Technical Report on Temperatures for API Cement Operating Thickening Time Tests

1993 Report from the API Task Group on Cementing Temperature Schedules

API TECHNICAL REPORT 10TR3
FIRST EDITION, MAY 1999

REAFFIRMED, MAY 2005

AMERICAN PETROLEUM INSTITUTE

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FOREWORD

The American Petroleum Institute (API) Committee 10 (now Subcommittee 10) formed a Task Group in the mid-1980s charged with updating the squeeze-cementing well-simulation test schedules in API Spec 10 (now API Specifications 10A and RP 10B) using a large collection of new temperature data. Temperatures in the squeeze schedules had not been updated since 1953. The collection of new temperature data was the largest ever available for consideration in developing temperature correlations for cementing test schedules. Eventually, the scope of the Task Groups work expanded to update all the well-simulation test schedules using the new temperature data. The potential benefit to the industry was great.

One goal of the Task Group was to develop the most accurate temperature correlations from the data. Several methods of developing correlations from data were investigated. Rigorous and thorough analysis of the data was required and eventually completed. Finally, a correlation was developed using statistical regression techniques that provided the lowest error based on the data.

The correlation predicted temperatures that were higher than any previous temperatures in well-simulation test schedules at depths shallower than about 10,000 feet. This was alarming to users of the test schedules since each set of schedules had been used for about 20 years without evidence of widespread problems with the predicted temperatures.

The new temperature data was scrutinized once more. The correlation methods and results were reviewed. Previous temperature data sets and the correlations developed from them were investigated. All of this was done to:

1. Understand the representative range of data contained in each set of data.
2. Determine and understand the methods used to develop the correlations.
3. Compare previous methods to the methods selected by this Task Group and critically evaluate each.
4. Select the best methods for development of correlations from the new temperature data.

Results of this entire effort are summarized in this report. It is our desire to improve understanding about how temperature correlations used in API well-simulation test schedules were developed. Each data set used to develop correlations was not representative of all cementing operations. Even the most precise correlations developed from the data may not reflect true cementing temperatures. Therefore, each correlation has limitations on the accuracy of predicted temperatures for a specific cementing operation. However, we firmly believe that the temperature correlations prepared by us and those before us are of value to the industry.

Finally, this document has been prepared to leave a clear understanding of the data, analysis, and methods upon which the recommendations made and adopted by API Committee 10 in June 1991 are based. We leave this document as a tool to assist those who may perform similar work in the future.

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Report on Temperatures for API Cement Operating Thickening Time Tests

1 Scope

Temperature is the single most important variable affecting cement hydration [1]. Therefore, accurate information about temperatures in a well is critical to cementing operations. Many variables affect wellbore temperature, and measurement of temperature during an actual cementing operation is difficult. However, since the early 1940s temperature data has been gathered, analyzed and converted into estimates of wellbore temperatures with depth. These estimates of temperature versus depth have been incorporated into American Petroleum Institute (API) guides for testing cement formulations since the late 1940s. The API well-simulation test schedules have been valuable tools for the petroleum industry as guides for testing cement formulations in the laboratory and as estimations of wellbore temperatures for cementing operations.

Work performed by the 1984–91 API Task Group on Cementing Temperature Schedules to update the temperatures in API well-simulation test schedules is summarized in this report. The Task Group reviewed the largest set of temperature data available to the industry to date. Changes were proposed to temperatures in the well-simulation test schedules in API Specification 10, 5th, Edition, based upon review of the data.

This report documents:

a. The proposed changes for temperatures.

b. The process used to develop the proposed changes.

c. The process used to develop temperatures in API Specification (Spec) 10, 5th Edition well-simulation test schedules.

d. The comparison of temperature data sets used to develop the proposed changes to temperatures in API Spec 10, 5th Edition, well-simulation test schedules.

Additionally, this report compiles most of the temperature data collected by the industry to date into a single document that may serve others involved in similar efforts in the future.

1.1 HISTORY OF API THICKENING TIME TEST SCHEDULES

The API has served as the focal point for gathering temperature information useful in cementing operations for over fifty years. Standardized cementing well-simulation test schedules containing temperatures for primary and remedial (squeeze) cementing operations have been prepared from data sets of temperatures measured in wells. The first test schedules were published in API Code 32, 1st Edition, issued February 1948. A second edition was published in June 1950. These documents were issued as tentative codes.

Both editions of API Code 32 contained well-simulation test schedules for casing-cementing operations for depths down to and including 18,000 feet. The depth range for schedules was the same as the format in API Spec 10, 5th Edition. Test schedules start at a depth of 1,000 feet and are incriminated on even numbered depths from 2,000 feet to the deepest depth of the schedules.

Temperatures for the well-simulation test schedules in API Code 32 were based upon a correlation developed from data collected by Farris in 1941[2]. Eight data points were collected from wells along the Gulf Coast of Texas and Louisiana. Geothermal temperature gradients for these wells ranged from 1.05°F/100 feet to 1.63°F/100 feet. The average temperature gradient was about 1.35°F/100 feet. A single correlation for circulating temperature with depth was developed from this data.

API Code 32 was replaced by API Recommended Practice (RP) 10B for the 3rd Edition of the testing procedures and well-simulation test schedules, which was issued in April 1953. Squeeze-cementing well-simulation test schedules for depths down to and including 16,000 feet first appeared in this document.

Temperatures in the casing and squeeze-cementing test schedules did not change until the 19th Edition of API RP 10B issued in January 1974. A single temperature depth correlation was used for casing-cementing well-simulation test schedules from February 1948 until January 1974. A separate, single temperature and depth correlation was used for squeeze-cementing well simulation test schedules from April 1953 until changes were proposed by this Task Group in June 1991.

Although the temperatures did not change for over twenty years, there were other changes in the schedules. The 3rd and 4th Editions of API RP 10B were issued as tentative standards. The tentative classification was removed for the 5th Edition issued in May 1956. Also, a 9,000-foot well-simulation schedule for both casing and squeeze-cementing appeared in the 5th Edition and remained through the 10th Edition issued in March 1961.

A casing-cementing well-simulation schedule for 20,000 feet and a squeeze-cementing well-simulation schedule for 18,000 feet first appeared in the 11th Edition of API RP 10B issued in March 1962. In March 1964, the 13th Edition of API RP 10B was published and the squeeze-cementing well-simulation schedules were extended for use as plug-back cementing well-simulation schedules. This was indicated by a change of title for Table 9.2 of that document which is shown as “Basis for Squeeze and Plug Back Cementing Well-Simulation Test Schedules”.

Liner cementing well-simulation test schedules first appeared in the 14th Edition of RP 10B issued in March 1965. Liner schedules were based upon temperatures and pressures from the casing schedules; and times to temperature and pressure from the squeeze and plug-back cementing schedules.

Hesitation squeeze-cementing well-simulation schedules were included as alternate schedules and classified as tentative in the 17th Edition issued in April 1971. The hesitation squeeze schedules were an extension of the squeeze and plug-back cementing schedules from previous editions. Hesitation squeeze schedules increased the temperature of the slurry from the squeeze temperature to the static temperature at a rate of about 0.2°F/min after reaching the squeeze pressure for the schedule. The static temperature for these alternate schedules was calculated using a geothermal temperature gradient of 1.5°F/100 ft. Cycling of the stirring of the slurry was also performed during this second temperature ramp to simulate intermittent pumping during the squeeze operation.

Significant changes to the test schedules occurred in the 19th Edition of RP 10B issued in January 1974. Six casing schedules corresponding to depths of 1,000 ft, 6,000 ft, 8,000 ft, 10,000 ft, 14,000 ft and 16,000 ft were designated as casing cement specification test schedules. These schedules were the same as those originally published in API Code 32 up through the 18th Edition of API RP 10B. New casing-cementing well-simulation test schedules were issued with a tentative classification. These schedules contained temperatures correlated on depth and geothermal temperature gradient. Temperatures for these test schedules were higher than temperatures for previous schedules at some depths. No changes to liner, squeeze or hesitation squeeze schedules occurred in this edition.

Temperatures for liner cementing well-simulation schedules were correlated to temperature gradients in April 1977 when the 20th Edition of API RP 10B was issued. A 20,000-ft liner schedule was added. The tentative classification for the casing-cementing schedules was dropped for this edition.

In April 1979, the 20th Edition of API Spec 10A, was issued but did not contain test schedules. Spec 10A was a specification for oil well cements and cement additives. The 21st Edition of API RP 10B was published in December 1979, with the following equation shown for calculation of temperature gradient:

$$\text{Temperature Gradient} = \frac{\text{BHLT} - 80°\text{F}}{\text{Depth}/100\ \text{ft}} \qquad (1)$$

where

Temperature Gradient = °F/100 ft,

BHLT = bottom-hole log temperature, °F,

Depth = well depth, ft,

80°F = Surface temperature.

The API Spec 10, 1st Edition, replaced API RP 10B when it issued in January 1982. Equation 1 shown above was modified to the following:

$$\text{Temperature Gradient} = \frac{\text{BHT} - 80°\text{F}}{\text{Depth}/100\ \text{ft}} \qquad (2)$$

where

Temperature Gradient = °F/100 ft,

BHT = bottom-hole temperature, °F,

Depth = well depth, ft,

80°F = Surface temperature.

A footnote was added to clarify the source of bottom-hole temperature used to calculate the temperature gradients in the casing and liner cementing well-simulation test schedules.

Four other editions of API Spec 10 have been issued. The 5th Edition was issued on July 1, 1990, and contains the well-simulation test schedules as described to this point. Changes proposed by this Task Group are based upon the schedules in API Spec 10, 5th Edition.

Note: As of the publication date of this Technical Report, 10TR3, the 5th Edition of Spec 10 has been replaced by API Spec 10A, 22nd Edition January 1995, and API RP 10B, 22nd Edition, December 1997.

1.2 MEASUREMENT AND COLLECTION OF TEMPERATURE DATA

Temperature data used to prepare correlations for well-simulation test schedules were not collected during actual cementing operations. All of the data used has come from mechanical temperature sensors run on drill pipe prior to running the casing to be cemented into the well. Ideally, the drilling fluid (mud) is circulated for a sufficiently long period of time to allow the temperature in the wellbore around the temperature sensor to reach a nearly steady-state condition as illustrated in Figure 1.

Temperatures in the well-simulation test schedules are predicted values based upon correlations of measured temperature versus depth, developed from sets of temperature data. They should be considered as estimates and serve as general reference information. The actual temperatures during a cementing operation or during circulation of the mud with casing run into the wellbore may vary significantly from the temperatures in the API tables.

However, it is important to note that temperatures in the well-simulation test schedules have served the industry well. Temperatures in the original schedules published in 1948 were used for 26 years by the industry worldwide. Temperatures in the present test schedules have been used for nearly 20 years.

1.3 1984–91 API TASK GROUP ON CEMENTING TEMPERATURE SCHEDULES

The 1984–91 API Task Group on Cementing Temperature Schedules started as a Work Group in API Committee 10 in the latter half of 1984. The Work Group was assigned to review a new set of measured temperature data, consider present industry practices in primary and remedial cementing operations, and make recommendations to Committee 10 regarding the cementing well simulation test schedules in API Spec 10, 5th Edition.

Based upon review of the temperature information, the Work Group recommended that temperatures in the cementing test schedules be revised. Additionally, the Work Group recommended industry surveys of field cementing operations for both primary and remedial cementing to determine if other variables in the thickening time test schedules, such as pressures and times to reach temperature and pressure, needed to be updated as well. Surveys of field cementing operations were last conducted in the late 1950s and the pressures and times to temperature and pressure in the API Spec 10, 5th Edition cementing schedules are based upon data from those surveys.

The Work Group's recommendations were accepted by the Steering Committee of API Committee 10 and a Task Group was formed to conduct the work. The following general charges were given to the Task Group:

a. Prepare new temperature correlations based upon the body of new temperature data.

b. Compare the predicted temperatures from the new correlation(s) with temperatures in the API Spec 10, 5th Edition, well-simulation test schedules

c. Conduct surveys of field operations for primary and remedial cementing.

d. Prepare new time and pressure schedules for primary and remedial cementing operations from the survey data.

e. Compare the new time and pressure schedules to the times and pressures in the API Spec 10, 5th Edition well-simulation test schedules.

f. Propose new well-simulation test schedules or changes to the API Spec 10, 5th Edition, thickening time test schedules.

All of these assignments were completed. The Task Group reached agreement on the most difficult assignment—new temperatures for the well-simulation test schedules. Surveys of field operations are completed. The results of the survey of squeeze operations were documented in 1987 [3]. New time and pressure schedules have been prepared for squeeze cementing operations. Documentation of other surveys of field cementing operations is in progress.

