NIPER-609
Distribution Category UC-122
August 1992

STATUS REPORT

DEVELOPMENT OF A CHEMICAL FLOODING EOR LITERATURE DATABASE SYSTEM

Project BE4A, FY92 Annual Research Plan, Milestone 4

by

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Work Performed for the
Department of Energy
Under Cooperative Agreement
DE-FC22-83FE60149

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SUMMARY

Chemical flooding is a flexible enhanced oil recovery (EOR) method and has the potential of recovering more residual crude oil than other available methods. The capability to adjust an injected chemical formulation for a wide range of reservoir conditions and crude oil types remains a valid strong point for this technology. It has been identified by the Department of Energy (DOE) as an important oil production technique targeted for Class 1 reservoirs. For many U.S. domestic oil reservoirs[1], chemical flooding may be the only viable EOR method.

Most of the work conducted on chemical flooding EOR has been focused on sulfonate-type surfactants, according to the literature. Petroleum sulfonates have been widely investigated. Field tests using these chemicals have been implemented with limited success, both technically and economically. There are other potentially applicable surfactants. Other sulfonate-type surfactants may be more expensive to manufacture, but their performance potential in harsher reservoir conditions oftentimes offsets their higher costs. Several fairly recent reviews of the state of the art provide an overview of the direction of the technology.[2-7] Ethoxylated sulfonates[8-10] and carboxylates[11-17] have also been given much attention recently because of their improved performance in or tolerance for higher salinity conditions. NIPER has conducted studies on several carboxymethylated ethoxylated surfactants (CME), and these studies have shown that CME surfactants have significantly better tolerance for high salinity ranges.[18-19]

The volume of information on research performed in this area is fairly significant. To identify key areas of research that will need attention, the development of a database system was proposed in the Annual Plan for FY92. The ultimate goal of this work is to develop a system of identifying surfactants, or combinations of surfactants, that can be applied to targeted reservoir conditions. The overall system draws upon knowledge or information from the literature as well as on-going research in this area. The capability to identify structure-performance correlations from the multitude of combinations of surfactant types and structures that can be used in these formulations will be extremely helpful. The identification of chemical systems that strike a balance between cost and effectiveness will be critical in determining targeted applications of this technology.

This status report, as part of Milestone 4 of the BE4A Annual Plan, discusses some of the salient features of the present system. The database system in its present form is a two-part

system. One part is primarily a compilation of available literature in the chemical EOR area, and it contains the referenced sources of the information that will be linked to a second section of the system. As research on development of this technology continues, the Reference section of the database will be updated. The second section of the system contains information that has been filtered from the literature. Much of the work that needs to be done will be focused on this part of the database. In this section, all data on different surfactants that have been studied and reported can be compiled to develop a system for identifying surfactant structure-performance correlations.

ACKNOWLEDGMENTS

This work was sponsored by the U.S. Department of Energy under cooperative agreement DE-FC22-83FE60149. The author wishes to thank Gerardo Mañalac, DOE/AWU summer student for his valuable assistance in performing the task of data entry of the literature information into the Reference section of the database system.

DETAILS OF THE DATABASE DEVELOPMENT

The primary consideration in the development of the database system is the type of computer platform that will support the system. On the basis of this criterion, FoxBASE+ was chosen because of the file transfer capability of this database program from both PC DOS and Macintosh formats. The database is currently being developed for Macintosh computers but can be easily converted or adapted to PC-based formats for wider distribution. The choice of a relational database, as opposed to a flat-file database, is necessary because of the volume of information that will be handled and the dynamic linking that will be needed in the database. The robust capability of a relational database and the multi-computer platform portability will be beneficial because this tool will also serve as a vehicle for technology transfer to interested parties in the petroleum industry.

The database system has been developed in two sections. One part contains information directly obtained from journal references. This section is primarily a compilation of available information in the area of chemical flooding EOR. Information in this section of the database will be linked to the Surfactant section of the database system. Additional information or literature references will be added to the database as research in this EOR area continues.

