION INVOLVES THE INJECTION OF AN AQUEOUS SURFACTANT SLUG IMMEDIATELY BEFORE AND IMMEDIATELY FOLLOWING CARBON DIOXIDE INJECTION. THE BASIC PURPOSE AND CLAIMED RESULT OF THIS INVENTION IS TWOFOLD. FIRST, THE INITIAL AQUEOUS SLUG WILL REDUCE CARBON DIOXIDE SOLUTION IN THE CONNATE WATER, SINCE THE SURFACTANT IS CHOSEN SO AS TO REDUCE SOLUBILITY OF CO₂; MOST SURFACTANTS HAVE THE OPPOSITE EFFECT. SECOND, THE FOLLOW UP AQUEOUS SLUG WILL MORE EFFECTIVELY DRIVE THE CARBON DIOXIDE BY VIRTUE OF LOWER CO₂ LOSS INTO IT.

COMMENTS:

----- 1. NO DISCUSSION OF THE RELATIVE ECONOMICS OF ADDITIONAL CO₂ REQUIRED AGAINST SURFACTANT REQUIREMENT IS MADE.
2. IF REDUCED CO₂ SOLUBILITY IS DESIRED, COULD BRINE BE USED OR MADE TO ACHIEVE THE SAME RESULT?

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

46. WEST, URTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).

KEYWORDS:

OTHER LABORATORY STUDIES

ADDITIVES (LAB. EXP.)
U.S. PATENT

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65. LENOIR, J.M.: "HOW CARBON DIOXIDE AFFECTS KS", HYDROCARBON PROCESSING (JAN., 1967) V.46, NO.1, 191-196.

ABSTRACT:

----- WHEN CARBON DIOXIDE FORMS A MIXTURE WITH A SYSTEM OF HYDROCARBONS, THE EQUILIBRIUM RATIO FOR EACH COMPONENT IN THE MIXTURE CHANGES FROM THE IDEAL VALUE. THIS WORK IS A GRAPHICAL CORRELATION OF VARIOUS MIXTURE PARAMETERS TO EVALUATE EQUILIBRIUM RATIOS.

THE EVALUATION OF CARBON DIOXIDE EQUILIBRIUM RATIOS IS OBTAINED BY CORRECTING PUBLISHED VALUES; THE CORRECTION FACTOR VARIES WITH TEMPERATURE, CARBON DIOXIDE CONCENTRATION, AND THE HYDROCARBON LIQUID COMPOSITION. IT IS DETERMINED THROUGH USE OF AN INTERMEDIATE CORRECTION FACTOR AND A VOLATILITY ADJUSTMENT TERM.

FOR ADJUSTING HYDROCARBON EQUILIBRIUM RATIOS, A TOTAL OF 177 DATA POINTS WERE COMPUTED WITH THE CORRELATION WITH A MEAN ERROR OF 4.77%. NO CORRECTION IS REQUIRED UP TO 125 F. FOR HYDROCARBON EQUILIBRIUM RATIOS, CORRECTIONS ARE REQUIRED UP TO 250 F; 217 DATA POINTS HAD A MEAN ERROR OF 4.5%.
2. A SOUND THEORETICAL BASIS FOR THIS PAPER IS REQUIRED TO MORE ACCURATELY EVALUATE WHAT CAUSES VARIOUS TEMPERATURE AND COMPOSITIONAL EFFECTS BEFORE IT CAN BE PROPERLY APPLIED TO THE MULTI-COMPONENT SYSTEM OF RESERVOIR OIL.

COMMENTS:

----- 1. THIS PAPER COULD BE OF GOOD USE IN DESIGNING SEPARATION FACILITIES.

2. A SOUND THEORETICAL BASIS FOR THE METHOD OF THIS PAPER IS REQUIRED BEFORE IT CAN BE PROPERLY APPLIED TO MULTICOMPONENT SYSTEMS.

EXHIBITS:

----- 4 TABLES, 10 FIGURES

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.

KEYWORDS:

CORRELATIONS
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE

BINARY SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

66. MCFARLANE, R.C., MUELLER, T.D. AND MILLER, F.G.:
"UNSTEADY-STATE DISTRIBUTIONS OF FLUID COMPOSITIONS
IN TWO-PHASE OIL RESERVOIRS UNDERGOING GAS INJECTION",
SOC. PET. ENG. J. (MAR., 1967) 61-74.

ABSTRACT:

----- IT HAS BEEN OBSERVED IN GAS STORAGE PROJECTS
IN DEPLETED OIL RESERVOIRS THAT ADDITIONAL OIL MAY BE RECOVERED
AND THAT THE COMPOSITION OF THE STORAGE GAS MAY BE ALTERED.
THE MODELLING OF THIS PROBLEM INCLUDES FINITE DIFFERENCE
EVALUATION OF TWO-PHASE FLOW WITH COMPOSITIONAL VARIATION.

AN EXAMPLE CALCULATION PRESENTS SIMULATED RESULTS FOR A
FIELD IN TEXAS, WHICH HAD SECONDARY OIL RECOVERY IN LIQUIDS AND
VAPORIZED PRODUCTS AS A RESULT OF GAS CYCLING AND STORAGE. IT
WAS FOUND THAT FOR PROPER EVALUATION OF THE RESERVOIR,
COMPOSITIONAL SIMULATION WAS REQUIRED.

COMMENTS:

- 1. THIS PAPER CONTAINS EXCELLENT EXAMPLES WHERE
COMPOSITIONAL SIMULATION IS REQUIRED.
2. IT SHOULD BE NOTED THAT PRESSURES COMPARED WELL BETWEEN
ANALYTIC AND NUMERICAL TECHNIQUES. (FIGURE 7)
3. IT SHOULD ALSO BE NOTED THAT THE OIL RECOVERY PREDICTED
BY SIMULATION EXCEEDED THAT OBTAINED IN THE PHYSICAL MODEL
STUDY, WHICH WAS SLIGHTLY HIGHER THAN ACTUAL HELD RECOVERY.
IT IS SUGGESTED THAT THIS RESULTS FROM THE SIMULATION BEING
LINEAR RATHER THAN RADIAL.

EXHIBITS:

----- 15 FIGURES

KEYWORDS:

FINITE DIFFERENCE MODELS
COMPARISONS WITH LAB. RESULTS
OTHER MODELLING

ANALYTICAL MODELLING
COMPOSITIONAL MODELS
COMPARISONS WITH FIELD RESULTS
MISCELLANEOUS DATA

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67. MULDER, F.R.: "FORMATION FLOODING BY SULPHUR DIOXIDE FOR RECOVERING OIL AND GAS", U.S. PATENT 3,353,597 (NOV. 21, 1967).

ABSTRACT:

----- THE BASIC CONCEPT OF THIS PATENT INVOLVES THE USE OF LIQUID SULPHUR DIOXIDE AS A SLUG OR AN ADDITIVE TO ALCOHOL OR OTHER SLUG OR WATER; THE SULPHUR DIOXIDE INCREASES OIL RECOVERY OVER WATERFLOODING.

SEVERAL DIFFERENT PROCESSES ARE POSTULATED TO BE OCCURRING IN SULPHUR DIOXIDE FLOODING. FIRST, THE PERMEABILITY OF THE ROCK IS INCREASED, APPARENTLY FROM REACTION OF THE SULPHUR DIOXIDE WITH THE ROCK. SECONDLY, THE SULPHUR DIOXIDE IS MISCIBLE WITH OIL AND HAS A HIGH SOLUBILITY IN WATER, SO THAT A MISCIBLE DISPLACEMENT MAY BE ACHIEVED. THIRDLY, REACTION OF SULPHUR DIOXIDE WITH LIMESTONE OR DOLOMITE PRODUCES CARBON DIOXIDE; ALSO, MAGNESIUM BISULFITE IS PRODUCED AS A REACTION PRODUCT WITH DOLOMITE AND MAY (BY WETTABILITY) RELEASE OIL FROM PORE WALLS.

COMMENTS:

----- 1. THE AMOUNT OF SULPHUR DIOXIDE REQUIRED TO SUBSTANTIALLY ENHANCE OIL RECOVERY CAN BE AS SMALL AS ONE-TENTH OF ONE PERCENT OF A PORE VOLUME.

2. THE PROCESS WAS SUCCESSFUL IN THE LABORATORY EVEN FOR LLOYDMINSTER (2700 CP) OIL.

3. USE OF SULPHUR DIOXIDE AS A BUFFER OR ADDITIVE FOR CARBON DIOXIDE FLOODING MIGHT BE A PLAUSIBLE EXTENSION OF THIS PATENT.

EXHIBITS:

----- 10 FIGURES

ADDITIONAL REFERENCES:

----- MUSKAT: PRINCIPLES OF OIL PRODUCTION (1949) 703.

CROSS REFERENCES:

33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).

53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
WETTABILITY (LAB. EXP.)
HEAVY OIL (LAB. EXP.)
U.S. PATENT

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
CARBONATE (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
OTHER LABORATORY STUDIES
ALTERNATE TECHNOLOGIES

68. SANTOURIAN, M.: "TRANSITION ZONE FORMATION IN OIL PRODUCTION",
U.S. PATENT 3,295,601 (JAN. 3, 1967).

ABSTRACT:

----- THIS INVENTION RELATES TO A METHOD FOR
ESTABLISHING A TRANSITION ZONE DOWNHOLE AROUND AN INJECTION
WELL IN A MISCIBLE FLUID DRIVE. THE TRANSITION ZONE IS
DESIRED SO AS TO REDUCE OR PREVENT VISCOUS FINGERING.

THE METHOD INVOLVES "HUFF-AND-PUFF" INJECTION OF CO₂ AND
HYDROCARBON GASES OR OTHER GASES. ALL PRODUCTION ON THE "PUFF"
PART OF THE CYCLE IS REINJECTED, AND THEN FOLLOWED BY ADDITIONAL
CO₂ INJECTION. AFTER SEVERAL CYCLES, A TRANSITION ZONE OF OIL
WITH GAS IN SOLUTION IS BUILT UP. THE TRANSITION ZONE HAS A
GRADUALLY VARYING VISCOSITY AND DENSITY FROM CO₂ TO ORIGINAL
OIL.

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THE INVENTION SUGGESTS THAT THE SIZE OF THE TRANSITION
ZONE WILL BE BETWEEN 0.01 AND ONE PORE VOLUME, AND THAT PRESSURES
DURING THE HUFF-AND-PUFF SHOULD BE BETWEEN 500 AND 4000 PSIG.

COMMENTS:

- 1. NO RATIONALE IS PRESENTED FOR OPTIMIZING
THE SIZE OF THE TRANSITION ZONE.
2. NO LABORATORY OR FIELD RESULTS ARE PRESENTED IN THIS
PATENT.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)

KEYWORDS:

SOAK OPERATION
FIELD MOBILITY RATIO
U.S. PATENT

FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
ENRICHED AND HIGH PRESSURE GAS

69. THOMPSON, J.L.: "A LABORATORY STUDY OF AN IMPROVED WATER-DRIVEN LPG SLUG PROCESS", SOC. PET. ENG. J. (SEP., 1967) 319-324.

ABSTRACT:

----- THIS PAPER DESCRIBES A METHOD WHEREBY AN LPG SLUG IS INJECTED, FOLLOWED BY A CARBON DIOXIDE SLUG, AND FINALLY BY WATER. IT WAS FOUND THAT CARBON DIOXIDE DISPLACEMENT OF LPG IS ESSENTIALLY PERFECT ABOVE MISCIBILITY PRESSURES IN THE LABORATORY, BUT THAT DISPLACEMENT EFFICIENCY DECREASES LINEARLY BELOW THE MISCIBILITY PRESSURE.

A DISPLACEMENT TEST WAS CONDUCTED IN A LINEAR HOMOGENEOUS SYSTEM WITH LPG AND CO2 SLUGS LARGE ENOUGH TO AVOID INTERFERENCE BETWEEN BANKS. IT WAS FOUND THAT A SIGNIFICANT PORTION OF THE CO2 WAS RECOVERED THROUGH PRODUCTION IN SOLUTION IN THE WATER.

COMMENTS:

- 1. A LEADING LPG SLUG HELPS TO REDUCE CHANNELING BY CO2.
2. A FOLLOW UP CO2 SLUG IN LPG FLOODING ALLOWS RECOVERY OF ESSENTIALLY ALL LPG ABOVE CO2-LPG MISCIBILITY PRESSURE.
3. THE RESIDUAL CARBON DIOXIDE LEFT AT WATER BREAKTHROUGH IS PRODUCED FROM SOLUTION IN THE WATER.

EXHIBITS:

----- 7 FIGURES CONTAINING EXPERIMENTAL RESULTS.

ADDITIONAL REFERENCES:

----- FRANCIS: J.PH.CH. (1954) V.58, 1099.

CROSS REFERENCES:

- 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES
LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
LABORATORY INSTABILITIES
MISCIBILITY (LAB. EXP.)
LPG

70. THURBER, S.S. AND PIRSON, S.J.: "THE EFFECT OF DIFFERENTIAL DEPLETION ON RECOVERY BY SOLUTION - GAS DRIVE", PAPER 1887, SPE-AIME 42ND ANN. FALL MTG., HOUSTON, TX. (OCT., 1967),

ABSTRACT:

----- DIFFERENTIAL DEPLETION IS THE TERM APPLIED TO THAT PHENOMENON IN SOLUTION-GAS DRIVE RESERVOIRS IN WHICH LARGE PRESSURE AND SATURATION GRADIENTS DEVELOP AS A RESULT OF HIGH PRODUCTION RATES, HIGH OIL VISCOSITIES, OR LOW FORMATION PERMEABILITIES.

THE RESULTS OF THIS STUDY INDICATE THAT THE EFFECT OF DIFFERENTIAL DEPLETION ON RECOVERY IS TO INCREASE INITIAL GAS-OIL RATIOS AND AFFECT THE TIME AT WHICH AN ABANDONMENT RATE IS REACHED, WHILE THE ULTIMATE RECOVERY OF OIL AND GAS IS FAIRLY INSENSITIVE TO DIFFERENTIAL DEPLETION.

COMMENTS:

----- 1. THE METHOD OF SIMULATION PRESENTED HERE MAY BE APPLICABLE TO MODELLING OF THE BLOW-DOWN CYCLE AFTER CO₂ INJECTION.

2. THIS STUDY INDICATES THAT ULTIMATE RECOVERY FROM BLOW-DOWN MAY BE CALCULATED WITHIN ENGINEERING ACCURACY USING SIMPLE, STEADY-STATE METHODS.

3. THE RESULTS OF THIS STUDY INDICATE THAT, FOR HIGH PRODUCING RATES, A MORE NEARLY CONSTANT PRODUCING GAS-OIL RATIO IS OBTAINED THAN FOR DECLINING OR LOW PRODUCING RATES. THIS FACTOR COULD INFLUENCE FACILITIES DESIGN.

EXHIBITS:

----- 9 TABLES, 38 FIGURES

ADDITIONAL REFERENCES:

- 1. WEST, GARVIN, AND SHELDON:
TRANS., AIME (1954) V.201, 217-229.
2. LEVINE AND PRATS: TRANS., AIME (1961) V.222, 11-142-152.

KEYWORDS:

FINITE DIFFERENCE MODELS

OTHER MODELLING

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71. BRIGHAM, W.E. AND DEW, J.N.: "TERTIARY OIL RECOVERY METHOD",
U.S. PATENT 3,410,341 (NOV. 12, 1968).

ABSTRACT:

----- THIS PATENT DESCRIBES A METHOD FOR MISCIBLE
FLOODING AFTER WATERFLOODING. THE BASIC RATIONALE FOR THE
PATENT IS THAT THE RESIDUAL OIL AFTER WATERFLOODING WILL NOT
BE CONTACTED BY THE INJECTED MISCIBLE FLUID, WHICH WILL SIMPLY
DISPLACE WATER.

IN ORDER TO ACCOMPLISH MISCIBLE FLOODING, THE PATENT INVOLVES
INJECTING A SUBSTANCE SOMEWHAT SOLUBLE IN WATER, BUT MORE SOLUBLE
IN THE RESIDUAL OIL, FOLLOWED BY A SECOND MATERIAL MISCIBLE WITH
THE FIRST SUBSTANCE AND THE RESERVOIR OIL, AND THEN INJECTING A
THIRD MATERIAL SOLUBLE IN THE SECOND MATERIAL AS A DRIVE FLUID.
THE RECOMMENDED SLUG SIZES ARE 0.0005 TO 0.02 PORE VOLUMES FOR THE
FIRST MATERIAL, AND 0.05 TO 0.2 PORE VOLUMES FOR THE SECOND
MATERIAL.

COMMENTS:

----- THIS INVENTION COULD PROVE USEFUL WHERE CONTACTING
THE RESIDUAL OIL IS A PROBLEM.

EXHIBITS:

----- 5 FIGURES

CROSS REFERENCES:

- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
MISCIBILITY (LAB. EXP.)

TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
U.S. PATENT

72. FERRELL, H.H. AND MATHEWS, R.R.: "IN SITU PREPARATION OF SURFACE ACTIVE AGENTS IN SUBTERRANEAN FORMATIONS", U.S. PATENT 3,392,782 (JULY 16, 1968).

ABSTRACT:

----- THIS INVENTION INVOLVES CREATION OF A SURFACTANT IN-SITU TO AID OIL RECOVERY IN SECONDARY RECOVERY PROCESSES. THE METHOD INVOLVES INJECTION OF A SLUG OF ANHYDROUS AMMONIA, FOLLOWED BY AN AROMATIC HYDROCARBON SLUG, THEN A SULFORATING AGENT, AND FINALLY A DRIVE FLUID, WHICH MAY BE CO₂ CONTAINING TWO TO FIVE PERCENT AMMONIA.

THE (OPTIONAL) FIRST SLUG DISPLACES CONNATE WATER, SO THAT THE SECOND AND THIRD SLUGS MAY MORE EFFECTIVELY COMBINE TO FORM A SURFACTANT. THE PURPOSE OF AMMONIA IN THE CO₂ DRIVE FLUID IS TO NEUTRALIZE SULFONIC ACID FORMED.

NUMEROUS MATERIALS FOR THE INITIAL SLUG, THE AROMATIC SLUG, THE SULFORATING AGENT, AND THE DRIVE FLUID ARE SPECIFIED IN THE PATENT.

COMMENTS:

- 1. AN EXAMINATION OF THE RELATIVE ECONOMICS OF THIS METHOD AGAINST OTHER METHODS WOULD BE ENLIGHTENING.
2. AN EVALUATION AND DETERMINATION OF THE METHOD WHEREBY A SURFACTANT ASSISTS OIL RECOVERY WITH (MISCIBLE OR NON-MISCIBLE) CO₂ FLOODING MIGHT BE USEFUL.

EXHIBITS:

----- 1 TABLE

CROSS REFERENCES:

S 13. PRATS, CLOSMAN: U.S. PAT. 3,259,187 (JULY 5, 1966).

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
ADDITIVES (LAB. EXP.)
U.S. PATENT

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
OTHER LABORATORY STUDIES
ALTERNATE TECHNOLOGIES

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73. HOLM, L.W. AND WOERTZ, B.B.: "PETROLEUM RECOVERY METHOD",
U.S. PATENT 3,411,583 (NOV. 19, 1968).

ABSTRACT:

----- THIS PATENT INVOLVES A VARIANT OF THE CARBON
DIOXIDE "HUFF-AND-PUFF" PROCESS WHEREIN A SPARINGLY OIL-SOLUBLE
GAS IS INJECTED AFTER THE CO₂ SLUG.

THE BASIC PURPOSE OF THE PATENT IS TO RECOVER OIL BY THE
CO₂ PROCESS AS A RESULT OF THE VISCOSITY REDUCTION OF THE OIL
WHEN CONTACTED WITH CO₂. THE FOLLOWUP SLUG OF GAS (NITROGEN
OR AIR) CHANNELS THROUGH THE CO₂ SATURATED OIL AND PROVIDES
PRESSURE SUPPORT DURING THE BACKFLOW STAGE OF THE CYCLE. THE
METHOD IS PARTICULARLY APPLICABLE TO RECOVERY OF HEAVY, VISCOUS
CRUDES.

COMMENTS:

----- THIS PATENT PROVIDES A SUCCINCT PICTURE OF THE
CARBON DIOXIDE SOAK MECHANISM.

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
19. RZASA, TERWILLIGER: U.S. PATENT 2,822,872 (FEB. 11, 1958).
23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
59. MURPHREE, UGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).

KEYWORDS:

FIELD MISCIBLE APPLICATION
FIELD MOBILITY RATIO

SOAK OPERATION
FIELD IMMISCIBLE APPLICATION
U.S. PATENT

74. SHARP, L.G.: "METHOD OF RECOVERING OIL BY IN-SITU PRODUCED CARBON DIOXIDE", CAN. PATENT 785,071 (MAY 14, 1968).

ABSTRACT:

----- THIS PATENT INVOLVES INJECTING AN "OXIDIZING FLUID" CONTAINING AT LEAST 66% BY VOLUME OF OXYGEN TO PRODUCE A GASEOUS PHASE MISCIBLE WITH RESERVOIR OIL, AND THEN DRIVING THE RESERVOIR OIL AND GASEOUS PHASE TO A PRODUCTION WELL. THE GASEOUS PHASE WILL BE MAINLY CARBON DIOXIDE.

A SECOND PART OF THE PATENT DESCRIBES A COMBUSTION SOAK OPERATION, WHEREIN AIR IS INJECTED FIRST AND THE WELL IS THEN HEATED TO START COMBUSTION. AFTER THE COMBUSTION HAS PROCEEDED THROUGH ABOUT 10% OF A PORE VOLUME, THE WELL IS BACKFLOWED UNTIL TRACE QUANTITIES OF OIL ARE RECOVERED. THEN, THE "OXIDIZING FLUID" IS INJECTED AND COMBUSTION REINITIATED TO GENERATE THE GASEOUS PHASE (CO₂). COMBUSTION IS THEN HALTED AND THE OIL AND CARBON DIOXIDE ARE DRIVEN TO THE PRODUCING WELL.

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COMMENTS:

----- THE BASIC THRUST OF THIS PATENT IS THAT THE CARBON DIOXIDE GENERATED BY COMBUSTION OR LOW TEMPERATURE OXIDATION OF CRUDE OIL IS IMPORTANT TO OIL RECOVERY.

CROSS REFERENCES:

50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).

KEYWORDS:

OTHER LABORATORY STUDIES
FIELD SECONDARY RECOVERY
CO₂ SOURCE

LABORATORY INJECTION PROCESS
SOAK OPERATION
CANADIAN PATENT
ALTERNATE TECHNOLOGIES

75. ANON.: "SACROC PROPOSES CO2 FLOOD FOR HUGE KELLY-SNYDER FIELD",
OIL & GAS J. (SEP. 8, 1969) 36.

ABSTRACT:

----- THIS ARTICLE DISCUSSES A PROPOSAL BY STANDARD OIL
CO. OF TEXAS, A DIVISION OF CHEVRON, TO INITIATE A CO2 DRIVE
AT SACROC. THE CO2 WOULD BE PIPED 200 MILES FROM GAS WELLS
IN WEST TEXAS, WHERE IT HAD BEEN VENTED.

KEYWORDS:

CARBONATE FIELD
OTHER FIELD INFORMATION

FIELD TERTIARY RECOVERY
TRANSPORTATION

76. BEER, H.: "COMPRESSIBILITY FACTORS FOR THE ARGON - CARBON DIOXIDE SYSTEM", CAN. J. CH. ENG. (FEB., 1969) V.47, 92-94.

ABSTRACT:

----- REDLICH AND KWONG'S EQUATION OF STATE FOR COMPRESSIBLE GASES WAS USED TO COMPUTE COMPRESSIBILITY FACTORS FOR BINARY GAS MIXTURES. DATA FOR METHANE-CARBON DIOXIDE AND ARGON-CARBON DIOXIDE UP TO PRESSURES OF 200 ATM (3000 PSI) AND TEMPERATURES UP TO 450 K (350 F) IN THE WHOLE RANGE OF COMPOSITION WERE OBTAINED. THE MEAN DEVIATION BETWEEN EXPERIMENTAL AND CALCULATED VALUES OF THE COMPRESSIBILITY FACTOR WAS 2.2%.

IT WAS FOUND THAT A GOOD METHOD FOR DETERMINING THE CONSTANTS FOR THE REDLICH-KWONG EQUATION OF STATE WAS TO COMPUTE 'B' USING A LINEAR WEIGHTING AND TO COMPUTE 'A' USING A SQUARE ROOT WEIGHTING. MAXIMUM ERRORS WERE FOUND AT LOW TEMPERATURES (70 F), HIGH PRESSURES, AND HIGH CONCENTRATIONS OF CO₂ (80% OR MORE).

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COMMENTS:

----- THE MAIN RESULT OF THIS STUDY IS THAT THE REDLICH-KWONG EQUATION OF STATE PROVIDES A METHOD FOR COMPUTING COMPRESSIBILITY FACTORS WHICH IS SUITABLE FOR MOST ENGINEERING PURPOSES.

EXHIBITS:

----- 1 TABLE, 3 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
EQUATIONS OF STATE

THEORETICAL PHYSICAL PROPERTIES
CORRELATIONS
LAB. PROCEDURES AND APPARATUS

77. GILLILAND, H.E.: "IN SITU RETORTING OF OIL SHALE USING CO2 AS HEAT CARRIER", U.S. PATENT 3,480,082 (NOV. 25, 1969).

ABSTRACT:

----- THIS INVENTION UTILIZES CARBON DIOXIDE AS A HEAT CARRIER FOR SURFACE OR IN SITU RETORTING OF OIL SHALE. MANY DEPOSITS OF OIL SHALE ARE FOUND ASSOCIATED WITH CARBONATE MINERALS SUCH AS NAHCOLITE, DAWSONITE, CALCITE, DOLOMITE, TRONA, WEGSCHEIDERITE, ETC. THE CLAIM IS MADE THAT HEATING OF THE SHALE IN A CO2 ATMOSPHERE REDUCES THE DECOMPOSITION OF THESE CARBONATE MINERALS AND HENCE REDUCES THE AMOUNT OF DUST FORMED. THE DUST FORMED, ESPECIALLY IN SURFACE RETORTING OPERATIONS, CREATES OPERATING PROBLEMS AND AIR POLLUTION, SO THAT MITIGATION OF THIS EFFECT COULD BE IMPORTANT.

CARBON DIOXIDE HAS A HIGH HEAT CAPACITY AND SHOULD PROVE SUITABLE FOR HEATING THE OIL SHALE TO THE HIGH TEMPERATURES (1000 TO 1500+ F) NECESSARY TO GASIFY OR LIQUEFY THE HYDROCARBONS CONTAINED IN OIL SHALE. A MINIMUM CO2 PRESSURE OF 500 PSIG IS REQUIRED.

COMMENTS:

----- THIS PATENT COULD PROVE USEFUL IN OIL SHALE DEVELOPMENT, ESPECIALLY WHERE BOTH SURFACE AND IN SITU RETORTING ARE BEING DONE IN A SINGLE LOCALE. IN SUCH INSTANCE, THE EXCESS CO2 PRODUCED BY IN SITU RETORTING COULD PERHAPS BE USED FOR SURFACE RETORTING.

EXHIBITS:

----- 2 FIGURES

KEYWORDS:

OTHER FIELD INFORMATION
ALTERNATE TECHNOLOGIES

U.S. PATENT
MISCELLANEOUS DATA

78. GUPTA, V.S.: "MEASUREMENT AND PREDICTION OF PHASE EQUILIBRIA IN LIQUID CARBON DIOXIDE - HYDROCARBON TERNARY SYSTEMS", PH.D. DISSERTATION, PA. STATE U. (1969).

ABSTRACT:

----- EQUILIBRIUM VAPOR-LIQUID COMPOSITIONS WERE MEASURED ON THREE TERNARY CO₂ NORMAL HYDROCARBON SYSTEMS (CO₂ - HEXANE - HEXADECANE, CO₂ - DECANE - HEXADECANE, CO₂ - DODECANE - HEXADECANE) AT 80 F, 990 PSIA AND 1185 PSIA. GENERALLY, THREE DIFFERENT OVERALL MIXTURE COMPOSITIONS WERE MEASURED AT EACH TEMPERATURE AND PRESSURE. SOME OF THE DATA WERE USED TO DETERMINE EMPIRICAL PARAMETERS IN TWO EQUATIONS (MARGULES AND VAN LAAR) FOR ACTIVITY COEFFICIENTS AND IN THE BENEDICT-WEBB-RUBIN EQUATION OF STATE. ALL THREE EQUATIONS WERE USED TO CALCULATE PHASE EQUILIBRIUM BEHAVIOR, WITH ONLY MODERATE SUCCESS. THE BIBLIOGRAPHY CONTAINS 50 REFERENCES, INCLUDING SEVERAL ON PHASE BEHAVIOR OF CO₂ MIXTURES WITH SIMPLE HYDROCARBONS.

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COMMENTS:

----- GOOD REVIEW OF SOME ASPECTS OF THEORY OF LIQUID MIXTURES; DATA USEFUL FOR BASIC ILLUSTRATION OF PHASE BEHAVIOR OF CO₂ - HYDROCARBON MIXTURES AND FOR CHECKING OTHER CALCULATION METHODS. NOT DIRECTLY APPLICABLE TO RESERVOIR ANALYSIS FOR CO₂ FLOODING.

EXHIBITS:

----- 1 TABLE, 19 FIGURES

CROSS REFERENCES:

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- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
 - 9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
 - 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
 - 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
 - 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE

THEORETICAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

79. HOLM, L.W.: "SECONDARY RECOVERY PROCESS FOR LOW PRESSURE OIL-BEARING RESERVOIRS", CAN. PATENT 825,475 (OCT. 21, 1969).

ABSTRACT:

----- THIS PATENT INVOLVES PRODUCING OIL FROM A LOW PRESSURE RESERVOIR BY INJECTING AN OIL-MISCIBLE SOLVENT IN AMOUNTS SUFFICIENT TO RAISE THE RESERVOIR PRESSURE TO AT LEAST 700 PSI. A SLUG OF CARBON DIOXIDE IS THEN INJECTED FOLLOWED BY AN AQUEOUS DRIVE FLUID, ALL THE WHILE MAINTAINING THE RESERVOIR AT A PRESSURE OF AT LEAST 700 PSI.

COMMENTS:

----- IT IS NOT CLEAR FROM THE PATENT OFFICE RECORD EXACTLY WHY THIS IS CONSIDERED AN INVENTION.

KEYWORDS:

FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION

WATER INJECTION
FIELD TERTIARY RECOVERY
CANADIAN PATENT

80. JENSEN, R.H.: "HETERGENEDUS PHASE BEHAVIOR OF SOLID CARBON DIOXIDE IN LIGHT HYDROCARBONS AT CRYOGENIC TEMPERATURES", PH.D. DISSERTATION, U. KS., LAWRENCE, KS. (1969).

ABSTRACT:

----- SOLUBILITIES OF SOLID CO₂ IN LIQUID ETHANE, PROPANE AND N-BUTANE WERE MEASURED FROM THE TRIPLE POINT OF THE HYDROCARBON (OR THE MIXTURE EUTECTIC, IN SOME CASES) TO THE TRIPLE POINT OF CO₂. COMPOSITION RANGE STUDIED WAS 8 TO 100 MOLE % CO₂. LIQUID-VAPOR COMPOSITION WERE ALSO DETERMINED FOR EACH OF 10 TERNARY MIXTURES OF CO₂-CH₄-C₂H₆ IN SOLID-LIQUID-VAPOR EQUILIBRIUM, AND THE DATA WERE USED TO CONSTRUCT TERNARY PHASE DIAGRAM. VAPOR PRESSURES OF SATURATED SOLUTIONS OF CO₂ IN LIQUID C₂H₆, C₃H₈, AND N-C₄H₁₀ WERE MEASURED FROM 0.01 ATM TO THE CO₂ TRIPLE POINT. A TABLE GIVES LITERATURE DATA SOURCES FOR CO₂ SOLUBILITY AND VAPOR PRESSURE DATA FOR 21 BINARY AND TERNARY SYSTEMS; ALL THESE DATA ARE FOR TEMPERATURES BELOW 216 K (THE CO₂ TRIPLE POINT) AS ARE THE SYSTEMS STUDIED IN THIS THESIS. THE DATA WERE USED TO DETERMINE CONSTANTS IN EMPIRICAL EQUATIONS FOR SOLUBILITY AND VAPOR PRESSURES, AND TO CALCULATE HEATS OF MIXING. THE BIBLIOGRAPHY CONTAINS 45 REFERENCES, PRINCIPALLY TO CRYOGENIC SYSTEMS AND TO BASIC REFERENCES ON MIXTURES AND THEIR PROPERTIES.

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COMMENTS:

----- NOT DIRECTLY APPLICABLE TO RESERVOIR PROBLEMS IN CO₂ MISCIBLE FLOODING - POSSIBLY OF INTEREST FOR SEPARATION AND RECYCLING CO₂. ALSO IS USEFUL DATA FOR CHECKING PHASE BEHAVIOR CALCULATIONS FROM MULTICOMPONENT EQUATION OF STATE.

EXHIBITS:

----- 28 TABLES, 41 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
BINARY SYSTEMS
EFFECTS OF PRESSURE
SOLUBILITY

THEORETICAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE
EQUILIBRIUM RATIOS

81. KEITH, P.C.: "COMBINATION METHODS INVOLVING THE MAKING OF GASEOUS CARBON DIOXIDE AND ITS USE IN CRUDE OIL RECOVERY", U.S. PATENT 3,442,332 (MAY 6, 1969).

ABSTRACT:

----- TWO BASIC TOPICS ARE COVERED BY THIS INVENTION - THE USE OF CARBON DIOXIDE IN CONJUNCTION WITH STEAM AS A RECOVERY PROCESS, AND THE SOURCE OF CARBON DIOXIDE AS A RECOVERY AGENT.

THREE BASIC ADVANTAGES ARE INVOLVED IN INJECTING CARBON DIOXIDE AND STEAM. FIRST, THE CO₂ PASSES THROUGH THE OIL AND CREATES A CHANNEL FOR HEAT TO CONTACT CRUDE OIL. SECONDLY, THE CO₂ HELPS REDUCE VISCOSITY. THIRD, BY BUBBLING CO₂ THROUGH HOT BRACKISH WATER, STEAM BECOMES SATURATED WITH CO₂ FOR INJECTING WITHOUT HAVING TO TREAT THE GENERATOR FEEDWATER. THE PROCESS IS APPLICABLE FOR BOTH SOAK AND DRIVE OPERATIONS, AND IS SAID TO WORK BEST AT A RATIO OF ABOUT 900 LB (8MCF) OF CO₂ PER COLD WATER EQUIVALENT BARREL OF STEAM.

THE SOURCES FOR CARBON DIOXIDE SUGGESTED INCLUDE AMMONIA PLANTS AND THE CO₂ PRODUCED IN PROCESSING A HYDROCARBON FEED.

COMMENTS:

----- 1. THIS IS ONE OF THE EARLIER PAPERS TO SUGGEST THE USE OF WASTE CO₂ FROM AMMONIA OR PROCESSING PLANTS AS AN OIL RECOVERY AGENT.

2. SOLUBILITY OF CARBON DIOXIDE IS REDUCED AT ELEVATED TEMPERATURES AND LOW PRESSURES WHICH IS THE OPTIMUM ENVIRONMENT FOR STEAM DRIVES. THE FEEDWATER AND STEAM IS RENDERED CORROSIVE BY THE TREATMENT WITH CARBON DIOXIDE; THUS, THE PATENT IS OF QUESTIONABLE VALUE.

EXHIBITS:

----- 4 FIGURES

CROSS REFERENCES:

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- 3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
 - 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
 - 18. HAVERFIELD: U.S. PATENT 2,729,291 (JAN. 3, 1956).
 - 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
 - 22. HOLM: TRANS., AIME (1959) 225.
 - 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
 - 43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
 - 45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
 - 49. LEWIS: U.S. PATENT 3,193,006 (JULY 6, 1965).

KEYWORDS:

FIELD SECONDARY RECOVERY
ADDITIVES (FIELD)
U.S. PATENT
SEPARATION

SOAK OPERATION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION
CO₂ SOURCE
ALTERNATE TECHNOLOGIES

82. VAIROGS, J.: "EFFECT OF CO₂ ON THE PHASE BEHAVIOR OF NORMAL PARAFFINS", PH.D. DISSERTATION, OK. STATE U., STILLWATER, OK, (1969).

ABSTRACT:

----- VAPOR-LIQUID EQUILIBRIUM RATIOS (K-VALUES) ON TWO ISOTHERMS (150 AND 200 F) WERE DETERMINED FROM 100 PSIA TO THE SINGLE PHASE PRESSURES FOR A MIXTURE OF N-PARAFFINS (C₁, C₂, C₃, C₅, C₆, C₁₀). THESE MEASUREMENTS WERE REPEATED WITH A "LOW" AND "HIGH" CONCENTRATION OF CO₂ ADDED TO THE HYDROCARBON MIXTURE AND A CORRELATION WAS DEVELOPED FOR THE K-VALUES. ADDITION OF CO₂ GENERALLY DECREASED HYDROCARBON K-VALUES, EXCEPT FOR DECANE. THE AVERAGE RATIOS OF HYDROCARBON K VALUES WITH CO₂ TO THOSE, WITHOUT CO₂ ARE APPROXIMATELY 0.8 AT 150 F AND 0.6 AT 250 F, WITH A SMALL DEPENDENCE ON CO₂ CONCENTRATION AT EACH TEMPERATURE. BIBLIOGRAPHY CONTAINS 81 REFERENCES.

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COMMENTS:

----- BASIC DATA FOR CO₂ HYDROCARBON SYSTEMS, USEFUL FOR CHECKING CALCULATION METHODS, NOT DIRECTLY APPLICABLE TO RESERVOIR ANALYSIS OR PREDICTION OF CO₂ FLOOD PERFORMANCE.

EXHIBITS:

----- 22 TABLES, 28 FIGURES

CROSS REFERENCES:

5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
8. POETTMANN: TRANS., AIME (1951) 141.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.

KEYWORDS:

THEORETICAL PHYSICAL PROPERTIES
CORRELATIONS
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
EFFECTS OF TEMPERATURE

EXPERIMENTAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

83. HOLM, L.W. AND O'BRIEN, L.J.: "CARBON DIOXIDE TEST FLOOD AT THE MEAD-STRAWN FIELD", PAPER 3103, SPE-AIME 45TH ANN. FALL MTG., HOUSTON, TX. (OCT., 1970).

ABSTRACT:

----- THIS PAPER PRESENTS RESULTS OF A CO₂ TEST FLOOD IN THE UPPER STRAWN SAND OF THE MEAD FIELD, JONES, CO., TEXAS. THESE RESULTS INCLUDE INJECTION DATA, PRODUCTION HISTORIES AND PROJECTIONS AND CORE ANALYSIS DATA. A PRESSURE CORE BARREL WAS USED TO CORE BEHIND THE FLOOD FRONT.

THE CORE DATA AND PRODUCTION HISTORIES FROM THE CO₂ TEST FLOOD AREA, COMPARED TO SIMILAR DATA FROM AREAS THAT HAD BEEN WATERFLOODED, CONFIRMED LABORATORY EXPERIMENTS WHICH SHOWED 50 TO 100% MORE OIL RECOVERY BY CO₂ FLOOD THAN BY WATERFLOOD. NO CHANNELING OF CO₂ TO THE PRODUCING WELLS OCCURRED, AND AT 400 FEET FROM THE INJECTOR, NO GRAVITY OVERRIDE WAS OBSERVED. THE OIL SATURATIONS 400 FEET FROM THE INJECTOR WERE LESS THAN THOSE OBSERVED IN A HOLE 60 FEET FROM THE INJECTOR.

COMMENTS:

----- THIS WORK CONFIRMS THAT CARBON DIOXIDE WHEN USED FOR SECONDARY RECOVERY CAN DISPLACE CRUDE OIL TO VERY LOW RESIDUAL SATURATIONS. THE ABSENCE OF CHANNELING AND GRAVITY OVERRIDE IS ENCOURAGING, BUT THE HIGHER RESIDUAL OIL SATURATION NEAR THE INJECTION WELL AS COMPARED TO A WELL 400 FEET FROM THE INJECTOR IS ANOMALOUS AND GIVES RISE TO QUESTIONS ABOUT THE CONTROL OVER TEST RESULTS AND INTERPRETATIONS.

EXHIBITS:

----- 5 TABLES, 15 FIGURES, INCLUDING CORE ANALYSES AND PRODUCTION RECORDS.

CROSS REFERENCES:

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- 8. POETTMANN: TRANS., AIME (1951) 141.
 - 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
 - 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
 - 22. HOLM: TRANS., AIME (1959) 225.
 - 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
 - 40. HOLM: PROD. MO. (SEP., 1963 A) 6.

KEYWORDS:

SANDSTONE FIELD
FIELD RESIDUAL SATURATIONS

WATER INJECTION
OTHER FIELD INFORMATION

84. PARTOVI-NAJAFABADI, N.R.: "EXPERIMENTAL STUDY OF OIL RECOVERY FROM POROUS MATERIAL BY MEANS OF CARBON DIOXIDE FLOODING", PH.D. DISSERTATION, TX. A&M U., COLLEGE STATION, TX. (1970).

ABSTRACT:

----- BEREA SANDSTONE CORES (3.5' - 4.5' LONG, 4 SQ. IN CROSS-SECTIONAL AREA, AIR PERM 100-200 MD., 18% POROSITY) WERE CLEANED, MOUNTED, SATURATED WITH SYNTHETIC BRINE UNDER VACUUM, THEN FLOODED WITH "MANY" PORE VOLUMES OF CRUDE OIL AT 100 F. CORES WERE THEN WATERFLOODED AT AN AVERAGE PRESSURE OF 1000 PSIG TO A WOR ABOVE 100.

AFTER WATERFLOODING, DISPLACEMENT EXPERIMENTS WERE RUN WITH CARBONATED WATER OR WITH PURE CO₂, FOLLOWED BY A "BLOWDOWN" CYCLE, WITH PRESSURE REDUCED IN 50 PSI INCREMENTS AT THE CORE OUTFLOW END AND WATER INJECTED AT THE INFLOW END. MOST DISPLACEMENTS WERE CONDUCTED AT AN AVERAGE PRESSURE OF 1000 PSIG, WITH A FEW AT LOWER PRESSURES. A "HEAVY" EAST TEXAS CRUDE (23.8 API AND 50.4 CP AT 100 F) AND A "LIGHT" WEST TEXAS CRUDE (25.2 API AND 5.2 CP AT 100 F) WERE USED. SWELLING FACTORS, VISCOSITIES, AND CO₂ SOLUBILITIES WERE ALSO MEASURED ON BOTH CRUDES AS FUNCTIONS OF CO₂ PRESSURE UP TO 1000 PSIG.

SIMILAR BEHAVIOR WAS OBSERVED DURING DISPLACEMENT OF RESIDUAL OIL BY CARBONATED WATER AND BY CO₂, WITH LITTLE RECOVERY OF THE "LIGHT" OIL COMPARED TO THE "HEAVY" OIL. FOR BOTH OILS, MOST OF THE RECOVERY WAS OBTAINED BY "BLOWDOWN".

COMMENTS:

----- DATA ON SWELLING, VISCOSITY, AND SOLUBILITY MAY BE USEFUL, SINCE ONLY A FEW SUCH MEASUREMENTS HAVE BEEN REPORTED ELSEWHERE. IT IS SOMEWHAT DIFFICULT TO RELATE THESE RESULTS TO RESERVOIR PERFORMANCE, AND TO RECONCILE CONFLICTING REPORTS OF CARBONATED WATER PERFORMANCE. THERE WAS NO UNIFORMITY IN TERMINATING THE WATERFLOOD; E.G., EXPERIMENT B-1, WITH WEST TEXAS CRUDE, STOPPED WATERFLOODING AT WOR=110, AND A SUBSEQUENT CARBONATED WATERFLOOD REDUCED THE STOCK-TANK OIL SATURATION FROM 36.4% PV TO 34.7% PV, A DIFFERENCE OF 1.7%. IN EXPERIMENT C-1, WITH EAST TEXAS CRUDE, WATERFLOODING WAS STOPPED AT WOR=130, AT AN OIL SATURATION OF 42.7% PV. SUBSEQUENT CARBONATED WATERFLOODING REDUCED STOCK-TANK OIL SATURATION TO 34.8% PV, A DIFFERENCE OF 7.9% PV. THE DIFFERENCE IN SATURATION REDUCTION BETWEEN THESE TWO CARBONATED WATERFLOOD EXPERIMENTS (6.2%) IS ALMOST EXACTLY EQUAL TO THE DIFFERENCE IN WF RESIDUAL SATURATION (6.3%). ALTHOUGH TWO DIFFERENT CORES WERE USED, THIS OBSERVATION COUPLED WITH THE FACT THAT WF OIL RECOVERY WAS STILL INCREASING AT TERMINATION OF THE WF IN C-1, SUGGESTS THAT DIFFERENCES IN CO₂ OR CARBONATED WATERFLOOD BEHAVIOR MAY HAVE BEEN DUE TO FAILURE TO ESTABLISH TRUE WATERFLOOD RESIDUAL OIL SATURATION BEFORE STARTING THE TERTIARY DISPLACEMENTS.

THE "BLOWDOWN" CYCLES SUGGEST THAT CO₂ MAY RECOVER SOME OIL

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IF A RESERVOIR CAN BE REPRESSURED WITH CO₂ AND DEPLETED A SECOND TIME, ALTHOUGH THE EFFECT OF WATER INJECTION DURING THIS PART OF THE EXPERIMENTS IS DIFFICULT TO EVALUATE.

EXHIBITS:

----- 7 TABLES, 42 FIGURES

ADDITIONAL REFERENCES:

- 1. SWARTZ: PHYSICS (1931) V.1, 245.
2. MARTIN: OIL & GAS J. (DEC. 13, 1951) 82-86.
3. WEBER: OIL & GAS J. (JAN. 25, 1951) 171-172.
4. SQUIRES: PROD. MON. (JULY, 1951) V.15, 29-31.
5. YADAV: M.S. THESIS, TX. A&M U. (1967).
6. PARTOVI-NAJAFABADI: M.S. THESIS, TX. A&M U. (1968).

CROSS REFERENCES:

- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.

KEYWORDS:

PURE CARBON DIOXIDE BEHAVIOR
MULTICOMPONENT SYSTEMS
SOLUBILITY
LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)
EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
OIL SWELLING
VISCOSITY
TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES

85. RALFSNIDER, P.J.: "IN-SITU FORMED CO2 DRIVE FOR OIL RECOVERY",
U.S. PATENT 3,532,165 (OCT. 6, 1970).

ABSTRACT:

----- THE PURPOSE OF THIS INVENTION IS TO CREATE CARBON
DIOXIDE IN SITU BY A CHEMICAL REACTION OF SULFURIC ACID FOLLOWED
BY SATURATED SODIUM CARBONATE SOLUTION. ALTERNATELY, SODIUM
BICARBONATE MAY BE USED WITH SULFURIC ACID, OR SULFUR DIOXIDE MAY
BE FOLLOWED BY SODIUM CARBONATE TO CREATE CARBON DIOXIDE.

COMMENTS:

----- AN ECONOMIC COMPARISON BETWEEN USING CHEMICAL
REACTIONS AS DESCRIBED IN THE PATENT TO CREATE CO2 AND OTHER
SOURCES WOULD BE ENLIGHTENING.

CROSS REFERENCES:

37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
64. GILCHRIST: U.S. PATENT 3,344,857 (OCT., 1967).
67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
72. FERRELL, MATHEWS: U.S. PATENT 3,392,782 (JULY 16, 1968).
S 13. PRATS, CLOSMAN: U.S. PAT. 3,259,187 (JULY 5, 1966).

KEYWORDS:

WATER INJECTION
OTHER FIELD INFORMATION
CO2 SOURCE

FIELD SECONDARY RECOVERY
U.S. PATENT
ALTERNATE TECHNOLOGIES

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86. STALKUP, F.I.: "DISPLACEMENT OF OIL BY SOLVENT AT HIGH WATER SATURATION", SOC. PET. ENG. J. (DEC., 1970) 337-348.

ABSTRACT:

----- DISPLACEMENTS OF LABORATORY OILS BY PROPANE IN LONG, CONSOLIDATED SANDSTONE CORES IN THE PRESENCE OF HIGH WATER SATURATIONS HAVE SHOWN THAT RECOVERIES APPROACHING 100% MAY BE REALIZED BY CONTINUOUS WATER-PROPANE INJECTION, ALTHOUGH MANY PORE VOLUMES OF SOLVENT MAY BE NECESSARY TO EFFECT THE DISPLACEMENT.

SOME OF THE OIL IS BLOCKED BY WATER WHEN WATER SATURATION IS HIGH AND IS BY-PASSED BY THE SOLVENT FRONT. ROCK WETTABILITY MAY BE AN IMPORTANT FACTOR AND THE TRAPPING OF OIL MAY NOT BE AS SEVERE FOR WEAKLY WATER-WET ROCKS AS IT IS FOR STRONGLY WATER WET ROCKS. IT APPEARS THAT THE STAGNANT OIL MAY BE RECOVERED BY MOLECULAR DIFFUSION INTO THE FLOWING MISCIBLE PHASE; COMPUTATIONS INDICATE THAT EXPERIMENTS IN LABORATORY-SIZE CORES MAY SHOW MUCH POORER DISPLACEMENT EFFICIENCY THAN THAT WHICH MIGHT ACTUALLY OCCUR IN THE FIELD.

COMMENTS:

----- 1. THE ASPECT OF ROCK WETTABILITY AFFECTING THE AMOUNT OF OIL BY-PASSED COULD BE IMPORTANT IN COMPARING LABORATORY AND FIELD RESULTS.
2. THE RESULTS OF THIS STUDY INDICATE THAT PROPER SCALING OF MOLECULAR DIFFUSION MAY BE NECESSARY FOR LABORATORY MODELLING OF TERTIARY MISCIBLE PROCESS.

EXHIBITS:

----- 2 TABLES, 13 FIGURES

CROSS REFERENCES:

28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

TERTIARY RECOVERY (LAB. EXP.)
LABORATORY INSTABILITIES
MISCIBILITY (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
WETTABILITY (LAB. EXP.)
LPG

87. COAN, C.R. AND KING, A.D., JR.: "SOLUBILITY OF WATER IN COMPRESSED CARBON DIOXIDE, NITROUS OXIDE, AND ETHANE. EVIDENCE FOR HYDRATION OF CARBON DIOXIDE AND NITROUS OXIDE IN THE GAS PHASE", J. AM. CH. SOC. (APR. 21, 1971) 1857-1862.

ABSTRACT:

----- THIS PAPER REPORTS MEASUREMENTS OF THE SOLUBILITY OF WATER IN COMPRESSED CARBON DIOXIDE, NITROUS OXIDE, AND ETHANE FOR PRESSURES RANGING FROM 1 TO 60 ATM AND TEMPERATURES RANGING FROM 25 TO 100 C. THE MEASUREMENTS WERE CARRIED OUT TO ASSESS THE NATURE AND SIGNIFICANCE OF ANY CHEMICAL FORCES THAT MIGHT EXIST BETWEEN WATER AND THE GASES CO₂ AND N₂O IN THE GAS PHASE. THIS INFORMATION IS VALUABLE IN THAT IT PROVIDES THERMODYNAMIC QUANTITIES USEFUL IN INTERPRETING THE LIQUID PHASE PROPERTIES OF THESE SAME SYSTEMS.

THE SOLUBILITY OF A LIQUID IN A COMPRESSED GAS IS DETERMINED BY TWO FACTORS: VARIATIONS IN THE FUGACITY OF THE LIQUID PHASE AND DEVIATIONS FROM IDEAL BEHAVIOR OF THE FUGACITY OF THE LIQUID COMPONENT IN THE GAS PHASE. DEVIATIONS FROM IDEALITY ARE MAINLY CAUSED BY PAIR INTERACTIONS BETWEEN MOLECULES OF THE LIQUID COMPONENT AND THOSE OF THE GAS. AS A CONSEQUENCE OF THIS, SOLUBILITY DETERMINATIONS FOR LIQUIDS IN COMPRESSED GASES CAN BE USED TO PROVIDE ACCURATE VALUES OF SECOND CROSS VIRIAL COEFFICIENTS REPRESENTING SUCH DEVIATIONS FROM IDEALITY.

THE SECOND CROSS VIRIAL COEFFICIENTS HAVE BEEN EVALUATED FROM THE DATA, AND THOSE INVOLVING WATER WITH CARBON DIOXIDE OR NITROUS OXIDE ARE CONSIDERABLY MORE NEGATIVE THAN THOSE FOR WATER WITH ETHANE. THIS IS INTERPRETED AS INDICATING THAT A REVERSIBLE HYDRATION REACTION OCCURS BETWEEN CO₂ OR N₂O AND WATER VAPOR IN THE GAS PHASE.

COMMENTS:

----- 1. THE METHOD FOR DETERMINATION OF SECOND CROSS VIRIAL COEFFICIENTS COULD HAVE APPLICATION TO OTHER EQUATIONS OF STATE AS WELL.

2. THE INTERPRETATION OF CO₂ HYDRATION COULD BE IMPORTANT IN EXAMINATION OF THE PROPERTIES OF INJECTED CO₂.

EXHIBITS:

----- 2 TABLES, 4 FIGURES, INCLUDING MEASURED DATA AND COMPARISON WITH OTHER DATA.

ADDITIONAL REFERENCES:

- 1. HILDEBRAND AND SCOTT: SOLUBILITY OF NONELECTROLYTES (1964).
2. PRASNITZ AND BEESON: A.I.C.H.E. J. (1959) V.5, 161.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES CORRELATIONS

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HYDROCARBON COMPONENTS
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
EQUILIBRIUM RATIOS

NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
SOLUBILITY
LAB. PROCEDURES AND APPARATUS

88. HEARN, C.L. AND HOLMES, C.S.: "OPTIMUM OIL RECOVERY FOR CARBON DIOXIDE INJECTION", U.S. PATENT 3,620,304 (NOV. 16, 1971).

ABSTRACT:

----- THE OBJECTIVES OF THIS INVENTION ARE TO PROVIDE FOR THE MISCIBLE DISPLACEMENT OF OIL FROM RESERVOIRS, PROVIDE A METHOD FOR DETERMINING OPTIMAL CONDITIONS FOR DISPLACEMENT FROM LABORATORY DATA, AND TO USE THE PHASE BEHAVIOR AND PHYSICAL PROPERTIES OF CARBON DIOXIDE UNDER SPECIFIC CONDITIONS OF TEMPERATURE AND PRESSURE TO ENHANCE MISCIBLE DISPLACEMENT.

THE INVENTION CALLS FOR DETERMINING THE BUBBLE POINT OF THE RESERVOIR OIL, AND THEN PERFORMING TESTS IN THE LABORATORY TO ASCERTAIN THE OPTIMUM INJECTION PRESSURE ABOVE THE BUBBLE POINT. OPTIMUM CONDITIONS ARE DEFINED HERE AS THOSE RESULTING IN HIGH OIL RECOVERY FOR MINIMUM VOLUME OF CO₂ INJECTED. THE CARBON DIOXIDE SLUG MAY THEN BE FOLLOWED BY NITROGEN, AIR, FLUE GAS, OR WATER.

GENERALLY, THE OPTIMUM INJECTION PRESSURE IS FOUND TO BE FROM 1 TO 250 PSI ABOVE THE BUBBLE POINT PRESSURE; FURTHERMORE, IT IS SUGGESTED THAT THE RESERVOIR TEMPERATURE SHOULD BE LESS THAN 200 F.

COMMENTS:

----- 1. ALTHOUGH THE METHOD IS STATED TO BE VIABLE IN DEPLETED RESERVOIRS, IT APPARENTLY WOULD REQUIRE REPRESSURING TO THE BUBBLE POINT PRIOR TO CO₂ INJECTION, WHICH COULD BE EXPENSIVE.

2. FOR RECOVERY FROM RESERVOIRS AT OR NEAR THE ORIGINAL BUBBLE POINT, THIS PATENT MAY INDICATE THAT MAXIMUM RECOVERY WOULD BE OBTAINED BY INJECTING CARBON DIOXIDE FROM THE BEGINNING, RATHER THAN FIRST PRODUCING A FIELD ON PRIMARY DEPLETION.

EXHIBITS:

----- 3 FIGURES

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
60. BOSTON: U.S. PATENT 3,346,046 (OCT. 10, 1967).

KEYWORDS:

EFFECTS OF TEMPERATURE
OTHER PHYSICAL PROPERTIES

EFFECTS OF PRESSURE
SOLUBILITY
U.S. PATENT

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89. HOLM, L.W.: "USE OF SOLUBLE OILS FOR OIL RECOVERY",
J. PET. TECH. (DEC., 1971) 1475-1483.

ABSTRACT:

----- SOLUBLE OILS, WHICH ARE SELECTED COMBINATIONS OF
HYDROCARBONS, SURFACTANT, A STABILIZING AGENT, AND WATER,
CAN COMPLETELY REMOVE THE OIL THEY CONTACT IN A POROUS MEDIUM.
THE SOLUBLE OIL IS MISCIBLE WITH RESERVOIR OIL AND SPONTANEOUSLY
EMULSIFIES WITH WATER. THE COMPOSITION OF THE SOLUBLE OIL, WHICH
CAN BE CHARACTERIZED BY ITS PHASE BEHAVIOR, DETERMINES ITS
EFFECTIVENESS AS A RECOVERY AGENT.

GENERALLY, THE SOLUBLE OIL MUST BE DISPLACED BY THICKENED
WATER (POLYMERIC SOLUTION) FOR BEST RESULTS. RECOVERY IS
AFFECTED BY THE VISCOSITY OF THE EMULSION FORMED BETWEEN
THE SOLUBLE OIL AND FOLLOW UP WATER, AND BY BYPASSING OF THE
SOLUBLE OIL.

COMMENTS:

----- 1. THE BASIC CONCLUSION OF THIS PAPER IS THAT
SOLUBLE OILS MAY PROVIDE AN EFFICIENT RECOVERY METHOD.
2. ONE OF THE INTERESTING RESULTS OF THIS PAPER IS
THAT WATER OR BRINE, WITH SOME SOLUBLE OILS, IS NOT DRIVEN
TO THE OUTLET. THIS COULD PROVE USEFUL FOR TERTIARY
RECOVERY.

EXHIBITS:

----- 3 TABLES, 9 FIGURES

CROSS REFERENCES:

36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.

KEYWORDS:

NON-HYDROCARBON COMPONENTS
VISCOSITY

SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
ADDITIVES (LAB. EXP.)

HYDROCARBON COMPONENTS
TERNARY SYSTEMS
LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
OTHER LABORATORY STUDIES

90. PARRISH, D.R.: "CARBON DIOXIDE SLUG DRIVE", U.S. PATENT 3,586,107 (JUNE 22, 1971).

ABSTRACT:

----- THIS PATENT DESCRIBES A MODIFICATION BY THE AUTHOR AS REGARDS THE DESIGN OF CO2 FLOODING PROJECTS. THE INVENTION CALLS FOR THE INJECTION OF AIR OR FLUE GAS IMMEDIATELY AFTER CO2 SLUG INJECTION TO PROVIDE A PROTECTIVE BANK BETWEEN WATER AND CO2.

THIS BANK BASICALLY SERVES TWO PURPOSES: FIRST, SINCE AIR OR FLUE GAS IS CHEAPER THAN CO2, THE TRAPPED GAS SATURATION WILL BE COMPOSED OF A RELATIVELY CHEAP FLUID. SECONDLY, BECAUSE AIR AND FLUE GAS ARE LESS SOLUBLE IN WATER THAN CO2, AN IMPROVEMENT IN MOBILITY RATIO IS POSTULATED. IT IS ASSUMED IN THE PATENT THAT DISPLACEMENT OF CO2 BY AIR OR FLUE GAS IS PERFECT. ALSO, IT IS CLAIMED THAT THE RESERVOIR OIL SHOULD HAVE A MINIMUM API GRAVITY OF 30 DEGREES FOR PROPER APPLICATION.

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COMMENTS:

----- 1. THE CONCEPT OF HAVING A LESS EXPENSIVE FLUID TRAPPED IS INTRIGUING; THE PROTECTIVE BANK CONCEPT COULD REDUCE OVERALL CO2 REQUIREMENTS, IF SUCCESSFUL.

2. THE SUGGESTION THAT MORE FLUE GAS OR AIR WOULD REMAIN IN A FREE STATE BEHIND THE WATER FRONT, HENCE REDUCING EFFECTIVE PERMEABILITY TO WATER AND IMPROVING MOBILITY RATIO IS NOT DOCUMENTED.

3. POSSIBLE ADDITIONAL OPERATING OR CORROSION PROBLEMS RESULTING FROM INJECTING AIR OR FLUE GAS ARE NOT ADDRESSED.

EXHIBITS:

----- 2 FIGURES

CROSS REFERENCES:

- 19. RZASA, TERWILLIGER: U.S. PATENT 2,822,872 (FEB. 11, 1958).
- 26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C
- 33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).
- 50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).
- 54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
- 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
- 68. SANTOURIAN: U.S. PATENT 3,295,601 (JAN. 3, 1967).
- 71. BRIGHAM, DEW: U.S. PATENT 3,410,341 (NOV. 12, 1968).

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
FLUE GAS (LAB. EXP.)

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
U.S. PATENT

91. RATHMELL, J.J., STALKUP, F.I. AND HASSINGER, R.C.:
"A LABORATORY INVESTIGATION OF MISCIBLE DISPLACEMENT BY
CARBON DIOXIDE", PAPER 3483, SPE-AIME 46TH ANN. FALL MTG.,
NEW ORLEANS, LA. (OCT., 1971).

ABSTRACT:

----- CORE DISPLACEMENT EXPERIMENTS WERE PERFORMED IN
6 TO 60 FOOT LONG BOISE OUTCROP SANDSTONE CORES WITH CARBON
DIOXIDE AT VARIOUS PRESSURES. THREE RESERVOIR OILS WERE
SYNTHESIZED FROM STOCK TANK OILS BY ADDING APPROPRIATE AMOUNTS
OF METHANE, CARBON DIOXIDE, ETHANE, ETC., TO ACHIEVE
COMPOSITIONS BELIEVED TO BE REPRESENTATIVE OF RESERVOIR
FLUID AT THE START OF MISCIBLE DISPLACEMENT. FRONTAL
VELOCITIES OF 10 TO 20 FEET/DAY WERE USED, AND THE INDIVIDUAL
EXPERIMENTS WERE TERMINATED WHEN THE GOR REACHED 30 MCF/BBL.

GENERALLY, IT WAS FOUND THAT VISCOUS FINGERING AND CORE
LENGTH EFFECTS WERE IMPORTANT FACTORS OPERATING IN THE LABORATORY
EXPERIMENTS. IT WAS FOUND THAT MISCIBILITY WAS ACHIEVED AT LOWER
PRESSURES WITH CO₂ THAN WITH METHANE AND THAT DISPLACEMENT BY CO₂
MAY YIELD VERY EFFICIENT RECOVERY BY VAPORIZATION AND SWELLING OF
HEAVY ENDS.

COMMENTS:

- 1. THIS PAPER ILLUSTRATES THE PROBLEMS WITH CORE
LENGTH EFFECTS THAT MAY OCCUR IN LABORATORY EXPERIMENTS.
2. THE OBSERVATION CAN BE MADE BASED ON THE RESULTS
PRESENTED THAT AT PRESSURES CLOSE TO BUT NOT EXCEEDING THE
MISCIBILITY PRESSURE, VERY HIGH RECOVERIES (WITHIN A FEW
PERCENT OF THOSE FOR MISCIBLE DISPLACEMENT) MAY BE EXPECTED.

EXHIBITS:

----- 5 TABLES, 18 FIGURES, INCLUDING DISPLACEMENT
RESULTS AND PSEUDO-TERNARY PHASE DIAGRAMS

CROSS REFERENCES:

- 9. SAXON, BRESTON, MACFARLANE: PROD. MD. (NOV., 1951) 8.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 7. HUTCHINSON, BRAUN: A.I.C.H.E. J. (1961) 64.
S 11. REAMER, SAGE: J. CH. & ENG. DATA (JAN., 1965) 49.
S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
EFFECTS OF PRESSURE
OIL SWELLING
MULTIPLE CONTACT MISCIBILITY
LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS

TERNARY SYSTEMS
DENSITY
FIRST CONTACT MISCIBILITY
LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
CHROMATOGRAPHIC EFFECTS

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92. THOMPSON, J.A., EMERICK, G.M. AND KASTROP, J.E.:
"INTEGRATION/COORDINATION: KEYS TO SACROC FIELD OPERATIONS",
PET. ENG. (DEC., 1971) 48-56.

ABSTRACT:

----- WATER INJECTION IN THE SACROC UNIT (CANYON REEF RESERVOIR, KELLY SNYDER FIELD) STARTED IN 1954. THE USE OF CARBON DIOXIDE IN CONJUNCTION WITH WATER INJECTION IS EXPECTED TO RECOVER AN ADDITIONAL 200+ MILLION BARRELS OF OIL. THE EXISTING OIL RECOVERY PROGRAM HAD GROWN FROM APPROXIMATELY 50,000 BARRELS PER DAY IN 1965 TO OVER 200,000 BARRELS PER DAY IN 1971. OVERALL DESIGN WAS FOR 244,000 BARRELS OF OIL PER DAY, WITH 400,000 BARRELS OF WATER AND 230 MCF OF GAS. THE PROPOSED CARBON DIOXIDE INJECTION RATE IS 200 MCFD.

THE UNIT CONTAINS 15 LACT STATIONS AND WILL ULTIMATELY HAVE OVER 100 PRODUCTION MANIFOLDS. THERE ARE THREE WATER SOURCES DEVELOPED FOR WATER INJECTION PROGRAMS AT SACROC: LAKE J.B. THOMAS 15 MILES SOUTHWEST OF THE UNIT, 18 SANTA ROSA WATER WELLS, AND PRODUCED WATER. THERE ARE FIVE HIGH-PRESSURE WATER INJECTION STATIONS, WITH A COMBINED CAPACITY OF 500,000 BWPD AT 2000 PSI.

THE PLAN FOR CARBON DIOXIDE INJECTION CALLS FOR FILLING UP WITH WATER, THEN INJECTING ALTERNATE SLUGS OF CO₂ (6% HCPV) AND WATER (3% PV) UNTIL CO₂ OCCUPIES ABOUT 20% OF A HCPV. WATER WILL THEN BE INJECTED THROUGH THE REMAINING LIFE OF THE AFFECTED AREA. DEVELOPMENT WILL BE ON NINE-SPOTS AND PRESSURES WILL BE KEPT HIGH TO INSURE MISCIBILITY.

COMMENTS:

----- THIS IS A GOOD PAPER ON THE FACILITIES REQUIRED FOR A LARGE SCALE INJECTION PROJECT.

EXHIBITS:

----- 14 FIGURES

KEYWORDS:

-----	CARBONATE FIELD
WATER INJECTION	FIELD TERTIARY RECOVERY
FACILITIES	OPERATIONS
OTHER FIELD INFORMATION	TRANSPORTATION

93. VAIRGS, J.: "RECOVERY OF OIL BY LOW PRESSURE MISCIBLE GAS INJECTION", U.S. PATENT 3,623,552 (NOV. 30, 1971).

ABSTRACT:

----- THE PURPOSE OF THIS PATENT IS TO REDUCE OR PREVENT VISCOUS FINGERING FROM OCCURRING IN THE RESERVOIR WHEN CARBON DIOXIDE IS INJECTED. THIS PURPOSE IS ACHIEVED BY CREATING AN INTERMEDIATE LIQUID PHASE BETWEEN THE INJECTED GAS AND VIRGIN OIL WHICH IS INTERMEDIATE IN DENSITY AND VISCOSITY BETWEEN THE INJECTED GAS AND VIRGIN OIL.

THE PROCESS IS SAID TO WORK FOR PRESSURES BETWEEN 1100 AND 1400 PSIG AND TEMPERATURES FROM 90 TO 110 F, AND IS DESIGNED FOR SHALLOW RESEVOIRS. THE PATENT IS SPECIFICALLY FOR CARBON DIOXIDE AND ETHANE INJECTION, IN ANY PROPORTIONS, WITH OTHER GASES (METHANE, NITROGEN, OR CARBON MONOXIDE) IN CONCENTRATIONS UP TO 20 VOLUME PERCENT.

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COMMENTS:

----- THE KEY OBSERVATIONS OF THIS PATENT ARE THAT MISCIBILITY CAN BE ACHIEVED AT PRESSURES AS LOW AS 800 PSIG, AND THAT AN INTERMEDIATE LIQUID PHASE MAY BE CREATED, WHICH COULD REDUCE VISCOUS FINGERING EFFECTS.

EXHIBITS:

----- 2 FIGURES

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
- 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
- 46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
- 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
- 79. HOLM: CAN. PATENT 825,475 (OCT. 21, 1969).

KEYWORDS:

GENERAL PHASE BEHAVIOR
SECONDARY RECOVERY (LAB. EXP.)
LABORATORY INSTABILITIES
IMPURITIES (LAB. EXP.)
U.S. PATENT

LABORATORY INJECTION PROCESS
MOBILITY RATIO (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
OTHER LABORATORY STUDIES
ENRICHED AND HIGH PRESSURE GAS

94. WEISSMAN, S. AND DUBRO, G.A.: "DIFFUSION COEFFICIENTS FOR CO₂-CH₄", J. CH. PH. (MAR, 1, 1971) V.54, NO.5, 1881-1883.

ABSTRACT:

----- MUTUAL DIFFUSION COEFFICIENTS FOR THE CARBON DIOXIDE - METHANE SYSTEM WERE MEASURED FROM 293 TO 370 K. THESE MEASUREMENTS EXTEND THE TEMPERATURE RANGE OF PREVIOUSLY MEASURED VALUES BY ABOUT 75 K. THE EXPERIMENTAL VALUES OF THE DIFFUSION COEFFICIENT ARE IN EXCELLENT AGREEMENT WITH VALUES DERIVED FROM THE COMPOSITION DEPENDENCE OF THE VISCOSITY OF THE MIXTURE, PROVIDED THAT THE RATIO OF COLLISION INTEGRALS BETWEEN THE TWO COMPONENTS IS EVALUATED USING EXPERIMENTAL QUANTITIES. THE EQUATIONS USED ARE BASED ON MASON AND MONCHICK, AND ARE IDENTICAL IN FORM TO THOSE OBTAINED FROM THE CHAPMAN-ENSKOG THEORY.

COMMENTS:

----- THE GENERAL EXPRESSIONS FOR TRANSPORT PROPERTIES OBTAINED FROM THE CHAPMAN-ENSKOG THEORY ARE VALID FOR BINARY SYSTEMS, AS WELL AS FOR MONATOMIC, POLAR, AND POLYATOMIC GASES.

EXHIBITS:

----- 2 TABLES, 1 FIGURE

KEYWORDS:

CORRELATIONS
BINARY SYSTEMS
VISCOSITY

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
DIFFUSION COEFFICIENTS

95. WEST, J.M. AND KROH, C.G.: "CARBON DIOXIDE COMPRESSED TO SUPERCRITICAL VALUES", PET. ENG. (DEC., 1971) 63-66.

ABSTRACT:

----- THIS PAPER DESCRIBES THE OPERATIONS AND FACILITIES FOR THE PIPELINE AND INJECTION SYSTEM FOR SACROC. FOUR COLLECTION STATIONS HAVE COMPRESSORS FOR COLLECTING CO₂ FROM NATURAL GAS STRIPPING PLANTS; THEN A BOOSTER STATION KEEPS THE PIPELINE PRESSURES ABOVE A SET LIMIT FOR THE 220 MILE 16 INCH TRANSMISSION PIPELINE. THE 200 MMCFD OF CO₂ IS THEN BOOSTED TO 2400 PSI FOR INJECTION. MORE THAN 80000 HP OF COMPRESSION ARE REQUIRED FOR PIPELINING.

THE PIPELINE, BOOSTER STATION, AND INJECTION STATIONS ALL OPERATE IN THE SUPERCRITICAL REGION. IT WAS FOUND THAT THE PROPERTIES OF CO₂ CAN BE PREDICTED ALLOWING FOR CHANGES IN COMPOSITION OVER THE ENTIRE RANGE OF PRESSURES AND TEMPERATURES TO BE ENCOUNTERED FOR THE PROJECT.

COMMENTS:

----- THIS IS A GOOD BASIC OPERATIONS PAPER ON THE GATHERING, TRANSMISSION, TREATING, AND INJECTION OF CO₂.

EXHIBITS:

----- 3 FIGURES

KEYWORDS:

COMPRESSION
OTHER FIELD INFORMATION
TRANSPORTATION

IMPURITIES (FIELD)
CO₂ SOURCE
SEPARATION

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96. WHITE, R.W.: "OIL RECOVERY BY CO₂: PAST AND FUTURE",
PET. ENG. (DEC., 1971) 58-60.

ABSTRACT:

----- THIS PAPER PROVIDES A QUICK OVERVIEW AS OF 1971 OF
CARBON DIOXIDE AS AN OIL RECOVERY AGENT. KEY POINTS NOTED IN THIS
PAPER ARE:

1. AT PRESSURES BELOW MISCIBILITY PRESSURE, DISPLACEMENT
EFFICIENCY IS STILL EXCELLENT.
2. CARBONATED WATERFLOODING WAS NOT PROFITABLE, MAINLY
BECAUSE IT DOES NOT GET ENOUGH CO₂ INTO THE OIL AND HAS
A LESS FAVORABLE MOBILITY RATIO THAN WATERFLOODING.
3. A FIELD TEST USING PRESSURED CORE BARREL AT MEAD-STRAWN
DEMONSTRATED THAT DISPLACEMENT OF OIL IN THE FIELD WAS
AS GOOD AS THAT IN THE LABORATORY.
4. PROGRAMS UNDER DEVELOPMENT AT THE TIME OF THIS PAPER
INCLUDE SACROC, NORTH CROSS UNIT, GILLOCK SOUTH FIELD,
AND WILLARD UNIT.

COMMENTS:

----- THIS IS AN OVERVIEW PAPER AND DOES NOT CONTAIN ANY
NEW INFORMATION.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

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13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
 22. HOLM: TRANS., AIME (1959) 225.
 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
 - S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
 - S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.

KEYWORDS:

WATER INJECTION
FIELD MOBILITY RATIO
OTHER FIELD INFORMATION

RESIDUAL SATURATION (LAB. EXP.)
FIELD IMMISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
CO₂ SOURCE

97. YUDOVICH, A., ROBINSON, R.L., JR. AND CHAO, K.C.: "PHASE EQUILIBRIUM OF CARBON DIOXIDE IN THE METHANE - CARBON DIOXIDE - N-DECANE SYSTEM", A.I.C.H.E. J. (SEP., 1971) V.17, NO.5, 1152-1159.

ABSTRACT:

----- THIS PAPER USES EXPERIMENTAL AND PUBLISHED DATA TO EVALUATE THE PHASE BEHAVIOR OF CARBON DIOXIDE IN METHANE - CARBON DIOXIDE- N-DECANE SYSTEM. A CHROMATOGRAPHIC TECHNIQUE WAS USED TO DETERMINE VAPOR-LIQUID EQUILIBRIUM RATIOS. USING THIS DATA COMBINED WITH RESULTS OF A PREVIOUS STUDY OF THE PARTIAL VOLUMETRIC BEHAVIOR OF CARBON DIOXIDE OF INFINITE DILUTION IN GASEOUS METHANE, THE ACTIVITY COEFFICIENT OF CARBON DIOXIDE IN THIS TERNARY SYSTEM WAS DETERMINED. THE ACTIVITY COEFFICIENTS THUS OBTAINED WERE CORRELATED BASED ON A COMBINED SCATCHARD-HILDEBRAND AND FLORY-HUGGINS MODEL, WITH AN AVERAGE ABSOLUTE ERROR OF LESS THAN TWO PERCENT.

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COMMENTS:

----- BY COMBINING THE SCATCHARD-HILDEBRAND AND FLORY-HUGGINS EQUATIONS, ACCURATE REPRESENTATIONS FOR LIQUID-PHASE ACTIVITY COEFFICIENTS ARE OBTAINED.

EXHIBITS:

----- 1 TABLE, 8 FIGURES

CROSS REFERENCES:

44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.

KEYWORDS:

CORRELATIONS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS
LAB. PROCEDURES AND APPARATUS

EXPERIMENTAL PHYSICAL PROPERTIES
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE
OTHER PHYSICAL PROPERTIES
CHROMATOGRAPHIC EFFECTS

98. BISHNOI, P.R. AND ROBINSON, D.B.: "MIXING RULES IMPROVE BWR USE", HYDROCARBON PROCESSING (NOV., 1972) 150-156.

ABSTRACT:

----- THE BWR (BENEDICT-WEBB-RUBIN) EQUATIONS, USED WITH SOME NEW MIXING RULES, HAVE SATISFACTORILY PREDICTED PHASE BEHAVIOR AND COMPRESSIBILITY FACTORS FOR HYDROCARBON-NONHYDROCARBON MIXTURES. COMPRESSIBILITY FACTORS OF SOUR NATURAL GAS MIXTURES AND THE PHASE BEHAVIOR FOR BINARY AND TERNARY SYSTEMS CONTAINING HYDROCARBON AND NONHYDROCARBON COMPONENTS WERE EXPERIMENTALLY STUDIED. THE EXPERIMENTAL RESULTS WERE IN GOOD AGREEMENT WITH PREDICTIONS. THE MAXIMUM ERROR SEEN WAS 5% AND MEAN STANDARD ERROR IN PREDICTION WAS 1.4%. MIXTURES CONTAINING HIGH CONCENTRATION OF HYDROGEN SULFIDE AND/OR CARBON DIOXIDE WERE PREDICTED WITH THE SAME ACCURACY AS OTHERS.

MIXING RULES ARE PRESENTED. A SET OF BWR PARAMETERS FOR EACH COMPONENT IN THE MIXTURE AND ONE INTERACTION PARAMETER FOR EACH BINARY PAIR IN THE SYSTEM ARE REQUIRED. PUBLISHED VALUES OF INTERACTION PARAMETERS WERE REVISED AS NECESSARY. THE FUGACITY OF ANY MIXTURE COMPONENTS CAN ALSO BE CALCULATED FROM THIS DEVELOPMENT.

COMMENTS:

----- THE ACCURACY OF THE PREDICTIONS MADE BY THIS DEVELOPMENT IS EXCELLENT. THIS CORRELATION COULD BE USED IN COMPOSITIONAL SIMULATION FOR MISCIBLE PROCESSES.

EXHIBITS:

----- 4 TABLES, 12 FIGURES

ADDITIONAL REFERENCES:

----- A TOTAL OF 47 REFERENCES ARE CITED.

CROSS REFERENCES:

5. ULDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF PRESSURE
DENSITY

CORRELATIONS
HYDROCARBON COMPONENTS
BINARY SYSTEMS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
OTHER PHYSICAL PROPERTIES

99. BYARS, C.: "CARBON DIOXIDE GROWS AS RECOVERY TOOL",
OIL & GAS J. (AUG. 7, 1972) 22-24.

ABSTRACT:

----- TWO MISCIBLE RECOVERY PROJECTS WERE RECENTLY
ANNOUNCED IN CROSSETT AND WASSON FIELDS. SHELL IS THE UNIT OPERATOR
IN THE CROSSETT FIELD, LOCATED IN CRANE AND UPTON COUNTIES OF WEST
TEXAS. THE FIELD WAS DISCOVERED IN 1944 AND THE ORIGINAL OIL IN
PLACE WAS 51 MMBBL. THE 1,120 ACRE RESERVOIR IS COMPOSED OF A
SILICEOUS CARBONATE ROCK KNOWN AS TRIPOLITIC CHERT. THE DEVONIAN
IS LOCATED AT 5,300 FEET AND HAS AN AVERAGE POROSITY OF 27% AND
AVERAGE PERMEABILITY OF 55 MD.

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THE CROSSETT FIELD WAS UNITIZED IN 1964 AND THE INJECTION OF
PRODUCED GAS STARTED FOR PRESSURE MAINTENANCE. INJECTION OF CO2
STARTED IN APRIL, 1972 AT A RATE OF 20 MMCFD AT 17,000 PSI LINE
PRESSURE. 73 BCF OF CO2 WILL BE INJECTED. THE PROJECT IS EXPECTED
TO RECOVER AN ADDITIONAL 8.9 MMBBL OF OIL. CUMULATIVE OIL PRODUCTION
HAS REACHED 6.9 MMBBLS, AND THE RATE IS CURRENTLY 1600 B/D.