A document titled "Proposed Replacement for Appendix E (API Spec 10) Operating Thickening Time Tests" was accepted by API Committee 10 for letter ballot at the June, 1991 Annual Standardization Conference held in San Diego, California. This document contained the changes to the well-simulation test schedules recommended by the Task Group. The recommended changes were accepted by API Committee 10 after passing the letter ballot. This report documents the data, methods and process used to develop the new temperature correlations proposed by the Task Group to API Committee 10.

2 References

Note: Numbers correspond to numbers in brackets found in report text.

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3 Definitions

A consistent and accurate set of definitions is important to the understanding and use of this document. The following definitions are accurate for the terms used herein.

3.1 assumed surface temperature (AST): The assumed temperature at the surface used for purposes of calculating a pseudo-temperature gradient (PsTG). The PsTG is used to develop testing schedules of temperature and pressure versus time at various PsTG levels and depths. The 1969–74 Data Set and the 1974 Data Set used an AST value of 75°F for calculation of the PsTG values listed in API Spec 10, 5th Edition. The 1984 Data Set used an AST value of 80°F, as does the 1974–84 AllMuds3 Subset and 1991 Hybrid Correlation.

3.2 circulating temperature (CT): The temperature of any fluid at any specified depth in a well while it is being circulated.

3.3 gradient: See *pseudo-temperature gradient*.

3.4 maximum recorded bottom-hole static temperature (MaxRBHST): The maximum temperature recorded at the bottom of a wellbore, after a static period (noncirculation normally of up to 24 hours or more) and prior to start of circulation. The longer the static period of noncirculation, the closer the MaxRBHST will approach the undisturbed formation temperature (UFT). The MaxRBHST value is preferably determined by a temperature sensor run in the drill-string that is tripped into the wellbore during a clean-up trip, after logging, and prior to running casing. Maximum recorded log temperatures are sometimes used in field operations.

3.5 minimum recorded bottom-hole circulating temperature (MinRBHCT): The minimum temperature recorded at the bottom of a wellbore, after a period of circulation time sufficiently long to achieve a nearly stabilized or nearly steady-state circulating temperature. The MinRBHCT is usually determined by a temperature sensor run in the drill-string that is tripped into the wellbore during a clean-up trip, after logging, and prior to running casing. The temperature is obtained, after some time period of circulating the wellbore, prior to tripping the pipe off bottom. Note that the MinRBHCT is dependent upon well geometry, fluid properties, and circulation rate, etc., and is not necessarily the minimum bottom-hole circulating temperature of a cement slurry.

3.6 operating thickening time: The elapsed time between the initial application of pressure and temperature to the cement slurry and the occurrence of a consistency value of 100 Bearden units of consistency (Bc). Times to other consistency values may also be reported, along with the operating thickening time, at the users request. An example of the recommended reporting format follows:

Operating Thickening Time, hours, minutes = 4:33
Time to 70 Bc, hours, minutes = 4:30
Time to 40 Bc, hours, minutes = 4:22

3.7 predicted bottom-hole circulating temperature (PBHCT): The predicted temperature obtained from correlations developed from temperature data sets for the bottom-hole depth and pseudo-temperature gradient (PsTG). This is a calculated value based on field data, and associated correlation techniques, used to develop the schedules and equations. The PBHCT is used for both casing and liner schedules. Note that the actual wellbore temperature is dependent upon well geometry, fluid properties, and circulation rate, etc. The PBHCT is not necessarily the bottom-hole circulating temperature of a cement slurry.

3.8 predicted squeeze temperature (PSqT): The predicted squeeze temperature obtained from correlations developed from squeeze temperature data sets the selected depth and PsTG. This is a calculated value based on field data, and associated correlation techniques. Note that the actual wellbore squeeze temperature is dependent upon well geometry, fluid properties, and circulation rate, circulating time and inlet temperature of fluid.

3.9 pseudo-temperature gradient (PsTG): A temperature change, per unit of depth, determined by a calculation using an assumed surface temperature (AST) defined as 80°F, and a maximum recorded bottom-hole static temperature (MaxRBHST) as follows:

$$\text{PsTG} = \frac{\text{MaxRBHST} - 80°\text{F}}{\text{TVD}/100\ \text{ft}}$$

where

PsTG = pseudo temperature gradient, °F/100 ft,

MaxRBHST = maximum recorded bottom-hole static temperature, °F,

TVD = true vertical depth, ft.

3.10 pseudo undisturbed temperature (PsUT): Temperature at a given depth calculated as follows:

$$\text{PsUT} = \text{PsTG} \times (\text{True Vertical Depth}/100) + 80°\text{F}$$

The PsUT at the bottom of the wellbore is equal to the maximum recorded bottom-hole temperature (MaxRBHT).

It is intended that the static time for this calculation equal or exceed 24 hours.

3.11 recorded squeeze temperature (RSqT): Temperature recorded at the end of the workstring at the calculated time when a volume of fluid equal to the work-string internal volume has been circulated. The RSqT is usually determined by a temperature sensor run in the work-string that is tripped into the wellbore during a clean-up trip. The work-string for the 1991 AllMuds3 Subset was at the bottom of the wellbore, and, generally, the data was collected after logging and prior to running casing. Note that the actual wellbore squeeze temperature is dependent upon well geometry, fluid properties, and circulation rate, circulating time and inlet temperature of fluid.

3.12 static time: The amount of time between the end of the last circulation of the wellbore and the time when the maximum recorded bottom-hole temperature (MaxRBHT) was observed at the bottom, or lowest point, in the wellbore.

3.13 thickening time: The time that a slurry remains in a fluid state under a given set of temperature, pressure and shear conditions.

3.14 undisturbed formation temperature (UFT): The geologic formation temperature, at a depth, prior to the first penetration by a drill bit; or, the temperature attained, at a depth, in a well after the well is shut-in for a period long enough to return to the adjacent undisturbed (virgin) geologic formation temperature.

4 Temperature Data Sets Used to Develop Correlations for Well Simulation Test Schedules

Four sets of data have been used to prepare correlations for use in well-simulation test schedules. The earliest body of information is that reported by Farris in the 1940s which was used to prepare the first test schedules published in API Code 32 in February 1948. Only casing-cementing well-simulation test schedules were prepared from this data. For convenience, this will be referred to as the 1948 Data Set corresponding to the first time test schedules using this data appeared in an API document.

A small set of data was collected about 1950 for squeeze cementing operations. There is little published on this; but a reference found in the API archives [4] contains 6 data points used to construct the squeeze schedules which first appeared in the 4th Edition of API RP 10B which was issued in 1953. This data set will be referred to as the 1953 Squeeze Data Set.

Another body of temperature information was collected by an API Task Group between about 1969 and 1974. A portion of this data was used to prepare the temperature correlations for casing- and liner-cementing well-simulation test schedules that appeared in the 19th Edition of API RP 10B, in January 1974. All of the data collected during this period is referred to as the 1969–74 Data Set throughout the remainder of this report.

A subset of the 1969–74 Data Set containing 41 data points was used to develop correlations for updating the temperatures in the casing- and liner-cementing well-simulation test schedules. The updated temperatures first appeared in the 19th Edition of API RP 10B in January 1974. This subset of data will be referred to as the 1974 Data Set throughout this report.

The temperature data used by the 1984–91 Task Group was collected in the late 1970s and into the mid-1980s. This is the largest single collection of temperature data made available to the industry for use in development of temperatures for cementing well-simulation schedules. This data will be referred to as the 1984 Data Set.

The 1974 Data Set, nine data points from the 1969–74 Data Set, and 150 data points from the 1984 Data Set, were combined by the Task Group to prepare the correlations which were adopted by API Committee 10 in 1991. The combination of these two data sets formed a large, master data set which will be referred to as the 1974–84 Combined Master Data Set.

Several subsets were extracted from the 1974–84 Combined Master Data Set. Temperature-versus-depth correlations were developed for each of these subsets as part of the re-analysis work performed by the Task Group. One of these subsets was used to prepare the temperature correlations that were accepted by API Committee 10 in 1991. This subset will be referred to as the 1974–84 AllMuds3 Subset later in this report.

4.1 GENERAL INFORMATION ABOUT EACH TEMPERATURE DATA SET

4.1.1 1948 Data Set

A total of eleven temperature data points were collected by Farris in the early to mid 1940s [5]. Five data points were published in the 1941 reference previously cited in this report. A seventh data point appeared in a 1942 Stanolind Oil and Gas Company laboratory report [6]. Eight data points were shown in a graph of circulating temperature-versus-depth in API Code 32. Seven of the eight data points were those already published in the literature. The eighth data point was not previously published; and the depth and temperature coordinates were picked from the graph in API Code 32. No other data were published in the open literature or company reports that could be located. The eight data points used to develop the first temperature correlations for well-simulation test schedules are is listed in Appendix A, Table A-1.

Mechanical recording devices carried in bundle carriers on the outside of drill pipe or drill collars were used by Farris to collect the data. Similar devices were used to collect data in the 1974 Data Set and the 1984 Data Set. Some improvements were made in the tools over the years and different types of carriers were developed. A reasonable description of the tools and carriers used to collect the data are provided in references at the end of this report [7,8].

4.1.2 1953 Squeeze Data Set

Five data points were collected in 1950 as part of squeeze cementing operations. Tools were run in a tubing string and 100 barrels of salt water was circulated to cool the wellbore prior to the squeeze operation. The squeeze temperature was the temperature recorded at the end of the salt water circulation. Data points published in API archives dated July 27, 1950 are listed in Appendix B, Table B-1.

4.1.3 1969–74 Data Set and 1974 Data Set

Data in the 1969-74 Data Set was collected during the period between 1969 and 1974; was collected by a relatively small group of people; and was gathered with a small number of tools. Much of the data was collected under the supervision of the people who served on the API Task Group during that period. Often, multiple temperature-recording devices were run on the drill pipe in a well. This was done to find the point of the highest temperature in a well, or to gather information on the temperatures higher in a well during circulation from a lower point. Although multiple data points may have been recorded, only the measurement by the device closest to the circulation point was considered valid for developing cementing temperature schedules.

A total of 102 data points was compiled from minutes of API meetings [9,10] and company record [11]. This number of data represents what is believed to be most of the temperature data (from recording devices closest to the circulation point) collected during the 1969 to 1974 period. Of these total data points, about 88 were given further consideration for developing temperature correlations for well-simulation test schedules by the 1969–74 Task Group. The 14 data points eliminated from consideration were from wells in which an oil base mud (oil mud) was the drilling/circulating fluid, or wells with temperature gradients less than 0.8°F/100 ft, or greater than about 2.1°F/100 ft.

The 1974 Data Set is a subset of the 1969–74 Data Set containing 41 data points. The 1974 Data Set was used to prepare the temperatures that appear in the well-simulation test schedules in API Spec 10, 5th Edition. A list of the actual data points used to prepare these temperature correlations was not found in API archives. However, a plot of the proposed temperature correlations prepared from the data was located in API archives that had the individual (41) data points plotted along with the curves. Correlation of the hand-picked coordinates for temperature and depth identified the 41 data points used from other data in the 1974 Data Set. Generally, all the data used were from wells drilled with water muds having temperature gradients between 0.8°F/100 ft and 2.00°ft/100 feet. The data points and general criteria used to select the 41 data points were confirmed by two members of the 1984–91 Task Group who were also members of the 1969–74 Task Group [12,13].

The 102 data points collected between 1969 and 1974 are contained in a Table C-1 in Appendix C. Table C-2 contains the 88 data points given further consideration for developing a temperature correlation. The 1974 Data Set, that are the 41 data points used to prepare the temperature correlations used in API Spec 10, 5th Edition, well-simulation test schedules, is listed in Appendix D, Table D-1. A summary of the general characteristics of the 1974 Data Set is provided in Table 1.

The footnote that first appeared in API Spec 10, 1st Edition, regarding bottom-hole temperatures used to calculate temperature gradients for the well-simulation test schedules is based upon all the data (88 data points) considered by the 1969–74 Task Group. Data in Table 1 refers only to the characteristics of the 41 data points used to construct the temperature correlations from the 1974 Data Set.

4.1.4 1984 Data Set

A body of temperature information was collected by Halliburton Services in cooperation with many operators between the late 1970s and mid-1980s. This body of data was provided to the API in the mid-1980s for use by this Task Group. A larger number of people and tools were involved with collecting the 1984 Data Set.

A total of 175 data points were provided to the 1984–91 Task Group for analysis. The general characteristics of the 1984 Data Set are listed in Table 2.

There are some differences between the 1974 Data Set and the 1984 API Data Set. These differences will be discussed in greater detail in the next section of this report. A listing of data in the 1984 Data Set is provided in Appendix E, Table E-1.