To date, 663 entries of referenced articles have been entered into the Reference section of the database; some additional references cited by these articles have yet to be entered. An additional 3,700 entries, containing a significant amount of data on adsorption calorimetry as well as other surfactant information, are being ported from a separate database file. These additional entries will

be sorted prior to being appended to the new database system. Figure 1 shows an example of the database entry fields for this section of the system. The "Reference" field refers to the reference number of the particular article in the database. This field is the critical link between the two sections of the database. Additional comments regarding this link will be discussed later in the report. The "Cross_ref" field refers to the status of the article as to whether or not it has been entered or cataloged in the Surfactant section of the database. The "On-file" field refers to the status of the article as to whether or not a physical copy of the article is in the Surfactant Reference filing cabinet. The "Authors" and "Title" fields list all the authors or contributors and the title of the article. The "Abstract" and "Conclusion" fields are the scanned-in copies of the abstract and conclusions of the original article. The "Comment" field refers to specific comments or keywords selected by the readers or researchers to help identify the article. Examples of the contents of the "Abstract", "Conclusion" and "Comment" fields are also shown in Fig. 1. The "Source" and "Year_pub" fields refer to the source of the refereed article and the date of publication, respectively. Table 1 shows a listing of the database characteristics of each of these fields.

Table 1. Field characteristics of Reference database section

Field Name	Type	Field Name	Type
Reference	Numeric	Abstract	Memo
Cross_ref	Logical	Conclusion	Memo
On_file	Logical	Comment	Memo
Authors	Character	Source	Character
Title	Character	Year_pub	Numeric

Figure 2 shows an example of a report form that can be generated when using this section of the database system. In this example, "Reference" number 8 was arbitrarily selected, depending on user-selected types of sorts. The files or records can be sorted or filtered based on keywords, authors, dates, titles, and reference sources.

Reference	8
Cross_ref	
On_file	T
Authors	Sharma, M. K. Shah, D. O..
Title	Macro- and Microemulsions in Enhanced Oil Recovery
Abstract	**memo**
Conclusion	**memo**
Comment	**memo**
Source	Macro- and Microemulsions, Theory and Applications
Year_pub	1984

Abstract

The physicochemical aspects of micro- and macroemulsions have been discussed in relation to enhanced oil recovery processes. The interfacial parameters (e. g. interfacial tension, interfacial viscosity, interfacial charge, contact angle, etc.) responsible for enhanced oil recovery by chemical flooding are described. In oil/brine/surfactant/alcohol systems, a middle phase micro-emulsion in equilibrium with excess oil and brine forms in a

Conclusion

1. A surf. mixture behaves as a linear average of its components.
2. The behavior of "off-scale" surfactants can be predicted. Disadvantage may be the possible augmentation of any dependence of (μmin) on the surf. concentration and the danger of selective adsorption on the reservoir rock.

Comment

Good discussion of macro- and microemulsions.

FIGURE 1. - Example of field entries for the Reference section of the database.

Reference No.: 8 **Cross-Referenced?:** .F. **File on Hand?:** .T.

Title: Macro- and Microemulsions in Enhanced Oil Recovery

Authors: Sharma, M. K. Shah, D. O.

Source: Macro- and Microemulsions, Theory and Applications

Abstract: The physicochemical aspects of micro- and macroemulsions have been discussed in relation to enhanced oil recovery processes. The interfacial parameters (e. g. interfacial tension, interfacial viscosity, interfacial charge, contact angle, etc.) responsible for enhanced oil recovery by chemical flooding are described. In oil/brine/surfactant/alcohol systems, a middle phase microemulsion in equilibrium with excess oil and brine forms in a narrow salinity range. The salinity at which equal volumes of brine and oil are solubilized in the middle phase microemulsions is termed as the optimal salinity. The optimal salinity of the system can be shifted to a desired value by varying the concentration and structure of alcohol. It was observed that the formulations consisting of ethoxylated sulfonates and petroleum sulfonates are relatively insensitive to divalent cations. The results show that a minimum in coalescence rate, interfacial tension, surfactant 1088, apparent viscosity and a maximum in

Conculsion:
1. A surf. mixtures behave as a linear average of its components.
2. The behavior of "off-scale" surfactants can be predicted. Disadvantage may be the possible augmentation of any dependence of μmin on the surf. concentration and the danger of selective adsorption on the reservoir rock.
3. The surf. equivalent weights is an important property, with μmin increasing smoothly with increasing equivalent weight when the basic structure of the surfactant is unchanged.
4. Surf. molecular structure is far more important that structure in the oil phase and is the cause of the large μmin differences found between surfactants of same equivalents weights.