THE WASSON FIELD LOCATED IN YOAKUM COUNTY, WEST TEXAS, WAS
DISCOVERED IN 1936. THE ANTICLINAL STRUCTURE HAS A PRODUCTIVE
AREA OF 63,500 ACRES. THE SAN ANDRES RESERVOIR HAS AN AVERAGE
POROSITY OF 7% AND PERMEABILITY OF 3 MD. THE EFFECTIVE PAY
THICKNESS IS 180 FEET. THE WILLARD UNIT IS OPERATED BY ARCO.
CO2 INJECTION IS SCHEDULED TO START IN SEPTEMBER, 1972. PHASE I
OF THIS PROJECT IS EXPECTED TO RECOVER AN ADDITIONAL 13 MMBLS OF
OIL. THIS IS EXPECTED TO REACH 60 MMBLS AFTER THE PROJECT HAS
BEEN EXPANDED TO FULL SCALE. THE ESTIMATED ORIGINAL OIL IN PLACE
WAS 622 MMBLS. ABOUT 86 MMBLS OF THE 33 API CRUDE HAS ALREADY
BEEN PRODUCED.

COMMENTS:

----- THIS REPORT OUTLINES THE MAJOR PLANS IN THE TWO
CO2 INJECTION PROGRAMS AT CROSSETT AND WASSON FIELDS IN WEST
TEXAS. NO PERFORMANCE HISTORY IS AVAILABLE; IN FACT ONE OF THE
PROJECTS HAD NOT STARTED WHEN IT WAS BEING REPORTED.

EXHIBITS:

----- 2 FIGURES

KEYWORDS:

CARBONATE FIELD
FIELD TERTIARY RECOVERY
FIELD ECONOMICS
OTHER FIELD INFORMATION

WATER INJECTION
COMPRESSION
FACILITIES
CO2 SOURCE

100. CLARIDGE, E.L.: "PREDICTION OF RECOVERY IN UNSTABLE MISCIBLE FLOODING", SOC. PET. ENG. J. (APR., 1972) 143-155.

ABSTRACT:

----- EXISTING METHODS OF PREDICTING AREAL COVERAGE AND LINEAR DISPLACEMENT EFFICIENCY HAVE BEEN COMBINED TO DEVELOP A CORRELATION FOR ESTIMATING OIL RECOVERY IN UNSTABLE MISCIBLE 5-SPOT PATTERN FLOODS. THE CORRELATION IS BASED ON A VISCOUS-DRAW, RATHER THAN GRAVITY DOMINATED FLUID FLOW IN POROUS MEDIA. THE IDEAL GEOMETRIC PATTERN ALSO ASSUMES A HOMOGENEOUS ISOTROPIC SINGLE-LAYER SYMMETRY. KOVAL'S EQUATION FOR VOLUMETRIC SWEEP EFFICIENCY AT INTERMEDIATE THROUGHPUTS, HAS BEEN COMBINED WITH CAUDLE AND WITTE'S FOR INVADDED AREA. EMPIRICAL EQUATIONS HAVE BEEN DEVELOPED THAT FIT CAUDLE AND WITTE'S BREAKTHROUGH CURVES. IT REACHES PERFECT SWEEP AT A MOBILITY RATIO OF ZERO RATHER THAN 0.17. EFFECTS OF VARIOUS FACTORS INCLUDING INITIAL GAS SATURATION, MOBILE WATER SATURATION, RESERVOIR STRATIFICATION, AND FLUID DENSITY DIFFERENCES ARE CONSIDERED.

OIL RECOVERY FOR A SERIES OF ASSUMED SLUG SIZES IN A FIVE-SPOT CO₂ SLUG WATERFLOOD PILOT TEST HAVE BEEN ESTIMATED BY THIS CORRELATION. ECONOMIC OPTIMUM SLUG SIZE VARIES WITH CO₂ COST. PERFORMANCE PREDICTION IS THEREFORE IMPORTANT TO PROPER ECONOMIC EVALUATION. A CORRELATION FOR EVALUATING OPTIMUM CO₂ SLUG SIZE AND PROJECT PROFITABILITY HAS ALSO BEEN DEVELOPED.

COMMENTS:

- 1. THE PROPOSED CORRELATION SHOULD BE USEFUL FOR ENGINEERING ESTIMATION.
2. ANY CORRELATION SHOULD BE USED WITH CAUTION, UNTIL ITS APPLICABILITY TO PARTICULAR SITUATIONS HAS BEEN ESTABLISHED. IN PARTICULAR, THIS PAPER WOULD NOT BE APPLICABLE TO TERTIARY MISCIBLE METHODS OR RESERVOIRS WITH GRAVITY EFFECTS.

EXHIBITS:

----- 2 TABLES, 4 FIGURES

ADDITIONAL REFERENCES:

----- A TOTAL OF 84 REFERENCES IN ADDITION TO THOSE IN THE MASTER LIST OF THIS STUDY ARE CITED.

CROSS REFERENCES:

-
6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
29. HABERMANN: TRANS., AIME (1960) 264.

31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
42. KOVAL: TRANS., AIME (1963) 145.
51. SIMON, GRAUE: TRANS., AIME (1965) 102.
69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
S 16. LEE: OIL & GAS J. (OCT. 28, 1968) 84.
S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.

KEYWORDS:

ANALYTICAL MODELLING
MIXING ZONE MODELS

BUCKLEY-LEVERETT MODELLING
OTHER MODELLING

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101. HEARN, C.L. AND RELPH, J.L.: "HIGH DENSITY MISCIBLE FLUID INJECTION WITH AQUIFER ENCROACHMENT", U.S. PATENT 3,687,198 (AUG. 22, 1972).

ABSTRACT:

----- IN THIS INVENTION, A METHOD OF CONTROLLING WATER INFLUX AND IMPROVING OIL RECOVERY BY INJECTING A HIGH DENSITY OIL-MISCIBLE FLUID AT THE WATER-OIL CONTACT IS DESCRIBED. THE DENSITY OF THE INJECTED FLUID MUST BE INTERMEDIATE BETWEEN THAT OF THE AQUIFER WATER AND THE RESERVOIR OIL, SO THAT THE AQUIFER WATER DOES NOT OVERRIDE THE RESERVOIR OIL. THE FLUID RENDERS RESERVOIR OIL MORE MOBILE BY DISSOLVING AND SWELLING IT. WITH THIS ARRANGEMENT, OIL DISPLACEMENT BY THE AQUIFER WATER IS MORE EFFICIENT AND LESS RESIDUAL OIL IS LEFT BEHIND THE DRIVEN OIL BANK. THE WATER DRIVE UNDER THE ARRANGEMENT IS NOT INHIBITED BY GRAVITY SEGREGATION. IT IS CLAIMED THAT CARBON DIOXIDE IS A MISCIBLE GAS SUITED FOR THIS PURPOSE. MISCIBILITY CAN BE ACHIEVED BETWEEN CO₂ AND THE RESERVOIR FLUID AT THE PREVAILING RESERVOIR TEMPERATURE BY MAINTAINING THE RESERVOIR AT A SUFFICIENTLY HIGH PRESSURE.

STUDIES WERE CONDUCTED IN THE LABORATORY TO OBTAIN DATA FOR EVALUATING CO₂ MISCIBLE GAS DISPLACEMENT OF RESERVOIR OIL. THE INJECTION PRESSURES DURING THE TESTS WERE BETWEEN 1200 PSIG AND 4,900 PSIG AT TEMPERATURES OF 92 F AND 194 F. THE RECOVERIES OBTAINED WERE BETWEEN 85% AND 99% OF THE OIL IN THE CORE. CARBON DIOXIDE ALSO HAS OTHER ADVANTAGES FOR MISCIBLE DISPLACEMENT THAT ARE PRESENTED.

COMMENTS:

- 1. THIS PATENT DOCUMENTS THE FACT THAT, UNDER CERTAIN CONDITIONS, CO₂ DENSITY MAY EXCEED OIL DENSITY.
2. THE INVENTION IS ONE OF THE METHODS OF USING CO₂ TO MISCIBLY DISPLACE RESERVOIR OIL, AND, IF SUCCESSFUL, MIGHT PROVE TO REDUCE CO₂ REQUIREMENTS UNDER CERTAIN SPECIAL RESERVOIR CONDITIONS.
3. THE PROBLEM OF WATER CONING MAY RENDER THE PROCESS LESS EFFICIENT.

EXHIBITS:

----- 6 FIGURES

CROSS REFERENCES:

- 46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).

KEYWORDS:

PURE CARBON DIOXIDE BEHAVIOR
DENSITY
SOLUBILITY

HYDROCARBON COMPONENTS
OIL SWELLING
U.S. PATENT

102. HSI, C. AND LU, B.: "VAPOR-LIQUID EQUILIBRIA OF HYDROCARBON SYSTEMS CONTAINING HYDROGEN SULFIDE AND CARBON DIOXIDE", CAN. J. CH. ENG. (FEB., 1972) V.50, 144-147.

ABSTRACT:

----- A PREVIOUS METHOD OF PREDICTING PHASE EQUILIBRIA OF NORMAL FLUID MIXTURES HAS BEEN MODIFIED AND EXTENDED TO NINE BINARY AND THREE TERNARY HYDROCARBON SYSTEMS CONTAINING HYDROGEN SULFIDE AND CARBON DIOXIDE. THE PREVIOUS METHOD INVOLVES AN ITERATION SCHEME THAT EMPLOYS THE REDLICH-KWONG EQUATION OF STATE. THE MODIFICATION CALLS FOR THE DETERMINATION OF THE SYSTEM PRESSURE BY ADOPTING A FALSE POSITION METHOD. PROBLEMS OF UNDERFLOW AND OVERFLOW HAVE BEEN ELIMINATED AND CONVERGENCE IS MORE RAPIDLY ACHIEVED.

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VAPOR-LIQUID EQUILIBRIA HAVE BEEN PREDICTED SATISFACTORILY BY THE NEW APPROACH. HOWEVER, LARGE DEVIATIONS EXIST BETWEEN THE PREDICTED AND LITERATURE VALUES FOR THE BINARY CARBON DIOXIDE-METHANE SYSTEM, DUE TO THE SCATTERING OF EXPERIMENTAL RESULTS. ALL THE OTHER SYSTEMS PREDICTED, INCLUDING THE CARBON DIOXIDE-PROPANE, THE CARBON DIOXIDE-BUTANE, AND THE HYDROGEN SULFIDE-N-BUTANE SYSTEMS, WERE IN GOOD AGREEMENT WITH EXPERIMENTAL RESULTS. AZEOTROPIC POINTS HAVE BEEN PREDICTED WITH AVERAGE DEVIATION OF 1.8% AND 1% FOR THE HYDROGEN SULFIDE-ETHANE SYSTEM AT 70 F AND HYDROGEN SULFIDE PROPANE SYSTEM AT 100 F RESPECTIVELY. THREE TERNARY SYSTEMS AT SIX CONDITIONS WERE ALSO PREDICTED WITH 0.3% AVERAGE DEVIATION.

COMMENTS:

----- THE METHOD PRESENTED IN THIS PAPER IS NOT AS COMPLETE AS MORE RECENT WORK (E.G. FUSSELL & YANOSIK, 1975).

EXHIBITS:

----- 2 TABLES, INCLUDING FLOW SHEET FOR IMPROVED CALCULATION METHOD, 7 FIGURES.

ADDITIONAL REFERENCES:

----- REDLICH AND KWONG: CHEM. REV. (1949) V.44, 233.

CROSS REFERENCES:

5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.

KEYWORDS:

CORRELATIONS
HYDROCARBON COMPONENTS
BINARY SYSTEMS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE

GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF PRESSURE
OTHER PHYSICAL PROPERTIES

103. KESTIN, J., RO, S.T. AND WAKEHAM, W.A.: "VISCOSITY OF CARBON DIOXIDE IN THE TEMPERATURE RANGE 25-700 C", J. CH. PH. (APR. 15, 1972) V.56, NO.8, 4114-4118.

ABSTRACT:

----- A PRECISE DETERMINATION OF VISCOSITY OF CARBON DIOXIDE AT A PRESSURE OF 1 ATM AND A HIGH TEMPERATURE RANGE OF 25 C TO 700 C IS PRESENTED. ROTATIONAL COLLISION NUMBERS FOR CARBON DIOXIDE HAVE BEEN ESTABLISHED. BOTH THE KINETIC THEORY OF POLYATOMIC GASES AND RELIABLE THERMAL CONDUCTIVITY DATA WERE USED. BOTH ROTATIONAL AND VIBRATIONAL MOTIONS CONTRIBUTE TO THE INTERNAL SPECIFIC HEAT OF CARBON DIOXIDE. THESE ARE OF THE SAME ORDER OF MAGNITUDE AND CAN BE EQUATED TO THE SELF-DIFFUSION COEFFICIENT OF CO₂. THE CALCULATED ROTATIONAL COLLISION NUMBERS ARE IN GOOD AGREEMENT WITH THOSE MEASURED DIRECTLY.

COMMENTS:

----- THIS PAPER IS OF LITTLE INTEREST TO THE PETROLEUM INDUSTRY.

EXHIBITS:

----- 4 TABLES, 3 FIGURES

KEYWORDS:

PURE CARBON DIOXIDE BEHAVIOR
VISCOSITY

EFFECTS OF TEMPERATURE
DIFFUSION COEFFICIENTS

104. MASSEY, J.A. AND CRAMER, T.D.: "CARBON DIOXIDE INJECTION MAY GIVE HIGH SACROC OIL RECOVERY", OIL & GAS J. (APR. 10, 1972) 124-138.

ABSTRACT:

----- THE SACROC UNIT LOCATED IN SCURRY COUNTY, WEST TEXAS COMPRISES 98% OF THE KELLY-SNYDER FIELD. THE FIELD WAS DISCOVERED IN 1948 AND BY 1951 MORE THAN 2,000 WELLS HAD BEEN DRILLED. THE RESERVOIR PRESSURE FELL RAPIDLY, AND IT BECAME APPARENT THAT A PRESSURE MAINTENANCE PROGRAM WOULD BE REQUIRED. THE UNIT WAS FORMED IN 1953, AND A WATERFLOOD PROJECT WAS STARTED IN 1954.

THE WATERFLOOD PROJECT WAS VERY SUCCESSFUL. AN ULTIMATE RECOVERY OF APPROXIMATELY 50% OF THE OIL IN PLACE WAS EXPECTED. THE ESTIMATED PRIMARY RECOVERY EFFICIENCY WAS ONLY 18%. A STUDY OF ENHANCED RECOVERY METHODS INDICATED THAT A CO₂ SLUG DRIVEN BY WATER WAS MOST FEASIBLE. LABORATORY TESTS CONFIRMED CO₂ MISCIBILITY WITH SACROC CRUDE OIL AT THE PREVAILING RESERVOIR TEMPERATURE AND PRESSURE. IT WAS ESTIMATED THAT A 20% HYDROCARBON PORE VOLUME SLUG OF CO₂ WOULD BE OPTIMUM. AN ADDITIONAL 16% OF THE OIL IN PLACE WAS EXPECTED OVER WATERFLOODING. THE PROJECT WAS APPROVED BY THE TEXAS RAILROAD COMMISSION IN DECEMBER, 1969 AND THE UNIT ALLOWABLE WAS INCREASED FROM 174 MBPD TO 244 MBPD.

FURTHER STUDIES SHOWED THAT ALTERNATE CO₂ AND WATER INJECTION WOULD RECOVER MORE OIL THAN A CONTINUOUS CO₂ SLUG FOLLOWED BY WATER. MISCIBILITY PRESSURE WAS EXPECTED TO BE IN THE RANGE OF 1,450 TO 1,600 PSI. PREWATER INJECTION STARTED IN WELLS WHOSE BOTTOM HOLE PRESSURES WERE BELOW 1600 PSI. A 6% PV CO₂ SLUG WAS INJECTED FOLLOWING SUFFICIENT INCREASE IN RESERVOIR PRESSURE BY THE PREWATER INJECTION. THIS WAS FOLLOWED BY A 37% PV SLUG OF WATER. ALTERNATE CO₂ AND WATER INJECTION CONTINUED UNTIL A TOTAL OF 20% PV OF CO₂ HAD BEEN INJECTED. AN ADDITIONAL 230 MILLION BARRELS OF OIL IS EXPECTED TO BE RECOVERED FROM SACROC UNIT AS AS RESULT OF THE MISCIBLE PROJECT FOR 630 BCF OF CO₂ INJECTION.

COMMENTS:

- 1. ONE QUESTIONS HOW MUCH THE INCREASE OF ALLOWABLE INFLUENCED THE DECISION TO ATTEMPT A MISCIBLE FLOOD.
2. EXTENSIVE AUXILLARY OPERATIONS INCLUDING THE SUPPLY AND TRANSPORTATION OF CO₂ AND THE NETWORK DISTRIBUTION OF THE PRODUCTION ARE DISCUSSED IN THE ARTICLE.
3. THIS PAPER WAS FIRST PRESENTED AT THE 2ND ANNUAL MEETING OF API DIVISION OF PRODUCTION, HOUSTON (MARCH, 1972) AND WAS ORIGINALLY ENTITLED "CARBON DIOXIDE INJECTION PROJECT SACROC UNIT, SCURRY COUNTY, TEXAS".

EXHIBITS:

----- 7 FIGURES

KEYWORDS:

----- CARBONATE FIELD

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WATER INJECTION
FIELD MISCIBLE APPLICATION
FIELD ECONOMICS
OPERATIONS
CO2 SOURCE
TRANSPORTATION

FIELD TERTIARY RECOVERY
MOBILITY CONTROL
FACILITIES
OTHER FIELD INFORMATION
CO2 SUPPLY
MISCELLANEOUS DATA

105. TODD, M.R. AND LONGSTAFF, W.J.: "THE DEVELOPMENT, TESTING, AND APPLICATION OF A NUMERICAL SIMULATOR FOR PREDICTING MISCIBLE FLOOD PERFORMANCE", J. PET. TECH. (JULY, 1972) 874-882.

ABSTRACT:

----- A METHOD OF MODIFYING AN EXISTING 3-PHASE SIMULATOR TO PROPERLY SIMULATE A MISCIBLE DISPLACEMENT IS PRESENTED. DISPERSION EFFECTS ON EFFECTIVE FLUID PROPERTIES HAVE BEEN REPRESENTED EMPIRICALLY. PUBLISHED RESULTS OF PHYSICAL MODEL EXPERIMENTS WERE PREDICTED. GREENKORN, ET AL'S EXPERIMENTS ON MISCIBLE DISPLACEMENT IN DEVELOPED FIVE-SPOTS WERE ALSO DUPLICATED BY THE MODEL. A MODEL EVALUATION OF AN ALTERNATIVE CONFIGURATION FOR HIGH PRESSURE GAS MISCIBLE FLOODING IN A WATERED-OUT FIELD IS ALSO PRESENTED.

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MODEL PREDICTIONS ARE AFFECTED BY THE CHOICE OF A MIXING PARAMETER. ALL EXPERIMENTAL DATA CONSIDERED WERE BRACKETED BY PREDICTIONS BASED ON MIXING PARAMETER VALUES BETWEEN 0 AND 1. PHYSICAL MODEL EXPERIMENTS AGREED WITH MODEL PREDICTIONS WITH A VALUE OF TWO-THIRDS. GREENKORN, ET AL'S EXPERIMENTS WERE DUPLICATED WITH A VALUE OF ONE-HALF. FIELD MISCIBLE FLOOD SHOULD BE ADEQUATELY SIMULATED WITH A MIXING PARAMETER OF THE ORDER OF ONE-THIRD.

HETEROGENEITY EFFECTS WERE SIMULATED USING PSEUDO RELATIVE PERMEABILITY CURVES; THIS IS ONLY VALID FOR A UNIT MOBILITY RATIO. THE NECESSARY MODIFICATIONS ARE INCLUDED FOR BOTH 3-COMPONENT AND 4-COMPONENT MODELS. LIMITATIONS OF THE MODEL ARE ALSO DISCUSSED. ESSENTIALLY THE MODEL IS UNSUITED FOR MULTIPLE CONTACT MISCIBLE DISPLACEMENTS, AND FOR SYSTEMS EXHIBITING STRONG GRAVITY SEGREGATION. IT IS ALSO UNSUITED FOR HIGHLY STRATIFIED RESERVOIRS WITH COMMUNICATING LAYERS.

COMMENTS:

- 1. THIS PAPER IS THE FOUNDATION FOR NUMERICAL SIMULATION OF THE MISCIBLE DISPLACEMENT PROCESS.
2. THE SUGGESTED MODIFICATIONS TO AN EXISTING 3-PHASE SIMULATOR ARE SIMPLE AND EASY TO UNDERSTAND.
3. ALTHOUGH THE MIXING PARAMETER VALUE FOR FIELD PROCESS IS SAID TO BE OF THE ORDER OF ONE-THIRD, BY MATCHING EARLY FIELD RESPONSE TO THE MISCIBLE FLOOD IT MAY BE POSSIBLE TO OBTAIN A BETTER VALUE.

EXHIBITS:

----- 11 FIGURES

ADDITIONAL REFERENCES:

----- GREENKORN, JOHNSON, AND HARING:
J. PET. TECH. (NOV., 1965) 1329.

CROSS REFERENCES:

21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
29. HABERMANN: TRANS., AIME (1960) 264.
42. KOVAL: TRANS., AIME (1963) 145.

KEYWORDS:

FINITE DIFFERENCE MODELS
COMPARISONS WITH LAB. RESULTS

MIXING ZONE MODELS
OTHER MODELLING

106. YARBOROUGH, L.: "VAPOR-LIQUID EQUILIBRIUM DATA FOR MULTI-COMPONENT MIXTURES CONTAINING HYDROCARBON AND NONHYDROCARBON COMPONENTS", J. CH. & ENG. DATA (1972) V.17, NO.2, 129-133.

ABSTRACT:

----- EXPERIMENTAL VAPOR-LIQUID EQUILIBRIUM PHASE COMPOSITION DATA AND K VALUES ARE PRESENTED FOR 43 MULTI-COMPONENT MIXTURES. THESE MIXTURES CONTAIN NORMAL PARAFFIN HYDROCARBONS (METHANE, ETHANE, PROPANE, PENTANE, HEPTANE, AND DECANE), AN AROMATIC COMPOUND (TOLUENE), AND NON-HYDROCARBON COMPONENTS (NITROGEN, CARBON DIOXIDE, AND HYDROGEN SULFIDE). THE PRESSURE RANGE IS FROM 100 TO 4,500 PSIA.

COMPONENT PURITIES WERE 99 MOLE PERCENT MINIMUM (HYDROCARBON) 99.9 MOLE PERCENT (NITROGEN), 99.99 MOLE PERCENT (CARBON DIOXIDE), AND 99.6 MOLE PERCENT (HYDROGEN SULFIDE). PURITIES WERE VERIFIED BY CHROMATAGRAPHIC AND MASS SPECTROGRAPHIC ANALYSIS. MIXTURES OF N-PARAFFINS, WITH AND WITHOUT NON-HYDROCARBON COMPONENTS, AND MIXTURES OF N-PARAFFINS AND TOLUENE, WITH AND WITHOUT NON-HYDROCARBON COMPONENTS, WERE STUDIED. DETAILED DATA ON OVERALL MIXTURE COMPOSITIONS, PHASE COMPOSITIONS, K VALUES, TOTAL VOLUMES, SATURATION PRESSURES, AND PHASE DISTRIBUTION ARE TABULATED IN THE MICROFILM EDITION OF THIS JOURNAL. THE MICROFILM EDITION ALSO CONTAINS DETAILED PHASE EQUILIBRIUM DATA ON THE METHANE-NORMAL HEPTANE BINARY AT 0 AND MINUS 40 F.

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COMMENTS:

----- THIS PAPER PRESENTS A COMPREHENSIVE COMPILATION OF EXPERIMENTAL DATA ON MULTICOMPONENT MIXTURES CONTAINING CARBON DIOXIDE, AND IS USEFUL FOR DEVELOPING AND TESTING METHODS OF CALCULATING PHASE EQUILIBRIUM DATA FOR MULTICOMPONENT MIXTURES; FOR EXAMPLE, IN DEVELOPING COMPOSITIONAL SIMULATION MODELS.

EXHIBITS:

----- ONE TABLE IS GIVEN IN THE PAPER. THREE LENGTHY TABLES (COMPRISING 61 PAGES OF DATA) ARE IN THE MICROFILM EDITION. THERE ARE 8 FIGURES.

ADDITIONAL REFERENCES:

- 1. REAMER, SAGE: J. CHEM. ENG. DATA, (1963) V.8, 508.
2. VAIROGS, KLEKERS, EDMISTER: A.I.C.H.E. J., (1971) V.17, 308.

CROSS REFERENCES:

- 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS

GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE

EFFECTS OF TEMPERATURE
EQUILIBRIUM RATIOS

DENSITY
SEPARATION

107. DICHARRY, R.M., PERRYMAN, T.L. AND RONQUILLE, J.D.:
"EVALUATION AND DESIGN OF A CO2 MISCIBLE FLOOD PROJECT --
SACROC UNIT, KELLY-SNYDER FIELD", J. PET. TECH. (NOV., 1973)
1309-1318.

ABSTRACT:

----- A SUMMARY OF THE METHODS USED IN EVALUATING
ALTERNATIVES, AND DESIGNING THE CO2 MISCIBLE FLOOD PROJECT IN
THE SACROC UNIT, KELLY-SYNDER FIELD IN SCURRY COUNTY, WEST TEXAS,
IS PRESENTED. THE FIELD WAS DISCOVERED IN 1948 AND CONTAINED AN
ESTIMATED 2.73 BILLION STB OF OIL ORIGINALLY IN PLACE. THE PRIMARY
PRODUCTION MECHANISM WAS SOLUTION GAS DRIVE WITH AN ESTIMATED 19%
OOIP ULTIMATE PRIMARY RECOVERY. THE AVERAGE RESERVOIR PRESSURE
DROPPED BY ABOUT 50% DURING THE FIRST FIVE YEARS OF PRODUCTION.
IT BECAME OBVIOUS THAT SOME FORM OF PRESSURE MAINTENANCE WAS
REQUIRED AND THE FIELD WAS UNITIZED IN MARCH, 1953.

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THE UNIT CONSTITUTES ABOUT 98% OF THE KELLY-SYNDER FIELD. A
WATER INJECTION PROGRAM STARTED IN SEPTEMBER, 1954. ALTHOUGH THE
PROJECT WAS VERY ENCOURAGING, A TECHNICAL COMMITTEE WAS FORMED
TO INVESTIGATE POTENTIAL FOR FURTHER RECOVERIES IMPROVEMENT. A
WATER-DRIVEN CO2 MISCIBLE DRIVE WAS RECOMMENDED BY THE COMMITTEE
IN 1968. THE PROJECT WAS APPROVED BY THE TEXAS RAILROAD COMMISSION
IN DEC., 1969. VARIOUS LABORATORY TESTS AND ENGINEERING STUDIES
WERE CONDUCTED. RESULTS OF TWO MODELS WERE IN RELATIVELY GOOD
AGREEMENT ON ULTIMATE RECOVERY EFFICIENCIES OF A CO2 SLUG UNDER
A WATER ALTERNATING GAS (WAG) PROCESS. THE RESULTS SHOWED THAT
ALTERNATELY INJECTING SLUGS OF CO2 AND WATER WOULD BE MORE EFFECTIVE
THAN CONTINUOUSLY INJECTING A SINGLE CO2 SLUG DRIVEN BY WATER. A
PRE-INJECTION OF WATER WAS ALSO FOUND TO IMPROVE RECOVERY. UNDER
THIS PROGRAM AN ESTIMATED 230 MILLION BBLs ADDITIONAL RECOVERY IS
EXPECTED OVER THE ORIGINAL WATERFLOOD PROGRAM.

COMMENTS:

- 1. THE PAPER CONTAINS DETAILED RESERVOIR AND RESERVOIR
FLUID DATA FOR SACROC.
2. THE MODELS USED IN THIS STUDY WERE MOBIL'S LINEAR SYSTEM
SIMULATOR AND CHEVRON'S SIMULATOR MODELED AS AN INVERTED 9-SPOT.
BOTH MODELS WERE IN GOOD AGREEMENT. THE SIMULATED RESULTS WERE
NOT COMPARED TO LABORATORY RESULTS.

EXHIBITS:

----- 7 TABLES, 5 FIGURES

CROSS REFERENCES:

- 22. HOLM: TRANS., AIME (1959) 225.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).

KEYWORDS:

----- BUCKLEY-LEVERETT MODELLING

SLIM-TUBE DISPLACEMENTS

MIXING ZONE MODELS

108. GEFFEN, T.M.: "IMPROVED OIL RECOVERY COULD HELP EASE ENERGY SHORTAGE", WORLD OIL (OCT., 1973) 84-88.

ABSTRACT:

----- FUTURE OIL SUPPLIES WILL BE DERIVED FROM FURTHER EXPLORATION, SECONDARY RECOVERY AND TERTIARY RECOVERY OPERATIONS. SECONDARY RECOVERY OPERATIONS (PRIMARY WATERFLOODING) HAVE RECOVERED MUCH OIL AT RELATIVELY LOW COSTS. TERTIARY RECOVERY PROCESSES EMERGED AS A RESULT OF ENORMOUS RESEARCH INVESTMENTS. CONTINUED LARGE INITIAL INVESTMENTS, AND LONG DELAYS IN INCOME MAY BE EXPECTED. THE FOUR TERTIARY RECOVERY METHODS WITH IMMEDIATE COMMERCIAL APPLICATION INCLUDE HYDROCARBON MISCIBLE, CO2 MISCIBLE, WATER MISCIBLE AND THERMAL PROCESSES. THE ADVANTAGES AND LIMITATIONS OF THESE PROCESSES ARE EXAMINED. SOME FUNDAMENTAL CONCEPTS AND A SCREENING GUIDE TO FIELD APPLICATION ARE ALSO PRESENTED. A BRIEF OUTLOOK FOR THE FUTURE OF TERTIARY RECOVERY IS GIVEN.

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COMMENTS:

----- 1. THIS PAPER HAS BEEN EXTRACTED FROM "IMPROVED OIL RECOVERY EXPECTATIONS WHEN APPLYING AVAILABLE TECHNOLOGY" PRESENTED AT THE 3RD ANNUAL MEETING OF API DIVISION OF PRODUCTION DENVER, COLORADO (1973).

2. THE SCREENING GUIDE INCLUDED IN THIS PAPER SUMMARIZES TENTATIVE CRITERIA FOR PROSPECTIVE CANDIDATES FOR MISCIBLE DISPLACEMENT PROCESSES.

EXHIBITS:

----- 2 TABLES INCLUDING SCREENING GUIDE, 2 FIGURES

KEYWORDS:

GENERAL ECONOMICS

SCREENING CRITERIA
MISCELLANEOUS DATA

109. HILL, E.P., POWER, G.G. AND LONGO, L.D.: "A MATHEMATICAL MODEL OF CARBON DIOXIDE TRANSFER IN THE PLACENTA AND ITS INTERACTION WITH OXYGEN", AM. J. PHYSIOLOGY (FEB., 1973) V.224, NO.2, 283-299.

ABSTRACT:

----- THIS PAPER DESCRIBES A MODEL FOR THE CALCULATION OF KINETICS AND EQUILIBRIA FOR CARBON DIOXIDE TRANSFER IN THE PLACENTA.

COMMENTS:

----- THE MODEL OF THIS PAPER MIGHT BE USEFUL FOR DEVELOPING OR MODELING SEPARATION FACILITIES.

EXHIBITS:

----- 33 TABLES, 19 FIGURES

KEYWORDS:

OTHER MODELLING

MISCELLANEOUS DATA

110. HOLM, L.W.: "RESIDUAL OIL - CAN WE RECOVER IT ECONOMICALLY ?",
PET. ENG. (DEC., 1973) 17-22.

ABSTRACT:

----- AN ADDITIONAL 1 BILLION BARRELS OF OIL ARE EXPECTED FROM SOME NINE ON-GOING ENHANCED RECOVERY PROJECTS. THE EXPECTATIONS AND PERFORMANCE OF THESE FIELD ARE BRIEFLY OUTLINED. RESIDUAL OIL RECOVERY IS AFFECTED BY VARIOUS PHYSICAL FACTORS INCLUDING CAPILLARY RETENTION FORCES, MOBILITY RELATIONSHIPS AND RESERVOIR HETEROGENEITY. THESE ARE EXAMINED BROADLY AS TO HOW THEY AFFECT THE VARIOUS ENHANCED RECOVERY PROCESSES. SEVERAL TECHNIQUES HAVE BEEN DEVELOPED THAT OVERCOME THESE PHYSICAL BARRIERS TO RESIDUAL OIL RECOVERY; HIGHLIGHTS OF THESE TECHNIQUES ARE PRESENTED.

CHANNELING, FINGERING AND GRAVITY SEGREGATION MUST BE OVERCOME TO ACHIEVE PROFITABLE OPERATIONS IN LPG, ENRICHED GAS AND HIGH PRESSURE GAS INJECTION PROCESSES. DOWNDIP FLOODING, PRE-INJECTION OF SMALL AMOUNTS OF WATER, AND ALTERNATE INJECTION OF WATER AND MISCIBLE MATERIAL ARE SOME PRACTICAL MEASURES TO COMBAT THESE PROBLEMS. ADEQUATE VOLUMES OF MISCIBLE SLUG ARE ESSENTIAL. CARBONATED WATERFLOODING HAS NOT BEEN SUCCESSFUL AS A RECOVERY PROCESS; RATHER, THE EFFECTIVE WAY TO USE CARBON DIOXIDE IN AN ENHANCED RECOVERY PROCESS IS AS A SLUG. OIL RECOVERY UNDER CO2 FLOOD IS MAXIMIZED IF A MISCIBLE DISPLACEMENT IS ACHIEVED. THE MISCIBILITY PRESSURE DEPENDS UPON THE OIL COMPOSITION AND RESERVOIR CONDITIONS OF TEMPERATURE AND PRESSURE. FUTURE APPLICATIONS OF THE VARIOUS ENHANCED RECOVERY PROCESSES WILL BE DEPENDENT UPON ECONOMIC CONSIDERATIONS. EACH PROJECT IS UNIQUE, AND THE PROFITABILITY OF EACH CASE MUST BE EXAMINED CAREFULLY.

COMMENTS:

- 1. THE TEXT WAS ABBREVIATED FROM A TALK DELIVERED UNDER THE DISTINGUISHED LECTURE SERIES.
2. ONE OF THE EXHIBITS SHOWS A SUMMARY ECONOMIC ANALYSIS OF CO2 OR CHEMICAL FLOOD. ALTHOUGH BASED ON 1973 DOLLARS, IT CAN BE USED AS A COMPARATIVE GUIDE TO ECONOMICS OF SUCH PROJECTS.

EXHIBITS:

----- 8 FIGURES

KEYWORDS:

EMULSIONS
SANDSTONE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
MOBILITY CONTROL
FIELD ECONOMICS

FOAMS
CARBONATE FIELD
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD MOBILITY RATIO
FIELD RESIDUAL SATURATIONS
OTHER FIELD INFORMATION

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111. RIGHTMIRE, C.T. AND HANSHAW, B.B.: "RELATIONSHIP BETWEEN THE CARBON ISOTOPE COMPOSITION OF SOIL CO₂ AND DISSOLVED CARBONATE SPECIES IN GROUNDWATER", WATER RESOURCES RES. (AUG., 1973) V.9, NO.4, 958-967.

ABSTRACT:

----- THIS PAPER PRESENTS A CARBONATE GEOCHEMISTRY STUDY OF AN ARTESIAN RECHARGE IN AN AREA OF WEST CENTRAL FLORIDA. SAMPLES OF SOIL GAS, SOIL ORGANIC MATTER (SOM) AND GROUND LITTER WERE COLLECTED AT SEVERAL SITES COVERING THE AREA, AND ANALYZED MASS SPECTROMETRICALLY TO DETERMINE THEIR COMPOSITION OF CARBON ISOTOPE. ADEQUATE CARE WAS TAKEN TO ENSURE GOOD SAMPLES, AND A UNIFORMITY OF SAMPLING TECHNIQUE. PUBLISHED HYDROGEOLOGICAL AND CARBONATE GEOCHEMISTRY DATA OF THIS AREA WERE BACKGROUND FOR THE PRESENT WORK. MUCH OF THE AREA IS UNDERLAIN BY A NONARTESIAN AQUIFER COMPOSED OF UNDIFFERENTIATED CLASTIC DEPOSITS, MOSTLY QUARTZ SAND AND CLAYEY QUARTZ SAND. THE AREA OF PRINCIPLE RECHARGE IS NORTH AND WEST OF POLK CITY, FLORIDA. THE CLIMATE IS SUBTROPICAL AND HAS AN AVERAGE ANNUAL TEMPERATURE OF 72 F, AND AN AVERAGE RAINFALL OF 52 INCHES. THE LUSH TROPICAL VEGETATION HAS BEEN CLEARED IN THE LAST 100 YEARS AND A GRASSLAND FLORA IS NOW DOMINANT IN SOME AREAS.

IT WAS DIFFICULT TO ESTABLISH A DEFINITIVE VALUE FOR THE COMPOSITION OF CARBON ISOTOPE IN THE ENTIRE AREA. THE ANALYSIS OF DISSOLVED CARBONATE IN THE FLONDAN ARTESIAN AQUIFER INDICATED THAT THE SOIL CO₂ SOURCE AT THE TIME OF RECHARGE WAS WITHIN THE RANGE OF -25 +/- 5%. THE VALUE USUALLY RANGES BETWEEN -18.7% AND -29.5% FOR VEGETATION, AND FROM -22.4% TO -24.1% FOR SOM. THE DOMINANT VEGETATION TYPE IN THE RECHARGE AREA AFFECTS THE CARBON ISOTOPE COMPOSITION OF THE SOIL CO₂ DISSOLVED BY INFILTRATING WATER. MORE STUDIES ARE UNDERWAY.

COMMENTS:

----- 1. THIS PAPER ON CARBONATE GEOCHEMISTRY STUDY SHOULD BE USEFUL IN ESTIMATING THE AMOUNT OF CO₂ REQUIRED FOR A MISCIBLE FLOOD, ESPECIALLY IN RESERVOIRS WITH AQUIFERS BELIEVED TO CONTAIN SOME DISSOLVED CO₂.

2. THE METHOD OF ANALYSIS CAN ALSO BE USED FOR PRODUCED FLUID FROM A CO₂ MISCIBLE FLOOD IN ORDER TO EVALUATE PERFORMANCE OF THE FLOOD.

EXHIBITS:

----- 3 TABLES, 4 FIGURES

KEYWORDS:

LAB. PROCEDURES AND APPARATUS

MISCELLANEOUS DATA

112. SHELTON, J.L. AND MORRIS, E.E.: "CYCLIC INJECTION OF RICH GAS INTO PRODUCING WELLS TO INCREASE RATES FROM VISCOUS OIL RESERVOIRS", J. PET. TECH. (AUG., 1973) 890-896.

ABSTRACT:

----- THE IMPORTANCE OF OIL VISCOSITY AND RESERVOIR ENERGY TO OIL RECOVERY IN VISCOUS-OIL RESERVOIRS IS DISCUSSED. VARIOUS METHODS ARE NOW KNOWN TO REDUCE OIL VISCOSITY AND INCREASE RESERVOIR ENERGY. THE SEPARATE EFFECTS OF VISCOSITY REDUCTION AND ENERGY INCREASE MECHANISMS IN ACHIEVING OIL RATE INCREASES FROM GAS INJECTION ARE CONSIDERED.

THE INJECTION OF COMBUSTION EXHAUST GASES CAN IMPROVE OIL RECOVERY. OIL VISCOSITY IS REDUCED BY THE ABSORPTION OF CARBON DIOXIDE IN THE CRUDE, WHILE RESERVOIR ENERGY INCREASES AT THE SAME TIME. RICH HYDROCARBON AND OTHER GASES CAN ALSO BE USED FOR THIS PURPOSE. ASPHALT PRECIPITATION CAN OCCUR IN SOME CRUDES AT HIGH PROPANE CONCENTRATION. AN UPPER LIMIT ON THE COMPOSITION OF AN ENRICHING COMPONENT AS AN INJECTED GAS SHOULD BE DETERMINED THROUGH LABORATORY TESTS. STRATIFIED RESERVOIRS GENERALLY SHOW POOR CONTACT BETWEEN INJECTED FLUID AND RESERVOIR FLUID. THE PROCESS IS ALSO NOT SUITED FOR RESERVOIRS WITH ZONES OF HIGH WATER SATURATION.

COMMENTS:

----- ALTHOUGH GAS INJECTION IN VISCOUS OIL RESERVOIRS CAN YIELD REDUCED VISCOSITY AND INCREASED RESERVOIR ENERGY AS DISCUSSED, A FEASIBILITY STUDY IS ALWAYS NECESSARY TO EVALUATE THE EFFECTIVENESS AND ECONOMICS OF THE PROCESS IN PARTICULAR RESERVOIRS.

EXHIBITS:

----- 11 FIGURES

KEYWORDS:

SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FLUE GAS FIELD APPLICATIONS

SOAK OPERATION
FIELD IMMISCIBLE APPLICATION
OTHER FIELD INFORMATION

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113. ALLEN, J.C. AND TATE, J.F.: "MULTIPLE SOLVENT MISCIBLE FLOODING TECHNIQUE FOR USE IN PETROLEUM FORMATION OVERLAYING AND IN WATER SATURATED POROUS FORMATIONS", U.S. PATENT 3,823,777 (JULY 16, 1974).

ABSTRACT:

----- THIS INVENTION RELATES TO THE USE OF MULTIPLE SOLVENT INJECTION AT AN OIL-WATER CONTACT. THE SOLVENT MUST HAVE A DENSITY INTERMEDIATE BETWEEN THAT OF THE OIL AND WATER, AND, FOR EASE OF RECOVERY OF THE SOLVENT, SHOULD HAVE A BOILING POINT LESS THAN THAT OF THE OIL. THE PATENT IS DIRECTED TO ACTIVE WATER DRIVE RESERVOIRS CONTAINING OIL WITH A VISCOSITY GENERALLY OF 50 CP OR MORE.

THE MULTIPLE SOLVENTS, WHICH MAY INCLUDE CO₂, CS₂, CARBON TETRACHLORIDE, AND LPG, BASICALLY FOLLOW ALONG THE OIL-WATER CONTACT UNTIL THEY ARE CONED INTO THE PRODUCING WELL, DURING WHICH TIME THEY DISSOLVE OIL AND REDUCE OIL VISCOSITY AND HENCE AID OIL RECOVERY. AT THE SAME TIME, WATER CONING IS REDUCED BY THE PRESENCE OF THE SOLVENT CONE.

THE PURPOSE OF MULTIPLE SOLVENTS IS TO ACHIEVE THE PROPER DENSITY AND BOILING POINT. A FIELD EXAMPLE IS PRESENTED WHERE A MIXTURE OF 62% CARBON DISULFIDE AND 38% BUTANE WAS INJECTED INTO A RESERVOIR CONTAINING 100 CP OIL; NO PERFORMANCE DATA ARE GIVEN.

COMMENTS:

----- GRAVITY STABILIZED CO₂ FLOODING WOULD APPEAR TO HAVE MORE PROMISE THAN THIS INVENTION; FURTHERMORE, IT IS NOT EVIDENT THAT WATER CONING WOULD IN FACT BE PREVENTED WITH THIS INVENTION.

EXHIBITS:

----- 1 TABLE, 1 FIGURE

KEYWORDS:

FIELD MISCIBLE APPLICATION
ADDITIVES (FIELD)
LPG
ALTERNATE TECHNOLOGIES

FIELD SECONDARY RECOVERY
FIELD MOBILITY RATIO
U.S. PATENT
SEPARATION
MISCELLANEOUS DATA

114. ANON.: "SHELL STARTS MISCIBLE CO2 PILOT IN MISSISSIPPI'S
LITTLE CREEK FIELD", OIL & GAS J. (SEP. 2, 1974) 52-53.

ABSTRACT:

----- THIS IS A NEWS ARTICLE, CONTAINING NO INFORMATION
TO APPRAISE THE SUCCESS OF CO2 FLOODING. PICTURES OF FACILITIES
ARE INCLUDED.

EXHIBITS:

----- 7 FIGURES

KEYWORDS:

SANDSTONE FIELD
FIELD MISCIBLE APPLICATION

FIELD TERTIARY RECOVERY
TRANSPORTATION

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115. BURNETT, D.B.: "SECONDARY RECOVERY USING CARBON DIOXIDE",
U.S. PATENT 3,811,502 (MAY 21, 1974).

ABSTRACT:

----- THIS INVENTION RELATES TO A PROCESS OF INJECTING A
SLUG OF CARBON DIOXIDE AT A MINIMUM MISCIBILITY PRESSURE AND
THEREAFTER DRIVING IT AND OIL TO PRODUCING WELLS. THE INVENTION
RESIDES IN THE USE OF LABORATORY SLIM-TUBE TESTS TO DETERMINE THE
MINIMUM MISCIBILITY PRESSURE, AND THEN USING A FIELD PRESSURE EQUAL
TO OR GREATER THAN THIS VALUE.

COMMENTS:

----- THE USE OF SLIM-TUBE DISPLACEMENTS TO DETERMINE THE
MINIMUM MISCIBILITY PRESSURE IS NOW A COMMONLY USED TECHNIQUE, AND
THE ART HAS ADVANCED CONSIDERABLY SINCE THE TIME OF THIS PATENT.

EXHIBITS:

----- 2 FIGURES

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
93. VAIRGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).

KEYWORDS:

SLIM-TUBE DISPLACEMENTS

TERNARY SYSTEMS
U.S. PATENT

116. BURNETT, D.B.: "SINGLE WELL OIL RECOVERY METHOD USING CARBON DIOXIDE", U.S. PATENT 3,841,406 (OCT. 15, 1974).

ABSTRACT:

----- THIS PATENT RELATES TO THE CARBON DIOXIDE SOAK PROCESS, WHEREIN A LIMITED AMOUNT OF SLIGHTLY SOLUBLE GAS IS INJECTED PRIOR TO CO2 INJECTION. METHANE, NITROGEN, OR OTHER GAS SLIGHTLY SOLUBLE IN THE OIL MAY BE USED; METHANE IS PREFERRED AS IT SWELLS THE OIL SOME AND ALSO REDUCES ITS VISCOSITY SLIGHTLY. THE SLIGHTLY SOLUBLE GAS PROVIDES ENERGY FOR PRODUCTION ON THE BACKFLOW CYCLE OF THE SOAK.

COMMENTS:

----- IT IS NOT DEMONSTRATED THAT THIS INVENTION WILL WORK ANY BETTER THAN A SOAK USING CARBON DIOXIDE ALONE.

EXHIBITS:

----- 2 TABLES

CROSS REFERENCES:

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- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
 - 26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)
 - 41. HOLM: U.S. PATENT 3,075,918 (JAN. 29, 1963 B).
 - 73. HOLM, WOERTZ: U.S. PATENT 3,411,583 (NOV. 19, 1968).
 - S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).

KEYWORDS:

OTHER LABORATORY STUDIES

U.S. PATENT

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117. BURNETT, D.B., ALSTON, R.B. AND LIM, F.H.: "SECONDARY RECOVERY USING CARBON DIOXIDE AND AN INERT GAS", U.S. PATENT 3,811,501 (MAY 21, 1974).

ABSTRACT:

----- THIS INVENTION INVOLVES USING AN INERT GAS, SUCH AS A METHANE, AIR, NITROGEN, WATER, ETC., IN A CARBON DIOXIDE SLUG FOR CO₂ MISCIBLE FLOODING. IT IS CLAIMED THAT MISCIBILITY CAN BE ACHIEVED WITH LESS CO₂ IF THE INERT GAS IS ADDED IN THE CORRECT PROPORTION

LABORATORY RESULTS USING CARBON DIOXIDE AND METHANE AT 1500 PSI AND 130 F SHOWED THAT FOR 0% METHANE, 96% RECOVERY OF THE OIL WAS OBTAINED, FOR 5% METHANE, 95% RECOVERY WAS SEEN, WHILE FOR 10% METHANE, 78% RECOVER OCCURRED; WITH 20% METHANE IN THE SLUG, ONLY 70% RECOVERY WAS OBTAINED.

COMMENTS:

----- 1. THE LABORATORY RESULTS PRESENTED DEMONSTRATE THAT LOSS OF MISCIBILITY MAY RESULT FROM ONLY A FEW PERCENT IMPURITIES.

2. LABORATORY RESULTS ARE PRESENTED ONLY FOR METHANE; IT MAY BE THAT NITROGEN OR OTHER GASES LESS SOLUBLE IN OIL WOULD HAVE AN EVEN MORE DRASTIC EFFECT ON MISCIBILITY AT SMALL CONCENTRATIONS.

3. EVEN IF A COST SAVINGS COULD BE OBTAINED BY DILUTING THE CO₂, IT IS DOUBTFUL THAT THIS SAVINGS WOULD OFFSET THE OIL LOST; HENCE, THIS INVENTION IS NOT RECOMMENDED FOR APPLICATION.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

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- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
 - 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
 - 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
 - 46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
 - 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
 - 54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
 - 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
 - 88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
 - 93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
 - 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).

KEYWORDS:

ADDITIVES (LAB. EXP.)
OTHER LABORATORY STUDIES

IMPURITIES (LAB. EXP.)
U.S. PATENT

118. BURNETT, D.B. AND LIM, F.H.: "SECONDARY RECOVERY USING MIXTURES OF CARBON DIOXIDE AND LIGHT HYDROCARBONS", U.S. PATENT 3,811,503 (MAY 21, 1974).

ABSTRACT:

----- THIS PATENT RELATES TO A MISCIBLE SLUG PROCESS WHEREIN THE SLUG IS COMPOSED IN THE MAIN PART OF CARBON DIOXIDE, WITH SOME LPG AS WELL. THE THRUST OF THE INVENTION IS THAT MISCIBILITY CAN BE ACHIEVED WITH A MIXTURE OF CO2 AND LPG AT A LOWER PRESSURE THAN WITH CO2 ALONE. CONVERSELY, FOR A GIVEN PRESSURE LIMIT, MORE OIL MAY BE RECOVERED WITH A MIXTURE OF CO2 AND LPG THAN WITH CO2 ALONE, EVEN IF MISCIBILITY IS ACHIEVED IN BOTH INSTANCES.

IN A SERIES OF SLIM TUBE TESTS, IT WAS FOUND THAT FOR A GIVEN RESERVOIR OIL AT 1250 PSI AND 130 F, 80% OIL RECOVERY WAS OBTAINED WITH A SLUG OF 100% CO2, AND 96% RECOVERY WAS OBTAINED WITH A SLUG OF 90% CO2 & 10% LPG.

COMMENTS:

----- THIS PATENT HAS PROMISE FOR EXTENDING CO2 FLOODING TO SHALLOWER RESERVOIRS OR FOR ENHANCING CO2 MISCIBLE FLOODING.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

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- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
 - 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
 - 46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
 - 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
 - 54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
 - 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
 - 88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
 - 93. VAIRGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
 - 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).

KEYWORDS:

ADDITIVES (LAB. EXP.)
U.S. PATENT

MISCIBILITY (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS
LPG

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119. DICHARRY, R.M. AND McNALLY, R.: "LANDMARK CO2 INJECTION PROJECT PAYING OFF AT SACROC", PET. ENG. (DEC., 1974) 22-25.

ABSTRACT:

----- THIS PAPER DISCUSSES THE PERFORMANCE AND PROGRESS OF THE CO2 INJECTION PROGRAM AT THE SACROC UNIT, KELLY-SNYDER FIELD, IN WEST TEXAS. THE UNIT, WHICH IS ONE OF THE BIGGEST JOINT VENTURE OPERATIONS IN THE U.S., IS BEING OPERATED BY CHEVRON OIL CO. THE UNIT IS DIVIDED INTO THREE GEOGRAPHIC AREAS SO THAT THE CO2 INJECTION CAN BE ALTERNATELY SWITCHED AMONG 9-SPOT PATTERNS FOR INJECTION IN THE THREE AREAS. CO2 INJECTION IN PHASE 1 STARTED IN JANUARY, 1972 AT A RATE OF 10 MMCFD AND EXPANDED TO A FULL-SCALE RATE OF 175 MMCFD BY MAY, 1972. 55 OF THE PLANNED 66 INJECTION WELLS WERE BEING USED. CO2 PRODUCTION WAS BEING DETECTED IN 100 OF THE 236 PRODUCING PATTERN WELLS. THE TOTAL PRODUCTION HAD REACHED 3 MMCFD BY NOVEMBER, 1972. THE HIGH CO2 CUT WELLS WERE SHUT IN UNTIL REMOVAL FACILITIES WERE INSTALLED IN JULY, 1973. OIL PRODUCTION REACHED 100 MBPD BY SEPTEMBER, 1973. THIS MORE THAN TRIPLED FROM THE INITIAL RATE OF 30 MBPD IN EARLY 1972.

IN NOVEMBER, 1973, SOME 17 PATTERNS WITH THE WORST CO2 BREAKTHROUGH WERE CONVERTED TO A THREE TO ONE WATER-TO-GAS INJECTION RATIO. CO2 INJECTION REACHED 185 MMCFD DURING OCTOBER, 1973, BUT HAD BEEN REDUCED TO 120 MCFD BY JANUARY, 1974. THE CO2 PRODUCTION, WHICH STABILIZED AT APPROXIMATELY 25 MMCFD BETWEEN FEBRUARY AND APRIL, 1974, HAD DECLINED TO 22 MMCFD BY DECEMBER. 126.3 BCF (13% PV) OF CO2 HAD BEEN INJECTED BY AUGUST, 1974 WHICH IS 65% OF THE ORIGINALLY PLANNED 20% PV. 8% OF THE CO2 INJECTED HAD BEEN PRODUCED. THE CURRENT CO2 INJECTION RATE IS BETWEEN 70 MMCFD AND 90 MMCFD. OIL PRODUCTION IS 87 MBPD WITH 56 MBPD OF WATER.

PHASE II CO2 INJECTION STARTED IN MARCH, 1974 AT AN APPROXIMATE RATE OF 72 MMCFD. ALTHOUGH SOME CO2 BREAKTHROUGH HAS BEEN OBSERVED, PRODUCED VOLUME IS STILL NOT SIGNIFICANT. PLANS ARE UNDERWAY FOR PHASE III TO START DURING THE SECOND QUARTER OF 1975. THE PRODUCTION FROM THE ENTIRE FIELD IS EXPECTED TO REACH AN AVERAGE OF 210 MBPD DURING 1975.

COMMENTS:

----- MORE PERFORMANCE BEHAVIOR OF THE SACROC UNIT IS REVIEWED. THE CO2 PROJECT HAS BEEN QUITE SATISFACTORY.

EXHIBITS:

----- 5 FIGURES

KEYWORDS:

CARBONATE FIELD
FIELD TERTIARY RECOVERY
OPERATIONS

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

120. FESMIRE, C.J., SIMON, R., DICHARRY, R.M. AND VORHIS, F.H.:
"APPLICATION OF COMPRESSIBILITY FACTORS FOR HIGH RATIO
CARBON DIOXIDE - METHANE GAS MIXTURES", PAPER 5052,
SPE-AIME 49TH ANN. FALL MTG., HOUSTON, TX. (OCT., 1974).

ABSTRACT:

----- THIS PAPER PRESENTS THE MEASURED COMPRESSIBILITY
FACTORS FOR HIGH-RATIO CO₂-NATURAL GAS MIXTURES AT SUPERCRITICAL
PRESSURE CONDITIONS. ACCURATE VALUES FOR COMPRESSIBILITY FACTORS
ARE ESSENTIAL TO PROPER DESIGN AND OPERATION OF THE SACROC UNIT
CO₂ INJECTION PROJECT, IN SCURRY COUNTY, TEXAS. THE PROJECT
REQUIRED 200 MMCFD OF CO₂ TO BE TRANSPORTED OVER 200 MILES BY A
"SUPERCRITICAL PRESSURE STATE" PIPELINE SYSTEM. THE DATA
WERE COMPARED WITH OTHER EXPERIMENTAL DATA AND VALUES CALCULATED
WITH TWO PUBLISHED CORRELATIONS. AVERAGE DIFFERENCES BETWEEN
THESE DATA AND THOSE OF REAMER WAS 3.1%, THE MAXIMUM WAS 10.9%.
REAMER'S FLUID SAMPLE DID NOT CONTAIN ANY ETHANE. THE SIGNIFICANT
DIFFERENCE BETWEEN THESE RESULTS WAS THEREFORE THE EFFECT OF ETHANE.
AVERAGE DEVIATION OF EXPERIMENTAL DATA AND THOSE OBTAINED FROM ONE
CORRELATION USING CORRESPONDING-STATE METHOD WAS 3.8%. THE
DIFFERENCE WAS AS MUCH AS 13% AT LOWER TEMPERATURES. COMPARISON
WITH ANOTHER SET OF CORRELATIONS USING THE B-W-R EQUATION OF STATE
GAVE AN AVERAGE DEVIATION OF 3.2%. LARGER DISCREPANCIES WERE
OBSERVED AT 49 F BELOW 1500 PSIA. THESE RESULTS CONFIRMED THE
NEED FOR EXPERIMENTAL DATA, ESPECIALLY IN THE CRITICAL REGION,
RATHER THAN RELYING ON ESTIMATES.

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COMMENTS:

----- THE COMPRESSIBILITY CHART PRESENTED IS ESSENTIALLY
COMPLETE FOR NORMAL PIPELINE TEMPERATURES, BUT IT WOULD BE MORE
USEFUL IF IT EXTENDED THROUGH THE RANGE OF RESERVOIR TEMPERATURES
THAT MAY BE ENCOUNTERED.

EXHIBITS:

----- 8 TABLES, 2 FIGURES

CROSS REFERENCES:

- 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.

KEYWORDS:

PURE CARBON DIOXIDE BEHAVIOR
EFFECTS OF PRESSURE
OTHER PHYSICAL PROPERTIES

EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
TRANSPORTATION

121. GUGNONI, R.J., ELDRIGE, J.W., OKAY, V.C. AND LEE, T.J.:
"CARBON DIOXIDE - ETHANE PHASE EQUILIBRIUM AND DENSITIES FROM
EXPERIMENTAL MEASUREMENTS AND THE B-W-R EQUATION",
A.I.C.H.E. J. (MAR., 1974) V.20, NO.2, 357-362.

ABSTRACT:

----- THE BEHAVIOR OF THE CARBON DIOXIDE-ETHANE MINIMUM BOILING AZEOTROPE SYSTEM WAS STUDIED IN THE LABORATORY. THE OBJECTIVE WAS TO FIND A BASIS FOR DEVELOPING CORRELATIONS FOR VAPOR-LIQUID EQUILIBRIUM COMPOSITIONS AND VAPORIZATION EQUILIBRIUM CONSTANTS. SUCH CORRELATION IS IMPORTANT FOR THE DESIGN OF EFFICIENT CRYOGENIC DISTILLATION TOWERS. TOTAL VAPOR PRESSURE AND LIQUID DENSITY WERE MEASURED AS A FUNCTION OF SATURATED LIQUID COMPENSATION AT -25 F, 0 F, AND 50 F. THE RANGE OF LIQUID COMPOSITIONS COVERED WAS 0 TO 80 MOLE % OF CO₂ AT 50 F AND 0 F TO 100% AT OTHER ISOTHERMS. THE DATA WERE ADEQUATELY CORRELATED BY THE BENEDICT-WEBB-RUBIN EQUATION WITH A MODIFIED MIXING RULE. THE MAXIMUM DEVIATION OF THE PRESSURE DATA FROM THE CORRELATING EQUATION WAS 2% AND THE AVERAGE DEVIATION WAS 0.8%. THE VAPOR-LIQUID COMPOSITION AND EQUILIBRIUM CONSTANTS FOR BOTH COMPONENTS WERE ADEQUATELY PREDICTED FOR TEMPERATURES RANGING BETWEEN -70 AND +50 F. THE COMPOSITIONS OF THE AZEOTROPE SHIFTED GRADUALLY TOWARDS A HIGHER ETHANE CONTENT AS THE TEMPERATURES AND PRESSURE DECREASED. THE BINARY INTERACTION COEFFICIENT FOR THE MODIFIED MIXING RULE WAS INVERSELY PROPORTIONAL TO THE TEMPERATURE. A COMPARISON OF THE PRESENT DEVELOPMENT AND PREVIOUS WORK IS ALSO PRESENTED.

COMMENTS:

- 1. THE ACCURACY OF THE CORRELATION AS PRESENTED BY THIS PAPER IS WITHIN ENGINEERING TOLERANCE.
2. THE CORRELATION SHOULD ALSO BE USEFUL IN THE DESIGN OF A CARBON DIOXIDE-ETHANE MISCIBLE DISPLACEMENT PROGRAM.
3. THE CORRELATION AT 100% CO₂ SYSTEM SHOULD ADEQUATELY DEPICT SLUG BEHAVIOR IN A CO₂ MISCIBLE PROCESS.

EXHIBITS:

----- 3 TABLES, 9 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
EQUILIBRIUM RATIOS

CORRELATIONS
BINARY SYSTEMS
EFFECTS OF PRESSURE
DENSITY
OTHER PHYSICAL PROPERTIES

122. HAMAM, S.E. AND LU, B.C.: "VAPOR-LIQUID EQUILIBRIUM IN THE ETHANE-CARBON DIOXIDE SYSTEM", CAN. J. CH. ENG. (APR., 1974) V.52, 283-286.

ABSTRACT:

----- VAPOR-LIQUID EQUILIBRIUM COMPOSITIONS WERE MEASURED FOR THE BINARY SYSTEM ETHANE-CARBON DIOXIDE AT TEMPERATURES FROM -60 TO +60 F AND PRESSURES FROM 100 TO 830 PSIA. THE DATA OBTAINED WERE FOUND TO BE THERMODYNAMICALLY CONSISTENT AND COMPARED FAVORABLY WITH VALUES PREDICTED WITH A MODIFIED REDLICH-KWONG EQUATION OF STATE: THE ERROR IN PRESSURE AVERAGED LESS THAN 1% AND THE ERROR IN CONCENTRATION IN THE VAPOR PHASE AVERAGED ABOUT 2%.

COMMENTS:

----- THE MODIFIED REDLICH-KWONG EQUATION ACCURATELY PREDICTS THE BEHAVIOR OF THIS SIMPLE SYSTEM.

EXHIBITS:

----- 4 TABLES, 2 FIGURES

CROSS REFERENCES:

102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE

CORRELATIONS
BINARY SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

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123. HENDERSON, L.E.: "CARBON DIOXIDE MISCIBLE DISPLACEMENT IN THE NORTH CROSS (DEVONIAN) UNIT, PROJECT DESIGN AND PERFORMANCE", PAPER 4737, SPE-AIME IMPROVED OIL RECOVERY SYMP., TULSA, OK. (APR., 1974).

ABSTRACT:

----- ESSENTIALLY THE SAME MATERIAL AS IN HENDERSON, 1974B (REF. #24), ALTHOUGH THE LATTER HAS A DIFFERENT TITLE AND HAS BEEN EDITED.

CROSS REFERENCES:

- 42. KOVAL: TRANS., AIME (1963) 145.
105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.

KEYWORDS:

FIELD SECONDARY RECOVERY
IMPURITIES (FIELD)
MIXING ZONE MODELS

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
FINITE DIFFERENCE MODELS
COMPARISONS WITH FIELD RESULTS

124. HENDERSON, L.E.: "THE USE OF NUMERICAL SIMULATION TO DESIGN A CARBON DIOXIDE MISCIBLE DISPLACEMENT PROJECT", J. PET. TECH. (DEC., 1974) 1327-1334.

ABSTRACT:

----- THE NORTH CROSS (DEVONIAN) UNIT IN WEST TEXAS ORIGINALLY CONTAINED 53 MMSTB 44 API OIL AT 104 F, 2500 PSIG. AVERAGE DEPTH IS ABOUT 5500' AND BUBBLE POINT PRESSURE WAS 232 PSIG. AVERAGE POROSITY AND PERMEABILITY ARE 21% AND 3 MD, RESPECTIVELY. THE UNIT WAS PRODUCED ON PRIMARY SOLUTION GAS DRIVE FROM 1944 UNTIL 1964, WHEN GAS REINJECTION COMMENCED. RESERVOIR PRESSURE WAS 1600 - 1700 PSIG IN MID-1971.

NUMERICAL SIMULATION WAS USED TO MATCH THE FIELD HISTORY, USING A TWO-DIMENSIONAL AREAL GRID; GAS-OIL RELATIVE PERMEABILITY WAS ADJUSTED TO MATCH GOR'S, RESERVOIR PRESSURE AND OIL PRODUCTION. UNIFORM POROSITY AND PERMEABILITY WAS ASSUMED.

FOR THE CO₂ FLOOD SIMULATION, A TWO-DIMENSIONAL VERTICAL GRID WAS USED TO ESTIMATE GRAVITY EFFECTS BY A HISTORY MATCH RUN FOLLOWED BY CO₂ INJECTION; A SIMILAR MODEL WAS USED TO DETERMINE SENSITIVITY TO BOTH GRAVITY AND RANDOM HETEROGENEITY. SUBSEQUENT COMPARISON BETWEEN THE TWO-DIMENSIONAL AREAL MODEL FOR CO₂ INJECTION AND THE TWO-DIMENSIONAL VERTICAL MODELING SHOWED SIMILAR BEHAVIOR. ALL CO₂ SIMULATIONS USED A MIXING-PARAMETERS MISCIBLE DISPLACEMENT MODEL. DIFFERENT PATTERNS AND PRODUCED GAS OPTIONS WERE MODELED, RESULTING IN THE SELECTION OF FOUR INVERTED NINE-SPOT PATTERNS AND REINJECTION OF UNSEPARATED PRODUCED GAS.

FIELD INJECTION USING 93% CO₂, 7% METHANE GAS PIPELINED 60 MILES FROM THE VAL VERDE BASIN STARTED INTO TWO WELLS IN APRIL, 1972. TWO MORE INJECTION WELLS WERE ACTIVATED IN JULY, 1972, AND TWO MORE IN NOVEMBER, 1973. INJECTIVITY HAS DECLINED GRADUALLY, INSTEAD OF INCREASING AS EXPECTED. AS OF SEPTEMBER, 1974 (0.05 HCPV INJECTED) ONE WELL HAD RESPONDED, WITH A PRODUCTION INCREASE OVER 10 MONTHS FROM ABOUT 50 TO 250 BOPD, ACCOMPANIED BY A DECREASE IN PRODUCING GOR AND MEASURABLE (ABOUT 5%) CO₂ CONCENTRATION IN THE OBSERVED GAS. PREDICTED RECOVERY DUE TO CO₂ INJECTION IS 20 MMSTB, OR 38% OF THE OIL ORIGINALLY IN PLACE, COMPOUNDED TO AN ESTIMATED ULTIMATE UNDER PRIMARY AND GAS REINJECTION OF 19%.

COMMENTS:

----- AN EARLY PREDICTION OF RESERVOIR PERFORMANCE USING KOVAL'S K-FACTOR METHOD IS MENTIONED BUT NOT SHOWN. IT WOULD BE VERY USEFUL TO PRACTICING ENGINEERS IN SMALL COMPANIES TO KNOW HOW THIS COMPARED WITH THE SIMULATOR. NO MENTION WAS MADE OF VARYING GAS-OIL RELATIVE PERMEABILITIES DURING THE 2-D VERTICAL SIMULATIONS. SINCE THESE WERE DETERMINED BY A 2-D AREAL LISTING MATCH, ITS POSSIBLE GRAVITY EFFECTS WERE NOT PROPERLY MODELED.

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EXHIBITS:

----- 14 FIGURES

CROSS REFERENCES:

42. KOVAL: TRANS., AIME (1963) 145.
105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.

KEYWORDS:

FIELD SECONDARY RECOVERY
IMPURITIES (FIELD)
MIXING ZONE MODELS

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
FINITE DIFFERENCE MODELS
COMPARISONS WITH FIELD RESULTS

125. HOLM, L.W. AND JOSENDAL, V.A.: "MECHANISMS OF OIL DISPLACEMENT BY CARBON DIOXIDE", J. PET. TECH. (DEC., 1974) 1427-1438.

ABSTRACT:

----- CARBON DIOXIDE CAN EFFICIENTLY DISPLACE OIL FROM RESERVOIRS BY VARIOUS MECHANISMS INCLUDING SOLUTION GAS DRIVE, HYDROCARBON VAPORIZATION, IMMISCIBLE DRIVE, AND DIFFERENT CONDITIONS OF MISCIBLE DRIVES. THIS PAPER PRESENTS EXPERIMENTAL DATA ILLUSTRATING THE VARIOUS CO₂ DISPLACEMENT MECHANISMS AND SHOWING HOW THEY DIFFER FROM OTHER MISCIBLE DISPLACEMENT MECHANISMS. THE EXPERIMENTS WERE CONDUCTED IN LONG SLIM TUBES PACKED WITH SAND, AND IN BEREA AND BOISE CONSOLIDATED SANDSTONE SYSTEMS OF VARIOUS LENGTHS. THE VOLUMES, VISCOSITIES AND DENSITIES OF CO₂, RESERVOIR OIL AND WATER WERE MEASURED WITH CONVENTIONAL PVT EQUIPMENT.

THE SOLUTION GAS DRIVE MECHANISM WAS CLEARLY ESTABLISHED. A HEAVY LOW GRAVITY STOCK TANK OIL WAS PARTLY RECOVERED FROM A 4 FT LONG BEREA SANDSTONE BY THIS MECHANISM. CO₂ GOES INTO SOLUTION WITH OIL INCREASING AS PRESSURE INCREASES, AND COMES OUT OF SOLUTION AS PRESSURE DECREASES. IN THIS TEST, CO₂ WAS INJECTED AT 900 PSI AND ALLOWED TO SATURATE A PORTION OF THE OIL. THE FLUIDS WERE PRODUCED FROM THE INJECTION END. 14% OF THE OIL-IN-PLACE WAS RECOVERED WHEN THE PRESSURE WAS REDUCED TO 400 PSIG. 4 1/2% MORE WAS RECOVERED AS PRESSURE DECLINED FURTHER TO 200 PSIG. OIL RECOVERY WAS ALSO ENHANCED BY SWELLING AND OIL VISCOSITY REDUCED BY CO₂.

THIS STUDY ALSO SHOWED THAT THE EXTRACTION OF HYDROCARBON (C₅ TO C₃₀) FROM CRUDE OIL IN PLACE BY CO₂ CAN ACHIEVE A DISPLACEMENT EFFICIENCY APPROACHING 100%. CO₂ DOES NOT ACHIEVE DIRECT MISCIBLE DISPLACEMENT AT PRACTICAL PRESSURES AND DOES NOT DEPEND ON LIGHT HYDROCARBONS (C₂-C₄) FOR MISCIBILITY. A CORRELATION BASED ON THE METHOD OF BENHAM ET AL IS PRESENTED TO DETERMINE THE OPTIMUM DISPLACEMENT PRESSURE FOR CO₂ FLOODS. METHANE AFFECTS THE OPTIMUM PRESSURE. ITS PRESENCE IN THE INJECTED CO₂ INCREASES THE OPTIMUM PRESSURE, WHILE ITS PRESENCE IN THE RESERVOIR OIL REDUCES THE OVERALL RECOVERY EFFICIENCY OF THE DISPLACEMENT PROCESS. ALTHOUGH LONGER TRANSITION ZONES, AND HIGHER RESIDUAL OIL ARE DEVELOPED AT LOWER PRESSURES, FAVORABLE MOBILITY IS ACHIEVED AT FLOODING PRESSURES LOWER THAN THE OPTIMUM.

COMMENTS:

- 1. THIS PAPER ESTABLISHES THE CONCEPT OF CO₂ DISPLACEMENT MECHANISMS THROUGH EXPERIMENTAL DATA.
2. THE CORRELATION PRESENTED CAN BE USED TO PREDICT PRESSURE REQUIRED FOR MISCIBLE DISPLACEMENT FOR ENGINEERING ESTIMATION.

EXHIBITS:

----- 6 TABLES, 12 FIGURES INCLUDING EXPERIMENTAL DATA.

ADDITIONAL REFERENCES:

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----- DE NEVERS: SOC. PET. ENG. J.
(MAR., 1963) 237-242.

CROSS REFERENCES:

13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
22. HOLM: TRANS., AIME (1959) 225.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
38. CRAWFORD, NEILL, BUCY, CRAWFORD: J. PET. TECH. (MAR., 1963) 237.
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
51. SIMON, GRAUE: TRANS., AIME (1965) 102.
83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.

KEYWORDS:

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
OTHER LABORATORY STUDIES

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
OIL CHARACTERIZATION (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS

126. HUANG, E.T. AND TRACHT, J.H.: "THE DISPLACEMENT OF RESIDUAL OIL BY CARBON DIOXIDE", PAPER 4735, SPE-AIME IMPROVED OIL RECOVERY SYMP., TULSA, OK. (APR., 1974).

ABSTRACT:

----- THIS PAPER PRESENTS EXPERIMENTAL DATA FOR THE DISPLACEMENT AND PHASE BEHAVIOR OF CO₂ INJECTION IN WATERED-OUT CORES. A 36 API WEST TEXAS OIL WAS INVESTIGATED AT 90 F AND 1250 PSIG. THIS STUDY SHOWED THAT CO₂ EFFICIENTLY SWELLS THE OIL. THE SWELLING OF THE OIL REACHES A MAXIMUM OF ABOUT 45% AT A CO₂ CONCENTRATION OF 70 MOLE PERCENT. A CO₂-RICH LIQUID PHASE IS FORMED IN ADDITION TO A HYDROCARBON-RICH LIQUID PHASE AT HIGHER CO₂ CONCENTRATIONS. SIGNIFICANT AMOUNTS OF LIGHT AND INTERMEDIATE HYDROCARBONS CONTAINED IN THE OIL ARE EXTRACTED INTO THE CO₂-RICH LIQUID BASE. IN THIS STUDY, THE CONTINUOUS CO₂ DRIVE PROCESS ACHIEVED A MAXIMUM RECOVERY OF 69% OF THE RESIDUAL OIL FROM A WATERED-OUT BEREA CORE, AND 66% FROM A SAND PACKED TUBE. THE MINIMUM CO₂ SLUG SIZE REQUIRED IN A WATER-DRIVEN CO₂ PROCESS FOR MAXIMUM RECOVERY WAS 42% PV FOR THE BEREA CORE AND 27% PV FOR THE SAND PACKED CORE. THE SLUG SIZES IN BOTH CASES WERE SLIGHTLY GREATER THAN THE RESIDUAL OIL SATURATIONS.

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MISCIBILITY BETWEEN CO₂ AND THE WEST TEXAS OIL WAS NOT ACHIEVED AT THE CONDITIONS INVESTIGATED. THE SITUATION REMAINED THE SAME EVEN AT 200 F AND 2000 PSIA. HOWEVER, UPON ENRICHING THE INJECTED CO₂ STREAM WITH 42% PROPANE, MISCIBILITY WAS ACHIEVED AT 90 F FOR PRESSURES ABOVE 695 PSIA. OVER 90% RECOVERY OF RESIDUAL OIL FROM THE BEREA CORE WAS RECOVERED BY THE 42% PROPANE-ENRICHED CO₂ DRIVE PROCESS. IT WAS ALSO ESTABLISHED THAT CO₂ SWELLING AND CO₂ EXTRACTION OF OIL WERE TWO DOMINANT MECHANISMS RESPONSIBLE FOR RECOVERING OIL FROM WATERED-OUT CORES DURING CO₂ INJECTION.

COMMENTS:

- 1. THE RESULTS OF THIS PAPER ON THE TOPICS OF SWELLING AND CO₂ EXTRACTION OF OIL REINFORCE THE RESULTS OF HOLM AND JOSENDAL (1974).
2. THE RESULTS INDICATING ENHANCEMENT OF MISCIBILITY BY PROPANE ENRICHMENT ARE IN ACCORD WITH THE RESULTS OF BURNETT AND LIM (1974 D).

EXHIBITS:

----- 4 TABLES, 9 FIGURES

CROSS REFERENCES:

- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
22. HOLM: TRANS., AIME (1959) 225.
31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.

141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.

KEYWORDS:

LAB. PROCEDURES AND APPARATUS
TERTIARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
OTHER LABORATORY STUDIES

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
ADDITIVES (LAB. EXP.)
LPG

127. KULKARNI, A.A., LUKS, K.D. AND KOHN, J.P.: "PHASE EQUILIBRIA BEHAVIOR OF SYSTEMS CARBON DIOXIDE - 2-METHYLNAPHTHALENE AND CARBON DIOXIDE - N-DECANE - 2-METHYLNAPHTHALENE", J. CH. & ENG. DATA (1974) V.19, NO.4, 349-354.

ABSTRACT:

----- THIS PAPER PRESENTS A PHASE BEHAVIOR STUDY OF THE CO₂-2 METHYLNAPHTHALENE BINARY SYSTEM. THE LIQUID-VAPOR, SOLID-LIQUID VAPOR, AND LIQUID-LIQUID VAPOR PHASE BEHAVIOR OF THIS SYSTEM WERE INVESTIGATED. THE LIQUID-LIQUID VAPOR EQUILIBRIA OF THE TERNARY SYSTEM CO₂ - 2 METHYLNAPHTHALENE - N-DECANE WERE ALSO STUDIED IN DETAIL. THE OBJECTIVE WAS TO OBTAIN DETAILED MULTI-COMPONENT, MULTI-PHASE DATA NEEDED TO UNDERSTAND THE SELECTIVITY BEHAVIOR OF CARBON DIOXIDE. THE DISTRIBUTION OF HYDROCARBONS IN THE INDIVIDUAL LIQUID PHASES WAS MEASURED AND THE LOCATION OF LIQUID-LIQUID-VAPOR LOCI IN A PRESSURE-TEMPERATURE SPACE WAS ESTABLISHED. LIQUID-VAPOR ISOTHERMS WERE DETERMINED ON THE BINARY SYSTEM AT FOUR DIFFERENT TEMPERATURES, THE LOWEST BEING JUST ABOVE THE MELTING POINT OF 2 METHYLNAPHTHALENE. PARTIAL MOLER VOLUMES WERE INDEPENDENT OF THE COMPOSITION OVER THE RANGE OF MOLE FRACTIONS ENCOUNTERED. THE TERNARY LIQUID-LIQUID-VAPOR LOCUS EXHIBITED EITHER AN UPPER CRITICAL SOLUTION TEMPERATURE (UCST) OF THE TWO LIQUID PHASES OR K-TYPE TERMINATION AT THE UPPER END OF THE LOCUS, DEPENDING UPON INITIAL MOLE RATIO OF THE HYDROCARBONS.

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THE CO₂-RICH LIQUID PHASE SELECTIVELY EXTRACTED LOWER ALKANES (N-DECANE) FROM MULTI-RING AROMATICS (2 METHYLNAPHTHALENE). IN GENERAL, THE CO₂-RICH LIQUID PHASE SELECTIVELY EXTRACTS THE SUBSTANCE WHICH IS MORE MISCIBLE WITH IT IN THE TEMPERATURE RANGE OF INVESTIGATION. HYPOTHETICALLY IT IS MORE USEFUL TO CONSIDER THE MISCIBILITY RELATIONSHIP OF CO₂ WITH INDIVIDUAL HYDROCARBONS, RATHER THAN ITS CHEMICAL GROUPING, WHEN CONSIDERING ITS SELECTIVE SOLVENT BEHAVIOR. THIS PAPER ALSO PRESENTS DATA ON THE DEPRESSION IN THE FREEZING POINT OF 2 METHYLNAPHTHALENE UPON THE ADDITION OF N-DECANE AT 1 ATMOSPHERE AND ON THE ELEVATION IN THE FREEZING POINT OF 2 METHYLNAPHTHALENE DUE TO PRESSURIZATION.

COMMENTS:

- 1. UNDERSTANDING OF SELECTIVE EXTRACTION CONCEPTS IS IMPORTANT TO SUCCESSFUL CO₂ MISCIBLE PROCESS. ASPHALTENES MAY BE DEPOSITED WHEN LOWER MOLECULAR WEIGHT COMPONENTS ARE EXTRACTED.
2. THE PAPER REPORTS THAT MORE WORK IS IN PROGRESS ON SOME OF THE HYPOTHESES RESULTING FROM THIS STUDY.