4.2 GENERAL COMPARISON OF 1974 DATA SET AND THE 1984 DATA SET

The 1974 Data Set and the 1984 Data Set are different in several areas. One of the most basic differences is in the way the data was collected. The 1974 Data Set was collected by a small group of people and a small number of tools. Also, a smaller group of operations were sampled, and correspondingly, the geographical area from which the data was taken was smaller as compared to the 1984 Data Set. Therefore, the consistency of measuring, collecting, and compiling the data was relatively good. Unfortunately, all of this is not well documented in the API archives.

The 1984 Data Set was compiled from data taken by a larger group of people and by a larger number of tools. The negative aspects of this are that the consistency in collecting the data and consistency in the measuring devices (one tool versus another) may be somewhat poorer. The positive aspects are that a greater number of operations and a larger geographical area were sampled. However, both data sets contain only data from the United States. Most, if not all, of the data is from the Gulf Coast (onshore and offshore Texas, Louisiana, Mississippi, Alabama) and the Mid Continent Region (Oklahoma, Kansas, Colorado, etc.).

The tools used to measure and record the data in the 1969–74, 1974 and 1984 Data Sets were similar. However, the temperature sensor tools were in different flow streams while the temperature was measured. The temperature sensor tools were located in carriers on the outside of the drill collars during the collection of data in the 1969–74 and 1974 Data Sets (and the 1948 Data Set, as well). Therefore, the temperature of the fluid flowing past the sensor in the annulus was measured and recorded.

Most of the data collected for the 1984 Data Set were from temperature sensor tools carried in slots machined into the inside wall of the carrier sub. The temperature of the fluid flowing down the inside of the drill string was recorded in this configuration. The difference in temperature between the fluid flowing inside the drill pipe and in the annulus should be small once the circulating temperature has reached a nearly steady-state condition.

Another significant difference between the two data sets is in the type of fluids circulated during the temperature measurement. Data in the 1974 Data Set was primarily from wells where water muds were circulated. A few data points for wells where oil muds were circulated are contained in the 1969–74 Data Set. However, only water muds were considered in the 41 data point subset used to develop the temperature correlations shown in API Spec 10, 5th Edition, well-simulation test schedules. The 1969–74 Task Group compared the circulating temperatures for water muds and oil muds and noticed some difference. Unfortunately, the small number of data points for oil muds was inadequate for conclusive comparison; therefore the oil mud data were not used [14].

The 1984 Data Set is composed of nearly equal numbers of data for oil muds and water muds. Figure 2 shows the distribution of mud types for the 1984 Data Set. Forty-nine percent of the new temperature data is from wells where oil muds were circulated. Forty-five percent of the data is for water muds. Only about six percent of the data did not identify the type of fluid circulated.

Static time information is another area where the 1974 Data Set and the 1984 Data Set differ. Static time is the amount of time between the end of the last circulation of the wellbore and when the temperature recording device was at the bottom (or lowest point) in the wellbore. The measuring device was allowed to remain for a period of time prior to the start of circulation in order to record the maximum temperature. This maximum temperature is listed in all tables for both data sets as the maximum recorded bottom-hole static temperature (MaxRBHST). The MaxRBHST may differ from the undisturbed formation temperature (UFT) of the adjacent geologic formation depending upon the length of time since the last circulation of the wellbore. The longer a wellbore is allowed to remain quiescent, the closer the MaxRBHST should be to the UFT.

The average static time for both data sets is greater than 24 hours. The average static time for the 1984 Data Set is about four hours longer than the average for the 1974 Data Set. However, only 39 percent of the records in the 1984 Data Set have static time information provided while 73% of the records in the 1974 Data Set have static time information. The distribution of static time information and static time ranges for both data sets is provided in Figures 3, 4, 5 and 6.

A pseudo temperature gradient (PsTG) was calculated from the difference between the MaxRBHST and an assumed surface temperature (AST) and the true vertical depth of the well. The AST used to calculate the PsTG was different for the two data sets. The temperature gradient for the 1974 Data Set was calculated using an AST of 75°F as follows:

$$\text{PsTG} = \frac{(\text{MaxRBHST} - 75°\text{F}) \times 100}{\text{TVD}} \tag{3}$$

where

PsTG = pseudo-temperature gradient, degrees°F/100 ft,

MaxRBHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

TVD = true vertical depth, ft.

The temperature gradient for the 1984 Data Set was calculated using an AST of 80°F according to the equation below:

$$\text{PsTG} = \frac{(\text{MaxRBHST} - 80°\text{F}) \times 100}{\text{TVD}} \tag{4}$$

where

PsTG = pseudo-temperature gradient, °F/100 ft

MaxRBHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

TVD = true vertical depth, ft.

The true temperature gradient may be different from the PsTG depending upon the difference between the MaxRBHST and the UFT at the depth the temperature measurement was made. The longer the wellbore is allowed to remain quiescent, the closer the MaxRBHST should be to the UFT. The choice of 80°F or 75°F for the AST is arbitrary and makes some difference in the PsTG. The tables in Appendix C and Appendix D, which contain the 1969–74 Data Set and the 1974 Data Set, have the PsTG calculated with both ASTs for comparison.

Finally, data relating to the temperature for a simulated squeeze cementing operation were collected for the 1984 Data Set. No similar information was collected for the 1974 Data Set. This will be discussed in greater detail later in this report.

4.2.1 Temperature Correlation from the 1948 Data Set

Eight pairs of recorded circulating temperature and depth were plotted on semi-log paper. A best fit line was constructed through the data points for the correlation used for casing cementing well-simulation test schedules in API Code 32. The plot of data was included in API Code 32 showing the individual data points and the line drawn through them. The individual points were removed from the plot in the API RP 10B, 3rd Edition, published in 1953.

No specific information was found to indicate the method used to construct the line through the data points. Since the data is plotted on semi-log paper, one assumption is that the line could have been hand-drawn. However, the line could have been constructed through regression analysis of the data. The line appears to fit an exponential regression equation of the general type:

$$\ln(\text{Temperature}) = a + b\,(\text{Depth}) \tag{5}$$

where

Temperature = recorded circulating temperature, °F,

Depth = depth at which temperature was recorded, ft,

a, b = regression constants.

Applying this type of regression equation to the data in Appendix A gives the following:

$$\ln(\text{PBHCT}) = 4.179699 + (0.00008065267 \times \text{Depth})$$

where

PBHCT = bottom-hole circulating predicted by the correlation for a specified depth, °F.

Predicted temperatures from this equation are compared against the data and the predicted values listed in API Code 32, 1st Edition, in Figure 7. As shown in the figure, there is good correlation between the data, the predicted values along the regression curve and the values from the well-simulation test schedules in API Code 32.

4.2.2 Temperature Correlation from the 1950 Squeeze Data Set

Six pairs of recorded temperature data versus depth are believed to have been used for construction of the first squeeze temperature correlation. No record of the data used or the method employed to generate the line representing the predicted squeeze temperature with depth was found in API archives. The same assumptions made for the casing cementing temperature correlation can be made for this data.

If exponential regression analysis were used, the following equation results:

$$\ln(\text{PSqT}) = 4.380674 + (0.00008234938 \times \text{Depth})$$

where

PSqT = squeeze temperature predicted by the correlation for a specified depth, °F.

Predicted temperatures from this equation are compared against the data and the predicted values listed in API RP 10B, 3rd Edition, in Figure 8.

4.2.3 Temperature Correlation from the 1974 Data Set

The criteria used to select the 41 data points used to develop the temperatures in the API Spec 10, 5th Edition, well-simulation test schedules were discussed in a previous section. The general criteria are re-stated below for convenience of the reader:

a. Wells where only water muds were the circulation fluid.

b. Wells with temperature gradients between 0.8°F and 2.1°F/100 ft.

The selected data points were grouped according to ranges of PsTG. For example, all data points between 0.8 and 0.99 were used for the 0.9°F/100 ft PsTG group. Similar groups were formed which represent the 1.1, 1.3, 1.5, 1.7 and 1.9°F/100 ft gradients listed in the tables in API Spec 10, 5th Edition.

The minimum recorded bottom-hole circulating temperature (MinRBHCT) measured by the temperature sensor during circulating of the drilling fluid was plotted against the depth at which the temperature was recorded for the data in each gradient range group. A line was hand-drawn to represent the trend of the data in each gradient range grouping. Each line began at 75°F as the intercept for zero depth, which corresponds to the AST used to calculate the temperature gradients. Obviously, all of the lines were not the same and some of the lines from the different gradients intersected. To correct this, the lines were re-drawn (by hand) to eliminate the intersections and to more uniformly space out the different generalized gradient (0.9, 1.1, etc.) curves. [12,13]

4.2.4 Temperature Correlations from the 1984 Data Set

The main goal of the 1984–91 API Task Group was to develop updated temperature schedules using all suitable, available data in conjunction with accepted statistical and engineering methods. The Task Group considered several approaches and each will be discussed in this section.

The first method required grouping data into subsets according to the PsTG ranges as done for the correlation developed from the 1974 Data Set. A "best fit" (lowest total error) of the data using a regression analysis program could be obtained. Since different general types of equations could provide the best fit for data in each PsTG group, there was a high potential for intersection of the different lines representing each PsTG using this method.

Another approach using the PsTG groups would be to fit each subset to the same general type of equation. The coefficients of the equation could vary but the chance of the various lines intersecting would be reduced. However, the error for the predicted temperatures may be increased.

The Task Group chose a two-step approach. First, the entire data set was statistically analyzed using multiple regression techniques and correlation coefficients to identify variables in the data set that had the greatest effect on circulating or squeeze temperatures. Second, after these variables were identified, a mathematical correlation would be developed from all the suitable temperature data for casing and squeeze cementing temperatures which provided the lowest possible error. No grouping of data into PsTG subsets as discussed previously was performed.

As mentioned earlier, many variables affect the circulating or squeeze temperature in a wellbore. Unfortunately, neither the 1974 Data Set nor the 1984 Data Set had a lot of information about many of the variables other than MaxRBHST, MinRBHCT, and true vertical depth. Some analysis was performed to evaluate the effect of drilling fluid type (oil base or water base muds), circulating rate, circulating time, inlet temperature of the circulated fluid and well geometry on the circulating temperature. No clearly distinguishable effects were observed or determined from the data collected.

Numerous general equation types were evaluated to develop correlations for predicted bottom-hole circulating temperature (PBHCT) and predicted squeeze temperature (PSqT). Two of the most common types used by the 1984-91 Task Group are provided below.

$$\text{PBHCT (or PSqT)} = 80°\text{F} + [(A \times \text{PsTG}^{B}) \times (\text{TVD}^{C})] \quad (6)$$

where

PBHCT = predicted bottom-hole circulating temperature, °F,

PSqT = predicted squeeze temperature, degrees°F,

PsTG = temperature gradient, degrees°F/100 ft,

TVD = true vertical depth, ft,

80°F = assumed surface temperature, °F,

A, B and C = constants.

$$\text{PBHCT (or PSqT)} = 80°\text{F} + \frac{A + [B \times (\text{TVD} \times \text{PsTG} \times 0.1)]}{1 + (C \times \text{TVD} \times 0.00001)} \quad (7)$$

where

PBHCT = predicted bottom-hole circulating temperature, °F,

PSqT = predicted squeeze temperature, °F,

PsTG = temperature gradient, °F/100 ft,

TVD = true vertical depth, ft,

80°F = assumed surface temperature, °F,

A, B and C = constants.

Equation 6 was used by members of the Task Group to prepare correlations for comparison within the Task Group meetings, but Equation 7 was used to prepare the final correlations. Dr. Franklin Kemp, a statistician with Amoco Production Company, identified Equation 7 as being more precise and easier to use than Equation 6.

4.2.5 Acceptance of the Temperature Correlations Developed from the 1984 Data Set

The PBHCTs from this new correlation were, in general, higher than the temperatures in API Spec 10, 5th Edition, well-simulation test schedules for casing-cementing operations at depths shallower than 10,000 ft. Table 3 compares the predicted circulating temperatures for the correlations developed from the 1948, 1974, and 1984 Data Sets. Table 4 compares the predicted squeeze temperatures for the 1953 and 1984 Data Sets.

Higher PBHCTs from the correlation developed from the 1984 Data Set concerned members of the Task Group for two reasons. First, the temperatures predicted by the correlations developed from the 1974 Data Set had been used successfully for over ten years without apparent problems. Second, the temperatures predicted by the 1974 Data Set correlation were higher, in general, than the temperatures predicted by the correlation from the 1948 Data Set at depths shallower than 10,000 ft. The correlation based upon the 1948 Data Set had been used for 25 years without apparent, widespread problems. Therefore, an increase in temperatures in the test schedules did not appear to be warranted, based upon the success of previous temperature correlations.