Comment: Good discussion of macro- and microemulsions.

Year of Publications: 1984

FIGURE 2. - Example of Report Form for the Reference section of the database.

The second section of the database system contains the information that has been obtained from the above-mentioned reports. Much of the work that needs to be done will be focused on this section of the database. All the data on the different surfactants that have been studied and reported will be compiled in this section for the purpose of developing a system to identify surfactant structure-performance correlations. Figure 3a shows an example of the database entry fields for this section of the system. The "Reference" field refers to the Reference Number of the particular article in the database. This field is the link between the two sections of the database. The "Anionic" field refers to the type of the surfactant as to whether or not it is an anionic surfactant. The "Surftype" and "Surfname" fields refer to the type and commercial name of surfactant system reported. The "Hydrophobe", "Hydrophile" and "Smolweight" fields refer to the hydrophobe and hydrophile structure of the surfactant and its molecular weight. The "EO", "PO" and "HLB" fields refer to the particular structure of the chemical, in particular, the number of degrees of ethoxylation or propoxylation as well as the hydrophilic-lipophillic balance (HLB). The "Structure" field refers to a representation of the molecular structure of the surfactant. The "Temp_C", "Saline_TDS", "Mulvalency" fields refer to the specifics of the conditions under which the particular surfactant was tested, i.e, the temperature and salinity conditions as well as the presence of multivalent ions. The "Oil_name", "Oil_grav", "Carbchain", "Oil_MW" "Synthetic", "Asph_para" fields all refer to type of oil used in the study, the hydrocarbon chain length of the oil, its molecular weight, and the asphaltic/paraffinic content of the oil. "Cosurf_add" refers to the status of whether or not cosurfactants were used in the study. "Corsur1nam", "Cosur2nam", "Cosur1type" and "Cosur2type" refer to the specific names and types of cosurfactants added. "Experiment", "Phase_beh", "Coreflood", "IFT", "Adsorp" and "Date_test" refer to the status of whether or not specific laboratory and field tests were conducted using the chemical. The "Figure_1" field contains scanned-in images of selected figures or graphs from the article that has been referenced. An example of a scanned-in image entry in this field is shown in Fig. 3b. The database characteristics of each of the fields in the Surfactant section are presented in Table 2.