EXHIBITS:

----- 11 TABLES, 2 FIGURES

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.

44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
BINARY SYSTEMS
EFFECTS OF PRESSURE
MISCIBILITY, UNDIFFERENTIATED

GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE
OTHER PHYSICAL PROPERTIES

128. TAKAHASHI, S.: "THE DIFFUSION OF GASES AT HIGH PRESSURES.
V. THE DIFFUSION OF CTH₃ IN THE CO₂ - AR SYSTEM",
BULL. CH. SOC. JAPAN (JUNE, 1974) V.47, NO.6, 1342-1345.

ABSTRACT:

----- THIS PAPER PRESENTS EXPERIMENTAL DATA FOR THE
DIFFUSION COEFFICIENTS OF RADIOACTIVE METHANE (CTH₃) IN ARGON
AND IN MIXTURES OF CARBON DIOXIDE WITH ARGON. THE MOLE FRACTIONS
OF ARGON IN THE MIXTURE WERE 0.719, 0.497, 0.245. MEASUREMENTS
WERE MADE IN THE 15 TO 250 ATM. (225 TO 3750 PSIA) PRESSURE RANGE,
AT 25, 50 AND 75 C (77, 122 AND 167 F). THE COMPOSITIONS OF THE
MIXTURE WERE DETERMINED BY ABSORBING CARBON DIOXIDE FROM SAMPLES
INTO A POTASSIUM HYDROXIDE SOLUTION. THE EXPERIMENT CONFIRMED
THAT THE CONCENTRATION OF RADIOACTIVE METHANE WAS PROPORTIONAL
TO THE IONIZATION CURRENT FOR PURE ARGON AND FOR MIXTURES IN THE
RANGES INVESTIGATED.

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COMMENTS:

----- THE PAPER IS RELEVANT TO CO₂ FLOODING.

EXHIBITS:

----- 3 TABLES, 5 FIGURES

KEYWORDS:

CORRELATIONS
NON-HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
BINARY SYSTEMS
EFFECTS OF PRESSURE
DIFFUSION COEFFICIENTS

129. WHELAN, T.: "METHANE, CARBON DIOXIDE AND DISSOLVED SULFATE FROM INTERSTITIAL WATER OF COASTAL MARSH SEDIMENTS", ESTUARINE & COASTAL MARINE SCI. (1974) V.2, 407-415.

ABSTRACT:

----- THE DEPTH DISTRIBUTIONS OF DISSOLVED METHANE, CARBON DIOXIDE, CHLORIDE AND SULFATE IN INTERSTITIAL WATERS ARE REPORTED FROM THREE SUBENVIRONMENTS IN THE COASTAL MARSH SEDIMENTS OF SOUTH LOUISIANA. RELATIVELY SMALL VERTICAL GRADIENTS OF METHANE AND CARBON DIOXIDE WITH THE LOW HYDROSTATIC HEAD ABOVE THE SEDIMENT COLUMN AND THE HIGH DEGREE OF UNCONSOLIDATION SUGGEST THAT GAS IS MIGRATING UPWARD THROUGH THE SEDIMENT COLUMN. IN TWO OF THE THREE AREAS STUDIED, THE CO₂ CONCENTRATION WAS GREATER THAN THAT PREDICTED FOR MICROBIAL REDUCTION PROCESSES.

COMMENTS:

----- THIS PAPER IS NOT REALLY RELEVANT TO CO₂ MISCIBLE FLOODING.

EXHIBITS:

----- 2 TABLES, 3 FIGURES

KEYWORDS:

MISCELLANEOUS DATA

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MISCELLANEOUS DATA

130. ALLEN, J.C. AND TATE, J.F.: "VERTICAL DOWNWARD GAS-DRIVEN MISCIBLE BLANKET FLOODING OIL RECOVERY PROCESS", U.S. PATENT 3,878,892 (APR. 22, 1975).

ABSTRACT:

----- THIS PATENT DESCRIBES A VERTICAL DOWNWARD GAS-DRIVEN MISCIBLE BLANKET OIL RECOVERY PROCESS WHEREIN THE SPREADING RATE OF THE SOLVENT BANK ON TOP OF THE OIL COLUMN IS INCREASED BY ADDING A HIGH DENSITY SOLVENT SUCH AS CARBON DISULFIDE OR CARBON TETRACHLORIDE. SUFFICIENT DENSE SOLVENT IS INJECTED ALONG WITH THE CONVENTIONAL SOLVENT TO INCREASE THE DENSITY OF THE RESULTING MIXTURE TO A VALUE ONLY SLIGHTLY LESS THAN THE DENSITY OF THE RESERVOIR OIL, SO THAT A STABLE BLANKET WILL BE MAINTAINED WITH INCREASED RATE AND EXTENT OF SPREADING OF THE SOLVENT BLANKET OR TOP OF THE OIL COLUMN. THE MISCIBLE BLANKET IS DISPLACED DOWNWARD BY INJECTING GAS SUCH AS NATURAL GAS OR CARBON DIOXIDE INTO THE UPPER PORTION OF THE RESERVOIR.

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COMMENTS:

----- 1. A LARGE RATIO BETWEEN THE APPARENT THICKNESS OF THE RESERVOIR AND THE WELL SPACING OR LATERAL EXTENT OF THE RESERVOIR WOULD BE NECESSARY FOR THIS INVENTION TO BE SUCCESSFULLY APPLIED.

2. THIS INVENTION MIGHT BE USEFUL IN EXTENDING THE GRAVITY STABILIZED CO2 MISCIBLE CONCEPT TO SHALLOWER RESERVOIRS WHERE CO2 MISCIBILITY PRESSURE CANNOT BE OBTAINED.

EXHIBITS:

----- 4 FIGURES

CROSS REFERENCES:

53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).

KEYWORDS:

OTHER FIELD INFORMATION

U.S. PATENT

131. BROWN, L.P.: "PROCESS FOR CARBON DIOXIDE MANUFACTURE",
U.S. PATENT 3,885,624 (MAY 27, 1975).

ABSTRACT:

----- THIS INVENTION RELATES TO A METHOD FOR PRODUCING
CARBON DIOXIDE FOR OIL RECOVERY. THE METHOD INVOLVES REMOVING
CARBON DIOXIDE FROM FLUE GAS, USING A BOREHOLE FOR THE SEPARATION
"VESSEL". THE CARBON DIOXIDE IS THEN INJECTED DOWN THE ANNULUS
TO THE FORMATION.

COMMENTS:

- 1. THIS INVENTION MAY BE CONSIDERED TO BE A
VARIANT OF THAT OF DOTTS AND STEVENS (1963), WHICH IS NOT EVEN
CITED BY THIS PATENT.
2. THERE ARE A LOT OF STRINGS OF PIPE IN THE HOLE WITH THIS
PROCESS.
3. THIS PATENT IS VERY SIMILAR TO BROWN (1976 A).

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
18. HAVERFIELD: U.S. PATENT 2,729,291 (JAN. 3, 1956).
39. DOTTS, STEVENS: U.S. PATENT 3,097,917 (JULY 16, 1963).
49. LEWIS: U.S. PATENT 3,193,006 (JULY 6, 1965).
81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
132. BROWN: U.S. PATENT 3,871,451 (MAR. 18, 1975 B).

KEYWORDS:

U.S. PATENT
SEPARATION

CO2 SOURCE
MISCELLANEOUS DATA

132. BROWN, L.P.: "PRODUCTION OF CRUDE OIL FACILITATED BY INJECTION OF CARBON DIOXIDE", U.S. PATENT 3,871,451 (MAR. 18, 1975).

ABSTRACT:

----- THIS PATENT IS ESSENTIALLY THE SAME AS THAT OF BROWN (1975 A), BUT IS GRANTED ON THE BASIS OF BEING A GENERAL CO2 SOURCE RATHER THAN A SOURCE OF CO2 FOR INJECTION.

EXHIBITS:

----- 1 FIGURE, IDENTICAL TO THAT OF BROWN (1975 A)

CROSS REFERENCES:

- 39. DOTTS, STEVENS: U.S. PATENT 3,097,917 (JULY 16, 1963).
81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
131. BROWN: U.S. PATENT 3,885,624 (MAY 27, 1975 A).

KEYWORDS:

U.S. PATENT
SEPARATION

CO2 SOURCE
MISCELLANEOUS DATA

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133. BURNETT, D.B. AND LIM, F.H.: "SECONDARY RECOVERY USING MIXTURES OF CARBON DIOXIDE AND LIGHT HYDROCARBONS", CAN. PATENT 980,245 (DEC. 23, 1975).

ABSTRACT:

----- THIS IS THE CANADIAN PATENT GRANTED FOR THE PROCESS OF U.S. PATENT 3,811,503 (BURNETT AND LIM, 1974 D).

CROSS REFERENCES:

- 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).

KEYWORDS:

ADDITIVES (LAB. EXP.)
CANADIAN PATENT

MISCIBILITY (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS
LPG

134. BURNETT, D.B., LIM, F.H. AND ALSTON, R.B.: "SECONDARY RECOVERY USING CARBON DIOXIDE AND AN INERT GAS", CAN. PATENT 980,244 (DEC. 23, 1975).

ABSTRACT:

----- THIS IS THE CANADIAN PATENT GRANTED FOR THE PROCESS OF U.S. PATENT 3,811,501 (BURNETT, ALTON AND LIM, 1974 C).

CROSS REFERENCES:

117. BURNETT, ALSTON, LIM: U.S. PATENT 3,811,501 (MAY 21, 1974 C).

KEYWORDS:

ADDITIVES (LAB. EXP.)
OTHER LABORATORY STUDIES

IMPURITIES (LAB. EXP.)
CANADIAN PATENT

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135. CARLIN, J.T.: "TERTIARY OIL RECOVERY PROCESS INVOLVING MULTIPLE CYCLES OF GAS-WATER INJECTION AFTER SURFACTANT FLOOD", U.S. PATENT 3,882,940 (MAY 13, 1975).

ABSTRACT:

----- THIS INVENTION RELATES TO A VARIANT OF THE SURFACTANT OR MICELLAR FLOODS, WHEREIN ALTERNATE CYCLES OF WATER AND A GAS SUCH IS CARBON DIOXIDE ARE INJECTED FOLLOWING THE SURFACTANT AND POLYMER. IN LABORATORY EXPERIMENTS, THE RESIDUAL OIL SATURATION FOLLOWING A STRAIGHT CHEMICAL FLOOD RANGED FROM 11 TO 24%; AFTER FOLLOWUP WITH ALTERNATE GAS-WATER INJECTION, THE RESIDUAL OIL SATURATION WAS 6 TO 13%.

IT IS SUGGESTED THAT THE ALTERNATING GAS-WATER SLUGS GENERATE A MIXING ACTION IN THE FORMATION CAUSING ADDITIONAL OIL TO MOVE. ALSO, THE GAS MAY DESORB SURFACTANT FROM FORMATION ROCK, MAKING MORE SURFACTANT AVAILABLE FOR OIL DISPLACEMENT.

COMMENTS:

- 1. THIS PATENT IS AN INVENTION FOR IMPROVING SURFACTANT FLOODING, RATHER THAN FOR CO2 FLOODING.
2. THE ADDITION OF A SURFACTANT MIGHT IMPROVE CO2 FLOODING.

EXHIBITS:

----- 5 TABLES, 1 FIGURES

CROSS REFERENCES:

90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
U.S. PATENT
ALTERNATE TECHNOLOGIES

TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES
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MISCELLANEOUS DATA

136. CROCKETT, D.H.: "CO2 PROFILE CONTROL AT SACROC",
PET. ENG. (NOV., 1975) 44-52.

ABSTRACT:

----- THIS PAPER DISCUSSES A SUCCESSFUL CONTROL OF CO2 INJECTION PROFILE AT THE SACROC UNIT. THIS FIELD, DISCOVERED IN 1948, PRODUCED BY SOLUTION GAS DRIVE UNTIL 1954 WHEN A CENTERLINE WATER INJECTION PROGRAM STARTED. THE WATER INJECTION MAINTAINED PRESSURE ABOVE THE BUBBLE POINT BEFORE CO2 INJECTION STARTED IN JANUARY, 1972. PROFILE COVERAGE OF THE INJECTED CO2 WAS POOR AND AND BREAKTHROUGH OCCURRED EARLY IN MANY WELLS. AS A RESULT FIELD PRODUCTION WAS CURTAILED UNTIL CO2 REMOVAL FACILITIES WERE COMPLETED. A CONSISTENTLY EFFECTIVE METHOD OF CONTROLLING THE DOWNHOLE INJECTION PROFILE HAS BEEN IDENTIFIED. IT INVOLVES PLACING A LINER ACROSS THE PAY, FOLLOWED BY THE INSTALLATION OF DOWNHOLE FLOW CONTROL EQUIPMENT. THE METHOD WAS TESTED IN TWO WELLS IN THE PHASE II PATTERN IN SACROC UNIT. THE GROSS PAY THICKNESS IN THE TWO WELLS WAS 601 FT AND 496 FT. THE WELLS WERE ORIGINALLY COMPLETED WITH 5 1/2 INCH CASING AND 4 3/4 INCH OPEN HOLE. 4 1/2 INCH LINERS WERE SET AND CEMENTED IN PLACE AFTER THE WELLS WERE UNDERREAMED. 27 INTERVALS OF 359 FT WERE PERFORATED WITH 2 JSPF. THE PERFORATIONS WERE SELECTIVELY TREATED WITH 20 GAL/FT OF 20% HYDROCHLORIC ACID. INJECTION PROFILE SURVEYS WERE RUN IN BOTH WELLS THREE WEEKS AFTER ALTERNATE CO2 AND WATER INJECTION STARTED. DOWNHOLE FLOW CONTROL EQUIPMENT WAS INSTALLED FOUR WEEKS LATER. THEN, 1.5% PV OF WATER AND CO2 WERE ALTERNATELY INJECTED. SUBSEQUENT PROFILE COVERAGE SHOWED MUCH IMPROVEMENT. ALTHOUGH CO2 BREAKTHROUGH HAD OCCURRED IN FIVE OFFSET WELLS, CO2 PRODUCTION REMAINED FAIRLY LOW. THE TWO PATTERN AREAS SHOWED BETTER PERFORMANCES THAN THE AVERAGE PATTERN IN PHASE I. ADDITIONAL DOWNHOLE FLOW CONTROL EQUIPMENT HAS BEEN INSTALLED IN OTHER PATTERNS WITH SEVERE CO2 BREAKTHROUGH; THE PRODUCED CO2 CUT WAS STABILIZED OR REDUCED BY THIS IN MOST CASES. ECONOMIC JUSTIFICATION OF THE METHOD HAS NOT BEEN FULLY ESTABLISHED.

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COMMENTS:

----- THIS METHOD OF STABILIZING THE INJECTION PROFILE APPEARS VERY PROMISING.

EXHIBITS:

----- 6 FIGURES

KEYWORDS:

CARBONATE FIELD
FIELD TERTIARY RECOVERY
FIELD ECONOMICS

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

137. DEPARTMENT OF ENERGY (FORMERLY ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION): "ENHANCED OIL AND GAS RECOVERY AND IMPROVED DRILLING METHODS", DOE QUARTERLY PUBLICATION (1975,1976,1977, 1978,1979).

ABSTRACT:

----- THESE REPORTS, WHICH ARE ISSUED QUARTERLY BY THE U.S. DEPARTMENT OF ENERGY, CONTAIN USEFUL INFORMATION ON THE OBJECTIVES, BACKGROUND, AND TECHNICAL PROGRESS OF DOE SPONSORED FIELD PROJECTS AND SUPPORTING RESEARCH. A NUMBER OF TOPICS ARE COVERED, INCLUDING CHEMICAL FLOODING, CARBON DIOXIDE INJECTION, THERMAL/HEAVY OIL PROJECTS, WESTERN GAS STUDIES, EASTERN GAS STUDIES, IMPROVED DRILLING METHODS, RESIDUAL OIL STUDIES, ENVIRONMENTAL STUDIES, AND PETROLEUM TECHNOLOGY.

THE CO2 FIELD PROJECTS INCLUDE GRANNY'S CREEK FIELD, WEST VA., GRIFFITHSVILLE FIELD, WEST VA., ROCK CREEK FIELD, WEST VA., AND WEEKS ISLAND RESERVOIR, LA. SUPPORTING RESEARCH IS BEING PERFORMED ON CORROSION PROBLEMS, OIL RECOVERY, AND DISPLACEMENT OF RESIDUAL OIL.

KEYWORDS:

GENERAL PHASE BEHAVIOR
LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
CARBONATED WATER (LAB. EXP.)
OTHER LABORATORY STUDIES
WATER INJECTION
CORROSION
CANADIAN PATENT
ALTERNATE TECHNOLOGIES

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
IMPURITIES (LAB. EXP.)
SANDSTONE FIELD
FIELD TERTIARY RECOVERY
FACILITIES
GENERAL ECONOMICS
MISCELLANEOUS DATA

138. FAULKNER, B.L.: "RESERVIOR ENGINEERING DESIGN OF TERTIARY MISCIBLE GAS DRIVE PILOT PROJECT", PAPER 5539, SPE-AIME 50TH ANN. FALL MTG., DALLAS, TX. (SEP., 1975).

ABSTRACT:

----- ALTHOUGH THE PROJECT NAME IS NOT GIVEN, THIS PAPER DESCRIBES THE USE OF A FIVE-LAYER STREAMTUBE MODEL TO MATCH WATERFLOOD RESPONSE AND TO PREDICT TERTIARY PERFORMANCE OF AN ACID-GAS (70% CO₂, 29% H₂S, 1% HC) MISCIBLE DISPLACEMENT PILOT IN THE SLAUGHTER FIELD, HOCKLEY COUNTY, TEXAS. SIX NEW INJECTION WELLS AND 2 NEW PRODUCERS WERE DRILLED TO CREATE TWO ADJACENT 6-ACRE FIVE-SPOT PATTERNS, AND WATER INJECTION BEGAN NOVEMBER 29, 1972. PRODUCTION AND INJECTION GRAPHS ARE GIVEN THROUGH MAY 1975, AS ARE RESERVOIR PARAMETERS AND GAS ANALYSES.

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ALTHOUGH A STREAMLINE MAP WAS DEVELOPED FOR THE PILOT AND SURROUNDING AREA, BOTH THE WATERFLOOD MATCH AND THE TERTIARY PREDICTIONS WERE PERFORMED WITH 1/8 OF A BOUNDED FIVE-SPOT USING 10 STREAMTUBES AND FIVE LAYERS (LAYER PROPERTIES ARE GIVEN IN THE PAPER). THE LINEAR DISPLACEMENTS MODEL USED WITHIN EACH STREAMTUBE IS NOT DESCRIBED IN DETAIL, ALTHOUGH IT IS APPARENTLY BASED ON A CORRELATION FOR MIXING IN ONE-DIMENSIONAL LABORATORY DISPLACEMENTS, INCLUDING A CORRECTION FOR MOVABLE WATER.

BASED ON THE MODEL RESULTS, A 28.6% HCPV ACID-GAS SLUG IS TO BE INJECTED, WHICH CORRESPONDS TO 20% HCPV AFTER ALLOWING FOR SOLUBILITY OF CO₂ IN WATER, INJECTED ALTERNATELY WITH WATER AT A GROSS ACID GAS-WATER RATIO OF 1.2 RESERVOIR BARRELS PER RESERVOIR BARREL, FOLLOWED BY A CHASE GAS SLUG (ALSO INJECTED ALTERNATELY WITH WATER) OF 30% HCPV. PREDICTED PEAK TERTIARY RESPONSE IS ONE-HALF THE OBSERVED PEAK WATERFLOOD RATE OF ABOUT 400 BOPD WITH ULTIMATE TERTIARY RECOVERY OF 33.1% OF OOIP, HIGHER THAN THE ESTIMATED SECONDARY ULTIMATE OF 30.3% OF OOIP.

COMMENTS:

----- 1. THIS PILOT AND ONE NEARLY (USING ENRICHED GAS) COULD PROVIDE SOME OF THE MOST SIGNIFICANT FIELD DATA YET FOR TERTIARY MISCIBLE PROCESSES, SINCE BOTH PILOTS WERE WATERFLOODED FIRST, WITH GOOD DATA COLLECTION. DATA ON BOTH PROJECTS ARE RELEASED QUARTERLY.

2. IT IS NOTEWORTHY THAT A MAJOR COMPANY, WITH SOPHISTICATED MODELING CAPABILITY, HAS USED A RELATIVELY SIMPLE STREAMTUBE MODEL FOR ACTUAL RESERVOIR DESIGN OF AN IMPORTANT PROJECT. THE AUTHOR ESSENTIALLY ATTRIBUTES THIS CHOICE TO A SAVING IN COMPUTATIONAL TIME AND REDUCTION IN NUMERICAL DISPERSION. ONE WONDERS IF A THREE-DIMENSIONAL MISCIBLE SIMULATION STUDY WOULD LEAD TO DIFFERENT DESIGN CONCLUSIONS, AND WHETHER THE METHOD ACTUALLY USED IS CONSIDERED TO BE MORE REALISTIC. SINCE OTHER WORK WITHIN THE SAME COMPANY HAS GENERATED AN APPARENTLY RELIABLE ONE-DIMENSIONAL COMPOSITIONAL DISPLACEMENT MODEL, A PRACTICAL RELIABLE MODEL MIGHT BE OBTAINED BY USING IT TO DESCRIBE EACH STREAMTUBE.

EXHIBITS:

----- 4 TABLES, 8 FIGURES

ADDITIONAL REFERENCES:

----- HALL AND GEFFEN: TRANS., AIME
(1957) V.210, 48-57.

CROSS REFERENCES:

29. HABERMANN: TRANS., AIME (1960) 264.
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD RESIDUAL SATURATIONS
COMPARISONS WITH FIELD RESULTS
CARBONATE FIELD
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
MIXING ZONE MODELS
OTHER MODELLING

139. FREY, R.P.: "WEST TEXAS UNIT RESPONDS TO CO2 FLOOD",
OIL & GAS J. (JULY 28, 1975) 99-105.

ABSTRACT:

----- THIS PAPER IS A BRIEF REPORT ON PROJECT DESIGN,
SURFACE FACILITIES, DOWN-HOLE FACILITIES, SURVEILLANCE, AND
INJECTIVITY PROBLEMS IN SHELL'S NORTH CROSS (DEVONIAN) UNIT CO2
FLOOD.

COMMENTS:

----- 1. MORE COMPLETE PERFORMANCE DATA ARE GIVEN IN
PONTIUS & THAN (1977).
2. FACILITIES DESCRIPTION IS THE MOST USEFUL CONTENT OF
THIS ARTICLE.

EXHIBITS:

----- 3 FIGURES

KEYWORDS:

FIELD SECONDARY RECOVERY
CORROSION
IMPURITIES (FIELD)
OPERATIONS
CO2 SOURCE

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
COMPRESSION
FACILITIES
OTHER FIELD INFORMATION
TRANSPORTATION

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140. SCHREMP, F.W. AND ROBERSON, G.R.: "EFFECT OF SUPERCRITICAL CARBON DIOXIDE ON CONSTRUCTION MATERIALS", SOC. PET. ENG. J. (JUNE, 1975) 227-233.

ABSTRACT:

----- LABORATORY TESTS WERE CONDUCTED TO DETERMINE THE THE EFFECT OF SUPERCRITICAL CO₂ ON WELDED X-60 PIPELINE STEEL AND OTHER MATERIALS. THE OBJECTIVE WAS TO EVALUATE THE SUSCEPTIBILITY TO DAMAGE OF THE GATHERING AND PIPELINE NETWORK AT SACROC. THE CO₂ MAY CONTAIN 3% TO 15% LIGHT HYDROCARBONS - CHIEFLY METHANE WITH UP TO 300 PPM H₂S AND SATURATING AMOUNTS OF WATER. THE LINE TEMPERATURES VARY FROM 45 TO 120 F.

PIPE SAMPLES WERE MACHINED TO A STANDARD ASA 37 1/2 DEGREE LEVEL WITH A 1/16 INCH BEAD. WELDING WAS DONE BY A CONTRACT PIPELINE WELDER TO SIMULATE FIELD CONDITIONS. TESTS WERE CONDUCTED AT VARIOUS CONDITIONS WITH CO₂ CONTAINING VARIOUS AMOUNTS OF WATER AND H₂S. A VARIETY OF CEMENT PIPE LININGS WERE ALSO EXAMINED.

THE TESTS SHOWED THAT PROPERLY WELDED X-60 PIPELINE STEEL WAS NOT SUSCEPTIBLE TO ENVIRONMENTAL FAILURE IN SUPERCRITICAL CO₂, AND CORROSION RATES WERE LESS THAN 0.02 MILS PER YEAR. CEMENT LINED PIPE SHOWED NO DETERIORATION OR SEPARATION FROM THE PIPE WALL. PLASTIC SEALS WERE SUSCEPTIBLE TO DAMAGE, ALTHOUGH SEALS CONSTRUCTED FROM TEFLON, SEMI-RIGID POLYURETHANES AND ETHYLENE PROPYLENE RUBBER WERE NOT. THIN FILM COATING AND CENTRIFUGALLY CAST CEMENT WERE FOUND TO BE ACCEPTABLE AS PIPE LININGS.

COMMENTS:

----- THE RESULTS OF THESE TESTS SHOULD BE A USEFUL GUIDE FOR FUTURE PROJECTS.

EXHIBITS:

----- 7 TABLES, 3 FIGURES

CROSS REFERENCES:

95. WEST, KROH: PET. ENG. (DEC., 1971 B) 63.

KEYWORDS:

CORROSION

OTHER LABORATORY STUDIES
MISCELLANEOUS DATA

141. SHELTON, J.L. AND SCHNEIDER, F.N.: "THE EFFECTS OF WATER INJECTION ON MISCIBLE FLOODING METHODS USING HYDROCARBONS AND CARBON DIOXIDE", SOC. PET. ENG. J. (JUNE, 1975) 217-226.

ABSTRACT:

----- A LABORATORY STUDY OF LINEAR DISPLACEMENTS IN BERE A SANDSTONE CORES IS PRESENTED. THE FOLLOWING FACTORS WERE INVESTIGATED: (1) THE DEPENDENCE OF OIL TRAPPING BY WATER ON RELATIVE PERMEABILITY AND WETABILITY; (2) THE DEVELOPMENT AND GROWTH OF FLUID BANKS; (3) A COMPARISON OF FIRST CONTACT AND MULTIPLE CONTACT MISCIBLE DISPLACEMENT UNDER BOTH SECONDARY AND TERTIARY CONDITIONS; (4) THE EFFECT OF FLOW RATE AND SYSTEM LENGTH ON MULTIPLE CONTACT MISCIBLE DISPLACEMENT; AND (5) THE DISPLACEMENT OF OIL BY THE SIMULTANEOUS INJECTION OF SOLVENT AND WATER. UNDER THE CONDITIONS OF THESE EXPERIMENTS THE FOLLOWING CONCLUSIONS WERE REACHED:

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1. OIL TRAPPED BY WATER DISPLACEMENT IN WATER WET ROCK CAN BE DETERMINED BY THE ENVELOPE BETWEEN DRAINAGE AND IMBIBITION RELATIVE PERMEABILITY CURVES.

2. TRAPPED OIL IS NOT EASILY CONTACTED BY SOLVENT IN EITHER FIRST CONTACT OR MULTIPLE CONTACT MISCIBILITY DISPLACEMENTS.

3. WETTING PHASE RESIDUAL IS MORE EASILY CONTACTED BY SOLVENT DISPLACEMENT AND IS NOT SUBJECT TO DIFFUSION EFFECTS; HENCE, MOBILE WATER WOULD HAVE LITTLE EFFECT ON MISCIBLE DISPLACEMENT IN AN OIL WET SYSTEM.

4. TERTIARY OIL CAN BE MISCIBLY DISPLACED BY SINGLE CONTACT OR MULTIPLE CONTACT MISCIBLE SOLVENTS; OIL RECOVERY AND MIXING ZONE LENGTHS ARE COMPARABLE UNDER SECONDARY AND TERTIARY CONDITIONS.

5. A VERY SHORT FLUID TRAVEL LENGTH IS REQUIRED TO DEVELOP MULTIPLE CONTACT MISCIBILITY.

6. A TERTIARY BANK WILL NOT DEVELOP IN SHORT CORES BECAUSE OF INSUFFICIENT MIXING ZONE LENGTH.

7. RESIDUAL OIL SATURATION IN MULTIPLE CONTACT MISCIBLE DISPLACEMENT INCREASES WITH INJECTION RATE DUE TO LIMITED TIME FOR DIFFUSION CONTACT OF TRAPPED OIL BY SOLVENT.

8. INJECTING BOTH WATER AND SOLVENT SIMULTANEOUSLY EFFECTIVELY DISPLACES OIL IN AN OIL WET ROCK BUT IN A WATER WET ROCK INJECTED WATER TRAPS A PORTION OF SOLVENT AND OIL.

9. IN A WATER WET SYSTEM, WATER SATURATIONS HIGHER THAN CONNATE INCREASE THE CONTACT TIME REQUIRED FOR DIFFUSION TO ASSIST IN RECOVERING THE TRAPPED NON-WETTING PHASE.

COMMENTS:

----- A THOROUGH UNDERSTANDING OF THIS PAPER IS ADVISABLE FOR ANY PERSON BEGINNING TO STUDY MISCIBLE DISPLACEMENT, PARTICULARLY MULTIPLE CONTACT PROCESSES SUCH AS CO₂. IT IS AN EXTREMELY CAREFUL INVESTIGATION OF FACTORS AFFECTING FUNDAMENTAL MECHANISMS OF THIS PROCESS.

DATA INCLUDE SHORT CORE MISCIBLE DISPLACEMENTS, CORE

PROPERTIES, COMPOSITION OF RESERVOIR OILS AND DISPLACING GASES, LONG CORE FLOODING TESTS, AND COMPARISON OF SECONDARY AND TERTIARY PERFORMANCE FOR FIRST CONTACT MISCIBLE DISPLACEMENT, RELATIVE PERMEABILITY CURVES, RECOVERY VS INJECTION CURVES, SCHEMATICS TO ILLUSTRATE BANK FORMATION, EFFECT OF CONTACT TIME ON RESIDUAL SATURATION, EFFECT OF DISPLACEMENT RATE ON RESIDUAL OIL, COMPARISON OF SECONDARY AND TERTIARY RECOVERIES BY CO₂, COMPARISON OF FIRST CONTACT AND CO₂ MISCIBLE DISPLACEMENTS, AND WETTING AND NON-WETTING PHASE MIXING BEHAVIOR.

EXHIBITS:

----- 5 TABLES, 10 FIGURES

ADDITIONAL REFERENCES:

- 1. RAIMOND AND TORCASO:
SOC. PET. ENG. J. (MAR., 1964) 49-55.
2. THOMAS, COUNTRYMAN, AND FATT: SOC. PET. ENG. J.
(SEP., 1963) 189-196.
3. OWENS AND ARCHER: J. PET. TECH. (JULY, 1971) 873-878.

CROSS REFERENCES:

- 86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

FIRST CONTACT MISCIBILITY
SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)

MULTIPLE CONTACT MISCIBILITY
TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)

142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: IMPROVED OIL-RECOVERY FIELD REPORTS, SPE-AIME QUARTERLY PUBLICATION (1975,1976,1977, 1978,1979).

ABSTRACT:

----- THE IMPROVED OIL-RECOVERY FIELD REPORTS ARE QUARTERLY PUBLICATIONS DEVELOPED FOR MORE TIMELY REPORTING ON THE PROGRESS OF ON-GOING FIELD TESTS OF IMPROVED OIL-RECOVERY METHODS. THE REPORTS INCLUDE GEOLOGICAL AND ENGINEERING DATA FROM FIELD TEST RESULTS VOLUNTARILY PROVIDED BY OPERATORS, WITHOUT INTERPRETATION AS TO TECHNICAL OR ECONOMIC MEANING. AMONG THE FIELDS COVERED ARE CHEMICAL FLOODS, COMBUSTIONS, POLYMER INJECTION, CO2 FLOOD, STEAM DRIVES, MISCIBLE GAS DRIVES, CAUSTIC WATERFLOODS, LOW-TENSION WATERFLOODS, AND COMPRESSED AIR INJECTION.

KEYWORDS:

CARBONATE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FIELD AREAL SWEEP
OPERATIONS
ENRICHED AND HIGH PRESSURE GAS
SANDSTONE FIELD
SOAK OPERATION
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD MOBILITY RATIO
FIELD RESIDUAL SATURATIONS
OTHER FIELD INFORMATION
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143. SPIVAK, A., PERRYMAN, T.L. AND NORRIS, R.A.: "A COMPOSITIONAL SIMULATION STUDY OF THE SACROC UNIT CO2 PROJECT", PANEL DISC. NO.13, ADV. IN SIMULATION OF PET. RESERVOIRS BY MATH. METHODS, WORLD PET. CONG., TOKYO, JAPAN (MAY, 1975) 187-200.

ABSTRACT:

----- THE SACROC UNIT COVERING APPROXIMATELY 5000 ACRES AND CONTAINING 1259 WELLS WAS SUCCESSFULLY SIMULATED WITH A COMPOSITIONAL MATHEMATICAL MODEL. THE EFFECTS OF VARIOUS PARAMETERS SUCH AS PRESSURE, WATER-CO2 INJECTION RATIO, AND SLUG SIZES ON FIELD PERFORMANCE WERE STUDIED. OVERALL PROJECT PERFORMANCE, ECONOMICS, AND INCREMENTAL RECOVERY WERE LESS FAVORABLE THAN ORIGINALLY EXPECTED. HOWEVER, THE STUDY SHOWED REASONABLE PROMISE. IT WAS ESTABLISHED THAT PERFORMANCE WOULD INCREASE WITH INCREASING PRESSURE. THE STUDY ALSO SHOWED THAT CO2 BREAKTHROUGH COULD BE EFFECTIVELY CONTROLLED BY INCREASING THE WATER TO CO2 INJECTION RATIO, AND DECREASING THE SLUG SIZE. BASED ON THIS INFORMATION SIXTEEN PATTERNS CONTRIBUTING THE LARGEST VOLUMES OF CO2, WERE PLACED ON THREE-TO-ONE WAG INSTEAD OF THE ONE-TO-ONE RATIO ORIGINALLY USED. AN IMMEDIATE DECREASE IN CO2 PRODUCTION WAS NOTICED FROM THESE PATTERNS, CONSISTENT WITH PREDICTIONS OF OF THE MODEL. THE SLUG SIZES WERE ALSO DECREASED FROM THE ORIGINAL PLAN. A SUMMARY OF THE PERFORMANCE HISTORY, AND THE EXPANSION PLANS IN THE SACROC UNIT, KELLY-SYNDER FIELD ARE ALSO PRESENTED.

COMMENTS:

- 1. FROM THIS STUDY, THE PRESSURE REQUIRED FOR MISCIBILITY IN THE FIELD (2700 PSI) WAS FOUND TO BE HIGHER THAN ORIGINALLY THOUGHT (1850 PSI).
2. RESERVOIR HETEROGENEITY WAS FOUND TO BE THE DOMINANT FACTOR AFFECTING PERFORMANCE AT SACROC.
3. GOOD AGREEMENT EXISTS BETWEEN SIMULATED AND ACTUAL PERFORMANCE.
4. FIGURE 5 AND TABLE III INDICATE SLIGHT PERCENTAGE GAIN FROM INCREASING PRESSURE FROM 2300 PSI TO 2700 PSI (THE REVISED MISCIBILITY PRESSURE).

EXHIBITS:

----- 7 TABLES, 8 FIGURES, INCLUDING RESULTS OF ONE-, TWO- AND THREE-DIMENSIONAL SIMULATION.

KEYWORDS:

FINITE DIFFERENCE MODELS
COMPARISONS WITH FIELD RESULTS

COMPOSITIONAL MODELS
OTHER MODELLING

144. STRELZOFF, S.: "CHOOSING THE OPTIMUM CO₂-REMOVAL SYSTEM",
CH. ENG. (SEP. 15, 1975) 115-120.

ABSTRACT:

----- THIS PAPER DISCUSSES THE ADVANTAGES AND
DISADVANTAGES OF COMMON METHODS USED IN CO₂ ABSORPTION PROCESSES.
THE OPTIMUM SYSTEM DEPENDS ON THE PRIMARY PROCESS VARIABLES
INVOLVED, AND THE TYPE OF ABSORBENT USED. TYPICAL PROCESS
VARIABLES INCLUDE ABSORPTION PRESSURE, CO₂ CONCENTRATION, THE
AMOUNT OF NON-CO₂ CONTAMINANTS PRESENT, AND THE AMOUNT OF STEAM
GENERATED. DEPENDING ON THESE, EITHER A PHYSICAL OR CHEMICAL
ABSORBENT MAY BE SELECTED. WHILE CHEMICAL ABSORBENTS REMOVE
CO₂ TO A LOWER PARTIAL PRESSURE IN A TREATED GAS, PHYSICAL
ABSORBENTS CARRY MORE CO₂ AT HIGHER CO₂ PARTIAL PRESSURE.
ECONOMICS OF CO₂ REMOVAL MAY BE IMPROVED BY UTILIZING THE
PROPORTIONALITY BETWEEN PARTIAL PRESSURES AND PHYSICAL
ABSORPTION FOR SOLVENT GENERATION BY SIMPLE FLASHING. WHILE
PHYSICAL ABSORBENTS CAN BE REGENERATED COMPLETELY BY STRIPPING
WITH AN INERT GAS, CHEMICAL SOLVENTS ARE NOT SUITABLE FOR FLASH
DESORPTION AND HAVE TO BE REGENERATED WITH HEAT. THE VAPOR-
LIQUID EQUILIBRIUM CURVES FOR CO₂ IN THE ABSORBENT AT THE
CONDITIONS OF ABSORPTION AND THE HEAT REQUIREMENTS FOR ABSORBENT
REGENERATION WITH ITS UTILITY BALANCE ARE FACTORS THAT MUST BE
CONSIDERED FOR AN OPTIMUM PROCESS FOR CO₂ REMOVAL.

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THE MOST WIDELY USED METHODS OF CO₂ REMOVAL INCLUDE WATER
SCRUBBING, ABSORPTION BY MONOETHANOLAMINE (MEA) SOLUTIONS, AND
ABSORPTION BY HOT POTASSIUM CARBONATE SOLUTIONS. THESE ARE
EXAMINED CLOSELY IN THIS PAPER.

COMMENTS:

- 1. THE PAPER COVERS THE FUNDAMENTALS OF CO₂
REMOVAL PROCESSES.
2. CO₂ REMOVAL FROM THE PRODUCTION STREAM IS AN INTEGRAL
PART OF A CO₂ INJECTION PROCESS. THE CO₂ SO REMOVED MAY BE
RECYCLED.
3. THE ECONOMICS OF A CO₂-FLOOD IS DEPENDENT ON THE
EFFICIENCY OF THE CO₂ REMOVAL UNIT.

EXHIBITS:

----- 2 TABLES, 7 FIGURES, INCLUDING SCHEMATIC DESIGNS
FOR SEVERAL METHODS OF CO₂ SEPARATION.

KEYWORDS:

MISCELLANEOUS DATA

SEPARATION
MISCELLANEOUS DATA

145. ANON.: "SACROC CO2 FLOOD PROGRESSES", OIL & GAS J.
(NOV. 15, 1976) 41.

ABSTRACT:

----- THE CO2 INJECTION PROGRAM AT SACROC IS EXPECTED TO ENTER ITS THIRD AND FINAL PHASE BEFORE THE END OF 1976. THERE HAS BEEN CONCERN OVER A SHORTAGE OF CO2 FOR INJECTION. ABOUT 130 MMCFD TO 150 MMCFD ARE CURRENTLY BEING DELIVERED. THE CO2 CONTAINS ABOUT 353 PPM OF H2S WHICH COMPLIES WITH TEXAS NEW RULE 36, GOVERNING FIELD HANDLING OF H2S. THE GAS IS SUPPLIED BY CANYON REEF CARRIERS, INC. FROM THE VAL VERDE BASIN. SOME IS ALSO PRODUCED FROM THE FIELD.

COMMENTS:

----- THIS IS A NEWS REPORT AND NOT OF TECHNICAL INTEREST.

KEYWORDS:

CO2 SOURCE

OTHER FIELD INFORMATION
CO2 SUPPLY

146. ANON.: "SHELL PLANS CO2 PILOT FOR BIG WASSON FIELD",
OIL & GAS J. (NOV. 1, 1976) 26.

ABSTRACT:

----- A CO2 INJECTION PILOT IS PLANNED FOR WASSON FIELD, DENVER UNIT, IN WEST TEXAS. THE UNIT, OPERATED BY SHELL, IS PRODUCING AN AVERAGE OF 172 B/D PER WELL IN 832 WELLS. PRODUCTION (WHICH PEAKED AT 151 MBPD IN NOVEMBER, 1975) IS CURRENTLY 145 MBPD. CUMULATIVE PRODUCTION TO DATE IS 508 MMBBL OF OIL. THE SAN ANDRES RESERVOIR WAS DISCOVERED IN 1936, AND COVERS 62,500 ACRES. THE ORIGINAL RESERVOIR PRESSURE WAS 1,805 PSI; THE CURRENT RESERVOIR PRESSURE IS 1,000 PSI. THE DENVER UNIT COVERS 25,505 ACRES WITH AN AVERAGE OIL-PAY THICKNESS OF 137 FEET AND GAS-PAY THICKNESS OF 75 FEET. THE RATIO OF GAS CAP VOLUME TO OIL VOLUME IS ESTIMATED TO BE 0.17. THE AVERAGE DEPTH TO THE TOP OF THE PAY IS 4,800 FEET.

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IT IS ESTIMATED THAT UP TO 280 MILLION BBLs OF ADDITIONAL OIL CAN ULTIMATELY BE RECOVERED BY CO2 INJECTION. A FULL-SCALE PROGRAM IS EXPECTED TO START IN THE 1980'S IF THE PILOT TEST IS SUCCESSFUL.

COMMENTS:

----- THIS ARTICLE IS A NEWS REPORT DESCRIBING THE PROPOSED FLOOD; MORE COMPLETE INFORMATION IS NOW AVAILABLE.

EXHIBITS:

----- 1 FIGURE

KEYWORDS:

CARBONATE FIELD
FIELD MISCIBLE APPLICATION

FIELD TERTIARY RECOVERY
OTHER FIELD INFORMATION

147. ARNOLD, C.W.: "CHEMICAL CHALLENGES IN THE QUEST FOR ENHANCED OIL RECOVERY", SYMP. ON ADV. IN PET. RECOVERY, NEW YORK (APR., 1976) 225-230.

ABSTRACT:

----- THIS PAPER DISCUSSES ENHANCED RECOVERY METHODS AND IN PARTICULAR THOSE PROCESSES UTILIZING AQUEOUS SOLUTIONS OF SURFACTANTS AND OR POLYMERS. THE POTENTIAL RESERVE ADDITIONS IN THE U.S. THROUGH ENHANCED RECOVERY METHODS ARE REVIEWED. THE CHALLENGES AND CONSIDERATIONS FOR EFFECTIVE APPLICATION OF THE PROCESS ARE ALSO PRESENTED.~ THE PAPER ALSO DISCUSSES THE GENERAL CONCEPT AND OUTLOOK OF THE PROCESSES.

COMMENTS:

----- THIS PAPER CONCENTRATES ON SURFACTANT AND POLYMER FLOODING. IT ONLY MENTIONED CO2 FLOODING AS ONE OF THE METHODS OF ENHANCED RECOVERY AVAILABLE.

EXHIBITS:

----- 1 FIGURE

KEYWORDS:

MISCELLANEOUS DATA

MISCELLANEOUS DATA
MISCELLANEOUS DATA

148. BRUMMETT, W.M., JR., EMANUEL, A.S. AND RONQUILLE, J.D.:
"RESERVOIR DESCRIPTION BY SIMULATION AT SACROC - A CASE
HISTORY", J. PET. TECH. (OCT., 1976) 1241-1255.

ABSTRACT:

----- IN 1971, THE SACROC ENGINEERING COMMITTEE PROPOSED
A NUMERICAL RESERVOIR-SIMULATION STUDY FOR BETTER RESERVOIR
DESCRIPTION. THE 3-PHASE, 2 DIMENSIONAL AREAL, HISTORY MATCHED
MODEL OF THE SACROC UNIT IS PRESENTED IN THIS PAPER. IT PROVIDES
A GOOD DESCRIPTION OF THE AREAL DISTRIBUTION OF PORE VOLUME, AND
TRANSMISCIBILITY DATA AS A FUNCTION OF TIME. AN EXTENSIVE
EVALUATION OF BOTH THE SIMULATION RESULTS AND THE BASIC INPUT DATA,
CONSIDERED GOOD, SHOWED THAT THE HISTORY MATCHED MODEL CLOSELY
APPROXIMATES THE ACTUAL RESERVOIR REFLECTED BY THE PERFORMANCE OF
THE ACTIVE WELLS. OTHER SIGNIFICANT BENEFITS ARE DERIVED FROM THE
STUDY. FIELD AND 2-D VERTICAL CROSS-SECTION SIMULATION DATA
INDICATE VERTICAL PRESSURE EQUILIBRIUM; HENCE, IT IS FELT THAT
THE 2-D AREAL SIMULATION SHOULD BE VALID. THE METHOD OF ROUTINE
INDIVIDUAL WELL, HISTORY MATCHED NUMERICAL SIMULATIONS, IN RESERVOIRS
CONTAINING NUMEROUS INDIVIDUAL WELL COMPLETIONS, IS UPHELD AS
ADEQUATE.

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COMMENTS:

- 1. THE PAPER DISCUSSES METHODS USED IN ARRIVING
AT THE VARIOUS INPUT DATA FOR THE SIMULATION MODEL, WHICH SHOULD
PROVE USEFUL IN MODELING OTHER CO2 FLOODS.
2. THE AUTHORS' STATEMENT THAT THE EXISTENCE OF VERTICAL PRESSUR
EQUILIBRIUM IMPLIES THAT 2-D AREAL SIMULATION IS VALID MUST BE
TAKEN WITH A GRAIN OF SALT, AS IT IS BASED ON LIMITED INFORMATION
DURING THE CO2 INJECTION PHASE AND DOES NOT EXCLUDE THE POSSIBILITY
OF GRAVITY OVERRIDE.

EXHIBITS:

----- 3 TABLES, 14 FIGURES

CROSS REFERENCES:

- 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.

KEYWORDS:

FINITE DIFFERENCE MODELS

COMPARISONS WITH FIELD RESULTS

149. BURNETT, D.B.: "SECONDARY RECOVERY USING CARBON DIOXIDE",
CAN. PATENT 981,575 (JAN. 13, 1976).

ABSTRACT:

----- THIS IS THE CANADIAN PATENT GRANTED FOR THE PROCESS
OF U.S. PATENT 3,811,502 (BURNIT, 1974 A).

CROSS REFERENCES:

115. BURNETT: U.S. PATENT 3,811,502 (MAY 21, 1974 A).

KEYWORDS:

SLIM-TUBE DISPLACEMENTS

TERNARY SYSTEMS
CANADIAN PATENT

150. CORNELIUS, A.J.: "RESERVOIR TREATMENT BY INJECTING MIXTURE OF CO2 AND HYDROCARBON GAS", U.S. PATENT 3,995,693 (DEC. 7, 1976).

ABSTRACT:

----- THIS PATENT RELATES TO THE INJECTION OF A MIXTURE OF CO2 AND HYDROCARBON GAS INTO AN OIL-BEARING FORMATION WITH ONE (OR MORE) OF THREE CONCEPTS IN MIND. FIRST BY BACKFLOWING THE INJECTION WELL, A CO2 ENRICHED STREAM IS OBTAINED, SINCE THE OIL NEAR THE INJECTION WELL WILL HAVE BEEN SATURATED BY CO2 AT THE INJECTION PRESSURE. SECONDLY, BY PRODUCING FROM AN UPDIP WELL, A HYDROCARBON ENRICHED STREAM IS OBTAINED, SINCE MUCH OF THE INJECTED CO2 WILL HAVE GONE INTO SOLUTION ALONG THE WAY FROM THE INJECTION WELL TO THE PRODUCTION WELL. FINALLY, ADDITIONAL OIL MAY BE RECOVERED FROM THE (PRESUMABLY DEPLETED AND ABANDONED) RESERVOIR AS A RESULT OF SWELLING, VISCOSITY REDUCTION, AND IN SOME INSTANCES, MISCIBILITY.

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COMMENTS:

----- 1. AS AN OIL RECOVERY METHOD, THIS PATENT IS NOT NEW, AND OTHER METHODS OF SEPARATION WOULD PROBABLY BE LESS EXPENSIVE.

2. AS A CO2 STORAGE SYSTEM WHERE RECYCLED CO2 CAN BE USED IN OTHER RESERVOIRS OR FIELDS, THIS PATENT COULD PROVE USEFUL.

3. ONE FACET NOT MENTIONED IN THIS PATENT IS A COMMONLY OBSERVED PHENOMENON OF GAS STORAGE IN DEPLETED OIL RESERVOIRS: THAT THE HYDROCARBON GAS STREAM IS ENRICHED BY ITS CONTACT WITH THE RESIDUAL OIL.

EXHIBITS:

----- 1 TABLE

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
- 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
- 26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C).
- 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
- 118. BURNETT, LIM: U.S. PATENT 3,811,503 (MAY 21, 1974 D).
- 132. BROWN: U.S. PATENT 3,871,451 (MAR. 18, 1975 B).

KEYWORDS:

FIELD TERTIARY RECOVERY
FIELD RESIDUAL SATURATIONS
OTHER FIELD INFORMATION
CO2 SOURCE

FIELD MISCIBLE APPLICATION
ADDITIVES (FIELD)
U.S. PATENT
SEPARATION

151. DAVALOS, J., ANDERSON, W.R., PHELPS, R.E. AND KIDNAY, A.J.:
"LIQUID-VAPOR EQUILIBRIA AT 250.00 K FOR SYSTEMS CONTAINING
METHANE, ETHANE, AND CARBON DIOXIDE", J. CH. & ENG. DATA
(1976) V.21, NO.1, 81-84.

ABSTRACT:

----- LIQUID-VAPOR EQUILIBRIA FOR THE BINARY SYSTEMS
METHANE-ETHANE, METHANE-CARBON DIOXIDE, AND ETHANE-CARBON DIOXIDE
AND THE TERNARY SYSTEM METHANE-ETHANE-CARBON DIOXIDE WERE MEASURED
AT 250 K (-10 F) FOR PRESSURES OF 13 TO 80 ATM (200 TO 1200 PSI).
ADDITIONAL LIQUID-VAPOR MEASUREMENTS ARE REPORTED FOR METHANE-
CARBON DIOXIDE AT 230 AND 270 K (-46 AND +26 F).

THE TERNARY SYSTEM RESULTS SHOW A MINIMUM FOR METHANE
CONCENTRATION IN THE VAPOR CURVE, WHILE THE LIQUID CURVE IS
MONOTONIC. THE TWO PHASE REGION EXPANDS AND MOVES AWAY FROM THE
METHANE AXIS AS THE PRESSURE IS INCREASED.

COMMENTS:

----- THE EXPERIMENTAL RESULTS PRESENTED HERE COMPARE
WELL WITH OTHER PUBLISHED DATA AND ARE FELT TO BE RELIABLE.

EXHIBITS:

----- 4 TABLES, 6 FIGURES

CROSS REFERENCES:

- 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
BINARY SYSTEMS
EFFECTS OF PRESSURE

HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF TEMPERATURE

152. DOSCHER, T.M. AND WISE, F.A.: "ENHANCED CRUDE OIL POTENTIAL - AN ESTIMATE", J. PET. TECH. (MAY, 1976) 575-585.

ABSTRACT:

----- THIS PAPER EXAMINES PUBLISHED API DATA ON DOMESTIC RESERVES OF CRUDE OIL IN THE U.S. AND OBSERVES THAT WHILE DOMESTIC DEMANDS ARE STRIKINGLY INCREASING, DISCOVERY RATES OF NEW RESERVES ARE LOW. THE LARGE FIELDS DISCOVERED IN THE 1930'S AND 1940'S ARE BEING DEPLETED; UNLESS NEW DOMESTIC SOURCES OF CRUDE OIL ARE DISCOVERED AND DEVELOPED SOON OR AN ECONOMICALLY VIABLE SUBSTITUTE FOR OIL IS DISCOVERED, UNPLEASANT EFFECTS WILL RESULT. THE CUMULATIVE OIL RESERVOIR RECOVERY EFFICIENCY HAS ALSO BEEN DECREASING FOR A NUMBER OF YEARS AS A RESULT OF THE SEQUENCES IN WHICH THE DIFFERENT TYPES OF FIELDS WERE DISCOVERED. IN ADDITION TO DISCOVERING LARGE NEW DOMESTIC SOURCES OF CRUDE OIL, THERE IS A POTENTIAL FOR A SIZEABLE ADDITION TO THE DOMESTIC RESERVES BY INCREASING THE RECOVERY EFFICIENCY. ALTHOUGH TARGETS CAN BE SPELLED OUT, TERTIARY RECOVERY POTENTIAL CAN NOT BE QUANTIFIED AT THIS TIME. THIS PAPER MAKES RETROSPECTIVE ANALYSIS OF RECOVERY EFFICIENCIES IN THE VARIOUS FIELDS IN THE COUNTRY; AN INCREASE IN RECOVERY EFFICIENCY EXISTS FOR ANY PARTICULAR RESERVOIR WITH TIME. TECHNOLOGICAL DEVELOPMENT MAKES THE INCREASE IN RECOVERY EFFICIENCY POSSIBLE AND PERMITS OIL TO BE PRODUCED FROM DEEPER, HIGHER PRESSURE AND HIGHER TEMPERATURE RESERVOIRS. OIL IS ALSO BEING PRODUCED FROM HOSTILE OFFSHORE AND TUNDRA ENVIRONMENTS. SECONDARY AND TERTIARY RECOVERY METHODS HAVE EMERGED AS A RESULT OF IMPROVED TECHNOLOGY. DEFINITIVE SUCCESS IS BEING ACHIEVED IN EXPERIMENTAL AND PILOT OPERATIONS. AN ADDITIONAL RECOVERY TARGET OF 1 MILLION B/D BY 1990 MAY BE DIFFICULT, BUT FORESEEABLE .

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MISCIBLE FLOODING USING CARBON DIOXIDE SHOWS GOOD PROMISE. HIGHLIGHTS OF THE PROCESS AND THE POTENTIAL OF CO2 FOR ENHANCED RECOVERY ARE ALSO PRESENTED. THE HISTORY OF LPG FLOODING OFFERS A USEFUL GUIDE FOR DEALING WITH CO2 FLOODING.

COMMENTS:

----- THIS PAPER SUGGESTS A NATIONAL ENERGY POLICY TO EXPLORE EVERY POSSIBLE WAY TO MAKE ENERGY AVAILABLE; IT IS NOT A TECHNICAL PAPER.

EXHIBITS:

----- 5 TABLES, 19 FIGURES

CROSS REFERENCES:

142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.

KEYWORDS:

CO2 SOURCE

MISCELLANEOUS DATA

153. EVELEIN, K.A., MOORE, R.G. AND HEIDEMANN, R.A.: "CORRELATION OF THE PHASE BEHAVIOR IN THE SYSTEMS HYDROGEN SULFIDE-WATER AND CARBON DIOXIDE-WATER", IND. ENG. CH., PROCESS DES. DEV., (1976) V.15, NO.3, 423-428.

ABSTRACT:

----- THIS PAPER USES THE REDLICH-KWONG EQUATION TO CORRELATE CARBON DIOXIDE-WATER AND HYDROGEN SULFIDE-WATER PHASE BEHAVIOR. EMPIRICAL INTERACTION PARAMETERS WERE EMPLOYED IN THE MIXING RULES FOR BOTH A AND B. THE THREE-PHASE PRESSURES WHICH WERE PREDICTED FOR THESE TWO SYSTEMS BY THE PROPOSED CORRELATIONS AGREE WITH EXPERIMENTAL DATA TO WITHIN 5 PSI. GOOD ACCURACY WAS OBTAINED FOR THE PREDICTED PHASE BEHAVIOR OF THE HYDROGEN SULFIDE-WATER SYSTEM TO PRESSURES OF 70 ATM (1000 PSI) AT 311 K (100 F) AND TO 200 ATM (3000 PSI) AT 444 K (340 F). THE WATER CONTENT OF SATURATED CARBON DIOXIDE WAS PREDICTED ACCURATELY UP TO 500 ATM (7500 PSI) AT 298 K (76 F) AND UP TO 1000 ATM (15,000 PSI) AT 523 K (480 F). THE CORRESPONDING CALCULATED SOLUBILITY OF CARBON DIOXIDE IN WATER IS OF VARIABLE ACCURACY, BUT IS ACCURATE TO WITHIN ABOUT 0.7 MOLE PERCENT THROUGHOUT THE RANGE OF PRESSURES AND TEMPERATURES CORRELATED.

COMMENTS:

----- THIS PAPER PRESENTS AN ESSENTIALLY COMPLETE TREATMENT OF THE CARBON DIOXIDE-WATER SYSTEM.

EXHIBITS:

----- 5 TABLES, 10 FIGURES

ADDITIONAL REFERENCES:

----- 1. WIEBE AND GADDY: J. AM. CH. SOC. (1939) V.61, 315.

2. WIEBE AND GADDY: J. AM. CH. SOC. (1940) V.62, 815.

3. WIEBE AND GADDY: J. AM. CH. SOC. (1941) V.63, 475.

THESE PAPERS CONTAIN THE EXPERIMENTAL DATA FOR THE CO₂-WATER SYSTEM.

CROSS REFERENCES:

87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.

KEYWORDS:

NON-HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE

CORRELATIONS
BINARY SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

154. FUSSELL, D.D. AND YANOSIK, J.L.: "AN ITERATIVE SEQUENCE FOR PHASE-EQUILIBRIA CALCULATIONS INCORPORATING THE REDLICH-KWONG EQUATION OF STATE", PAPER 6050, SPE-AIME 51ST ANN. FALL TECH. CONF. & EXHBN., NEW ORLEANS, LA. (OCT., 1976).

ABSTRACT:

----- A METHOD IS PRESENTED FOR CALCULATION OF PHASE EQUILIBRIA IN TWO PHASE SYSTEMS FROM THE REDLICH-KWONG EQUATION OF STATE. IN CONTRAST TO PREVIOUS METHODS, THE ONE CONTAINED IN THIS PAPER CONVERGES IN THE CRITICAL REGION AND CAN BE USED TO STUDY MULTIPLE CONTACT MISCIBLE OIL RECOVERY METHODS INVOLVING CO2 OR RICH GAS INJECTION.

EQUATIONS ARE DEVELOPED FOR PHASE ENVELOPE AND CRITICAL POINT CALCULATIONS. ERROR CRITERIA ARE GIVEN, ALONG WITH METHODS OF CHOOSING ITERATION VARIABLES. EXAMPLE APPLICATIONS INCLUDE CALCULATIONS FOR THE CARBON DIOXIDE-NORMAL BUTANE-NORMAL DECANE SYSTEM. THE METHOD CONVERGES IN THE CRITICAL REGION FOR THIS TERNARY SYSTEM. ANOTHER EXAMPLE IS THE CALCULATION OF THE MOLE FRACTION OF LIQUID VS PRESSURE IN A TWO PHASE MULTICOMPONENT RESERVOIR OIL SYSTEM.

COMMENTS:

----- SUFFICIENT DETAIL IS GIVEN TO ALLOW DEVELOPMENT OF APPROPRIATE COMPUTER PROGRAMS FOR USING THIS METHOD. REFERENCES ARE GIVEN TO CLARIFY OR EXPAND UPON THERMODYNAMIC CONCEPTS, INCLUDING THE REDLICH-KWONG EQUATION OF STATE. THE METHOD MIGHT BE USEFUL TO INVESTIGATE CHARACTERIZATION OF CRUDE OIL COMPONENTS FOR PSEUDO-TERNARY PHASE DIAGRAMS, AS WELL AS TO DEVELOP SCREENING TECHNIQUES FOR REPLACING SLIM TUBE DISPLACEMENT EXPERIMENTS.

EXHIBITS:

----- 3 TABLES, 4 FIGURES

ADDITIONAL REFERENCES:

- 1. REDLICH AND KWONG: CHEM. REV., (1949) V.44, 233.
2. ZUDKEVITCH AND JOFFE: A.I.C.H.E. J., (1970) V.16, 112-119.

KEYWORDS:

THEORETICAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS
MULTIPLE CONTACT MISCIBILITY

GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
OIL PROPERTIES CHARACTERIZATION
COMPOSITIONAL MODELS

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155. HAMAM, S.E. AND LU, B.C.: "PHASE EQUILIBRIA FOR THE SYSTEM PROPANE-ETHANE-CARBON DIOXIDE", CAN. J. CH. ENG. (AUG., 1976) V.54, 333-336.

ABSTRACT:

----- VAPOR-LIQUID EQUILIBRIUM DATA FOR THE TERNARY SYSTEM PROPANE-ETHANE-CARBON DIOXIDE WERE DETERMINED EXPERIMENTALLY AT 244 AND 267 K (-20 AND +20 F). THE PRESSURES INVESTIGATED RANGED FROM 88 TO 433 PSIA. THE DATA OBTAINED COMPARED FAVORABLY WITH THE VALUES PREDICTED WITH A MODIFIED REDLICH-KWONG EQUATION OF STATE: PRESSURES AGREED TO WITHIN 3% AND COMPOSITION OF THE VAPOR PHASE TO WITHIN 1.4 MOLE %.

COMMENTS:

----- ONE OF THE KEY RESULTS OF THIS PAPER IS THAT THE HYDROCARBON-HYDROCARBON BINARY INTERACTION COEFFICIENTS MAY BE ASSUMED TO BE ZERO WITHOUT ANY LOSS OF ACCURACY. IF THIS OBSERVATION CAN BE GENERALIZED, IT MAY BE POSSIBLE TO GREATLY REDUCE COMPUTING TIME WITH EQUATION OF STATE METHODS.

EXHIBITS:

----- 3 TABLES, 2 FIGURES

ADDITIONAL REFERENCES:

----- CHUCH AND PRAUSNITZ: IND. & ENG. CH. FUND. (1967) V.6, 492.

CROSS REFERENCES:

122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
S 49. HAMAM, LU: J. CH. & ENG. DATA (1976 A) 200.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE

CORRELATIONS
TERNARY SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS

156. HAYNES, C.A.: "HYDROCARBON RECOVERY FROM EARTH STRATA",
U.S. PATENT 3,986,556 (OCT. 19, 1976).

ABSTRACT:

----- THIS PATENT PRESENTS A METHOD FOR IN-SITU CATALYTIC
CRACKING OF OIL; A METHOD FOR IN-SITU CATALYST REGENERATION IS
ALSO PRESENTED. THE CATALYST REGENERATION PRODUCTS (CO, CO₂, AND
WATER) STIMULATE PRODUCTION BY REDUCING HYDROCARBON VISCOSITY AND
SURFACE TENSION.

COMMENTS:

----- AN ECONOMIC AND TECHNICAL EVALUATION INCLUDING THE
EFFECTS OF ABSORPTION, CATALYST DEBILITATION, RELATIVE COST OF
CATALYST AND OIL, PLUGGING, CONTACT TIME OF CATALYST WITH
REGENERATING FLUID, ETC., SHOULD DEMONSTRATE THIS PROCESS TO BE
NON-FEASIBLE.

EXHIBITS:

----- 1 TABLE, 7 FIGURES

KEYWORDS:

U.S. PATENT

ALTERNATE TECHNOLOGIES

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157. HERBECK, E.F., HEINTZ, R.C. AND HASTINGS, J.R.: "FUNDAMENTALS OF TERTIARY OIL RECOVERY, PART 5 - CARBON DIOXIDE MISCIBLE PROCESS", PET. ENG. (MAY, 1976) 114-120.

ABSTRACT:

----- MISCIBILITY IN A CO₂ - FLOOD PROCESS IS ACHIEVED ONLY AFTER SEVERAL CONTACTS BETWEEN THE INJECTED CO₂ AND THE RESERVOIR FLUID. THE MINIMUM MISCIBILITY PRESSURE IN THE CASE OF CO₂ IS LESS THAN 1,500 PSI FOR MANY RESERVOIRS. CO₂ CAN ALSO EXTRACT HEAVIER COMPONENTS OF HYDROCARBONS IN THE RANGE OF C₆ TO C₃₀ AND ACHIEVE MISCIBILITY EVEN WITH CRUDE OILS THAT HAVE LITTLE INTERMEDIATE (C₂ TO C₆) COMPONENTS. THIS MAKES THE PROCESS MORE VERSATILE. IT IS PARTICULARLY SUITED FOR RESERVOIRS CONTAINING CRUDE OILS WITH 25 API AND ABOVE. A PRACTICAL UPPER LIMIT OF OPERATING PRESSURE IN A CO₂ INJECTION PROCESS IS 6000 PSI; THE LOWER LIMIT IS 1500 PSI. THE DENSITY OF CO₂ IS CLOSE TO THAT OF CRUDE OIL AND APPROACHES THAT OF WATER UNDER SOME RESERVOIR CONDITIONS. AS A RESULT, EFFECTS OF GRAVITY OVERRIDE ARE MINIMIZED IN THIS PROCESS. THE PROCESS ALSO GIVES BETTER SWEEP EFFICIENCY THAN HYDROCARBON MISCIBLE PROCESSES BECAUSE CO₂ VISCOSITY IS TWO TO FOUR TIMES HIGHER THAN HYDROCARBON SOLVENTS, OVER USUAL RANGES OF PRESSURE. HOWEVER, ALTERNATE CO₂ AND WATER INJECTION IS OFTEN NECESSARY TO ACHIEVE A REASONABLE MISCIBILITY RATIO. CO₂ WITH WATER FORMS CARBONIC ACID WHICH IS HIGHLY CORROSIVE. SPECIAL METAL ALLOYS AND COATINGS MAY BE REQUIRED FOR FACILITIES. DUAL INJECTION SYSTEMS FOR WATER AND CO₂ ARE USUALLY USED. AVAILABILITY AND COST OF CO₂ ARE IMPORTANT ECONOMIC FACTORS THAT SHOULD BE CONSIDERED IN THIS PROCESS.

SACROC UNIT IN SCURRY COUNTY, TEXAS, OPERATED BY CHEVRON OIL CO., HAS THE LARGEST CO₂ MISCIBLE PROJECT IN OPERATION. THE MAJOR RESERVOIR IN THIS UNIT HAD 2.75 BILLION BARRELS OF OIL ORIGINALLY IN PLACE. IT IS EXPECTED THAT THIS PROCESS WILL RECOVER AN ADDITIONAL 230 MMBLS OF OIL FROM THE SACROC UNIT. OTHER FIELD EXPERIENCES WITH CO₂ INJECTION INCLUDE THE SHELL OPERATED NORTH CROSS (DEVONIAN) UNIT IN CROSSETT FIELD, CRANE CNTY, WEST TEXAS, AND SHELL'S LITTLE CREEK FIELD IN LINCOLN AND PIKE COUNTIES, MISSISSIPPI.

COMMENTS:

----- 1. THE FUNDAMENTAL CONCEPTS OF THE CO₂ INJECTION PROCESS DISCUSSED IN THIS PAPER SHOULD HELP IN UNDERSTANDING THE PROCESS BETTER.

2. THE PAPER GIVES A SUMMARY OF IMPORTANT RESERVOIR AND FLUID DATA AND GENERAL PERFORMANCE OF THE SACROC UNIT NORTH CROSS UNIT AND THE LITTLE CREEK FIELD OPERATIONS.

EXHIBITS:

----- 2 TABLES, 2 FIGURES

CROSS REFERENCES:

32. KENNEDY, THODOS: A.I.C.H.E. J. (DEC., 1961) 625.
 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
 114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
 S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.

KEYWORDS:

SANDSTONE FIELD
 WATER INJECTION
 FIELD TERTIARY RECOVERY
 FIELD MOBILITY RATIO
 MOBILITY CONTROL
 CORROSION
 OTHER FIELD INFORMATION

CARBONATE FIELD
 FIELD SECONDARY RECOVERY
 FIELD MISCIBLE APPLICATION
 FIELD AREAL SWEEP
 FIELD RESIDUAL SATURATIONS
 FIELD ECONOMICS
 SCREENING CRITERIA

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158. HOLM, L.W.: "STATUS OF CO₂ AND HYDROCARBON MISCIBLE OIL RECOVERY METHODS", J. PET. TECH. (JAN., 1976) 76-84.

ABSTRACT:

----- THIS PAPER REVIEWS THE STATE OF THE ART IN MISCIBLE RECOVERY METHODS. BASIC MISCIBLE DISPLACEMENT PROCESSES ARE DISCUSSED INCLUDING LPG (PROPANE) GAS, ENRICHED (CONDENSING) GAS, HIGH PRESSURE (VAPORIZING) GAS, CARBON DIOXIDE AND MUTUAL SOLVENT PROCESSES. THE PROBLEMS ASSOCIATED WITH EACH METHOD AND THE VARIOUS IMPROVEMENTS DEVELOPED TO COMBAT THESE PROBLEMS ARE ALSO DISCUSSED.

THIS PAPER ALSO PRESENTS PAST AND CURRENT FIELD APPLICATIONS, AND A CURRENT APPRAISAL OF MISCIBLE RECOVERY PROCESSES.

ALTHOUGH CO₂ IS NOT MISCIBLE WITH RESERVOIR OILS, IT GENERATES A MISCIBLE SOLVENT IN-SITU THROUGH A MECHANISM SIMILAR TO THAT OF HIGH PRESSURE GAS MISCIBLE DISPLACEMENT. AT APPROPRIATE PRESSURES, CO₂ EXTRACTS HEAVIER HYDROCARBONS (C₅ - C₃₀) FROM THE OIL CREATING A MISCIBLE DISPLACEMENT FRONT. MISCIBILITY IS NOT DEPENDENT ON THE PRESENCE OF LIGHT HYDROCARBON IN THE RESERVOIR OIL AND CAN BE ACHIEVED AT PRESSURES AS LOW AS 1100 TO 3000 PSI. THE PROCESS IS APPLICABLE TO RESERVOIRS IN WHICH THE OIL HAS DEPLETED THE GAS AND INTERMEDIATE COMPONENTS. ONLY CRUDE OILS HAVING GRAVITIES ABOVE ABOUT 28 DEGREES API SHOULD BE CONSIDERED. ASPHALT PRECIPITATION AND HIGH VISCOSITY CONTRAST BETWEEN THE OIL AND CO₂ MAY POSE PROBLEMS. CO₂ IS IMMISCIBLY DISPLACED BY WATER. HOWEVER, THE CO₂ LEFT BY SUCH DISPLACEMENTS IMPROVES DISPLACEMENT MOBILITY AND IS BENEFICIAL TO FURTHER OIL RECOVERY BY PRESSURE DEPLETION. THE REQUIRED CO₂ SLUG MAY RANGE FROM 15% TO 25% PV AT RESERVOIR CONDITIONS DEPENDING ON THE RELATIVE PERMEABILITY OF THE RESERVOIR ROCK.

PROBLEMS ENCOUNTERED IN MISCIBLE PROCESSES ARE DUE LARGELY TO GRAVITY SEGREGATION, DIFFERENCES IN FLUID VISCOSITIES AND RESERVOIR HETEROGENEITY. DEAD-END PORES, AND PORES THAT ARE PARTIALLY SHIELDED FROM WATER MAY TRAP SOLVENT RESULTING IN LOSS OF SLUG MATERIAL AND EARLY LOSS OF MISCIBILITY. MAJOR TECHNIQUES DEVELOPED TO IMPROVE THE CONFORMANCE OF MISCIBLE DISPLACEMENT PROCESSES INCLUDE ALTERNATE AND PRE-SOLVENT WATER INJECTION, VERTICAL DISPLACEMENT, SELECTIVE INJECTION, AND DISPLACEMENT BY A SOLUBLE OIL SLUG DRIVEN WITH WATER. EXAMPLES OF SUCCESSFUL FIELD PROJECTS ARE THE HIGH PRESSURE GAS INJECTION IN THE FAIRWAY FIELD, TEXAS, THE CO₂ FLOOD IN THE SACROC UNIT, KELLY SNYDER FIELD, TEXAS, AND THE WASSON FIELD, TEXAS. OTHERS ARE THE ENRICHED GAS AND LPG FLOODS IN THE GOLDEN SPIKE, THE SOUTH WARD AND THE SOUTH SWAN HILLS FIELDS.

COMMENTS:

----- THE PAPER GIVES A GENERAL HIGHLIGHT OF THE MISCIBLE DISPLACEMENT PROCESS. THE CONCENTRATION OF ALL THE VARIOUS EXPERIENCES IN ONE PAPER SHOULD HELP PLANNING OF ENHANCED RECOVERY PROCESSES.

EXHIBITS:

----- 7 TABLES, 7 FIGURES

CROSS REFERENCES:

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26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
29. HABERMANN: TRANS., AIME (1960) 264.
31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 21. BLANTON, MCCASKILL, HERBECK: J. PET. TECH. (OCT., 1970) 1209.
S 34. HOLM: PAPER SPE 3774 (1972).
S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.

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KEYWORDS:

SANDSTONE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD MOBILITY RATIO
MOBILITY CONTROL
FIELD ECONOMICS
LPG

CARBONATE FIELD
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
FIELD RESIDUAL SATURATIONS
ENRICHED AND HIGH PRESSURE GAS
CO2 SOURCE

159. KENNEDY, J.L.: "STUDY ANALYZES EFFECT OF OIL PRICE ON ENHANCED RECOVERY'S FUTURE ROLE", OIL & GAS J. (DEC. 27, 1976) 185-191.

ABSTRACT:

----- THIS ARTICLE DISCUSSES A RECENT ECONOMIC STUDY OF ENHANCED-OIL-RECOVERY (EOR) PROCESSES WHICH WAS ADOPTED BY THE NATIONAL PETROLEUM COUNCIL (NPC). THE REPORT WAS PREPARED BY THE COORDINATING SUB-COMMITTEE OF THE TECHNOLOGY TASK GROUP OF THE NPC COMMITTEE ON ENHANCED RECOVERY TECHNIQUES. THE ENHANCED RECOVERY METHODS CONSIDERED INCLUDE CHEMICAL FLOODING, CO₂ MISCIBLE FLOODING AND THERMAL RECOVERY. 245 KNOWN RESERVOIRS IN CALIFORNIA, LOUISIANA AND TEXAS WERE USED AS A DATA BASE. THESE WERE EXTRAPOLATED FOR ALL RESERVOIRS IN THE U.S.; ONLY RESERVOIRS DISCOVERED ON OR BEFORE DEC. 31, 1975 WERE INCLUDED. COSTS WERE ESTIMATED EITHER AS PROCESS DEPENDENT OR PROCESS INDEPENDENT. ADDITIONAL OIL RECOVERY FROM THE RESERVOIR FOR ANY EOR PROCESS WAS ESTABLISHED. DISCOUNTED CASH FLOW RATES OF RETURN (DCFROR) WERE CALCULATED FOR EACH SET OF ECONOMIC PARAMETERS CONSIDERED. THE RESULTS WERE COMPARED WITH A MINIMUM RATE OF RETURN CRITERION. THE RESULTS WERE ALSO EXTRAPOLATED FOR ALL RESERVOIRS IN THE THREE STATES, AND FOR THE WHOLE COUNTRY.

POTENTIAL ULTIMATE RECOVERY IS HEAVILY DEPENDENT ON OIL PRICE. THE THREE TYPES OF EOR PROCESSES STUDIED HAVE EQUAL POTENTIAL AT A PRICE OF OIL OF \$15/BBL. INCREMENTAL OIL RECOVERY FROM EOR CAN RANGE FROM 4 BILLION BARRELS TO 33 BILLION BBLs DEPENDING ON WHETHER THE OIL PRICE IS \$5/BBL OR \$25/BBL. LITTLE INCREMENTAL PRODUCTION IS EXPECTED FROM CO₂ MISCIBLE FLOOD PROJECTS BEFORE THE MID-1980'S. AT PEAK PRODUCTION IN THE YEAR 2,000, THE CO₂ MISCIBLE PROCESS MAY YIELD AN ADDITIONAL 500 MBPD IF OIL PRICES ARE \$10/BBL OR 1.1 MBPD IF THE PRICE REACHES \$25/BBL. ABOUT 47% OF THE PROCESS COSTS ARE CO₂ PURCHASE. THE SUPPLY OF CO₂ IS A MAJOR CONSTRAINT ON THE PROCESS. POTENTIAL DEMAND FAR EXCEEDS SUPPLY.

COMMENTS:

----- THE PAPER CONTAINS SCREENING CRITERIA FOR SELECTION OF VARIOUS EOR CANDIDATES.

EXHIBITS:

----- 7 TABLES, 11 FIGURES

CROSS REFERENCES:

- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).

KEYWORDS:

SCREENING CRITERIA
CO₂ SOURCE
TRANSPORTATION

GENERAL ECONOMICS
CO₂ SUPPLY
MISCELLANEOUS DATA

160. LEWIN AND ASSOCIATES, INC.: "THE POTENTIAL AND ECONOMICS OF ENHANCED OIL RECOVERY", PREPARED UNDER U.S. F.E.A. CONTRACT NO. CO-03-50222-000, WASHINGTON, D.C. (APR., 1976).

ABSTRACT:

----- THIS STUDY WAS UNDERTAKEN TO ASSIST THE FEDERAL ENERGY ADMINISTRATION IN ITS CONSIDERATION OF WHAT COMBINATION OF ECONOMIC REGULATION AND INCENTIVE STRATEGIES WILL OPTIMIZE THE SUPPLY OF TERTIARY OIL AT THE LOWEST LONG-TERM COST.

CONCERNING MISCIBLE METHODS, IT IS STATED THAT THREE FLUIDS HAVE BEEN TRIED: ALCOHOLS, HYDROCARBONS (ENRICHED GAS, HIGH PRESSURE GAS, AND LPG), AND CO₂. INTEREST IS BECOMING MORE FOCUSED ON CO₂ SINCE ALCOHOLS ARE EXPENSIVE AND THE LOWER MOLECULAR WEIGHT ALCOHOLS LOSE MISCIBILITY WITH SOME OILS WHILE THE HIGHER MOLECULAR WEIGHT ALCOHOLS LOSE SOLUBILITY IN WATER; HYDROCARBON MISCIBLE METHODS ARE RAPIDLY BECOMING MORE EXPENSIVE AS WELL. IT IS STATED THAT THE MAJOR CONSTRAINT TO CO₂ MISCIBLE FLOODING IS THE SUPPLY OF CO₂.

EXHIBIT 5 PRESENTS A SCREENING GUIDE FOR CARBON DIOXIDE FLOODING WHICH IS SUMARIZED IN THE ABSTRACT FOR LEWIN (1976 B).

COMMENTS:

----- 1. EXHIBIT III-1 SHOWS THE DISTRIBUTION OF API GRAVITY, DEPTH, AND RESIDUAL OIL SATURATION FOR CO₂ AND HYDROCARBON MISCIBLE FLOODS. THIS MAY BE USEFUL FOR COMPARISON.

2. EXHIBIT V-7 CONTAINS A DETAILED OUTLINE OF THE COSTS ASSOCIATED WITH CARBON DIOXIDE FLOODING THAT MAY BE USEFUL FOR ENGINEERING AND ECONOMIC FEASIBILITY STUDIES.

CROSS REFERENCES:

- 108. GEFFEN: WORLD OIL (OCT., 1973) 84.
142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
158. HOLM: J. PET. TECH. (JAN., 1976) 76.
161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).

KEYWORDS:

FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
OTHER FIELD INFORMATION
GENERAL ECONOMICS
LPG
CO₂ SUPPLY

FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD ECONOMICS
SCREENING CRITERIA
ENRICHED AND HIGH PRESSURE GAS
CO₂ SOURCE
MISCELLANEOUS DATA

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161. LEWIN AND ASSOCIATES, INC.: "RESEARCH AND DEVELOPMENT IN ENHANCED OIL RECOVERY", PREPARED UNDER U.S. E.R.D.A. CONTRACT NO. E (49-18) 2294, WASHINGTON, D.C. (DEC., 1976).