The Task Group presented the correlation developed from the 1984 Data Set to the general membership of API Committee 10 for review. The comments regarding the 1984 Data Set, temperature correlations developed from the 1984 Data Set, and methods used by the Task Group to prepare the correlations are summarized from this review as follows:

a. PBHCTs for casing/liner cementing operations are too high based upon industry experience from numerous cementing operations, particularly at depths shallower than 10,000 ft.
b. The higher PSqTs are of less concern than the higher PBHCTs. There is generally a greater temperature range for squeeze-cementing operations due to various techniques and well preparation times.
c. Calculation of temperature gradient. Some members of the Task Group and others in Committee 10 wanted the temperature gradient calculated from the UFT.
d. Short static times. This is related to the temperature gradient issue and can be a significant factor in squeeze cementing operations as well as primary cementing operations. The longer the static time, the closer the MaxRBHST is expected to be to the UFT.
e. The 1984 Data Set is not a good representation of temperature data for most of the cementing operations performed.

The correlation developed from the 1984 Data Set was believed to be the most accurate and precise based upon the data. However, most Task Group and Committee 10 members did not know if the correlation developed from the previous data sets, particularly the 1974 Data set, was an equally accurate and precise representation of that data. A detailed analysis of the 1974 Data Set was conducted prior to addressing the concerns noted above.

4.3 RE-ANALYSIS OF THE 1974 DATA SET AND TEMPERATURE CORRELATION

Re-analysis of the data and methods used to develop the temperatures in the API Spec 10, 5th Edition, well-simulation test schedules was performed using statistical methods. This was done to determine if the temperatures predicted by the hand-drawn curves were representative of the best correlation which could be developed from the data. General results of the analysis of the 1974 API Data Set are presented in this section.

Three methods were used to re-analyze the data. Two methods involved leaving the data from the 41 data point subset in the PsTG groupings used by the 1969–1974 Task Group. Each PsTG group was curve fit to Equation 5 and Equation 6. Equation 5 was similar to the equation type used by Farris to develop the earliest correlations for the well-simulation test schedules.

The third method was similar to the approach adopted by the 1984-91 Task Group. All of the 41 data points were used to determine the coefficients of the equation the data was not grouped according to PsTG for this analysis. Equation 6 was also used to develop the correlation from this data set with this method. Results from the correlations developed by all three methods are compared with the temperatures in the API Spec 10, 5th Edition in Table 5.

4.3.1 Correlation Developed Using Equation 5

The following can be observed by comparing the predicted temperatures from this correlation method with the temperatures in API Spec 10, 5th Edition.

The correlation predicts higher temperatures at 1,000 ft depth for all gradients. Predicted temperatures range from 3°F-lower to 3°F-higher than the Spec 10 temperatures at 2,000 ft. At 4,000 ft, predicted temperatures are from 2°F-lower to 12°F-higher. Predicted temperatures are 6°F to 12°F higher for the 1.3°F, 1.7°F and 1.9°F/100 ft gradients at this depth.

Correlation temperatures were 4°F lower to 16°F higher at 6,000 feet; and all predicted temperatures were higher for gradients greater than 1.1°F/100 ft. Results for 8,000 ft were similar with predicted temperatures from 6°F-lower to 13°F-higher. Predicted temperatures were higher for gradients greater than 1.1°F/100 ft at this depth. A similar trend can be seen at 10,000 ft.

Predicted temperatures for the 12,000 ft depth ranged from 7°F-lower to 12°F-higher than the API Spec 10 temperatures. There was generally good agreement at the 1.1, 1.3 and 1.5°F/100 ft gradients. Lower temperatures were predicted for the 0.9°F/100 ft gradient, and higher temperatures were predicted for the 1.7°F and 1.9°F/100 ft gradients. The trend was similar at 14,000 ft. At 16,000 ft, there was good agreement on temperatures for gradients of 0.9 through 1.5°F/100 ft. Predicted temperatures for the 1.7°F and 1.9°F/100 ft gradients were 18°F and 48°F higher, respectively. All predicted temperatures higher at 18,000 feet and 20,000 ft.

Correlations developed by this method predicted temperatures generally lower than those listed in API Spec 10, 5th Edition, for the 0.9°F/100 ft gradient for depths shallower than 16,000 ft. Higher temperatures were predicted for depths deeper than 16,000 ft. The correlation developed for the 1.1°F/100 ft gradient predicted slightly lower temperatures at depths down to 12,000 ft. Higher temperatures were predicted for depths below 14,000 ft. The correlation developed for the 1.3°F/100 ft temperature gradient predicted higher temperatures at all depths except 12,000 ft.

Predicted temperatures and API Spec 10 temperatures were about the same for the 1.5°F/100 ft gradient except at the two deepest depths. Much higher temperatures were predicted by the correlation at 18,000 ft and 20,000 ft. All predicted temperatures from the correlation were higher than Spec 10 temperatures at the 1.7°F and 1.9°F/100 ft gradients.

Temperatures predicted from this correlation method were generally higher at depths shallower than 10,000 ft. There was generally good agreement at 12,000 to 16,000 ft for gradients of 1.5°F/100 ft or lower. The correlation predicted temperatures that did not agree closely with API Spec 10 temperatures at depths greater than 16,000 ft.

4.3.2 Correlation Developed Using Equation 6

At the 0.9°F/100 ft PsTG, the correlation based on grouping of data based upon temperature gradient predicts higher temperatures than those listed in API Spec 10, 5th Edition, at depths down to and including 16,000 ft. At 18,000 ft the predicted temperatures are the same. The correlation based on gradient grouping predicts a lower temperature than API Spec 10 at 20,000 ft.

Using all 41 points to develop a correlation with Equation 6 results in predicted temperatures lower than those listed in API Spec 10, 5th Edition, for the 0.9°F/100 ft gradient at depths down to and including 12,000 ft. Predicted temperatures from the correlation match API Spec 10 temperatures at 14,000 ft and 16,000 ft. The correlation from this method predicts a higher temperature at 20,000 ft than the temperature listed in API Spec 10.

The correlation developed using the gradient-grouping method predicts lower temperatures than those listed in API Spec 10, 5th Edition, for depths down to and including 10,000 ft for the 1.1°F/100 feet gradient. Predicted temperatures are essentially the same as API Spec 10 temperatures at deeper depths for this gradient. The correlation developed from ungrouped data predicts lower temperatures down to and including 4,000 ft. Predicted temperatures from the correlation match the API Spec 10 temperatures at 6,000 ft and 8000 ft. Slightly higher temperatures are predicted by the correlation at the other depths.

For the 1.3°F/100 ft PsTG, API Spec 10, 5th Edition, temperatures are higher at 1,000, 2,000, 18,000 and 20,000 ft than the temperatures predicted by the correlation developed from data within this gradient group. Higher temperatures are predicted from the correlation at depths from 6,000 feet down to and including 14,000 feet. Temperatures at other depths are essentially the same as those listed in API Spec 10. The comparative trend for the correlation developed from non-grouped data is similar.

The predicted temperature from the correlations agrees well with the API Spec 10, 5th Edition, temperatures for the 0.9°F/100 ft gradient. Predicted temperatures at the 1.1°F/100 ft gradient are all higher than the API Spec 10 temperatures for all the depths shown. The predicted temperatures are all higher than the API Spec 10 temperatures at depths shallower than 16,000 ft for all other gradients.

Grouping the data results in a correlation that predicts lower temperatures than those listed in API Spec 10, 5th Edition, at depths through 14,000 ft for the 1.5°F/100 ft gradient. Higher temperatures are predicted for deeper depths. Not grouping the data results in a correlation that predicts higher temperatures at depths from 4,000 ft down through 14,000 ft. Lower temperatures are predicted for depths greater than 16,000 ft.

The correlation developed from grouped data for the 1.7°F/100 ft gradient predicts higher temperatures than those listed in API Spec 10, 5th Edition, at depths through 12,000 ft. Lower temperatures are predicted for deeper depths. Not grouping the data results in a correlation that predicts higher temperatures at depths from 4,000 ft down through 14,000 ft. Lower temperatures are predicted for depths of 16,000 ft or more.

Higher temperatures are predicted from the correlation developed from grouped data at depths greater than 2,000 ft for the 1.9°F/100 ft gradient. The correlation developed from all 41 data points that were not grouped predicts higher temperatures at 4,000 ft down through 10,000 ft. Temperatures lower than those listed in API Spec 10, 5th Edition, are predicted for depths deeper than 12,000 ft for this gradient.

4.3.3 Summary and Conclusions of Re-Analysis of 1974 Data Set

There are 66 temperatures in the API Spec 10, 5th Edition casing cementing well-simulation schedules. This number comes from the eleven schedule depths with six temperatures per depth corresponding to the different gradients. The correlation developed from ungrouped data using Equation 6 predicts higher temperatures for 47% of the depth and gradient pairs. Most of the higher temperatures, 71%, are at depths equal to, or shallower, than 12,000 ft. The results are essentially the same for the correlation developed from grouped data using Equation 6.

Predicted temperatures from the correlation method using grouped data and Equation 5 were higher in 68% of the depth and gradient pairs than the temperatures listed in API Spec 10, 5th Edition. Only 58% of the higher temperatures were at depths equal to or shallower than 12,000 ft.

It appears from this analysis that temperatures in API Spec 10, 5th Edition, are slightly lower, in general, than the values predicted from correlations developed from the data for depths between about 4,000 ft and 12,000 ft.

4.4 DISCUSSION OF CONCERNS ABOUT THE 1984 DATA SET AND TEMPERATURE CORRELATIONS

Results of the re-analysis of the 1974 API Data Set provided valuable insight into the temperatures in the API Spec 10, 5th Edition, well-simulation test schedules. However, this did not resolve any of the issues identified in the review of the Task Group's work by Committee 10. Each of these concerns was carefully considered and a discussion of each follows.

4.4.1 PBHCTs are Too High

Concerns that the PBHCTs from the new correlations are too high was difficult to address. Re-analysis of the 1974 API

Data Set showed that the temperatures in API Spec 10, 5th Edition, are not entirely supported by the data used to prepare them. Clearly, the hand-drawn correlations are not the lowest error correlations for the data set. Correlations developed from the 1984 Data Set and the 1974 Data Set using various methods of analysis showed similar PBHSTs. Further, the new correlations have lower error in predicted versus measured temperatures for the data sets from which they were developed. However, the temperatures in the API Spec 10, 5th Edition, have been used successfully for over two decades to design cement formulations.

Two key issues regarding the 1974 Data Set and the 1984 Data Set were identified by the Task Group. First, both data sets have little temperature data for depths shallower than 10,000 ft, and no data for depths shallower than 7,000 ft. Significant error in predicting bottom-hole circulating temperatures could be expected for depth ranges which were not represented in the data used to develop the mathematical correlation. Secondly, by the measured temperatures in both data sets are not cementing temperatures. The data is a measurement of temperatures during circulation of the mud down the drill pipe.

The time for fluid from the surface to reach to bottom of the well (or lowest point of circulation in the well) may be significantly shorter unless the pumping rate down the drill pipe is adjusted to give the same time to the bottom of the well as would occur during circulation down the casing. However, if this is done, the fluid velocity in the annulus between drill pipe and borehole wall may be lower than the fluid velocity in the annulus between casing and borehole wall. Also, the difference in surface area of the casing combined with the difference in annular clearance may produce different circulating temperatures due to differences in heat transfer.

The starting temperature at the surface of the fluid being circulated could significantly influence the BHCT, particularly in shallow wells. The muds circulated are in a closed system. The overall temperature of the mud on the surface decreases when the well is not being circulated. After circulation starts, the overall temperature of the mud volume on the surface increases as heat is retained by the mud as it returns to the surface from the wellbore. Some information on mud circulating temperatures was contained in the 1984 Data Set. This information is plotted in Figures 9, 10, 11, 12, 13 and 14.

Figure 9 shows data for the Initial Mud Inlet temperature at the start of circulation (with temperature recording device and drill pipe run into the well). Linear regression analysis of the data using the measured inlet temperature and depth resulted in the line shown on the plot. The trend clearly shows that the inlet temperature is higher for shallower depths. The inlet temperature for data at depths shallower than 10,000 ft is generally around 100°F. The Final Mud Inlet temperature data (just before circulation ended) is plotted in Figure 10. The overall fluid temperature increased. Final inlet temperatures were over 100°F for nearly all data.

Figures 11 and 12 show a similar trend for the Initial Mud Outlet (return line at surface) and Final Mud Outlet temperatures. Figures 13 and 14 compare the initial and final temperatures for both the inlet and outlet for the circulation period. The average circulating time for the 1984 Data Set was just slightly more than six hours. A complete listing of mud temperature data is provided in Appendix F, Table F-1.