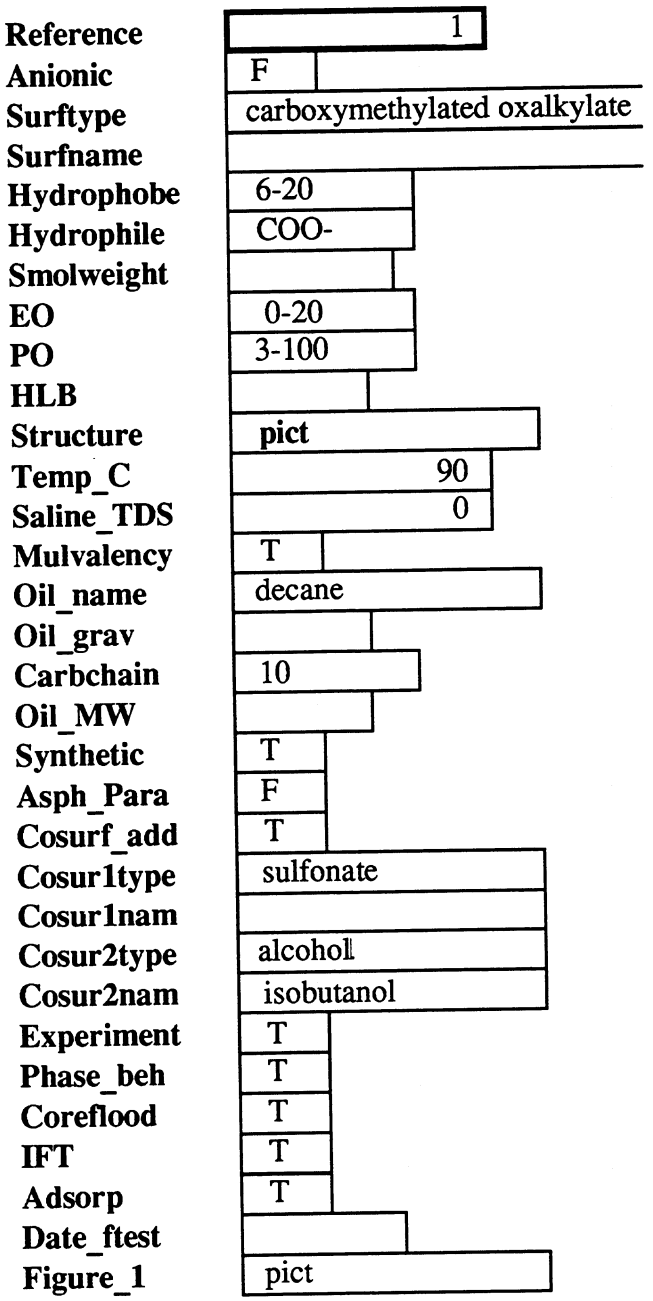


FIGURE 3a. - Example of field entries for the Surfactant section of the database.

structure

$R\text{-}(OC_3H_6)_m(OC_2H_4)_nOCH_6COO\text{-}$

figure_1

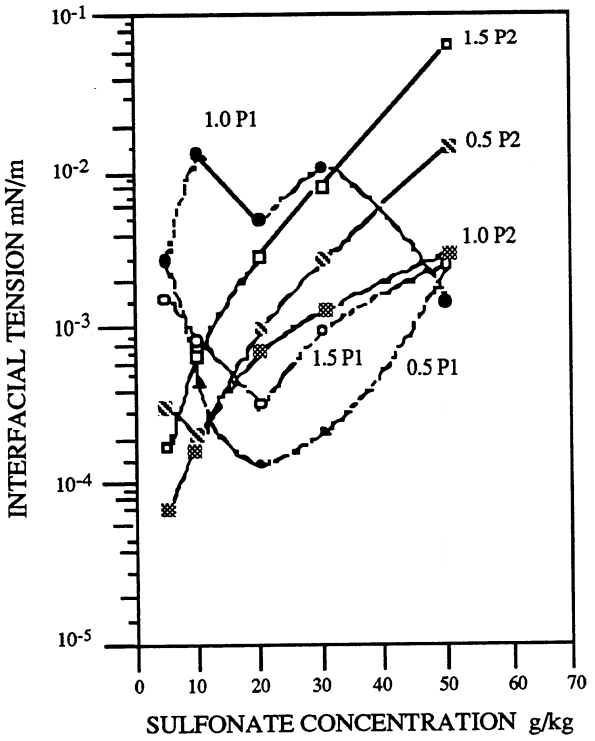


FIGURE 3b. - Examples of the "Structure" and "Figure_1" field entries for the Surfactant section of the database.

Table 2. Field characteristics of Surfactant database section

Field Name	Type	Field Name	Type
Reference	Numeric	Carbchain	Character
Anionic	Logical	Oil_MW	Numeric
Surftype	Character	Synthetic	Logical
Surfname	Character	Asph_Para	Logical
Hydrophobe	Character	Cosurf_Add	Logical
Hydrophile	Character	Cosur1type	Character
Smolweight	Numeric	Cosur1nam	Character
EO	Character	Cosur2type	Character
PO	Character	Cosurf2nam	Character
HLB	Numeric	Experiment	Logical
Structure	Picture	Phase_beh	Logical
Temp_C	Numeric	Coreflood	Logical
Saline_TDS	Numeric	IFT	Logical
Mulvalency	Logical	Adsorp	Logical
Oil_name	Character	Date_test	Numeric
Oil_grav	Numeric	Figure_1	Picture

Figures 4a and 4b show examples of report forms that can be generated when using this section of the database system. In this example, "Reference" numbers 1 and 177 were arbitrarily selected, showing an example of the "Structure" and "Figure_1" fields, respectively.

As previously mentioned, the primary link between the two database sections is the "Reference" field. Figure 5 shows a pictorial of the dynamic link between these two sections. Sorts or searches can be issued, and the results of this command can be reported in a single report form. In situations where referenced articles contain information on multiple surfactants tested, the end result would be multiple entries in the Surfactant section of the database with reference to a single "Reference" number on the primary Reference section of the system.