ABSTRACT:

----- ON PAGE II-8 IN THE OVERVIEW SECTION, CRITERIA FOR THE APPLICATION OF SELECTED EOR METHODS ARE PRESENTED. FOR A CO₂ MISCIBLE FLOOD, THEIR CRITERIA ARE: CRUDE VISCOSITY LESS THAN 12 CP; OIL GRAVITY ABOVE 30 DEGREES API; RESIDUAL OIL SATURATION BEFORE MISCIBLE FLOODING > 25%; RESERVOIR DEPTH GREATER THAN 3000 FEET; ORIGINAL BOTTOM HOLE PRESSURE GREATER THAN 1500 PSIA; NONE TO WEAK GAS CAP, FRACTURES, AND NATURAL WATER DRIVE. THEY ALSO STATE THAT THIN PAY SECTIONS ARE PREFERRED. ALSO, HOMOGENEOUS HIGH DIP FORMATIONS ARE PREFERRED, AND IN THE CASE OF HORIZONTAL RESERVOIRS, THE VERTICAL PERMEABILITY SHOULD BE LOW.

RECOMMENDATIONS FOR THE FUTURE USE OF CO₂ MISCIBLE FLOOD INCLUDED ACCELERATING THE APPLICATION OF THE PROCESS PRIOR TO THE WATERFLOOD RESIDUAL BEING REACHED. IN THE GULF COAST WHERE THERE ARE MANY HIGH DIP RESERVOIRS GRAVITY-STABILIZING THE CARBON DIOXIDE DRIVE IS RECOMMENDED.

IN THE PROGRAM SECTION OF THE REPORT, PROBLEMS ASSOCIATED WITH THE PROCESS ARE DISCUSSED. THE FIRST IS THE CLAIM THAT THE HIGHER THE OIL SATURATION BEFORE FLOODING THE HIGHER THE RECOVERY. THE EXPERIENCE IN SACROC IS CITED WHERE SUCCESS IS ACHIEVED WITH HIGHER OIL SATURATIONS THAN WITH LOWER RESIDUALS. THIS IS THOUGHT TO BE SO BECAUSE OF THE GREATER ROLE FINGERING PLAYS IN RECOVERY WHEN ONLY A SMALL VOLUME OF OIL IS PRESENT. IT IS SUGGESTED THAT WHERE FEASIBLE, A BANK OF CRUDE BEFORE THE CO₂ SLUG WOULD HELP. THE SECOND PROBLEM IS THE UNCERTAINTY IN THE ACTUAL LEVEL AND DISTRIBUTION OF THE RESIDUAL OIL. THIS UNCERTAINTY CAN MAKE PROJECT SUCCESS HIGHLY SPECULATIVE. THIRD IS THE PROBLEM OF MOBILITY CONTROL. THE VISCOSITY OF SUPER-CRITICAL CARBON DIOXIDE IS OF THE ORDER OF 0.2 CP, LEADING TO UNFAVORABLE VISCOSITY RATIOS. THE FOURTH PROBLEM IS THE FACT THAT MISCIBILITY IS NOT ALWAYS ACHIEVED EVEN AFTER MULTIPLE CONTACT. THE FIFTH PROBLEM CONCERNS THE AVAILABILITY OF NEARBY, NATURALLY OCCURRING CARBON DIOXIDE. COST ESCALATION RESULTS FROM PROBLEMS IN TRANSPORTING, PURIFYING, PRESSURIZING AND CYCLING CARBON DIOXIDE. A SIXTH DEALS WITH THE DIFFICULTY IN EXTRACTING CARBON DIOXIDE FROM MANUFACTURING OPERATIONS OR FROM STACK GASES. AT PRESENT, THIS IS VERY EXPENSIVE TO DO WITH THE DEGREE OF PURITY DESIRED FOR MISCIBLE FLOOD INJECTION.

IN THE METHODOLOGY SECTION OF THE REPORT, EXHIBIT V-7 GIVES A LIST AND BRIEF DISCUSSION OF COST ELEMENTS FOR CO₂ MISCIBLE PROJECTS.

COMMENTS:

----- THE PARTS OF THE REPORT DEALING WITH CO₂ MISCIBLE FLOODING SERVE AS A GOOD INTRODUCTION TO THIS ENHANCED RECOVERY PROCESS. ALSO VALUABLE IS A LISTING OF VARIOUS AREAS WHERE

MORE RESEARCH IS NECESSARY, AND A LIST OF FIELD PROJECTS.

KEYWORDS:

OTHER FIELD INFORMATION
GENERAL ECONOMICS

SCREENING CRITERIA
MISCELLANEOUS DATA

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162. NATIONAL PETROLEUM COUNCIL: "ENHANCED OIL RECOVERY", N.P.C.
(DEC., 1976).

ABSTRACT:

----- THIS STUDY PRESENTS A DETAILED OVERVIEW OF ENHANCED OIL RECOVERY. BASIC COSTS, SCREENING CRITERIA, AND MECHANISMS FOR CO2 MISCIBLE FLOODING ARE PRESENTED.

THE STUDY CONCLUDES THAT SEVERAL FACTORS INFLUENCE AND TEND TO DELAY PRODUCTION WITH THE CO2 MISCIBLE PROCESS. THE MOST SIGNIFICANT FACTOR IS THE TIME REQUIRED TO FIND AND DEVELOP CO2 RESERVES AND TO JUSTIFY AND BUILD APPROPRIATE PIPELINE NETWORKS TO TRANSPORT THE CO2 TO WHERE IT IS NEEDED.

COMMENTS:

----- THIS REPORT HAS A GOOD ANALYSIS OF THE COSTS AND ECONOMICS OF CO2 FLOODING.

CROSS REFERENCES:

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28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
123. HENDERSON: PAPER SPE 4737 (1974 A).
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
158. HOLM: J. PET. TECH. (JAN., 1976) 76.
186. WARNER: J. PET. TECH. (OCT., 1977) 1339.
MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C) (10
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.

KEYWORDS:

SANDSTONE FIELD	CARBONATE FIELD
FRACTURED RESERVOIRS	SOAK OPERATION
WATER INJECTION	FIELD SECONDARY RECOVERY
FIELD TERTIARY RECOVERY	FIELD MISCIBLE APPLICATION
FIELD IMMISCIBLE APPLICATION	FIELD MOBILITY RATIO
FIELD AREAL SWEEP	MOBILITY CONTROL
FIELD RESIDUAL SATURATIONS	COMPRESSION
IMPURITIES (FIELD)	FIELD ECONOMICS
FACILITIES	COMPOSITIONAL MODELS
SNG	CO2 SOURCE
CO2 SUPPLY	TRANSPORTATION
SEPARATION	MISCELLANEOUS DATA

163. SPELLER, F.N., JR.: "PROCESSES FOR SECONDARILY RECOVERING OIL", U.S. PATENT 3,964,545 (JUNE 22, 1976).

ABSTRACT:

----- THIS PATENT RELATES TO A METHOD WHEREIN AIR IS INJECTED INTO THE FORMATION TO PRESSURIZE IT AND MAINTAIN MOBILITY OF THE OIL BY DILUTION WITH CARBON DIOXIDE. CARBON DIOXIDE IS PRODUCED AS A BY-PRODUCT OF THE AIR INJECTION, EITHER BY AUTO-OXIDATION OF CARBONACEOUS MATERIALS IN THE RESERVOIR ROCK OR BY IGNITION OF THE OIL IN THE RESERVOIR. THE EFFICIENCY OF OXIDATION IS OBSERVED BY TESTING THE OXYGEN CONTENT OF PRODUCED GAS; IT IS DESIRABLE TO HOLD THE OXYGEN CONTENT TO LESS THAN 3% BY VOLUME, OR THE OIL VISCOSITY WILL INCREASE AND CO₂ WILL NOT BE PROPERLY CREATED.

COMMENTS:

----- THE MAJOR CONCEPT OF THIS PATENT IS THAT CO₂ CREATION IS A MAJOR FACTOR IN THE RECOVERY OF OIL BY COMBUSTION METHODS.

EXHIBITS:

----- 1 FIGURE

CROSS REFERENCES:

- 37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).

KEYWORDS:

CORROSION
OTHER FIELD INFORMATION

FLUE GAS FIELD APPLICATIONS
U.S. PATENT

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164. ANON.: "ARCO PLANS COLORADO-TO-TEXAS CO2 LINE", OIL & GAS J.
(SEP. 5, 1977) 53.

ABSTRACT:

----- PLANS ARE UNDERWAY BY ARCO FOR THE CONSTRUCTION OF A 375 MILE PIPELINE TO TRANSPORT CARBON DIOXIDE FROM WALSENBURG, COLORADO, TO THE WASSON AND SEMINOLE FIELDS IN WEST TEXAS. DELINEATION DRILLING TO DETERMINE THE POTENTIAL SIZE OF THE CO2 PROJECT IS NEAR COMPLETION. THIRTEEN WELLS HAVE BEEN DRILLED AND NINE ARE COMPLETED. UNCONFIRMED SOURCES ESTIMATE THE POTENTIAL CO2 RESERVE AS ABOUT 2 TRILLION CU. FT. THE PIPELINE IS EXPECTED TO DELIVER ABOUT 300 MMCFD OF CO2, AND ESTIMATED TO COST \$140 MILLION.

THE CO2 WILL BE INJECTED IN MISCIBLE FLOODS IN THE WEST TEXAS FIELDS. PRODUCED CO2 WILL BE REINJECTED IN OTHER WEST TEXAS FIELDS WITH CO2 FLOOD POTENTIAL. 50 TO 70 MMBBL OF ADDITIONAL OIL ARE EXPECTED TO BE PRODUCED AT THE WASSON UNIT AT A COST OF \$400 MILLION.

SHELL IS ALSO CONSIDERING A CONSTRUCTION OF A 500 MILE CO2 PIPE TO WEST TEXAS FROM SOUTHWESTERN COLORADO. AMOCO, HOWEVER, WHICH HAS BEEN EXPLORING FOR GAS IN NORTHEASTERN NEW MEXICO FOR 3 YEARS, HAS NOT YET ANNOUNCED ANY PLANS FOR PIPELINE CONSTRUCTION.

COMMENTS:

----- THE SEARCH FOR CO2 IS BEING INTENSIFIED. IT IS BELIEVED THAT DEMAND WILL FAR EXCEED SUPPLY.

KEYWORDS:

CO2 SUPPLY

CO2 SOURCE
TRANSPORTATION

165. ANON.: "SHELL TO TRY FIRST CO2 PILOT IN HOT GULF COAST RESERVIOR", OIL & GAS J. (AUG. 29, 1977).

ABSTRACT:

----- PRELIMINARY WORK HAS BEGUN ON A CO2 INJECTION PILOT IN THE 8 ACRE 'S' SAND RESERVOIR B IN WEEKS ISLAND FIELD, IBERIA PARISH, LA. THE RESERVOIR, LOCATED AT ABOUT 12,800 FT., IS ISOLATED Laterally BY FAULTS AND IS BACKED UP AGAINST A SALT DOME. IT HAS AN AVERAGE TEMPERATURE OF 225 F AND PRESSURE OF 5100 PS. THE PROGRAM IS BEING CONDUCTED BY SHELL IN CONJUNCTION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION. THE PROGRAM, IF SUCCESSFUL, IS EXPECTED TO ADD 26 MMBBL OF POTENTIAL RECOVERY TO LARGE FIELDS LOCATED ALONG THE GULF COAST.

ABOUT 50,000 TONS OF CO2 MIXED WITH UP TO 15% METHANE WILL BE INJECTED, AT A RATE OF ABOUT 130 TONS/DAY (2 MMCFD). THE SLUG WILL BE INJECTED AT THE ORIGINAL GAS-OIL CONTACT, AND DISPLACED DOWN-DIP. THE DISPLACEMENT WILL BE CONTROLLED BY WATER PRODUCTION FROM A DOWN-DIP WELL. OIL PRODUCTION IS EXPECTED TO BEGIN DURING THE THIRD YEAR. ABOUT 270,000 BBL OF OIL OR 99% OF THE OIL IN PLACE IS EXPECTED TO BE RECOVERED.

COMMENTS:

----- THIS ARTICLE IS A NEWS RELEASE.

KEYWORDS:

FIELD SECONDARY RECOVERY
MOBILITY CONTROL

SANDSTONE FIELD
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

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166. BILHARTZ, H.L., JR.: "CASE HISTORY: A PRESSURE CORE HOLE", PAPER 6389, SPE-AIME PERMIAN BASIN OIL & GAS RECOVERY CONF., MIDLAND, TX. (MAR., 1977).

ABSTRACT:

----- THIS PAPER PRESENTS THE RESULTS OF THE PRESSURE CORE PROGRAM AT THE WILLARD UNIT, WASSON FIELD, CO2 PILOT TEST. THE OBJECTIVE OF THE PROGRAM WAS TO EVALUATE THE EFFECTIVENESS OF THE CO2 FLOODING. PRESSURE CORING WAS ELECTED TO PREVENT LOSS OF FLUIDS BY GAS EXPANSION. EIGHTEEN PRESSURE CORES WERE SUCCESSFULLY RECOVERED OUT OF 19 ATTEMPTED. SOME PRECAUTIONS WERE TAKEN TO ENSURE THIS SUCCESS. THE PRECAUTIONS AND OUTLINES OF FIELD PROCEDURES OF THE OPERATION ARE DISCUSSED.

THE RESERVOIR (SAN ANDRES DOLOMITE) HAS A GROSS PAY INTERVAL OF 160 FEET. THE PILOT AREA HAD BEEN DEPLETED DOWN TO 800 PSI BEFORE THE TEST BEGAN. WATER WAS FIRST INJECTED TO REPRESSURE THE PILOT AREA ABOVE MINIMUM MISCIBILITY PRESSURE. CO2 AND WATER WERE INJECTED IN A ONE-TO-ONE RATIO. THE RESPONSE TO MISCIBLE FLOOD WAS OBSERVED AT A LOGGING OBSERVATION WELL IN SEVEN MAJOR STRATA OF INTEREST. A CORE HOLE WAS DRILLED AS A PART OF THE TEST TO COMPLEMENT LOG RESPONSE AND PROVIDE ADDITIONAL INFORMATION. DURING CORING THE OVERBALANCE PRESSURE WAS MAINTAINED AT 100 PSI, TO MINIMIZE FILTRATE INVASION. THE RESERVOIR PRESSURE WAS CONTINUOUSLY MONITORED AT AN INJECTION WELL LOCATED 40 FEET SOUTH OF THE CORING LOCATION, AND AT A SAMPLING WELL LOCATED 85 FEET TO THE NORTH. THE CIRCULATION RATE DURING CORING WAS KEPT AT 150 GPM TO MINIMIZE EROSION IN REGIONS OF SMALL CLEARANCE WITHIN THE CORE BARREL AND TO MINIMIZE PRESSURE GRADIENT THROUGH THE THROAT OF THE CORE BIT. API FLUID LOSS WAS MAINTAINED AT LESS THAN 5 CC WITH A NEGLIGIBLE SPURT LOSS. NO SURFACE ACTIVE AGENT WAS ADDED TO THE MUD SYSTEM AND THE INTERFACIAL TENSION BETWEEN THE OIL AND THE MUD FILTRATE WAS GREATER THAN 1.5 DYNES/CM. THE H2S ASSOCIATED WITH THE CO2 IN THE WILLARD UNIT WAS WELL CONTAINED DURING CORING. MUD PH WAS MAINTAINED ABOVE 9.5 AND BASIC ZINC CARBONATE WAS ADDED TO SCAVENGE ANY H2S THAT MIGHT ENTER THE WELL BORE.

SEVERAL MECHANICAL PROBLEMS WERE ENCOUNTERED AND OVERCOME DURING THE CORING. A SUMMARY OF THESE AND OTHER SUGGESTIONS FOR SUCCESSFUL HIGH PRESSURE CORING ARE ALSO DISCUSSED.

COMMENTS:

----- THIS EXPERIMENT IS QUITE RELEVANT TO CO2 FLOODING. EVALUATION BY ANALYSIS OF CORES CAN EASILY BE MEANINGFUL IF THE CORING IS PROPER AND SUCCESSFULLY DONE.

EXHIBITS:

----- 6 FIGURES

ADDITIONAL REFERENCES:

----- 1. HAGEDORN AND BLACKWELL: PAPER SPE 3692, (1972).

2. SEWELL: API DRILL. & PROD. PRAC. (1939) 69-78
3. MURPHY AND OWENS: PAPER SPE 3793, (1972).

KEYWORDS:

OPERATIONS

OTHER FIELD INFORMATION

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167. BROWN, A., WU, C.H. AND KONOPNICKI, D.T.: "COMBINED MULTIPLE SOLVENT AND THERMAL HEAVY OIL RECOVERY", U.S. PATENT 4,004,636 (JAN. 25, 1977).

ABSTRACT:

----- THIS PATENT RELATES TO A COMBINATION METHOD FOR OIL RECOVERY, WHEREIN THE INJECTION OF A MULTIPLE SOLVENT IS FOLLOWED BY THE INJECTION OF STEAM. THE MULTIPLE SOLVENT CONSISTS OF A MATERIAL WHICH IS GASEOUS AND ONE WHICH IS LIQUID, SUCH THAT THE MIXTURE CAN BE LIQUIFIED IN THE RESERVOIR. THE GASEOUS SOLVENT CAN BE CO₂, METHANE, ETC. THE LIQUID SOLVENT IS USED TO PROVIDE OIL VISCOSITY REDUCTION, WHILE THE GASEOUS SOLVENT PROVIDES ENERGY FOR A SOLUTION GAS DRIVE.

THE MULTIPLE SOLVENT IS INJECTED WHILE THE PRODUCING WELLS ARE SHUT-IN. AFTER THE SOLVENT SLUG HAS BEEN INJECTED, ENOUGH PRODUCTION IS ALLOWED TO CAUSE THE FORMATION PRESSURE TO BE 10 TO 50% ABOVE THE VAPOR PRESSURE OF THE SOLVENT MIXTURE. THEN, STEAM IS INJECTED; THE STEAM HEATS THE RESERVOIR AND THE SOLVENT AND RELEASES THE GASEOUS SOLVENT FROM THE MIXTURE. THE GREAT EXPANSION OF THE GASEOUS SOLVENT THEN DRIVES OIL TO THE PRODUCING WELL. LABORATORY RESULTS INDICATE UP TO 75% RECOVERY OF THE OIL IN PLACE.

COMMENTS:

----- THE SUBSEQUENT PRESSURE REDUCTION BEFORE INJECTING STEAM WILL CAUSE LIBERATION OF MOST OF ANY CARBON DIOXIDE THAT WAS EARLIER DISSOLVED. STEAM ADVANCE AND CONSEQUENT TEMPERATURE INCREASE WILL ALSO REDUCE SOLUTION OF CO₂. IN ADDITION, CORROSION POTENTIAL IS SHARPLY INCREASED BY THE ADDITION OF CO₂ TO STEAM DRIVE. (THE POTENTIAL USE OF LOW VOLATIVITY SOLVENTS WITH STEAM NEEDS STUDY.)

EXHIBITS:

----- 1 TABLE

CROSS REFERENCES:

19. RZASA, TERWILLIGER: U.S. PATENT 2,822,872 (FEB. 11, 1958).

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
OTHER LABORATORY STUDIES
LPG

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
U.S. PATENT
ALTERNATE TECHNOLOGIES

168. CAMY, J.P. AND EMANUEL, A.S.: "EFFECT OF GRID SIZE IN THE COMPOSITIONAL SIMULATION OF CO2 INJECTION", PAPER 6894, SPE-AIME 52ND ANN. FALL TECH. CONF. & EXHBN., DENVER, CO. (OCT., 1977).

ABSTRACT:

----- THIS PAPER PRESENTS TECHNIQUES FOR DERIVING PSEUDO-FUNCTIONS FOR REDUCING DISPERSION AND MIXING ERRORS IN A MULTICOMPONENT FINITE DIFFERENCE COMPOSITIONAL SIMULATOR. PSEUDO FUNCTIONS ARE OBTAINED IN FINE-GRID MODELS FOR USE IN LARGE SCALE COARSE GRID MODELS. PARTICULAR CONCERN IS GIVEN TO CO2 INJECTION, ALTHOUGH THE CONCEPTS CAN BE EXTENDED TO OTHER GAS INJECTION PROBLEMS. NUMERICAL DISPERSION CAUSES DIFFICULTIES IN SIMULATING THE MOVEMENT OF A SHARP SATURATION FRONT. THE PROBLEM BECOMES MORE COMPLICATED IN COMPOSITIONAL MODELS BY THE DISPERSION OF BOTH COMPOSITIONAL AND SATURATION FRONTS. CELL SIZE IS ONE OF THE MOST IMPORTANT PARAMETERS CONTROLLING DISPERSION AND MIXING PROBLEMS. THE RESULTS FROM A COMPOSITIONAL SIMULATION MODEL MAY VARY WITH CELL SIZES, DUE TO NUMERICAL DISPERSION, NONLINEARITY OF FLASH EQUATIONS USED AND NONLINEAR DEPENDENCE OF SATURATION ON TOTAL MOBILITY.

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THE METHOD DESCRIBED WAS USED IN A SIMULATION OF A CONTINUOUS CO2 INJECTION. PSEUDO RELATIVE PERMEABILITY AND PSEUDO K-VALUE CURVES WERE CALCULATED WITH 50 CELLS, AND THEN APPLIED TO 5 CELL GRIDS. THE IMPROVEMENT DERIVED FROM THE USE OF THE PSEUDO CURVES IS SUBSTANTIAL. THE CO2 CONCENTRATION AND GAS SATURATION PROFILES ARE REPRODUCED ACCURATELY. CO2 BREAKTHROUGH TIME AGREED IN BOTH CASES, WITH PSEUDO CURVES. THE RESERVOIR PRESSURE CALCULATIONS FROM THE TWO SYSTEMS COMPARED MUCH BETTER WITH THAN WITHOUT THE PSEUDO CURVES. THE METHOD HAS ALSO BEEN USED FOR SIMULATING VARIOUS OTHER PROBLEMS. IN ALL CASES, THE PSEUDO CURVES EFFECTIVELY REDUCE GRID SIZE SENSITIVITY. IT IS ALSO POSSIBLE TO SIMULATE LARGE AREAS WITH FEW GRID POINTS. THE RANGE OF PRESSURES, RATES, SLUG SIZE AND COMPOSITION IN THE COARSE GRID MODEL MUST BE CLOSE TO THAT USED IN DERIVING THE PSEUDO FUNCTIONS FOR PROPER APPLICATION.

COMMENTS:

----- THE TECHNIQUE PRESENTED REQUIRES THAT AT LEAST ONE RUN BE MADE WITH A FINE GRID. THE PSEUDO FUNCTIONS OBTAINED FROM THIS ARE SUBSEQUENTLY USED IN RUNS WITH COARSER GRIDS.

EXHIBITS:

----- 1 TABLE, 19 FIGURES

ADDITIONAL REFERENCES:

----- HEARN: J. PET. TECH. (JULY, 1971) 805.

CROSS REFERENCES:

105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).

S 40. NOLEN: PAPER SPE 4274 (1973).

S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

KEYWORDS:

FINITE DIFFERENCE MODELS

OTHER MODELLING

169. CLARIDGE, E.L.: "A METHOD OF DESIGN OF GRADED VISCOSITY BANKS", PAPER 6848, SPE-AIME 52ND ANN. FALL TECH. CONF. & EXHBN., DENVER, CO. (OCT., 1977).

ABSTRACT:

----- THIS PAPER PRESENTS A METHOD FOR DESIGN OF GRADED BANKS IN RESERVOIR DISPLACEMENT PROCESSES. THE AIM IS TO PREVENT VISCOUS FINGERING AND IMPROVE AREAL SWEEP EFFICIENCY IN SUCH PROCESSES. VISCOUS FINGERING OCCURS DESPITE THE DIFFUSIONAL BLENDING THAT OCCURS AT THE SURFACE OF THE FINGER. THE VISCOUS FINGERS GROW FASTER THAN THE DIFFUSION BAND MODERATES THEM. THE DESIGN METHOD PRESENTED IN THIS PAPER IS BASED ON KOVAL'S EQUATIONS WHICH DEFINE THE DIMENSIONLESS LENGTH OF A FINGERING ZONE. IT IS POSSIBLE TO CONTROL VISCOUS FINGERING WITHIN ACCEPTABLE LIMITS BY USING A GRADED BANK. ILLUSTRATIONS ARE MADE WITH LPG MISCIBLE, AND POLYMER FLOODING. THE LIMITATIONS OF THE METHOD ARE ALSO DISCUSSED.

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COMMENTS:

----- ALTHOUGH THE ILLUSTRATIONS ARE MADE FOR LPG MISCIBLE AND POLYMER FLOODING, THE METHOD CAN BE APPLIED TO CO2 FLOODING.

EXHIBITS:

----- 1 TABLE, 5 FIGURES

CROSS REFERENCES:

42. KOVAL: TRANS., AIME (1963) 145.

KEYWORDS:

LPG

LABORATORY INSTABILITIES
MISCELLANEOUS DATA

170. DOSCHER, T.M.: "CO2 FLOODING BEST BET FOR ENHANCED RECOVERY IN GULF OF MEXICO AREA", OIL & GAS J. (MAY 2, 1977) 213-223.

ABSTRACT:

----- THIS PAPER PRESENTS AN OVERVIEW OF THE RESERVOIRS IN THE OUTER CONTINENTAL SHELF (OCS) AND TAKES A LOOK AT THE ENHANCED RECOVERY PROCESSES THAT MAY BE APPLICABLE TO THEM. THE PROCESSES CONSIDERED INCLUDE STEAM FLOODING, POLYMER FLOODING, CHEMICAL FLOODING AND CO2 FLOODING. IT IS CLEAR THAT BOTH STEAM AND POLYMER FLOODING ARE NOT SUITED FOR APPLICATION IN THE GULF OF MEXICO BASED ON GENERAL SCREENING CRITERIA. ALTHOUGH CHEMICAL FLOODING HAS ACHIEVED SOME PROVEN SUCCESSES IN OPERATIONS WHERE WELL PATTERNS HAVE BEEN GENERALLY SMALL, ITS APPLICATION IN THE GULF OF MEXICO MAY BE ECONOMICALLY UNATTRACTIVE. CARBON DIOXIDE FLOODING IS THE ONLY ENHANCED OIL RECOVERY METHOD THAT IS TECHNICALLY FEASIBLE. CO2 WILL PROBABLY BE MISCIBLE WITH MOST OF THE CRUDES IN THE GULF OF MEXICO RESERVOIRS. THE SEDIMENTS IN THE GULF OF MEXICO ARE UPTURNED AGAINST SALT DOMES, THEREBY HAVING SOME DIP WHICH CAN BE ADVANTAGEOUSLY USED FOR ENHANCED RECOVERY WITH CO2 INJECTION. AVAILABILITY AND COST OF CO2 ARE MAJOR FACTORS THAT AFFECT ECONOMICS. THE SELLING PRICES OF CRUDE WHICH WILL BE PRODUCED IS ALSO OF MAJOR CONCERN.

API'S ESTIMATE OF ULTIMATE RECOVERY FROM THE GULF OF MEXICO IS 6.5 BILLION BBLs OF OIL. ONLY ABOUT 2.1 BILLION BARRELS REMAIN TO BE PRODUCED BY CONVENTIONAL TECHNOLOGY. THE ORIGINAL OIL IN PLACE WAS 14.3 BILLION BARRELS. THE ESTIMATE ASSUMED A RECOVERY EFFICIENCY OF 50%. INITIAL OIL SATURATION RANGED BETWEEN 65% AND 80%. THE RESIDUAL OIL SATURATION AFTER A 50% RECOVERY SHOULD EXCEED 30%. THE RESERVOIRS ARE RELATIVELY SMALL; BASED ON 100 LARGE RESERVOIRS, THE MEAN SIZE IS 22 THOUSAND ACRE-Feet AND THE MEDIAN VALUE IS 15 MAF. THE TERTIARY RECOVERY TARGET IN THESE LARGER RESERVOIRS SHOULD AVERAGE ABOUT 8 MMSTBO A PIECE.

COMMENTS:

----- THE PAPER DEMONSTRATES THE FEASIBILITY AND PRACTICALITY OF CO2 INJECTION FOR ENHANCED OIL RECOVERY IN THE GULF OF MEXICO.

KEYWORDS:

CO2 SOURCE

GENERAL ECONOMICS
MISCELLANEOUS DATA

171. HANSEN, P.W.: "A CO2 TERTIARY RECOVERY PILOT, LITTLE CREEK FIELD, MISSISSIPPI", PAPER 6747, SPE-AIME 52ND ANN. FALL TECH. CONF. & EXHBN., DENVER, CO. (OCT., 1977).

ABSTRACT:

----- A 31 ACRE CO2 TERTIARY FLOOD PILOT, COMPRISING ONE CO2 INJECTION WELL AND THREE PRODUCING WELLS IN A SEMI-CONFINED QUARTER NINE-SPOT ARRAY, WAS CONDUCTED IN THE LOWER TUSCALOOSA (UPPER CRETACEOUS) SAND RESERVOIRS OF LITTLE CREEK FIELD, MISSISSIPPI, FROM 1974 THROUGH 1977. PILOT CONFINEMENT WAS PROVIDED BY A PINCH OUT ON ONE EDGE AND BY WATER INJECTION INTO FIVE WELLS SURROUNDING THE PILOT AREA. THE ENTIRE FIELD, CONTAINING 6200 PRODUCTIVE ACRES, WAS WATERFLOODED FROM 1962 TO 1970.

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THE AVERAGE NET PAY THICKNESS IN THE PILOT AREA IS 22 FEET, WITH AN AVERAGE POROSITY OF 23.4%, RESIDUAL OIL SATURATION AFTER WATERFLOODING OF 21%, AND A GEOMETRIC MEAN PERMEABILITY OF 33 MD. DEPTH IS ALMOST 11,000 FEET AND RESERVOIR TEMPERATURE IS 248 F. RESERVOIR PRESSURE OF 5100 PSIG AT THE PILOT START UP WAS SLIGHTLY ABOVE THE INITIAL RESERVOIR PRESSURE OF 4840 PSIG AND THE MISCIBILITY PRESSURE OF 4500 PSIG.

OIL RECOVERY DUE TO CO2 FLOODING WAS 122 MSTB OR 61% OF THE ESTIMATED 200 MSTB IN PLACE AT THE START OF CO2 INJECTION. WATER PRODUCTION WAS 924 MBBLS, AND GAS PRODUCTION (PRINCIPALLY CO2) WAS 2.21 BCF, CORRESPONDING TO A CUMULATIVE WATER-OIL RATIO OF 7.6 AND A PRODUCED CO2-OIL RATIO OF 18.1 MCF/STB. TOTAL CO2 INJECTED, INCLUDING RECYCLING, WAS 3.37 BCF OR 27.6 MCF PER STB OIL RECOVERED.

SOME OF THE OPERATING PROBLEMS AND SOLUTIONS ARE DISCUSSED - E.G., CORROSION, FREEZING, SAND PRODUCTION, ETC.

COMMENTS:

----- 1. DATA CANNOT BE USED TO MAKE DIRECT COMPARISON WITH WATERFLOOD BEHAVIOR BECAUSE A DIFFERENT PATTERN WAS USED FOR THE CO2 PILOT.

2. COMPUTER SIMULATIONS WERE USED IN THE PILOT DESIGN, BUT NO COMPARISONS ARE GIVEN WITH ACTUAL FIELD PERFORMANCE.

3. NO DETAILED CO2 - RESERVOIR FLUID DATA ARE GIVEN.

4. PHYSICAL MODEL STUDIES ARE MENTIONED BUT NOT DOCUMENTED.

5. TRACER TESTS FOLLOWING TERMINATION OF CO2 INJECTION WERE CONDUCTED, BUT RESULTS ARE NOT REPORTED IN THIS PAPER.

6. BECAUSE OF COMMENTS 1 THROUGH 4, LITTLE USE CAN BE MADE BY OTHERS OF THIS TEST.

ADDITIONAL REFERENCES:

----- CRONQUIST: J. PET. TECH.
(MAY, 1968) 522-533.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
COMPRESSION

SANDSTONE FIELD
FIELD TERTIARY RECOVERY
CORROSION
OPERATIONS

172. JOHNSTON, J.W.: "A REVIEW OF THE WILLARD (SAN ANDRES) UNIT CO2 INJECTION PROJECT", PAPER 6388, SPE-AIME PERMIAN BASIN OIL & GAS RECOVERY CONF., MIDLAND, TX. (MAR., 1977).

ABSTRACT:

----- TWO FIELD TESTS ARE DESCRIBED FOR CO2 INJECTION IN THE SAN ANDRES DOLOMITE, WILLARD UNIT, WASSON FIELD, TEXAS.

IN THE "PHASE I" TEST, 8 INJECTION WELLS IN TWO ROWS OF A LINE DRIVE WATERFLOOD PATTERN, SEPARATED BY A ROW OF PRODUCERS, WERE SELECTED FOR INJECTION OF AN ACID GAS (95% CO2, 4% H2S, 1% HYDROCARBONS) FOLLOWING INJECTION OF ABOUT 22% OF A HYDROCARBON PORE VOLUME OF WATER. INJECTION PRESSURE AVERAGED 1480 PSIG AT THE WELL HEADS, AND TOTAL INJECTION RATE AVERAGED 1620 RESERVOIR BPD. ACID GAS INJECTION WAS TERMINATED AFTER A 4.4% HCPV SLUG, AND THE WELLS WERE RETURNED TO WATER INJECTION. APPROXIMATELY 18 MONTHS AFTER TERMINATING GAS INJECTION, ONLY 3% OF THE GAS HAD BEEN PRODUCED. NO EFFECT OF ACID GAS INJECTION ON OIL PRODUCTION WAS REPORTED.

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IN THE "PILOT" TEST, WATER AND CO2 WERE INJECTED INTO ONE WELL, WITH A WELL 100' AWAY USED FOR REPEATED LOGGING TO OBSERVE FLUID SATURATION CHANGES, AND A WELL 125' AWAY USED TO SAMPLE FLUIDS AND MONITOR PRESSURES. A HOLE WAS DRILLED AND PRESSURE CORED 35' FROM THE INJECTOR AFTER INJECTION OF 87,000 RESERVOIR BARRELS OF CO2. ANALYSES OF DATA FROM THE "PILOT" WERE INCOMPLETE AS OF THE PUBLICATION DATE.

OPERATING PROBLEMS FOR BOTH TESTS ARE DISCUSSED, AND THE DATA COLLECTION AND SURVEILLANCE PROGRAM DESCRIBED.

COMMENTS:

----- THIS PAPER CONTAINS A USEFUL DESCRIPTION OF FIELD PROCEDURES, SURVEILLANCE AND DATA PROGRAM, BUT LITTLE INTERPRETATION OF RESULTS IS GIVEN.

EXHIBITS:

----- 2 TABLES, 10 FIGURES

ADDITIONAL REFERENCES:

- 1. DOWNS AND GOHEL:
J. PET. TECH. (MAY, 1974) 557.
2. GHOURI, OSBORNE, AND MAGNUSON:
J. PET. TECH. (JUNE, 1974) 595.

CROSS REFERENCES:

- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
166. BILHARTZ: PAPER SPE 6389 (1977).

KEYWORDS:

CARBONATE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
IMPURITIES (FIELD)

FRACTURED RESERVOIRS
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
OPERATIONS

173. MCREE, B.C.: "CO2: HOW IT WORKS, WHERE IT WORKS",
PET. ENG. (NOV., 1977) 52-63.

ABSTRACT:

----- CO2 FLOODING IS THE MOST VERSATILE ENHANCED OIL RECOVERY (EOR) PROCESS. IT HAS VIRTUALLY NO LIMITATIONS. A SHELL PROJECT MAY RECOVER 90% OF OOIP IN THE 12,800 FT. SAND OF WEEKS ISLAND FIELD, LOUISIANA. IT IS BEING CONDUCTED UNDER A \$5.5 MILLION CONTRACT WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (ERDA) IN A DEEP, HIGH-TEMPERATURE, HIGH SALINITY RESERVOIR WHERE OTHER CHEMICAL METHODS ARE IMPRACTICAL.

CO2 IS ABOUT 1.5 TIMES HEAVIER THAN AIR AT STANDARD CONDITIONS. ABOVE THE CRITICAL TEMPERATURE, 88 F, IT CAN EXIST AS A GAS OR A DENSE FLUID DEPENDING ON THE PRESSURE. IT IS VERY SOLUBLE IN OIL FIELD LIQUIDS. A TON OF COMMERCIAL CO2 YIELDS 17,168 CU. FT. OF GAS AT STANDARD CONDITIONS, AND A BARREL OF LIQUID CO2 AT -10 F YIELDS 3151 SCF OF GAS.

CARBON DIOXIDE PROMOTES OIL RECOVERY FOR MANY REASONS. CRUDE OIL VISCOSITY MAY BE REDUCED BY 10 TO 100 TIMES BY CO2. THIS GIVES BETTER DISPLACEMENT MOBILITY RATIO AND IMPROVED SWEEP EFFICIENCY. CO2 SWELLS THE CRUDE AND STRIPS CRUDE COMPONENTS TO FORM A HYDROCARBON BAND THAT PROMOTES MISCIBILITY. THE INTERFACIAL TENSION BETWEEN RESERVOIR WATER AND CRUDE IS REDUCED BY THE PRESENCE OF CO2 THEREBY ALLOWING MORE EFFECTIVE DISPLACEMENT. ADDITIONAL OIL RECOVERY IS ALSO ACHIEVED BY SOLUTION GAS DRIVE AS CO2 IS RELEASED DUE TO PRESSURE DEPLETION. CARBONATED WATER DRIVE HAS BEEN INEFFECTIVE; HOWEVER, ALTERNATE SLUGS OF CO2 AND WATER MAY RESULT IN A BETTER PERFORMANCE.

A SURVEY OF FOURTEEN CURRENT FIELD CO2 PROJECTS IS PRESENTED. INCLUDED ARE THE BAKER SAND IN RICHIE FIELD, ARKANSAS; NACATOCH SAND IN LICK CREEK FIELD, ARKANSAS; THE LITTLE CREEK FIELD, MISSISSIPPI; THE NORTH COWDEN UNIT IN GRAYBURG FIELD, WEST TEXAS, AND SHELL'S CROSSETT FIELD IN CRANE COUNTY TEXAS. OTHERS ARE SOUTH GILLOCK FIELD, KELLY SNYDER FIELD, MEAD-STRAWN FIELD, SLAUGHTER FIELD, AND WASSON FIELD, ALL IN TEXAS. ALSO INCLUDED ARE GRANNY'S CREEK FIELD, GRIFFITHVILLE FIELD, AND ROCK CREEK FIELD, ALL IN WEST VIRGINIA.

COMMENTS:

----- 1. THE PAPER DEMONSTRATES THE VERSATILITY OF CO2 FLOODING AS AN ENHANCED RECOVERY METHOD.

2. IT ALSO OBSERVES THE IMPORTANT PROBLEM OF FINDING AN ECONOMICAL SOURCE OF CO2. THIS IS A MAJOR CONSTRAINT FACING OPERATORS OF CO2 INJECTION PROJECTS.

3. AMOCO'S SOUTH GILLOCK FIELD IS SAID TO BE A COMPLEXLY FAULTED RESERVOIR, BUT NO PERFORMANCE DATA ARE AVAILABLE AND THE TEST WAS TERMINATED BECAUSE OF PREMATURE CO2 BREAKTHROUGH.

4. NO BIBLIOGRAPHY IS INCLUDED IN THIS PAPER.

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EXHIBITS:

----- 5 TABLES

KEYWORDS:

CARBONATE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FIELD AREAL SWEEP
OTHER FIELD INFORMATION

SANDSTONE FIELD
FRACTURED RESERVOIRS
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD MOBILITY RATIO
FIELD RESIDUAL SATURATIONS
SCREENING CRITERIA

174. NEWTON, L.E., JR. AND MCCLAY, R.A.: "CORROSION AND OPERATIONAL PROBLEMS, CO2 PROJECT, SACROC UNIT", PAPER 6391, SPE-AIME PERMIAN BASIN OIL & GAS CONF., MIDLAND, TX. (MAR., 1977).

ABSTRACT:

----- SOLUTIONS TO A NUMBER OF CORROSION AND OTHER OPERATING PROBLEMS ARE DESCRIBED. LITTLE TROUBLE WITH THE 220 MILE CANYON REEF CARRIERS CO2 SUPPLY PIPELINE HAS OCCURRED, SINCE ALL SOURCE CO2 IS DEHYDRATED TO LESS THAN 50 PPM H2O, LESS THAN THE SOLUBILITY LIMIT AT THE SUPERCRITICAL CONDITIONS USED IN THE PIPELINE, AND THE LINE USES API 5L X-60 STEELS, SELECTED FOR CO2 SERVICE AFTER LABORATORY TESTING. AT START-UP THE SUPPLY SYSTEM DISCHARGED A LARGE QUANTITY OF FINELY DIVIDED IRON SULFIDES, IRON OXIDES, IRON CARBONATES, ETC., APPARENTLY FORMED FROM RUST IN THE LINE DURING THE LONG FILL-UP PERIOD.

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MOST CORROSION PROBLEMS HAVE OCCURRED IN THE CO2 DISTRIBUTION SYSTEM, THE PRODUCED WATER DISTRIBUTION SYSTEM, WELLS FOR ALTERNATELY INJECTING CO2 AND WATER, ROD PUMPED WELLS, SUBMERSIBLE PUMPED WELLS, PRODUCTION FACILITIES, AND THE CO2 SEPARATION-REINJECTION FACILITIES. CORROSION HAS BEEN CONTROLLED ADEQUATELY BY SOME COMBINATION OF MATERIALS SELECTION, COATINGS, CATHODIC PROTECTION AND CHEMICAL INHIBITORS. OTHER PROBLEMS INCLUDE CARBONATE SCALE DEPOSITION, CONTROLLED BY CHEMICAL SCALE INHIBITORS, AND BUILDUP OF THIOSULFATES IN HOT POTASSIUM CARBONATE CO2 SEPARATION PLANTS, CONTROLLED BY OXYGEN MONITORING TO DETECT AND PREVENT AIR LEAKAGE INTO THE VAPOR RECOVERY SYSTEM.

COMMENTS:

----- USEFUL INFORMATION - TYPES OF CHEMICAL INHIBITION, COATINGS, AND METALS ARE GIVEN, BOTH THOSE THAT WORKED AND THOSE THAT DIDN'T. EVEN MORE USEFUL WOULD BE SOME UNIT COST FIGURES FOR CORROSION CONTROL - I.E., DOLLARS PER UNIT OF FLUID THROUGHPUT IN THE DIFFERENT SYSTEMS DESCRIBED.

EXHIBITS:

----- 5 FIGURES

ADDITIONAL REFERENCES:

----- 1. WEST: PAPER SPE 4804 (MAR. 12, 1974)

CROSS REFERENCES:

- 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
140. SCHREMP, ROBERSON: SOC. PET. ENG. J. (JUNE, 1975) 227.
148. BRUMMETT, EMANUEL, RONQUILLE: J. PET. TECH. (OCT., 1976) 1241.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION

CARBONATE FIELD
FIELD SECONDARY RECOVERY
CORROSION

COMPRESSION
FACILITIES
CO2 SOURCE
TRANSPORTATION

IMPURITIES (FIELD)
OPERATIONS
CO2 SUPPLY
SEPARATION

175. NORAN, D.: "DIVERSIFIED EQUIPMENT ASSISTS ENHANCED RECOVERY",
OIL & GAS J. (OCT. 17, 1977) 75-80.

ABSTRACT:

----- CHALLENGES ARE BEING POSED TO DESIGN AND EQUIPMENT ENGINEERS BY ENHANCED RECOVERY PROGRAMS. THIS PAPER DISCUSSES SOME OF THESE AND OUTLINES EQUIPMENT DESIGN VARIATIONS FOR DIFFERENT PROCESSES. EXPERIENCES AT FIELDS CURRENTLY UNDER CHEMICAL INJECTION, THERMAL RECOVERY, OR CO2 INJECTION PROGRAMS ARE REVIEWED. PENNZOIL'S CO2 INJECTION PROJECT IN WEST VIRGINIA IS PLANNED TO USE CO2 IN THE LIQUID STATE. THE CO2 WILL BE HAULED TO THE FIELD PLANT IN TANK TRUCKS, AND STORED AT APPROXIMATELY 0 F AND 250 PSI; FOUR TANKS EACH CAPABLE OF STORING 44 TONS OF CO2 HAVE BEEN INSTALLED. A TRIPLEX PUMP WILL PUMP THE CO2 AT THE DESIRED INJECTION PRESSURES. THE PUMP IS CHARGED WITH THE LIQUID AT 300 PSI BY A GEAR PUMP. THE CO2 WILL BE HEATED IN-LINE TO 70 F AND DELIVERED TO SIX INJECTION WELLS FROM AN INJECTION HEADER. THE HEADER IS BUILT TO ALLOW ALTERNATE WATER AND CO2 INJECTION INTO EACH WELL.

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CORROSION WILL BE MONITORED BY ULTRASONIC AND RADIOGRAPHIC NON-DESTRUCTIVE MEASUREMENTS, CORROSION COUPONS, ELECTRICAL RESISTANCE PROBES AND ANALYSIS (FOR IRON CONTROL) OF WATER AT SELECTED POINTS IN SHELL'S WEEKS ISLAND PROJECT IN LOUISIANA. CONTAMINATED GAS WILL BE DEHYDRATED AND USED AS FUEL. GAS WITH A CO2 CONTENT OVER 60% WILL BE FLARED DUE TO MECHANICAL RESTRICTIONS. NO CORROSION PROBLEMS ARE ANTICIPATED IN THE INJECTION WELL. THE PRODUCING WELLS WILL BE COMPLETED WITH DUAL STRINGS, INTERNALLY PLASTIC-COATED WITH SEALING RINGS IN THE INTEGRAL COUPLINGS.

THE GRANNY'S CREEK CO2 PROJECT HAS HAD THREE OPERATIONAL PROBLEMS INCLUDING THE HIGH PRESSURE INJECTION PUMP, METERING THE LIQUID CO2 AND THE CHANGE-OVER FROM CO2 TO WATER DURING INJECTION CYCLES. CORROSION HAS NOT BEEN A PROBLEM. HOWEVER, PARAFFIN HAS BEEN SO SERIOUS THAT THE TUBING HAS HAD TO BE STEAMED IN CERTAIN WELLS.

COMMENTS:

----- EQUIPMENT DESIGNS MAY VARY FOR DIFFERENT PROJECTS AND SHOULD BE TAILORED TO HANDLE OPERATIONS AND PROBLEMS EXPECTED DURING THE PROCESS. A NUMBER OF ADAPTATIONS MAY BE NECESSARY FROM TIME TO TIME.

EXHIBITS:

----- 1 TABLE, 4 FIGURES

KEYWORDS:

COMPRESSION
FACILITIES

CORROSION
IMPURITIES (FIELD)
OPERATIONS

176. OFFERINGA, J.: "CARBON-DIOXIDE-ASSISTED PRODUCTION FROM EXTENSIVELY FRACTURED RESERVOIRS", U.S. PATENT 4,042,029 (AUG. 16, 1977).

ABSTRACT:

----- THIS INVENTION PRESENTS A METHOD FOR EXTENDING CARBON DIOXIDE FLOODING TO FRACTURED RESERVOIRS. BASICALLY, THE METHOD UTILIZES GRAVITY TO ASSIST AND EFFECT THE RECOVERY. CARBON DIOXIDE IS INJECTED INTO A GAS LAYER ABOVE THE OIL COLUMN; AS OIL IS PRODUCED FROM THE BOTTOM OF THE COLUMN, THE CO₂ SWELLS THE OIL IT CONTACTS IN THE MATRIX BLOCKS AND HENCE CAUSES MATRIX PRODUCTION. THE INJECTION AND PRODUCTION RATES ARE CORRELATED SO THAT THE CARBON DIOXIDE DOES NOT IMMEDIATELY CHANNEL THROUGH THE FRACTURE NETWORK TO THE PRODUCING WELLS.

COMMENTS:

----- BELOW A CERTAIN INJECTION RATE, CO₂ WILL NOT MIGRATE RAPIDLY THROUGH THE FRACTURE SYSTEM TO THE PRODUCING WELLS. THIS RATE MAY BE SO LOW THAT THE PROCESS WOULD BE UNECONOMIC, EXCEPT WHEN THE MATRIX HAS RELATIVELY HIGH PERMEABILITY.

EXHIBITS:

----- 5 FIGURES

CROSS REFERENCES:

- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
49. LEWIS: U.S. PATENT 3,193,006 (JULY 6, 1965).
101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
116. BURNETT: U.S. PATENT 3,841,406 (OCT. 15, 1974 B).

KEYWORDS:

FRACTURED RESERVOIRS

CARBONATE FIELD
U.S. PATENT

177. PONTIOUS, S.B. AND THAM, M.J.: "NORTH CROSS (DEVONIAN) UNIT CO2 FLOOD - REVIEW OF FLOOD PERFORMANCE AND NUMERICAL SIMULATION MODEL", PAPER 6390, SPE-AIME PERMIAN BASIN OIL & GAS RECOVERY CONF., MIDLAND, TX. (MAR., 1977).

ABSTRACT:

----- BASIC FIELD HISTORY AND PROJECT DESIGN FOR THE NORTH CROSS (DEVONIAN) UNIT MISCIBLE CO2 FLOOD IS GIVEN IN THE ABSTRACT FOR HENDERSON (1974B). AT THE START OF CO2 INJECTION IN APRIL 1972, THE FIELD PRODUCTION RATE WAS 1480 BOPD. HENDERSON'S SIMULATION STUDY PREDICTED INITIAL RESPONSE 6 MONTHS AFTER START-UP, WITH CO2 BREAKTHROUGH 1 1/2 YEARS LATER AND A PEAK PRODUCTION RATE OF 4000 BOPD FOUR YEARS LATER (MID-1978), BASED ON A DESIGN INJECTION RATE OF 20 MMCF/D (93% CO2, 7% CH4) AND RE-INJECTION OF ALL PRODUCED GAS.

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PRODUCTION ROSE STEADILY FROM 1450 BOPD (9000 GOR) IN MID-1974 TO 2000 BOPD (6000 GOR) IN NOV. 1976. CUMULATIVE INCREMENTAL OIL (ACTUAL PRODUCTION LESS SIMULATOR PROJECTION FOR CONTINUED RESIDUE GAS CYCLING) WAS 926 MSTB OIL IN NOV. 1976. CO2 PRODUCTION RATE AT THAT TIME WAS 5.3% OF THE INJECTION RATE, AND CUMULATIVE CO2 PRODUCTION WAS 1.3% OF CUMULATIVE CO2 INJECTION OF 15% HCPV (27.7 BCF, 6.3 BCF BELOW THE DESIGN TARGET). NINE PRODUCERS HAD RESPONDED, AND ALL WELLS IN THE NORTH END WERE STILL DECLINING. THE BEST WELL INCREASED FROM 40 BOPD (8000 GOR) TO A PEAK RATE OF 300 BOPD (1300 GOR) IN DEC. 1974, THEN DECLINED TO 212 BOPD (4000 GOR, 60% CO2) IN NOV. 1976.

OBSERVED CO2 INJECTIVITIES ARE SIGNIFICANTLY BELOW PREDICTIONS GIVEN BY HENDERSON, ESPECIALLY AFTER SEVERAL YEARS OF INJECTION. THE LOSS IN INJECTIVITY WITH TIME IS GREATER FOR THE WELLS WITH LOWER INITIAL PRESSURES, LEADING THE AUTHORS TO CONCLUDE THAT MULTIPLE-PHASE BEHAVIOR AT PRESSURES BELOW THE MINIMUM MISCIBILITY PRESSURE CAUSE REDUCED MOBILITY DUE TO COMPLEX RELATIVE PERMEABILITY BEHAVIOR. THE PREVIOUS SIMULATION MODEL WAS MODIFIED BY INCORPORATING A PERMEABILITY REDUCTION FACTOR AS A FUNCTION OF PRESSURE AND OIL SATURATION. A GOOD MATCH WAS OBTAINED BETWEEN THE REVISED MODEL AND FIELD PERFORMANCE THROUGH NOVEMBER, 1975.

COMMENTS:

----- ALTHOUGH FIELD DATA ARE GIVEN THROUGH 1976, THE REVISED SIMULATOR PREDICTION IS SHOWN ONLY THROUGH 1975; ONE WONDERS WHAT THE LONG-TERM FORECAST MIGHT BE, SINCE PERFORMANCE IS GENERALLY WORSE THAN THE ORIGINAL PREDICTION. A REFERENCE IS INCLUDED TO AN INTERNAL COMPANY REPORT CONTAINING LABORATORY DISPLACEMENT TESTS; UNFORTUNATELY, NO DATA ARE GIVEN IN THE PAPER.

EXHIBITS:

----- 1 TABLE, 18 FIGURES

CROSS REFERENCES:

-
- 105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
 - 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
 - 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
 - 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
 - 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.

KEYWORDS:

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
MIXING ZONE MODELS

FIELD SECONDARY RECOVERY
FINITE DIFFERENCE MODELS
COMPARISONS WITH FIELD RESULTS

178. ROSMAN, A. AND ZANA, E.: "EXPERIMENTAL STUDIES OF LOW IFT DISPLACEMENT BY CO2 INJECTION", PAPER 6723, SPE-AIME 52ND ANN. FALL TECH. CONF. & EXHBN., DENVER, CO. (OCT., 1977).

ABSTRACT:

----- SEVERAL RECOVERY MECHANISMS HAVE BEEN IDENTIFIED AS OCCURRING WHEN CO2 DISPLACES OIL, INCLUDING SWELLING, VISCOSITY REDUCTION, VAPORIZATION OR EXTRACTION OF PORTIONS OF THE OIL, AND LOWERING THE INTERFACIAL TENSION OF THE OIL. WHEN THE INTERFACIAL TENSION BETWEEN THE OIL AND THE DISPLACING PHASE IS ZERO, A MISCIBLE DISPLACEMENT RESULTS.

THIS PAPER DESCRIBES AN EXPERIMENTAL TECHNIQUE DEVELOPED TO ISOLATE INTERFACIAL TENSION CHANGES FROM OTHER MECHANISMS. BASICALLY, THE METHOD INVOLVES MIXING CO2 AND RESERVOIR OIL BEFORE SATURATING THE CORE; THE MIXTURE IS THEN DISPLACED WITH SIMILARLY EQUILIBRATED GAS.

EXPERIMENTAL RESULTS SHOW THAT LOW INTERFACIAL TENSION (IFT) CO2 FLOODING RESULTED IN A 34 TO 39% REDUCTION IN RESIDUAL OIL SATURATION BEYOND WATERFLOODING. THIS INDICATES THAT INJECTED GAS (CO2) NEED ONLY BE ENRICHED TO A COMPOSITION WHICH LIES WITHIN A LOW IFT REGION AROUND THE CRITICAL POINT, RATHER THAN TO A CRITICAL COMPOSITION POINT WHERE MISCIBILITY IS OBTAINED, TO ACHIEVE AN EFFECTIVE DISPLACEMENT. THE RESULTS WERE CORRELATED WITH THE CAPILLARY NUMBER.

COMMENTS:

----- THIS PAPER IDENTIFIES A MECHANISM FOR THE FACT THAT RECOVERY AT PRESSURES NEAR MISCIBILITY PRESSURE ARE COMMONLY LITTLE DIFFERENT THAN THOSE AT OR ABOVE THE MISCIBILITY PRESSURE.

EXHIBITS:

----- 4 TABLES, 4 FIGURES INCLUDING COMPARISON OF LOW IFT FLOODING WITH WATERFLOODING

CROSS REFERENCES:

-
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
 - 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
 - 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
 - 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
 - 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).

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KEYWORDS:

LAB. PROCEDURES AND APPARATUS
SECONDARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
OTHER LABORATORY STUDIES

179. RUMP, W.M., HARE, M. AND PORTER, R.E.: "THE SUPPLY OF CARBON DIOXIDE FOR ENHANCED OIL RECOVERY", PREPARED FOR U.S. D.O.E. UNDER CONTRACT NO. EX-76-C-01-2515 (DEC., 1977).

ABSTRACT:

----- RESULTS ARE PRESENTED FROM A STUDY BY PULLMAN KELLOGG OF THE CARBON DIOXIDE SUPPLY SITUATION FOR MISCIBLE FLOODING OPERATIONS TO ENHANCE OIL RECOVERY. CANDIDATE OIL RESERVOIRS WERE IDENTIFIED AND CO₂ REQUIREMENTS AND POTENTIAL RECOVERY FOR SOME OF THESE WERE ESTIMATED. A SURVEY OF CARBON DIOXIDE SOURCES, INCLUDING COMBUSTION VENTS, CHEMICAL PROCESS STACKS, AND NATURALLY OCCURRING DEPOSITS, WAS CONDUCTED; THE SURVEY SHOWS THAT MORE THAN ENOUGH CARBON DIOXIDE IS AVAILABLE FROM ABOVE-GROUND SOURCES ALONE TO MEET EXPECTED DEMANDS. SYSTEMS TO PURIFY AND DELIVER CO₂ HAVE BEEN DESIGNED AND COSTED; THE LOWEST COST IS FOR CO₂ FROM NATURAL DEPOSITS.

COMMENTS:

----- 1. THIS STUDY IS REASONABLY COMPLETE AND MAY BE OF USE TO SYSTEMS OR PROCESS DESIGN PERSONNEL.

2. IN THE APPENDIX, IT IS SUGGESTED THAT A CONTINUOUS STRUCTURAL CHANGE OCCURS FROM "LIQUID" TO "VAPOR" IN THE SUPERCRITICAL REGION, BASED ON A LIMITED AMOUNT OF INFORMATION IN THE RUSSIAN TECHNICAL LITERATURE.

EXHIBITS:

----- 19 TABLES, 15 FIGURES, INCLUDE LOCATIONS OF SOURCES AND PROCESS FLOW SHEETS.

ADDITIONAL REFERENCES:

----- VOKALOVICH AND ALTUMIN: THERMOPHYSICAL PROPERTIES OF CARBON DIOXIDE, COLLET'S PUBL., LONDON (1968).

CROSS REFERENCES:

152. DOSCHER, WISE: J. PET. TECH. (MAY, 1976) 575.
161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).
162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.

KEYWORDS:

COMPRESSION
GENERAL ECONOMICS
CO₂ SUPPLY
SEPARATION

SCREENING CRITERIA
CO₂ SOURCE
TRANSPORTATION
MISCELLANEOUS DATA

180. SAN FILIPPO, G.P. AND GUCKERT, L.G.: "DEVELOPMENT OF A PILOT CARBON DIOXIDE FLOOD IN THE ROCK CREEK-BIG INJUN FIELD, ROANE COUNTY, WEST VIRGINIA", PAPER 6626, SPE-AIME 1977 EASTERN REGIONAL MTG., PITTSBURGH, PA. (OCT., 1977).

ABSTRACT:

----- ROCK CREEK FIELD, ROANE COUNTY, W. VA., HAS BEEN PRODUCING SINCE 1906 FROM THE LOWER MISSISSIPPIAN BIG INJUN SAND, INITIALLY BY SOLUTION GAS DRIVE AND SINCE 1935, BY LOW PRESSURE GAS RECYCLING. TOTAL RECOVERY IS ESTIMATED AT LESS THAN 40 MMSTBO, LEAVING POSSIBLY 150 MMSTBO REMAINING, ALTHOUGH PRODUCTION RECORDS DO NOT EXIST. IT IS STATED THAT THREE PILOT WATERFLOODS BEFORE 1960 PRODUCED A SMALL INCREASE IN OIL PRODUCTION BUT NO SIGNIFICANT OIL BANK, PRESUMABLY BECAUSE OF EARLY WATER BREAKTHROUGH.

A JOINT D.O.E. - PENNZOIL CO2 PILOT STARTED WITH WATER INJECTION IN OCTOBER, 1976 INTO EIGHT OF THIRTEEN PERIPHERAL WATER INJECTION WELLS ENCLOSING 53 ACRES CONTAINING TWO ADJACENT 10-ACRE FIVE-SPOT PATTERNS. THE OTHER FIVE PERIPHERAL INJECTORS WERE ACTIVATED IN NOVEMBER, 1976 AND THE SIX PATTERN INJECTORS WERE IN SERVICE BY APRIL, 1977; BY SEPTEMBER, 1977, CUMULATIVE WATER INJECTION WAS 97,000 BBLs IN THE PATTERN WELLS AND 480,000 BBLs IN THE PERIPHERAL. AFTER SUFFICIENT WATER INJECTION TO INCREASE PATTERN RESERVOIR PRESSURE FROM 991 PSI INITIALLY TO THE CO2 MISCIBILITY PRESSURE OF 1000 PSI (ESTIMATED FROM SLIM TUBE DISPLACEMENTS REPORTED IN THE PAPER), THE PLAN IS TO INJECT 15,000 TONS OF LIQUID CO2 ALTERNATING WITH SLUGS OF WATER, AT RATES OF 15 TO 20 TONS/DAY/WELL. THE BIG INJUN SAND RESERVOIR IN THE PILOT AREA IS ABOUT 2100 FEET DEEP, WITH A TEMPERATURE OF 73 F, AND AVERAGES 31.6 FEET NET PAY, 199.3 MD AIR PERMEABILITY, AND 21.7% POROSITY (BASED ON 5 MD PERMEABILITY CUT-OFF). THE OIL IS A PARAFFINIC BASE PENN GRADE CRUDE, 43 DEGREES API GRAVITY, 3.2 CP VISCOSITY AT RESERVOIR TEMPERATURE. WATER SATURATION CALCULATED FROM INDUCTION LOGS AVERAGES 50%.

DATA ARE PRESENTED FOR OIL AND CO2-OIL MIXTURE VISCOSITIES AND VOLUME FACTORS AND CO2 SOLUBILITIES AT SEVERAL CO2 PRESSURES. FIELD OPERATIONS, SUCH AS CO2 AND WATER HANDLING ARE DESCRIBED BRIEFLY.

COMMENTS:

----- THE PROJECT IN ITS EARLY STAGES (NO CO2 INJECTED), NO USABLE FIELD DATA). MODELLING IS MENTIONED, BUT NO DOCUMENTATION (E.G. PERFORMANCE FORECASTS) IS GIVEN. PILOT AREA CONTAINS SOME OLD WELLS (PARTICULARLY TWO PRODUCERS); THIS MAY RESULT IN PROBLEMS, PARTICULARLY IN INTERPRETATION. PAPER IS LARGELY DESCRIPTIVE

EXHIBITS:

----- 4 TABLES, 7 FIGURES

CROSS REFERENCES:

91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).

125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
177. PONTIOUS, THAM: PAPER SPE 6390 (1977).

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
MULTICOMPONENT SYSTEMS
OIL SWELLING
VISCOSITY
WATER INJECTION
FIELD MISCIBLE APPLICATION
OPERATIONS

HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
SOLUBILITY
SANDSTONE FIELD
FIELD TERTIARY RECOVERY
FACILITIES
SLIM-TUBE DISPLACEMENTS

181. SHELTON, J.L. AND YARBOROUGH, L.: "MULTIPLE PHASE BEHAVIOR IN POROUS MEDIA DURING CO₂ OR RICH-GAS FLOODING", J. PET. TECH. (SEP., 1977) 1171-1178.

ABSTRACT:

----- PHASE BEHAVIOR AND PHASE PROPERTIES OF MIXTURES OF DRIVE GASES WITH RECOMBINED RESERVOIR OILS WERE STUDIED WITH A VARIABLE-VOLUME WINDOWED CELL. SEVEN MIXTURES OF OIL WITH A RICH GAS WERE TESTED AT 105 F OVER A RANGE OF PRESSURES UP TO 5600 PSIA. FOR 6 MIXTURES, TWO LIQUID PHASES WERE OBSERVED BETWEEN 1300 AND 5600 PSIA, AND FOR TWO OF THESE, FOUR PHASES (ASPHALTENE SOLIDS, TWO LIQUIDS, GAS) WERE IN EQUILIBRIUM OVER A SMALL PRESSURE RANGE. PHASE DIAGRAMS ARE GIVEN.

SEVERAL EQUILIBRIUM CELL CONTACT STAGE EXPERIMENTS WERE RUN STARTING WITH A MIXTURE FORMING TWO LIQUID PHASES AT 2000 PSIA; DENSITIES, VISCOSITIES, AND COMPOSITION OF BOTH PHASES WERE MEASURED. AFTER REMOVING THE DRIVE-GAS-RICH PHASE, DRIVE-GAS WAS ADDED, EQUILIBRATED, AND PHASE PROPERTIES MEASURED, FOLLOWED BY TWO MORE REPETITIONS TO STUDY THE STRIPPING OF THE OIL-RICH PHASE BY DRIVE GAS OVERRUNNING, WHICH MAY LEAVE BEHIND RESIDUAL OIL SATURATION.

EIGHT MIXTURES OF OIL B WITH 59 TO 95 MOL% WERE STUDIED AT 94 F, AT PRESSURES UP TO 9000 PSIA. ALL EIGHT MIXTURES FORMED TWO LIQUID PHASES UNDER SOME CONDITIONS. DETAILED PHASE COMPOSITION ANALYSES WERE PERFORMED ON A NINTH MIXTURE (79 MOL% CO₂).

SIXTEEN-FOOT BEREA CORE DISPLACEMENT TESTS WERE PERFORMED IN THE PRESENCE OF CONNATE WATER WITH:

1. RICH GAS AT 2000 PSIA, OIL A
2. RICH GAS AT 2800 PSIA, OIL A
3. CO₂ AT 1450 PSIA, OIL B

PVT CELL TESTS SHOWED FORMATION OF SIGNIFICANT VOLUMES OF OIL-RICH IMMISCIBLE PHASES FOR SOME COMPOSITIONS OF SYSTEMS 1 AND 3, AND LITTLE FORMATION IN NO.2. BOTH 1 AND 3 LEFT A SIGNIFICANT RESIDUAL OIL SATURATION, IN CONTRAST TO 2.

COMMENTS:

----- THIS PAPER PRINCIPALLY ILLUSTRATES THE COMPLEXITY OF MISCIBLE PROCESSES UNDER SOME CONDITIONS - WITH FOUR PHASES OF DRIVE-GAS AND HYDROCARBONS COMBINED WITH WATER PRESENT, HOW VALID ARE OUR CLASSICAL RELATIVE PERMEABILITY CONCEPTS? NO QUANTITATIVE INFORMATION IS GIVEN TO SHOW THAT WATER PERMEABILITY MIGHT BE REDUCED DUE TO THE PRESENCE OF THE OIL-RICH PHASE RESIDUAL SATURATION. WETTABILITY CHANGES MIGHT HAVE OCCURRED DURING THE DISPLACEMENT EXPERIMENTS.

EXHIBITS:

----- 4 TABLES, 10 FIGURES

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ADDITIONAL REFERENCES:

- 1. SCHNEIDER AND OWENS:
PAPER 5554, SPE-AIME 50TH ANN. FALL TECH. CONF. & EXHIBITION
DALLAS, TX (SEP., 1975).
2. RUTHERFORD: SOC. PET. ENG. J. (DEC., 1962) 340.

CROSS REFERENCES:

- 126. HUANG, TRACHT: PAPER SPE 4735 (1974).
S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).

KEYWORDS:

GENERAL PHASE BEHAVIOR
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
MULTIPLE CONTACT MISCIBILITY
RESIDUAL SATURATION (LAB. EXP.)

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
EQUILIBRIUM RATIOS
SANDSTONE (LAB. EXP.)
CHROMATOGRAPHIC EFFECTS

182. SIAS, R.C.: "SULFONATE WATER FLOOD ADDITIVES AND METHOD OF USING SAME", U.S. PATENT 4,058,467 (NOV. 15, 1977).

ABSTRACT:

----- THIS PATENT RELATES TO A VARIANT OF THE SULFONATE WATERFLOOD PROCESS, WHEREIN THE SULFONATE IS SATURATED WITH CARBON DIOXIDE BEFORE INJECTION: THE CARBON DIOXIDE SUBSTANTIALLY REDUCES THE AMOUNT OF SULFONATE ADSORBED ON THE FORMATION DURING THE WATERFLOOD PROCESS.

COMMENTS:

----- IF VERIFIED BY FURTHER STUDIES, THIS INVENTION COULD CONSIDERABLY IMPROVE RECOVERY WITH SULFONATE WATERFLOODING.

EXHIBITS:

----- 2 TABLES ILLUSTRATING ADSORPTION REDUCTION.

KEYWORDS:

ALTERNATE TECHNOLOGIES

U.S. PATENT
MISCELLANEOUS DATA

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183. SIMON, R.: "OIL RECOVERY BY CO2 INJECTION", PHASE EQUILIBRIA AND FLUID PROPERTIES IN CHEMICAL INDUSTRY (1977) 241-255.

ABSTRACT:

----- VARIOUS AUTHORS HAVE ESTIMATED THAT FIVE TO TEN BILLION BARRELS OF U.S. CRUDE OIL MAY BE POTENTIALLY RECOVERABLE BY CO2 INJECTION. THIS RECOVERY RESULTS FROM CO2 DISSOLVING IN THE OIL, SWELLING IT, REDUCING ITS VISCOSITY, AND LOWERING ITS INTERFACIAL TENSION. ALSO, CO2 VAPORIZES THE VOLATILE PART OF THE OIL AND CARRIES IT FROM THE RESERVOIR IN THE GAS PHASE.

PHYSICAL PROPERTY CORRELATIONS AND DISPLACEMENT TESTS WITH CO2 - RESERVOIR OIL SYSTEMS ARE NEEDED TO CALCULATE THE EFFECT OF CO2 INJECTION. FURTHER RESEARCH IS NEEDED TO IMPROVE THE RELIABILITY OF PRESENT CALCULATION METHODS, PARTICULARLY FOR PREDICTING THE PROPERTIES OF MULTI-PHASE MIXTURES (SPECIFICALLY, K-FACTORS AND INTERFACIAL TENSION) AND UNDERSTANDING THE MASS TRANSFER THAT OCCURS AS A CO2 FRONT PROGRESSES THROUGH A RESERVOIR.

COMMENTS:

----- 1. THE AUTHOR HAS IDENTIFIED THE KEY SPOTS WHERE KNOWLEDGE IS LACKING ON CO2 FLOODING.

2. FIGURE 10 INDICATES THAT A RELATIVELY WIDE BAND EXISTS WHERE INTERFACIAL TENSION (IFT) IS REDUCED BY ONE OR TWO ORDERS OF MAGNITUDE; IF LOW IFT IS SUFFICIENT FOR GOOD RECOVERY BY CO2 FLOODING (ROSMAN AND ZANA, 1977) THEN IT MAY BE MUCH EASIER TO OBTAIN THAN MISCIBILITY.

3. THE DATA PRESENTED IN THIS CHAPTER ARE THOSE GIVEN BY SIMON AND GRAUE (1965) AND SIMON, ROSMAN, AND ZANA (1977 B).

EXHIBITS:

----- 14 FIGURES

CROSS REFERENCES:

51. SIMON, GRAUE: TRANS., AIME (1965) 102.
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.

KEYWORDS:

GENERAL PHASE BEHAVIOR
MULTICOMPONENT SYSTEMS
EFFECTS OF TEMPERATURE
OIL SWELLING
VISCOSITY
MULTIPLE CONTACT MISCIBILITY

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
DENSITY
SOLUBILITY
INTERFACIAL TENSION
COMPOSITIONAL MODELS

184. SIMON, R., ROSMAN, A. AND ZANA, E.: "PHASE BEHAVIOR PROPERTIES OF CO₂ - RESERVOIR OIL SYSTEMS", PAPER 6387, SPE-AIME PERMIAN BASIN OIL & GAS RECOVERY CONF., MIDLAND, TX. (MAR., 1977).

ABSTRACT:

----- THIS PAPER PRESENTS EXPERIMENTAL PHASE BEHAVIOR DATA FOR TWO CO₂ - RESERVOIR OIL SYSTEMS AT RESERVOIR PRESSURES AND TEMPERATURES. THE STUDY INCLUDED CO₂ CONCENTRATIONS FROM 0 TO 90% AT TEMPERATURES OF 130 AND 255 F FOR THE TWO DIFFERENT OILS AND PRESSURES RANGING TO 5000 PSI.

THE DATA INCLUDE: PRESSURE-COMPOSITION DIAGRAMS, WITH BUBBLE POINTS, DEW POINTS, AND CRITICAL POINTS; VAPOR-LIQUID EQUILIBRIUM COMPOSITIONS AND RELATED K VALUES; VAPOR AND LIQUID DENSITIES, COMPARED WITH VALUES CALCULATED BY THE REDLICH-KWONG EQUATION OF STATE; VAPOR AND LIQUID VISCOSITIES, COMPARED WITH PREDICTIONS BY THE LOHRENZ-BRAY-CLARK CORRELATION; AND INTERFACIAL TENSIONS, COMPARED WITH PREDICTIONS USING THE WEINAUG-KATZ PARACHOR EQUATION. COMPARISONS IN ALL CASES WERE RATHER POOR, INDICATING A NEED FOR IMPROVED CALCULATION METHODS.

COMMENTS:

- 1. IT IS VERY DISTURBING THAT WITH ALL THE WORK DONE IN THE PAST, THE DENSITY, VISCOSITY, AND INTERFACIAL TENSION COULD NOT BE MORE ACCURATELY PREDICTED.
2. AS SATURATION PRESSURE INCREASED, OIL DENSITY INCREASED AS WELL.

EXHIBITS:

----- 2 TABLES, 10 FIGURES INCLUDING EXPERIMENTAL RESULTS

KEYWORDS:

CORRELATIONS
HYDROCARBON COMPONENTS
EQUATIONS OF STATE
DENSITY
INTERFACIAL TENSION

EXPERIMENTAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
MULTICOMPONENT SYSTEMS
EFFECTS OF PRESSURE
VISCOSITY
EQUILIBRIUM RATIOS

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185. STRIGHT, D.H., JR., AZIZ, K., SETTARI, A. AND STARRATT, F.E.:
"CARBON DIOXIDE INJECTION INTO BOTTOM-WATER, UNDERSATURATED
VISCOUS OIL RESERVOIRS", J. PET. TECH. (OCT., 1977) 1248-1258.

ABSTRACT:

----- THIS PAPER ANALYZES THE POTENTIAL FOR USING CO2 TO INCREASE OIL RECOVERY FROM VISCOUS, UNDERSATURATED OIL RESERVOIRS WHERE THE OIL ZONE IS UNDERLAIN BY WATER. THESE RESERVOIRS ARE CONSOLIDATED WITH HIGH PERMEABILITY (500 TO 15,000 MD) AND POROSITY (20 TO 30%), MEDIUM OIL VISCOSITY (3 TO 100 CP), LOW SATURATION PRESSURE (50 TO 800 PSI) AND SOLUTION GAS-OIL RATIO (30 TO 250 SCF/BBL), AND HAVE BOTTOM WATER AND VARYING DEGREES OF WATER INFLUX. OIL RECOVERY IS CONTROLLED BY WATER CONING.

THE RESULTS OF A SINGLE WELL PILOT TEST ARE PRESENTED. NUMERICAL SIMULATION WAS USED TO MATCH WELL HISTORY AND TEST RESULTS TO EVALUATE THE POTENTIAL FOR IMPROVED RECOVERY. IT WAS FOUND THAT THE CYCLIC CO2 SOAK PROCESS DID NOT INCREASE EXPECTED ULTIMATE RECOVERY, NOR DID IT SIGNIFICANTLY ACCELERATE RECOVERY.

A CO2 DISPLACEMENT SCHEME WAS THEN EVALUATED, AND FOUND TO BE AN ATTRACTIVE SCHEME FOR SOME BOTTOM-WATER RESERVOIRS. FOR THE HYPOTHETICAL CASE EVALUATED, A CO2 COST OF 50 CENTS/MCF WAS THE MAXIMUM THAT COULD BE USED, AND STILL PROVIDE A REASONABLE RATE OF RETURN AND PAYOUT BASED ON ALBERTA ECONOMIC PARAMETERS.

COMMENTS:

----- THIS PAPER SUBSTANTIATES THE GENERAL CONCEPT THAT SOAK PROCESSES NORMALLY DO NOT INCREASE RESERVES, BUT RATHER ACCELERATE PRODUCTION (IF THEY MANAGE THAT).

EXHIBITS:

----- 1 TABLE, 16 FIGURES

CROSS REFERENCES:

- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
158. HOLM: J. PET. TECH. (JAN., 1976) 76.

KEYWORDS:

SOAK OPERATION
FIELD IMMISCIBLE APPLICATION
OPERATIONS
COMPARISONS WITH FIELD RESULTS

SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FIELD ECONOMICS
FINITE DIFFERENCE MODELS
OTHER MODELLING

186. WARNER, H.R., JR.: "AN EVALUATION OF MISCIBLE CO2 FLOODING IN WATERFLOODED SANDSTONE RESERVOIRS", J. PET. TECH. (OCT., 1977) 1339-1347.

ABSTRACT:

----- A FOUR-COMPONENT, MISCIBLE MIXING PARAMETER SIMULATOR WAS USED TO STUDY CARBON DIOXIDE FLOODING IN WATERFLOODED SANDSTONE RESERVOIRS. PROCESSES STUDIED INCLUDED CO2 INJECTION ALONE, A SLUG OF CO2 FOLLOWED BY WATER, ALTERNATE SLUGS OF CO2 AND WATER, AND SIMULTANEOUS INJECTION OF CO2 AND WATER. RESERVOIR DESCRIPTIONS WERE VARIED, INCLUDING KV TO KH RATIOS RANDOMLY HETEROGENEOUS, AND THREE STRATIFIED PERMEABILITY DISTRIBUTIONS. RELATIVE PERMEABILITY RELATIONSHIPS WERE NOT VARIED, AND ALL SIMULATIONS WERE FOR ONE-QUARTER OF A FIVE-SPOT PATTERN.

THE SIMULATOR STUDIES PREDICT THAT SIMULTANEOUS INJECTION OF CO2 AND WATER WOULD RECOVER ALMOST 50% OF THE POTENTIAL TERTIARY OIL; ALTERNATE SLUG INJECTION RECOVERED ABOUT 40% OF THE POTENTIAL TERTIARY OIL AND THE OTHER TWO PROCESS VARIATIONS EACH RECOVERED ABOUT 25% OF POTENTIAL TERTIARY OIL. GRAVITY SEGREGATION WAS THE MOST SERIOUS LIMITING FACTOR ON RECOVERY EFFICIENCY FOR ALL OF THE CO2 PROCESSES STUDIED. PRODUCED CO2 RANGED FROM 50% TO 80% OF THE AMOUNT INJECTED. RESULTS WERE INSENSITIVE TO WELL SPACING. A RANDOMLY HETEROGENEOUS RESERVOIR PERFORMED BETTER THAN A HOMOGENEOUS RESERVOIR. DEPENDING UPON THE LOCATION OF A SINGLE HIGH PERMEABILITY STREAK, A STRATIFIED RESERVOIR MAY PERFORM BETTER OR WORSE THAN A HOMOGENEOUS RESERVOIR.

COMMENTS:

----- SOME SENSITIVITY OF RESULTS TO GRID CONFIGURATION AND SPACING IS REPORTED. A TWO-DIMENSIONAL CROSS SECTIONAL GRID AGREES FAIRLY WELL WITH A THREE-DIMENSIONAL SIMULATION AND REQUIRES ABOUT ONE-FOURTH OF THE COMPUTING TIME. A TWO-DIMENSIONAL AREAL GRID GAVE MORE OPTIMISTIC RESULTS THAN EITHER OF THE OTHERS WHICH IS REASONABLE, CONSIDERING THAT GRAVITY EFFECTS PLAYED A DOMINANT ROLE IN THESE CALCULATIONS. RESULTS PRESENTED FOR PRIMARY RECOVERY (PRESUMABLY SOLUTION GAS DRIVE) AND WATERFLOODING DID NOT SHOW ANY APPRECIABLE VARIATION IN OVERALL RECOVERY PERFORMANCE WITH ANY OF THE PARAMETERS, IN CONTRAST TO THE CO2 FLOOD RESULTS.

EXHIBITS:

----- 9 TABLES, 12 FIGURES

CROSS REFERENCES:

-
- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
 - 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
 - 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
 - 105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
 - 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
 - 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
 - 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.

S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.