The trends seen in Figures 9 through 14 may be explained to some degree. Drilling operations cause a heating of the mud. Once drilling and circulating stop, the mud may begin to cool depending on surface conditions such as total volume, surface area and location of holding tanks (pits), ambient temperature and wind conditions, mechanical energy applied on surface (mixing equipment, circulation of holding tanks), and time. For shallow wells, the time required to perform operations (trip in and out of the hole, log, etc.) is generally less. Therefore, the mud has less time to cool. In deeper wells, the static time is generally greater because the time required to perform most operations is greater. Therefore, the mud has more time to cool.

4.4.2 PSqTs are Too High

Squeeze temperatures can vary significantly in a well depending upon the amount of circulation performed, the circulating rate and the type of fluid circulated. In many cases, these variables depend upon the mechanical configuration of the well in preparation for the squeeze-cementing operation.

The squeeze temperatures listed in the 1984 Data Set were collected using one technique. This technique will be described briefly. Once the drill pipe containing the temperature recording device was in place in the well, the well was not circulated for a period of time to allow the maximum temperature prior to circulation to be recorded. Next, circulation of the well was started. Circulation was stopped for a short period after one drill pipe volume had been pumped. This short static period allowed the change in temperature after the brief circulation to be recorded. Next, circulation was resumed. The generalized temperature profile recorded during this operation is illustrated in Figure 15.

The actual squeeze temperature in a well may be higher or lower than the predicted temperature from this correlation, depending upon the amount of circulation, circulating rate, and type of fluid circulated across the intended injection point.

4.4.3 Calculation of Temperature Gradient and Short Static Times

Some members of the Task Group and Committee 10 desired that the temperature gradients be based upon the true, undisturbed static temperature of the formations at any given depth. Temperature gradients calculated for both the 1974 Data Set and the 1984 Data Set used the maximum static temperature recorded by the temperature recording device on the drill pipe in the well.

These calculated temperature gradients were used to prepare the temperature schedules in API Spec 10 and the new temperature correlations.

Task Group members recognized three key issues regarding the calculation of temperature gradients. First, true, undisturbed static temperature data was not available to the Task Group for either the 1974 Data Set or the 1984 Data Set. Second, the maximum temperatures recorded for both data sets is most probably not the true static temperature of the surrounding formations. Third, the longer the static time since the last circulation of the wellbore, the closer the maximum temperature recorded by the measuring device should be to the true static temperature of the adjacent formations.

4.4.4 Temperature Data Sets are Not Representative of General Cementing Operations Conducted Within the Industry

There is no question that the bulk of the data from both the 1974 API Data Set and the 1984 Data Set is for relatively deep wells. This is evidenced by the fact that neither data set has usable data for depths shallower than 7,000 ft. Members of Committee 10 were advised of the need for data from depths shallower than 10,000 ft several years before this work was completed. No additional data within this depth range was received by the Task Group.

5 1974–84 Combined Master Data Set

The Task Group combined all of the 1974 Data Set and the 1984 Data Set into one data set as the initial step in an effort to develop accurate, representative temperature correlations for casing and squeeze cementing. A careful review of all the data was conducted and some data was eliminated from further consideration. The criteria used to eliminate data are listed below.

1. Offshore wells where the water depth is greater than 250 ft.
2. Offshore wells where the water depth is less than 250 ft, if the water depth was greater than 5% of the total well depth.
3. Data from up-hole temperature recording devices where circulation was at a deeper depth, and multiple subs were placed higher in the well.
4. Temperature gradients greater than 2.1°F/100 ft.
5. No BHCT listed.
6. Duplicate data sets.

The resulting data set was called the 1974–84 Combined Master Data Set and contained 200 data points. Forty-one data points were from the 1974 Data Set and nine data points were from the 1969-74 Data Set for wells with oil base muds. Twenty-five of the 175 data points from the 1984 Data Set were eliminated, leaving 150 points from this data set in the combined data group. A listing of all temperature data in the 1974–84 Combined Master Data Set is provided in Appendix G, Table G-1.

5.1 UPDATED TEMPERATURES FOR WELL SIMULATION TEST SCHEDULES

5.1.1 Subsets from the 1974–84 Combined Master Data Set

Eleven subsets were formed from data in the 1974–84 Combined Master Data Set. Each subset in the Selected Master Data Set for additional consideration. The selected subsets are described in the following list.

- AllMuds1—All mud types, only data records which had static time information listed.
- AllMuds2—All mud types, only data records with static times equal to or greater than 12 hours.
- AllMuds3—All mud types, only data records with static times equal to or greater than 24 hours.

- WaterMuds1—Water Muds only, all records.
- WaterMuds2—Water Muds only, only data records with static time information listed.
- WaterMuds3—Water Muds only, only data records with static times equal to or greater than 12 hours.
- WaterMuds4—Water Muds only, only data records with static times equal to or greater than 24 hours.

- OilMuds1—Oil Muds only, all records.
- OilMuds2—Oil Muds only, only data records with static time information listed.
- OilMuds3—Oil Muds only, only data records with static times equal to or greater than 12 hours.
- OilMuds4—Oil Muds only, only data records with static times equal to or greater than 24 hours.

For consideration of squeeze-cementing temperatures, only records with squeeze-cementing temperature information listed were used from the 1974–84 Combined Master Data Set and selected subsets.

A complete listing of the data in the 11 subsets described above for both casing and squeeze-cementing temperatures is provided in Appendix H, Tables H-1 through H-11.

5.1.2 Correlations Developed from Subsets

Separate temperature correlations were prepared for each subset using Equation 6 and Equation 7. These correlations were sent out to members of the Task Group for review. Predicted temperatures from correlations developed for each data subset varied for both the casing and squeeze cementing temperatures. There were some differences between the temperatures predicted for the circulation of oil muds or water muds. The equation type (Equation 6 or Equation 7) used to prepare the correlations also contributed to these differences.

After this review, the Task Group agreed to use 1974–84 Allmuds3 Subset and Equation 7 for development of new temperature correlations for casing and squeeze cementing. The 1974–84 Allmuds3 Subset contained 66 records for both oil and water muds with static times equal to or greater than 24 hours. Only 40 of these 66 records contained squeeze temperature information which could be used to prepare a mathematical correlation to predict squeeze temperatures. Other characteristics of the data set are shown in Table 6. The predicted temperatures-versus-depth for the casing and squeeze-cementing correlations developed from this data set are shown in Table 7.

5.2 PROPOSED UPDATED TEMPERATURE SCHEDULES

The predicted casing cementing temperatures from the correlation are still higher than temperatures in API Spec 10, 5th Edition, well-simulation test schedules for some gradients at depths shallower than 10,000 ft. This is shown in Table 8. Additionally, only 3% of the data points in the selected subset are for depths shallower than 10,000 ft. A listing of the data set and correlations developed by Dr. Kemp using Equation 7 are provided in Appendix I, Table I-1.

5.2.1 Casing (Primary) Cementing Temperatures

The Task Group developed the following, which were proposed to API Committee 10 as changes to the temperatures in casing-cementing well-simulation test schedules.

1. Use the casing cementing temperatures listed in the API Spec 10, 5th Edition, for depths shallower than 10,000 ft.
2. Use the correlation developed by Dr. Franklin Kemp from the 66 data points in the 1974–84 Allmuds3 Subset and Equation 7 for depths deeper than 10,000 ft.

The results of combining the API Spec 10, 5th Edition, temperatures with the new correlations are referred to as the 1991 Hybrid Correlation in the remainder of this report. Figures 16, 17, 18, 19, 20, and 21 show the results of plotting the BHCT versus depth for the 1991 Hybrid Correlation. In these figures, API Spec 10, 5th Edition, temperatures were used for depths down through 10,000 ft. Temperatures predicted from the new correlation are used for depths greater than 10,000 ft.

5.2.2 Squeeze Cementing Temperatures

The correlation developed by Dr. Kemp using the data points in 1974–84 Allmuds3 Subset of the 1974–84 Combined Master Data Set and Equation 7 was accepted by the Task Group for use at all depths. Note that only 40 of the records in the 1974–84 Allmuds3 Subset contained squeeze temperature information. Therefore, only 40 of the 66 total data points in the 1974-84 Allmuds3 Subset could be used to develop a mathematical correlation to predict squeeze temperatures. The temperatures predicted from this correlation are compared with the squeeze temperatures developed from the 1953 Squeeze Data Set which are the temperatures in the squeeze schedules in API Spec 10, 5th Edition in Table 9.

5.2.3 Comparison of Proposed Casing and Squeeze-Cementing Temperatures

The predicted temperatures for the 1991 Hybrid Correlation and the new Squeeze Correlation are compared in Table 10. The predicted casing cementing temperatures are higher than the predicted squeeze-cementing temperatures at 1,000 ft and 2,000 ft for the 0.9°F/100 ft gradient. Predicted squeeze-cementing temperatures are higher for all other gradients at all depths.

6 Summary

The accuracy of predicted cementing temperatures in the API cementing well-simulation test schedules remains unknown. These temperature predictions correlated with depth have been a useful tool for the industry for over half a century. Therefore, they must be, at least, reasonable estimates for cementing temperatures. However, they were not derived from temperature data measured during actual cementing operations.

The designed thickening time safety factors often employed by the industry [15] may provide protection from errors in temperatures for the bulk of cementing operations performed. The average depth of wells drilled throughout the world is about 5,000 ft and the largest percentage of wells drilled each year is less than about 12,000 ft [16]. The average cementing job time for casing strings within these depths is less than 2.5 hr. Therefore, the typical thickening time of cement slurries for these applications is about twice the actual job time. Gross errors in temperature predictions may be required before serious cementing problems become manifest.

The precision of correlations developed from different data sets has varied. It appears that the correlations developed from the 1948 Data Set and the 1953 Squeeze Data Set are supported well by the data. Similarly, the correlation developed from the 1984 Data Set was the lowest error correlation derived from the data. Based upon the work reported here, the correlation developed from the 1984 Data Set is the most precise correlation derived for any API temperature data set. The correlations developed from the 1974 Data Set may be less precise based upon data than correlations developed from the 1948 Data Set and the 1953 Squeeze Data Set.

Consideration was given to the data, the correlation method and industry experience with existing predicted temperatures before developing the 1991 Hybrid Correlation for casing-cementing temperatures. This correlation is not ideal but it reflects an attempt to balance accuracy and precision. Clearly, more data are needed, particularly at depths shallower than 10,000 feet. Once data for this depth range are collected, another Task Group should be assembled to develop an improved correlation.

Table 1—General Characteristics of 1974 Data Set Used to Prepare API Spec 10, 5th Edition, Temperature Schedules

Total number of data points	41	
Average well depth, ft	13,064	
Minimum well depth, ft	7,215	
Maximum well depth, ft	20,580	
Number of data points from depth shallower than 10,000 ft	8	(19.5%)
Number of records having static time (since last circulation) information	30	(73%)
Average static time, hr	25.7	
Minimum static time, hr	7	
Maximum static time, hr	42	
Number of records with static time equal to or greater than 12 hr	28	(68%)
Number of Records with Static Time equal to or greater than 24 hr	18	(44%)
Method of temperature gradient calculation, °F/100 ft	$\frac{(BHST-75) \times 100}{Depth}$	
Temperature gradient range (°F/100 ft)	0.80 to 2.05	
Average temperature gradient (°F/100 ft)	1.406	
Number of data points with gradients less than or equal to 1.4°F/100 ft	23	(56%)
Type of fluid circulated	Water-based muds only	
Number of records with circulating time information	21	(51%)
Average circulating time, hr	3.1	

Table 2—General Characteristics of the 1984 Data Set

Total Number of Data Points	175	
Average well depth, ft	13,344	
Minimum well depth, ft	1,097	
Maximum well depth, ft	24,985	
Number of data points from depths shallower than 10,000 ft	30	(17%)
Number of records having static times (since last circulation) information	68	(39%)
Average static time, hr	29.9	
Minimum static time, hr	3.75	
Maximum static time, hr	138	
Number of records with static time equal to or greater than 12 hr	60	(34%)
Number of records with static time equal to or greater than 24 hr	45	(26%)
Method of temperature gradient calculation, °F/100 ft	$\frac{\text{BHST}-80 \times 100}{\text{Depth}}$	
Temperature gradient range (°F/100 ft)	0.39 to 4.88	
Average Temperature Gradient (°F/100 ft)	1.498	
Number of data points with gradient less than or equal to 1.4°F/100 ft	93	(53%)
Number of data points with gradient greater than 2.00°F/100 ft	8	(5%)
Number of data points with gradient greater than 4.00°F/100 ft	4	(2%)
Type of fluid circulated	Oil and water-based drilling fluids	
Number of records for oil muds	86	
Number of records with water muds	79	
Number of records with unknown fluid type	10	
Number of records with circulation time information	136	(78%)
Average circulating time, hr	6.1	