SURFACTANT INFO

Reference: 1

Anionic: .F.

Surf Type: carboxymethylated oxalkylate

Surf Name:

Hydrophobe: 6-20

Hydrophile: COO-

Surf. M.W.:

Structure: R-$(OC_3H_6)_m(OC_2H_4)_nOCH_6COO$-

EO: 0-20

PO: 3-100

HLB:

TESTS CONDUCTED

Experimental?: .T.

Phase Behavior?: .T.

IFT Measurements?: .T.

Adsorption?: .T.

Coreflood?: .T.

Date of Field Test:

REPORTED CONDITIONS

Temp. °C: 90

Salinity, % TDS:

Multivalent ions?: .T.

Oil Name: decane

Oil Gravity:

HC Chain Length: 10

Oil M.W.:

Synthetic?: .T.

Asphaltene/Paraffin?: F.

Cosurfactant Added?: .T.

Cosurfactant 1 Type: sulfonate

Cosurfantant 1 Name:

Cosurfactant 2 Type: alcohol

Cosurfantant 2 Name: isobutanol

Selected Figures

FIGURE 4a. - Reference no. 1 example of Report Form for the Surfactant section of the database

SURFACTANT INFO

Reference: 177

Anionic: .T.

Surf Type: petroleum sulfonate

Surf Name: Petrostep 465 and 420

Hydrophobe:

Hydrophile:

Surf. M.W.:

Structure:

EO: 0

PO: 0

HLB:

REPORTED CONDITIONS

Temp. °C: 35

Salinity, % TDS:

Multivalent ions?: .T.

Oil Name: OK Crude

Oil Gravity: 0.85

HC Chain Length: 10

Oil M.W.:

Synthetic?: .F.

Asphaltene/Paraffin?: F.

Cosurfactant Added?: .T.

Cosurfactant 1 Type: alcohol

Cosurfantant 1 Name: 1-pentanol

Cosurfactant 2 Type:

Cosurfantant 2 Name:

TESTS CONDUCTED

Experimental?: .T.

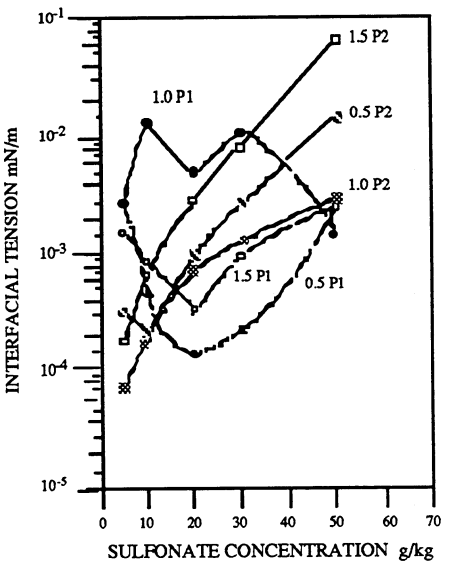
Phase Behavior?: .T.

IFT Measurements?: .T.

Adsorption?: .T.

Coreflood?: .T.

Date of Field Test:



Selected Figures

FIGURE 4b. - Reference no. 177 example of Report Form for the Surfactant section of the database