KEYWORDS:

MIXING ZONE MODELS

FINITE DIFFERENCE MODELS
OTHER MODELLING

187. ANON.: "NEW MEXICO CO2 DEVELOPMENT PLANNED", OIL & GAS J.
(SEP. 18, 1978) 67.

ABSTRACT:

----- THIS IS A NEWS RELEASE CONCERNING THE PROPOSED
BRAVO DOME CARBON DIOXIDE UNIT, WHICH WILL COVER 1.2 MILLION ACRES
IN NORTHEAST NEW MEXICO. AMOCO IS THE MAJOR LEASEHOLDER WITH 65%
INTEREST, AND HAS DRILLED 22 PRODUCERS IN 30 ATTEMPTS SO FAR. THE
CO2 IS 90% PURE AND LIES AT AN AVERAGE DEPTH OF 3000 FEET. THERE
ARE AN ESTIMATED 10 TCF OF CO2 RESERVES UNDER 720 THOUSAND PRODUCTIVE
ACRES, MAKING IT ONE OF THE LARGEST NATURAL DEPOSITS YET FOUND IN
THE U.S.

KEYWORDS:

MISCELLANEOUS DATA

CO2 SOURCE

MISCELLANEOUS DATA

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188. BAKER, L.E. AND LUKS, K.D.: "CRITICAL POINT AND SATURATION PRESSURE CALCULATIONS FOR MULTICOMPONENT SYSTEMS", PAPER 7478, SPE-AIME 53RD ANN. FALL TECH. CONF. & EXHBN., HOUSTON, TX, (OCT., 1978).

ABSTRACT:

----- AN IMPROVED METHOD IS PRESENTED TO CALCULATE PHASE DISTRIBUTIONS AND COMPOSITIONS FOR MULTICOMPONENT FLUIDS. THE METHOD IS BASED ON THE REDLICH-KWONG EQUATION OF STATE, AND ALLOWS DIRECT CALCULATION OF CRITICAL POINTS AND PHASE ENVELOPES FOR HYDROCARBON MIXTURES CONTAINING CO₂. SUFFICIENT DETAIL IS GIVEN FOR DEVELOPMENT OF THE COMPUTER PROGRAMS NECESSARY TO USE THE METHOD.

THE METHOD IS USED TO CALCULATE PRESSURE-COMPOSITION PHASE ENVELOPES FOR EXPERIMENTAL DATA MIXTURES: METHANE-PROPANE, CO₂-SYNTHETIC RESERVOIR OIL, AND CO₂-SACROC OIL. CALCULATED CRITICAL CONCENTRATIONS ARE WITHIN 0.8 MOL%, 10.0 MOL%, AND 1.0%, AND THE CRITICAL PRESSURE ERRORS ARE 3.6%, 6%, AND 10%, RESPECTIVELY.

THE PROCEDURE WOULD NEED TO BE EXTENDED FOR SYSTEMS THAT DO NOT HAVE A CRITICAL POINT, INCLUDING THOSE IN WHICH MORE THAN TWO PHASES CAN COEXIST.

COMMENTS:

----- 1. THE METHOD APPEARS CAPABLE OF CALCULATING RELATIVELY ACCURATE VALUES OF PHASE DENSITIES, DISTRIBUTIONS, COMPOSITIONS, AND SATURATION PRESSURES. THE SAME METHODS CAN BE USED WITH OTHER EQUATIONS OF STATE.

2. THIS METHOD COULD BE USED FOR SCREENING DIFFERENT RESERVOIR OILS, PERHAPS OBTAINING THE NEED FOR SLIM-TUBE DISPLACEMENTS. A FRUITFUL APPLICATION WOULD BE TO INVESTIGATE THE CHARACTERIZATION OF CRUDE OIL COMPONENTS FOR PSEUDO-TERNARY PHASE DIAGRAMS.

EXHIBITS:

----- 3 TABLES, 3 FIGURES, INCLUDING COMPOSITION OF OILS STUDIED; AND GRAPHICAL COMPARISON OF CALCULATED WITH EXPERIMENTAL DATA.

ADDITIONAL REFERENCES:

----- SEE REFERENCES IN PAPER FOR INFORMATION ON THERMODYNAMIC TOPICS, EQUILIBRIUM STAGE CALCULATIONS, AND COMPUTATIONAL METHODS, IN ADDITION TO THE FOLLOWING:

1. SPENCER, DANBERT, AND DANNER: A.I.CH.E. J. (1973) V.19, 522-527.
2. JOFFE AND FUDKEVITCH: CHEM. ENG. PROG. SYMPOSIUM SER. (1967) NO.81, 67, 43-51.
3. PENG AND ROBINSON: A.I.CH.E. J. (1977) V.23, 137-144.
4. ZUDKEVITCH AND JOFFE: A.I.CH.E. J. (1970) V.16, 112-119.

CROSS REFERENCES:

-
154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
 S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
 S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
 S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

KEYWORDS:

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THEORETICAL PHYSICAL PROPERTIES
 GENERAL PHASE BEHAVIOR
 BINARY SYSTEMS
 EQUATIONS OF STATE
 EFFECTS OF TEMPERATURE
 MULTIPLE CONTACT MISCIBILITY

EXPERIMENTAL PHYSICAL PROPERTIES
 HYDROCARBON COMPONENTS
 MULTICOMPONENT SYSTEMS
 EFFECTS OF PRESSURE
 EQUILIBRIUM RATIOS
 COMPOSITIONAL MODELS

189. BILHARTZ, H.L., JR. AND CHARLSON, G.S.: "CORING FOR IN-SITU SATURATIONS IN THE WILLARD UNIT CO2 FLOOD MINI-TEST", PAPER 7050, SPE-AIME FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK. (APR., 1978).

ABSTRACT:

----- A NON-PRODUCING CO2 FLOOD MINI-TEST USING ONE INJECTION WELL, A LOGGING OBSERVATION WELL, AND A FLUID SAMPLING/PRESSURE MONITORING WELL, WAS OPERATED IN A DEPLETED AREA OF THE WILLARD UNIT, WASSON FIELD, FROM AUGUST, 1972 UNTIL MAY, 1976. WATER WAS INJECTED UNTIL DECEMBER, 1973 TO RE-PRESSURE THE HIGHLY STRATIFIED SAN ANDRES DOLOMITE RESERVOIR AND TO WATERFLOOD THE AREA. SUBSEQUENTLY, CO2 AND WATER WERE INJECTED ALTERNATELY AS SMALL SLAGS UNTIL FEBRUARY, 1975, AT LOW RATES TO ENCOURAGE GRAVITY SEGREGATION. WATER WAS INJECTED CONTINUOUSLY AFTER FEBRUARY, 1975, AND A WELL 35 FEET FROM THE INJECTION WAS CORED WITH A PRESSURE-RETAINING BARREL IN APRIL, 1976. CORE PROGRAM DESIGN, INCLUDING THE CORING MUD SYSTEM, IS DESCRIBED, AS ARE ANALYTICAL PROCEDURES. RAW DATA ARE GIVEN FOR FULL DIAMETER SAMPLES, AXIALLY CUT CENTER PLUGS, AND "DONUT" SAMPLES, INCLUDING HORIZONTAL AND VERTICAL PERMEABILITIES, POROSITIES, AND FLUID SATURATIONS. INTERPRETED DATA ARE PRESENTED TO SHOW CORRELATIVE RESERVOIR STRATIFICATION, CO2 INVASION PROFILE, FREE CO2 SATURATION PROFILE, BLOWDOWN LOSSES, AND FILTRATE INVASION (DETERMINED BY USING TRITIATED MUD).

VERTICAL DISTRIBUTION OF CO2 APPEARS TO BE DETERMINED ENTIRELY BY PERMEABILITY STRATIFICATION WITH NO INDICATION OF GRAVITY SEGREGATION BETWEEN OR WITHIN STRATA.

COMMENTS:

----- THIS, TOGETHER WITH PAPERS ON THE WILLARD TEST, PROVIDES A LARGE AMOUNT OF FIELD, LABORATORY AND INTERPRETATIVE DATA, AND MODELLING EFFORTS ON ONE CARBONATE RESERVOIR WHICH ILLUSTRATES THE COMPLEXITY OF CO2 TERTIARY FIELD APPLICATIONS AND SHOULD CONTRIBUTE SIGNIFICANTLY TO UNDERSTANDING THE PROCESS EVENTUALLY. TWO OF THE MORE PERMEABLE STRATA WERE INVADDED BY CO2 BUT STILL HAD HIGH OIL SATURATION; THE AUTHORS POINT THIS OUT, BUT HAVE NO EXPLANATION. THE LACK OF OBSERVED GRAVITY SEGREGATION PROVIDES AN INTERESTING CONTRAST TO SCALED LABORATORY MODELS AND SIMULATION STUDIES, WHICH GENERALLY SHOW A PRONOUNCED GRAVITY EFFECT; THIS DOES NOT SEEM TO RESULT ENTIRELY FROM LOW VERTICAL PERMEABILITY.

EXHIBITS:

----- 2 TABLES, 13 FIGURES

ADDITIONAL REFERENCES:

- 1. HAGEDORN AND BLACKWELL: PAPER SPE 3692 (1972).
2. MURPHY AND OWENS: PAPER SPE 3793 (1972).

CROSS REFERENCES:

166. BILHARTZ: PAPER SPE 6389 (1977).
172. JOHNSTON: PAPER SPE 6388 (1977).
190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).

KEYWORDS:

WATER INJECTION
FIELD RESIDUAL SATURATIONS

CARBONATE FIELD
FIELD TERTIARY RECOVERY
OTHER FIELD INFORMATION

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190. BILHARTZ, H.L., CHARLSON, G.S., STALKUP, F.I. AND MILLER, C.C.:
"A METHOD FOR PROJECTING FULL-SCALE PERFORMANCE OF CO2
FLOODING IN THE WILLARD UNIT", PAPER 7051, SPE-AIME FIFTH
SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK.
(APR., 1978).

ABSTRACT:

----- FLOOD RESPONSE DURING WATERFLOODING AND ALTERNATE
INJECTION OF CO2 AND WATER WERE MONITORED AT AN OBSERVATION WELL
IN THE WILLARD UNIT OF WASSON FIELD. THE SAN ANDRES FORMATION
IS A HIGHLY STRATIFIED SEQUENCE OF MARINE MUDSTONE, WACKESTONES,
AND PACKSTONES. POROSITY AND PERMEABILITY DEVELOPMENT IS DOMINATED
BY DOLOMITIZATION, LEACHING, ANHYDRITE EMPLACEMENT AND FRACTURING,
RESULTING IN A EXTREMELY HETEROGENEOUS RESERVOIR.

OBSERVATIONS IN THE LOGGED WELL WERE MODELLED WITH A FOUR-
COMPONENT MIXING PARAMETER SIMULATOR FOR CO2 DISPLACEMENT AND A
BLACK OIL MODEL FOR PRIMARY PRODUCTION AND THE WATERFLOOD. THE
FOUR PRODUCTIVE ZONES ARE SEPARATED BY GEOLOGICAL BARRIERS TO
CROSSFLOW. ARRIVAL TIMES OF THE TERTIARY OIL BANK AND CO2
CALCULATED FROM THE SIMULATION AGREE REASONABLY WELL WITH THE LOG
OBSERVATIONS. IN TWO OF THE ZONES CO2 AND THE TERTIARY OIL BANKS
ARRIVED SIMULTANEOUSLY AND IN THE OTHER TWO THERE WAS AN APPRECIABLE
DELAY BETWEEN OIL BANK AND CO2 ARRIVAL. THERE WAS ONLY MODERATE
AGREEMENT BETWEEN SIMULATOR PREDICTIONS AND LOG ANALYSIS RESULTS
FOR THE SATURATION PROFILES OVER THE VERTICAL INTERVAL FOR THE
WATER INJECTION AND THE CO2 INJECTION EXPERIMENTS.

THE SIMULATION MODEL, AFTER MATCHING THE MINI-PILOT, WAS USED
TO PROJECT CO2 FLOOD RESPONSE ON FULL SCALE FLOODING. IN THIS
PREDICTION, THERE WAS SIMULTANEOUS BREAKTHROUGH OF TERTIARY OIL
AND CO2. STRATIFICATION INFLUENCED PERFORMANCE MORE THAN GRAVITY.
MOST OF THE INCREMENTAL OIL PRODUCTION OCCURRED AFTER CO2 BREAKTHROUGH
PROJECTED RECOVERY FOR FULL SCALE CO2 FLOODING WAS ABOUT 12% OF
OIL ORIGINALLY IN PLACE, USING A CO2 SLUG OF 20% OF A HYDROCARBON
PORE VOLUME. ABOUT 35% OF THE CO2 SLUG WAS EVENTUALLY PRODUCED.
THE PROJECTED RECOVERY COMPARES WITH WATERFLOOD RECOVERIES GIVEN
IN THE PAPER FOR THREE AREAS OF THE WILLARD UNIT RANGING FROM 8
TO 14% OF THE OIL ORIGINALLY IN PLACE.

COMMENTS:

----- THIS PAPER WOULD BE MORE USEFUL IF MORE DETAILS
WERE GIVEN ABOUT RESERVOIR PARAMETERS, SUCH AS POROSITY AND
PERMEABILITY IN THE LAYERED MODEL FOR SIMULATION. SOME DATA ON
OIL PROPERTIES IN MIXTURES WITH CO2 WOULD HELP IN DETERMINING
WHETHER THE MODEL RESULTS ARE REASONABLE. IN PARTICULAR, IT WOULD
HELP TO SEE HOW THE PEAK PRODUCTION OF CO2 (ABOUT 20% OF THE
INJECTION RATE) COMPARES WITH THE SOLUBILITY OF CO2 IN THE RESERVOIR
OIL AT THE PRESSURE PREDICTED BY THE SIMULATION.

EXHIBITS:

----- 1 TABLE, 13 FIGURES

CROSS REFERENCES:

-
83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
152. DOSCHER, WISE: J. PET. TECH. (MAY, 1976) 575.
158. HOLM: J. PET. TECH. (JAN., 1976) 76.
172. JOHNSTON: PAPER SPE 6388 (1977).
189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
206. STALKUP: PAPER SPE 7042 (1978).

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
FINITE DIFFERENCE MODELS

CARBONATE FIELD
FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
OTHER FIELD INFORMATION
OTHER MODELLING

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191. CHARLSON, G.S., BILHARTZ, H.L., JR. AND STALKUP, F.I.:
"USE OF TIME-LAPSE LOGGING TECHNIQUES IN EVALUATING THE
WILLARD UNIT CO2 FLOOD MINI-TEST", PAPER 7049, SPE-AIME
FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY,
TULSA, OK. (APR., 1978).

ABSTRACT:

----- THE GENERAL OPERATION OF THE WILLARD UNIT (WASSON
FIELD) SAN ANDRES DOLOMITE TERTIARY CO2 MINI-PILOT IS GIVEN IN THE
ABSTRACT FOR PRESSURE-RETAINING CORE RESULTS BY BILHARTZ AND
CHARLSON (1978). CHANGE IN TOTAL CO2 SATURATION (DISSOLVED AND
FREE) WERE MONITORED (+/- 10 SATURATION PERCENT) BY REPEATED
NEUTRON LOGGING OF A STEEL CASED OBSERVATION WELL AT EACH STAGE
OF THE TEST. SIMILARLY, THERMAL DECAY TIME (OR NEUTRON LIFETIME)
LOGS WERE USED TO FOLLOW CHANGES IN WATER SATURATION (+/- 20
SATURATION PERCENT) THROUGH THE CHANGES IN CHLORIDE CONTENT.

THE SAN ANDRES IS HIGHLY STRATIFIED, WITH EIGHT ZONES
(A THROUGH F) CORRELATIVE OVER THE TEST AREA. ZONE F WAS THE
ONLY ONE IN WHICH A TERTIARY OIL BANK PRECEDED THE ARRIVAL OF
CO2. NO GRAVITY EFFECTS WERE SEEN. RESIDUAL OIL SATURATIONS
COULD NOT BE DETERMINED QUANTITATIVELY BECAUSE OF UNCERTAINTIES
IN CO2 AND WATER SATURATION CHANGES COMPUTED FROM THE LOG RESPONSES.

COMMENTS:

----- THIS IS A USEFUL TECHNIQUE TO FOLLOW PROGRESS OF
FLOOD FRONTS AND PERHAPS COULD BE IMPROVED BY CASING WITH FIBERGLASS
INSTEAD OF STEEL PIPE AND USING INDUCTION LOG ALSO.

EXHIBITS:

----- 1 TABLE, 13 FIGURES

CROSS REFERENCES:

- 105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
166. BILHARTZ: PAPER SPE 6389 (1977).
172. JOHNSTON: PAPER SPE 6388 (1977).
189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
206. STALKUP: PAPER SPE 7042 (1978).

KEYWORDS:

CARBONATE FIELD
FIELD TERTIARY RECOVERY
FIELD RESIDUAL SATURATIONS

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

192. CONNER, W.D.: "GRANNY'S CREEK CO2 INJECTION PROJECT, CLAY COUNTY, WEST VIRGINIA", PREPARED FOR U.S. D.O.E. UNDER CONTRACT NO. EF-76-C-05-5302 (1978).

ABSTRACT:

----- THIS PAPER IS A PROGRESS REPORT ON THE D.O.E. SPONSORED GRANNY'S CREEK CO2 PROJECT IN WEST VIRGINIA. THIS PROJECT, RUN BY COLUMBIA GAS TRANSMISSION CORPORATION, IS A FIELD DEMONSTRATION TO EVALUATE THE EFFECTIVENESS OF USING CO2 TO RECOVER HIGH GRAVITY CRUDE OIL FROM SHALLOW WATERED-OUT RESERVOIRS.

THE RESERVOIR WAS REPRESSURED TO APPROXIMATELY 1000 PSI WITH WATER PRIOR TO CO2 INJECTION. A TOTAL OF 9800 TONS (168 MMCF) OF CO2 WAS INJECTED IN SEVERAL STAGES ALTERNATELY WITH WATER FOR MOBILITY CONTROL AND BETTER SWEEP EFFICIENCY. THE TEST IS BEING CONDUCTED IN A SINGLE NORMAL FIVE SPOT; OIL PRODUCTION FROM THE CENTRAL PRODUCER PEAKED SHORTLY AFTER CESSATION OF CO2 INJECTION AND CONTINUED UNTIL RECENTLY. THROUGH APRIL, 1978, APPROXIMATELY 8500 BBL ADDITIONAL OIL WERE RECOVERED BY CO2 INJECTION.

COMMENTS:

- 1. SEVERE OPERATIONAL PROBLEMS DUE TO EQUIPMENT FAILURE AND INCLEMENT WEATHER ADVERSELY AFFECTED THIS TEST.
2. THE AUTHOR STATES THAT ONLY 3 TO 6% OF THE INJECTED CO2 ENTERED THE PATTERN; THIS IS ONE OF THE MAJOR PROBLEMS WITH RUNNING A SINGLE NORMAL FIVE-SPOT PILOT: HOW DOES ONE DETERMINE THE EFFECTIVE INJECTION ?

EXHIBITS:

----- 8 FIGURES, INCLUDING PRODUCTION AND INJECTION DATA

KEYWORDS:

FRACTURED RESERVOIRS
FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
COMPRESSION
OPERATIONS

SANDSTONE FIELD
WATER INJECTION
FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
FACILITIES
OTHER FIELD INFORMATION

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193. GRAUE, D.J. AND BLEVINS, T.R.: "SACROC TERTIARY CO2 PILOT PROJECT", PAPER 7090, SPE-AIME FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK. (APR., 1978).

ABSTRACT:

----- TERTIARY OIL RECOVERY BY CO2 FLOODING WAS PILOT TESTED IN A WATERED-OUT AREA OF THE SACROC UNIT. A 2.3 BCF SLUG OF CO2 WAS INJECTED INTO 6 WELLS IN TWO ADJACENT, FIVE-SPOT PATTERNS OVER A PERIOD OF NINE MONTHS. RESIDUAL OIL WAS DISPLACED BY CO2: 64,000 STBO (3% OOIP) WERE RECOVERED.

THIS PAPER REPORTS ON THE ANALYSES OF THE FIELD DATA INCLUDING CHEMICAL TRACER, PULSE TEST, PRODUCED FLUID ANALYSES AND PRESSURE MEASUREMENTS. PERFORMANCE WAS HISTORY MATCHED WITH A COMPOSITIONAL STREAM TUBE SIMULATOR. THE VOLUMETRIC SWEEP EFFICIENCY OF THE CO2 WAS CALCULATED TO BE 33%. FLUID COMPOSITION DATA SHOWED THAT A SIGNIFICANT GAS SATURATION WAS CREATED BY CO2 INJECTION AND THAT INTERPHASE MASS TRANSFER ENRICHED THE PRODUCED FLUIDS IN INTERMEDIATE HYDROCARBONS. THE DATA AND SIMULATOR RESULTS SUGGEST THAT THE FLOODING MECHANISM WAS NOT STRICTLY MISCIBLE DISPLACEMENT. EVIDENCE OF CO2 DISSOLVING ROCK AND AGGRAVATING THE HETEROGENEITIES AND TENDENCIES OF CO2 TO CHANNEL WAS FOUND.

THE DATA FROM THE PILOT INDICATE THE CO2 REQUIREMENT FOR TERTIARY OIL RECOVERY AT SACROC IS 15 TO 20 MCF/BBL. THIS WILL GIVE AN INCREMENTAL RECOVERY OF 4 TO 6% OOIP AT THE START OF THE TERTIARY FLOOD, FOR A 30% PV SLUG OF CO2. THIS RECOVERY EFFICIENCY WAS NOT ECONOMIC AT \$15/BBL BUT WOULD BE ECONOMIC AT A PRICE OF \$20/BBL.

COMMENTS:

- 1. THIS IS A WELL DOCUMENTED STUDY OF TERTIARY CO2 FLOODING.
2. THE EXACT REASON WHEREBY THE MISCIBILITY PRESSURE BASED ON SIMULATION STUDIES WAS HIGHER THAN ORIGINALLY THOUGHT SHOULD BE DETERMINED. SPIVAK (1975) ARRIVED AT A SIMILAR RESULT FOR SACROC FIELD IN GENERAL.

EXHIBITS:

----- 6 TABLES, 17 FIGURES, INCLUDING RESERVOIR AND FLUID SAMPLE DATA, ECONOMICS, PRODUCTION DATA, AND SIMULATED PERFORMANCE.

CROSS REFERENCES:

-
152. DOSCHER, WISE: J. PET. TECH. (MAY, 1976) 575.
162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
177. PONTIOUS, THAM: PAPER SPE 6390 (1977).
178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
196. KANE: PAPER SPE 7091 (1978).

KEYWORDS:

FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
OTHER FIELD INFORMATION
COMPARISONS WITH FIELD RESULTS

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
FIELD ECONOMICS
COMPOSITIONAL MODELS
OTHER MODELLING

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194. GRAUE, D.J. AND ZANA, E.: "STUDY OF A POSSIBLE CO₂ FLOOD IN THE RANGELY FIELD, COLORADO", PAPER 7060, SPE-AIME FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK. (APR., 1978).

ABSTRACT:

----- FEASIBILITY OF CO₂ MISCIBLE TERTIARY RECOVERY FOR THE WEBER SANDSTONE RESERVOIR, RANGELY FIELD, COLORADO WAS STUDIED BY: 1. LABORATORY PHASE BEHAVIOR MEASUREMENTS COMPRISING CONSTANT COMPOSITION EXPANSIONS AND VAPOR-LIQUID EQUILIBRIUM DATA.

2. THREE DISPLACEMENT EXPERIMENTS ON WEBER SANDSTONE CORES AT 2600 PSIG, 160 F.

3. SLIM TUBE MINIMUM MISCIBILITY PRESSURE DETERMINATIONS AT THE RESERVOIR TEMPERATURE OF 160 F.

4. ONE-DIMENSIONAL COMPOSITIONAL RESERVOIR SIMULATIONS TO ESTIMATE RECOVERY EFFICIENCY AS A FUNCTION OF PRESSURE.

RECOMBINED RANGELY RESERVOIR OIL (32.8 DEGREES API, 320 PSIA BUBBLE POINT AT 160 F, 134 SCF/STB) WAS USED IN THE EXPERIMENTS, WITH TWO GAS MIXTURES (GAS 1: 95% CO₂, 5% CH₄; GAS 2: 85% CO₂, 10% N₂, 5% CH₄) TO STUDY THE EFFECT OF IMPURITIES ON MISCIBLE DISPLACEMENT. MINIMUM MISCIBILITY PRESSURE FOR GAS 2 WAS 3040 PSIA, VERSUS 2100 PSIA FOR GAS 1. NUMERICAL SIMULATION RESULTS FOR GAS 1 SHOWED LITTLE INCREASE IN RECOVERY EFFICIENCY WITH PRESSURE ABOVE 2300 PSI, IN AGREEMENT WITH SLIM TUBE RESULTS.

COMMENTS:

----- THE SIMULATION MODEL WAS MODIFIED FROM AN INTERCOMP PROGRAM TO ACCOUNT FOR RELATIVE PERMEABILITY, HYSTERESIS, CAPILLARY NUMBER EFFECTS AND CO₂ SOLUBILITY IN WATER; NO DETAILS ARE GIVEN. THE SIMULATOR PHASE DENSITY AND COMPOSITION ROUTINES WERE ADJUSTED IN AN UNDOCUMENTED WAY TO GIVE A BEST FIT TO EXPERIMENTAL DATA; CALCULATED LIQUID DENSITIES AT SATURATION PRESSURES ARE SHOWN TO BE IN CLOSE AGREEMENT WITH EXPERIMENTAL DATA. GENERAL USEFULNESS OF THIS PAPER WOULD BE GREATER IF THESE DETAILS WERE GIVEN.

EXHIBITS:

----- 7 TABLES, 8 FIGURES

ADDITIONAL REFERENCES:

- 1. HUPPLER: J. PET. TECH. (1969) 539.
2. JACOBSON: J. CAN. PET. TECH. (1972) V.11, 56-59.

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).

KEYWORDS:

GENERAL PHASE BEHAVIOR

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS

NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
OIL SWELLING
EQUILIBRIUM RATIOS
WETTABILITY
SANDSTONE (LAB. EXP.)
BUCKLEY-LEVERETT MODELLING
SLIM-TUBE DISPLACEMENTS

MULTICOMPONENT SYSTEMS
DENSITY
SOLUBILITY
MULTIPLE CONTACT MISCIBILITY
TERTIARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
HELE-SHAW MODELS
FRACTURED RESERVOIR MODELS

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195. HARE, M., PERLICH, H., ROBINSON, R., SHAH, M. AND ZIMMERMAN, F.:
"SOURCES AND DELIVERY OF CARBON DIOXIDE FOR ENHANCED OIL
RECOVERY", PREPARED UNDER U.S. D.O.E. CONTRACT NO. EX-76-C-01-251
(1978).

ABSTRACT:

----- THIS REPORT PRESENTS RESULTS FROM A COMPREHENSIVE
STUDY BY PULLMAN KELLOGG AND OTHERS OF THE CARBON DIOXIDE SUPPLY
SITUATION FOR MISCIBLE FLOODING OPERATIONS TO ENHANCE OIL RECOVERY.
A SURVEY OF CARBON DIOXIDE SOURCES WITHIN THE GEOGRAPHIC AREAS OF
POTENTIAL EOR ARE SHOWN ON FOUR REGIONAL MAPS WITH THE TABULAR DATA
FOR EACH REGION TO DESCRIBE THE SOURCES IN TERMS OF QUANTITY AND
QUALITY. EVALUATION OF ALL COSTS ASSOCIATED WITH DELIVERING CARBON
DIOXIDE FROM SOURCE TO DESTINATION ARE PRESENTED, AND SPECIFIC
ILLUSTRATIONS OF THE USE OF THE MAPS AND COST CHARTS ARE GIVEN.

COMMENTS:

----- THIS DOCUMENT IS COMPREHENSIVE ON THE SOURCES AND
DELIVERY COSTS OF CO₂.

EXHIBITS:

----- 25 TABLES, 79 FIGURES INCLUDING SOURCE MAPS AND
COST CHARTS.

CROSS REFERENCES:

- 152. DOSCHER, WISE: J. PET. TECH. (MAY, 1976) 575.
161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).
162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
179. RUMP, HARE, PORTER: D.O.E. CONTRACT (1977).
197. MCREE: D.O.E. CONTRACT (1978).
199. NORAN: OIL & GAS J. (MAR. 27, 1978).
200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
205. SHAH, WITTMAYER: D.O.E. CONTRACT (1978).
206. STALKUP: PAPER SPE 7042 (1978).
S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
S 59. CROW: OIL & GAS J. (JAN. 16, 1978) 23.

KEYWORDS:

CO₂ SOURCE
TRANSPORTATION

GENERAL ECONOMICS
CO₂ SUPPLY
MISCELLANEOUS DATA

196. KANE, A.V.: "PERFORMANCE REVIEW OF A LARGE SCALE CO₂-WAG PROJECT SACROC UNIT - KELLY SNYDER FIELD", PAPER 7091, SPE-AIME FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK. (APR., 1978).

ABSTRACT:

----- THIS PAPER REVIEWS THE PERFORMANCE OF THE CO₂ FLOOD AT SACROC. AS OF YEAR-END 1977, 344 BCF OF CO₂ AND 683 MMbbl OF WATER HAD BEEN INJECTED INTO THE PATTERN AREAS. THE CO₂ VOLUME INJECTED INTO THE THREE PHASE AREAS THAT SACROC WAS DIVIDED INTO FOR PROCESSING WAS EQUIVALENT TO 14.3, 10.0, AND 1.4% HCPV.

OIL PRODUCTION INCREASED FROM 173 MBPD IN 1972 TO A PEAK OF 210 MBPD IN LATE 1973, AND HAS SINCE DECLINED TO 140 MBPD. (ALTHOUGH NOT MENTIONED IN THIS PAPER, A SIZEABLE FRACTION OF THIS INCREASE MAY HAVE RESULTED FROM THE REMEDIAL WORK PERFORMED IN CONJUNCTION WITH THE CO₂ FLOOD AND TO INCREASED MARKET DEMAND FACTORS AND ALLOWABLES FOR SACROC).

PREMATURE BREAKTHROUGH OF CO₂ NECESSITATED ACCELERATED INSTALLATION OF CO₂ REMOVAL FACILITIES. TO MAINTAIN CONTROL OF CO₂ PRODUCTION, THE WAG RATIO WAS INCREASED AND A COSTLY ZONAL INJECTION CONTROL PROGRAM WAS CONDUCTED.

UPDATED PERFORMANCE PREDICTIONS INDICATE THAT INCREMENTAL OIL RECOVERY OVER WATERFLOODING WILL BE 5.7 TO 6.7% OOIP IN THE AREA PROCESSED WITH CO₂. DUE TO DIMINISHING ECONOMIC RETURNS AT HIGHER CO₂ SLUG SIZES, THE CO₂ SLUG LIMIT WAS REDUCED TO 12% HCPV IN EARLY 1977.

OVERALL CONCLUSIONS OF THIS PAPER ARE THAT SUBSTANTIAL RECOVERY OVER WATERFLOODING CAN BE OBTAINED WITH CO₂, AND THAT THE DOMINANT FACTOR CONTROLLING RECOVERY AT SACROC IS THE HETEROGENEITY. THE PROJECT HAS BEEN AN ECONOMIC SUCCESS, BUT FUTURE PROJECT PROFITABILITY AND RESERVES ARE HIGHLY SENSITIVE TO THE FUTURE PRICE OF CRUDE OIL.

COMMENTS:

----- 1. BASED ON THE SIMULATION STUDY OF RONQUILLE, BRUMMET AND EMANUEL, THE ESTIMATED ORIGINAL OIL IN PLACE WAS REDUCED FROM 2.73 TO 2.11 BILLION BARRELS.

2. THE INCREASED WAG RATIO CURRENTLY IN USE, AND THE EARLY BREAKTHROUGH OF CO₂ (WHICH TENDS TO SUPPORT THE CONCLUSION OF SPIVAK, PERRYMAN, AND NORRIS, 1975 THAT THE FLOOD WAS NOT MISCIBLE) INDICATE THAT THE KNOWLEDGE OF CO₂ FLOODING IS NOT COMPLETE; HOWEVER, THE OPERATOR STILL FEELS THE PROJECT HAS BEEN AN ECONOMIC SUCCESS.

EXHIBITS:

----- 4 TABLES, 19 FIGURES SUMMARIZING PROJECT PERFORMANCE

ADDITIONAL REFERENCES:

----- RONQUILLE, BRUMMETT, AND EMANUEL:
PAPER SPE 5536 (1975).

CROSS REFERENCES:

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- 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
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- 193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
- S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
- S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
- S 35. PERRYMAN: PET. ENG. (FEB., 1972) 35.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
FIELD ECONOMICS
OPERATIONS
COMPARISONS WITH FIELD RESULTS

CARBONATE FIELD
FIELD SECONDARY RECOVERY
MOBILITY CONTROL
FACILITIES
COMPOSITIONAL MODELS
SEPARATION

197. MCREE, B.C.: "WEST VIRGINIA CO2 OIL RECOVERY PROJECT INTERIM REPORT", PREPARED UNDER U.S. D.O.E. CONTRACT NO. E (46-1)-8024 (1978).

ABSTRACT:

----- THIS PAPER DESCRIBES THE GRIFFITHSVILLE BEREA SAND CO2 PILOT TEST IN WEST VIRGINIA, OPERATED UNDER A D.O.E. CONTRACT BY GUYAN OIL COMPANY. THE PILOT AREA CONSISTS OF NINE 10-ACRE, NORMAL FIVE-SPOT PATTERNS IN A SQUARE ARRAY; THE RESERVOIR HAS 14 NET FEET IN 24 FEET OF GROSS SAND WITH A PERMEABILITY OF 14 MD AND A POROSITY OF 12%. THE WATER SATURATION IN THE PILOT AREA IS 18%. TOTAL PRIMARY AND SECONDARY RECOVERY FROM THE 14 THOUSAND ACRE FIELD IS ABOUT 14 MMBO, REPRESENTING LESS THAN 20% RECOVERY.

THE FIELD WAS UNDERGOING A DUMP FLOOD PREVIOUS TO ITS BEING CONSIDERED FOR CO2 INJECTION; IN ATTEMPTING TO CORRECT THIS BY REPLUGGING OLD WELLS, AND BECAUSE OF SEVERE WINTERS, NO CO2 HAS YET BEEN INJECTED, EVEN THOUGH THE THREE YEAR CONTRACT WITH D.O.E. IS ABOUT TO EXPIRE. APPLICATION HAS BEEN MADE FOR AN EXTENSION OF THE CONTRACT.

COMMENTS:

- 1. THIS PAPER ILLUSTRATES THE PROBLEMS THAT MAY BE ENCOUNTERED IN TRYING TO APPLY NEW TECHNIQUES TO AN OLD OIL FIELD.
2. THIS TEST, TO DATE, HAS FAILED TO MEET ITS STATED OBJECTIVES.

EXHIBITS:

----- 2 FIGURES

KEYWORDS:

SANDSTONE FIELD
OPERATIONS

FACILITIES
OTHER FIELD INFORMATION

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198. METCALFE, R.S. AND YARBOROUGH, L.: "EFFECT OF PHASE EQUILIBRIA ON THE CO₂ DISPLACEMENT MECHANISM", PAPER 7061, SPE-AIME FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK. (APR., 1978).

ABSTRACT:

----- DISPLACEMENTS FROM 2" DIA X 8' BEREA SANDSTONE CORES OF 3 HYDROCARBON MIXTURES BY CO₂ WERE RUN TO STUDY RELATIONSHIPS BETWEEN CO₂ - HYDROCARBON PHASE BEHAVIOR AND CO₂ DISPLACEMENT PROCESSES. SYSTEM 1 CONTAINED 40 MOL% C₄ AND 60 MOL% C₁₀; SYSTEM 2 CONTAINED 25 MOL% C₁, 30 MOL% C₄, AND 45 MOL% C₁₀; SYSTEM 3 CONTAINED 35 MOL% C₁, 3 TO 6 MOL% OF EACH N-PARAFFIN FROM C₂ THROUGH C₈, 30 MOL% C₁₀, AND 5 MOL% C₁₄. VAPOR-LIQUID EQUILIBRIUM COMPOSITIONS FOR 13 MIXTURES OF CO₂ WITH SYSTEM 1 WERE MEASURED AT VARIOUS PRESSURES (1250 TO 1700 PSIA) AND 160 F. BUBBLE POINT AND DEW POINT PRESSURES WERE MEASURED AS FUNCTIONS OF CO₂ CONTENT IN MIXTURES OF CO₂ WITH SYSTEM 3 AT 120 AND 150 F. DISPLACEMENT TESTS ON EACH HYDROCARBON SYSTEM WERE RUN AT THREE DIFFERENT CO₂ PRESSURES TO COMPARE BEHAVIOR UNDER IMMISCIBLE, FIRST CONTACT MISCIBLE AND MULTIPLE CONTACT MISCIBLE CONDITIONS.

EFFLUENT COMPOSITIONS WERE MEASURED FREQUENTLY DURING THE TESTS. THE DATA ARE INTERPRETED AS SHOWING THAT, AT TEMPERATURES ABOVE ABOUT 120 F, CO₂ - RESERVOIR OIL SYSTEMS WILL HAVE A VAPOR PHASE IN EQUILIBRIUM WITH A SINGLE LIQUID PHASE, AND MULTIPLE CONTACT MISCIBILITY IS ATTAINED BY VAPORIZATION OF HYDROCARBON COMPONENTS THROUGH THE GAS-OIL FRACTION. AT LOWER TEMPERATURES, LIQUID-LIQUID AND LIQUID-LIQUID-VAPOR EQUILIBRIA ARE OBSERVED IN SOME SYSTEMS AND MULTIPLE CONTACT MISCIBILITY ARISES FROM CONDENSATION OF CO₂ INTO THE HYDROCARBON RICH PHASE.

DISPLACEMENT OF SYSTEM 3 BY CO₂ WAS MODELED MATHEMATICALLY BY USING SEQUENTIAL EQUILIBRIUM CONTACT STAGES AND REDLICH-KWONG EQUATION OF STATE PARAMETERS. ALTHOUGH DETAILED RESULTS ARE NOT GIVEN, THE AUTHORS CLAIM GOOD AGREEMENT BETWEEN EXPERIMENTAL MINIMUM MISCIBILITY PRESSURES, DETERMINED BY THE SLIM-TUBE METHOD, AND MODEL CALCULATIONS.

COMMENTS:

----- ALTHOUGH NOT DIRECTLY APPLICABLE TO DESIGN OF AN ENHANCED RECOVERY PROJECT, THE EXPERIMENTS REPORTED SHOW THAT MULTIPLE CONTACT MISCIBILITY CAN BE ATTAINED BY AT LEAST TWO MECHANISMS, I.E., VAPORIZATION AND CONDENSATION, WITH LITTLE DIFFERENCE IN DISPLACEMENT EFFICIENCY BETWEEN THE TWO MECHANISMS. MULTIPHASE FLOW CAN OCCUR UNDER SOME CONDITIONS, WHICH MAY BE IMPORTANT IN DETERMINING MOBILITY OR INJECTIVITY.

EXHIBITS:

----- 3 TABLES, 13 FIGURES

CROSS REFERENCES:

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8. POETTMANN: TRANS., AIME (1951) 141.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
22. HOLM: TRANS., AIME (1959) 225.
31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
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44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
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106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
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154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
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177. PONTIOUS, THAM: PAPER SPE 6390 (1977).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
PURE CARBON DIOXIDE BEHAVIOR
NON-HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
EFFECTS OF TEMPERATURE
FIRST CONTACT MISCIBILITY
LABORATORY INJECTION PROCESS
MISCIBILITY (LAB. EXP.)
HELE-SHAW MODELS
FRACTURED RESERVOIR MODELS

GENERAL PHASE BEHAVIOR
HYDROCARBON COMPONENTS
TERNARY SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS
MULTIPLE CONTACT MISCIBILITY
SANDSTONE (LAB. EXP.)
OTHER LABORATORY STUDIES
SLIM-TUBE DISPLACEMENTS
CHROMATOGRAPHIC EFFECTS

199. NORAN, D.: "GROWTH MARKS ENHANCED OIL RECOVERY", OIL & GAS J.
(MAR. 27, 1978).

ABSTRACT:

----- THIS ARTICLE IS A SURVEY OF ACTIVE ENHANCED RECOVERY PROJECTS IN THE U.S, CANADA, VENEZUELA, AND MOST OTHER OIL PRODUCING COUNTRIES. IN 1977, THE ARTICLE LISTS 15 ACTIVE HYDROCARBON MISCIBLE PROJECTS, 14 CO2 PROJECTS, AND 6 PROJECTS USING INERT OR FLUE GAS IN THE U.S., ACCOUNTING FOR APPROXIMATELY 110,000 B/D OF OIL PRODUCTION. FOR EACH PROJECT, FIELD NAME, LOCATION, OPERATOR, START DATE, AREA, WELL COUNT, FORMATION, ROCK TYPE, POROSITY, PERMEABILITY, DEPTH, OIL PROPERTIES, PREVIOUS PRODUCTION MECHANISM, ESTIMATED OIL SATURATION, TOTAL AND "ENHANCED" OIL PRODUCTION RATES ARE TABULATED. PLANNED PROJECTS ARE ALSO LISTED, AND THE TEXT CONTAINS A BRIEF DISCUSSION OF A FEW PROJECTS.

COMMENTS:

----- ALTHOUGH FEW DETAILS ARE GIVEN, THIS ARTICLE AND SIMILAR ONES PUBLISHED PERIODICALLY ARE GOOD SOURCES OF DATA ON THE GENERAL ACTIVITY AND THE DIFFERENT RESERVOIR AND OIL PROPERTIES WHERE MISCIBLE FIELD TRIALS ARE BEING PERFORMED. ALSO SOME CAPITAL ESTIMATES ARE GIVEN.

EXHIBITS:

----- 11 TABLES, 8 FIGURES

KEYWORDS:

SANDSTONE FIELD
FRACTURED RESERVOIRS
FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
CO2 SOURCE

CARBONATE FIELD
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
GENERAL ECONOMICS
TRANSPORTATION

200. OFFICE OF TECHNOLOGY ASSESSMENT: "ENHANCED OIL RECOVERY
POTENTIAL IN THE UNITED STATES", CONGRESS OF THE U.S.,
WASHINGTON, D.C. (JAN. 6, 1978).

ABSTRACT:

----- THIS STUDY PRESENTS A DETAILED OVERVIEW OF ENHANCED
OIL RECOVERY, AND WAS PREPARED FOR THE CONGRESS OF THE UNITED
STATES. THIS STUDY DETERMINED THAT CO2 MISCIBLE DRIVE MAY BE
EXPECTED TO PROVIDE 40 TO 50 PERCENT OF THE TOTAL POTENTIAL
ENHANCED OIL RECOVERY.

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APPENDIX B CONTAINS A CONCISE HISTORY OF CO2 FLOODING AND
SCREENING CRITERIA FOR ITS USE ARE PRESENTED. COSTS AND ESTIMATES
OF PRODUCTION, ALONG WITH PIPELINE COST AND DESIGN AND SENSITIVITY
ANALYSES ARE ALSO SHOWN.

COMMENTS:

----- THIS STUDY CONTAINS A SUCCINCT SUMMARY OF THE CO2
MISCIBLE PROCESS, AND IS RECOMMENDED FOR THE UNINITIATED DESIRING
SOME BACKGROUND IN THE ART.

CROSS REFERENCES:

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 - 137. DEPARTMENT OF ENERGY: (1975 -).
 - 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
 - 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
 - 161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).
 - 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
 - S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
 - S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 1

KEYWORDS:

CARBONATE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
COMPRESSION
OTHER FIELD INFORMATION
CO2 SOURCE
TRANSPORTATION

SANDSTONE FIELD
SOAK OPERATION
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
CORROSION
FIELD ECONOMICS
GENERAL ECONOMICS
CO2 SUPPLY
MISCELLANEOUS DATA

201. PERRY, G.E., GUILLORY, A.J., BARON, J.D., JOHNSTON, J.R. AND MORANVILLE, M.B.: "WEEKS ISLAND "S" SAND RESERVIOR B GRAVITY STABLE MISCIBLE CO2 DISPLACEMENT, IBERIA PARISH, LOUISIANA", PREPARED UNDER U.S. D.O.E. CONTRACT NO. EF-77-C-05-5232 (1978).

ABSTRACT:

----- SHELL OIL COMPANY IN CONJUNCTION WITH THE D.O.E. IS CONDUCTING A GRAVITY STABLE FIELD TEST OF THE MISCIBLE CO2 PROCESS. THE TEST IS BEING CONDUCTED IN A 12,800 FT DEEP GULF COAST RESERVOIR THAT HAS A DIP OF 32 DEGREES, A PERMEABILITY OF 3.5 DARCIES AND A POROSITY OF 27%.

THE MISCIBILITY AND PHASE BEHAVIOR OF THE CO2 - RESERVOIR OIL SYSTEM WAS INVESTIGATED. AT THE CURRENT RESERVOIR PRESSURE (WHICH IS THE PROPOSED OPERATING PRESSURE), OF 5200 PSI, THE DISPLACEMENT WILL BE IMMISCIBLE. LABORATORY MEASUREMENTS INDICATE THAT A GRAVITY STABLE DISPLACEMENT WILL STILL RECOVER A SUBSTANTIAL PORTION OF THE OIL, EVEN IF TRUE MISCIBILITY IS NOT REACHED.

COMMENTS:

----- 1. THE LABORATORY RESULTS INDICATED 94% OIL RECOVERY, EVEN THOUGH MISCIBILITY WAS NOT OBTAINED IN THE LABORATORY.
2. IF SUCCESSFUL, THIS PROJECT WOULD GREATLY EXTEND THE RANGE OF CO2 FLOODING.

EXHIBITS:

----- 2 TABLES, 7 FIGURES

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
SANDSTONE FIELD
FIELD MISCIBLE APPLICATION

TERTIARY RECOVERY (LAB. EXP.)
LABORATORY INSTABILITIES
OTHER LABORATORY STUDIES
FIELD TERTIARY RECOVERY
FACILITIES

202. PETERSON, A.V.: "OPTIMAL RECOVERY EXPERIMENTS WITH N2 AND CO2",
PET. ENG. (NOV., 1978) 40-50.

ABSTRACT:

----- THIS PAPER REPORTS ON EXPERIMENTS DONE WITH PAINTER RESERVOIR CRUDE OIL AND CARBON DIOXIDE OR NITROGEN. THE PAINTER RESERVOIR IN SOUTHWEST WYOMING PRODUCES FROM THE NUGGET SAND AT A DEPTH OF 9700 FT. THE NUGGET AVERAGES 13% POROSITY AND 20 MD BUT RANGES AS HIGH AS 20% POROSITY AND 500 MD. SMALL FRACTURES AND SLIPPAGE PLANES APPEAR IN CORES.

THE RESERVOIR OIL HAS AN ORIGINAL BUBBLE POINT AT ABOUT 4000 PSI WITH AN INITIAL SOLUTION GOR OF 2100 SCF/BBL. THE INITIAL OIL FORMATION VOLUME FACTOR IS 2.13. THE RESERVOIR HAS A GAS CAP COMPOSED OF 70% METHANE, 11% ETHANE AND 9% PROPANE AND BUTANE. THE GAS CAP EXHIBITS RETROGRADE BEHAVIOR.

EXPERIMENTS WERE RUN WITH BOTH NITROGEN AND CO2. NO SWELLING (0 TO 2%) WAS EXHIBITED WITH NITROGEN, WHILE 10 TO 140% SWELLING WAS ACHIEVED WITH CO2 AT PRESSURES BETWEEN 4000 AND 5500 PSI. THE CO2 WAS FIRST CONTACT MISCIBLE WITH THE CONDENSATE AND OIL AT RESERVOIR PRESSURES; NITROGEN IS NOT FIRST CONTACT MISCIBLE WITH EITHER, HOWEVER, ALTHOUGH ONLY ABOUT 5 CONTACTS ARE NEEDED FOR MISCIBILITY OF NITROGEN AND CONDENSATE.

SLIM TUBE EXPERIMENTS INDICATE RECOVERIES OF 91 TO 99% OF THE OIL IN PLACE WITH NITROGEN, AND 100% OF THE OIL IN PLACE WITH CO2. HOWEVER, CO2 IS MORE DENSE THAN THE OIL AT RESERVOIR CONDITIONS, WHILE NITROGEN IS LESS DENSE THAN THE CONDENSATE. WITH THIS IN MIND, THE POTENTIAL APPEARS HIGH FOR UTILIZING NITROGEN TO ACCELERATE AND IMPROVE THE RECOVERY OF HYDROCARBONS FROM THIS AND SIMILAR RESERVOIRS.

COMMENTS:

----- MAINLY BECAUSE OF THE UNUSUAL PROPERTIES OF THE CRUDE OIL AT RESERVOIR CONDITIONS, AND THE NATURE OF THE RESERVOIR ITSELF, NITROGEN MAY PROVE TO BE AN ECONOMIC AND EFFECTIVE MEANS OF ENHANCING HYDROCARBON RECOVERY AT PAINTER RESERVOIR, AND SIMILAR RESERVOIRS.

EXHIBITS:

----- 2 TABLES, 9 FIGURES INCLUDING EXPERIMENTAL RESULTS.

KEYWORDS:

HYDROCARBON COMPONENTS
MULTICOMPONENT SYSTEMS
DENSITY
SOLUBILITY
FIRST CONTACT MISCIBILITY
LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)

EXPERIMENTAL PHYSICAL PROPERTIES
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
OIL SWELLING
EQUILIBRIUM RATIOS
MULTIPLE CONTACT MISCIBILITY
SECONDARY RECOVERY (LAB. EXP.)
OTHER LABORATORY STUDIES

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PHYSICAL MODELS

ALTERNATE TECHNOLOGIES

203. RUMP, W.M., SHAH, M.N. AND COVER, A.E.: "COST AND AVAILABILITY OF CARBON DIOXIDE FOR ENHANCED OIL RECOVERY", PREPARED FOR U.S. D.O.E. UNDER CONTRACT NO. EX-76-C-01-2515 (1978).

ABSTRACT:

----- THIS PAPER IS A SUMMARY OF A STUDY OF THE COST AND AVAILABILITY OF CARBON DIOXIDE FOR ENHANCED OIL RECOVERY. BASICALLY, IT IS A DISTILLATION OF THE WORK OF RUMP, ET AL (1977).

EXHIBITS:

----- 2 TABLES, 1 FIGURE

KEYWORDS:

GENERAL ECONOMICS

CO2 SOURCE

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204. SAN FILIPPO, G.P. AND GUCKERT, L.G.: "PROGRESS OF THE PILOT CARBON DIOXIDE FLOOD IN THE ROCK CREEK - BIG INJUN FIELD, ROANE COUNTY, WEST VIRGINIA", PREPARED UNDER U.S. D.O.E. CONTRACT NO. EF-76-C-05-5301 (1978).

ABSTRACT:

----- THE ROCK CREEK CO2 PILOT IS DESCRIBED IN THE ABSTRACT FOR THE AUTHORS' 1977 PAPER; THE 1978 PAPER IS A BRIEF PROGRESS REPORT, COVERING OPERATIONS THROUGH MARCH, 1978. AT THAT TIME, THE PROJECT WAS 10 MONTHS BEHIND ORIGINAL SCHEDULE, PRINCIPALLY BECAUSE THE RESERVOIR PRESSURE INCREASED MORE SLOWLY THAN ORIGINALLY EXPECTED WITH CUMULATIVE WATER INJECTION. MONTHLY DATA ARE GIVEN FOR WATER INJECTION, AVERAGE PRESSURE, AND OIL, GAS, AND WATER PRODUCT NO CO2 HAD BEEN INJECTED BY APRIL 1, 1978, BUT WAS EXPECTED DURING THE SECOND QUARTER.

COMMENTS:

----- PRODUCTION CURVES SHOW SOME RESPONSE TO WATER INJECTION WITHIN A MONTH OR TWO AFTER BEGINNING WATER INJECTION IN THE PATTERN WELLS. OIL PRODUCTION INCREASED FROM 40 BBLS/MONTH TO 100 BBLS/MONTH WITHIN SIX MONTHS, BUT DECLINED SHARPLY IN 18 MONTHS TO ABOUT THE INITIAL LEVEL; WATER PRODUCTION INCREASED STEADILY EXCEPT FOR SOME ERRATIC SWINGS. IT APPEARS THAT LITTLE WATERFLOOD MOVABLE OIL SATURATION REMAINS IN PLACE. THE STATEMENT THAT MORE WATER WOULD BE NEEDED THAN THE AMOUNT ORIGINALLY CALCULATED TO BUILD UP RESERVOIR PRESSURE SUGGESTS THAT RECOVERY EFFICIENCY MIGHT HAVE BEEN HIGHER THAN THE 20% STATED IN THE 1977 PAPER.

EXHIBITS:

----- 4 FIGURES

KEYWORDS:

SANDSTONE FIELD
FIELD TERTIARY RECOVERY

WATER INJECTION
FIELD MISCIBLE APPLICATION

205. SHAH, R.P. AND WITTMAYER, E.E.: "A STUDY OF CO2 RECOVERY AND TERTIARY OIL PRODUCTION ENHANCEMENT IN THE LOS ANGELES BASIN", PREPARED FOR U.S. D.O.E. UNDER CONTRACT NO. EF-77-C-03-1582 (1978).

ABSTRACT:

----- THIS PAPER PRESENTS IN EVALUATION OF THE TECHNICAL FEASIBILITY OF ENHANCED RECOVERY OF CRUDE OIL THROUGH THE USE OF CARBON DIOXIDE FLOODING IN THE LOS ANGELES BASIN. THE STUDY INVOLVES AN EVALUATION OF CARBON DIOXIDE SOURCES, THE REQUIREMENTS FOR UPGRADING AND TRANSMITTING THE GAS AND NECESSARY MATERIAL SPECIFICATIONS. BASICALLY, THE SOURCE FOR CO2 IS AVAILABLE BY PROCESSING BY-PRODUCT STREAMS OF SIX OIL REFINERIES NEARBY OR BOILER DISCHARGE FROM SEVEN MAJOR ELECTRIC POWER PLANTS NEARBY. THE RECOMMENDED SEPARATION PROCESS IS THE MEA PROCESS.

COMMENTS:

----- 1. ALTHOUGH RETURNS ARE NOT YET IN AS TO WHETHER A SIGNIFICANT CO2 DEMAND COULD BE GENERATED IN THE L.A. BASIN, AT LEAST A CO2 SOURCE IS IDENTIFIED.

2. THE MATERIAL SPECIFICATIONS PRESENTED IN THIS REPORT MAY BE OF USE TO DESIGN AND FACILITIES ENGINEERS.

CROSS REFERENCES:

- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
179. RUMP, HARE, PORTER: D.O.E. CONTRACT (1977).
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).

KEYWORDS:

GENERAL ECONOMICS
CO2 SUPPLY
SEPARATION

CO2 SOURCE
TRANSPORTATION
MISCELLANEOUS DATA

206. STALKUP, F.I.: "CARBON DIOXIDE MISCIBLE FLOODING: PAST, PRESENT, AND OUTLOOK FOR THE FUTURE", PAPER 7042, SPE-AIME FIFTH SYMP. ON IMPROVED METHODS FOR OIL RECOVERY, TULSA, OK, (APR., 1978).

ABSTRACT:

----- PUBLISHED LITERATURE ON THE TECHNOLOGY OF CARBON DIOXIDE MISCIBLE FLOODING IS REVIEWED. MECHANISMS FOR ACHIEVING MISCIBILITY ARE BRIEFLY DISCUSSED AS ARE VARIABLES AFFECTING MISCIBILITY PRESSURE, PHASE BEHAVIOR, DISPLACEMENT EFFICIENCY, AND VOLUMETRIC SWEEP EFFICIENCY. PROCESS DESIGN VARIATIONS, SUCH AS DRIVING A CARBON DIOXIDE SLUG BY CONTINUOUS WATER INJECTION OR ALTERNATING SMALL VOLUMES OF CO₂ AND WATER IN THE SAME WELLS ARE REFERENCED. FIELD TESTING IS REVIEWED, AND AN APPENDIX CONTAINS A BRIEF SUMMARY OF FIELD TESTS AT SACROC (KELLY SYNDER FIELD), NORTH CROSS DEVONIAN (CROSSET FIELD), LITTLE CREEK, TWO FREDs, MEAD-STRAWN AND WILLARD (WASSON FIELD). BRIEFLY MENTIONED ARE AMOCO'S PILOT TESTS IN THE SLAUGHTER, LEVELLAND, AND NORTH COWDEN FIELDS IN WEST TEXAS AND THEIR SMALL PROJECT IN THE SOUTH GILROCK FIELD IN SOUTH TEXAS. SHELL'S PILOT TEST IN THE DENER UNIT OF WASSON FIELD IS MENTIONED BRIEFLY, ALONG WITH THEIR WEEKS ISLAND PROJECT IN LOUISIANA. FINALLY, THREE D.O.E. SPONSORED PROJECTS IN WEST VIRGINIA (GRANNY'S CREEK, ROCK CREEK AND GRIFFITHSVILLE) ARE MENTIONED.

COMMENTS:

----- THIS PAPER CONTAINS A CONSIDERABLE AMOUNT OF INFORMATION AND WOULD BE A GOOD STARTING POINT FOR A BEGINNING INVESTIGATOR IN CO₂ FLOODING. IT INCLUDES 61 REFERENCES TO OTHER PUBLICATIONS. IN ADDITION TO TOPICS MENTIONED IN THE ABSTRACT IT INCLUDES THE AUTHOR'S APPRAISAL OF THE STATE OF THE ART, A DISCUSSION OF CARBON DIOXIDE SOURCES, AND THE FUTURE OUTLOOK FOR CO₂ ENHANCED RECOVERY.

EXHIBITS:

----- 2 TABLES, 9 FIGURES

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 - 31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
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 - 38. CRAWFORD, NEILL, BUCY, CRAWFORD: J. PET. TECH. (MAR., 1963) 237.
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114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
123. HENDERSON: PAPER SPE 4737 (1974 A).
124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
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152. DOSCHER, WISE: J. PET. TECH. (MAY, 1976) 575.
158. HOLM: J. PET. TECH. (JAN., 1976) 76.
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162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
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191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
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KEYWORDS:

SANDSTONE FIELD
SOAK OPERATION
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD MOBILITY RATIO
MOBILITY CONTROL
OTHER FIELD INFORMATION

CARBONATE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FIELD AREAL SWEEP
FIELD RESIDUAL SATURATIONS
CO2 SOURCE

207. WATKINS, R.W.: "A TECHNIQUE FOR THE LABORATORY MEASUREMENT OF CARBON DIOXIDE UNIT DISPLACEMENT EFFICIENCY IN RESERVOIR ROCK", PAPER 7474, SPE-AIME 53RD ANN. FALL TECH. CONF. & EXHBN., HOUSTON, TX. (OCT., 1978).

ABSTRACT:

----- DISPLACEMENT EXPERIMENTS OF SYNTHESIZED WEST TEXAS SAN ANDRES CRUDE BY CO₂ WERE PERFORMED AT 109 F AND 2,000 PSIG; 17 OF THE RUNS WERE ON 12 INCH LONG BEREA SANDSTONE CORES AT VELOCITIES RANGING FROM .28 TO 15 FEET PER DAY, AND 13 RUNS WERE ON LOW PERMEABILITY SAN ANDRES CARBONATE CORES AT RATES RANGING FROM 0.22 FEET PER DAY TO 4 FEET PER DAY. IN SOME EXPERIMENTS THE CORE UNDER STUDY WAS PRECEDED BY A 4 TO 8 FOOT SECTION OF BEREA CORE OR BY A 100 TO 1000 CC MIXING CYLINDER. THESE "STABILIZERS" ALLOW THE FORMATION OF A CO₂-OIL TRANSITION ZONE EXTERNAL TO THE CORE BEING FLOODED. WITHOUT A FULLY DEVELOPED TRANSITION ZONE, VISCOUS FINGERING CAUSES OIL BYPASSING, WHICH MAY LEAD TO LOW ESTIMATES OF DISPLACEMENT EFFICIENCY OF OIL BY CO₂. WITH A STABILIZING SECTION VERY LOW RESIDUAL OIL SATURATIONS WERE OBTAINED FOR MISCIBLE DISPLACEMENTS, EVEN WITH SHORT CORES.

EXPERIMENTAL RESULTS CORRELATE WELL WITH A STABILITY RATIO THEORY OF MISCIBLE DISPLACEMENT FOR BOTH ROCK TYPES. THERE WAS LITTLE CORRELATION BETWEEN RESIDUAL OIL SATURATION AND CONTACT TIME OR FRONTAL ADVANCE RATE.

COMMENTS:

----- THIS PAPER IS A SIGNIFICANT CONTRIBUTION TO UNDERSTANDING CO₂ DISPLACEMENT IN LABORATORY EXPERIMENTS AND MAY EXPLAIN THE WIDE VARIATION OF RESULTS REPORTED BY OTHER AUTHORS. IT PROVIDES AN ALTERNATIVE EXPLANATION FOR THE EFFECTS OF LENGTH, DISPLACEMENT RATES, CO₂ SLUG SIZE, AND WETTABILITY REPORTED ELSEWHERE. HOWEVER, COMPARISON WITH OTHER PUBLISHED WORK USING THE STABILITY RATIO THEORY PRESENTED IN THIS PAPER IS REQUIRED TO DETERMINE IF OTHER DATA WOULD BEHAVE AS REGULARLY. IF SUBSTANTIATED, THE TECHNIQUE COULD BE USEFUL FOR LABORATORY MEASUREMENT OF DISPLACEMENT EFFICIENCY WITHOUT HAVING TO USE VERY LONG CORES OR EXTREMELY LOW FLOW RATES.

EXHIBITS:

----- 4 TABLES, 12 FIGURES

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 - 100. CLARIDGE: SOC. PET. ENG. J. (APR., 1972) 143.
 - 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.

158. HOLM: J. PET. TECH. (JAN., 1976) 76.
169. CLARIDGE: PAPER SPE 6848 (1977).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.

KEYWORDS:

DISPERSION
SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)

VISCOSITY
LAB. PROCEDURES AND APPARATUS
TERTIARY RECOVERY (LAB. EXP.)
CARBONATE (LAB. EXP.)
LABORATORY INSTABILITIES
MISCIBILITY (LAB. EXP.)

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208. WEISZ, P.B. AND ZAHNER, J.C.: "UTILIZATION OF LOW BTU NATURAL GAS", U.S. PATENT 4,093,029 (JUNE 6, 1978).

ABSTRACT:

----- THIS PATENT DESCRIBES A METHOD FOR CONVERTING NATURAL GAS CONTAINING MORE THAN ABOUT 50 MOLE PERCENT CO₂ TO A PURIFIED CO₂ PRODUCT STREAM (FOR TERTIARY OIL RECOVERY), LIQUID FUEL (METHANOL OR HYDROCARBONS), AND SULFUR (IF THE NATURAL GAS CONTAINS H₂S). INDIVIDUAL STEPS IN THE PROCESS UTILIZE CONVENTIONAL TECHNOLOGY, AND SEVERAL EXAMPLES ARE MENTIONED FOR EACH. AFTER SEPARATING THE ACID GASES (H₂S AND CO₂) FROM THE PLANT FEED, AN OPTIMAL MIXTURE OF CO₂ AND CH₄ IS FED TO A STEAM REFORMER, PRODUCING CO, CO₂, H₂, AND H₂O. AFTER CONDENSING THE WATER, THE GAS MIXTURE IS CONVERTED CATALYTICALLY TO METHANOL VIA AN EXOTHERMIC REACTION; HEAT REMOVAL IS USED TO GENERATE STEAM. CO₂ IN THE ACID GAS STREAM IS PURIFIED USING CONVENTIONAL SULFUR REMOVAL AND RECLAIMING METHODS.

COMMENTS:

----- USEFULNESS DEPENDS UPON SPECIFICS, SUCH AS PROXIMITY TO SUITABLE OIL RESERVOIRS FOR CO₂ ENHANCED RECOVERY APPLICATIONS, ABSENCE OF A PIPELINE TO SELL METHANE DIRECTLY WITHOUT CONVERSION TO METHANOL AND ECONOMICS. ALTHOUGH NOT CLAIMED IN THE PATENT, A MODIFICATION OF THIS PROCESS MIGHT BE USEFUL IN THE FINAL STAGES OF A CO₂ FLOOD, WHEN HYDROCARBON PRODUCTION HAS FALLEN TOO LOW TO JUSTIFY RE-INJECTION OF THE CO₂.

EXHIBITS:

----- 2 TABLES, 1 FIGURES

CROSS REFERENCES:

- 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
163. SPELLER: U.S. PATENT 3,964,545 (JUNE 22, 1976).

KEYWORDS:

FACILITIES
CO₂ SUPPLY

U.S. PATENT
SEPARATION

209. YELLIG, W.F. AND METCALFE, R.S.: "DETERMINATION AND PREDICTION OF CO₂ MINIMUM MISCIBILITY PRESSURES", PAPER 7477, SPE-AIME 53RD ANN. FALL TECH. CONF. & EXHBN., HOUSTON, TX. (OCT., 1978).

ABSTRACT:

----- THE AUTHOR PROPOSES THAT DISPLACEMENTS OF OIL BY CO₂ FROM SAND-PACKED 0.25" O.D. X 40' LONG STAINLESS STEEL TUBING COILS BE USED AS A STANDARD METHOD OF MEASURING MINIMUM MISCIBILITY PRESSURE (MMP). IN ADDITION TO DETERMINING THE OIL RECOVERY AT 1.2 HYDROCARBON PORE VOLUMES OF CO₂ INJECTED, AS A FUNCTION OF TEST PRESSURE, VISUAL OBSERVATIONS OF EFFLUENT FLUIDS ARE NEEDED TO DISTINGUISH MISCIBLE FROM IMMISCIBLE DISPLACEMENT. EXPERIMENTAL MMP'S ARE REPORTED FOR FOUR SYNTHETIC OIL MIXTURES CONTAINING DIFFERENT AMOUNTS OF LIGHT, INTERMEDIATE, AND HEAVY COMPONENTS, AT 95, 118, AND 150 F; FOR TWO OF THE MIXTURES, MMP'S ARE ALSO REPORTED AT 192 F. MMP DATA ARE ALSO TABULATED, FROM OTHER SOURCES, FOR 26 RESERVOIR OILS, AT RESERVOIR TEMPERATURES RANGING FROM 94 TO 214 F. MMP'S ARE RELATIVELY INSENSITIVE TO THE CONCENTRATION OF LIGHT AND INTERMEDIATE COMPONENTS AND TO INTERMEDIATE COMPONENT AVERAGE MOLECULAR WEIGHT. A SIMPLE CORRELATION, WITH A LINEAR INCREASE OF MMP WITH TEMPERATURE, IS VALID FOR UNDERSATURATED RESERVOIR OILS, AND IS MODIFIED FOR SATURATED OILS BY SETTING MMP EQUAL TO BUBBLE POINT PRESSURE (BPP) WHENEVER THE MMP ESTIMATED FROM THE TEMPERATURE CORRELATION IS LESS THAN THE BPP.

COMMENTS:

----- MMP HAS BEEN USED FOR SOME TIME AS A SCREENING CRITERION TO DETERMINE THE PRESSURE RANGE FOR CO₂ FLOODING. TO THE EXTENT THAT THIS IS VALID - I.E., THAT RECOVERY ON A RESERVOIR SCALE, PER UNIT OF CO₂ HANDLED, IS OPTIMIZED AT OR ABOVE THE LABORATORY-DETERMINED MMP, A STANDARDIZED PROCEDURE WOULD HAVE OBVIOUS ADVANTAGES, AND A PUBLICALLY AVAILABLE DATA BASE WOULD BE USEFUL. IF THE CORRELATION PROPOSED IS SUPPORTED BY ADDITIONAL DATA, PERHAPS IT WOULD ULTIMATELY SUFFICE, UNLESS IT CAN BE SHOWN THAT ACCURATE KNOWLEDGE OF MMP IS CRITICAL TO FIELD SUCCESS.

EXHIBITS:

----- 7 TABLES, 11 FIGURES

ADDITIONAL REFERENCES:

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2. JACOBSON: J. CAN. PET. (APRIL-JUNE 1972) V.11, 56-59.

CROSS REFERENCES:

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107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
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S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
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KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
EFFECTS OF TEMPERATURE
LAB. PROCEDURES AND APPARATUS
MISCIBILITY (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS

CORRELATIONS
MULTICOMPONENT SYSTEMS
MULTIPLE CONTACT MISCIBILITY
LABORATORY INJECTION PROCESS
OIL CHARACTERIZATION (LAB. EXP.)
SCREENING CRITERIA

210. ANON.: "FERC DECLINES AUTHORITY OVER PLANNED CO2 LINE",
OIL & GAS J. (APR. 23, 1979) 40.

ABSTRACT:

----- THIS ARTICLE IS A NEWS RELEASE ABOUT THREE TOPICS:

1. FERC RULING THAT CO2 PIPELINES AREN'T WITHIN ITS
JURISDICTION UNDER THE NATURAL GAS POLICY ACT BECAUSE THEY DON'T
CARRY GAS.

2. SHELL WON'T DECIDE UNTIL EARLY OR MID-1980 WHETHER TO
PROCEED WITH THE PIPELINE FROM MCELMO DOME, NEAR CORTEZ, CO. TO
WASSON FIELD, WEST TEXAS. THE CO2 INJECTION PILOT AT WASSON FIELD
IS IN PROGRESS.

3. THE 15-WELL PROGRAM TO TAP CO2 RESERVES AT MCELMO DOME IS
VIRTUALLY COMPLETED. NINE OF THE WELLS HAVE BEEN PRODUCTIVE, AND
THE FINAL TEST IS BEING DRILLED.

ADDITIONAL REFERENCES:

----- ANON.: OIL & GAS J. (SEP. 11, 1978) 35.

KEYWORDS:

TRANSPORTATION

CO2 SOURCE
MISCELLANEOUS DATA

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211. CONNER, W.D. AND WATTS, R.J.: "TERTIARY OIL RECOVERY BY CARBON DIOXIDE INJECTION, GRANNY'S CREEK FIELD, WEST VIRGINIA", PREPARED UNDER U.S. D.O.E. CONTRACT NO. EF-76-C-05-5302 (1979).

ABSTRACT:

----- THIS BOOKLET CONTAINS THE DATA PRESENTED IN CONNER (1978) ALONG WITH TABULATED VALUES FOR PRODUCTION AND INJECTION DATA AND GAS SAMPLE ANALYSES.

KEYWORDS:

FRACTURED RESERVOIRS
FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
COMPRESSION
OPERATIONS

SANDSTONE FIELD
WATER INJECTION
FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
FACILITIES
OTHER FIELD INFORMATION

212. DOSCHER, T.M. AND KUUSKRAA, V.A.: "CARBON DIOXIDE FOR THE RECOVERY OF CRUDE OIL", PAPER 7954, SPE-AIME CA. REGIONAL MTG. (APR., 1979).

ABSTRACT:

----- THE HISTORY OF THE USE OF CARBON DIOXIDE AS AN OIL RECOVERY AGENT HAS BEEN REVIEWED, WITH PARTICULAR CONCERN AS TO EVIDENCE FOR THE NEED FOR FRONTAL DISPLACEMENT TO OCCUR FOR SUCCESSFUL RECOVERY OF CRUDE. IN THE ABSENCE OF FRONTAL DISPLACEMENT (E.G., OIL BANK FORMATION), RECOVERY IS ACHIEVED BY SOLUTION, OIL PHASE EXPANSION, AND ITS DISPLACEMENT BY CO₂.

FROM A SIMPLE MATERIAL BALANCE CONSIDERATION, IT CAN BE SHOWN THAT IF AN OIL BANK IS NOT FORMED, THE EFFICIENCY OF CARBON DIOXIDE AS A DRIVING AGENT DEPENDS UPON INITIAL OIL SATURATION, OIL FORMATION VOLUME FACTOR, AND SOLUBILITY OF CARBON DIOXIDE IN THE CRUDE. FRONTAL DISPLACEMENT WOULD IMPROVE PERFORMANCE, BUT THE CONDITIONS REQUIRED FOR OIL BANK FORMATION HAVE APPARENTLY NOT BEEN SOUGHT IN FIELD TESTS CONDUCTED TO DATE. EVEN WITHOUT FRONTAL DISPLACEMENT, HOWEVER, ECONOMIC RECOVERY OF OIL BY CO₂ MAY ULTIMATELY BE ACHIEVED.

COMMENTS:

----- 1. THE CONCEPT OF WHETHER OR NOT A BANK IS FORMED PROBABLY EXPLAINS THE DIFFERENCE BETWEEN SECONDARY AND TERTIARY RECOVERY BY CO₂.

2. THIS PAPER REVIEWS THE GENERALLY POOR BEHAVIOR OF LPG FLOODS OF THE 1960'S AND NOTES MANY OF THE CONDITIONS FOR FAILURE OF SUCH OPERATIONS EXIST IN POTENTIAL APPLICATIONS OF CO₂.

3. IT HAS NOT BEEN ADEQUATELY DEMONSTRATED BY THIS PAPER THAT AN OIL BANK WAS NOT FORMED IN SOME OF THE CO₂ FLOODS CURRENTLY IN PROGRESS.

EXHIBITS:

----- 1 TABLE, 5 FIGURES

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- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 22. HOLM: TRANS., AIME (1959) 225.
- 126. HUANG, TRACHT: PAPER SPE 4735 (1974).
- 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 186. WARNER: J. PET. TECH. (OCT., 1977) 1339.
- 191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
- 196. KANE: PAPER SPE 7091 (1978).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
- S 6. WILSON: TRANS., AIME (1960) 223.
- S 7. HUTCHINSON, BRAUN: A.I.C.H.E. J. (1961) 64.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 867.

KEYWORDS:

FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FIELD ECONOMICS

FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
OTHER FIELD INFORMATION

213. WANG, G.C. AND LOCKE, D.C.: "A LABORATORY STUDY OF THE EFFECTS OF CO2 INJECTION SEQUENCE ON TERTIARY OIL RECOVERY", PAPER 7953, SPE-AIME CA. REGIONAL MTG. (APR., 1979).

ABSTRACT:

----- THIS PAPER PRESENTS THE RESULTS OF SLIM-TUBE CO2 DISPLACEMENT TESTS FOR A WATERFLOODED SAND-PACK. FOUR DIFFERENT CO2 - WATER SLUG DESIGNS WITH EQUAL TOTAL CO2 INJECTIONS WERE TESTED. IT WAS FOUND THAT THE CHANGE OF CO2 INJECTION SEQUENCE HAD NO SIGNIFICANT EFFECT ON OIL AND WATER RECOVERY AS LONG AS THE TOTAL AMOUNT OF CO2 INJECTED REMAINS CONSTANT; HOWEVER, THE SLUG SEQUENCE DID HAVE A REMARKABLE EFFECT ON THE PRODUCING CO2 - OIL RATIO. IT WAS ALSO FOUND THAT MORE THAN 60% OF THE INJECTED CO2 WAS TRAPPED AND/OR DISSOLVED IN THE AQUEOUS PHASE AFTER TERMINATION OF THE FLOOD.

A NUMERICAL LINEAR MODEL, USING A HIGGINS-LEIGHTON APPROACH WITH BUCKLEY-LEVERETT THEORY, WAS DEVELOPED TO STUDY THE SENSITIVITY TO SLUG INJECTION. THE MODEL SATISFACTORILY MATCHED LABORATORY DATA WITH MIXING PARAMETERS RANGING FROM 0.82 TO 1.00. HOWEVER, BECAUSE CO2 SOLUBILITY IN WATER WAS NOT TAKEN INTO ACCOUNT, THE MODEL WAS UNABLE TO MATCH CO2 PRODUCTION. FURTHER WORK WILL BE NEEDED TO CORRECT THIS.

COMMENTS:

- 1. AN OIL BANK WAS OBSERVED TO BUILD UP IN THE SAND PACK; THERE WAS NO GAS FLOW AT THE TIME OF OIL BANK BUILDUP.
2. BLOWDOWN RECOVERIES RANGED FROM 4.7 TO 8.6% OF THE OIL IN PLACE AFTER WATERFLOODING.

EXHIBITS:

----- 1 TABLE, 5 FIGURES

CROSS REFERENCES:

- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
169. CLARIDGE: PAPER SPE 6848 (1977).
186. WARNER: J. PET. TECH. (OCT., 1977) 1339.

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
BUCKLEY-LEVERETT MODELLING
COMPARISONS WITH LAB. RESULTS

LAB. PROCEDURES AND APPARATUS
TERTIARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES
MIXING ZONE MODELS
OTHER MODELLING

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S 1. BAYS, G.S.: "SECONDARY RECOVERY OF OIL FROM UNDERGROUND RESERVOIRS", U.S. PATENT 2,135,319 (NOV. 1, 1938).

ABSTRACT:

----- THIS INVENTION RELATES TO THE USE OF NATURAL GAS AS A SECONDARY RECOVERY TOOL IN RETROGRADE CONDENSATE RESERVOIRS. THE INVENTION INVOLVES INCREASING THE PRESSURE TO OBTAIN RETROGRADE VAPORIZATION BY INJECTING THE NATURAL GAS. THE PREFERRED PRESSURE RANGE IS 2500 TO 5000 PSIA.

COMMENTS:

----- THIS PATENT HAS EXTREMELY LIMITED PROSPECTS FOR APPLICATION TODAY.

EXHIBITS:

----- 1 FIGURE

KEYWORDS:

FIELD SECONDARY RECOVERY

U.S. PATENT

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- S 2. OFFERINGA, J. AND VANDERPOEL, C.: "DISPLACEMENT OF OIL FROM POROUS MEDIA BY MISCIBLE FLUIDS", TRANS., AIME (1954) V.201, 310-316.

ABSTRACT:

----- SCALED MODEL EXPERIMENTS ON THE RECOVERY OF OIL FROM POROUS MEDIA ARE REPORTED. THE EXPERIMENTS INVOLVED THE INJECTION OF LIQUID SOLVENTS DRIVEN BY WATER. SCALING RULES WERE DEVELOPED AND CHECKED BY EXPERIMENTS IN 1, 1.6 AND 3 METER TUBES. THE DIAMETERS WERE CHOSEN SO AS TO GIVE EQUAL LENGTH TO DIAMETER RATIOS. THE RESULTS OF THE TWO LARGER TUBES COINCIDED, BUT THE SMALLEST TUBE SHOWED APPRECIABLE DEVIATION.

THE RECOVERIES AT BREAKTHROUGH WERE EQUAL TO THOSE OBTAINED IN WATERFLOODING AT THE SAME VISCOSITY RATIO. VISCOUS FINGERING MIGHT THEREFORE BE THE DECISIVE RECOVERY PHENOMENON INVOLVED. THE MISCIBLE FLOOD WAS MORE EFFICIENT AFTER BREAKTHROUGH THAN WATERFLOOD. THIS WAS MORE PRONOUNCED AS THE OIL-SOLVENT VISCOSITY RATIO BECAME HIGHER. A RECIRCULATION PROCESS HAS BEEN INTRODUCED TO CUT DOWN ON THE AMOUNT OF SOLVENT REQUIRED AND IMPROVE ON THE ECONOMICS. THIS INVOLVES THE REINJECTION OF PRODUCED FLUID. WHILE A CONVENTIONAL SOLVENT SLUG OF 65% OF A PORE VOLUME RECOVERED 77% OF A 1100 CP VISCOSITY OIL IN PLACE, USING THE RECIRCULATION PROCESS, A 48% PV SLUG RECOVERED 81% OF THE OIL IN PLACE. ABOUT EQUAL AMOUNTS OF SOLVENT WERE LOST IN BOTH CASES.

COMMENTS:

----- 1. RULES FOR SCALING OF LABORATORY EXPERIMENTS ARE PRESENTED.

2. IN THE DISCUSSION BY R.A. MORSE AND THE REPLY BY THE AUTHORS, SOME QUESTIONS ARISE AS TO THE PROPER SCALING OF DIFFUSION IN RADIAL FLOW. THE AUTHORS STATE THAT A TRANSITION ZONE WILL NORMALLY NOT DEVELOP IN THE RESERVOIR, BUT A MORE COMPLETE ANALYSIS OF THIS PHENOMENON ON A THEORETICAL AND EXPERIMENTAL BASIS IS NECESSARY.