Table 3—Comparison of Predicted Casing-Cementing Temperatures from Correlations Developed from the 1948, 1974 and 1984 Data Sets

Depth ft	Data Set Correlation	Not Specified	Temperature Gradient, °F/100 ft 0.9	1.1	1.3	1.5	1.7	1.9
1,000	1948	80						
	1974		80	80	80	80	80	80
	1984		77	78	80	81	82	84
2,000	1948	91						
	1974		89	89	90	90	91	91
	1984		83	86	88	91	93	96
4,000	1948	103						
	1974		99	100	101	102	103	104
	1984		95	100	106	111	116	122
6,000	1948	113						
	1974		112	114	116	118	120	126
	1984		108	116	124	132	140	149
8,000	1948	125						
	1974		126	129	135	140	146	160
	1984		121	132	143	154	166	177
10,000	1948	144						
	1974		141	142	158	167	180	200
	1984		135	149	163	178	192	206
12,000	1948	172						
	1974		155	165	185	197	217	247
	1984		149	167	185	202	220	238
14,000	1948	206						
	1974		169	187	215	233	258	293
	1984		165	186	207	228	249	270
16,000	1948	248						
	1974		183	210	245	270	302	340
	1984		181	206	231	255	280	305
18,000	1948	300						
	1974		199	234	277	308	347	385
	1984		198	227	256	284	313	341
20,000	1948	340						
	1974		215	259	312	348	392	431
	1984		216	249	282	315	347	380

Note: 1984 Data Set Correlation: PBCHT = 80°F + ((0.00663574 x TG x Depth) – 8.49686) / (1– (0.00001162 x Depth))

where

PBHCT = predicted bottom-hole circulation temperature, °F,
TG = temperature gradient, °F/100 ft,
Depth = true vertical depth, ft.

Table 4—Comparison of Predicted Squeeze-Cementing Temperatures from Correlations Developed from the 1953 Squeeze and 1984 Data Sets

			Temperature Gradient, °F/100 ft					
Depth ft	Data Set Correlation	Not Specified	0.9	1.1	1.3	1.5	1.7	1.9
1,000	1950	89						
	1984		79	80	82	84	85	87
2,000	1950	98						
	1984		86	89	93	96	99	103
4,000	1950	116						
	1984		101	108	115	121	128	135
6,000	1950	136						
	1984		117	127	137	147	157	167
8,000	1950	159						
	1984		132	146	160	173	187	201
10,000	1950	186						
	1984		148	166	183	200	217	235
12,000	1950	213						
	1984		165	186	207	228	249	269
14,000	1950	242						
	1984		182	206	231	256	280	305
16,000	1950	271						
	1984		199	227	256	284	313	341
18,000	1950	301						
	1984		216	248	281	313	346	378
20,000	1950	340						
	1984		234	270	307	343	379	416

Note: 1984 Data Set Correlation: PSqT = 80°F + ((0.00821677 x TG x Depth) – 8.82971) / (1 – (0.000004812 x Depth))

where

PSqT = predicted squeeze temperature, °F,
TG = temperature gradient, °F/100 ft,
Depth = true vertical depth, ft.

Table 5—Predicted Casing-Cementing Temperatures from Correlations Developed from Re-Analysis of the 1974 Data Set

Depth ft	Data Grouping	Temperature Gradient, °F/100 ft 0.9	1.1	1.3	1.5	1.7	1.9
1,000	All Data (Equation 6)	78	79	79	80	81	81
	Gradient Groups (Equation 6)	87	78	79	76	83	80
	Gradient Groups (Equation 5)	83	81	87	81	85	85
	API Spec 10, 5th Ed.	80	80	80	80	80	80
2,000	All Data (Equation 6)	82	84	86	87	89	91
	Gradient Groups (Equation 6)	96	82	86	78	94	89
	Gradient Groups (Equation 5)	88	86	93	87	93	94
	API Spec 10, 5th Ed.	89	89	90	90	91	91
4,000	All Data (Equation 6)	93	97	102	106	111	115
	Gradient Groups (Equation 6)	112	94	102	87	117	114
	Gradient Groups (Equation 5)	97	98	107	103	111	116
	API Spec 10, 5th Ed.	99	100	101	102	103	104
6,000	All Data (Equation 6)	105	113	120	128	136	144
	Gradient Groups (Equation 6)	126	108	121	102	142	145
	Gradient Groups (Equation 5)	108	112	123	121	133	142
	API Spec 10, 5th Ed.	112	114	116	118	120	126
8,000	All Data (Equation 6)	119	130	141	153	164	176
	Gradient Groups (Equation 6)	140	125	143	124	169	182
	Gradient Groups (Equation 5)	120	127	142	142	158	173
	API Spec 10, 5th Ed.	126	129	135	140	146	160
10,000	All Data (Equation 6)	134	149	164	179	195	211
	Gradient Groups (Equation 6)	152	144	166	152	197	224
	Gradient Groups (Equation 5)	133	144	163	167	189	212
	API Spec 10, 5th Ed.	141	146	158	157	180	200
12,000	All Data (Equation 6)	150	169	188	208	228	248
	Gradient Groups (Equation 6)	165	164	191	186	226	270
	Gradient Groups (Equation 5)	148	164	187	197	225	259
	API Spec 10, 5th Ed.	155	165	185	197	217	247
14,000	All Data (Equation 6)	168	191	214	238	262	287
	Gradient Groups (Equation 6)	176	186	218	226	256	319
	Gradient Groups (Equation 5)	165	187	215	231	268	317
	API Spec 10, 5th Ed.	169	187	215	233	258	293
16,000	All Data (Equation 6)	185	213	241	269	298	328
	Gradient Groups (Equation 6)	188	209	246	273	286	372
	Gradient Groups (Equation 5)	183	212	247	272	320	388
	API Spec 10, 5th Ed.	183	210	245	270	302	340
18,000	All Data (Equation 6)	204	236	269	302	336	370
	Gradient Groups (Equation 6)	199	234	275	325	318	428
	Gradient Groups (Equation 5)	203	241	284	320	381	475
	API Spec 10, 5th Ed.	199	234	277	308	347	385

Table 5—Predicted Casing-Cementing Temperatures from Correlations Developed from Re-Analysis of the 1974 Data Set (Continued)

Depth ft	Data Grouping	Temperature Gradient, °F/100 ft 0.9	1.1	1.3	1.5	1.7	1.9
20,000	All Data (Equation 6)	223	260	298	336	375	414
	Gradient Groups (Equation 6)	210	260	305	385	350	487
	Gradient Groups (Equation 5)	226	275	327	376	455	582
	API Spec 10, 5th Ed.	215	259	312	348	392	431

Note: All Data Correlation: PBHCT = 75°F + (0.0003402 x (Depth$^{1.323}$) x (Gradient$^{1.1068}$))
Gradient Group Correlations Using Equation 6:
0.9 °F/100 ft Correlation: PBHCT = 75°F + (0.051767 x (Depth $^{0.80587}$) x (Gradient$^{1.0728}$))
1.1 °F/100 ft Correlation: PBHCT = 75°F + (0.0001808 x (Depth$^{1.4186}$) x (Gradient$^{-2.236}$))
1.3 °F/100 ft Correlation: PBHCT = 75°F + (0.0002884 x (Depth$^{1.3333}$) x (Gradient$^{1.4635}$))
1.5 °F/100 ft Correlation: PBHCT = 75°F + (0.0000006 x (Depth$^{2.0138}$) x (Gradient$^{0.29063}$))
1.7 °F/100 ft Correlation: PBHCT = 75°F + (0.0003674 x (Depth$^{1.1712}$) x (Gradient$^{3.6279}$))
1.9 °F/100 ft Correlation: PBHCT = 75°F + (0.0007252 x (Depth$^{1.4685}$) x (Gradient$^{-2.013}$))
Gradient Group Correlations Using Equation 5:
0.9 °F/100 ft Correlation: PBHCT = 2.71828$^{(4.367082+(0.00005263911 \times \text{Depth}))}$
1.1 °F/100 ft Correlation: PBHCT = 2.71828$^{(4.330189+(0.00006424241 \times \text{Depth}))}$
1.3 °F/100 ft Correlation: PBHCT = 2.71828$^{(4.397836+(0.00006959353 \times \text{Depth}))}$
1.5 °F/100 ft Correlation: PBHCT = 2.71828$^{(4.309401+(0.00008103202 \times \text{Depth}))}$
1.7 °F/100 ft Correlation: PBHCT = 2.71828$^{(4.360345+(0.00008796568 \times \text{Depth}))}$
1.9 °F/100 ft Correlation: PBHCT = 2.71828$^{(4.346576+(0.000100975 \times \text{Depth}))}$
where

PBHCT = predicted bottom-hole circulation temperature, °F,
Gradient = temperature gradient, °F/100 ft,
Depth = true vertical depth, ft.

Table 6—General Characteristics of the 1974–84 Allmuds3 Subset

Total Number of Data Points	66	
Average well depth, ft	15,251	
Minimum well depth, ft	7,750	
Maximum well depth, ft	28,840	
Number of data points from depths shallower than 10,000 ft	2	(3%)
Number of records having static time (since last circulation) information	66	(100%)
Average static time, hr	37.7	
Minimum static time, hr	24	
Maximum static time, hr	138	
Method of temperature gradient calculation, °F/100 ft	$\frac{(BHST-80) \times 100}{Depth}$	
Temperature gradient range (°F/100 ft)	0.80 to 2.07	
Average temperature gradient (°F/100 ft)	1.396	
Number of data points with gradients less than or equal to 1.4°F/100 ft	37	(56%)
Type fluid circulated	Water base and oil base muds	
Number of records with circulating time information	36	(55%)
Average circulating time, hr	6.7	

Table 7—Comparison of Predicted Casing and Squeeze-Cementing Temperatures from Correlations Developed from the 1974–84 Allmuds3 Subset and 1984 Data Set

Depth ft	Data Set Correlation	Operation Type	Temperature Gradient, °F/100 ft 0.9	1.1	1.3	1.5	1.7	1.9
1,000	1984 All Data	Casing	77	78	80	81	82	84
	1974–84 Allmuds3 Subset	Casing	75	77	78	79	80	81
	1984 All Data	Squeeze	79	80	82	84	85	87
	1974–84 Allmuds3 Subset	Squeeze	79	80	82	83	85	86
2,000	1984 All Data	Casing	83	86	88	91	93	96
	1974–84 Allmuds3 Subset	Casing	81	83	86	88	91	93
	1984 All Data	Squeeze	86	89	93	96	99	103
	1974–84 Allmuds3 Subset	Squeeze	86	89	92	95	98	101
4,000	1984 All Data	Casing	95	100	106	111	116	122
	1974–84 Allmuds3 Subset	Casing	92	98	103	108	113	118
	1984 All Data	Squeeze	101	108	115	121	128	135
	1974–84 Allmuds3 Subset	Squeeze	100	106	113	119	125	132
6,000	1984 All Data	Casing	108	116	124	132	140	149
	1974–84 Allmuds3 Subset	Casing	105	113	121	129	137	145
	1984 All Data	Squeeze	117	127	137	147	157	167
	1974–84 Allmuds3 Subset	Squeeze	115	124	134	144	153	163
8,000	1984 All Data	Casing	121	132	143	154	166	177
	1974–84 Allmuds3 Subset	Casing	118	129	140	151	162	173
	1984 All Data	Squeeze	132	146	160	173	187	201
	1974–84 Allmuds3 Subset	Squeeze	130	143	156	169	182	196
10,000	1984 All Data	Casing	135	149	163	178	192	206
	1974–84 Allmuds3 Subset	Casing	132	147	161	175	189	204
	1984 All Data	Squeeze	148	166	183	200	217	235
	1974–84 Allmuds3 Subset	Squeeze	146	163	179	196	213	229
12,000	1984 All Data	Casing	149	167	185	202	220	238
	1974–84 Allmuds3 Subset	Casing	148	165	183	201	219	236
	1984 All Data	Squeeze	165	186	207	228	249	269
	1974–84 Allmuds3 Subset	Squeeze	162	183	203	223	244	264
14,000	1984 All Data	Casing	165	186	207	228	249	270
	1974–84 Allmuds3 Subset	Casing	164	185	207	228	250	271
	1984 All Data	Squeeze	182	206	231	256	280	305
	1974–84 Allmuds3 Subset	Squeeze	179	204	228	252	276	300
16,000	1984 All Data	Casing	181	206	231	255	280	305
	1974–84 Allmuds3 Subset	Casing	182	207	233	258	284	309
	1984 All Data	Squeeze	199	227	256	284	313	341
	1974–84 Allmuds3 Subset	Squeeze	197	225	253	281	309	338

Table 7—Comparison of Predicted Casing and Squeeze-Cementing Temperatures from Correlations Developed from the 1974–84 Allmuds3 Subset and 1984 Data Set (Continued)

			Temperature Gradient, °F/100 ft					
Depth ft	Data Set Correlation	Operation Type	0.9	1.1	1.3	1.5	1.7	1.9
18,000	1984 All Data	Casing	198	227	256	284	313	341
	1974–84 Allmuds3 Subset	Casing	201	231	261	291	321	350
	1984 All Data	Squeeze	216	248	281	313	346	378
	1974–84 Allmuds3 Subset	Squeeze	215	248	280	312	344	376
20,000	1984 All Data	Casing	216	249	282	315	347	380
	1974–84 Allmuds3 Subset	Casing	222	256	291	326	360	395
	1984 All Data	Squeeze	234	270	307	343	379	416
	1974–84 Allmuds3 Subset	Squeeze	234	271	307	344	380	417

Note: 1984 All Data Set = 1984 Data Set consisting of 175 data points.
1974–84 Allmuds3 Subset = Allmuds3 Subset from the 1974–84 Combined Master Data Set consisting of 66 records. 66 data points for casing cementing and 40 data points for squeeze cementing.