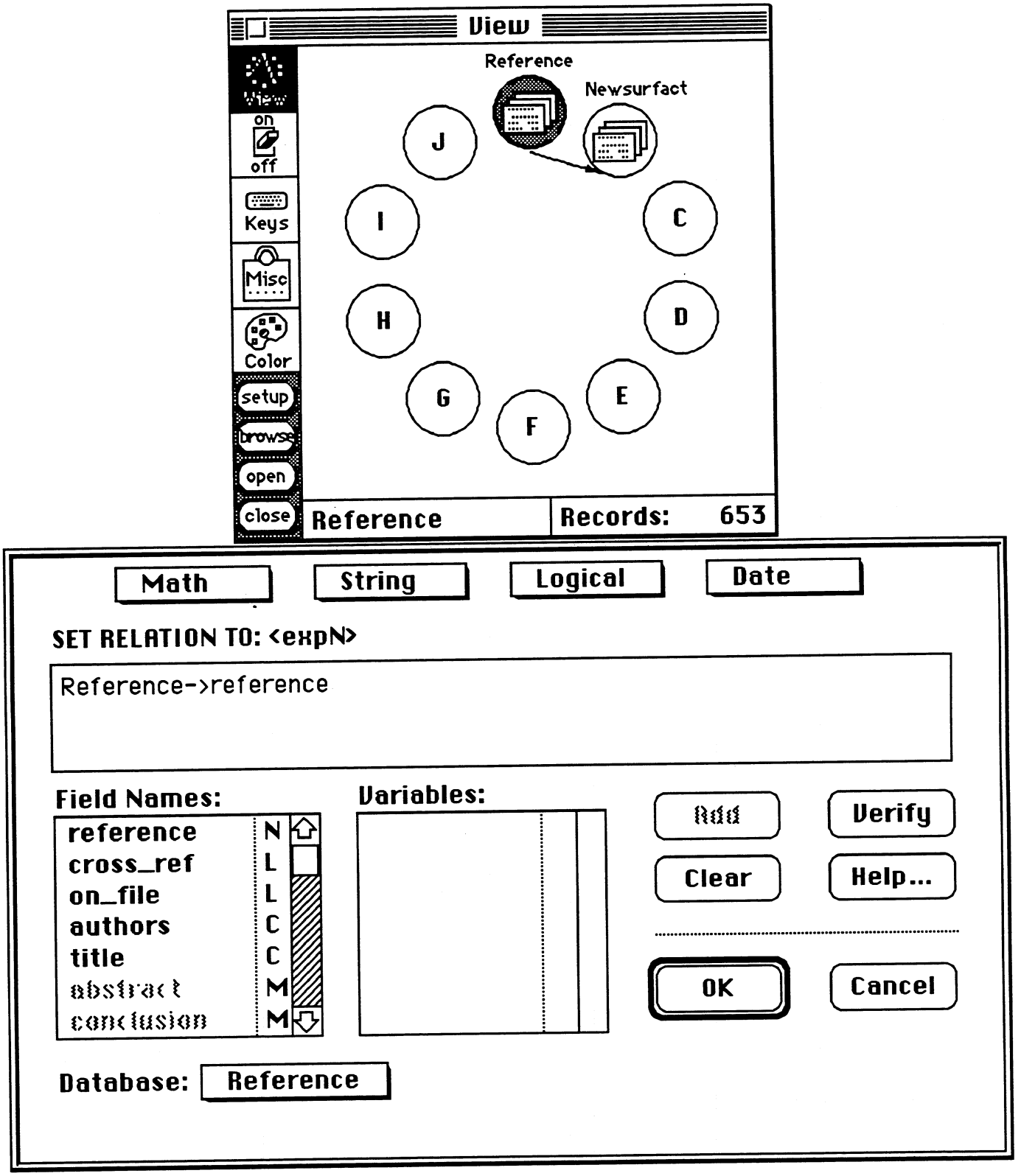


FIGURE 5. - Pictorial representation of the dynamic link between the two sections of the database system.

RECOMMENDATIONS FOR FURTHER WORK

The database would need to evolve into some level of an "expert" system to provide researchers or design engineers some guidelines for decision making pertaining to implementation of chemical flooding EOR projects. Such a system would give researchers the capability to identify structure-performance correlations of different surfactants and its combinations for specific applications. The system needs to be robust and flexible as well as operable in different computer platforms. These capabilities will be needed because this type of a tool will also serve as a vehicle for technology transfer to interested parties in the petroleum industry.

Much of the work that needs to be done will be an on-going process. Continuously updating the database system will be essential in maintaining it as a complete and current listing of the referenced articles in the public literature pertaining to surfactant flooding EOR. As articles and reports are published in the open literature, these additional references need to be incorporated into the system. The Reference section of the database now contains 663 entries. Continuing effort will be needed to enter the references cited by these articles into the system. An additional 3,700 entries, containing a significant amount of data on surfactant properties including adsorption calorimetry are being ported from a separate database file.

After the articles are entered into the Reference section, a major effort is necessary to catalog and cross-reference each article into the Surfactant section of the database. This task requires a researcher to examine diligently the individual articles in order to identify and input the salient points of the reference material into the Surfactant section. This step is critical in developing a system that will allow the user to cross-reference and identify all the research work that has been conducted on particular chemicals or formulations of interest.

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