EXHIBITS:

----- 2 TABLES, 4 FIGURES

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
SLIM-TUBE DISPLACEMENTS

SECONDARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
LABORATORY INSTABILITIES
OTHER LABORATORY STUDIES
SCREENING CRITERIA

S 3. KOCH, H.A., JR. AND SLOBOD, R.L.: "MISCIBLE SLUG PROCESS"
TRANS., AIME (1957) V.210, 40-47.

ABSTRACT:

----- THE MISCIBLE SLUG PROCESS IS AN ENHANCED OIL RECOVERY PROCESS WHICH INVOLVES THE INJECTION OF PROPANE OR LPG INTO THE RESERVOIR PRIOR TO GAS INJECTION. THE SLUG IS MISCIBLE WITH BOTH THE RESERVOIR OIL AND THE INJECTED GAS UNDER APPROPRIATE RESERVOIR CONDITIONS. WITH MISCIBLE DISPLACEMENTS, RECOVERIES ARE HIGH FROM THE AREA CONTACTED BY THE SLUG. HIGHLIGHTS OF THE PROCESS ARE PRESENTED IN THIS PAPER. LABORATORY STUDIES HAVE DEMONSTRATED THE FEASIBILITY OF USING A SMALL SLUG OF PROPANE TO MISCIBLY DISPLACE OIL FROM A LONG RESERVOIR. 95% RECOVERY OF THE OIL IN PLACE WAS ACHIEVED IN A 123-FT UNCONSOLIDATED SAND PACKED TUBE BY USING ABOUT 1.5% TOTAL PORE VOLUME OF PROPANE. MISCIBILITY CAN BE ACHIEVED AT PRESSURES AS LOW AS 1200 PSI AT A RESERVOIR TEMPERATURE OF 150 F.

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MAJOR FACTORS AFFECTING THE SIZE OF THE SLUG ARE THE RESERVOIR LENGTH, THE RESERVOIR FLUID COMPOSITION, AND THE RESERVOIR PRESSURE AT THE DISPLACEMENT FRONT. THE INJECTION RATE AND THE TYPE OF POROUS MEDIUM ALSO AFFECT SLUG SIZES, BUT TO A LESSER EXTENT. THE EFFECTS OF THESE FACTORS HAVE BEEN STUDIED AND ARE DISCUSSED IN THIS PAPER. EFFECTS OF GRAVITY AND RESERVOIR HETEROGENEITIES HAVE NOT BEEN COMPLETELY ESTABLISHED.

COMMENTS:

----- THE PAPER IS ONE OF THE EARLY EXPERIMENTAL STUDIES ON MISCIBLE SLUG PROCESS, AND HAS BEEN INSTRUMENTAL IN THE DEVELOPMENT OF FURTHER WORK.

EXHIBITS:

----- 4 TABLES, 9 FIGURES

ADDITIONAL REFERENCES:

----- SLOBOD AND KOCH: DRILL. & PROD. PRAC. (1953) 82.

CROSS REFERENCES:

S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES

LABORATORY INJECTION PROCESS
AREAL SWEEP (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
LPG

- S 4. CAUDLE, B.H. AND DYES, A.B.: "IMPROVING MISCIBLE DISPLACEMENT BY GAS-WATER INJECTION", TRANS., AIME (1958) V.213, 281-284.

ABSTRACT:

----- ALTHOUGH MISCIBLE DISPLACEMENTS CAN RECOVER ALL OF THE OIL IN THE AREA OF THE RESERVOIR CONTACTED BY THE DISPLACING FLUID, POOR MOBILITY RATIOS IN A GAS-DRIVEN MISCIBLE CAUSE POOR SWEEP EFFICIENCY AND LEAVE A SUBSTANTIAL AMOUNT OF OIL UNRECOVERED. THE SWEEP EFFICIENCY IN A HOMOGENEOUS 5-SPOT PATTERN IS ABOUT 60% AT ABANDONMENT. LABORATORY STUDIES HAVE CONFIRMED THAT THE SWEEP EFFICIENCY CAN BE GREATLY IMPROVED BY INJECTION OF A FLUID OF LOW MOBILITY (WATER) BEHIND THE DISPLACEMENT FRONT. THE STUDIES SHOW THAT ULTIMATE SWEEP EFFICIENCY IN A 5-SPOT PATTERN CAN REACH 90% AS A RESULT OF THIS. SIMULTANEOUS INJECTION OF WATER AND GAS IS SUGGESTED. THE RATIO OF GAS TO WATER IS DETERMINED BY THE RATIO OF THE MOBILITIES OF THE FLUIDS. ALTHOUGH ACTUAL OPTIMUM GAS-WATER INJECTION MAY NOT BE EXACTLY DETERMINED, SIMULTANEOUS WATER AND GAS INJECTION WILL GENERALLY YIELD BETTER RECOVERY OF OIL.

COMMENTS:

----- ALTHOUGH THE PAPER ADVOCATES SIMULTANEOUS GAS AND WATER INJECTION BEHIND THE MISCIBLE FRONT, THIS IS USUALLY NOT PRACTICAL. EXPERIENCE HAS SHOWN THAT ALTERNATE GAS AND WATER INJECTION IS MORE PRACTICAL AND CAN ACHIEVE SIMILAR RESULTS.

EXHIBITS:

----- 7 FIGURES, SHOWING EXPERIMENTAL RESULTS

CROSS REFERENCES:

- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.

KEYWORDS:

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
AREAL SWEEP (LAB. EXP.)
ANALYTICAL MODELLING
COMPARISONS WITH LAB. RESULTS

SECONDARY RECOVERY (LAB. EXP.)
MOBILITY RATIO (LAB. EXP.)
OTHER LABORATORY STUDIES
BUCKLEY-LEVERETT MODELLING
ENRICHED AND HIGH PRESSURE GAS

- S 5. CLARK, N.J., SHEARIN, H.M., SCHULTZ, W.P., GARMS, K. AND MORSE, J.L.: "MISCIBLE DRIVE - ITS THEORY AND APPLICATION", J. PET. TECH. (JUNE, 1958) 11-20.

ABSTRACT:

----- IN A MISCIBLE DRIVE, MATERIALS SUCH AS PROPANE, LPG OR GAS ARE INJECTED INTO A RESERVOIR UNDER CONDITIONS WHERE FLUID CAPILLARY FORCES ARE ELIMINATED. THE INJECTED FLUID THEN MISCIBLY DISPLACES THE OIL. THE VALUABLE INJECTED FLUID IS RECOVERED, AND LESS EXPENSIVE GAS FILLS THE RESERVOIR AT ABANDONMENT. PROPER ENGINEERING AND GEOLOGICAL EVALUATION IS ESSENTIAL TO THE SUCCESS OF THE PROCESS; MANY FACTORS MUST BE CONSIDERED FOR PROPER DESIGN AND CONDUCT OF THE OPERATION.

THE VARIOUS MISCIBLE DRIVE TECHNIQUES ARE DISCUSSED AND ANALYZED. THE FACTORS EFFECTING THEIR APPLICABILITY AND FEASIBILITY IN ANY GIVEN RESERVOIR ARE ALSO EXAMINED. OTHER OPERATIONAL CONSIDERATIONS INCLUDING ESTIMATION OF SLUG VOLUME REQUIRED ARE ALSO EXAMINED.

COMMENTS:

----- THE PAPER IS ONE OF THE BEST ON THE FUNDAMENTALS OF MISCIBLE DRIVE PROCESSES. IT APPLIES TO BOTH THEORETICAL CONCEPTS AND OPERATIONAL APPROACHES TO MISCIBLE PROCESSES. A NUMBER OF ON-GOING FIELD APPLICATIONS OF MISCIBLE DRIVE PROJECTS AT THE TIME THE PAPER WAS WRITTEN ARE LISTED.

EXHIBITS:

----- 1 TABLE, 31 FIGURES

ADDITIONAL REFERENCES:

----- SIXTY-FIVE REFERENCES COVERING LABORATORY INVESTIGATIONS, PATENTS, AND FIELD APPLICATIONS RELATING TO MISCIBLE DISPLACEMENTS ARE CITED BY THE PAPER.

CROSS REFERENCES:

- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
S 1. BAYS: U.S. PATENT 2,135,319 (NOV. 1, 1938).
S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

HYDROCARBON COMPONENTS
AREAL SWEEP (LAB. EXP.)
RESIDUAL SATURATION (LAB. EXP.)
OTHER LABORATORY STUDIES
ENRICHED AND HIGH PRESSURE GAS
THEORETICAL PHYSICAL PROPERTIES
OTHER PHYSICAL PROPERTIES
LABORATORY INSTABILITIES
HEAVY OIL (LAB. EXP.)
OTHER FIELD INFORMATION
LPG

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- S 6. WILSON, I.F.: "MISCIBLE DISPLACEMENT - FLOW BEHAVIOR AND PHASE RELATIONSHIPS FOR A PARTIALLY DEPLETED RESERVOIR", TRANS., AIME (1960) V.219, 223-228.

ABSTRACT:

----- A QUALITATIVE THEORY FOR SLUG DISPLACEMENT WAS ESTABLISHED FROM LABORATORY STUDIES. CONDITIONS OF A CALIFORNIA RESERVOIR WERE CLOSELY DUPLICATED DURING THE INVESTIGATIONS. A HIGH GAS SATURATION EXISTED IN THE CORES AT THE START OF THE DISPLACEMENT AND THE CORE TEMPERATURE WAS MAINTAINED ABOVE THE CRITICAL VALUES FOR THE SLUG MATERIALS USED. THE STUDIES WERE CONDUCTED WITH DRY GAS-ETHANE, PROPANE, AND DRY GAS-PROPANE SLUGS. TWO RESERVOIR FLUIDS OF SIMILAR PROPERTIES WERE ALSO USED. THE SLUG COMPOSITION REQUIRED TO ACHIEVE 100% OIL RECOVERY IN THE LABORATORY AGREED WELL WITH THAT PREDICTED BY PHASE BEHAVIOR STUDIES. ALTHOUGH BOTH RESERVOIR FLUIDS PRECIPITATED SOME ASPHALTIC MATERIAL IN THE CORES, THERE WERE NO ADVERSE EFFECTS ON THE DISPLACEMENTS UNDER MISCIBLE FLOW CONDITIONS.

THE THEORY PREDICTED THAT THE LENGTH OF THE RECOVERY FLUID - SLUG TRANSITION ZONE WOULD INCREASE WITH INCREASED INITIAL GAS SATURATION, AND DECREASE WITH INCREASED OIL SWELLING DURING MIXING OF SOLVENT SLUG AND RESERVOIR OIL.

COMMENTS:

----- THE PAPER CONFIRMS THAT MISCIBILITY CAN BE PREDICTED FROM PHASE BEHAVIOR.

EXHIBITS:

----- 5 TABLES, 7 FIGURES DOCUMENTING EXPERIMENTAL RESULTS

CROSS REFERENCES:

- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.

KEYWORDS:

CORRELATIONS
SECONDARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)

LABORATORY INJECTION PROCESS
SANDSTONE (LAB. EXP.)
ENRICHED AND HIGH PRESSURE GAS

- S 7. HUTCHINSON, C.A., JR. AND BRAUN, P.H.: "PHASE RELATIONS OF MISCIBLE DISPLACEMENT IN OIL RECOVERY", A.I.C.H.E. J. (1961) V.7, 64-72.

ABSTRACT:

----- THE MECHANISMS OF MISCIBLE DISPLACEMENT PROCESSES ARE PRESENTED BY A CONCEPTUAL ANALYSIS BASED ON THE TERNARY DIAGRAM. THE PHASE RELATIONS AND MASS TRANSFER PHENOMENA OF HIGH PRESSURE GAS, ENRICHED GAS, AND MISCIBLE SLUG PROCESSES ARE RELATED AND COMPARED. THE EFFECTS OF PRESSURE, TEMPERATURE AND INJECTED GAS COMPOSITION ON THE PRACTICALITY OF THE PROCESSES ARE EXPLAINED.

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ESSENTIALLY, THE CRICONDEBAR OF A CRUDE OIL IS LOWERED WHEN IT COMES IN CONTACT WITH A RICH GAS. A SINGLE PHASE MIXTURE CAN BE ACHIEVED IF THE RICH GAS COMPOSITION CONTAINS ENOUGH COMPONENTS OF INTERMEDIATE VOLATILITY SUCH AS ETHANE THROUGH HEXANE. WHEN LEAN GAS COMES IN CONTACT WITH RESERVOIR FLUID AT HIGH PRESSURES, IT BECOMES ENRICHED. THE ENRICHMENT IS MEASURED AFTER EACH CONTACT. THE COMBINATION OF THE INCREASINGLY ENRICHED GAS AND THE RESERVOIR OIL WILL EVENTUALLY FORM A SINGLE PHASE MIXTURE AT THE INJECTION PRESSURE. MISCIBILITY WILL ALSO RESULT IF A FLUID WITH MISCIBILITY PROPERTIES (E.G. LIQUID PROPANE) COMES IN CONTACT WITH A RESERVOIR FLUID.

THE VARIOUS PROCESSES HAVE DIFFERENT ADVANTAGES AND DISADVANTAGES THAT ARE ENUMERATED.

COMMENTS:

----- THIS PAPER EXPLAINS THE FUNDAMENTAL CONCEPTS OF THE VARIOUS MISCIBLE PROCESSES INCLUDING HIGH PRESSURE GAS, ENRICHED GAS AND MISCIBLE SLUG PROCESSES. UNDERSTANDING OF THESE CONCEPTS IS ESSENTIAL TO THE SUCCESS OF A MISCIBLE PROJECT.

EXHIBITS:

----- 1 TABLE, 21 FIGURES

ADDITIONAL REFERENCES:

- 1. HALL AND GEFFEN: TRANS., AIME (1957) V.210, 48.
2. SLOBOD AND KOCH: DRILL. & PROD. PRAC., AM. PET. INST. (1953) 82.

CROSS REFERENCES:

- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.

KEYWORDS:

HYDROCARBON COMPONENTS

TERNARY SYSTEMS

MULTICOMPONENT SYSTEMS
EFFECTS OF TEMPERATURE
MULTIPLE CONTACT MISCIBILITY
SECONDARY RECOVERY (LAB. EXP.)
MISCIBILITY (LAB. EXP.)
ENRICHED AND HIGH PRESSURE GAS

EFFECTS OF PRESSURE
FIRST CONTACT MISCIBILITY
LABORATORY INJECTION PROCESS
AREAL SWEEP (LAB. EXP.)
OTHER LABORATORY STUDIES
LPG

S 8. CORDINER, F.S. AND POPP, M.P.: "APPLICATION OF MISCIBLE PHASE DISPLACEMENT TECHNIQUES TO A WATER-DRIVE RESERVOIR - JOHNSON FIELD, CHEYENNE COUNTY, NEBRASKA", DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144-151.

ABSTRACT:

----- A GAS-DRIVEN MISCIBLE SLUG PROCESS HAS BEEN SUCCESSFULLY AND ECONOMICALLY CARRIED OUT IN THE 'J' SAND, JOHNSON FIELD, NEBRASKA. THE FIELD, LOCATED APPROXIMATELY 9 MILES NORTHEAST OF SIDNEY, NEBRASKA, WAS DISCOVERED IN APRIL, 1951. THE 'D' AND 'J' PRODUCING SANDS IN THE FIELD ARE OF LOWER CRETACEOUS AGE. THE 'J' SAND IS CHARACTERIZED BY A VERY FINE-GRAINED LOOSELY CONSOLIDATED KAOLIN-FILLED SANDSTONE OF MARINE ORIGIN. THE PRIMARY PRODUCING MECHANISM IN THE SAND IS A NATURAL WATER DRIVE. IT WAS ESTIMATED THAT 840 MMBL OF OIL, OR 45% OOIP WOULD BE RECOVERED UNDER PRIMARY DEPLETION. ABOUT 581 MMBL OF OIL OR APPROXIMATELY 31% OOIP HAD BEEN PRODUCED BY THE TIME PROPANE INJECTION STARTED IN MAY, 1958.

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A TOTAL OF 42,800 BBL OF PROPANE WAS INJECTED AT AN AVERAGE RATE OF 450 B/D. THE 5.5% PV PROPANE VOLUME WAS ARBITRARILY SELECTED BECAUSE THERE WERE LITTLE OR NO DATA AVAILABLE AT THE TIME TO DETERMINE THE MINIMUM SLUG SIZE REQUIRED. TESTS INDICATED THAT MISCIBILITY OF THE INJECTED FLUIDS WITH THE RESERVOIR CRUDE WOULD BE ACHIEVED AT 940 PSIA AT THE RESERVOIR PRESSURE OF 170 F. THE ORIGINAL RESERVOIR PRESSURE OF 1,090 PSIG HAD DECLINED TO 933 PSIG BEFORE THE INJECTION STARTED. RESERVOIR PRESSURE WAS MAINTAINED AT 1000 PSIG DURING THE INJECTION. GAS INJECTION STARTED IN SEP., 1958.

OIL RESPONSE WAS IMMEDIATE. THE PRODUCTION INCREASED FROM 225 BOPD PRIOR TO INJECTION TO A PEAK OF 450 BOPD. HOWEVER, GAS BREAKTHROUGH WAS OBSERVED EARLIER THAN HAD BEEN PREDICTED. THE RICH GAS PRODUCTION WAS RECYCLED. A RECOVERY OF 64% OF THE ORIGINAL OIL IN PLACE IS EXPECTED. RECOVERY WITHIN THE CONTACT AREA IS EXPECTED TO APPROACH 80%. THE PROJECT PAID OUT EARLY IN 1962 AFTER ABOUT 3.5 YEARS. THE ESTIMATED ANNUAL RATE OF RETURN FOR THE PROJECT WAS ABOUT 20%, MAKING IT ATTRACTIVE ECONOMICALLY.

COMMENTS:

----- THE JOHNSON 'J' SAND HAS A POOR PERMEABILITY DISTRIBUTION. HIGH PERMEABILITY ZONES SPREAD THROUGHOUT THE RESERVOIR. THIS ACCOUNTED FOR THE EARLY GAS BREAKTHROUGH. THE RECYCLING PROCESS HELPED TO HANDLE THE PRODUCED GAS. WATER INJECTION DID NOT STOP OR REDUCE GAS PRODUCTION. THE SIMULTANEOUS WATER AND GAS INJECTION BEING TRIED SHOULD CURTAIL THE RATE OF GAS PRODUCTION. MOBILITY RATIO CONTROL IS ESSENTIAL IN STRATIFIED RESERVOIRS.

EXHIBITS:

----- 1 TABLE, 8 FIGURES, INCLUDING GEOLOGIC AND RESERVOIR DESCRIPTION AND PROJECT AND INDIVIDUAL WELL PRIMARY AND SECONDARY RECOVERY DATA.

CROSS REFERENCES:

- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
OTHER FIELD INFORMATION

SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FIELD AREAL SWEEP
FIELD ECONOMICS
LPG

S 9. WIEMER, R.F.: "LPG-GAS INJECTION RECOVERY PROCESS, BURKETT UNIT, GREENWOOD COUNTY, KANSAS", J. PET. TECH. (OCT., 1963) 1067-1072.

ABSTRACT:

----- A PILOT TEST WAS CARRIED OUT AT THE WATERED-OUT PHILLIPS-OPERATED BURKELL UNIT, KANSAS, TO DETERMINE THE PRACTICAL VALUE OF LPG-GAS INJECTION PROCESS. IT WAS ESTIMATED THAT 63,250 BBL OF RESIDUAL OIL REMAINED IN THE 10 ACRE TRACT AT THE START OF THE INJECTION TEST. 18,131 BBL OF LPG, FOLLOWED BY 67,946 MCF OF DRY GAS WERE INJECTED. 12,120 BBL OF ADDITIONAL OIL WERE RECOVERED AS A RESULT OF THE LPG INJECTION. ONLY 1000 BBL OF LPG AND 19 MMCF OF THE GAS WERE RECOVERED. ABOUT 102% PORE VOLUME OF WATER HAD BEEN INJECTED BY THE CONCLUSION OF THE TEST IN MAY, 1963 WITH NO APPRECIABLE AMOUNT OF ADDITIONAL GAS OR LPG PRODUCED.

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THE POOL, DISCOVERED IN 1922, PRODUCES FROM THE BARTLESVILLE SAND AT A DEPTH OF 2,100 FT. THE RESERVOIR IS 3.5 MILES LONG BY 1 MILE WIDE, WITH AN AVERAGE THICKNESS OF 30 FEET. PERMEABILITIES ARE GENERALLY LOW, VARYING FROM LESS THAN 1 MD TO 40 MD WITH POOR CORRELATION FROM WELL TO WELL. THE PRIMARY OIL PRODUCTION PEAKED IN 1924 AT AN AVERAGE OF 2180 BOPD AND DECREASED TO 170 BOPD BY 1938 WHEN THE FIELD WAS UNITIZED. TOTAL PRIMARY PRODUCTION WAS 4.46 MMBBL AND 5.94 MMBBL WERE PRODUCED BY WATERFLOOD AFTER UNITIZATION.

ALTHOUGH AN OIL BANK WAS FORMED IN THE WATERED-OUT RESERVOIR, ADDITIONAL OIL RECOVERED IN THIS TEST WAS UNECONOMIC.

COMMENTS:

----- THERE IS NO EVIDENCE THAT THE UNRECOVERED LPG AND INJECTED GAS REMAINED IN THE PILOT AREA. THE POOR RECOVERY MIGHT BE BECAUSE MUCH OF THE LPG AND THE GAS NEVER CONTACTED THE RESIDUAL OIL.

EXHIBITS:

----- 1 TABLE, 11 FIGURES

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
OPERATIONS

SANDSTONE FIELD
FIELD TERTIARY RECOVERY
FIELD RESIDUAL SATURATIONS
LPG

S 10. FITCH, R.A. AND GRIFFITH, J.D.: "EXPERIMENTAL AND CALCULATED PERFORMANCE OF MISCIBLE FLOODS IN STRATIFIED RESERVOIRS", J. PET. TECH. (NOV., 1964) 1289-1298.

ABSTRACT:

----- A MEANS OF PREDICTING AND INTERPRETING MISCIBLE FLOODS HAS BEEN DEVELOPED. EXPERIMENTAL RESULTS AND A PERFORMANCE PREDICTION MODEL HAVE BEEN COMBINED IN THIS DEVELOPMENT. THE MODEL ASSUMES A MULTI-STRATA CONCEPT OF RESERVOIR PROPERTIES WITH NO CROSSFLOW BETWEEN STRATA. IT EXPLICITLY ALLOWS FOR VARIATIONS IN PATTERN, INJECTIVITY, AREAL SWEEP AND DISPLACEMENT EFFICIENCY. METHODS OF IMPROVING FLOOD EFFICIENCY HAVE BEEN INVESTIGATED. A COMPARISON WITH EXPERIMENTAL DATA IN A NO CROSSFLOW SITUATION SHOWED GOOD AGREEMENT. HOWEVER, SOME LIMITATIONS ARE IMPOSED ON APPLICABILITY TO A SYSTEM WITH DEFINITE CROSSFLOW OWING TO GRAVITY SEGREGATION.

THE DISPLACEMENT OF A MISCIBLE FRONT THROUGH A RESERVOIR WAS EXAMINED BY THE MODEL. THE DISTRIBUTION AND UTILIZATION OF SOLVENT WERE ALSO STUDIED. ALTERNATE GAS AND WATER INJECTION BEHIND A MISCIBLE FRONT SHOWED PERFORMANCE IMPROVEMENT OVER STRAIGHT INJECTION OF GAS. IN A STRATIFIED SYSTEM, ADDITIONAL IMPROVEMENT IN THE FLOOD PERFORMANCE WAS OBSERVED WITH ALTERNATE GAS-WATER INJECTION. PRE-INJECTION OF A SMALL VOLUME OF WATER AHEAD OF SOLVENT CAN IMPROVE THE DISTRIBUTION OF SOLVENT IN A STRATIFIED SYSTEM.

THE SOLVENT SLUG SHOULD BE SIZED SO THAT MISCIBILITY EXPIRES WHEN THE PRODUCING GOR BECOMES EXCESSIVE. ALTERNATELY, WHERE NO GOR PROBLEM IS ENVISAGED, THE OPTIMUM VOLUME OF SOLVENT IS THAT WHICH YIELDS ADDITIONAL OIL WORTH THE PRESENT VALUE OF THE INJECTED SOLVENT. DETAILED EXPERIMENTAL PROCEDURE AND RELEVANT EQUATIONS ARE GIVEN IN THE APPENDIX.

COMMENTS:

----- 1. THE TWO ALTERNATE CRITERIA FOR DETERMINING THE OPTIMUM VOLUME OF SOLVENT ARE NOT VERY CONVINCING. A MISCIBLE SLUG PROCESS IS USUALLY DESIGNED TO RECOVER AS MUCH ADDITIONAL OIL AS POSSIBLE WITH A LIMITED AMOUNT OF SOLVENT. ADEQUATE CONDITIONS OF RESERVOIR TEMPERATURE AND PRESSURE ARE REQUIRED TO MAINTAIN MISCIBILITY AND MAKE EFFECTIVE USE OF THE SOLVENT. SOLVENT DISTRIBUTION IN THE RESERVOIR ALSO AFFECTS THE EFFICIENCY AND EFFECTIVENESS OF SOLVENTS.

2. FOR PROPER APPLICATION OF THIS MODEL, DATA ARE REQUIRED RELATING INJECTIVITY, COMPOSITION OF PRODUCED FLUID, AND AREAL SWEEP TO INJECTION VOLUMES. WITH THIS AMOUNT OF INFORMATION, NO REAL CALCULATION OF PERFORMANCE IS REQUIRED.

EXHIBITS:

----- 2 TABLES, 18 FIGURES

ADDITIONAL REFERENCES:

- 1. HALL AND GEFFEN: TRANS., AIME (1957)
V.210, 48.
2. MUSKAT: PRINCIPLES OF OIL PRODUCTION (1949).
3. CRAIG, GEFFEN AND MORSE: TRANS., AIME (1953) V.204, 7.

CROSS REFERENCES:

- S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

ANALYTICAL MODELLING
COMPARISONS WITH LAB. RESULTS
OTHER MODELLING

BUCKLEY-LEVERETT MODELLING
COMPARISONS WITH FIELD RESULTS
LPG

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- S 11. REAMER, H.H. AND SAGE, B.H.: "PARTIAL VOLUMETRIC BEHAVIOR IN HYDROCARBON SYSTEMS. N-DECANE AND CARBON DIOXIDE IN THE LIQUID PHASE OF THE N-DECANE - CARBON DIOXIDE SYSTEM", J. CH. & ENG. DATA (JAN., 1965) V.4, NO.1, 49-57.

ABSTRACT:

----- PARTIAL MOLAL VOLUMES WERE EVALUATED FOR N-DECANE AND CARBON DIOXIDE FROM EXPERIMENTAL VOLUMETRIC DATA FOR THE N-DECANE - CARBON DIOXIDE SYSTEM AND CORRESPONDING INFORMATION FOR THE PURE COMPONENTS. THE DATA EXTEND TO PRESSURES OF 10000 PSIA FOR TEMPERATURES BETWEEN 40 AND 460 F. THE PARTIAL VOLUMES ARE PRESENTED IN GRAPHICAL AND TABULAR FORM.

COMMENTS:

----- THIS STUDY IS A CONTINUATION OF THAT OF REAMER AND SAGE (1963).

EXHIBITS:

----- 3 TABLES, 6 FIGURES

CROSS REFERENCES:

- 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.

KEYWORDS:

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS

THEORETICAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
OTHER PHYSICAL PROPERTIES

S 12. REISBERG, J.: "SECONDARY RECOVERY METHOD", U.S. PATENT
3,174,542 (MAR. 23, 1965).

ABSTRACT:

----- THIS INVENTION INVOLVES THE INJECTION OF A SOAP-
FORMING HIGH BOILING POINT NAPHTHENIC ACID HAVING A MOLECULAR WEIGHT
FROM 300 TO 400. THE ACID MAY BE CARRIED IN A LIGHT HYDROCARBON
CRUDE OIL OR ANY OTHER OIL-MISCIBLE LIQUID AND CONSTITUTES ABOUT
2.5% TO 10% OF THE SLUG. THE TOTAL SLUG SIZE MAY VARY BETWEEN 10%
AND 20% OF A PORE VOLUME. THIS IS FOLLOWED BY THE INJECTION OF
SEVERAL PORE VOLUMES OF ALKALI SOLUTION (E.G. SODIUM HYDROXIDE
SOLUTION) WHICH CONVERTS THE HIGH BOILING POINT NAPHTHENIC ACID TO
A SURFACE ACTIVE COMPOUND. AN EMULSIFIER OR INTERFACIAL TENSION-
REDUCING MATERIAL IS THEREBY FORMED IN-SITU, WHICH FACILITATES
THE DISPLACEMENT OF OIL IN THE FORMATION. THIS DISPLACEMENT MAY BE
ACCOMPLISHED BY FURTHER INJECTION OF AQUEOUS SOLUTION OR BY WATER
INJECTION. ADEQUATE VISCOSITY CONTROL (LESS THAN 2 TO 1 RATIO)
IMPROVES RECOVERY.

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ALTHOUGH SATURATED OR UNSATURATED ALIPHATIC MONOCARBOXYLIC
ACIDS MAY ALSO BE USED, NAPHTHENIC ACID IS READILY AVAILABLE AT
A REASONABLE COST. LABORATORY INVESTIGATIONS CONFIRMED THAT OVER
99% OF THE RESIDUAL OIL MAY BE RECOVERED THROUGH THIS PROCESS.
EXAMPLES OF LABORATORY TESTS SHOWING BENEFITS AND ADVANTAGES OF
THIS PROCESS ARE ALSO PRESENTED.

COMMENTS:

-----, THIS PATENT INVOLVES MISCIBILITY ONLY AS A CARRIER
FOR THE ACID AND HAS NO REAL RELAVANCE TO CARBON DIOXIDE FLOODING.

EXHIBITS:

----- 1 TABLE

KEYWORDS:

SECONDARY RECOVERY (LAB. EXP.)
SANDSTONE (LAB. EXP.)
U.S. PATENT

LABORATORY INJECTION PROCESS
TERTIARY RECOVERY (LAB. EXP.)
OTHER LABORATORY STUDIES
ALTERNATE TECHNOLOGIES

S 13. PRATS, M. AND CLOSMAN, P.J.: "SECONDARY RECOVERY OF HYDROCARBONS WITH SULFUR TRIOXIDE", U.S. PAT. 3,259,187 (JULY 5, 1966).

ABSTRACT:

----- THIS INVENTION IS SUITED FOR RESERVOIRS CONTAINING VISCOUS OIL WITH A MINOR AMOUNT OF AROMATIC COMPONENTS. THIS INVENTION INVOLVES THE INJECTION OF SULFUR TRIOXIDE, EITHER AS A PURE LIQUID OR IN THE FORM OF OLEUM, I.E. CONCENTRATED SULFURIC ACID WITH AN EXCESS OF SO₃. THE SULFUR TRIOXIDE REACTS WITH AROMATIC HYDROCARBON TO FORM PETROLEUM SULFONATES; THE HYDROCARBON SURFACE TENSION IS REDUCED BY CONTACT WITH SO₃ AND THE OIL MAY BE EFFECTIVELY DISPLACED. THE REACTION OF SO₃ WITH HYDROCARBON IS EXOTHERMIC. HIGH HEAT OF HYDRATION IS ALSO RELEASED WHEN SO₃ COMES INTO CONTACT WITH FORMATION WATER; OIL VISCOSITY IS REDUCED AT INCREASED TEMPERATURES EFFECTING BETTER RECOVERIES.

IN THE EVENT THAT THE FORMATION CONTAINS CALCITE, SULFURIC ACID FORMED FROM SULFUR TRIOXIDE REACTS WITH THE CALCITE AND BECOMES NEUTRALIZED. HEAT IS ALSO GENERATED BY THIS PROCESS. THE INVENTION IS NOT RECOMMENDED FOR FORMATIONS WITH ACID SOLUBLE MATERIALS, IN ORDER TO MOST EFFECTIVELY USE THE SULFUR TRIOXIDE.

COMMENTS:

----- THIS INVENTION IS DIRECTED MORE TOWARDS RESERVOIR HEATING FOR HEAVY OIL PRODUCTION THAN TO MISCIBLE DISPLACEMENT.

KEYWORDS:

ALTERNATE TECHNOLOGIES

U.S. PATENT
MISCELLANEOUS DATA

S 14. ROOF, J.G. AND BARON, J.D.: "CRITICAL LOCI OF BINARY MIXTURES OF PROPANE WITH METHANE, CARBON DIOXIDE, AND NITROGEN", J. CH. & ENG. DATA (JULY, 1967) V.12, NO.3, 292-293.

ABSTRACT:

----- MINIMUM MISCIBILITY PRESSURES WERE DETERMINED BY OBSERVATIONS IN A WINDOWED CELL FOR SYSTEMS OF PROPANE WITH METHANE, CARBON DIOXIDE, AND NITROGEN. THE CRITICAL PRESSURES AND TEMPERATURES FOR PROPANE-CARBON DIOXIDE MIXTURES AS A FUNCTION OF COMPOSITION ARE TABLED.

COMMENTS:

----- THE DESCRIPTION OF HOW BUBBLE POINTS OR DEW POINTS ARE DETERMINED EXPERIMENTALLY IS INFORMATIVE.

EXHIBITS:

----- 1 TABLE, 2 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
OTHER PHYSICAL PROPERTIES

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
LAB. PROCEDURES AND APPARATUS

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S 15. CHAMBERS, F.T.: "TERTIARY OIL RECOVERY COMBINATION WATER-GAS MISCIBLE FLOOD - HIBBERD POOL", PROD. MO. (JAN., 1968) 17-19.

ABSTRACT:

----- THE TERTIARY OIL RECOVERY FROM THE HIBBERD POOL IN IN SOUTH CUYAMA FIELD, BY THE PROCESS OF INJECTING PROPANE, GAS, AND WATER, HAS BEEN REVIEWED. THE FIELD IS LOCATED IN CALIFORNIA, AND WAS DISCOVERED IN 1950. THE HIBBERD ZONE OIL ACCUMULATION IS 4,300 FEET DEEP WITH TRAPPING AGAINST AN AXIAL FAULT. THE ZONE IS HETEROGENEOUS, AND HAS A MAXIMUM GROSS THICKNESS OF 60 FEET, WITH AVERAGE PERMEABILITY OF 270 MD AND POROSITY OF 23%.

PRODUCTION PEAKED AT 1700 BOPD IN 1952 AND DECLINED TO 460 BOPD BY EARLY 1954. THE PRIMARY ULTIMATE RECOVERY WAS ESTIMATED TO BE 2.24 MMBBL OR 31% OOIP. IN ORDER TO INCREASE THE RECOVERY EFFICIENCY, A UNIT WAS FORMED IN LATE 1954. THREE PRODUCING EDGE WATER WELLS WERE CONVERTED TO WATER INJECTION BETWEEN 1956 AND 1959. THE ESTIMATED OIL RECOVERY FROM THE WATERFLOOD WAS 3.3 MMBBL OR 41% OOIP. CUMULATIVE OIL PRODUCTION HAD REACHED 46% OF OOIP BY EARLY 1963. THE PRESSURES IN THE RESERVOIR WERE ALLOWED TO STABILIZE BEFORE PROPANE INJECTION STARTED IN APRIL, 1963. BY THE TIME THE PROPANE INJECTION WAS TERMINATED IN OCT., 1963, A TOTAL OF ABOUT EIGHT MILLION GALLONS (200 MMBL) OF PROPANE HAD BEEN INJECTED. DOWNWARD MOVEMENT OF THE INJECTED PROPANE WAS PREVENTED BY INJECTING WATER IN TWO OF THE WELLS. 140 MMCF OF GAS WERE INJECTED BEFORE WATER INJECTION STARTED AGAIN IN AUGUST, 1964, AT THE RATE OF 4,400 BBL/DAY.

THE ULTIMATE TERTIARY PRODUCTION WAS ESTIMATED TO BE 300 MMBL; ABOUT 220 MMBL HAD BEEN PRODUCED BY DEC., 1966. THE ULTIMATE PROPANE-OIL RATIO IS EXPECTED TO BE ABOUT 1 TO 3. PAYOUT OF THE MISCIBLE SLUG PROCESS OCCURRED IN MARCH, 1965.

COMMENTS:

----- THE PAPER DOES NOT REPORT ON THE DESIGN OF THE MISCIBLE PROCESS. THE PRODUCTION DATA ARE PROBABLY TOO ERRATIC FOR GOOD HISTORY MATCHING.

EXHIBITS:

----- 1 TABLE, 3 FIGURES

ADDITIONAL REFERENCES:

----- CSASZAR AND HOLM: PAPER SPE 447 (1962).

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

SANDSTONE FIELD
FIELD TERTIARY RECOVERY
FIELD ECONOMICS
LPG

S 16. LEE, A.L.: "WORK ON PHYSICAL PROPERTIES OF LNG",
OIL & GAS J. (OCT. 28, 1968) 84-86.

ABSTRACT:

----- ON-GOING RESEARCH PROGRAMS ON THE FUNDAMENTAL
PROPERTIES OF LNG ARE BRIEFLY DISCUSSED. THE AIM IS TO DEVELOP A
GENERALIZED EQUATION TO PREDICT THE BEHAVIOR OF LNG. PHYSICAL
PROPERTIES PRESENTED INCLUDE ENTHALPY AND THERMAL CONDUCTIVITY;
AT THE TIME OF PREPARATION OF THIS ARTICLE, STUDIES OF OTHER
PROPERTIES WERE IN PROGRESS.

A BRIEF PLANT LAYOUT OF AN LPG PLANT IS PRESENTED. BASED ON
1 BILLION SCF OF GAS STORED IN A DOUBLE-WALL ABOVE GROUND TANK,
WITH LIQUEFACTION OVER A 250-DAY PERIOD, AND REGASIFICATION OVER
15 DAYS, 38% OF THE CAPITAL INVESTMENT AND OPERATING COST OF AN
LPG FACILITY IS IN PURIFICATION AND LIQUEFACTION EQUIPMENT.
STORAGE FACILITIES ACCOUNT FOR 41% OF THE COST. OVER-DESIGN OF
THE FACILITY (LARGE SAFETY FACTORS) CONTRIBUTES MARKEDLY TO THE COST.

COMMENTS:

----- FURTHER RESEARCH AND APPLICATION MAY REDUCE
INVESTMENT AND OPERATING COSTS.

EXHIBITS:

----- 2 TABLES, 2 FIGURES

KEYWORDS:

OTHER PHYSICAL PROPERTIES
FACILITIES

FIELD ECONOMICS
LPG

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- S 17. ROBERTS, G., JR., ELKINS, L.E. AND GEFFEN, T.M.: "HOW PAN AMERICAN PRODUCTION RESEARCH 'FINDS' NEW RESERVES", OIL & GAS J. (JUNE 3, 1968) 77-82.

ABSTRACT:

----- A CONTROVERSIAL PAN AMERICAN CORPORATION BASIC PATENT ON MISCIBLE FLOODING, PENDING FOR 17 YEARS, COVERS THE INJECTION OF A SOLVENT (PROPANE) TO MISCIBLY DISPLACE RESERVOIR OIL. THE SOLVENT IS FOLLOWED WITH NATURAL GAS UNDER CONDITIONS THAT MAKE IT MISCIBLE WITH THE SOLVENT. ONE IMPROVEMENT PATENT SUGGESTS THAT WATER BE INJECTED AHEAD OF THE PROPANE SLUG. ANOTHER IMPROVEMENT PATENT SUGGESTS INJECTING WATER ALONG WITH THE GAS EITHER SIMULTANEOUSLY OR IN ALTERNATE SLUGS. THE IMPROVEMENT PATENTS ARE DESIGNED TO IMPROVE MOBILITY RATIO AND SWEEP EFFICIENCY. UNDER FAVORABLE CONDITIONS, MISCIBLE FLOODING MAY RECOVER 50% MORE OIL THAN WATERFLOODING.

CAUSES OF FAILURE IN EARLY MISCIBLE FLOOD TESTS MIGHT BE ATTRIBUTED TO INCOMPATIBLE VISCOSITIES OF INJECTED AND DISPLACED FLUIDS WHICH CAUSED FINGERING. MANY OF THE RESERVOIRS WERE ALSO TOO HETEROGENEOUS. THIS CONTRIBUTED TO POOR SWEEP EFFICIENCY AND RESULTING FAILURE OF THE PROCESS. THE RISK OF FAILURE TODAY IS MINIMIZED AS A RESULT OF EXPERIENCE AND IMPROVED TECHNOLOGY. GENERALLY, LPG MISCIBLE FLOODING IS NOT SUITABLE FOR RESERVOIRS WITH OIL VISCOSITY GREATER THAN ABOUT 5 CP.

COMMENTS:

- 1. THE INTERVIEW INDICATES AMOCO'S COMMITMENT TO ENHANCED RECOVERY THROUGH CONTINUED RESEARCH.
2. THE DETERMINING FACTOR IN DECIDING WHICH PROCESS TO PURSUE IS ECONOMICS.
3. NO PROCESS IS GOOD FOR ALL OCCASIONS, AND EACH PROJECT SHOULD BE CONSIDERED ON ITS OWN MERITS AND PECULIARITIES.
4. THE PATENT DESCRIBED IN THIS ARTICLE COULD NOT BE OBTAINED IN TIME FOR INCLUSION IN THIS STUDY.

EXHIBITS:

----- 1 FIGURE

KEYWORDS:

FIELD TERTIARY RECOVERY
FIELD MOBILITY RATIO
OTHER FIELD INFORMATION
U.S. PATENT

FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
SCREENING CRITERIA
LPG

S 18. ANON.: "FIRST MISCIBLE FLOODS TOPS 100 MILLION BBL",
OIL & GAS J. (SEP. 1, 1969) 66.

ABSTRACT:

----- THE MISCIBLE FLOOD PROJECT IN BLOCK 31 UNIT, CRANE
COUNTY, TEXAS, OPERATED BY ATLANTIC RICHFIELD, IS THE FIRST
OF ITS KIND, AND ONE OF THE MOST SUCCESSFUL IN THE INDUSTRY. MORE
THAN 100 MMBBL OF CRUDE OIL HAD BEEN PRODUCED FROM THIS
FIELD BY 1969. THE FIELD WAS DISCOVERED IN NOVEMBER, 1945 AND
PLACED ON HIGH PRESSURE GAS INJECTION IN 1949. THE INJECTED GAS
WAS CHANGED FROM NATURAL GAS TO LESS EXPENSIVE FLUE GAS IN 1966.

COMMENTS:

----- THE BLOCK 31 UNIT IS A CASE OF A SUCCESSFUL
MISCIBLE HIGH PRESSURE GAS INJECTION PROJECT.

EXHIBITS:

----- 1 FIGURE

KEYWORDS:

FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

FIELD SECONDARY RECOVERY
FLUE GAS FIELD APPLICATIONS
ENRICHED AND HIGH PRESSURE GAS

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S 19. BLEAKLEY, W.B.: "MISCIBLE FLOOD HIKES BLOCK 31'S OIL OUTPUT", OIL & GAS J. (OCT. 27, 1969) 67-70.

ABSTRACT:

----- THE BLOCK 31 (DEVONIAN) FIELD IN CRANE COUNTY, TEXAS IS EXPECTED TO PRODUCE MORE THAN 160 MMBBLS OF OIL AS A RESULT OF HIGH PRESSURE MISCIBLE GAS DISPLACEMENT. THE FIELD REACHED THE 100 MMBBL PRODUCTION MARK IN JULY, 1969. THE ESTIMATED OOIP WAS 260 MMBBLS OF WHICH 40 MMBBL WERE PRODUCIBLE UNDER PRIMARY. IT WAS ESTIMATED THAT ORDINARY GAS INJECTION (BELOW MISCIBILITY PRESSURE) WOULD RECOVER ABOUT 35% OF THE OOIP. ARCO ESTABLISHED THROUGH LABORATORY STUDIES THAT MISCIBILITY BETWEEN INJECTED GAS AND THE CRUDE OIL COULD BE ACHIEVED IF THE PRESSURE WAS MAINTAINED ABOVE 3500 PSI.

THE FIELD WAS DISCOVERED IN 1945 AND ARCO STARTED HIGH PRESSURE GAS INJECTION IN 1949. A UNIT WAS FORMED BETWEEN ARCO AND OTHER OPERATORS IN THE FIELD IN 1952, TO ASSURE THAT MISCIBILITY WOULD BE MAINTAINED THROUGHOUT THE FIELD. LATER STUDIES SHOWED THAT MISCIBILITY COULD BE ACHIEVED USING FLUE GAS AND A FLUE GAS PLANT WAS COMPLETED IN MARCH, 1966.

IT TOOK 9 YEARS BEFORE GAS BREAKTHROUGH WAS OBSERVED. FLUE GAS BREAKTHROUGH WAS OBSERVED 3 YEARS AFTER CONVERTING TO FLUE GAS INJECTION. HYDROCARBON GAS INJECTION CONTINUED IN SOME WELLS TO ENSURE THAT SURROUNDING WELLS WOULD PRODUCE HIGH QUALITY GAS FOR FUEL NEEDED TO GENERATE THE FLUE GAS. SOME OF THE PRODUCERS WERE CONVERTED TO INJECTION WELLS WHEN PRODUCING GOR'S BECAME TOO HIGH. NEW PRODUCERS WERE ALSO BEING DRILLED. THE RESERVOIR IS 1000 FEET THICK, HAS 15% POROSITY, 1 MD PERMEABILITY, 37% CONNATE WATER SATURATION, AND CONTAINS A 46 API CRUDE OIL, WITH INITIAL GOR OF 1300 SCF/BBL.

COMMENTS:

----- THE UNIT OPERATION WAS QUITE INSTRUMENTAL TO THE SUCCESS OF THE BLOCK 31 FIELD. WITHOUT IT, IT WOULD HAVE BEEN VERY DIFFICULT IF NOT IMPOSSIBLE TO MAINTAIN THE RESERVOIR PRESSURE ABOVE 3500 PSI AS REQUIRED FOR MISCIBILITY.

EXHIBITS:

----- 8 FIGURES

KEYWORDS:

FIELD SECONDARY RECOVERY
FLUE GAS FIELD APPLICATIONS
OPERATIONS

FIELD MISCIBLE APPLICATION
FACILITIES
ENRICHED AND HIGH PRESSURE GAS

S 20. JACOBY, R.H., MORRIS, E.E. AND ROBINSON, R.L.: "RECOVERY OF OIL BY MEANS OF ENRICHED GAS INJECTION", U.S. PATENT 3,465,823 (SEP. 9, 1969).

ABSTRACT:

----- THIS INVENTION INVOLVES THE INJECTION OF AN ENRICHED GAS INTO A VISCOUS OIL RESERVOIR TO REDUCE THE OIL VISCOSITY. WITH THE VISCOSITY OF OIL REDUCED, IT IS THEN ABLE TO FLOW AT THE EXISTING ENERGY LEVEL IN THE RESERVOIR. AFTER THE ENRICHED GAS INJECTION THE WELL IS LEFT TO SOAK FOR SEVERAL DAYS, AFTER WHICH IT IS PLACED ON PRODUCTION. IT IS CLAIMED THAT AN ENRICHED GAS MIXTURE CONTAINING LESS THAN 40% PROPANE BY WEIGHT AVOIDS ASPHALT PRECIPITATION WHILE REDUCING OIL OR TAR VISCOSITY.

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THE PROPOSED INJECTION PROCESS STARTS WITH THE INJECTION OF 50 TO 100 BARRELS OF CONDENSATE LIQUIDS TO ENHANCE INJECTIVITY BY WASHING AWAY ANY ACCUMULATION OF WAX. FINGERING OF THE INJECTED RICH GAS INTO OIL IMMEDIATELY AROUND THE WELLBORE IS ENCOURAGED; HENCE, THE HIGHEST INJECTION RATE POSSIBLE WITHOUT FRACTURING THE FORMATION IS RECOMMENDED. FIELD TESTS ON THIS CYCLIC PROCESS WERE MADE ON TWO WELLS IN OKLAHOMA, AND GOOD RESULTS ARE CLAIMED.

COMMENTS:

----- 1. THIS IS ONE OF THE BASIC PATENTS ON THE SOLVENT SOAK PROCESS; THIS PROCESS HAS RECENTLY BEEN APPLIED WITH SOME SUCCESS IN CALIFORNIA.

2. THE METHOD IS STATED TO WORK BETTER WITH LARGE SOLVENT SOAK VOLUMES.

3. INJECTION OF DRY GAS ALONE DID NOT RESULT IN ANY APPRECIABLE INCREASE IN OIL PRODUCTION.

EXHIBITS:

----- 2 TABLES

CROSS REFERENCES:

2. WAITZ: U.S. PATENT 1,295,243 (FEB. 25, 1919).

24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).

KEYWORDS:

SANDSTONE FIELD
FIELD IMMISCIBLE APPLICATION
U.S. PATENT

SOAK OPERATION
OTHER FIELD INFORMATION
LPG

S 21. BLANTON, J.R., MCCASKILL, N. AND HERBECK, E.F.: "PERFORMANCE OF A PROPANE SLUG PILOT IN A WATERED-OUT SAND - SOUTH WARD FIELD", J. PET. TECH. (OCT., 1970) 1209-1214.

ABSTRACT:

----- A PROPANE SLUG PILOT TEST WAS CARRIED OUT IN THE BENNETT SAND OF SOUTH WARD FIELD, WEST TEXAS. THE RESERVOIR IS AT A DEPTH OF 2400 FEET, AND HAS A GROSS THICKNESS OF 60 TO 80 FEET, 30 FEET OF WHICH IS CLEAN FRIABLE SAND WITH GOOD PERMEABILITY AND POROSITY. THE POOLS CONTAIN A 35 API GRAVITY CRUDE WITH A VISCOSITY OF 3 TO 4 CP. THE RESERVOIR WAS PRODUCED UNDER PRIMARY DEPLETION AND WATERFLOOD PRIOR TO THE PROPANE SLUG PILOT. THE RESIDUAL OIL SATURATION AFTER WATERFLOODING WAS 19.6% IN THE PILOT AREA. A TOTAL PROPANE SLUG OF 88 MBBL WAS INJECTED, OF WHICH AN ESTIMATED 30% ENTERED THE PILOT AREA. THE PROPANE WAS FOLLOWED BY 66 MMCF OF GAS; THIS IN TURN WAS FOLLOWED BY ALTERNATE GAS AND WATER INJECTION.

SIGNIFICANT RESPONSE TO PROPANE INJECTION WAS NOTICED AND 37 MBBL OF ADDITIONAL OIL HAD BEEN PRODUCED WHEN THE PILOT WAS TERMINATED IN JUNE, 1964. AN ESTIMATED 40 MBBL WOULD HAVE BEEN PRODUCED HAD THE TEST CONTINUED TO THE ECONOMIC LIMIT.

IN THIS TEST, OF THE OIL REMAINING AFTER THE WATERFLOOD, 37% WAS RECOVERED. WITH THE ESTIMATED 26,300 BBL OF PROPANE ENTERING THE PILOT AREA, THE RATIO OF RECOVERED OIL TO SLUG SIZE WAS 15 TO 1.

COMMENTS:

----- THE AIM OF THE PILOT TEST WAS BASICALLY TO DEMONSTRATE THE EFFECTIVENESS OF THE PROPANE SLUG PROCESS IN RECOVERING ADDITIONAL OIL. THIS WAS ACHIEVED AND ABOUT 37% OF THE REMAINING OIL AFTER WATERFLOOD WAS RECOVERED.

EXHIBITS:

----- 4 FIGURES, 2 TABLES

ADDITIONAL REFERENCES:

----- DYES, BRAUN AND COLES: TRANS., AIME (1957) V.210, 283-288.

CROSS REFERENCES:

S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.

KEYWORDS:

WATER INJECTION
FIELD RESIDUAL SATURATIONS

SANDSTONE FIELD
FIELD MISCIBLE APPLICATION
LPG

S 22. CRAIG, F.E., JR.: "A CURRENT APPRAISAL OF FIELD MISCIBLE SLUG PROJECTS", J. PET. TECH. (MAY, 1970) 529-536.

ABSTRACT:

----- THIS PAPER PRESENTS AN APPRAISAL OF THE VARIOUS MISCIBLE SLUG PROCESSES AND DISCUSSES PROCESS IMPROVEMENTS AND THEIR APPLICATION TO SEVERAL LARGE SCALE PROJECTS. RESEARCH AND ENGINEERING STUDIES ON THIS SUBJECT ARE BRIEFLY REVIEWED AND SUMMARIZED. BASED ON LABORATORY STUDIES, SIX PREFERRED RESERVOIR AND OPERATING CONDITIONS FOR PROPER APPLICATION OF MISCIBLE SLUG FLOODING HAVE BEEN IDENTIFIED. GRAVITY SEGREGATION OF THE OIL, SOLVENT, AND SCAVENGING GAS, AND CHANNELING AND BYPASSING OF OIL, ARE COMMON PROBLEMS. SOLVENT SLUG VOLUMES IN FIELD OPERATIONS ARE USUALLY FROM 2% TO 10% OF THE HYDROCARBON PORE VOLUME. SLUG DISTRIBUTION AND RESERVOIR SWEEP CAN BE IMPROVED BY PRESOLVENT WATER INJECTION. INJECTED SOLVENT MIGHT ALSO BE DISPLACED BY ALTERNATE OR SIMULTANEOUS GAS AND WATER INJECTION.

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ABOUT 40% OF FIELD MISCIBLE PROJECTS OPERATING UNDER VALID CONDITIONS ARE SHOWING ENCOURAGING RECOVERY EFFICIENCIES. SOME OF THE OTHER PROJECTS FAILED BECAUSE THE RESERVOIRS WERE TOTALLY UNSUITED FOR MISCIBLE SLUG PROCESS. OTHERS FAILED BECAUSE OF INSUFFICIENT LPG CONTENT IN INJECTED GAS, OR BECAUSE THE RESERVOIR PRESSURE WAS BELOW THE SINGLE-PHASE PRESSURE FOR PROPANE AND METHANE. A MEASURE OF SUCCESS OF THE PROJECT IS THE RATIO OF ADDITIONAL OIL RECOVERY (IN EXCESS OF RECOVERY BY DRY GAS INJECTION) TO THE SOLVENT SIZE. A PROJECT IS ENCOURAGING IF THE VALUE IS GREATER THAN TWO, AND GOOD, IF GREATER THAN 4. THOSE WITH VALUES LESS THAN 1 ARE POOR.

HIGHLIGHTS OF PERFORMANCE OF EIGHT FIELDS UNDERGOING MISCIBLE INJECTION PROGRAMS ARE GIVEN. THESE INCLUDE JOHNSON FIELD, NEBRASKA; BURKETT UNIT, KANSAS; NEALE FIELD, LOUISIANA; AND HIBBERD POOL, CALIFORNIA. OTHERS ARE THE LOBSTICK CARDIUM UNIT, THE GOLDEN SPIKE FIELD AND THE ANTE CREEK FIELD - ALL IN ALBERTA, CANADA.

COMMENTS:

----- MORE CURRENT PERFORMANCE APPRAISALS OF THE FIELD CASES MENTIONED HAVE BEEN PUBLISHED.

EXHIBITS:

----- 1 TABLE, 5 FIGURES

ADDITIONAL REFERENCES:

----- THIRTY-SEVEN ADDITIONAL REFERENCES ARE CITED BY THIS PAPER.

CROSS REFERENCES:

- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.

29. HABERMANN: TRANS., AIME (1960) 264.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.

KEYWORDS:

OIL CHARACTERIZATION (LAB. EXP.)
CARBONATE FIELD
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION
ENRICHED AND HIGH PRESSURE GAS

MISCIBILITY (LAB. EXP.)
SANDSTONE FIELD
WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
SCREENING CRITERIA
LPG

- S 23. GRIFFITH, J.D., BAITON, W. AND STEFFENSEN, R.J.: "ANTE CREEK - A MISCIBLE FLOOD USING SEPARATOR GAS AND WATER INJECTION", J. PET. TECH. (OCT., 1970) 1232-1238.

ABSTRACT:

----- THE ANTE CREEK FIELD LOCATED NORTHWEST OF EDMONTON, CANADA WAS DISCOVERED IN NOVEMBER, 1962. THE PRODUCING HORIZON IS THE SWAN HILLS MEMBER OF THE BEAVERHILL LAKE FORMATION AT 11000 FEET. THE FIELD CONTAINS VOLATILE, LOW VISCOSITY OIL (0.13 CP) AT AN INITIAL PRESSURE OF 5,173 PSIA. THE BUBBLE POINT PRESSURE IS 4,140 PSIA. THE RESERVOIR PRESSURE HAD DECLINED TO 4,290 PSI BY DECEMBER 1966, AND THE ESTIMATED PRIMARY RECOVERY WAS ONLY 16.2%. THE FIELD WAS UNITIZED IN MAY, 1968 AND MISCIBLE FLUID INJECTION STARTED A MONTH LATER.

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BASED ON CALCULATIONS USING BENHAM'S CORRELATION, THE INJECTION SOLVENT COMPRISED A C2-C4 BASE (MOLECULAR WEIGHT 36) WITH C1-N2 DILUTION. 50 TO 100 MMBL OF WATER WERE INITIALLY INJECTED IN EACH WELL TO REDUCE FINGERING. SOLVENT INJECTION WAS ALTERNATED WITH WATER AT A WATER-GAS RATIO OF 0.8. THIS WAS INCREASED TO BETWEEN 1.0 AND 1.2 IN TWO YEARS. THE PRODUCTION AT THE TIME OF THIS PAPER WAS 1,600 BOPD, THE FULL ALLOWABLE RATE, AND A TOTAL RECOVERY OF 23 MILLION BBL OR 62% OOIP IS EXPECTED.

COMMENTS:

----- 1. THE MISCIBLE PROJECT IS PERFORMING SATISFACTORILY. A LARGE PART OF THE JUSTIFICATION FOR THE PROJECT MAY HAVE BEEN INCREASED ALLOWABLE (550 TO 1600 BOPD).

2. THE EXPERIMENTAL RESULTS IN THE PAPER AGREE WELL WITH BENHAM'S CORRELATION.

EXHIBITS:

----- 4 TABLES, 11 FIGURES INCLUDING SIMULATED RESULTS

ADDITIONAL REFERENCES:

----- HIGGINS AND LEIGHTON: J. PET. TECH. (JUNE, 1962) 679-683.

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.

KEYWORDS:

CARBONATE FIELD
FIELD SECONDARY RECOVERY
OPERATIONS
FINITE DIFFERENCE MODELS
COMPARISONS WITH FIELD RESULTS

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION
COMPARISONS WITH LAB. RESULTS
ENRICHED AND HIGH PRESSURE GAS

S 24. HULL, P.: "SACROC: AN ENGINEERING CONSERVATION TRIUMPH",
OIL & GAS J. (AUG. 17, 1970) 57-62.

ABSTRACT:

----- THIS ARTICLE CONCERNS THE SACROC FIELD. THE
SACROC UNIT (KELLY-SYNDER FIELD) INITIALLY CONTAINED ALMOST
THREE BILLION BARRELS OF OIL. THE FIELD WAS DISCOVERED IN 1948
AND PRODUCED UNDER PRIMARY SOLUTION GAS DRIVE UNTIL 1954. DURING
THAT TIME, 128 MMBO WERE PRODUCED; EXTRAPOLATED PRIMARY ULTIMATE
RECOVERY WAS ABOUT HALF A BILLION BARRELS (19% OOIP). WATERFLOODING
STARTED IN 1954; ABOUT 300 MMBBLS OF OIL (10% OOIP) WERE
RECOVERED WITH THE WATERFLOOD AT THE TIME OF PREPARATION OF THIS
ARTICLE, WITH ALMOST 800 MMBBLS TO BE RECOVERED BY
WATERFLOODING. THE PROPOSED WATER-DRIVEN CO2 SLUG SHOULD
RECOVER AN ADDITIONAL 160 MMBBLS.

COMMENTS:

----- THIS PAPER CONTAINS A GOOD SUMMARY OF PRIMARY AND
SECONDARY RECOVERY BEHAVIOR AT SACROC.

EXHIBITS:

----- 1 TABLE, 6 FIGURES

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
OPERATIONS
GENERAL ECONOMICS
TRANSPORTATION

CARBONATE FIELD
FIELD TERTIARY RECOVERY
FACILITIES
OTHER FIELD INFORMATION
CO2 SOURCE
MISCELLANEOUS DATA

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- S 25. YARBOROUGH, L. AND SMITH, L.R.: "SOLVENT AND DRIVING GAS COMPOSITION FOR MISCIBLE SLUG DISPLACEMENT", SOC. PET. ENG. J. (SEP., 1970) 298-310.

ABSTRACT:

----- MISCIBILITY CONDITIONS IN BOTH LPG SLUG AND ENRICHED GAS PROCESSES WERE DETERMINED BY LABORATORY EXPERIMENTS. A WIDE RANGE OF RESERVOIR OIL PROPERTIES AND MISCIBILITY PRESSURES WERE INVESTIGATED. CASES WHERE THE DRIVING GAS CONTAINED LARGE AMOUNTS OF NITROGEN AND WHERE MISCIBILITY PRESSURES WERE LOW WERE ALSO EXAMINED FOR LPG SLUG FLOODING. MINIMUM MISCIBILITY PRESSURE INCREASED IN THE FORMER CASE, AND ONLY BY INJECTING AN ETHANE RICH BUFFER SLUG BETWEEN THE LPG AND THE DRIVING GAS COULD MISCIBILITY BE ACHIEVED IN THE LATTER.

FLUID COMPOSITIONS, RESERVOIR TEMPERATURE AND RESERVOIR PRESSURE WERE FACTORS THAT AFFECTED MISCIBILITY. THE PRIMARY MISCIBILITY CONTROL SHOULD BE THE PROPER SPECIFICATION OF THE SOLVENT AND THE DRIVING GAS COMPOSITION. CRITICAL PRESSURE LOCI AND TERNARY DIAGRAMS WERE OBTAINED FROM THE EXPERIMENTAL DATA. ALTHOUGH NEITHER OF THESE CAN ACCOUNT FOR THE PRESENCE OF MORE THAN 3 COMPONENTS, THEY STILL CAN BE USED FOR PRELIMINARY MISCIBILITY PREDICTIONS. THE CRITICAL LOCI CURVES GAVE ERRONEOUSLY OPTIMISTIC PREDICTIONS. BOTH THE BENEDICT-WEBB-RUBIN (BWR) EQUATION OF STATE AND THE BENHAM ET AL CORRECTION PREDICTED EXPERIMENTAL RESULTS SATISFACTORILY.

IT IS RECOMMENDED THAT THE BWR EQUATION OF STATE BE USED IN LPG MISCIBILITY PREDICTION. IN THE PRESENCE OF CO₂, THE BWR EQUATION WITH BINARY INTERACTION SHOULD BE USED. THE BENHAM ET AL CORRELATION IS ADEQUATE FOR MISCIBILITY PREDICTIONS IN ENRICHED GAS DRIVE.

COMMENTS:

----- THE BENEDICT-WEBB-RUBIN EQUATION OF STATE WAS FOUND TO BE SUPERIOR TO THE REDLICH-KWONG EQUATION OF STATE IN PREDICTING CONDITIONS FOR MISCIBILITY.

EXHIBITS:

----- 13 FIGURES, 6 TABLES

ADDITIONAL REFERENCES:

- 1. BENEDICT, WEBB, AND RUBIN: CHEM. ENG. PROG. (1951) V.47, 419.
2. BENEDICT, WEBB, AND RUBIN: CHEM. ENG. PROG. (1951) V.47, 449.
3. REDLICH AND KWONG: CHEM. REV. (1949) V.44, NO.1.
4. ZUDKEVITCH AND JOFFE: 64TH ANNUAL A.I.C.H.E. MEETING, NEW ORLEANS. (MARCH 16-20, 1969).
5. CHAO AND SEADER: A.I.C.H.E. J. (1961) V.7, 598.
6. HILDEBRAND AND SCOTT: SOLUBILITY OF NONELECTROLYTES (1950).

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.

KEYWORDS:

TERNARY SYSTEMS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
FIRST CONTACT MISCIBILITY
ENRICHED AND HIGH PRESSURE GAS

MULTICOMPONENT SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS
MULTIPLE CONTACT MISCIBILITY
LPG

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- S 26. ASANO, K., NAKAHARA, T. AND KOBAYASHI, R.: "K-VALUES AT ESSENTIALLY INFINITE DILUTION FOR CARBON DIOXIDE AND HYDROGEN SULFIDE IN THE METHANE - N-OCTANE SYSTEM AT LOW TEMPERATURES AND ELEVATED PRESSURES", J. CH. & ENG. DATA (1971) V.16, NO.1, 16-18.

ABSTRACT:

----- GAS-LIQUID PARTITION CHROMATOGRAPHY WAS USED TO DETERMINE THE INFINITE DILUTION EQUILIBRIUM RATIOS FOR CARBON DIOXIDE AND HYDROGEN SULFIDE IN THE METHANE-N-OCTANE SYSTEM AT TEMPERATURES FROM -40 TO +20 C (-40 TO +68 F) AND PRESSURES TO 1500 PSIA. CARBON DIOXIDE AND HYDROGEN SULFIDE SHOWED POSITIVE DEVIATIONS FROM RAULT'S LAW.

COMMENTS:

----- THIS PAPER IS OF MARGINAL INTEREST TO THE PETROLEUM INDUSTRY.

EXHIBITS:

----- 3 TABLES, 3 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES GENERAL PHASE BEHAVIOR
HYDROCARBON COMPONENTS TERNARY SYSTEMS
EQUILIBRIUM RATIOS CHROMATOGRAPHIC EFFECTS

S 27. EMMETT, W.R., BEAVER, K.W. AND MCCALED, J.A.: "LITTLE BUFFALO BASIN TENSLEEP HETEROGENEITY - ITS INFLUENCE ON DRILLING AND SECONDARY RECOVERY", J. PET. TECH. (FEB., 1971) 161-168.

ABSTRACT:

----- THE LITTLE BUFFALO BASIN FIELD, NORTHWESTERN WYOMING, WAS DISCOVERED IN 1943. THE FIELD ENCOMPASSES 1500 PRODUCTIVE SURFACE ACRES, AND CONTAINS FIVE RESERVOIRS. THE PENNSYLVANIAN TENSLEEP PRODUCES 20 API CRUDE, WITH A VISCOSITY THAT VARIES BETWEEN 42 CP AND 64 CP AT 128 F. THE RESERVOIR IS HIGHLY CROSS BEDDED AND HETEROGENEOUS.

THE PRIMARY RESERVOIR RECOVERY MECHANISM IS AN EDGE WATER DRIVE. DEVELOPMENT WAS COMPLETED IN 1958 ON 40 ACRE SPACING. PEAK PRODUCTION OF 6,500 BOPD WAS REACHED IN MID-1958. OWING TO THE VERY HIGH OIL-WATER VISCOSITY RATIO (60 TO 1), THE EXPECTED PRIMARY OIL RECOVERY BY NATURAL WATER DRIVE WAS ESTIMATED AT ONLY 14%. BETWEEN 1961 AND 1962, SEVENTEEN PERIPHERAL WELLS WERE CONVERTED TO GAS INJECTION. ESTIMATES OF THE PRODUCTION TREND DURING THE PERIOD FROM 1963 TO 1965 INDICATED THAT AN INCREMENTAL 10 MMBBL OF OIL (6% OOIP) WOULD BE RECOVERED BY GAS INJECTION. A ONE-WELL PILOT ALTERNATE GAS-WATER INJECTION WAS STARTED IN APRIL, 1966, AT A GAS-WATER INJECTION RATIO OF 1.6 TO 1. THE ULTIMATE RECOVERY FROM THE PILOT AREA WAS EXPECTED TO REACH 42% OF THE OIL IN PLACE. THE GAS-WATER INJECTION WAS EXPANDED TO THE SOUTH PERIPHERY OF THE TENSLEEP RESERVOIR IN NOVEMBER, 1966.

COMMENTS:

----- THIS PAPER INDICATES THAT ALTERNATE GAS AND WATER INJECTION IMPROVES THE DISPLACEMENT MOBILITY RATIO AND THEREBY YIELDS A BETTER RECOVERY, EVEN IN THE ABSENCE OF MISCIBILITY.

EXHIBITS:

----- 4 FIGURES, 1 TABLE

ADDITIONAL REFERENCES:

----- THOMAS: BULL. AAPG (NOV., 1965) V.49, 1867.

KEYWORDS:

SANDSTONE FIELD
FIELD TERTIARY RECOVERY
FIELD MOBILITY RATIO
OTHER FIELD INFORMATION

FIELD SECONDARY RECOVERY
FIELD IMMISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
GENERAL ECONOMICS

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- S 28. SARASHINA, E., ARAI, Y. AND SAITO, S.: "THE P-V-T-X RELATION FOR THE CARBON DIOXIDE - ARGON SYSTEM", J. CH. ENG. JAPAN, (1971) V.4, NO.4, 379-381.

ABSTRACT:

----- PRESSURE, VOLUME, AND COMPOSITIONS FOR THE CARBON DIOXIDE-ARGON SYSTEM WERE MEASURED AT 15 C (60 F) FOR PRESSURE TO 2200 PSI IN A GLASS CAPILLARY CELL. FROM THE DATA OBTAINED, FUGACITIES, PARTIAL MOLAR VOLUMES AND COMPRESSIBILITY FACTOR CHARTS WERE CONSTRUCTED. IT WAS FOUND THAT THERE IS A STRAIGHT-LINE RELATIONSHIP BETWEEN PRESSURE AND AVERAGE DENSITY OF COEXISTING LIQUID AND VAPOR PHASES.

COMMENTS:

----- THIS PAPER IS NOT RELEVANT TO THE PETROLEUM INDUSTRY.

EXHIBITS:

----- 3 TABLES, 5 FIGURES

KEYWORDS:

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS

EXPERIMENTAL PHYSICAL PROPERTIES
NON-HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE

S 29. WEST, J.: "LINE WILL MOVE 240 MMCFD OF CO2", OIL & GAS J.
(NOV. 8, 1971) 53-56.

ABSTRACT:

----- THIS ARTICLE DESCRIBES THE CONCEPTUAL
DESIGN, SYSTEM DESIGN, BID PROCEDURE, COMPRESSION REQUIREMENTS,
DEHYDRATION LIMITS, SYSTEM MONITORING, AND MATERIALS SELECTION
FOR THE PIPELINE FROM THE VAL VERDE BASIN TO SACROC. LINING
AND COATING FOR THE PIPE AND STARTUP PROVISIONS, AS WELL AS
INSPECTION GUIDELINES, ARE PRESENTED.

COMMENTS:

----- THIS IS A BASIC PAPER ON THE GAS TRANSMISSION
SYSTEM FOR SACROC, AND CONTAINS A CONSIDERABLE AMOUNT OF GOOD
INFORMATION.

EXHIBITS:

----- 1 TABLE, 2 FIGURES

KEYWORDS:

COMPRESSION
OTHER FIELD INFORMATION
CO2 SUPPLY

CORROSION
FACILITIES
CO2 SOURCE
TRANSPORTATION

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S 30. BALLARD, J.R. AND SMITH, L.R.: "RESERVOIR ENGINEERING DESIGN OF A LOW-PRESSURE RICH GAS MISCIBLE SLUG FLOOD". J. PET. TECH. (MAY, 1972) 599-605.

ABSTRACT:

----- IN GENERAL, RICH GAS MISCIBLE DISPLACEMENT IS APPLICABLE ONLY TO RESERVOIRS AT 1,400 PSI OR GREATER. HOWEVER, A RICH GAS DISPLACEMENT PROCESS HAD BEEN DESIGNED FOR A FIELD IN WEST TEXAS WITH AN AVERAGE PRESSURE OF 925 PSI AND TEMPERATURE OF 105 F. AS CONFIRMED IN THE LABORATORY, AN LPG-ENRICHED GAS MUST BE AT PRESSURES EXCEEDING 1300 PSI TO BE IN A SINGLE PHASE. THE MISCIBILITY PREDICTION BASED ON BENHAM CORRELATION ALSO SHOWED THAT THE LOWEST PRESSURE REQUIRED TO ACHIEVE MISCIBILITY WAS 1300 PSI. NEVERTHELESS, 1100 PSI WAS THE MAXIMUM ATTAINABLE OPERATING PRESSURE. THE DESIGN WAS THEREFORE FOCUSED ON A LIMITING 1100 PSI PRESSURE, USING A MIXTURE OF DEETHANIZER OVERHEAD (DEO) AND PROPANE.

THE LEVELLAND FIELD IS A HETEROGENEOUS LIMESTONE AT A DEPTH OF 4900 FEET. THE PAY SECTION CONTAINS 100 FEET OF NET PAY IN 250 FEET GROSS INTERVAL, WITH AN AVERAGE PERMEABILITY OF 2 MD. THE COEFFICIENT OF PERMEABILITY VARIATION IS 0.72. AT THE START OF THE MISCIBLE FLOOD, THE GAS SATURATION IN THE RESERVOIR WAS 10%.

A PHASE DIAGRAM OF PROPANE-DEO (7.5 TO 1) MIXTURE SHOWED THAT A SINGLE PHASE MIXTURE COULD BE ACHIEVED AT 1100 PSI AND ABOVE. IT WAS FOUND THAT APPROXIMATELY 43% PROPANE WOULD BE MISCIBLE WITH THE AVAILABLE PLANT RESIDUE GAS. EXPERIMENTAL MISCIBILITY FLOW TESTS WITH THE RESERVOIR OIL WERE CONDUCTED AS REPORTED BY YARBOROUGH AND SMITH (1970). BASED ON THE EXPERIMENTAL RESULTS ON 10 RUNS, THE LIMITS OF THE ENRICHED GAS COMPOSITION WERE SPECIFIED.

PERFORMANCE PREDICTIONS OF THE FLOOD WERE BASED ON A COMPUTER SIMULATION. THE MODEL WAS RADIAL WITH NO CROSS-FLOW BETWEEN LAYERS. BASED ON THE COMPUTER RESULTS, A 13% PV SLUG WAS CONSIDERED TO BE OPTIMAL AND SIGNIFICANT ADDITIONAL OIL RECOVERY COULD BE EXPECTED BY MISCIBLE FLOODING OVER WATERFLOODING. THE INCREMENTAL RECOVERY WAS EXPECTED FAIRLY EARLY IN THE LIFE OF THE PROJECT.

COMMENTS:

----- THIS PAPER DEMONSTRATES THAT MISCIBILITY CAN BE ACHIEVED BELOW NORMAL MINIMUM MISCIBILITY PRESSURES BY MIXING THE SOLVENT WITH SPECIAL FLUIDS. THIS MAY BE USEFUL WHERE THE RESERVOIR OR FACILITIES LIMIT INJECTION PRESSURES.

EXHIBITS:

----- 5 TABLES, 8 FIGURES SUMMARIZING LABORATORY AND SIMULATION RESULTS.

ADDITIONAL REFERENCES:

----- HALL AND GEFFEN: TRANS., AIME (1957) V.210, 48-57.

CROSS REFERENCES:

27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 7. HUTCHINSON, BRAUN: A.I.C.H.E. J. (1961) 64.
S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.

KEYWORDS:

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FIELD SECONDARY RECOVERY	CARBONATE FIELD
ADDITIVES (FIELD)	FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION	OPERATIONS
OTHER MODELLING	BUCKLEY-LEVERETT MODELLING
	ENRICHED AND HIGH PRESSURE GAS

- S 31. BUCHWALD, R.W., HARDY, W.C. AND NEIMAST, G.S.: "CASE HISTORIES OF IMPROVED RECOVERY PROJECTS", PAPER 3781, SPE-AIME IMPROVED OIL RECOVERY SYMP., TULSA, OK. (APR., 1972).

ABSTRACT:

----- THE STATUS AND EXPECTATIONS OF TWO MISCIBLE DISPLACEMENT AND THREE IN-SITU COMBUSTION PROJECTS ARE DISCUSSED. EACH FIELD REQUIRED COMPLETE RESERVOIR AND SATURATION DISTRIBUTION DEFINITION FOR SUCCESSFUL PLANNING AND OPERATION. GRAVITY AND MOBILITY FORCES DOMINATED THE MISCIBLE FLOODS. THESE MUST BE ADEQUATELY CONTROLLED TO ACHIEVE REASONABLE VERTICAL CONFORMANCE IN LOW-DIP RESERVOIRS.

THE HOLT D SAND RESERVOIR IN THE BASKINTON FIELD PRODUCED 525 MMBL OF OIL, 275 MMCF OF GAS AND 6 MMBL OF WATER BETWEEN MID-1956 AND JANUARY, 1962. DURING THIS TIME, RESERVOIR PRESSURE DECLINED 150 PSI FROM THE ORIGINAL 1,802 PSIG. A 210 MMBL PROPANE SLUG WAS INJECTED TO INITIATE A MISCIBLE FLOOD; THE SLUG WAS DRIVEN BY GAS. 960 MMBL OF OIL WERE PRODUCED BETWEEN APRIL, 1962 AND JULY, 1967 WITH A RESERVOIR PRESSURE DECLINE OF ONLY 20 PSI. WATER INJECTION IN A DOWNDIP WELL REPLACED GAS INJECTION AS A METHOD OF PRESSURE MAINTENANCE IN SEP., 1968. THIS TURNAROUND WAS CHOSEN AFTER A RESERVOIR STUDY INDICATED CONTINUATION OF THE MISCIBLE DRIVE MIGHT TRAP CONSIDERABLE OIL. THE PROPANE SLUG REMAINED HORIZONTAL AS INDICATED BY AN OBSERVATION WELL. AT THE TIME OF THIS PAPER, 45% OF THE OIL IN PLACE HAD BEEN RECOVERED.

BOAGNI RESERVOIR WAS DISCOVERED IN JUNE, 1944 BY SUN OIL CO. ITS ORIGINAL PRESSURE WAS 4,550 PSI AT 9600 FEET; WATER INJECTION WAS STARTED IN 1950. THE TOTAL RECOVERY BY PRIMARY AND PRESSURE MAINTENANCE OPERATIONS WAS ESTIMATED TO BE 3.5 MMBL OF OIL AND 3.4 BCF OF GAS. THIS AMOUNTS TO 60% OF THE OIL AND GAS ORIGINALLY IN PLACE. PROPANE INJECTION STARTED IN 1963, FOLLOWED BY GAS AND THEN WATER. THE PROJECT WAS NOT PARTICULARLY SUCCESSFUL. CHANNELING RESULTED IN EARLY PROPANE AND GAS BREAKTHROUGH. ALTHOUGH SIGNIFICANT INCREASES IN OIL RATE WERE NOTICED IN SOME WELLS. THERE WAS NO EVIDENCE OF ANY OIL BANK. ONLY 190 MMBL OF OIL COULD BE ATTRIBUTED TO THE TERTIARY PROCESS UPON TERMINATION OF THE PROJECT. DETAILS OF IN-SITU COMBUSTION PROJECTS IN THREE TEXAS OIL FIELDS ARE ALSO PRESENTED.

COMMENTS:

- 1. DETAILS OF THE BASKINTON FIELD PROPANE SLUG MISCIBLE PROJECT WERE PRESENTED BY LAUE, ET.AL.
2. ALTHOUGH THE BASKINTON FIELD WAS MORE SUCCESSFUL THAN THE BOAGNI FIELD, THE MISCIBILITY CONTROL PROGRAM WAS NOT PERFECT. DOWNDIP WATER INJECTION WAS NOT ORIGINALLY PLANNED, AND CAME ABOUT IN TRYING TO RECOVER BYPASSED OIL.
3. THE CHANNELING THAT REPORTEDLY CAUSED THE FAILURE OF THE BOAGNI PROJECT IS A RESULT OF POOR MISCIBILITY CONTROL.

EXHIBITS:

----- 3 TABLES, 19 FIGURES

ADDITIONAL REFERENCES:

- 1. LAUE, TEUBNER, AND CAMPBELL:
J. PET. TECH. (JUN., 1965) 661-663.
2. CLARK, ANDREEN AND WESSELY: PET. ENGR. (SEP., 1957) 321-326.
3. LEE: TRANS., AIME (1948) V.174, 41-66.

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.