1984 All Data Set Correlation: PBCHT = 80°F + ((0.00663574 x TG x Depth) – 8.49686)/(1 – (0.00001162 x Depth))
1984 All Data Set Correlation: PSqT = 80°F + ((0.00821677 x TG x Depth) – 8.82971)/(1 – (0.000004812 x Depth))
1974–84 Allmuds3 Subset Correlation: PBHCT = 80°F + ((0.006061 x TG x Depth) – 10.0915)/(1 – (0.000015052 x Depth))
1974–84 Allmuds3 Subset Correlation: PSqT = 80°F + ((0.0076495 x TG x Depth) – 8.2021)/(1 – (0.000008068 x Depth))

where

PBHCT = predicted bottom-hole circulating temperature, °F,
PSqT = predicted squeeze temperature, °F,
TG = temperature gradient, °F/100 ft,
Depth = true vertical depth, ft.

Table 8—Comparison of API Spec 10, 5th Edition, Well-Simulation Casing-Cementing Temperatures with Predicted Temperatures from the Correlation Developed from the 1974–84 Allmuds3 Subset

Depth ft	Data Set Correlation	Temperature Gradient, °F/100 ft 0.9	1.1	1.3	1.5	1.7	1.9
1,000	API Spec 10, 5th Ed.	80	80	80	80	80	80
	1974–84 Allmuds3 Subset	75	77	78	79	80	81
2,000	API Spec 10, 5th Ed.	89	89	90	90	91	91
	1974–84 Allmuds3 Subset	81	83	86	88	91	93
4,000	API Spec 10, 5th Ed.	99	100	101	102	103	104
	1974–84 Allmuds3 Subset	92	98	103	108	113	118
6,000	API Spec 10, 5th Ed.	112	114	116	118	120	126
	1974–84 Allmuds3 Subset	105	113	121	129	137	145
8,000	API Spec 10, 5th Ed.	126	129	135	140	146	160
	1974–84 Allmuds3 Subset	118	129	140	151	162	173
10,000	API Spec 10, 5th Ed.	141	142	158	167	180	200
	1974–84 Allmuds3 Subset	132	147	161	175	189	204
12,000	API Spec 10, 5th Ed.	155	165	185	197	217	247
	1974–84 Allmuds3 Subset	148	165	183	201	219	236
14,000	API Spec 10, 5th Ed.	169	187	215	233	258	293
	1974–84 Allmuds3 Subset	164	185	207	228	250	271
16,000	API Spec 10, 5th Ed.	183	210	245	270	302	340
	1974–84 Allmuds3 Subset	182	207	233	258	284	309
18,000	API Spec 10, 5th Ed.	199	234	277	308	347	385
	1974–84 Allmuds3 Subset	201	231	261	291	321	350
20,000	API Spec 10, 5th Ed.	215	259	312	348	392	431
	1974–84 Allmuds3 Subset	222	256	291	326	360	395

Note: API SPEC 10, 5th Ed. Casing Cementing Temperatures are from a correlation developed from the 1974 Data Set 1974–84 Allmuds3 Subset Correlation: PBHCT = 80°F + ((0.006061 x TG x Depth) – 10.0915)/(1 – (0.000015052 x Depth))

where

PBHCT = predicted bottom-hole circulating temperature, °F,
TG = temperature gradient, °F/100 ft,
Depth = true vertical depth, ft.

Table 9—Comparison of API Spec 10, 5th Edition, Squeeze-Cementing Well-Simulation Temperatures with Predicted Temperatures from the Correlation Developed from the 1974–84 Allmuds3 Subset

		Temperature Gradient, °F/100 ft						
Depth ft	Data Set Correlation	Not Specified	0.9	1.1	1.3	1.5	1.7	1.9
1,000	API Spec 10, 5th Ed.	89						
	1974–84 Allmuds3 Subset		79	80	82	83	85	86
2,000	API Spec 10, 5th Ed.	98						
	1974–84 Allmuds3 Subset		86	89	92	95	98	101
4,000	API Spec 10, 5th Ed.	116						
	1974–84 Allmuds3 Subset		100	106	113	119	125	132
6,000	API Spec 10, 5th Ed.	136						
	1974–84 Allmuds3 Subset		115	124	134	144	153	163
8,000	API Spec 10, 5th Ed.	159						
	1974–84 Allmuds3 Subset		130	143	156	169	182	196
10,000	API Spec 10, 5th Ed.	186						
	1974–84 Allmuds3 Subset		146	163	179	196	213	229
12,000	API Spec 10, 5th Ed.	213						
	1974–84 Allmuds3 Subset		162	183	203	223	244	264
14,000	API Spec 10, 5th Ed.	242						
	1974–84 Allmuds3 Subset		179	204	228	252	276	300
16,000	API Spec 10, 5th Ed.	271						
	1974–84 Allmuds3 Subset		197	225	253	281	309	338
18,000	API Spec 10, 5th Ed.	301						
	1974–84 Allmuds3 Subset		215	248	280	312	344	376
20,000	API Spec 10, 5th Ed.	340						
	1974–84 Allmuds3 Subset		234	271	307	344	380	417

Note: API Spec 10, 5th Edition Squeeze Temperatures are from a correlation developed from the 1950 Squeeze Data Set. 1974–84 Allmuds3 Subset Correlation: PSqT = 80°F + ((0.0076495 x TG x Depth) – 8.2021) /(1 – (0.000008068 x Depth))

where

PSqT = predicted squeeze temperature, °F,
TG = temperature gradient, °F/100 ft,
Depth = true vertical depth, ft.

Table 10—Comparison of Predicted Casing and Squeeze-Cementing Temperatures from the 1991 Hybrid Correlation and the Correlation Developed from the 1974–84 Allmuds3 Subset

			Temperature Gradient, °F/100 ft					
Depth ft	Data Set Correlation	Operation Type	0.9	1.1	1.3	1.5	1.7	1.9
1,000	1991 Hybrid Correlation	Casing	80	80	80	80	80	80
	1974–84 Allmuds3 Subset	Squeeze	79	80	82	83	85	86
2,000	1991 Hybrid Correlation	Casing	89	89	90	90	91	91
	1974–84 Allmuds3 Subset	Squeeze	86	89	92	95	98	101
4,000	1991 Hybrid Correlation	Casing	99	100	101	102	103	104
	1974–84 Allmuds3 Subset	Squeeze	100	106	113	119	125	132
6,000	1991 Hybrid Correlation	Casing	112	114	116	118	120	126
	1974–84 Allmuds3 Subset	Squeeze	115	124	134	144	153	163
8,000	1991 Hybrid Correlation	Casing	126	129	135	140	146	160
	1974–84 Allmuds3 Subset	Squeeze	130	143	156	169	182	196
10,000	1991 Hybrid Correlation	Casing	141	142	158	167	180	200
	1974–84 Allmuds3 Subset	Squeeze	146	163	179	196	213	229
12,000	1991 Hybrid Correlation	Casing	148	165	183	201	219	236
	1974–84 Allmuds3 Subset	Squeeze	162	183	203	223	244	264
14,000	1991 Hybrid Correlation	Casing	164	185	207	228	250	271
	1974–84 Allmuds3 Subset	Squeeze	179	204	228	252	276	300
16,000	1991 Hybrid Correlation	Casing	182	207	233	258	284	309
	1974–84 Allmuds3 Subset	Squeeze	197	225	253	281	309	338
18,000	1991 Hybrid Correlation	Casing	201	231	261	291	321	350
	1974–84 Allmuds3 Subset	Squeeze	215	248	280	312	344	376
20,000	1991 Hybrid Correlation	Casing	222	256	291	326	360	395
	1974–84 Allmuds3 Subset	Squeeze	234	271	307	344	380	417

Note: 1991 Hybrid Correlation for Casing-Cementing Temperatures uses temperatures from the Casing-Cementing Well-Simulation Test Schedules in API Spec 10, 5th Edition, for depths from 1,000 ft through 10,000 ft. Temperatures for depths deeper than 10,000 ft are predicted from the correlation developed from the1974–84 Allmuds3 Subset.

1974–84 Allmuds3 Subset Correlation: $PBHCT = 80°F + ((0.006061 \times TG \times Depth) - 10.0915)/(1 - (0.000015052 \times Depth))$

1974–84 Allmuds3 Subset Correlation: $PSqT = 80°F + ((0.0076495 \times TG \times Depth) - 8.2021)/(1 - (0.000008068 \times Depth))$

where

PBHCT = predicted bottom-hole circulating temperature, °F,
PSqT = predicted squeeze temperature, °F,
TG = temperature gradient, degrees F/100 ft,
Depth = true vertical depth, ft.

APPENDIX A—1948 DATA SET (FARRIS DATA)

Table A-1—1948 Data Set

	Depth ft	BHST °F	BHCT °F	Circulation Rate BPM	Mud Temperature, Inlet, °F	°F Outlet	Temperature Gradient A °F/100 ft	Temperature Gradient B °F/100 ft
	5,310	136	109.5	10.1	96	105	1.149	1.055
	8,150	195	122.0	4.2	110	115	1.472	1.411
	8,150	195	121.5	8.7	114	116	1.472	1.411
	8,300	215	127.5	12.1	117	121	1.687	1.627
	9,301	185	136.5	11.0	120	122	1.183	1.129
	9,923	192	137.0	9.6	117	121	1.179	1.129
	10,924	244	156.0	11.3	120	133	1.547	1.501
	14,100 [a]	–	219.0	9.7	–	–		
Average	7,507			9.6	113.4	119	1.384	1.323

[a] Estimated from chart in API Code 32, 1st Edition.
Temperature Gradient A = ((BHST – 75 °F) X 100) / Depth
Temperature Gradient B = ((BHST – 80 °F) X 100) / Depth

where

Temperature Gradient = temperature gradient, °F / 100 ft,
BHST = Maximum recorded temperature prior to circulation, °F,
Depth = True vertical depth, ft.

APPENDIX B—1953 SQUEEZE DATA SET

Table B-1—1953 Squeeze Data Set

Depth ft	BHSqT °F
3,500	118
6,000	112
6,000	116
7,000	153
7,000	154
10,500	194

APPENDIX C—1969–74 DATA SHEET

$$\text{Temperature Gradient A} = \frac{(\text{BHST} - 75°\text{F}) \times 100}{\text{Depth}}$$

where

Temperature Gradient A = temperature gradient, °F/100 ft,

BHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

Depth = true vertical depth, ft.

$$\text{Temperature Gradient B} = \frac{(\text{BHST} - 80°\text{F}) \times 100}{\text{Depth}}$$

where

Temperature Gradient B = temperature gradient, °F/100 ft,

BHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

Depth = true vertical depth, ft.