KEYWORDS:

SANDSTONE FIELD
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD MOBILITY RATIO
OTHER FIELD INFORMATION

WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD IMMISCIBLE APPLICATION
MOBILITY CONTROL
LPG

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S 32. CONNALLY, C.A., JR.: "TERTIARY MISCIBLE FLOOD IN PHEGLEY UNIT, WASHINGTON COUNTY, COLORADO", PAPER 3775, SPE-AIME IMPROVED OIL RECOVERY SYMP., TULSA, OK. (APR., 1972).

ABSTRACT:

----- A SLUG OF LPG FOLLOWED BY SLUGS OF NATURAL GAS ALTERNATED WITH WATER AND FINALLY DRIVEN BY FURTHER WATER INJECTION WAS USED IN A MISCIBLE DISPLACEMENT SCHEME FOR TERTIARY RECOVERY IN THE MUDDY D SAND RESERVOIR, PHEGLEY UNIT, COLORADO. THE TERTIARY PROJECT WAS APPLIED FULL-SCALE TO THE SMALL (9.6 MM BBL PV) RESERVOIR AT A TIME WHEN A SUCCESSFUL WATERFLOOD WAS APPROACHING COMPLETION. AN ADDITIONAL BANK OF OIL WAS PRODUCED BUT THE OIL RATE DECLINED RAPIDLY WITH PREMATURE GAS BREAKTHROUGH. IT WAS CONCLUDED THAT THE VOLUMETRIC SWEEP WITH THE MISCIBLE FLUID WAS RELATIVELY INEFFICIENT BECAUSE OF AN UNFAVORABLE MOBILITY RATIO. ALSO, IT WAS POSSIBLE THAT A SIGNIFICANT PORTION OF THE OIL BANKED-UP WITHIN THE RESERVOIR WAS BYPASSED AFTER BREAKTHROUGH OF GAS AT THE PRODUCTION WELLS.

COMMENTS:

----- THIS PAPER CONTAINS WATERFLOOD DATA IN ADDITION TO DATA FOR THE TERTIARY MISCIBLE FLOOD.

EXHIBITS:

----- 2 TABLES AND 4 FIGURES, DEPICTING RESERVOIR CHARACTERISTICS, GEOLOGY AND PRODUCTION HISTORY.

KEYWORDS:

WATER INJECTION

FIELD TERTIARY RECOVERY

FIELD MOBILITY RATIO

FIELD RESIDUAL SATURATIONS

SANDSTONE FIELD

FIELD SECONDARY RECOVERY

FIELD MISCIBLE APPLICATION

FIELD AREAL SWEEP

LPG

S 33. DESBRISAY, C.L. AND DANIEL, E.L.: "SUPPLEMENTAL RECOVERY DEVELOPMENT OF THE INTISAR 'A' AND 'D' REEF FIELDS, LIBYAN ARAB REPUBLIC", J. PET. TECH. (JULY, 1972) 785-796.

ABSTRACT:

----- ENHANCED RECOVERY PROCESSES STARTED EARLY IN THE PRODUCING LIFE OF THE INTISAR "A" AND "D" FIELDS LOCATED IN THE SIRTE BASIN IN THE EAST-CENTRAL PART OF THE LIBYAN ARAB REPUBLIC. BOTTOM WATER INJECTION AT A PEAK RATE OF ABOUT 500 MBPD MAINTAINED RESERVOIR PRESSURE AT 2700 PSIG IN THE INTISAR "A" FIELD. THE INTISAR "D" FIELD WAS UNDER A COMBINATION MISCIBLE GAS-WATER DISPLACEMENT PROGRAM. THE RESERVOIR PRESSURE IN THE "D" FIELD WAS MAINTAINED AT ABOUT 3800 PSIG TO ENSURE GAS MISCIBILITY IN OIL. PERFORMANCE OF BOTH FIELDS WAS IN GOOD AGREEMENT WITH MODELS, AND A COMBINED RECOVERY EFFICIENCY ABOVE 60% WAS EXPECTED.

BOTH FIELDS WERE DISCOVERED IN 1967. THE RESERVOIRS ARE CARBONATE ROCKS OF PALEOCENE AGE, AND HAVE A GROSS PAY THICKNESS OF ABOUT 1200 FEET. THE POROSITY OF BOTH FIELDS IS ABOUT 20%, BUT THE PERMEABILITY OF THE "D" FIELD IS 90 MD WHILE THE "A" FIELD IS BOTH RESERVOIRS WERE INITIALLY UNDERSATURATED.

PRIMARY RECOVERY IN THE "A" FIELD WAS ESTIMATED TO BE 28% OOIP IT WAS PREDICTED THAT RECOVERY WITH WATER INJECTION WOULD BE 46% AT 80% SWEEP. THE FIELD WAS PLACED ON PRODUCTION IN FEBRUARY, 1968. WATER INJECTION STARTED IN JULY OF 1968, AND BY THE END OF 1970, 347 MMBSL OF WATER HAD BEEN INJECTED AND 328 MMBSL OF OIL HAD BEEN PRODUCED. THE "D" FIELD WAS PLACED ON PRODUCTION IN OCTOBER, 1968. WATER INJECTION STARTED ONE MONTH LATER, AND CRESTAL GAS INJECTION FOR MISCIBLE DISPLACEMENT STARTED IN DECEMBER, 1969. IT WAS ESTIMATED THAT PRIMARY DEPLETION WOULD RECOVER LESS THAN 8% OOIP, AND THAT WATERFLOOD RECOVERY WOULD BE ABOUT 40%. MODEL PREDICTION SHOWED THAT AS MUCH AS 80% RECOVERY MIGHT BE ACHIEVED WITH THE MISCIBLE PROCESS.

GAS COMPOSITION AND MISCIBILITY CONDITIONS WERE ROUGHLY DETERMINED BY THE CORRELATIONS OF BENHAM ET AL. A GAS WITH 68 MOLE PER CENT METHANE PLUS ENOUGH HEAVIER COMPONENTS TO PROVIDE A C2+ MOLECULAR WEIGHT OF 44 WAS SELECTED. THE MISCIBILITY PRESSURE WAS ESTIMATED TO BE 3800 PSIG. LABORATORY TESTS CONFIRMED THAT MISCIBILITY COULD BE ACHIEVED BETWEEN 3500 AND 4000 PSIG. NUMERICAL SIMULATION WITH A COMPOSITIONAL MODEL SHOWED MISCIBILITY COULD BE OBTAINED WITH 66% METHANE, BUT THAT AT 75% METHANE IMMISCIBLE DISPLACEMENT WOULD OCCUR. THE MODEL ALSO SHOWED THAT THE ULTIMATE RECOVERY WOULD BE INSENSITIVE TO THE WITHDRAWAL RATE OWING TO HIGH PERMEABILITY IN THE "D" FIELD.

COMMENTS:

----- THE 'D' FIELD IS AN EXAMPLE OF A SUCCESSFUL APPLICATION OF MISCIBLE PROCESSES TO A HIGH PERMEABILITY CARBONATE RESERVOIR.

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EXHIBITS:

----- 3 TABLES, 10 FIGURES, SHOWING GEOLOGIC AND RESERVOIR
SETTING AND SIMULATED AND ACTUAL FIELD PERFORMANCE.

ADDITIONAL REFERENCES:

- 1. DESBRISAY AND CROSBY: PET. ENG.
(FEB., 1970) 45-48.
2. COFFEY: PET. ENG. (JUNE, 1971) 40-43.
3. LANTZ: SOC. PET. ENG. J. (JUNE, 1970) 192-202.
4. BOYD: WORLD OIL (JAN., 1972) 51-54.

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
FIELD RESIDUAL SATURATIONS
FINITE DIFFERENCE MODELS
COMPARISONS WITH FIELD RESULTS
CARBONATE FIELD
FIELD SECONDARY RECOVERY
FIELD AREAL SWEEP
OPERATIONS
COMPOSITIONAL MODELS
ENRICHED AND HIGH PRESSURE GAS

S 34. HOLM, L.W.: "PROPANE-GAS-WATER MISCIBLE FLUIDS IN WATERED-OUT AREA OF THE ADENA FIELD, COLORADO", PAPER 3774, SPE-AIME IMPROVED OIL RECOVERY SYMP., TULSA, OK. (APR., 1972).

ABSTRACT:

----- TWO FIELD TESTS OF MISCIBLE DISPLACEMENT PROCESSES WERE CARRIED OUT IN 40 ACRE AREAS OF THE ADENA FIELD. THE AREAS WERE PREVIOUSLY LINE-DRIVE WATERFLOODED, LEAVING 30% RESIDUAL OIL SATURATION. BOTH TESTS INVOLVED INJECTING A SLUG OF PROPANE, FOLLOWED BY A SLUG OF GAS, AND DRIVEN FINALLY BY WATER. IN THE SECOND TEST, THE GAS INJECTION WAS ALTERNATED WITH WATER.

SOLUBILITY DATA SHOWED THAT MISCIBILITY COULD BE ACHIEVED AT 1000 PSI AT THE RESERVOIR TEMPERATURE OF 180 F. AN IMMEDIATE RESPONSE TO THE MISCIBLE PROCESS WAS OBSERVED. ONE WELL IN THE FIRST TEST INCREASED IN PRODUCTION FROM 20 TO 347 BOPD WITHIN TWO MONTHS. 30 MMBL (15% PV) OF PROPANE HAD BEEN INJECTED AT THE TIME OF PROPANE BREAKTHROUGH. OVERALL, ON THE FIRST TEST, 105 MMBL OF PROPANE WERE INJECTED, AND 50 MMBL OF OIL AND 77 MMBL OF PROPANE WERE RECOVERED. A 50 MMBL (5% PV) SLUG OF PROPANE AND ALTERNATE SLUGS COMPRISING A TOTAL OF 168 MMCF OF GAS (30% PV) AND 40 MMBL (4.7% PV) OF WATER WERE INJECTED IN THE SECOND FIELD TEST; ADDITIONAL WATER WAS USED AS A DRIVE FLUID. THERE WERE NO INDICATIONS OF PROPANE CHANNELING DURING THE PROPANE INJECTION. ABOUT 50% OF THE GAS INJECTED WAS LOST BY CHANNELING OUT OF THE PILOT AREA, AND 30 MMBL PROPANE WAS LEFT AS A RESIDUAL HYDROCARBON PHASE. ONE WELL IN THIS FIELD PEAKED AT 106 BOPD AND PRODUCED A TOTAL OF 25,200 BBL OF STOCK-TANK OIL. WOR DECREASED IN THIS WELL FROM 50 TO 8. INCREMENTAL OIL PRODUCTION IN ANOTHER WELL WAS 3600 BBL. YET ANOTHER WELL INCREASED PRODUCTION FROM 5 TO 25 BOPD FOLLOWING THE MISCIBLE PROCESS.

ALTHOUGH PROPANE MOBILIZED THE RESIDUAL OIL CONTACTED, CHANNELING AFFECTED THE OVERALL PERFORMANCE OF THE PROCESS. THE CHANNELING WAS INITIATED BY UNFAVORABLE MOBILITY RATIO AND ACCENTUATED BY THE EXISTING WATERFLOOD WHICH PREVENTED THE SPREADING OF THE FLUID. THE ECONOMICS OF THE PROCESS WERE ALSO POORLY AFFECTED BY THE AMOUNT OF THE UNRECOVERED PROPANE.

COMMENTS:

----- ALTHOUGH A SUBSTANTIAL AMOUNT OF PROPANE (0.5 BBL OF PROPANE PER BBL OF OIL RECOVERED) WAS LOST AS RESIDUAL, THE PROJECT WAS SAID TO BE PROFITABLE.

EXHIBITS:

----- 5 TABLES, 9 FIGURES SHOWING ACTUAL PRODUCTION AND GEOLOGIC DATA.

ADDITIONAL REFERENCES:

- 1. WEYLER AND SAYRE:
J. PET. TECH. (AUG., 1959) 13.
2. HALL AND GEFFEN: J. PET. TECH. (FEB., 1957) 48.

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CROSS REFERENCES:

31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
OTHER FIELD INFORMATION

SANDSTONE FIELD
FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
FIELD RESIDUAL SATURATIONS
LPG

S 35. PERRYMAN, T.L.: "WORKOVERS: KEY TO SACROC RESERVOIR CONTROL",
PET. ENG. (FEB., 1972) 35-38.

ABSTRACT:

----- THIS PAPER DETAILS THE WORKOVER PROGRAM FOR SACROC
PRIOR TO CO2 INJECTION. THE SACROC UNIT HAS 1250 WELLS AND WAS
OPERATED UNDER A CENTERLINE WATER INJECTION PROGRAM SINCE 1954.
THE WATER FRONT IN MANY AREAS OF THE RESERVOIR HAD ADVANCED A
CONSIDERABLE DISTANCE FROM THE INJECTION WELLS, RESULTING IN
INCREASED INJECTION PRESSURES AND DIFFICULTY IN TRANSMITTING
PRESSURE TO AREAS AHEAD OF THE FLOOD FRONT. TO MINIMIZE
PRESSURE LOSSES, THE EXTENSIVE WORKOVER PROGRAM WAS PLANNED.

A TOTAL OF 561 WELLS WERE WORKED ON, THE MOST COMMON PRACTICE
BEING DEEPENING AND/OR PERFORATING. OTHER WELLS REQUIRED
STIMULATION, WITH A TYPICAL JOB USING 25 GAL OF 28% HCL ACID PER
POROSITY FOOT. APPROXIMATELY 120 WELLS WERE CONVERTED FOR WATER
OR CO2 INJECTION. ABOUT 50 WELLS REQUIRED CASING LEAK REPAIRS.

COMMENTS:

----- THE KEY PURPOSE BEHIND THE WORKOVER PROGRAM AT
SACROC WAS TO BE ABLE TO MEET INCREASED MARKET DEMAND FACTORS AND
MAXIMUM EFFICIENT RATES.

EXHIBITS:

----- 1 TABLE, 6 FIGURES

KEYWORDS:

CORROSION
OPERATIONS

FACILITIES
OTHER FIELD INFORMATION

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S 36. BESSERER, G.J. AND ROBINSON, D.B.: "EQUILIBRIUM-PHASE PROPERTIES OF I-BUTANE - CARBON DIOXIDE SYSTEM", J. CH. & ENG. DATA (1973) V.18, NO.3, 298-301.

ABSTRACT:

----- VAPOR AND LIQUID EQUILIBRIUM-PHASE COMPOSITIONS AND REFRACTIVE INDICES WERE DETERMINED FOR THE I-BUTANE-CARBON DIOXIDE SYSTEM AT 100, 160, 220, AND 250 F FROM THE VAPOR PRESSURE OF I-BUTANE TO PRESSURES IN THE CRITICAL REGION. THE EQUILIBRIUM RATIOS FOR EACH COMPONENT WERE CALCULATED AT EACH TEMPERATURE FROM THE PHASE COMPOSITION DATA. THE EQUILIBRIUM-PHASE DENSITIES WERE CALCULATED FROM THE MEASURED PHASE COMPOSITION AND REFRACTIVE INDEX DATA BY USE OF THE LORENTZ-LORENZ MOLAR REFRACTIVITY RELATIONSHIP.

COMMENTS:

----- SIMILAR DATA FOR THE N-PENTANE-CARBON DIOXIDE SYSTEM ARE PRESENTED IN BESSERER AND ROBINSON (1973 B).

EXHIBITS:

----- 1 TABLE, 4 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
DENSITY

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
REFRACTIVE INDEX

- S 37. BESSERER, G.J. AND ROBINSON, D.B.: "EQUILIBRIUM-PHASE PROPERTIES OF N-PENTANE - CARBON DIOXIDE SYSTEM", J. CH. & ENG. DATA (1973) V.18, NO.4, 416-419.

ABSTRACT:

----- VAPOR LIQUID EQUILIBRIUM-PHASE COMPOSITIONS AND REFRACTIVE INDICES WERE DETERMINED FOR THE N-PENTANE-CARBON DIOXIDE SYSTEM AT 40, 100, 160, AND 220 F FROM THE VAPOR PRESSURE OF I-BUTANE TO PRESSURES IN THE CRITICAL REGION. THE EQUILIBRIUM RATIOS FOR EACH COMPONENT WERE CALCULATED AT EACH TEMPERATURE FROM THE PHASE COMPOSITION DATA. THE EQUILIBRIUM-PHASE DENSITIES WERE CALCULATED FROM THE MEASURED PHASE COMPOSITION AND REFRACTIVE INDEX DATA BY USE OF THE LORENTZ-LORENZ MOLAR REFRACTIVITY RELATIONSHIP.

COMMENTS:

----- SIMILAR DATA FOR THE I-BUTANE-CARBON DIOXIDE SYSTEM ARE PRESENTED IN BESSERER AND ROBINSON (1973A).

EXHIBITS:

----- 2 TABLES, 5 FIGURES

ADDITIONAL REFERENCES:

----- POETTMANN AND KATZ: IND. & ENG. CH. (1945) V.37, NO.9, 947.

CROSS REFERENCES:

S. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
BINARY SYSTEMS

HYDROCARBON COMPONENTS
REFRACTIVE INDEX

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- S 38. HUIE, N.C., LUKS, K.D. AND KOHN, J.P.: "PHASE-EQUILIBRIUM BEHAVIOR FOR SYSTEMS CARBON DIOXIDE - N-EICOSANE AND CARBON DIOXIDE - N-DECANE - N-EICOSANE", J. CH. & ENG. DATA (1973) V.18, NO.3, 311-313.

ABSTRACT:

----- PHASE-EQUILIBRIUM BEHAVIOR OF THE BINARY MIXTURE CO₂-N-EICOSANE WAS STUDIED FOR VAPOR-LIQUID, SOLID-LIQUID-VAPOR, AND LIQUID-LIQUID-VAPOR SYSTEMS. THE TERNARY SYSTEM CO₂-N-DECANE-N-EICOSANE WAS STUDIED FOR THE LIQUID-LIQUID-VAPOR SYSTEM IN THE TEMPERATURE RANGE OF 37 TO 100 C (100 TO 212 F), AND CO₂-FREE SELECTIVITIES BETWEEN THE LIQUID PHASES ARE PRESENTED.

COMMENTS:

----- THIS PAPER IS AN INVESTIGATION FOR THE USE OF CO₂ AS A SELECTIVE LIQUID SOLVENT, AND HAS LITTLE APPLICATION TO THE PETROLEUM INDUSTRY, ALTHOUGH IT MAY BE USEFUL FOR THE CHEMICAL INDUSTRY.

EXHIBITS:

----- 7 TABLES

CROSS REFERENCES:

- 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).

KEYWORDS:

CORRELATIONS
HYDROCARBON COMPONENTS
TERNARY SYSTEMS
OTHER PHYSICAL PROPERTIES
EXPERIMENTAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
LAB. PROCEDURES AND APPARATUS

- S 39. METCALFE, R.S., FUSSELL, D.D. AND SHELTON, J.L.:
"A MULTICELL EQUILIBRIUM SEPARATION MODEL FOR THE STUDY OF
MULTIPLE CONTACT MISCIBILITY IN RICH GAS DRIVE",
SOC. PET. ENG. J. (JUNE, 1973) 147-155.

ABSTRACT:

----- THIS PAPER DISCUSSES A MULTI-CELL EQUILIBRIUM FLASH
SEPARATION MODEL DEVELOPED TO STUDY THE EFFECTS OF FLUID FLOW AND
FLUID PROPERTIES ON MISCIBILITY. THE MODEL CAN PREDICT NECESSARY
COMPOSITION FOR MISCIBILITY IN A LINEAR SYSTEM, AND COMPUTE
COMPOSITIONAL CHANGES OCCURRING IN THE TRANSITION ZONE AND EFFLUENT
VOLUMES AND COMPOSITIONS.

MODEL PREDICTIONS WITH DIFFERENT TYPES OF FLUID COMPOSITIONS
WERE COMPARED WITH THE CORRELATION OF BENHAM ET AL. THE MODEL
SHOWED THAT THE BENHAM CORRELATION IS GENERALLY CONSERVATIVE, BUT
ACCEPTABLY ACCURATE, IN PREDICTING MINIMUM ENRICHMENT COMPOSITION.
HOWEVER, BENHAM'S CORRELATION IS NOT ALWAYS CONSERVATIVE AND
DEPENDING ON THE LOCATION OF THE CRITICAL POINT, MORE ENRICHMENT
MAY BE REQUIRED FOR MISCIBILITY THEN PREDICTED BY THE CORRELATION.

THE MODEL IS AN EXTENSION OF THE WORK OF COOK ET AL. IT
CONSISTS OF A NUMBER OF CONSTANT-TEMPERATURE, CONSTANT-PRESSURE
CELLS IN SERIES. THE FIRST INJECTION OF ABOUT 20% OF THE CELL
VOLUME WOULD BE TO CELL #1. THIS WOULD BE FLASHED TO OBTAIN THE
RESULTING LIQUID AND GAS COMPOSITION. THE FLUID SUBSEQUENTLY HAD
THREE OPTIONS TO MOVE TO THE NEXT CELL, WHILE MORE INJECTION WAS
MADE TO CELL #1. THE OPTIONS FOR MOVING FLUID FROM CELL TO CELL
ARE:

1. STAGNANT OIL: ALL OIL REMAINED IN THE CELL WHILE ALL GAS
MOVED TO THE NEXT CELL. CELL VOLUME IN THIS CASE WAS NOT CONSTANT.
2. CONSTANT CELL VOLUME: EXCESS OIL VOLUME AND ALL THE GAS
VOLUME WERE MOVED TO THE NEXT CELL.
3. PHASE MOBILITY CONCEPT: THIS WAS THE MOST REALISTIC AS
A RESERVOIR PROCESS. THE FLUID FLOW WAS DETERMINED BY THE PHASE
MOBILITY. A FIXED CELL VOLUME WAS MAINTAINED, AND THE RATIO OF
GAS TO LIQUID MOVED WAS THE RATIO OF THE MOBILITIES.

THE PHASE EQUILIBRIUM DATA ARE BASED ON AMOCO'S MODIFIED
REDLICH-KWONG EQUATION OF STATE REPORTED BY ZUDKEVITCH & JOFFE AND
FUSSEL & YARBOROUGH.

IT WAS CONCLUDED THAT PHASE MOBILITY THROUGH RELATIVE
PERMEABILITY AND PVT PROPERTIES HAD A SIGNIFICANT EFFECT ON THE
DEVELOPMENT OF MISCIBILITY AND THAT SUCH A MODEL WOULD BE A USEFUL
GUIDE FOR LABORATORY TESTS IN OBTAINING THE MINIMUM INTERMEDIATE
HYDROCARBON COMPOSITION IN A RICH-GAS INJECTION PROCESS.

COMMENTS:

----- THE AMOCO CELL-TO-CELL COMPOSITIONAL MODEL COMPARES
FAVORABLY WITH THE BENHAM CORRELATION FOR MOST CASES. IT IS
NOTEWORTHY THAT THE MODEL SHOWED THAT MORE ENRICHMENT MIGHT BE

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REQUIRED THAN PREDICTED BY THE BENHAM CORRELATION FOR SYSTEMS WHOSE CRITICAL POINTS ARE IN CERTAIN LOCATIONS OF THE TERNARY DIAGRAM, BUT THESE SYSTEMS ARE SELDOM ENCOUNTERED IN PRACTICE.

EXHIBITS:

----- 3 TABLES, 12 FIGURES

ADDITIONAL REFERENCES:

- 1. ZUDKEVITCH AND JOFFE: A.I.CH.E. J. (1970) V.16, NO.1.
2. FUSSEL AND YARBOROUGH: SOC. PET. ENG. J. (APR., 1972) 96-102

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.

KEYWORDS:

THEORETICAL PHYSICAL PROPERTIES
TERNARY SYSTEMS
EQUATIONS OF STATE
EFFECTS OF TEMPERATURE
MULTIPLE CONTACT MISCIBILITY

CORRELATIONS
MULTICOMPONENT SYSTEMS
EFFECTS OF PRESSURE
EQUILIBRIUM RATIOS
ENRICHED AND HIGH PRESSURE GAS

S 40. NOLEN, J.S.: "NUMERICAL SIMULATION OF COMPOSITIONAL PHENOMENA IN PETROLEUM RESERVOIRS"; PAPER 4274, SPE-AIME 3RD SYMP. ON NUM. SIMULATION OF RESERVOIR PERFORMANCE, HOUSTON, TX. (JAN., 1973).

ABSTRACT:

----- THIS PAPER PRESENTS A NUMERICAL COMPOSITIONAL MODEL THAT MIGHT BE USED FOR SIMULATION OF MISCIBLE PROCESSES. NUMERICAL DISPERSION WAS ELIMINATED WITHOUT INCREASING THE AVERAGE COMPUTER TIME. THE AUTHOR SUGGESTS THAT FOR CONSISTENCY, THE DENSITIES AND VISCOSITIES OF BOTH OIL AND GAS PHASES SHOULD BE BASED ON THE SAME CORRELATION, AND THE K-VALUE SHOULD APPROACH UNITY AS THE PRESSURE APPROACHES CONVERGENCE PRESSURE. THIS ENSURES THAT THE COMPOSITION OF GAS AND LIQUID ARE THE SAME AT THE CRITICAL POINT. THE K-VALUES CAN BE CALCULATED BY THE SAME EQUATION OF STATE FOR CALCULATING DENSITIES, BUT THIS UNDULY INCREASES COMPUTATION TIME AND EXPENSES; IT IS SIMPLER TO USE SEPARATE CORRELATIONS FOR K FACTORS.

THE MODIFICATION OF THE REDLICH-KWONG EQUATION OF STATE BY LEE AND EDMISTER WAS FOUND ACCURATE IN PREDICTING BOTH OIL AND GAS DENSITIES UNDER RESERVOIR CONDITIONS. THE PHASE BEHAVIOR DATA WERE FITTED BY USING THE MACDONALD K-VALUE CORRELATION. THE PROBLEM OF NUMERICAL DISPERSION DUE TO SPATIAL AND TIME TRUNCATION ERROR IN THE SOLUTION OF THE FINITE DIFFERENCE EQUATIONS WAS ELIMINATED USING THE METHOD OF CHARACTERISTICS (GARDNER ET AL, 1964). THIS METHOD WAS FOUND TO BE THE MOST PRACTICAL APPROACH.

COMMENTS:

----- THIS PAPER IS A FUNDAMENTAL ONE ON NUMERICAL SIMULATION OF COMPOSITIONAL PHENOMENA. IT CONCENTRATES ON CONCEPTS RATHER THAN MATHEMATICAL FORMULATION.

EXHIBITS:

----- 10 FIGURES, 3 TABLES

ADDITIONAL REFERENCES:

- 1. LEE AND EDMISTER:
IND. & ENG. CHEM. FUND. (1971) V.10.
2. MCDONALD: REPORT UT-71-A TX. PET. RES. COMM. (1971).
3. GARDNER, PEACEMAN, AND POZZI: SOC. PET. ENG. J. (1964) 26-36
4. LOHRENZ, CLARK, AND FRANCIS: J. PET. TECH. (1963)
1233-1238.

KEYWORDS:

COMPOSITIONAL MODELS

FINITE DIFFERENCE MODELS
COMPARISONS WITH LAB. RESULTS

S 41. HARVEY, M.T., JR., SHELTON, J.L. AND KELM, C.H.:
"FIELD INJECTIVITY EXPERIENCES WITH MISCIBLE RECOVERY
PROJECTS USING ALTERNATE RICH GAS AND WATER INJECTION",
PAPER 4738, SPE-AIME IMPROVED OIL RECOVERY SYMP., TULSA, OK.
(APR., 1974).

ABSTRACT:

----- FOUR FIELD EXAMPLES OF MISCIBLE DISPLACEMENT PROCESS
ARE PRESENTED. WATER INJECTIVITY IN ONE OF THE FIELDS WAS REDUCED
DRASTICALLY AFTER THE FIRST CYCLE OF RICH GAS INJECTION. LABORATORY
TESTS CARRIED OUT ON CORES FROM THIS FIELD SHOWED UNUSUALLY HIGH
TRAPPED GAS SATURATION WHICH DECREASED THE RELATIVE PERMEABILITY
TO WATER. ALTHOUGH NO SPECIFIC CAUSE OR REMEDY HAS BEEN ESTABLISHED
IT IS SUSPECTED THAT A UNIQUE RESERVOIR AND/OR FLUID CHARACTERISTIC
COMBINATION WAS RESPONSIBLE. AS A RESULT, IT MIGHT BE DESIRABLE
TO CARRY OUT A SINGLE WELL INJECTION RATE TEST, UNDER ANY PROPOSED
FIELD INJECTION PROCEDURE, BEFORE A FULL-SCALE FIELD EXPANSION IS
UNDERTAKEN.

THE AVERAGE WATER INJECTION RATE PRIOR TO THE RICH GAS
INJECTION WAS 320 B/D IN THE ANOMALOUS FIELD. THIS DROPPED TO
125 B/D DURING THE FIRST CYCLE WATER INJECTION. PRESSURE FALL-OFF
TESTS CONDUCTED DID NOT DISCLOSE ANY SKIN DAMAGE, BUT THE
TRANSMISCIBILITY FOR THE FIELD DROPPED FROM 56 MD-FT/CP TO 22
MD-FT/CP BETWEEN PRE-RICH GAS WATER AND THE FIRST CYCLE WATER
INJECTION. ATTEMPTED REMEDIAL ACTIONS INCLUDED HYDROCARBON
CLEAN-UP BY XYLENE INJECTION, TRAPPED GAS ELIMINATION BY CO₂
INJECTION, LEASE CRUDE INJECTION AND ACID TREATMENT. NONE OF
THESE RESTORED THE WATER INJECTIVITY. ALTHOUGH THE OTHER FIELDS
ARE SIMILAR IN MANY WAYS, THEY DID NOT INDICATE ANY LOSS OF WATER
INJECTIVITY DURING THE MISCIBLE DISPLACEMENT PROCESS.

COMMENTS:

----- THE PROBLEM FIELD DISCUSSED IN THIS PAPER IS ALSO
DISCUSSED BY BALLARD AND SMITH (1972).

EXHIBITS:

----- 2 TABLES, 1 FIGURE DEPICTING RESERVOIR SIMILARITIES
AND RESPONSE ANOMALIES.

CROSS REFERENCES:

28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 29
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

CARBONATE FIELD
FIELD TERTIARY RECOVERY
OPERATIONS
ENRICHED AND HIGH PRESSURE GAS

S 42. ANON.: "MISCIBLE FLOOD TO RECOVER EXTRA 100 MILLION BBLs",
OIL & GAS J. (MAY 26, 1975) 82-84.

ABSTRACT:

----- THIS ARTICLE IS A REVIEW OF A PAPER PRESENTED AT THE 9TH WORLD PETROLEUM CONGRESS. THE PAPER REPORTED ON THE PROGRESS OF THE MISCIBLE FLOOD AT THE SOUTH SWAN HILLS OIL RESERVOIR, ALBERTA, CANADA. THE RESERVOIR IS A CARBONATE REEF IN THE BEAVERHILL LAKE FORMATION OF MIDDLE DEVONIAN AGE. THE RESERVOIR WAS DISCOVERED IN 1959 AND CONTAINED AN ESTIMATED 890 MMBBL OOIP. IT WAS PUT ON WATERFLOOD IN 1963 AND THE MISCIBLE DISPLACEMENT STARTED IN 1973. THE INJECTED SOLVENT WAS ENRICHED HYDROCARBON GAS. A 10% PV SLUG OF THIS WOULD BE INJECTED ALTERNATELY WITH WATER IN THE RATIO OF 1.2 TO 1. THE SOLVENT WOULD BE DRIVEN BY ALTERNATE INJECTION OF LEAN GAS AND WATER ALSO IN THE RATIO OF 1.2 TO 1. 30% PV OF GAS WOULD BE INJECTED. THIS PROCESS WOULD LATER BE CONVERTED TO WATER INJECTION THROUGH ULTIMATE DEPLETION.

BOTH EXPERIMENTAL AND MATHEMATICAL MODEL STUDIES WERE CONDUCTED. IT WAS CONFIRMED EXPERIMENTALLY THAT THE ALTERNATE INJECTION OF WATER WOULD REDUCE THE MOBILITY OF THE INJECTED SOLVENT. THE MODEL STUDY SHOWED THAT HORIZONTAL PERMEABILITY WOULD DOMINATE FLOW. ALTHOUGH BOTH WATER AND SOLVENT FLOWED TOGETHER OVER MOST OF THE SECTION, SOME SEGREGATION WAS NOTICED. THE SOLVENT TENDED TO FLOW HIGHER, WHILE WATER FLOWED LOWER IN THE SECTION. TESTS CONDUCTED ON CORES SHOWED ABOUT 5% RESIDUAL OIL SATURATION AND NO SIGNIFICANT EFFECT OF MOBILE WATER ON THE RESIDUAL OIL SATURATION.

A RECOVERY FACTOR OF 65% WAS EXPECTED FOR THE MISCIBLE PROCESS. THIS AMOUNTED TO 116 MMBBL OF OIL OVER WATERFLOOD, 29MM RESERVOIR BBL OF ENRICHED GAS, 23 MMBBL OF WATER AND 1 MMBBL OF PRE-INJECTION WATER HAD BEEN INJECTED IN 18 MONTHS. THE PRE-INJECTION WATER WAS NECESSARY TO BRING RESERVOIR PRESSURE UP TO MISCIBILITY CONDITIONS.

SIGNIFICANT PERMEABILITY ORIENTATION WAS EVIDENT AND SEVERAL OF THE WELLS SHOWED POOR DISTRIBUTION OF THE INJECTED FLUID. SOME BREAKTHROUGH OF INJECTED FLUID WAS ALREADY NOTICED. OTHER PROBLEMS WERE BEING IDENTIFIED TO IMPROVE THE DISTRIBUTION OF THE INJECTION FLUID.

COMMENTS:

----- 1. THE USE OF WATER INJECTION FOR MOBILITY CONTROL IS BEING PUT INTO PRACTICE; THE EFFECTIVENESS OF THE PROCESS IS CONFIRMED BY LABORATORY STUDIES.

2. LIKE MOST FIELD EXPERIENCES, LACK OF ADEQUATE KNOWLEDGE OF THE RESERVOIR MAY AFFECT FLUID DISTRIBUTION AND SWEEP EFFICIENCY AND HENCE THE PERFORMANCE OF THE PROCESS.

EXHIBITS:

----- 3 FIGURES

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
FIELD RESIDUAL SATURATIONS
OPERATIONS

CARBONATE FIELD
FIELD TERTIARY RECOVERY
FIELD MOBILITY RATIO
MOBILITY CONTROL
FACILITIES
OTHER FIELD INFORMATION

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S 43. BOUCK, L.S., HEARN, C.L. AND DOHY, G.: "PERFORMANCE OF A MISCIBLE FLOOD IN THE BEAR LAKE CARDIUM UNIT, PEMBINA FIELD, ALBERTA, CANADA", J. PET. TECH. (JUNE, 1975) 672-678.

ABSTRACT:

----- THE PROGRESS OF A MISCIBLE FLOOD LOCATED IN THE PEMBINA FIELD, ALBERTA IS REPORTED. GRAVITY SEGREGATION HAS BEEN THE DOMINANT FLOW MECHANISM, AND THE PERFORMANCE HAS BEEN ADVERSELY AFFECTED BY SOLVENT CHANNELING, GRAVITY INDUCED OVERRIDING AND SEGREGATION OF STRIPPED SOLVENT GAS. WHILE UP-DIP WELLS EXPERIENCE GOR PROBLEMS, DOWN STRUCTURE WELLS LOCATED NEAR THE INJECTION WELLS PRODUCE WATER. THE PROBLEMS OF MISCIBLE FINGERING AND POOR SWEEP EFFICIENCY CAUSED BY UNFAVORABLE MOBILITY RATIO HAVE BEEN ACCENTUATED BY FORMATION HETEROGENEITY.

SIMULATION MODELING SHOWED EVIDENCE OF WATER/GAS SEGREGATION AND A TENDENCY FOR A HIGH-METHANE CONTENT GAS PHASE TO DEVELOP IN THE REGION OF THE SOLVENT-OIL FRONT. THE ALTERNATE GAS-WATER INJECTION HAS BEEN INEFFECTIVE FOR MOBILITY CONTROL OWING TO GRAVITY SEGREGATION. THE INDIVIDUAL WELL PERFORMANCE HAS BEEN STRONGLY INFLUENCED BY NEAR WELL RESERVOIR STRUCTURE AND WELL COMPLETION INTERVAL.

THE PROJECT DESIGN WAS INFLUENCED BY THE PREVIOUS EXPERIENCE IN THE CARDIUM FIELD. SOLVENT COMPOSITION WAS 60% LPG (PROPANE OR BUTANE) AND 40% METHANE, AND THE MINIMUM MISCIBILITY PRESSURE WAS 2100 PSI. A PRE-SOLVENT WATER INJECTION WAS EXPECTED TO IMPROVE THE DISTRIBUTION OF THE SLUG IN THE VARIOUS STRATA, AND 1.2 MMBSL OF SOLVENT AND 2.8 MMBSL OF BUFFER GAS (MOSTLY METHANE) WAS TO BE INJECTED IN SLUGS ALTERNATED WITH WATER. OIL PRODUCTION HAD RISEN FROM 600 BOPD TO 4000 BOPD AND 58 MMBO WAS PRODUCED BETWEEN THE START OF THE PROJECT IN 1968, AND JANUARY, 1973.

COMMENTS:

----- ALTHOUGH A NUMBER OF PROBLEMS HAVE BEEN EXPERIENCED AT THE BEAR LAKE CARDIUM UNIT, THE RICH GAS DRIVE MISCIBLE PROJECT HAS IMPROVED OIL RECOVERY OVER WHAT WAS EXPECTED FROM WATERFLOOD.

EXHIBITS:

----- 4 TABLES, 8 FIGURES

ADDITIONAL REFERENCES:

----- GILLAND: J. CAN. PET. TECH. (1969) 66-74.

CROSS REFERENCES:

27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
S 40. NOLEN: PAPER SPE 4274 (1973).

KEYWORDS:

WATER INJECTION
FIELD AREAL SWEEP
OTHER FIELD INFORMATION
COMPOSITIONAL MODELS

SANDSTONE FIELD
FIELD MISCIBLE APPLICATION
MOBILITY CONTROL
FINITE DIFFERENCE MODELS
ENRICHED AND HIGH PRESSURE GAS

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S 44. HARDY, J.H. AND ROBERTSON, N.: "MISCIBLE DISPLACEMENT BY HIGH-PRESSURE GAS AT BLOCK 31", PET. ENG. (NOV., 1975) 24-28.

ABSTRACT:

----- THE UNIVERSITY BLOCK 31 FIELD IN CRANE COUNTY, TEXAS IS THE WORLD'S FIRST LARGE SCALE MISCIBLE DISPLACEMENT PROJECT WITH HIGH-PRESSURE GAS INJECTION. THE 7840 ACRE UNIT CONTAINS A RESERVOIR WITH FIVE PRODUCING HORIZONS OF WHICH THE DEVONIAN IS THE DOMINANT. THE DEVONIAN IS A LOW PERMEABILITY CRYSTALLINE LIMESTONE FORMATION INTERSPERSED WITH CHERT AND EXISTING AT A DEPTH OF ABOUT 8500 FEET.

THE UNIT HAD PRODUCED 130 MMBBL OF OIL FOLLOWING THE MISCIBLE DISPLACEMENT PROJECT INITIATED IN 1949. THE ESTIMATED PRIMARY RECOVERY WAS 69 MMBBL. THE FIELD WAS DISCOVERED IN 1945 AND WAS UNITIZED IN 1952 WITH ATLANTIC RICHFIELD AS OPERATOR. THE INJECTED GAS WAS CONVERTED TO FLUE GAS IN 1966. THE PLANT CAPACITY OF 54 MMCFD WAS CONSIDERED THE LARGEST IN THE WORLD. THE FLUE GAS IS MADE UP OF ABOUT 87% N₂, 12% CO₂ AND 1% CO.

FLUE GAS BREAKTHROUGH (INCREASING GOR AND DECREASING GAS QUALITY) WAS A MAJOR PROBLEM AT THE UNIT. CONTROL MEASURES HAVE INCLUDED THE CONVERSION OF HIGH GOR WELLS TO INJECTORS AND INFILL DRILLING IN AREAS OF LOW GAS SATURATION WITH COMPLETION LIMITED TO LOW GAS SATURATION ZONES. PRODUCTION WAS KEPT AT 16 MBPD WITH THE ADDITION OF INFILL WELLS. ALTHOUGH AVERAGE FIELD GOR WAS ABOUT 6800 SCF/BBL, THE NEW INFILL WELLS HAD A GOR OF 2250 SCF/BBL.

COMMENTS:

----- 1. THE ESTIMATED PRIMARY RECOVERY IN THIS PAPER IS QUOTED AT 69 MMBBL AS OPPOSED TO 40 MMBBL QUOTED BY BLEAKEY (1969).

2. THE PRODUCTION DATA PRESENTED ARE NOT INTERPRETABLE IN THAT REGULATORY AND OPERATING CONSTRAINTS ARE NOT DISCUSSED.

EXHIBITS:

----- 5 FIGURES SHOWING PRODUCTION HISTORY AND INJECTION PATTERNS.

CROSS REFERENCES:

- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).

KEYWORDS:

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
FLUE GAS FIELD APPLICATIONS
OPERATIONS

FIELD TERTIARY RECOVERY
FIELD AREAL SWEEP
FACILITIES
ENRICHED AND HIGH PRESSURE GAS

S 45. TEJA, A.S.: "THE PREDICTION OF AZEOTROPIC BEHAVIOR AND SATURATED LIQUID DENSITIES IN THE CARBON DIOXIDE - ETHANE SYSTEM", A.I.CH.E. J. (MAY, 1975) V.21, NO.3, 618-620.

ABSTRACT:

----- EQUATION OF STATE METHODS FOR CALCULATION OF VAPOR-LIQUID EQUILIBRIA REQUIRE EXTENSIVE MODIFICATION FOR PROPER ACCURACY AND ARE DIFFICULT TO USE, ESPECIALLY FOR PREDICTIVE PURPOSES. THIS PAPER WAS WRITTEN TO ALERT READERS THAT THE EXTENDED FORM OF THE CORRESPONDING STATES PRINCIPLE CAN BE USED INSTEAD OF AN EQUATION OF STATE. THIS METHOD IS SUCCESSFULLY APPLIED TO CALCULATION OF AZEOTROPIC STATES AND LIQUID DENSITIES FOR THE BINARY CARBON DIOXIDE-ETHANE SYSTEM. SHAPE FACTORS NECESSARY FOR CALCULATIONS WITH OTHER (N-ALKANE) SYSTEMS ARE PRESENTED IN LELAND AND CHAPPELEAR.

COMMENTS:

----- THE METHOD USED IN THIS PAPER MAY PROVE USEFUL FOR COMPOSITIONAL SIMULATION AND CERTAINLY DESERVES FURTHER STUDY.

EXHIBITS:

----- 2 TABLES, 2 FIGURES

ADDITIONAL REFERENCES:

----- 1. ROWLINSON AND WATSON: CHEM. ENG. SCI. (1969) V.24, 1565.
2. LELAND AND CHAPPALEAR: IND. & ENG. CH. (1968) V.60, NO.7, 15.

CROSS REFERENCES:

121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.

KEYWORDS:

HYDROCARBON COMPONENTS
EQUATIONS OF STATE
DENSITY
THEORETICAL PHYSICAL PROPERTIES
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
OTHER PHYSICAL PROPERTIES

S 46. ANON.: "GAS MISCIBLE PROJECTS MOVE AT SLOW PACE",
OIL & GAS J. (APR., 1976) 126-127.

ABSTRACT:

----- THIS REPORT CONTAINS A SURVEY OF ON-GOING MISCIBLE AND CO2 PROJECTS. THE POTENTIAL AND PROBLEMS OF THE PROJECTS ARE BRIEFLY SUMMARIZED. TEN MISCIBLE PROJECTS AND EIGHT CO2 SCHEMES ARE INCLUDED. THE FIELDS ARE ALL OVER THE COUNTRY AND ARE OPERATED BY DIFFERENT COMPANIES. ALSO REPORTED ARE PENNZOIL AND GUYAN'S PLANS FOR A CO2 PROJECT IN BIG INJUN AND BEREA ZONES RESPECTIVELY AT THE ROCK CREEK FIELD. THE PLANNED CO2 INJECTION IN ANETH FIELD, UTAH, BY PHILLIPS IS ALSO REPORTED.

COMMENTS:

----- A TABLE LISTING THE VARIOUS HYDROCARBON MISCIBLE PROJECTS REPORTED IS ATTACHED. THE TABLE SHOWS THE LOCATION OF THE VARIOUS FIELDS AND THE OPERATORS. IT ALSO GIVES INFORMATION ABOUT THE RESERVOIR FLUID AND FORMATION, THE AREAS INVOLVED, AND PERFORMANCE OF THE MISCIBLE PROJECT.

EXHIBITS:

----- 1 TABLE

KEYWORDS:

CARBONATE FIELD
FIELD SECONDARY RECOVERY
FLUE GAS FIELD APPLICATIONS
ENRICHED AND HIGH PRESSURE GAS

SANDSTONE FIELD
WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION
LPG

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S 47. BRANNAN, G. AND WHITINGTON, H.M., JR.: "ENRICHED MISCIBLE FLOODING - A CASE HISTORY OF THE LEVELLAND UNIT SECONDARY MISCIBLE PROJECT", PAPER 5826, SPE-AIME 51ST ANN. FALL MTG., NEW ORLEANS, LA. (OCT., 1976).

ABSTRACT:

----- AN UNEXPECTED DECREASE IN WATER INJECTIVITY IN THE LEVELLAND FIELD, HOCKLEY COUNTY, TEXAS WAS OBSERVED, FOLLOWING THE INITIAL INJECTION OF RICH GAS. 15000 GALLONS OF INTERFACE ACID WAS INJECTED TO RESTORE WATER INJECTIVITY AND THE RESPONSE WAS GOOD. THE RESERVOIR PERFORMANCE WAS SHOWING INDICATIONS OF GOOD VOLUMETRIC SWEEP AND ACCEPTABLE CONFORMANCE TO THE PAY.

THE FIELD WAS PREVIOUSLY UNDER PRESSURE MAINTENANCE GAS INJECTION. THE MISCIBLE PROJECT INVOLVED CYCLIC INJECTION OF RICH GAS AND WATER, CHASED BY RESIDUE GAS ALTERNATELY INJECTED WITH WATER. THIS WOULD BE WATERFLOODED FINALLY TO AN ECONOMIC LIMIT. THE ULTIMATE PRIMARY OIL RECOVERY WAS ESTIMATED TO BE 17% OOIP. ADDITIONAL RECOVERY BY MISCIBLE FLOOD WOULD BE 55% OOIP AS OPPOSED TO 44% OOIP EXPECTED FROM WATERFLOODING. CUMULATIVE PRODUCTION AT THE INITIATION OF THE PROJECT WAS 9% OOIP, AND CURRENT PRODUCTION AT THE TIME OF THE PAPER WAS 13% OOIP. THE OIL PRODUCTION IN THE FIRST YEAR (1971) OF THE PROJECT AVERAGED 850 BOPD. THIS MORE THAN DOUBLED IN 1976 TO 1855 BOPD, AND GAS PRODUCTION HAD DECLINED FROM 2700 TO 1750 MCFD, NOT WITHSTANDING PEAK RESPONSE HAD NOT YET OCCURRED.

COMMENTS:

----- THERE IS A GENERAL OPTIMISM ABOUT THE PERFORMANCE OF THE MISCIBLE PROJECT, AND THE OPERATOR IS APPARENTLY PLEASED WITH THE PROJECT.

EXHIBITS:

----- 2 TABLES, 9 FIGURES

CROSS REFERENCES:

181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).

KEYWORDS:

WATER INJECTION
FIELD MISCIBLE APPLICATION
OTHER FIELD INFORMATION

CARBONATE FIELD
FIELD TERTIARY RECOVERY
MOBILITY CONTROL
ENRICHED AND HIGH PRESSURE GAS

- S 48. FUSSELL, D.D., SHELTON, J.L. AND GRIFFITH, J.D.: "EFFECT OF RICH GAS COMPOSITION ON MULTIPLE-CONTACT MISCIBLE DISPLACEMENT - A CELL-TO-CELL FLASH MODEL STUDY", SOC. PET. ENG. J. (DEC., 1976) 310-316.

ABSTRACT:

----- A CELL-TO-CELL FLASH MODEL WITH A PHASE MOBILITY OPTION WAS USED TO SIMULATE RICH GAS DISPLACEMENT PROCESS IN AN OIL RESERVOIR. FIVE DIFFERENT COMPOSITIONS OF RICH GAS MIXTURE WERE INVESTIGATED. THE EFFECTS OF RICH GAS COMPOSITION ON THE PHYSICAL PROPERTIES OF THE TRANSITION ZONE EXISTING BETWEEN THE GAS AND THE RESERVOIR OIL WERE STUDIED. IT WAS FOUND THAT THE TRANSITION ZONE MIGHT CONTAIN EITHER ONE OR TWO SIGNIFICANT TWO-PHASE ZONES, DEPENDING ON THE SOLVENT CONTENT OF THE RICH GAS (C2-C4) IN A MISCIBLE DISPLACEMENT. A THIRD TWO-PHASE ZONE MIGHT ALSO BE PRESENT IN AN IMMISCIBLE DISPLACEMENT. THE AVERAGE CONCENTRATION OF SOLVENT IN THE TRANSITION ZONE WAS A FUNCTION OF THE SOLVENT CONCENTRATION IN THE INJECTED GAS.

FOUR OF THE RICH GAS COMPOSITIONS USED RESULTED IN MISCIBLE DISPLACEMENTS. THE DIRECTION OF ENRICHMENT (INCREASING SOLVENT CONCENTRATION) WAS FOUND TO BE OPPOSITE TO THE DIRECTION OF FLOW. THE LOCATION OF RICH GAS COMPOSITION WITH RESPECT TO THE CRITICAL TIE LINE ON A TERNARY DIAGRAM FOR A CONDITION OF MISCIBILITY WAS IN AGREEMENT WITH THE CORRELATION OF BENHAM ET AL. THE FIFTH RICH GAS COMPOSITION WAS THE LEANEST OF THE GASES. IT RESULTED IN AN IMMISCIBLE DISPLACEMENT. STRIPPING OR VAPORIZATION OF THE LIQUID PHASE OCCURRED WHEN THE OVERALL FLUID COMPOSITION REACHED THE CRITICAL TIE LINE. THE STRIPPING PROCESS WAS A FUNCTION OF THE RICH GAS COMPOSITION. A LESS EFFICIENT STRIPPING MECHANISM AND LONGER STRIPPING ZONE WITH A SHORT ENRICHMENT ZONE WERE OBSERVED WITH LEANER COMPOSITIONS.

THE VALIDITY OF THE MODEL WAS ESTABLISHED WITH AN "EXCELLENT" AGREEMENT BETWEEN THE PREDICTED AND EXPERIMENTAL LIQUID-PHASE COMPOSITION. ESSENTIALLY, THE MODEL USED A MODIFIED REDLICH-KWONG EQUATION OF STATE FOR VAPOR-LIQUID EQUILIBRIUM. ALTHOUGH THE MODEL COULD PREDICT ZONE COMPOSITION, IT DID NOT GIVE ANY INFORMATION ABOUT THE SIZE OF THE TRANSITION ZONE. THE AUTHORS SUGGESTED MAKING AN INDEPENDENT DETERMINATION USING SUCH WORKS AS PRESENTED BY HALL AND GEFFEN OR CRAIG AND BRAY.

COMMENTS:

----- THE CELL-TO-CELL COMPOSITIONAL MODEL IS IMPORTANT IN INVESTIGATING THE COMPOSITIONAL CHANGES THAT MIGHT OCCUR DURING A MISCIBLE DISPLACEMENT. IT MAY BE USED TO DETERMINE THE REQUIRED COMPOSITIONS FOR MISCIBILITY AS WELL AS DETERMINE CONDITIONS UNDER WHICH MISCIBILITY MIGHT BE LOST. IT IS, HOWEVER, NOT SUITABLE FOR RECOVERY PREDICTION.

EXHIBITS:

----- 4 TABLES, 5 FIGURES

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ADDITIONAL REFERENCES:

- 1. FUSSEL AND YARBOROUGH:
SOC. PET. ENG. J. (APR., 1972) 96-102.
2. HALL AND GEFFEN: TRANS., AIME (1957) V.210, 48.
3. CRAIG AND BRAY: PROC. 8TH WORLD PET. CONGRESS, MOSCOW
(1971) V.3, 275-285.

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.

KEYWORDS:

CORRELATIONS
HYDROCARBON COMPONENTS
EQUATIONS OF STATE
EQUILIBRIUM RATIOS

THEORETICAL PHYSICAL PROPERTIES
GENERAL PHASE BEHAVIOR
MULTICOMPONENT SYSTEMS
VISCOSITY
OTHER PHYSICAL PROPERTIES

S 49. HAMAM, S.E. AND LU, B.C.: "ISOTHERMAL VAPOR-LIQUID EQUILIBRIA IN BINARY SYSTEM PROPANE - CARBON DIOXIDE", J. CH. & ENG. DATA (1976) V.21, NO.2, 200-204.

ABSTRACT:

----- ISOTHERMAL VAPOR-LIQUID EQUILIBRIA IN THE BINARY SYSTEM PROPANE-CARBON DIOXIDE WERE DETERMINED OVER THE COMPLETE CONCENTRATION RANGE AT -20 AND +20 F FOR PRESSURES FROM 73 TO 379 PSIA. THE DATA OBTAINED WERE THERMODYNAMICALLY CONSISTENT AND COMPARED WELL WITH VALUES PREDICTED BY A MODIFIED REDLICH-KWONG EQUATION OF STATE.

COMMENTS:

----- THE RESULTS OF THIS STUDY MAY BE USEFUL IN CALIBRATING EQUATIONS OF STATE.

EXHIBITS:

----- 4 TABLES, 4 FIGURES

CROSS REFERENCES:

- 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.

KEYWORDS:

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE

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S 50. HERBECK, E.F., HEINTZ, R.C. AND HASTINGS, J.R.:
"FUNDAMENTALS OF TERTIARY OIL RECOVERY: PART 2 - LPG MISCIBLE
SLUG PROCESS", PET. ENG. (FEB., 1976) 58-66.

ABSTRACT:

----- MISCIBLE DISPLACEMENT PROCESSES ELIMINATE CAPILLARY FORCES AND YIELD COMPLETE RECOVERY IN AREAS CONTACTED BY THE DISPLACING FLUIDS. LIGHT LIQUID HYDROCARBON SUCH AS NAPHTHA, KEROSENE, GASOLINE, OR LIQUID LPG PRODUCTS SUCH AS ETHANE, PROPANE OR BUTANE ARE MISCIBLE WITH TYPICAL RESERVOIR OIL. WHILE THESE HAVE 'FIRST-CONTACT' MISCIBILITY, LEAN GAS AND ENRICHED GAS HAVE MULTI-CONTACT MISCIBILITY WITH RESERVOIR OIL. LIQUID HYDROCARBON BECOMES IMMEDIATELY MISCIBLE WITH RESERVOIR OIL ON INITIAL CONTACT. PROPANE HAS BEEN MOST COMMONLY USED FOR LPG MISCIBLE SLUG PROCESS. ALTHOUGH ITS APPLICABILITY TO TERTIARY RECOVERY WAS NOTED FROM THE BEGINNING, IT WAS ORIGINALLY MEANT TO BE USED AS A SECONDARY RECOVERY PROCESS.

THE PROCESS INVOLVES INJECTING BETWEEN 2-10% OF RESERVOIR PORE VOLUME OF PROPANE (5% IS GENERALLY CONSIDERED OPTIMUM), INTO THE RESERVOIR. THIS IS FOLLOWED BY GAS OR BOTH GAS AND WATER. THE INJECTION OF GAS AND WATER REDUCES THE PERMEABILITY TO GAS, AND IMPROVES OVERALL COMBINED MOBILITY RATIO OF THE DISPLACEMENT SYSTEM. THE WATER-GAS RATIO TO BE INJECTED IS DETERMINED BY THE RELATIVE PERMEABILITY, VISCOSITIES AND FLUID SATURATIONS. EXPERIENCE HAS SHOWN THAT IT IS NOT PRACTICAL TO INJECT THE WATER AND GAS SIMULTANEOUSLY. ALTERNATE INJECTION OF EACH, OVER A PERIOD OF SEVERAL DAYS IS COMMONLY EMPLOYED.

THE CRITICAL TEMPERATURE FOR PROPANE IS 206 F. ABOVE THIS TEMPERATURE IT CAN ONLY EXIST IN THE GASEOUS PHASE, IRRESPECTIVE OF THE PRESSURE. THE MISCIBILITY PRESSURE OF LPG WITH RESERVOIR OIL, UNDER NORMAL RANGES OF RESERVOIR TEMPERATURE, IS BETWEEN 100 AND 1300 PSIA. AS A RESULT OF THIS, A RESERVOIR CANDIDATE FOR LPG MISCIBLE SLUG PROCESS CANNOT BE TOO DEEP (TEMPERATURE ABOVE 206 F) OR TOO SHALLOW (CANNOT SUSTAIN PRESSURES BETWEEN 1100 AND 1300 PSI). THE OIL VISCOSITY SHOULD NOT EXCEED 5 TO 10 CP FOR ACCEPTABLE MOBILITY RATIOS. THE PROBLEM OF GRAVITY SEGREGATION IS MINIMIZED IF THE RESERVOIR IS THIN, AND ITS PERMEABILITY DOES NOT EXCEED 50 MD. RESIDUAL OIL SATURATION AFTER A SECONDARY RECOVERY PROCESS MUST BE HIGH BEFORE A RESERVOIR IS CONSIDERED FOR TERTIARY RECOVERY.

GRAVITY SEGREGATION AND POOR SWEEP EFFICIENCY ARE COMMON PROBLEMS WITH THIS PROCESS. IT IS, HOWEVER, THE MISCIBLE PROCESS WITH THE LEAST MISCIBILITY PRESSURE REQUIREMENT WHICH MIGHT BE USED IN SHALLOWER RESERVOIRS. AVAILABILITY OF PROPANE AND FACILITIES TO RECOVER PROPANE SHOULD ALSO BE A CONSIDERATION IN THE PLANNING.

PROPANE HAS BEEN USED AS A TERTIARY RECOVERY AGENT IN A NUMBER OF FIELDS INCLUDING THE SOUTH WARD FIELD, WARD COUNTY

TEXAS. THERE, 37% OF THE OIL LEFT IN THE 10 ACRE PILOT AREA WAS RECOVERED, AND 1.5 BBL OF OIL WERE PRODUCED PER BARREL OF PROPANE INJECTED. A SMALL SCALE PROJECT WAS ALSO CONDUCTED IN THE HIBBERD POOL OF SOUTH CUYAMA FIELD, CALIFORNIA. THE TERTIARY RECOVERY WAS ABOUT 3 BBL OF OIL PER BARREL OF PROPANE USED. ARCO OPERATED BOTH THE ABOVE FIELDS. OTHER FIELD EXAMPLES INCLUDE PHILLIPS PETROLEUM'S BURKETT UNIT IN KANSAS, MARATHON OIL'S JOHNSON FIELD IN NEBRASKA AND UNION'S ADENA FIELD IN COLORADO.

COMMENTS:

----- 1. A GRAPH SHOWING MINIMUM MISCIBILITY PRESSURE AT VARIOUS TEMPERATURES FOR MISCIBLE SLUG AND DRIVING GAS DRIVES IS INCLUDED. THIS MAY BE USED FOR A QUICK MISCIBILITY PRESSURE ESTIMATE.

2. THE PAPER ALSO INCLUDES GENERAL CRITERIA FOR THE SELECTION OF RESERVOIR CANDIDATES FOR LPG MISCIBLE PROCESS.

EXHIBITS:

----- 1 TABLE, 2 FIGURES

CROSS REFERENCES:

- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
S 21. BLANTON, MCCASKILL, HERBECK: J. PET. TECH. (OCT., 1970) 1209.
S 32. CONNALLY: PAPER SPE 3775 (1972).
S 34. HOLM: PAPER SPE 3774 (1972).

KEYWORDS:

FIRST CONTACT MISCIBILITY
FIELD SECONDARY RECOVERY
FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
FLUE GAS FIELD APPLICATIONS
OTHER FIELD INFORMATION
ENRICHED AND HIGH PRESSURE GAS

WATER INJECTION
FIELD TERTIARY RECOVERY
FIELD MOBILITY RATIO
MOBILITY CONTROL
FIELD ECONOMICS
SCREENING CRITERIA
LPG

S 51. HERBECK, E.F., HEINTZ, R.C. AND HASTINGS, J.R.:
"FUNDAMENTALS OF TERTIARY OIL RECOVERY: PART 3 - ENRICHED
GAS MISCIBLE SLUG PROCESS", PET. ENG. (MAR., 1976) 84-88.

ABSTRACT:

----- THE ENRICHED GAS PROCESS IS A MULTIPLE-CONTACT
MISCIBLE PROCESS. THE INJECTED GAS USUALLY CONTAINS A LARGE AMOUNT
OF INTERMEDIATE HYDROCARBONS C2-C6 (ETHANE THROUGH HEXANE). ON
THE INITIAL CONTACT WITH THE RESERVOIR OIL, THESE INTERMEDIATE
HYDROCARBONS ARE STRIPPED FROM THE GAS AND ABSORBED INTO THE OIL.
MISCIBILITY IS ACHIEVED AFTER SEVERAL SUCH CONTACTS. MISCIBILITY
BETWEEN THE GAS AND THE RESERVOIR OIL IS A FUNCTION OF THE AMOUNT
OF C2-C6 PRESENT IN THE OIL, AS WELL AS THE RESERVOIR TEMPERATURE
AND PRESSURE. THE PROCESS DESIGN IS THEREFORE FLEXIBLE. ABOUT
10% TO 20% OF A RESERVOIR PORE VOLUME OF ENRICHED GAS IS INJECTED
IN THIS PROCESS. THIS MAY BE FOLLOWED BY LESS VALUABLE LEAN GAS
OR LEAN GAS AND WATER.

TYPICAL PRESSURES NEEDED FOR MISCIBILITY VARY BETWEEN 1500
AND 3000 PSI. THE PROCESS IS MORE SUITED FOR RESERVOIRS CONTAINING
HIGH GRAVITY CRUDE OIL WITH VISCOSITY NOT EXCEEDING 5 TO 10 CP.
GRAVITY SEGREGATION IS MINIMIZED IN LOW PERMEABILITY
FORMATIONS. LESS PRESSURE IS GENERALLY REQUIRED IN THIS PROCESS
THAN IN THE LEAN GAS PROCESS. ENRICHED GAS ALSO COSTS LESS THAN
PROPANE OR OTHER LPG. THE MOBILITY RATIO OF THE DISPLACEMENT IS ALWAYS
POOR; POOR SWEEP EFFICIENCY IS THEREFORE A COMMON PROBLEM. GRAVITY
OVERRIDE IS ALSO COMMON IN THICK PERMEABLE RESERVOIRS. DISPERSION
OF THE MISCIBLE FRONT MAY OCCUR AS A
RESULT OF HETEROGENEITIES, VISCOUS FINGERING AND GRAVITY
OVERRIDE, LEADING TO LOSS OF MISCIBILITY.

THE SEELIGSON FIELD IN TEXAS OPERATED BY EXXON AND THE ANTE
CREEK FIELD IN ALBERTA OPERATED BY AMOCO ARE TWO INDUSTRY
EXPERIENCES.

COMMENTS:

- 1. LEAN GAS MAY BE REPLACED BY LESS EXPENSIVE
FLUE GAS.
2. MOBILITY CONTROL CAN BE ACHIEVED BY ALTERNATE GAS AND
WATER INJECTION.

EXHIBITS:

----- 2 FIGURES

ADDITIONAL REFERENCES:

----- WALKER AND TURNER: J. PET. TECH.
(APR., 1968) 369-373.

CROSS REFERENCES:

- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.

KEYWORDS:

FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
SCREENING CRITERIA

FIELD MOBILITY RATIO
OTHER FIELD INFORMATION
ENRICHED AND HIGH PRESSURE GAS

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S 52. HERBECK, E.F., HEINTZ, R.C. AND HASTINGS, J.R.:
"FUNDAMENTALS OF TERTIARY OIL RECOVERY: PART 4 - HIGH PRESSURE
LEAN GAS MISCIBLE PROCESS", PET. ENG. (APR., 1976) 66-72.

ABSTRACT:

----- LIKE THE ENRICHED GAS PROCESS, THE HIGH PRESSURE
LEAN GAS MISCIBLE PROCESS IS A 'MULTIPLE-CONTACT' MISCIBLE PROCESS.
THE INTERMEDIATE HYDROCARBON COMPONENTS C2-C6 ARE TRANSFERRED FROM
THE RESERVOIR OIL TO THE INJECTED GAS ON FIRST CONTACT. MORE C2-C6
ARE TRANSFERRED AS FURTHER CONTACTS ARE MADE UNTIL MISCIBILITY IS
ACHIEVED BETWEEN THE GAS AND THE RESERVOIR OIL. BECAUSE THE
TRANSFER OF HYDROCARBON COMPONENTS IS BY THE VAPORIZATION OF THE
COMPONENTS, THE PROCESS IS ALSO KNOWN AS VAPORIZING GAS DRIVE.
MISCIBILITY IS GENERALLY ACHIEVED AT HIGH PRESSURES (OVER 3000
PSI). IT IS ESSENTIAL THAT THE CRUDE OIL CONTAINS A HIGH
CONCENTRATION OF C2-C6. IT MUST ALSO BE UNDERSATURATED AT THE
GAS FRONT PRESSURE. RESIDUAL ASPHALTINE RESIDUE OF VOLUME EQUAL
TO ABOUT 5% OF THE RESERVOIR PORE VOLUME IS USUALLY LEFT BEHIND
IN THE PROCESS. FLUE GAS MAY EFFECTIVELY BE USED TO REPLACE THE
MORE EXPENSIVE LEAN GAS WITHOUT APPRECIABLY INCREASING THE REQUIRED
MINIMUM PRESSURE FOR MISCIBILITY. LIKE OTHER GAS MISCIBLE PROCESSES,
GRAVITY OVERRIDE IS MINIMIZED IF THE RESERVOIR IS THIN AND OF LOW
PERMEABILITY. THE SWEEP EFFICIENCY IN THIS PROCESS IS GENERALLY
HIGHER THAN THAT FOR PROPANE, AND ENRICHED GAS, BUT LOWER THAN
THAT FOR WATERFLOOD.

BLOCK 31 FIELD OPERATED BY ATLANTIC RICHFIELD IS THE FIRST
FIELD APPLICATION OF THE PROCESS. OVER 130 MMBBL OF OIL HAVE
BEEN PRODUCED FROM THIS FIELD AND AN ULTIMATE RECOVERY OF 60% OOIP
IS EXPECTED. FAIRWAY FIELD IN EAST TEXAS, OPERATED BY HUNT OIL
CO. IS ANOTHER FIELD APPLICATION OF THIS PROCESS. ULTIMATE
RECOVERY IN THE FIELD IS EXPECTED TO REACH 50% OF OOIP.

COMMENTS:

----- ALTERNATE GAS AND WATER INJECTION CAN IMPROVE
SWEEP EFFICIENCY AS ALREADY ESTABLISHED BY SEVERAL PUBLISHED
LABORATORY AND FIELD REPORTS.

EXHIBITS:

----- 3 FIGURES

ADDITIONAL REFERENCES:

----- 1. KOCH AND HUTCHINSON:
TRANS., AIME (1958) V.213, 7-10.
2. LACKLAND AND HURFORD: J. PET. TECH. (MAR., 1973)
354-358.

CROSS REFERENCES:

S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.

KEYWORDS:

FIELD MISCIBLE APPLICATION
FIELD AREAL SWEEP
SCREENING CRITERIA

FIELD MOBILITY RATIO
FLUE GAS FIELD APPLICATIONS
ENRICHED AND HIGH PRESSURE GAS

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S 53. HWANG, S.C., LIN, H., CHAPPELEAR, P.S. AND KOBAYASHI, R.:
"DEW POINT STUDY IN THE VAPOR-LIQUID REGION OF THE METHANE -
CARBON DIOXIDE SYSTEM", J. CH. & ENG. DATA (1976) V.21, NO.4,
493-497.

ABSTRACT:

----- THIS PAPER REPORTS RESULTS OF A STUDY OF THE VAPOR
PHASE CONCENTRATIONS ALONG ISOTHERMS IN THE VAPOR-LIQUID REGION
SURROUNDING THE VAPOR-SOLID REGION FOR THE METHANE-CARBON DIOXIDE
SYSTEM. TEMPERATURES FROM -65 TO -184 F WERE INVESTIGATED. THE
PRESSURE RANGE COVERED FROM THE THREE PHASE SOLID-LIQUID-VAPOR
LOCUS TO THE CRITICAL POINT OR THE VAPOR PRESSURE OF METHANE.

COMMENTS:

----- THIS PAPER MIGHT BE USEFUL IN DESIGN OF A CRYOGENIC
SEPARATION PROCESS FOR SEPARATING CARBON DIOXIDE AND NATURAL GAS.

EXHIBITS:

----- 2 TABLES, 6 FIGURES

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS
EFFECTS OF TEMPERATURE

- S 54. KALRA, H., KRISHNAN, T.R. AND ROBINSON, D.B.: "EQUILIBRIUM-PHASE PROPERTIES OF CARBON DIOXIDE - N-BUTANE AND NITROGEN - HYDROGEN SULFIDE SYSTEMS AT SUBAMBIENT TEMPERATURES" J. CH. & ENG. DATA (1976) V.21, NO.2, 222-225.

ABSTRACT:

----- VAPOR AND LIQUID EQUILIBRIUM PHASE COMPOSITIONS WERE DETERMINED AT 50, 1.1, AND -49.3 F FOR THE N-BUTANE-CARBON DIOXIDE SYSTEM. EQUILIBRIUM PHASE DENSITIES WERE CALCULATED FROM THE MEASURED PHASE COMPOSITION AND REFRACTIVE INDEX.

COMMENTS:

----- THIS PAPER CONTINUES THE DEVELOPMENTS OF BESSERER AND ROBINSON (1973A).

EXHIBITS:

----- 6 TABLES, 5 FIGURES

ADDITIONAL REFERENCES:

- 1. BESSERER AND ROBINSON: CAN. J. CH. ENG. (1971) V.49, NO.5, 651.
2. BESSERER AND ROBINSON: J. CH. ENG. DATA (1975) V.20, NO.2, 157.
3. BISHNOI, MIRANDA AND ROBINSON: HYDROCARBON PROCESSING (1974) V.53, NO.11, 197.
4. POETTMANN AND KATZ: IND. ENG. CH. (1949) V.41, 475.

CROSS REFERENCES:

- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.

KEYWORDS:

EXPERIMENTAL PHYSICAL PROPERTIES
HYDROCARBON COMPONENTS
EFFECTS OF PRESSURE
DENSITY

GENERAL PHASE BEHAVIOR
BINARY SYSTEMS
EFFECTS OF TEMPERATURE
REFRACTIVE INDEX

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S 55. ANON.: "OKLAHOMA FIELD GETS FLUE GAS INJECTION",
OIL & GAS J. (SEP. 12, 1977) 54.

ABSTRACT:

----- THE FIRST PHASE OF A 5-PART MISCIBLE FLUE GAS
INJECTION IN THE EAST BINGER FIELD , OKLAHOMA,
HAD BEGUN. THE 13000 ACRE FIELD WAS UNITIZED AND PHILLIPS
PETROLEUM CO. WAS THE OPERATOR. THE FIRST PHASE OPERATION
INVOLVED THE INJECTION OF 6 MMCFD OF GAS. TOTAL INJECTION
WOULD REACH 30 MMCFD WHEN THE OTHER FOUR UNITS WERE COMPLETED.
THE PROJECT, WHICH WOULD COST \$83 MILLION, WAS EXPECTED TO TRIPLE
PRODUCTION IN THE 77 WELLS IN THE FIELD. THE ULTIMATE RECOVERY
WAS EXPECTED TO BE BOOSTED FROM 16 TO 44 MMBBL.
ONE-THIRD OF THE GAS PRODUCTION WOULD BE USED TO FUEL THE
COMPRESSORS WHILE FLUE GAS WOULD BE REINJECTED.

COMMENTS:

----- THIS IS A NEWS REPORT.

KEYWORDS:

FIELD SECONDARY RECOVERY
FLUE GAS FIELD APPLICATIONS
OTHER FIELD INFORMATION

FIELD MISCIBLE APPLICATION
FIELD ECONOMICS
MISCELLANEOUS DATA

S 56. RIETZEL, G.A. AND CALLOW, G.O.: "POOL DESCRIPTION AND PERFORMANCE ANALYSIS LEADS TO UNDERSTANDING GOLDEN SPIKE'S MISCIBLE FLOOD", J. PET. TECH. (JULY, 1977) 867-872.

ABSTRACT:

----- THE RESERVOIR OF THE GOLDEN SPIKE D3'A' POOL WAS POORLY UNDERSTOOD AT THE START OF THE MISCIBLE FLOOD IN 1964. THE RESERVOIR, BASED ON THE ANALYSIS OF THE AVAILABLE WELL DATA AND PRECEEDNG GAS FLOOD PERFORMANCE, WAS ERRONEOUSLY THOUGHT TO BE HOMOGENEOUS. THIS LED TO HIGH EXPECTATIONS FOR THE MISCIBLE PROCESS. BY THE END OF 1975, THE POOL HAD BEEN EXTENSIVELY DEVELOPED AND 52 INFILL WELLS HAD BEEN DRILLED. THE FIELD PERFORMANCE THROUGH 1975 SHOWED AN INCREASE IN THE OIL RECOVERY DUE TO THE MISCIBLE FLOODING, AND 44% OF THE ORIGINAL OIL IN PLACE HAD BEEN PRODUCED.

THE INFILL DRILLING AND PERFORMANCE ANALYSIS ESTABLISHED THE EXISTENCE OF A MAJOR IMPERMEABLE BARRIER AND OTHER SMALLER BARRIERS. THESE AFFECTED THE RECOVERY PERFORMANCE. GAS OVERRAN THE BARRIER AND LEVELLED OUT, AND THE INJECTED LPG SOLVENT DISPERSED INTO THE SECONDARY GAS CAP. THE OIL ON THE BARRIER WAS BYPASSED AND A POOR RECOVERY EFFICIENCY RESULTED. IT BECAME EVIDENT THAT NO FURTHER BENEFITS COULD BE DERIVED FROM SOLVENT INJECTION, AND THE POOL REVERTED TO GAS DRIVE.

THE PERFORMANCE HISTORY WAS MATCHED ON A COMPUTER MODEL INCORPORATING THE REFINED RESERVOIR DESCRIPTION. THE MODEL SHOWED THAT THE POOR PERFORMANCE WAS DUE TO A REDUCED SWEEP EFFICIENCY DUE TO THE BARRIER AND THE SMALL BANK SIZE. THE KEY CONTROLLING PARAMETER WAS THE HORIZONTAL PERMEABILITY. CHANGES IN VERTICAL PERMEABILITY AND OIL RELATIVE PERMEABILITY HAD NO EFFECTS ON THE VOLUME OF OIL BYPASSED. GRAVITY SEGREGATION WAS EVIDENT FROM GAS-SOLVENT AND SOLVENT-OIL INTERFACES WHICH WERE SHARP-FRONTED WITH NO FINGERING. THE STUDY SHOWED THAT 30 MMBBLS OF SOLVENT INJECTED WOULD INCREASE OIL RECOVERY BY ONLY 10 MMBO AS AGAINST 69 MMBO EXPECTED. THE ULTIMATE RECOVERY WITH THE CONTINUED GAS INJECTION WAS PREDICTED TO BE 67% OF THE ORIGINAL OIL IN PLACE.

COMMENTS:

----- ALTHOUGH A MISCIBLE DISPLACEMENT PROCESS IS BETTER DESIGNED AND PLANNED IF ADEQUATE INFORMATION ABOUT THE RESERVOIR IS AVAILABLE AT THE BEGINNING OF THE PROJECT, THIS IS SELDOM THE CASE. THE GOLDEN SPIKE EXAMPLE SHOWS HOW THIS CAN AFFECT PERFORMANCE AND EXPECTATIONS.

EXHIBITS:

----- 1 TABLE, 14 FIGURES, CONSTITUTING GEOLOGIC DESCRIPTION.

CROSS REFERENCES:

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KEYWORDS:

CARBONATE FIELD
FIELD MISCIBLE APPLICATION
FINITE DIFFERENCE MODELS
OTHER MODELLING

FIELD TERTIARY RECOVERY
OTHER FIELD INFORMATION
COMPARISONS WITH FIELD RESULTS
LPG

S 57. ROTHROCK, R.J. AND CRAWFORD, P.B.: "NITROGEN FLOOD",
PET. ENG. (AUG., 1977) 22-26.

ABSTRACT:

----- THIS PAPER REPORTS ON THE FIRST FIELD PRODUCTION
PROJECT UTILIZING PURE NITROGEN SYNTHESIZED FROM AIR FOR INJECTION
INTO A RESERVOIR. TWO RESERVOIRS OF THE FORCHE FIELD OF POINTE
COUPEE PARISH IN SOUTH LOUISIANA ARE BEING INJECTED WITH A
COMBINATION OF METHANE AND NITROGEN. THE FIELD WAS DISCOVERED IN
1966 WITH AN INITIAL RESERVOIR PRESSURE OF 11000 PSI, AND PRODUCED
UNDER SOLUTION GAS DRIVE UNTIL A PRESSURE MAINTENANCE PROGRAM BEGAN
IN 1971.

LABORATORY STUDIES HAVE SHOWN THAT THE INJECTION OF NITROGEN
AT HIGH PRESSURES BETWEEN 5000 PSIG AND 8000 PSIG SHOULD RESULT IN
A MISCIBLE DISPLACEMENT OF THE 43 API CRUDE AT 280 F.
THE INJECTION OF A COMBINATION OF METHANE AND NITROGEN SHOULD
RESULT IN A MISCIBLE DISPLACEMENT AT LOWER PRESSURES THAN INJECTION
OF PURE NITROGEN. THE RECOVERY SHOULD THEREFORE EXCEED THE
ESTIMATED 50% EXPECTED FROM PRESSURE MAINTENANCE ALONE.

COMMENTS:

----- THE PAPER HIGHLIGHTS THE CRYOGENIC SEPARATION
OF NITROGEN AND OXYGEN FROM AIR AT -300 F.

EXHIBITS:

----- 1 TABLE, 4 FIGURES

KEYWORDS:

FIELD SECONDARY RECOVERY
FACILITIES
OTHER FIELD INFORMATION
SEPARATION

SANDSTONE FIELD
FIELD MISCIBLE APPLICATION
OPERATIONS
CO2 SOURCE
ALTERNATE TECHNOLOGIES

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S 58. RUSHING, M.D., THOMASSON, B.C., REYNOLDS, B. AND CRAWFORD, P.B.:
"MISCIBLE DISPLACEMENT WITH NITROGEN", PET. ENG. (NOV., 1977)
26-30.

ABSTRACT:

----- RESULTS OF LABORATORY TESTS ON MISCIBLE DISPLACEMENT BY HIGH PRESSURE NITROGEN INJECTION ARE PRESENTED. THE PRESSURE RANGED FROM 3000 TO 5000 PSI AT 150 F. A 54.4 API GRAVITY CRUDE CONTAINING 700 SCF/BBL DISSOLVED GAS WAS USED. OIL RECOVERY RANGED FROM 65% TO 90% AS PRESSURE INCREASED, AND AN AVERAGE RESIDUAL OIL SATURATION OF 10% WAS OBTAINED AT 5000 PSI. GAS BREAKTHROUGH IN AN IMMISCIBLE DISPLACEMENT OCCURS EARLY, AND GOR INCREASES SLOWLY WHILE LATE GAS BREAKTHROUGH AND RAPID INCREASE IN GOR THEREAFTER OCCURRED FOR MISCIBLE DISPLACEMENT. IN THE DISPLACEMENT PROCESS, NITROGEN IS PROGRESSIVELY ENRICHED UNTIL MISCIBILITY IS ACHIEVED. AFTER MISCIBILITY HAS BEEN ACHIEVED DISPLACEMENT EFFICIENCY APPROACHES 100%. THE PROCESS MAY NOT BE WELL SUITED FOR RESERVOIRS CONTAINING HEAVY CRUDES. CRUDES OF 35 API GRAVITY AND HIGHER ARE BETTER SUITED FOR HIGH PRESSURE NITROGEN INJECTION.

COMMENTS:

----- THIS PAPER CONTAINS SOME FUNDAMENTAL CONCEPTS OF HIGH PRESSURE NITROGEN INJECTION THAT CAN GIVE A BETTER UNDERSTANDING OF THE PROCESS.

EXHIBITS:

----- 5 FIGURES

KEYWORDS:

LABORATORY INJECTION PROCESS
OIL CHARACTERIZATION (LAB. EXP.)
OTHER LABORATORY STUDIES

MISCIBILITY (LAB. EXP.)
HEAVY OIL (LAB. EXP.)
ALTERNATE TECHNOLOGIES

S 59. CROW, P.: "PROSPECTS SEEN BRIGHTER FOR U.S. LNG AND SNG",
OIL & GAS J. (JAN. 16, 1978) 23-28.

ABSTRACT:

----- THE PAPER DISCUSSES THE POLITICS OF LNG IMPORTS.
ARGUMENTS FOR AND AGAINST INCREASED IMPORTS ARE HIGHLIGHTED. THE
INCREASED COST OVER AND ABOVE THE COST OF DOMESTIC GAS IS ONE
FACTOR AFFECTING THE SLOW PROGRESS OF LNG PROJECTS. HOWEVER,
COMPANIES ARE MORE CONCERNED WITH GOVERNMENT PROJECT APPROVAL AND
PRICING POLICY. PREDICTIONS ARE MADE FOR FUTURE DOMESTIC GAS SUPPLY
AND DEMAND THROUGH 2000. DOMESTIC PRODUCTION MUST DECLINE BEYOND THE
1990'S AND THE DEVELOPMENT OF ALTERNATE GAS SUPPLIES OUGHT TO START
NOW. WHETHER THESE ALTERNATIVE SUPPLIES ARE AVAILABLE WHEN THEY
ARE MOST NEEDED WILL DEPEND LARGELY ON ACTIONS TAKEN BY THE CONGRESS
AND THE ADMINISTRATION.

COMMENTS:

----- ONE OF THE ARGUMENTS FOR INCREASED LPG IMPORTS IS
THAT IT WILL REDUCE OIL CONSUMPTION AND EVENTUALLY YIELD FEWER
ENERGY DOLLARS LEAVING THE U.S. THIS SHOULD ALSO CURTAIL THE
EVER-INCREASING PRICE OF OIL. ALTHOUGH SOME OF THE OPEC NATIONS
WILL SUPPLY THE IMPORTED OIL, THEIR SOURCE OF INCOME WILL NOT BE
LIMITED TO OIL AND A MORE STABLE WORLD PETROLEUM PRICING MAY EVOLVE.

EXHIBITS:

----- 2 TABLES, 2 FIGURES

KEYWORDS:

SNG
ALTERNATE TECHNOLOGIES

LPG
CO2 SUPPLY
MISCELLANEOUS DATA

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S 60. LOFTON, L.K. AND MORSE, R.A.: "THE EFFECTS OF INJECTION PRESSURE ON CONDENSING GAS DRIVE RECOVERY", PAPER 7472, SPE-AIME 53RD ANN. FALL MTG., HOUSTON, TX. (OCT., 1978).

ABSTRACT:

----- A COMPUTER SIMULATION STUDY OF AN UNDERSATURATED RESERVOIR WAS PERFORMED. GAS WAS INJECTED AT THE RESERVOIR CREST AND PRODUCED FROM THE BASE OF THE STRUCTURE. THIS STUDY PRESENTED CRITERIA FOR DEVELOPING AN EFFICIENT CONDENSING GAS DRIVE. THE MODEL DUPLICATED LABORATORY TEST RESULTS ACCURATELY. THE OIL RECOVERIES AT GAS BREAKTHROUGH DETERMINED IN THE LABORATORY AND CALCULATED WITH THE BUCKLEY-LEVERETT FRACTIONAL FLOW THEORY COMPARED CLOSELY WITH THE MODEL.

SOLUBILITY EFFECTS IMPROVED THE DISPLACEMENT AND SWEEP EFFICIENCIES OF THE CONDENSING GAS DRIVE. THE MODEL SHOWED THAT FRACTIONAL OIL RECOVERY WAS IN DIRECT PROPORTION TO THE RESERVOIR GAS VOLUME INJECTED AND WAS INVERSELY PROPORTIONAL TO THE WITHDRAWAL RATE. THIS PROPORTIONALITY BECAME LESS PRONOUNCED AS PRESSURE AND GAS SOLUBILITY INCREASED. AS GAS SOLUBILITY IN OIL INCREASED, RECOVERY BECAME LESS SENSITIVE TO THE WITHDRAWAL RATES AT HIGH INJECTION PRESSURE AND MORE OIL WAS RECOVERED. THE INJECTION PRESSURE AFFECTED THE RELATIONSHIP BETWEEN OIL WITHDRAWAL RATES AND FRACTIONAL OIL RECOVERY AT GAS BREAKTHROUGH.

COMMENTS:

----- 1. ALTHOUGH THE MODEL ACCURATELY PREDICTED THE RESULTS OF LABORATORY TESTS, IT WAS NOT ESTABLISHED THAT THE TESTS THEMSELVES REFLECT RESERVOIR BEHAVIOR.

2. USEFUL OBSERVATIONS WERE MADE WHICH COULD IMPROVE THE DESIGN AND PERFORMANCE OF A CONDENSING GAS DRIVE PROCESS.

3. THE SIMPLIFIED APPROACH PRESENTED HERE MAY BE CAPABLE OF MODIFICATION TO MODEL MISCIBLE DISPLACEMENTS.

EXHIBITS:

----- 6 TABLES, 5 FIGURES

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 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
 93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
 115. BURNETT: U.S. PATENT 3,811,502 (MAY 21, 1974 A).
 116. BURNETT: U.S. PATENT 3,841,406 (OCT. 15, 1974 B).
 117. BURNETT, ALSTON, LIM: U.S. PATENT 3,811,501 (MAY 21, 1974 C).
 118. BURNETT, LIM: U.S. PATENT 3,811,503 (MAY 21, 1974 D).
 130. ALLEN, TATE: U.S. PATENT 3,878,892 (APR. 22, 1975).
 131. BROWN: U.S. PATENT 3,885,624 (MAY 27, 1975 A).
 132. BROWN: U.S. PATENT 3,871,451 (MAR. 18, 1975 B).
 133. BURNETT, LIM: CAN. PATENT 980,245 (DEC. 23, 1975 A).
 134. BURNETT, LIM, ALSTON: CAN. PATENT 980,244 (DEC. 23, 1975 B).
 135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
 149. BURNETT: CAN. PATENT 981,575 (JAN. 13, 1976).
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150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
156. HAYNES: U.S. PATENT 3,986,556 (OCT. 19, 1976).
163. SPELLER: U.S. PATENT 3,964,545 (JUNE 22, 1976).
167. BROWN, WU, KONOPNICKI: U.S. PATENT 4,004,636 (JAN. 25, 1977).
176. OFFERINGA: U.S. PATENT 4,042,029 (AUG. 16, 1977).
182. SIAS: U.S. PATENT 4,058,467 (NOV. 15, 1977).
S 1. BAYS: U.S. PATENT 2,135,319 (NOV. 1, 1938).
S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).
S 13. PRATS, CLOSMAN: U.S. PAT. 3,259,187 (JULY 5, 1966).
S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).

VI. MISCELLANEOUS

- 18. HAVERFIELD: U.S. PATENT 2,729,291 (JAN. 3, 1956).
- 38. CRAWFORD, NEILL, BUCY, CRAWFORD: J. PET. TECH. (MAR., 1963) 237.
- 39. DOTTS, STEVENS: U.S. PATENT 3,097,917 (JULY 16, 1963).
- 41. HOLM: U.S. PATENT 3,075,918 (JAN. 29, 1963 B).
- L 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
- I 49. LEWIS: U.S. PATENT 3,193,006 (JULY 6, 1965).
- S 50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).
- T 77. GILLILAND: U.S. PATENT 3,480,082 (NOV. 25, 1969).
- 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
- 95. WEST, KROH: PET. ENG. (DEC., 1971 B) 63.
- 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
- 108. GEFFEN: WORLD OIL (OCT., 1973) 84.
- 109. HILL, POWER, LONGO: AM. J. PHYSIOLOGY (FEB., 1973) 283.
- 111. RIGHTMIRE, HANSHAW: WATER RESOURCES RES. (AUG., 1973) 958.
- 114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
- 129. WHELAN: ESTUARINE & COASTAL MARINE SCI. (1974) 407.
- 131. BROWN: U.S. PATENT 3,885,624 (MAY 27, 1975 A).
- 132. BROWN: U.S. PATENT 3,871,451 (MAR. 18, 1975 B).
- 135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
- 137. DEPARTMENT OF ENERGY: (1975 -).
- 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
- 144. STRELZOFF: CH. ENG. (SEP. 15, 1975) 115.
- 145. ANON.: OIL & GAS J. (NOV. 15, 1976 B) 41.
- 147. ARNOLD: SYMP. ON ADV. IN PET. RECOVERY (1976) 225.
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
- 152. DOSCHER, WISE: J. PET. TECH. (MAY, 1976) 575.
- 156. HAYNES: U.S. PATENT 3,986,556 (OCT. 19, 1976).
- 159. KENNEDY: OIL & GAS J. (DEC. 27, 1976) 185.
- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- 161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 164. ANON.: OIL & GAS J. (SEP. 5, 1977 A) 53.
- 169. CLARIDGE: PAPER SPE 6848 (1977).
- 170. DOSCHER: OIL & GAS J. (MAY 2, 1977) 213.
- 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
- 179. RUMP, HARE, PORTER: D.O.E. CONTRACT (1977).
- 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
- 182. SIAS: U.S. PATENT 4,058,467 (NOV. 15, 1977).
- 187. ANON.: OIL & GAS J. (SEP. 18, 1978) 67.
- S 195. HARE, PERLICH, ROBINSON, SHAH, ZIMMERMAN: D.O.E. CONTRACT (1978).
- U 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- B 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
- J 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- E 203. RUMP, SHAH, COVER: D.O.E. CONTRACT (1978).
- C 205. SHAH, WITTMAYER: D.O.E. CONTRACT (1978).
- T 206. STALKUP: PAPER SPE 7042 (1978).
- 208. WEISZ, ZAHNER: U.S. PATENT 4,093,029 (JUNE 6, 1978).
- 210. ANON.: OIL & GAS J. (APR. 23, 1979) 40.
- S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).
- S 13. PRATS, CLOSMAN: U.S. PAT. 3,259,187 (JULY 5, 1966).

S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.
S 59. CROW: OIL & GAS J. (JAN. 16, 1978) 23.

DETAILED SUBJECT CATEGORIES

1. THEORETICAL PHYSICAL PROPERTIES

- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- L 47. MUIRBRUOK: PH.D. DISSERTATION, U. CA. (1964).
- I 48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
- S 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
- T 61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
- 62. DAVIES, PONTER, CRAINE: CAN. J. CH. ENG. (DEC., 1967) 372.
- 76. BEER: CAN. J. CH. ENG. (FEB., 1969) 92.
- 78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
- 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
- 82. VAIROGS: PH.D. DISSERTATION, OK. STATE U. (1969).
- 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
- 188. BAKER, LUKS: PAPER SPE 7478 (1978).
- S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
- S 11. REAMER, SAGE: J. CH. & ENG. DATA (JAN., 1965) 49.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
- S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
- S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

2. EXPERIMENTAL PHYS. PROPERTIES

- 3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
- 8. POETTMANN: TRANS., AIME (1951) 141.
- 11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
- 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
- 32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
- 47. MUIRBRUOK: PH.D. DISSERTATION, U. CA. (1964).
- 48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
- 56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
- 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
- 61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
- 62. DAVIES, PONTER, CRAINE: CAN. J. CH. ENG. (DEC., 1967) 372.
- 76. BEER: CAN. J. CH. ENG. (FEB., 1969) 92.
- 78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
- S 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
- U 82. VAIROGS: PH.D. DISSERTATION, OK. STATE U. (1969).
- B 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
- J 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
- E 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- C 94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
- T 97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
- 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
- 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
- 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
- 122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.

- 127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
- 128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
- 151. DAVALOS, ANDERSON, PHELPS, KIDNAY: J. CH. & ENG. DATA (1976) 81.
- 155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
- 188. BAKER, LUKS: PAPER SPE 7478 (1978).
- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- 202. PETERSON: PET. ENG. (NOV., 1978) 40.
- 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
- S 26. ASANO, NAKAHARA, KOBAYASHI: J. CH. & ENG. DATA (1971) 16.
- S 28. SARASHINA, ARAI, SAITO: J. CH. ENG. JAPAN (1971) 379.
- S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
- S 37. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 B) 416.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 49. HAMAM, LU: J. CH. & ENG. DATA (1976 A) 200.
- S 53. HWANG, LIN, CHAPPELEAR, KOBAYASHI: J. CH. & ENG. DATA (1976) 493.
- S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

3. CORRELATIONS

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- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
- 32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
- 45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
- 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
- 48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
- 56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
- 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
- 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
- 61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
- 65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.
- 76. BEER: CAN. J. CH. ENG. (FEB., 1969) 92.
- 82. VAIROGS: PH.D. DISSERTATION, OK. STATE U. (1969).
- 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
- 94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
- 97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
- 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
- 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
- 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
- 122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
- 128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
- 153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
- 155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
- 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
- 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 6. WILSON: TRANS., AIME (1960) 223.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.

S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

4. GENERAL PHASE BEHAVIOR

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14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
82. VAIRGS: PH.D. DISSERTATION, OK. STATE U. (1969).
93. VAIRGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
137. DEPARTMENT OF ENERGY: (1975 -).
154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
188. BAKER, LUKS: PAPER SPE 7478 (1978).
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
S 11. REAMER, SAGE: J. CH. & ENG. DATA (JAN., 1965) 49.
S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
S 26. ASANO, NAKAHARA, KOBAYASHI: J. CH. & ENG. DATA (1971) 16.
S 28. SARASHINA, ARAI, SAITO: J. CH. ENG. JAPAN (1971) 379.
S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.
S 49. HAMAM, LU: J. CH. & ENG. DATA (1976 A) 200.
S 53. HWANG, LIN, CHAPPELEAR, KOBAYASHI: J. CH. & ENG. DATA (1976) 493.
S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

5. PURE CARBON DIOXIDE BEHAVIOR

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32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
103. KESTIN, RO, WAKEHAM: J. CH. PH. (APR. 15, 1972) 4114.
120. FESMIRE, SIMON, DICHARRY, VORHIS: PAPER SPE 5052 (1974).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).

6. HYDROCARBON COMPONENTS

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3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.

48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
51. SIMON, GRAUE: TRANS., AIME (1965) 102.
56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
62. DAVIES, PONTER, CRAINE: CAN. J. CH. ENG. (DEC., 1967) 372.
78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
82. VAIRGOS: PH.D. DISSERTATION, OK. STATE U. (1969).
84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
151. DAVALOS, ANDERSON, PHELPS, KIDNAY: J. CH. & ENG. DATA (1976) 81.
154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
188. BAKER, LUKS: PAPER SPE 7478 (1978).
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
202. PETERSON: PET. ENG. (NOV., 1978) 40.
- S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 11. REAMER, SAGE: J. CH. & ENG. DATA (JAN., 1965) 49.
- S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
- S 26. ASANO, NAKAHARA, KOBAYASHI: J. CH. & ENG. DATA (1971) 16.
- S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
- S 37. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 B) 416.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
- S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.
- S 49. HAMAM, LU: J. CH. & ENG. DATA (1976 A) 200.
- S 53. HWANG, LIN, CHAPPELEAR, KOBAYASHI: J. CH. & ENG. DATA (1976) 493.
- S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

7. NON-HYDROCARBON COMPONENTS

3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.

78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
 82. VAIRGOS: PH.D. DISSERTATION, OK. STATE U. (1969).
 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
 L 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
 I 127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
 S 128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
 T 153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
 202. PETERSON: PET. ENG. (NOV., 1978) 40.
 S 28. SARASHINA, ARAI, SAITO: J. CH. ENG. JAPAN (1971) 379.

8. BINARY SYSTEMS

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5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
 56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
 61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
 65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.
 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
 94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
 122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
 127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
 128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
 151. DAVALOS, ANDERSON, PHELPS, KIDNAY: J. CH. & ENG. DATA (1976) 81.
 153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
 188. BAKER, LUKS: PAPER SPE 7478 (1978).
 S 11. REAMER, SAGE: J. CH. & ENG. DATA (JAN., 1965) 49.
 S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
 S S 28. SARASHINA, ARAI, SAITO: J. CH. ENG. JAPAN (1971) 379.
 U S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
 B S 37. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 B) 416.
 J S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
 E S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
 C S 49. HAMAM, LU: J. CH. & ENG. DATA (1976 A) 200.
 T S 53. HWANG, LIN, CHAPPELEAR, KOBAYASHI: J. CH. & ENG. DATA (1976) 493.
 S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

9. TERNARY SYSTEMS

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14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.
78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
115. BURNETT: U.S. PATENT 3,811,502 (MAY 21, 1974 A).
127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
149. BURNETT: CAN. PATENT 981,575 (JAN. 13, 1976).
151. DAVALOS, ANDERSON, PHELPS, KIDNAY: J. CH. & ENG. DATA (1976) 81.
155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
- S 26. ASANO, NAKAHARA, KOBAYASHI: J. CH. & ENG. DATA (1971) 16.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.

10. MULTICOMPONENT SYSTEMS

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8. POETTMANN: TRANS., AIME (1951) 141.
15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
82. VAIROGS: PH.D. DISSERTATION, OK. STATE U. (1969).
84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
188. BAKER, LUKS: PAPER SPE 7478 (1978).
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
202. PETERSON: PET. ENG. (NOV., 1978) 40.
209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
- S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

11. EQUATIONS OF STATE

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- L 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
 I 48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
 S 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
 T 61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
 76. BEER: CAN. J. CH. ENG. (FEB., 1969) 92.
 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
 120. FESMIRE, SIMON, DICHARRY, VORHIS: PAPER SPE 5052 (1974).
 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
 122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
 153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
 155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
 188. BAKER, LUKS: PAPER SPE 7478 (1978).
 S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
 S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
 S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
 S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

12. EFFECTS OF PRESSURE

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3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
 8. POETTMANN: TRANS., AIME (1951) 141.
 22. HOLM: TRANS., AIME (1959) 225.
 32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
 45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
 48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
 56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
 61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
 65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.
 78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
 82. VAIRGS: PH.D. DISSERTATION, OK. STATE U. (1969).
 S 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
 U 88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
 B 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
 J 94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
 E 97. YUDOVICH, ROBINSON, CHAU: A.I.CH.E. J. (SEP., 1971) 1152.
 C 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
 T 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
 120. FESMIRE, SIMON, DICHARRY, VORHIS: PAPER SPE 5052 (1974).
 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
 122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.

127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.
151. DAVALOS, ANDERSON, PHELPS, KIDNAY: J. CH. & ENG. DATA (1976) 81.
153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
188. BAKER, LUKS: PAPER SPE 7478 (1978).
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
202. PETERSON: PET. ENG. (NOV., 1978) 40.
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
- S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
- S 28. SARASHINA, ARAI, SAITO: J. CH. ENG. JAPAN (1971) 379.
- S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
- S 49. HAMAM, LU: J. CH. & ENG. DATA (1976 A) 200.
- S 53. HWANG, LIN, CHAPPELEAR, KOBAYASHI: J. CH. & ENG. DATA (1976) 493.
- S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

13. EFFECTS OF TEMPERATURE

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3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
8. POETTMANN: TRANS., AIME (1951) 141.
22. HOLM: TRANS., AIME (1959) 225.
32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
51. SIMON, GRAUE: TRANS., AIME (1965) 102.
56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
61. BUXTON, CAMPBELL: SOC. PET. ENG. J. (MAR., 1967) 80.
65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.
78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
82. VAIRGS: PH.D. DISSERTATION, OK. STATE U. (1969).
87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
103. KESTIN, RO, WAKEHAM: J. CH. PH. (APR. 15, 1972) 4114.
106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
120. FESMIRE, SIMON, DICHARRY, VORHIS: PAPER SPE 5052 (1974).
121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.

- 151. DAVALOS, ANDERSON, PHELPS, KIDNAY: J. CH. & ENG. DATA (1976) 81.
- 153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
- 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
- 155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 188. BAKER, LUKS: PAPER SPE 7478 (1978).
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- L 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- I S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
- T S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
- S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
- S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
- S 53. HWANG, LIN, CHAPPELEAR, KOBAYASHI: J. CH. & ENG. DATA (1976) 493.
- S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

14. DENSITY

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- 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
- 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
- 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
- 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
- 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
- 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- 202. PETERSON: PET. ENG. (NOV., 1978) 40.
- S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
- S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
- S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

15. OIL SWELLING

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- 11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
- 45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
- S 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
- U 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- B 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
- J 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- E 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- C 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- T 202. PETERSON: PET. ENG. (NOV., 1978) 40.

16. SOLUBILITY

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- 3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
- 11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
- 14. FRANCIS: J. PH. CH. (DEC., 1954) 1099.
- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 22. HOLM: TRANS., AIME (1959) 225.
- 45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
- 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
- 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
- 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX, A&M U. (1970).
- 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
- 88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
- 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- 202. PETERSON: PET. ENG. (NOV., 1978) 40.

17. VISCOSITY

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- 3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
- 11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
- 32. KENNEDY, THODOS: A.I.C.H.E. J. (DEC., 1961) 625.
- 45. WELKER, DUNLOP: TRANS., AIME (1963) 873.
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
- 56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
- 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX, A&M U. (1970).
- 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
- 94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
- 103. KESTIN, RO, WAKEHAM: J. CH. PH. (APR. 15, 1972) 4114.
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
- 207. WATKINS: PAPER SPE 7474 (1978).
- S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

18. INTERFACIAL TENSION

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- 3. BEECHER, PARKHURST: TRANS., AIME (1926) 51.
- 11. JOHNSON, MACFARLANE, BRESTON: PROD. MO. (NOV., 1952) 16.
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).

19. REFRACTIVE INDEX

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- S 36. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 A) 298.
- S 37. BESSERER, ROBINSON: J. CH. & ENG. DATA (1973 B) 416.
- S 54. KALRA, KRISHNAN, ROBINSON: J. CH. & ENG. DATA (1976) 222.

20. EQUILIBRIUM RATIOS

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S
T
- 8. POETTMANN: TRANS., AIME (1951) 141.
 - 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
 - 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
 - 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
 - 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
 - 65. LENOIR: HYDROCARBON PROCESSING (JAN., 1967) 191.
 - 78. GUPTA: PH.D. DISSERTATION, PA. STATE U. (1969).
 - 80. JENSEN: PH.D. DISSERTATION, U. KS. (1969).
 - 82. VAIROGS: PH.D. DISSERTATION, OK. STATE U. (1969).
 - 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
 - 97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
 - 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
 - 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
 - 122. HAMAM, LU: CAN. J. CH. ENG. (APR., 1974) 283.
 - 153. EVELEIN, MOORE, HEIDEMANN: IND. & ENG. CH. (1976) 423.
 - 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
 - 155. HAMAM, LU: CAN. J. CH. ENG. (AUG., 1976 B) 333.
 - 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
 - 184. SIMON, ROSMAN, ZANA: PAPER SPE 6387 (1977 B).
 - 188. BAKER, LUKS: PAPER SPE 7478 (1978).
 - 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
 - 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
 - 202. PETERSON: PET. ENG. (NOV., 1978) 40.
 - S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
 - S 26. ASANO, NAKAHARA, KOBAYASHI: J. CH. & ENG. DATA (1971) 16.
 - S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.
 - S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

21. DIFFUSION COEFFICIENTS

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- 32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.
- 62. DAVIES, PONTER, CRAINE: CAN. J. CH. ENG. (DEC., 1967) 372.
- 94. WEISSMAN, DUBRO: J. CH. PH. (MAR., 1971) 1881.
- 103. KESTIN, RO, WAKEHAM: J. CH. PH. (APR. 15, 1972) 4114.
- 128. TAKAHASHI: BULL. CH. SOC. JAPAN (JUNE, 1974) 1342.

22. OIL PROPERTIES CHARACTERIZATION

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- S
U
B
J
E
C
T
- 51. SIMON, GRAUE: TRANS., AIME (1965) 102.
 - 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).

23. MISCIBILITY, UNDIFFERENTIATED

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- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.

24. FIRST CONTACT MISCIBILITY

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- 27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- 202. PETERSON: PET. ENG. (NOV., 1978) 40.
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.

25. MULTIPLE CONTACT MISCIBILITY

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- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
- 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
- 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 188. BAKER, LUKS: PAPER SPE 7478 (1978).
- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- 202. PETERSON: PET. ENG. (NOV., 1978) 40.
- 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 25. YARBOROUGH, SMITH: SOC. PET. ENG. J. (SEP., 1970) 298.
- S 39. METCALFE, FUSSELL, SHELTON: SOC. PET. ENG. J. (JUNE, 1973) 147.

26. DISPERSION

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- 207. WATKINS: PAPER SPE 7474 (1978).

27. WETTABILITY

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- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).

28. EMULSIONS

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- 110. HOLM: PET. ENG. (DEC., 1973) 17.

29. FOAMS

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- 110. HOLM: PET. ENG. (DEC., 1973) 17.

30. OTHER PHYSICAL PROPERTIES

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- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 32. KENNEDY, THODOS: A.I.CH.E. J. (DEC., 1961) 625.

- 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
- 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
- 58. JOFFE, ZUDKEVITCH: I & EC FUND. (NOV., 1966) 455.
- 88. HEARN, HOLMS: U.S. PATENT 3,620,304 (NOV. 16, 1971).
- 97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
- 98. BISHNOI, ROBINSON: HYDROCARBON PROCESSING (NOV., 1972) 150.
- 102. HSI, LU: CAN. J. CH. ENG. (FEB., 1972) 144.
- L 120. FESMIRE, SIMON, DICHARRY, VORHIS: PAPER SPE 5052 (1974).
- I 121. GUGNONI, ELDRIGE, OKAY, LEE: A.I.CH.E. J. (MAR., 1974) 357.
- S 127. KULKARNI, LUKS, KOHN: J. CH. & ENG. DATA (1974) 349.
- T S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
- S 11. REAMER, SAGE: J. CH. & ENG. DATA (JAN., 1965) 49.
- S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
- S 16. LEE: OIL & GAS J. (OCT. 28, 1968) 84.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 45. TEJA: A.I.CH.E. J. (MAY, 1975) 618.
- S 48. FUSSELL, SHELTON, GRIFFITH: SOC. PET. ENG. J. (DEC., 1976 A) 310.

31. LAB. PROCEDURES AND APPARATUS

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- 5. OLDS, REAMER, SAGE, LACEY: IND. & ENG. CH. (MAR., 1949) 475.
- 9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
- 12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
- 15. MELDRUM, NIELSEN: PROD. MO. (AUG., 1955) 22.
- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
- 22. HOLM: TRANS., AIME (1959) 225.
- 29. HABERMANN: TRANS., AIME (1960) 264.
- 31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
- 36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
- 43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
- 44. REAMER, SAGE: J. CH. & ENG. DATA (OCT., 1963) 508.
- 47. MUIRBROOK: PH.D. DISSERTATION, U. CA. (1964).
- 48. BUXTON: PH.D. DISSERTATION, U. OK. (1965).
- 56. DEWITT, THODOS: CAN. J. CH. ENG. (JUNE, 1966) 148.
- 57. GILMORE, COMINGS: A.I.CH.E. J. (NOV., 1966) 1172.
- 67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
- 69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
- 76. BEER: CAN. J. CH. ENG. (FEB., 1969) 92.
- 87. COAN, KING: J. AM. CH. SOC. (APR., 1971) 1857.
- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- 97. YUDOVICH, ROBINSON, CHAO: A.I.CH.E. J. (SEP., 1971) 1152.
- 111. RIGHTMIRE, HANSHAW: WATER RESOURCES RES. (AUG., 1973) 958.
- 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
- S 126. HUANG, TRACHT: PAPER SPE 4735 (1974).
- U 137. DEPARTMENT OF ENERGY: (1975 -).
- B 178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
- J 207. WATKINS: PAPER SPE 7474 (1978).
- E 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- C 213. WANG, LOCKE: PAPER SPE 7953 (1979).
- T S 14. ROOF, BARON: J. CH. & ENG. DATA (JULY, 1967) 292.
- S 38. HUIE, LUKS, KOHN: J. CH. & ENG. DATA (1973) 311.
- S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

32. LABORATORY INJECTION PROCESS

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9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.
26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
29. HABERMANN: TRANS., AIME (1960) 264.
31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
42. KOVAL: TRANS., AIME (1963) 145.
43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).
53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
60. BOSTON: U.S. PATENT 3,346,046 (OCT. 10, 1967).
67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
71. BRIGHAM, DEW: U.S. PATENT 3,410,341 (NOV. 12, 1968).
72. FERRELL, MATHEWS: U.S. PATENT 3,392,782 (JULY 16, 1968).
74. SHARP: CAN. PATENT 785,071 (MAY 14, 1968).
84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
126. HUANG, TRACHT: PAPER SPE 4735 (1974).
135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
137. DEPARTMENT OF ENERGY: (1975 -).
167. BROWN, WU, KONOPNICKI: U.S. PATENT 4,004,636 (JAN. 25, 1977).
178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
202. PETERSON: PET. ENG. (NOV., 1978) 40.
209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
213. WANG, LOCKE: PAPER SPE 7953 (1979).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
- S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
- S 6. WILSON: TRANS., AIME (1960) 223.
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).

- S 58. RUSHING, THOMASSON, REYNOLDS, CRAWFORD: PET. ENG. (NOV., 1977) 26.
S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

33. SECONDARY RECOVERY (LAB. EXP.)

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- L 9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
I 10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
S 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
S 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
T 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.
26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
29. HABERMANN: TRANS., AIME (1960) 264.
31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
42. KOVAL: TRANS., AIME (1963) 145.
43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
60. BOSTON: U.S. PATENT 3,346,046 (OCT. 10, 1967).
67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
72. FERRELL, MATHEWS: U.S. PATENT 3,392,782 (JULY 16, 1968).
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
137. DEPARTMENT OF ENERGY: (1975 -).
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
167. BROWN, WU, KONOPNICKI: U.S. PATENT 4,004,636 (JAN. 25, 1977).
178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
202. PETERSON: PET. ENG. (NOV., 1978) 40.
207. WATKINS: PAPER SPE 7474 (1978).
S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
S 6. WILSON: TRANS., AIME (1960) 223.
S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).
S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

34. TERTIARY RECOVERY (LAB. EXP.)

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- S U B J E C T
9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.

40. HOLM: PROD. MO. (SEP., 1963 A) 6.
71. BRIGHAM, DEW: U.S. PATENT 3,410,341 (NOV. 12, 1968).
84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
126. HUANG, TRACHT: PAPER SPE 4735 (1974).
135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
137. DEPARTMENT OF ENERGY: (1975 -).
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
207. WATKINS: PAPER SPE 7474 (1978).
213. WANG, LOCKE: PAPER SPE 7953 (1979).
- S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).

35. SANDSTONE (LAB. EXP.)

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9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
42. KOVAL: TRANS., AIME (1963) 145.
46. WEST, ORTLOFF, REESON: U.S. PATENT 3,084,743 (APR. 9, 1963).
67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
71. BRIGHAM, DEW: U.S. PATENT 3,410,341 (NOV. 12, 1968).
72. FERRELL, MATHEWS: U.S. PATENT 3,392,782 (JULY 16, 1968).
84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
126. HUANG, TRACHT: PAPER SPE 4735 (1974).
135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
137. DEPARTMENT OF ENERGY: (1975 -).
141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
167. BROWN, WU, KONOPNICKI: U.S. PATENT 4,004,636 (JAN. 25, 1977).
178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
202. PETERSON: PET. ENG. (NOV., 1978) 40.
207. WATKINS: PAPER SPE 7474 (1978).
213. WANG, LOCKE: PAPER SPE 7953 (1979).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.

S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
 S 6. WILSON: TRANS., AIME (1960) 223.
 S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).

36. CARBONATE (LAB. EXP.)

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L 22. HOLM: TRANS., AIME (1959) 225.
 I 31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
 S 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
 T 37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
 67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
 207. WATKINS: PAPER SPE 7474 (1978).

37. MOBILITY RATIO (LAB. EXP.)

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16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
 20. BEESON, ORTLOFF: TRANS., AIME (1959) 336.
 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
 29. HABERMANN: TRANS., AIME (1960) 264.
 31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
 36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
 42. KOVAL: TRANS., AIME (1963) 145.
 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
 93. VAIRUGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
 207. WATKINS: PAPER SPE 7474 (1978).
 S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
 S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.

38. AREAL SWEEP (LAB. EXP.)

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16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
 29. HABERMANN: TRANS., AIME (1960) 264.
 31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
 33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).
 S 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
 U 36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
 B 42. KOVAL: TRANS., AIME (1963) 145.
 J 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
 E S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
 C S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
 T S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
 S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
 S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
 S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

39. LABORATORY INSTABILITIES

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- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
- 29. HABERMANN: TRANS., AIME (1960) 264.
- 31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
- 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
- 42. KOVAL: TRANS., AIME (1963) 145.
- 60. BOSTON: U.S. PATENT 3,346,046 (OCT. 10, 1967).
- 69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
- 86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
- 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
- 93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
- 169. CLARIDGE: PAPER SPE 6848 (1977).
- 201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
- 207. WATKINS: PAPER SPE 7474 (1978).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
- S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11

40. RESIDUAL SATURATION (LAB. EXP.)

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- 10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
- 12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
- 13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
- 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
- 22. HOLM: TRANS., AIME (1959) 225.
- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
- 31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
- 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
- 36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
- 37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
- 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
- 71. BRIGHAM, DEW: U.S. PATENT 3,410,341 (NOV. 12, 1968).
- 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
- 86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
- 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
- 96. WHITE: PET. ENG. (DEC., 1971) 58.
- 135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
- 137. DEPARTMENT OF ENERGY: (1975 -).
- 141. SHELTON, SCHNEIDER: SOC. PET. ENG. J. (JUNE, 1975) 217.
- 178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
- 181. SHELTON, YARBOROUGH: J. PET. TECH. (SEP., 1977) 1171.
- 201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
- 207. WATKINS: PAPER SPE 7474 (1978).
- 213. WANG, LOCKE: PAPER SPE 7953 (1979).
- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
- S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11

41. MISCIBILITY (LAB. EXP.)

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13. WHORTON, BROWNSCOMBE, DYES: U.S. PATENT 2,623,596 (DEC. 30, 1952).
17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
22. HOLM: TRANS., AIME (1959) 225.
27. BENHAM, DOWDEN, KUNZMAN: TRANS., AIME (1960) 229.
28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
29. HABERMANN: TRANS., AIME (1960) 264.
31. HOLM: A.I.CH.E. J. (JUNE, 1961) 179.
33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).
35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
40. HOLM: PROD. MO. (SEP., 1963 A) 6.
42. KOVAL: TRANS., AIME (1963) 145.
53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
60. BOSTON: U.S. PATENT 3,346,046 (OCT. 10, 1967).
69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
71. BRIGHAM, DEW: U.S. PATENT 3,410,341 (NOV. 12, 1968).
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
118. BURNETT, LIM: U.S. PATENT 3,811,503 (MAY 21, 1974 D).
126. HUANG, TRACHT: PAPER SPE 4735 (1974).
133. BURNETT, LIM: CAN. PATENT 980,245 (DEC. 23, 1975 A).
135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
137. DEPARTMENT OF ENERGY: (1975 -).
194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
207. WATKINS: PAPER SPE 7474 (1978).
209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
213. WANG, LOCKE: PAPER SPE 7953 (1979).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
- S 6. WILSON: TRANS., AIME (1960) 223.
- S 7. HUTCHINSON, BRAUN: A.I.CH.E. J. (1961) 64.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 58. RUSHING, THOMASSON, REYNOLDS, CRAWFORD: PET. ENG. (NOV., 1977) 26.

42. WETTABILITY (LAB. EXP.)

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6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.

43. OIL CHARACTERIZATION (LAB.)

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- 12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
- 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
- 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
- 67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
- 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
- 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
- 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
- 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 58. RUSHING, THOMASSON, REYNOLDS, CRAWFORD: PET. ENG. (NOV., 1977) 26.

44. HEAVY OIL (LAB. EXP.)

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- 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
- 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
- 67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
- S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
- S 58. RUSHING. THOMASSON, REYNOLDS, CRAWFORD: PET. ENG. (NOV., 1977) 26.

45. CARBONATED WATER (LAB. EXP.)

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- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
- 7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
- 9. SAXON, BRESTON, MACFARLANE: PROD. MO. (NOV., 1951) 8.
- 12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
- 22. HOLM: TRANS., AIME (1959) 225.
- 25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
- 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
- 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
- 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
- 137. DEPARTMENT OF ENERGY: (1975 -).

46. FLUE GAS (LAB. EXP.)

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- 37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
- 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).

47. ADDITIVES (LAB. EXP.)

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- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
- 7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
- 12. MACFARLANE, BRESTON, NEIL: PROD. MO. (NOV., 1952) 23.
- 64. GILCHRIST: U.S. PATENT 3,344,857 (OCT., 1967).
- 72. FERRELL, MATHEWS: U.S. PATENT 3,392,782 (JULY 16, 1968).
- 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
- 117. BURNETT, ALSTON, LIM: U.S. PATENT 3,811,501 (MAY 21, 1974 C).
- 118. BURNETT, LIM: U.S. PATENT 3,811,503 (MAY 21, 1974 D).

- 126. HUANG, TRACHT: PAPER SPE 4735 (1974).
- 133. BURNETT, LIM: CAN. PATENT 980,245 (DEC. 23, 1975 A).
- 134. BURNETT, LIM, ALSTON: CAN. PATENT 980,244 (DEC. 23, 1975 B).

48. IMPURITIES (LAB. EXP.)

- L 93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
- I 117. BURNETT, ALSTON, LIM: U.S. PATENT 3,811,501 (MAY 21, 1974 C).
- S 134. BURNETT, LIM, ALSTON: CAN. PATENT 980,244 (DEC. 23, 1975 B).
- T 137. DEPARTMENT OF ENERGY: (1975 -).

49. OTHER LABORATORY STUDIES

- 10. BRESTON, MACFARLANE: PROD. MO. (NOV., 1952) 36.
- 16. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,437 (NOV. 22, 1955 A).
- 17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
- 20. BEESON, ORTLOFF: TRANS., AIME (1959) 338.
- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
- 22. HOLM: TRANS., AIME (1959) 225.
- 25. MARTIN: U.S. PATENT 2,875,833 (MAR. 3, 1959 B).
- 26. MARTIN, HESSEL, HAMMER, RUST: U.S. PATENT 2,875,832 (MAR. 3, 1959 C)
- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
- 29. HABERMANN: TRANS., AIME (1960) 264.
- 31. HOLM: A.I.C.H.E. J. (JUNE, 1961) 179.
- 33. SLOBOD, KOCH: U.S. PATENT 2,968,350 (JAN. 17, 1961).
- 35. HOLM: U.S. PATENT 3,065,790 (NOV. 27, 1962 A).
- 36. HOLM, CSASZAR: SOC. PET. ENG. J. (JUNE, 1962 B) 129.
- 37. BOND, HOLM: U.S. PATENT 3,072,185 (JAN. 8, 1963).
- 40. HOLM: PROD. MO. (SEP., 1963 A) 6.
- 42. KOVAL: TRANS., AIME (1963) 145.
- 43. MENZIE, NIELSEN: TRANS., AIME (1963) 1247.
- 46. WEST, ORTLOFF, BEESON: U.S. PATENT 3,064,743 (APR. 9, 1963).
- 50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).
- 64. GILCHRIST: U.S. PATENT 3,344,857 (OCT., 1967).
- 67. MULDER: U.S. PATENT 3,353,597 (NOV. 21, 1967).
- 69. THOMPSON: SOC. PET. ENG. J. (SEP., 1967) 319.
- 72. FERRELL, MATHEWS: U.S. PATENT 3,392,782 (JULY 16, 1968).
- 74. SHARP: CAN. PATENT 785,071 (MAY 14, 1968).
- 84. PARTOVI-NAJAFABADI: PH.D. DISSERTATION, TX. A&M U. (1970).
- 89. HOLM: J. PET. TECH. (DEC., 1971) 1475.
- 93. VAIROGS: U.S. PATENT 3,623,552 (NOV. 30, 1971).
- 116. BURNETT: U.S. PATENT 3,641,406 (OCT. 15, 1974 B).
- S 117. BURNETT, ALSTON, LIM: U.S. PATENT 3,811,501 (MAY 21, 1974 C).
- U 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
- B 126. HUANG, TRACHT: PAPER SPE 4735 (1974).
- J 134. BURNETT, LIM, ALSTON: CAN. PATENT 980,244 (DEC. 23, 1975 B).
- E 135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
- C 137. DEPARTMENT OF ENERGY: (1975 -).
- T 140. SCHREMP, ROBERSON: SOC. PET. ENG. J. (JUNE, 1975) 227.
- 167. BROWN, WU, KONOPNICKI: U.S. PATENT 4,004,636 (JAN. 25, 1977).
- 178. ROSMAN, ZANA: PAPER SPE 6723 (1977).
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- 201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)

- 202. PETERSON: PET. ENG. (NOV., 1978) 40.
- 213. WANG, LOCKE: PAPER SPE 7953 (1979).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
- S 3. KOCH, SLOBOD: TRANS., AIME (1957) 40.
- S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
- S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
- S 7. HUTCHINSON, BRAUN: A.I.C.H.E. J. (1961) 64.
- S 12. REISBERG: U.S. PATENT 3,174,542 (MAR. 23, 1965).
- S 58. RUSHING, THOMASSON, REYNOLDS, CRAWFORD: PET. ENG. (NOV., 1977) 26.
- S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

50. SANDSTONE FIELD

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- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
- 7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
- 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 63. DAVISON: WORLD OIL (MAR., 1967) 98.
- 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
- 114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
- 137. DEPARTMENT OF ENERGY: (1975 -).
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 165. ANON.: OIL & GAS J. (AUG. 29, 1977 C) 25.
- 171. HANSEN: PAPER SPE 6747 (1977).
- 173. MCREE: PET. ENG. (NOV., 1977) 52.
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- 185. STRIGHT, AZIZ, SETTARI, STARRATT: J. PET. TECH. (OCT., 1977) 1248.
- 192. CONNER: D.O.E. CONTRACT (1978).
- 197. MCREE: D.O.E. CONTRACT (1978).
- 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- 201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
- 204. SAN FILIPPO, GUCKERT: D.O.E. CONTRACT (1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
- S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
- S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).
- S 21. BLANTON, MCCASKILL, HERBECK: J. PET. TECH. (OCT., 1970) 1209.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 27. EMMETT, BEAVER, MCCAULEY: J. PET. TECH. (FEB., 1971) 161.
- S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
- S 32. CONNALLY: PAPER SPE 3775 (1972).
- S 34. HOLM: PAPER SPE 3774 (1972).
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.
- S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
- S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

51. CARBONATE FIELD

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- 75. ANON.: OIL & GAS J. (SEP. 8, 1969 B) 36.
- 92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
- 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- L 110. HOLM: PET. ENG. (DEC., 1973) 17.
- I 119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
- S 123. HENDERSON: PAPER SPE 4737 (1974 A).
- T 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
- 136. CROCKETT: PET. ENG. (NOV., 1975) 44.
- 138. FAULKNER: PAPER SPE 5539 (1975).
- 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 146. ANON.: OIL & GAS J. (NOV. 1, 1976 C) 26.
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 172. JOHNSTON: PAPER SPE 6388 (1977).
- 173. MCREE: PET. ENG. (NOV., 1977) 52.
- 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
- 176. OFFERINGA: U.S. PATENT 4,042,029 (AUG. 16, 1977).
- 177. PONTIOUS, THAM: PAPER SPE 6390 (1977).
- 189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
- 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- 191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
- 193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
- 196. KANE: PAPER SPE 7091 (1978).
- 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
- S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
- S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
- S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
- S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
- S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 867.

52. FRACTURED RESERVOIRS

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- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 172. JOHNSTON: PAPER SPE 6388 (1977).
- 173. MCREE: PET. ENG. (NOV., 1977) 52.
- 176. OFFERINGA: U.S. PATENT 4,042,029 (AUG. 16, 1977).
- 192. CONNER: D.O.E. CONTRACT (1978).
- 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
- 211. CONNER, WATTS: D.O.E. CONTRACT (1978).

53. SOAK OPERATION

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- 2. WAITZ: U.S. PATENT 1,295,243 (FEB. 25, 1919).
- 50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).
- 63. DAVISON: WORLD OIL (MAR., 1967) 98.
- 68. SANTOURIAN: U.S. PATENT 3,295,601 (JAN. 3, 1967).
- 73. HOLM, WOERTZ: U.S. PATENT 3,411,583 (NOV. 19, 1968).
- 74. SHARP: CAN. PATENT 785,071 (MAY 14, 1968).
- 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
- 112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 185. STRIGHT, AZIZ, SETTARI, STARRATT: J. PET. TECH. (OCT., 1977) 1248
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).

54. WATER INJECTION

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- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
- 7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
- 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
- 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
- 52. ANON.: OIL & GAS J. (APR. 18, 1966) 60.
- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 79. HOLM: CAN. PATENT 825,475 (OCT. 21, 1969).
- 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
- 85. RALFSNIDER: U.S. PATENT 3,532,165 (OCT. 6, 1970).
- 92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
- 96. WHITE: PET. ENG. (DEC., 1971) 58.
- 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
- 136. CRUICKETT: PET. ENG. (NOV., 1975) 44.
- 137. DEPARTMENT OF ENERGY: (1975 -).
- 138. FAULKNER: PAPER SPE 5539 (1975).
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 171. HANSEN: PAPER SPE 6747 (1977).
- 172. JOHNSTON: PAPER SPE 6388 (1977).
- 173. MCKEE: PET. ENG. (NOV., 1977) 52.
- 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- 189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
- 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- 191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
- 192. CONNER: D.O.E. CONTRACT (1978).
- 196. KANE: PAPER SPE 7091 (1978).
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).

- 204. SAN FILIPPO, GUCKERT: D.O.E. CONTRACT (1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
- S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
- S 21. BLANTON, MCCASKILL, HERBECK: J. PET. TECH. (OCT., 1970) 1209.
- L S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- I S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
- S S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
- T S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
- S 32. CONNALLY: PAPER SPE 3775 (1972).
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 34. HOLM: PAPER SPE 3774 (1972).
- S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.
- S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
- S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.

55. FIELD SECONDARY RECOVERY

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- 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
- 4. STRAIGHT: U.S. PATENT 1,978,655 (OCT. 30, 1934).
- 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
- 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
- 34. STONE: U.S. PATENT 2,944,373 (AUG. 1, 1961).
- 50. SHARP: U.S. PATENT 3,174,543 (MAR. 23, 1965).
- 52. ANON.: OIL & GAS J. (APR. 18, 1966) 60.
- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
- 63. DAVISON: WORLD OIL (MAR., 1967) 98.
- 74. SHARP: CAN. PATENT 785,071 (MAY 14, 1968).
- 79. HOLM: CAN. PATENT 825,475 (OCT. 21, 1969).
- 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
- 85. RALFSNIDER: U.S. PATENT 3,532,165 (OCT. 6, 1970).
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
- 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
- 123. HENDERSON: PAPER SPE 4737 (1974 A).
- 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
- 138. FAULKNER : PAPER SPE 5539 (1975).
- S 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
- U 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- B 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- J 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- E 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- C 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- T 165. ANON.: OIL & GAS J. (AUG. 29, 1977 C) 25.
- 172. JOHNSTON: PAPER SPE 6388 (1977).
- 173. MCCREE: PET. ENG. (NOV., 1977) 52.
- 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
- 177. PONTIOUS, THAM: PAPER SPE 6390 (1977).

- 185. STRIGHT, AZIZ, SETTARI, STARRATT: J. PET. TECH. (OCT., 1977) 1248.
- 196. KANE: PAPER SPE 7091 (1978).
- 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- 212. DOSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
- S 1. BAYS: U.S. PATENT 2,135,319 (NOV. 1, 1938).
- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
- S 18. ANON.: OIL & GAS J. (SEP. 1, 1969 A) 66.
- S 19. BLEAKLEY: OIL & GAS J. (OCT. 27, 1969) 67.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
- S 27. EMMETT, BEAVER, MCCAULEY: J. PET. TECH. (FEB., 1971) 161.
- S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
- S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
- S 32. CONNALLY: PAPER SPE 3775 (1972).
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
- S 55. ANON.: OIL & GAS J. (SEP. 12, 1977 B) 54.
- S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

56. FIELD TERTIARY RECOVERY

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- 6. MARTIN: PROD. MO. (JULY, 1951 A) 18.
- 7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
- 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
- 75. ANON.: OIL & GAS J. (SEP. 8, 1969 B) 36.
- 79. HOLM: CAN. PATENT 825,475 (OCT. 21, 1969).
- 92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
- 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
- 119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
- 136. CROCKETT: PET. ENG. (NOV., 1975) 44.
- 137. DEPARTMENT OF ENERGY: (1975 -).
- 138. FAULKNER : PAPER SPE 5539 (1975).
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 146. ANON.: OIL & GAS J. (NOV. 1, 1976 C) 26.
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 171. HANSEN: PAPER SPE 6747 (1977).
- 172. JOHNSTON: PAPER SPE 6388 (1977).
- 173. MCCREE: PET. ENG. (NOV., 1977) 52.
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
- 189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
- 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- 191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
- 192. CONNER: D.O.E. CONTRACT (1978).

193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
 201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978).
 204. SAN FILIPPO, GUCKERT: D.O.E. CONTRACT (1978).
 206. STALKUP: PAPER SPE 7042 (1978).
 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
 L 212. DOSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
 I S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
 S S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
 T S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
 S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
 S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
 S 27. EMMETT, BEAVER, MCCAULEY: J. PET. TECH. (FEB., 1971) 161.
 S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
 S 32. CONNALLY: PAPER SPE 3775 (1972).
 S 34. HOLM: PAPER SPE 3774 (1972).
 S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).
 S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
 S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
 S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
 S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
 S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 867.

57. FIELD MISCIBLE APPLICATION

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23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).
 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
 29. HABERMANN: TRANS., AIME (1960) 264.
 34. STONE: U.S. PATENT 2,944,373 (AUG. 1, 1961).
 52. ANON.: OIL & GAS J. (APR. 18, 1966) 60.
 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
 54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
 68. SANTOURIAN: U.S. PATENT 3,295,601 (JAN. 3, 1967).
 73. HOLM, WOERTZ: U.S. PATENT 3,411,583 (NOV. 19, 1968).
 79. HOLM: CAN. PATENT 825,475 (OCT. 21, 1969).
 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
 110. HOLM: PET. ENG. (DEC., 1973) 17.
 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
 114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
 119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
 123. HENDERSON: PAPER SPE 4737 (1974 A).
 S 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
 U 136. CROCKETT: PET. ENG. (NOV., 1975) 44.
 B 138. FAULKNER: PAPER SPE 5539 (1975).
 J 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
 E 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
 C 146. ANON.: OIL & GAS J. (NOV. 1, 1976 C) 26.
 T 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).

165. ANON.: OIL & GAS J. (AUG. 29, 1977 C) 25.
171. HANSEN: PAPER SPE 6747 (1977).
172. JOHNSTON: PAPER SPE 6388 (1977).
173. MCREE: PET. ENG. (NOV., 1977) 52.
174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
177. PONTIOUS, THAM: PAPER SPE 6390 (1977).
180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).
192. CONNER: D.O.E. CONTRACT (1978).
193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
196. KANE: PAPER SPE 7091 (1978).
199. NORAN: OIL & GAS J. (MAR. 27, 1978).
200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
204. SAN FILIPPO, GUCKERT: D.O.E. CONTRACT (1978).
206. STALKUP: PAPER SPE 7042 (1978).
211. CONNER, WATTS: D.O.E. CONTRACT (1979).
212. DOSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
- S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
- S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
- S 18. ANON.: OIL & GAS J. (SEP. 1, 1969 A) 66.
- S 19. BLEAKLEY: OIL & GAS J. (OCT. 27, 1969) 67.
- S 21. BLANTON, MCCASKILL, HERBECK: J. PET. TECH. (OCT., 1970) 1209.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
- S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
- S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
- S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
- S 32. CONNALLY: PAPER SPE 3775 (1972).
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 34. HOLM: PAPER SPE 3774 (1972).
- S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.
- S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
- S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
- S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
- S 51. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAR., 1976 B) 84.
- S 52. HERBECK, HEINTZ, HASTINGS: PET. ENG. (APR., 1976 C) 66.
- S 55. ANON.: OIL & GAS J. (SEP. 12, 1977 B) 54.
- S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 800.
- S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

58. FIELD IMMISCIBLE APPLICATION

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1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
73. HOLM, WOERTZ: U.S. PATENT 3,411,583 (NOV. 19, 1968).
96. WHITE: PET. ENG. (DEC., 1971) 58.
110. HOLM: PET. ENG. (DEC., 1973) 17.

- 112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 173. MCREE: PET. ENG. (NOV., 1977) 52.
- 185. STRIGHT, AZIZ, SETTARI, STARRATT: J. PET. TECH. (OCT., 1977) 1248.
- 193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
- L 199. NORAN: OIL & GAS J. (MAR. 27, 1978).
- I 206. STALKUP: PAPER SPE 7042 (1978).
- S 212. DUSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
- T S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).
- S 27. EMMETT, BEAVER, MCCAULEY: J. PET. TECH. (FEB., 1971) 161.
- S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).

59. FIELD MOBILITY RATIO

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- 29. HABERMANN: TRANS., AIME (1960) 264.
- 68. SANTOURIAN: U.S. PATENT 3,295,601 (JAN. 3, 1967).
- 73. HOLM, WOERTZ: U.S. PATENT 3,411,583 (NOV. 19, 1968).
- 96. WHITE: PET. ENG. (DEC., 1971) 58.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 173. MCREE: PET. ENG. (NOV., 1977) 52.
- 206. STALKUP: PAPER SPE 7042 (1978).
- S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
- S 27. EMMETT, BEAVER, MCCAULEY: J. PET. TECH. (FEB., 1971) 161.
- S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
- S 32. CONNALLY: PAPER SPE 3775 (1972).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
- S 51. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAR., 1976 B) 84.
- S 52. HERBECK, HEINTZ, HASTINGS: PET. ENG. (APR., 1976 C) 66.

60. FIELD AREAL SWEEP

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- 23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).
- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
- S 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- U 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- B 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- J 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- E 173. MCREE: PET. ENG. (NOV., 1977) 52.
- C 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- T 192. CONNER: D.O.E. CONTRACT (1978).
- 193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- 211. CONNER, WATTS: D.O.E. CONTRACT (1979).

- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
- S 32. CONNALLY: PAPER SPE 3775 (1972).
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 34. HOLM: PAPER SPE 3774 (1972).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.
- S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
- S 51. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAR., 1976 B) 84.
- S 52. HERBECK, HEINTZ, HASTINGS: PET. ENG. (APR., 1976 C) 66.

61. MOBILITY CONTROL

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- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 68. SANTOURIAN: U.S. PATENT 3,295,601 (JAN. 3, 1967).
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 165. ANON.: OIL & GAS J. (AUG. 29, 1977 C) 25.
- 192. CONNER: D.O.E. CONTRACT (1978).
- 196. KANE: PAPER SPE 7091 (1978).
- 206. STALKUP: PAPER SPE 7042 (1978).
- 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
- S 34. HOLM: PAPER SPE 3774 (1972).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.
- S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.

62. FIELD RESIDUAL SATURATIONS

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- 23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).
- 53. BRIGHAM, DEW, REED: U.S. PATENT 3,249,157 (MAY 3, 1966).
- 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
- 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
- 96. WHITE: PET. ENG. (DEC., 1971) 58.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 138. FAULKNER : PAPER SPE 5539 (1975).
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 173. MCCREE: PET. ENG. (NOV., 1977) 52.
- 189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
- 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- 191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).

193. GRADE, BLEVINS: PAPER SPE 7090 (1978 A).
 206. STALKUP: PAPER SPE 7042 (1978).
 212. DOSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
 S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
 S 21. BLANTON, MCCASKILL, HERBECK: J. PET. TECH. (OCT., 1970) 1209.
 S 27. EMMETT, BEAVER, MCCALED: J. PET. TECH. (FEB., 1971) 161.
 S 32. CONNALLY: PAPER SPE 3775 (1972).
 L S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
 J S 34. HOLM: PAPER SPE 3774 (1972).
 S S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
 T

63. CORROSION

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137. DEPARTMENT OF ENERGY: (1975 -).
 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
 140. SCHREMP, ROBERSON: SOC. PET. ENG. J. (JUNE, 1975) 227.
 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
 163. SPELLER: U.S. PATENT 3,964,545 (JUNE 22, 1976).
 171. HANSEN: PAPER SPE 6747 (1977).
 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
 175. NORAN: OIL & GAS J. (OCT. 17, 1977) 75.
 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
 S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
 S 35. PERRYMAN: PET. ENG. (FEB., 1972) 35.

64. COMPRESSION

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95. WEST, KROH: PET. ENG. (DEC., 1971 B) 63.
 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
 171. HANSEN: PAPER SPE 6747 (1977).
 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
 175. NORAN: OIL & GAS J. (OCT. 17, 1977) 75.
 179. RUMP, HAFE, PORTER: D.O.E. CONTRACT (1977).
 192. CONNER: D.O.E. CONTRACT (1978).
 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
 S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.

65. FLUE GAS FIELD APPLICATIONS

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S
 U 1. SQUIRES: U.S. PATENT 1,249,232 (DEC. 4, 1917).
 B 4. STRAIGHT: U.S. PATENT 1,978,655 (OCT. 30, 1934).
 J 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
 E 41. HOLM: U.S. PATENT 3,075,918 (JAN. 29, 1963 B).
 C 55. DAVISON: PET. EQUIP. (MAR.-APR., 1966) 6.
 T 63. DAVISON: WORLD OIL (MAR., 1967) 98.
 112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
 163. SPELLER: U.S. PATENT 3,964,545 (JUNE 22, 1976).
 S 18. ANON.: OIL & GAS J. (SEP. 1, 1969 A) 66.
 S 19. BLEAKLEY: OIL & GAS J. (OCT. 27, 1969) 67.

- S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
- S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
- S 52. HERBECK, HEINTZ, HASTINGS: PET. ENG. (APR., 1976 C) 66.
- S 55. ANON.: OIL & GAS J. (SEP. 12, 1977 B) 54.

66. ADDITIVES (FIELD)

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- 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
- 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
- S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.

67. IMPURITIES (FIELD)

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- 95. WEST, KROH: PET. ENG. (DEC., 1971 B) 63.
- 123. HENDERSON: PAPER SPE 4737 (1974 A).
- 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
- 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 172. JOHNSTON: PAPER SPE 6388 (1977).
- 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
- 175. NORAN: OIL & GAS J. (OCT. 17, 1977) 75.

68. FIELD ECONOMICS

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- 18. HAVERFIELD: U.S. PATENT 2,729,291 (JAN. 3, 1956).
- 63. DAVISON: WORLD OIL (MAR., 1967) 98.
- 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 136. CROCKETT: PET. ENG. (NOV., 1975) 44.
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 158. HOLM: J. PET. TECH. (JAN., 1976) 76.
- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 185. STRIGHT, AZIZ, SETTARI, SYARRATT: J. PET. TECH. (OCT., 1977) 1248.
- 193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
- 196. KANE: PAPER SPE 7091 (1978).
- 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
- 212. DOSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
- S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
- S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
- S 16. LEE: OIL & GAS J. (OCT. 28, 1968) 84.
- S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
- S 55. ANON.: OIL & GAS J. (SEP. 12, 1977 B) 54.

69. FACILITIES

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- 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
- 55. DAVISON: PET. EQUIP. (MAR.-APR., 1966) 6.

63. DAVISON: WORLD OIL (MAR., 1967) 98.
 92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
 137. DEPARTMENT OF ENERGY: (1975 -).
 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
 L 175. NORAN: OIL & GAS J. (OCT. 17, 1977) 75.
 I 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
 S 192. CONNER: D.O.E. CONTRACT (1978).
 T 196. KANE: PAPER SPE 7091 (1978).
 197. MCREE: D.O.E. CONTRACT (1978).
 201. PERRY, GUILLORY, BARON, JOHNSTON, MORANVILLE: D.O.E. CONTRACT (1978)
 208. WEISZ, ZAHNER: U.S. PATENT 4,093,029 (JUNE 6, 1978).
 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
 S 16. LEE: OIL & GAS J. (OCT. 28, 1968) 84.
 S 19. BLEAKLEY: OIL & GAS J. (OCT. 27, 1969) 67.
 S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
 S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
 S 35. PERRYMAN: PET. ENG. (FEB., 1972) 35.
 S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
 S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
 S 57. RUTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

70. OPERATIONS

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7. MARTIN: PROD. MO. (MAY, 1951 B) 13.
 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
 55. DAVISON: PET. EQUIP. (MAR.-APR., 1966) 6.
 63. DAVISON: WORLD OIL (MAR., 1967) 98.
 92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
 119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
 137. DEPARTMENT OF ENERGY: (1975 -).
 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
 166. BILHARTZ,: PAPER SPE 6389 (1977).
 171. HANSEN: PAPER SPE 6747 (1977).
 172. JOHNSTON: PAPER SPE 6388 (1977).
 174. NEWTON, MCCLAY: PAPER SPE 6391 (1977).
 175. NORAN: OIL & GAS J. (OCT. 17, 1977) 75.
 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).
 185. STRIGHT, AZIZ, SETTARI, STARRATT: J. PET. TECH. (OCT., 1977) 1248.
 S 192. CONNER: D.O.E. CONTRACT (1978).
 U 196. KANE: PAPER SPE 7091 (1978).
 B 197. MCREE: D.O.E. CONTRACT (1978).
 J 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
 E S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
 C S 19. BLEAKLEY: OIL & GAS J. (OCT. 27, 1969) 67.
 T S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
 S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
 S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
 S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
 S 35. PERRYMAN: PET. ENG. (FEB., 1972) 35.

- S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).
- S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
- S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
- S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

71. OTHER FIELD INFORMATION

- 2. WAITZ: U.S. PATENT 1,295,243 (FEB. 25, 1919).
- 4. STRAIGHT: U.S. PATENT 1,978,655 (OCT. 30, 1934).
- 18. HAVERFIELD: U.S. PATENT 2,729,291 (JAN. 3, 1956).
- 23. LINDAUER: U.S. PATENT 2,855,003 (MAY 5, 1959).
- 24. MARTIN: U.S. PATENT 2,875,830 (MAR. 3, 1959 A).
- 29. HABERMANN: TRANS., AIME (1960) 264.
- 30. HICKOK, CHRISTENSEN, RAMSAY: J. PET. TECH. (DEC., 1960) 20.
- 34. STONE: U.S. PATENT 2,944,373 (AUG. 1, 1961).
- 38. CRAWFORD, NEILL, BUCY, CRAWFORD: J. PET. TECH. (MAR., 1963) 237.
- 49. LEWIS: U.S. PATENT 3,193,006 (JULY 6, 1965).
- 52. ANON.: OIL & GAS J. (APR. 18, 1966) 60.
- 54. CONNALLY, ELFRINK, SHARP: U.S. PATENT 3,262,498 (JULY 26, 1966).
- 55. DAVISON: PET. EQUIP. (MAR.-APR., 1966) 6.
- 59. MURPHREE, OGORZALY: U.S. PATENT 3,256,933 (JUNE 21, 1966).
- 63. DAVISON: WORLD OIL (MAR., 1967) 98.
- 75. ANON.: OIL & GAS J. (SEP. 8, 1969 B) 36.
- 77. GILLILAND: U.S. PATENT 3,480,082 (NOV. 25, 1969).
- 81. KEITH: U.S. PATENT 3,442,332 (MAY 6, 1969).
- 83. HOLM, O'BRIEN: PAPER SPE 3103 (1970).
- 85. RALFSNIDER: U.S. PATENT 3,532,165 (OCT. 6, 1970).
- 92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
- 95. WEST, KROH: PET. ENG. (DEC., 1971 B) 63.
- 96. WHITE: PET. ENG. (DEC., 1971) 58.
- 99. BYARS: OIL & GAS J. (AUG. 7, 1972) 22.
- 104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
- 110. HOLM: PET. ENG. (DEC., 1973) 17.
- 112. SHELTON, MORRIS: J. PET. TECH. (AUG., 1973) 890.
- 119. DICHARRY, MCNALLY: PET. ENG. (DEC., 1974) 22.
- 130. ALLEN, TATE: U.S. PATENT 3,878,892 (APR. 22, 1975).
- 136. CROCKETT: PET. ENG. (NOV., 1975) 44.
- 137. DEPARTMENT OF ENERGY: (1975 -).
- 139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
- 142. SOCIETY OF PETROLEUM ENGINEERS OF AIME: (1975 -).
- 145. ANON.: OIL & GAS J. (NOV. 15, 1976 B) 41.
- 146. ANON.: OIL & GAS J. (NOV. 1, 1976 C) 26.
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
- 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- 161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).
- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 163. SPELLER: U.S. PATENT 3,964,545 (JUNE 22, 1976).
- 165. ANON.: OIL & GAS J. (AUG. 29, 1977 C) 25.
- 166. BILHARTZ: PAPER SPE 6389 (1977).
- 173. MCCREE: PET. ENG. (NOV., 1977) 52.
- 189. BILHARTZ, CHARLSON: PAPER SPE 7050 (1978 A).
- 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- 191. CHARLSON, BILHARTZ, STALKUP: PAPER SPE 7049 (1978).

192. CONNER: D.O.E. CONTRACT (1978).
 193. GRADE, BLEVINS: PAPER SPE 7090 (1978 A).
 197. MCCREE: D.O.E. CONTRACT (1978).
 200. OFFICE OF TECHNOLOGY ASSESSMENT: (JAN., 1978).
 206. STALKUP: PAPER SPE 7042 (1978).
 211. CONNER, WATTS: D.O.E. CONTRACT (1979).
 212. DOSCHER, KUUSKRAA: PAPER SPE 7954 (1979).
- L S 5. CLARK, SHEARIN, SCHULTZ, GARMS, MORSE: J. PET. TECH. (JUNE, 1958) 11
 I S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
 S S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
 T S 17. ROBERTS, EDKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
 S 18. ANON.: OIL & GAS J. (SEP. 1, 1969 A) 66.
 S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).
 S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
 S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
 S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
 S 27. EMMETT, BEAVER, MCCALED: J. PET. TECH. (FEB., 1971) 161.
 S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.
 S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
 S 31. BUCHWALD, HARDY, NEIMAST: PAPER SPE 3781 (1972).
 S 34. HOLM: PAPER SPE 3774 (1972).
 S 35. PERRYMAN: PET. ENG. (FEB., 1972) 35.
 S 41. HARVEY, SHELTON, KELM: PAPER SPE 4738 (1974).
 S 42. ANON.: OIL & GAS J. (MAY 26, 1975) 82.
 S 43. BOUCK, HEARN, DUHY: J. PET. TECH. (JUNE, 1975) 672.
 S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
 S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
 S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
 S 51. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAR., 1976 B) 84.
 S 55. ANON.: OIL & GAS J. (SEP. 12, 1977 B) 54.
 S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 867.
 S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

72. ANALYTICAL MODELLING

42. KOVAL: TRANS., AIME (1963) 145.
 66. MCFARLANE, MUELLER, MILLER: SOC. PET. ENG. J. (MAR., 1967) 61.
 100. CLARIDGE: SOC. PET. ENG. J. (APR., 1972) 143.
 S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
 S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.

73. BUCKLEY-LEVERETT MODELLING

- S
 U 42. KOVAL: TRANS., AIME (1963) 145.
 B 100. CLARIDGE: SOC. PET. ENG. J. (APR., 1972) 143.
 J 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
 E 213. WANG, LOCKE: PAPER SPE 7953 (1979).
 C S 4. CAUDLE, DYES: TRANS., AIME (1958) 281.
 T S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
 S 30. BALLARD, SMITH: J. PET. TECH. (MAY, 1972) 599.
 S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

74. FINITE ELEMENT MODELS

75. FINITE DIFFERENCE MODELS

- 66. MCFARLANE, MOELLER, MILLER: SOC. PET. ENG. J. (MAR., 1967) 61.
- 70. THURBER, PIRSON: PAPER SPE 1887 (1967).
- 105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
- 123. HENDERSON: PAPER SPE 4737 (1974 A).
- 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
- 143. SPIVAK, PERRYMAN, NORRIS: WORLD PET. CONG. (1975) 187.
- 148. BRUMMETT, EMANUEL, RONQUILLE: J. PET. TECH. (OCT., 1976) 1241.
- 168. CAMY, EMANUEL: PAPER SPE 6894 (1977).
- 177. PONTIOUS, THAM: PAPER SPE 6390 (1977).
- 185. STRIGHT, AZIZ, SETTARI, STARRATT: J. PET. TECH. (OCT., 1977) 1248.
- 186. WARNER: J. PET. TECH. (OCT., 1977) 1339.
- 190. BILHARTZ, CHARLSON, STALKUP, MILLER: PAPER SPE 7051 (1978 B).
- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 40. NOLEN: PAPER SPE 4274 (1973).
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.
- S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 867.
- S 60. LOFTON, MURSE: PAPER SPE 7472 (1978).

76. VARIATIONAL MODELS

77. HELE-SHAW MODELS

78. PHYSICAL MODELS

- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
- 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
- 29. HABERMANN: TRANS., AIME (1960) 264.

79. SLIM-TUBE DISPLACEMENTS

- 17. WHORTON, BROWNSCOMBE: U.S. PATENT 2,724,438 (NOV. 22, 1955 B).
- 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
- 86. STALKUP: SOC. PET. ENG. J. (DEC., 1970) 337.
- 91. RATHMELL, STALKUP, HASSINGER: PAPER SPE 3483 (1971).
- 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
- 115. BURNETT: U.S. PATENT 3,811,502 (MAY 21, 1974 A).
- 118. BURNETT, LIM: U.S. PATENT 3,811,503 (MAY 21, 1974 D).
- 125. HOLM, JOSENDAL: J. PET. TECH. (DEC., 1974) 1427.
- 133. BURNETT, LIM: CAN. PATENT 980,245 (DEC. 23, 1975 A).
- 149. BURNETT: CAN. PATENT 981,575 (JAN. 13, 1976).
- 180. SAN FILIPPO, GUCKERT: PAPER SPE 6626 (1977).

- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.

80. MIXING ZONE MODELS

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- L 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
- I 42. KUVAL: TRANS., AIME (1963) 145.
- S 100. CLARIDGE: SOC. PET. ENG. J. (APR., 1972) 143.
- T 105. TODD, LONGSTAFF: J. PET. TECH. (JULY, 1972) 874.
- 107. DICHARRY, PERRYMAN, RONQUILLE: J. PET. TECH. (NOV., 1973) 1309.
- 123. HENDERSON: PAPER SPE 4737 (1974 A).
- 124. HENDERSON: J. PET. TECH. (DEC., 1974 B) 1327.
- 138. FAULKNER: PAPER SPE 5539 (1975).
- 177. PONTIOUS, THAM: PAPER SPE 6390 (1977).
- 186. WARNER: J. PET. TECH. (OCT., 1977) 1339.
- 202. PETERSON: PET. ENG. (NOV., 1978) 40.
- 213. WANG, LOCKE: PAPER SPE 7953 (1979).

81. COMPOSITIONAL MODELS

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- 66. MCFARLANE, MUELLER, MILLER: SOC. PET. ENG. J. (MAR., 1967) 61.
- 143. SPIVAK, PERRYMAN, NORRIS: WORLD PET. CONG. (1975) 187.
- 154. FUSSELL, YANOSIK: PAPER SPE 6050 (1976 B).
- 183. SIMON: PHASE EQ. & FLUID PROP. IN CH. IND. (1977 A) 241.
- 188. BAKER, LUKS: PAPER SPE 7478 (1978).
- 193. GRAUE, BLEVINS: PAPER SPE 7090 (1978 A).
- 194. GRAUE, ZANA: PAPER SPE 7060 (1978 B).
- 196. KANE: PAPER SPE 7091 (1978).
- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
- S 33. DESBRISAY, DANIEL: J. PET. TECH. (JULY, 1972) 785.
- S 40. NOLEN: PAPER SPE 4274 (1973).
- S 43. BOUCK, HEARN, DOHY: J. PET. TECH. (JUNE, 1975) 672.

82. FRACTURED RESERVOIR MODELS

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83. SCREENING CRITERIA

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- 108. GEFFEN: WORLD OIL (OCT., 1973) 84.
- S 157. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAY, 1976 D) 114.
- U 159. KENNEDY: OIL & GAS J. (DEC. 27, 1976) 185.
- B 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
- J 161. LEWIN & ASSOCIATES, INC.: E.R.D.A. CONTRACT (1976 B).
- E 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- C 173. MCREE: PET. ENG. (NOV., 1977) 52.
- T 179. RUMP, HARE, PORTER: D.O.E. CONTRACT (1977).
- 209. YELLIG, METCALFE: PAPER SPE 7477 (1978).
- S 2. OFFERINGA, VANDERPOEL: TRANS., AIME (1954) 310.
- S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
- S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.

S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
 S 51. HERBECK, HEINTZ, HASTINGS: PET. ENG. (MAR., 1976 B) 84.
 S 52. HERBECK, HEINTZ, HASTINGS: PET. ENG. (APR., 1976 C) 66.
 S 60. LOFTON, MORSE: PAPER SPE 7472 (1978).

84. COMPARISONS WITH LAB. RESULTS

20. BEESON, URTLOFF: TRANS., AIME (1959) 338.
 21. BLACKWELL, RAYNE, TERRY: TRANS., AIME (1959) 1.
 28. BLACKWELL, TERRY, RAYNE, LINDLEY, HENDERSON: TRANS., AIME (1960) 293
 42. KOVAL: TRANS., AIME (1963) 145.
 66. MCFARLANE, MUELLER, MILLER: SOC. PET. ENG. J. (MAR., 1967) 61.
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 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
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 S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
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73. HOLM, WOERTZ: U.S. PATENT 3,411,583 (NOV. 19, 1968).
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- E 90. PARRISH: U.S. PATENT 3,586,107 (JUNE 22, 1971).
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- T 101. HEARN, RELPH: U.S. PATENT 3,687,198 (AUG. 22, 1972).
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- 135. CARLIN: U.S. PATENT 3,882,940 (MAY 13, 1975).
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
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- 182. SIAS: U.S. PATENT 4,058,467 (NOV. 15, 1977).
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- 160. LEWIN & ASSOCIATES, INC.: F.E.A. CONTRACT (1976 A).
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- 162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
- 170. DUSCHER: OIL & GAS J. (MAY 2, 1977) 213.
- 179. RUMP, HARE, PORTER: D.O.E. CONTRACT (1977).
- 195. HARE, PERLICH, ROBINSON, SHAH, ZIMMERMAN: D.O.E. CONTRACT (1978).
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- S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.
- S 27. EMMETT, BEAVER, MCCAULEY: J. PET. TECH. (FEB., 1971) 161.

90. ENRICHED AND HIGH PRESSURE GAS

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- 29. HABERMANN: TRANS., AIME (1960) 264.
- 34. STONE: U.S. PATENT 2,944,373 (AUG. 1, 1961).
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 S 7. HUTCHINSON, BRAUN: A.I.C.H.E. J. (1961) 64.
 S 18. ANON.: OIL & GAS J. (SEP. 1, 1969 A) 66.
 L S 19. BLEAKLEY: OIL & GAS J. (OCT. 27, 1969) 67.
 I S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
 S S 23. GRIFFITH, BAITON, STEFFENSEN: J. PET. TECH. (OCT., 1970) 1232.
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 S 44. HARDY, ROBERTSON: PET. ENG. (NOV., 1975) 24.
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 S 47. BRANNAN, WHITINGTON: PAPER SPE 5826 (1976).
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 J S 7. HUTCHINSON, BRAUN: A.I.C.H.E. J. (1961) 64.
 E S 8. CORDINER, POPP: DRILL. & PROD. PRAC., AM. PET. INST. (1962) 144.
 C S 9. WIEMER: J. PET. TECH. (OCT., 1963) 1067.
 T S 10. FITCH, GRIFFITH: J. PET. TECH. (NOV., 1964) 1289.
 S 15. CHAMBERS: PROD. MO. (JAN., 1968) 17.
 S 16. LEE: OIL & GAS J. (OCT. 28, 1968) 84.
 S 17. ROBERTS, ELKINS, GEFFEN: OIL & GAS J. (JUNE 3, 1968) 77.
 S 20. JACOBY, MORRIS, ROBINSON: U.S. PATENT 3,465,823 (SEP. 9, 1969).

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 S 22. CRAIG: J. PET. TECH. (MAY, 1970) 529.
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 S 32. CONNALLY: PAPER SPE 3775 (1972).
 S 34. HOLM: PAPER SPE 3774 (1972).
 S 46. ANON.: OIL & GAS J. (APR. 5, 1976 A) 126.
 S 50. HERBECK, HEINTZ, HASTINGS: PET. ENG. (FEB., 1976 A) 58.
 S 56. RIETZEL, CALLOW: J. PET. TECH. (JULY, 1977) 867.
 S 59. CROW: OIL & GAS J. (JAN. 16, 1978) 23.

92. SNG

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S 59. CROW: OIL & GAS J. (JAN. 16, 1978) 23.

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 41. HOLM: U.S. PATENT 3,075,918 (JAN. 29, 1963 B).
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 96. WHITE: PET. ENG. (DEC., 1971) 58.
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 131. BROWN: U.S. PATENT 3,885,624 (MAY 27, 1975 A).
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 145. ANON.: OIL & GAS J. (NOV. 15, 1976 B) 41.
 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
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 159. KENNEDY: OIL & GAS J. (DEC. 27, 1976) 185.
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 170. DOSCHER: OIL & GAS J. (MAY 2, 1977) 213.
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 195. HARE, PERLICH, ROBINSON, SHAH, ZIMMERMAN: D.O.E. CONTRACT (1978).
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 S 24. HULL: OIL & GAS J. (AUG. 17, 1970) 57.

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S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

94. CO2 SUPPLY

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S 59. CROW: OIL & GAS J. (JAN. 16, 1978) 23.

95. TRANSPORTATION

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92. THOMPSON, EMERICK, KASTROP: PET. ENG. (DEC., 1971) 48.
95. WEST, KROH: PET. ENG. (DEC., 1971 B) 63.
104. MASSEY, CRAMER: OIL & GAS J. (APR. 10, 1972) 124.
114. ANON.: OIL & GAS J. (SEP. 2, 1974) 52.
120. FESMIRE, SIMON, DICHARRY, VORHIS: PAPER SPE 5052 (1974).
139. FREY: OIL & GAS J. (JULY 28, 1975) 99.
159. KENNEDY: OIL & GAS J. (DEC. 27, 1976) 185.
162. NATIONAL PETROLEUM COUNCIL: (DEC., 1976).
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S 29. WEST: OIL & GAS J. (NOV. 8, 1971 A) 53.

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39. DOTTS, STEVENS: U.S. PATENT 3,097,917 (JULY 16, 1963).
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47. MUIRBOOK: PH.D. DISSERTATION, U. CA. (1964).
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- 106. YARBOROUGH: J. CH. & ENG. DATA (1972) 129.
- 113. ALLEN, TATE: U.S. PATENT 3,823,777 (JULY 16, 1974).
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- 132. BROWN: U.S. PATENT 3,871,451 (MAR. 18, 1975 B).
- 144. STRELZOFF: CH. ENG. (SEP. 15, 1975) 115.
- 150. CORNELIUS: U.S. PATENT 3,995,693 (DEC. 7, 1976).
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- 179. RUMP, HARE, PORTER: D.O.E. CONTRACT (1977).
- 196. KANE: PAPER SPE 7091 (1978).
- 205. SHAH, WITTMAYER: D.O.E. CONTRACT (1978).
- 208. WEISZ, ZAHNER: U.S. PATENT 4,093,029 (JUNE 6, 1978).
- S 57. ROTHROCK, CRAWFORD: PET. ENG. (AUG., 1977) 22.

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- 198. METCALFE, YARBOROUGH: PAPER SPE 7061 (1978).
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