Table C-1—Most of the Recorded Temperature Data for the 1969–74 Data Set Compiled from API Records and Records of Participating Companies

Well Number	Observation	Depth ft.	Static Time hr	BHST °F	BHCT °F	Circulating Time, hr	Circulating Rate, BPM	Temp. Gradient A °F/100 ft	Temp. Gradient B °F/100 ft	Mud Type
	70	16,897	41.0	169.0	152.0			0.556	0.527	
3-1	16	12,235		156.0	158.0			0.662	0.621	
		1,5589	51.0	184.0	166.0		6.20	0.699	0.667	na
	73	15,320	48.0	189.0	158.0			0.744	0.711	
3-1	15	17210	33.0	218.0	189.0		6.80	0.831	0.802	w
2-3	67	18,510	29.0	229.0	190.0			0.832	0.805	na
		17,725	27.5	225.0	202.0			0.846	0.818	na
4-1	18	15,650		211.0	188.0			0.869	0.837	
		17,310	33.0	227.0	189.0	3.00	6.80	0.878	0.849	w
3-2	35	9,000		155.0	132.0			0.889	0.833	
5-2	39	10,424		169.0	146.0			0.902	0.854	
1-1	12	11,920	16.5	185.0	166.0	3.00	9.65	0.923	0.881	w
4-1	17	18,380	36.8	245.0	196.0		9.60	0.925	0.898	w
9-1	25	22,800	35.0	287.0	240.0		5.00	0.930	0.908	w
7-0	9	10,735		178.0	172.0			0.959	0.913	
	74	18,336	19.0	256.0	213.0			0.987	0.960	
7-2	42	16,088	32.0	234.0	202.0		9.10	0.988	0.957	w
14-2	54	15,731	18.8	232.5	205.0			1.001	0.969	na
7-2	43	12,328		200.0	187.0			1.014	0.973	
7-0	8	11,735	20.0	194.0	179.0		7.80	1.014	0.971	w
	71	17,882	25.0	258.0	207.0			1.023	0.995	
8-0	11	11,025		190.0	162.0			1.043	0.998	
3-3	68	22,225	55.0	307.0	265.0			1.044	1.021	na
3-3	69	17,760	55.0	261.0	245.0			1.047	1.019	
6-1	21	12,500		206.0	205.0			1.048	1.008	
11-2	51	8,438		164.0	149.0			1.055	0.995	
15-2	56	14,700	14.3	230.9	192.8			1.061	1.027	
2-1	14	10,540		187.0	169.0			1.063	1.015	
10-1	26	19,385	15.5	281.0	286.0			1.063	1.037	
	75	21,853	34	310.0	290.0			1.075	1.052	
10-1	27	18,920		280.0	262.0			1.084	1.057	
16-2	57	14,000	36.0	227.3	200.0			1.088	1.052	na
3-2	34	10,525	19.0	190.0	149.0		11.30	1.093	1.045	w
11-2	50	9,881	13.5	183.0	138.0		9.50	1.093	1.042	w
2-1	13	13,540	32.5	223.0	177.0	3.00	10.00	1.093	1.056	w
5-2	38	11,456	28.0	202.0	156.0		8.50	1.109	1.065	w
		22,650	60.0	328.0	268.0		6.40	1.117	1.095	na
4-2	36	12,000	32.0	211.0	192.0		2.80	1.133	1.092	w
4-0	5	22,725	47.5	333.0	286.0	5.00	4.80	1.135	1.113	w
4-2	37	10,000		189.0	184.0			1.140	1.090	
20-2	63	10,110	21.5	191.0	186.0			1.147	1.098	
		13,083	42.0	229.0	149.0	3.50	4.30	1.177	1.139	w
20-2	62	13,995	21.5	240.0	190.0			1.179	1.143	na
17-2	59	9,010	35.0	182.0	160.0			1.188	1.132	
1-2	31	7,219		162.0	140.0			1.205	1.136	
10-2	49	15,654		265.0	242.0			1.214	1.182	
15-2	55	17,930	14.3	294.5	265.0			1.224	1.196	na
8-1	23	16,400		279.0	265.0			1.244	1.213	
8-1	22	17,400	26.0	292.0	270.0		3.80	1.247	1.218	w
10-2	48	17,164	40.5	290.0	236.0		9.00	1.253	1.223	w

Table C-1—Most of the Recorded Temperature Data for the 1969–74 Data Set Compiled from API Records and Records of Participating Companies (Continued)

Well Number	Observation	Depth ft.	Static Time hr	BHST °F	BHCT °F	Circulating Time, hr	Circulating Rate, BPM	Temp. Gradient A °F/100 ft	Temp. Gradient B °F/100 ft	Mud Type
6-0	7	16,988		288.0	261.0		5.70	1.254	1.224	w
17-2	58	10,245	35.0	204.0	160.0			1.259	1.210	na
8-1	24	15,400		269.0	260.0			1.260	1.227	
18-2	60	18,240	13.0	308.0	290.0.			1.277	1.250	na
		9,308		196.0	153.0	3.00	5.60	1.300	1.246	w
8-2	45	14,013		260.0	242.0			1.320	1.285	
		12,310		239.0	191.0	3.00	8.00	1.332	1.292	w
2-0	2	13,875	26.5	260.0	217.0	4.00	6.70	1.333	1.297	w
6-1	20	17,700		312.0	311.0			1.339	1.311	
19-2	61	11,100	12.0	224.0	215.0			1.342	1.297	na
5-0	6	7,215	23.0	172.0	148.0	2.50	7.60	1.344	1.275	w
		9,160		199.0	152.0	3.00	9.50	1.354	1.299	w
6-1	19	20,580	20.0	354.0	344.0		6.00	1.356	1.331	w
		11,450	23.8	232.0	197.0	2.25	5.60	1.371	1.328	w
8-2	44	15,007	28.0	281.0	243.0		7.50	1.373	1.339	w
1-3	66	19,370	76.0	343.0	290.0			1.384	1.358	na
22-2	65	9,000	24.3	200.0	228.0			1.389	1.333	
2-2	33	9,896		213.0				1.395	1.344	
6-0	76	11,933		242.0	226.0			1.399	1.358	
		13,037		260.0	211.0		6.40	1.419	1.381	w
		16,300		315.0	292.0	4.00	3.30	1.472	1.442	w
		15,000		296.0	254.0	4.00	6.20	1.473	1.440	w
2-2	32	15,375	34.5	309.0	222.0	3.50	11.30	1.522	1.489	w
3-0	4	9,440		223.0	203.0			1.568	1.515	
		14,965		313.0	291.0	4.00	4.00	1.590	1.557	w
		13,148	36.0	287.0	205.0	3.00	12.30	1.612	1.574	w
		11,440	32.5	262.0	209.0			1.635	1.591	w
		19,850		401.0	351.0	4.00		1.642	1.617	o
		8,030		207.0	147.0	4.00	6.00	1.644	1.582	w
3-0	3	11,340	32.5	262.0	210.0	2.50		1.649	1.605	w
		18,179		384.0	292.0	3.75	8.53	1.700	1.672	o
6-2	40	12,515	25.0	289.0	235.0		7.75	1.710	1.670	w
21-2	64	12,900	24.3	300.0	250.0			1.744	1.705	na
1-2	30	8,395	7.0	223.0	199.0		5.00	1.763	1.703	
		15,520		350.0	295.0	4.00	5.30	1.772	1.740	w
		13,736	14.0	320.0				1.784	1.747	na
		12,187		293.0	226.0	3.00	3.00	1.789	1.748	o
13-2	53	12,929	19.0	307.0	288.0		10.00	1.794	1.756	w
6-2	41	8,494		228.0	224.0			1.801	1.742	
		16,035	68.0	364.0	285.0	4.00	3.80	1.802	1.771	o
		15,120	49.5	350.0	298.0		6.00	1.819	1.786	na
		18,000		412.0	360.0	4.00	3.20	1.872	1.844	o

Table C-1—Most of the Recorded Temperature Data for the 1969–74 Data Set Compiled from API Records and Records of Participating Companies (Continued)

Well Number	Observation	Depth ft.	Static Time hr	BHST °F	BHCT °F	Circulating Time, hr	Circulating Rate, BPM	Temp. Gradient A °F/100 ft	Temp. Gradient B °F/100 ft	Mud Type
1-2	29	6,776		202.0				1.874	1.800	
12-2	52	8,532	17.0	235.0	222.0		6.00	1.875	1.817	w
		12,180		312.0	221.0	4.00	5.00	1.946	1.905	o
		10,500	24.0	280.0	226.0	3.50	8.50	1.952	1.905	na
	72	12,400	44.5	321.0	231.0			1.984	1.944	
1-0	1	14,665	14.5	369.0	332.0	2.08	4.00	2.005	1.971	w
		12,294		325.0	250.0	4.00	4.70	2.034	1.993	w
1-2	28	7,905	10.0	236.0	155.0		5.00	2.037	1.973	
9-2	46	3,867	6.5	234.0	193.0		12.00	4.112	3.982	w
9-2	47	2,897		211.0	158.0			4.695	4.522	

Table C-2—88 Records Selected from the 1969–74 Data Set for Preparing Cementing Temperature Schedules in API Spec 10, 5th Edition

Well Number	Observation	Depth ft	Static Time hr	BHST °F	BHCT °F	Circulating Time, hr	Circulating Rate, BPM	Temp. Gradient A °F/100 ft	Temp. Gradient B °F/100 ft	Mud Type
3-1	15	17,210	33.0	218.0	189.0		6.80	0.831	0.802	w
2-3	67	18,510	29.0	229.0	190.0			0.832	0.805	w
		17,725	27.5	225.0	202.0			0.846	0.818	na
4-1	18	15,650		211.0	188.0			0.869	0.837	
		17,310	33.0	227.0	189.0	3.00	6.80	0.878	0.849	w
3-2	35	9,000		155.0	132.0			0.889	0.833	
5-2	39	10,424		169.0	146.0			0.902	0.854	
1-1	12	11,920	16.5	185.0	166.0	3.00	9.65	0.923	0.881	w
4-1	17	18,380	36.8	245.0	196.0		9.60	0.925	0.898	w
9-1	25	22,800	35.0	287.0	240.0		5.00	0.930	0.908	w
7-0	9	10,735		178.0	172.0			0.959	0.913	
	74	18,336	19.0	256.0	213.0			0.987	0.960	
7-2	42	16,088	32.0	234.0	202.0		9.10	0.988	0.957	w
14-2	54	15,731	18.8	232.5	205.0			1.001	0.969	w
7-2	43	12,328		200.0	187.0			1.014	0.973	
7-0	8	11,735	20.0	194.0	179.0		7.80	1.014	0.971	w
	71	17,882	25.0	258.0	207.0			1.023	0.995	w
8-0	11	11,025		190.0	162.0			1.043	0.998	
3-3	68	22,225	55.0	307.0	265.0			1.044	1.021	w
3-3	69	17,760	55.0	261.0	245.0			1.047	1.019	
6-1	21	12,500		206.0	205.0			1.048	1.008	
11-2	51	8,438		164.0	149.0			1.055	0.995	
15-2	56	14,700	14.3	230.9	192.8			1.061	1.027	
2-1	14	10,540		187.0	169.0			1.063	1.015	
10-1	26	19,385	15.5	281.0	286.0			1.063	1.037	w
	75	21,853	34.0	310.0	290.0			1.075	1.052	w
10-1	27	18,920		280.0	262.0			1.084	1.057	w
16-2	57	14,000	36.0	227.3	200.0			1.088	1.052	w
3-2	34	10,525	19.0	190.0	149.0		11.30	1.093	1.045	w
11-2	50	9,881	13.5	183.0	138.0		9.50	1.093	1.042	w
2-1	13	13,540	32.5	223.0	177.0	3.00	10.00	1.093	1.056	w
5-2	38	11,456	28.0	202.0	156.0		8.50	1.109	1.065	w
		2,2650	60.0	328.0	268.0		6.40	1.117	1.095	na
4-2	36	12,000	32.0	211.0	192.0		2.80	1.133	1.092	w
4-0	5	22,725	47.5	333.0	286.0	5.00	4.80	1.135	1.113	w
4-2	37	10,000		189.0	184.0			1.140	1.090	
20-2	63	10,110	21.5	191.0	186.0			1.147	1.098	
		13,083	42.0	229.0	149.0	3.50	4.30	1.177	1.139	w
20-2	62	13,995	21.5	240.0	190.0			1.179	1.143	w
17-2	59	9,010	35.0	182.0	160.0			1.188	1.132	
1-2	31	7,219		162.0	140.0			1.205	1.136	
10-2	49	15,654		265.0	242.0			1.214	1.182	
15-2	55	17,930	14.3	294.5	265.0			1.224	1.196	w
8-1	23	16,400		279.0	265.0			1.244	1.213	
8-1	22	17,400	26.0	292.0	270.0		3.80	1.247	1.218	w
10-2	48	17,164	40.5	290.0	236.0		9.00	1.253	1.223	w
6-0	7	16,988		288.0	261.0		5.70	1.254	1.224	w
17-2	58	10,245	35.0	204.0	160.0			1.259	1.210	w
8-1	24	15,400		269.0	260.0			1.260	1.227	
18-2	60	18,240	13.0	308.0	290.0			1.277	1.250	w

Table C-2—88 Records Selected from the 1969–74 Data Set for Preparing Cementing Temperature Schedules in API Spec 10, 5th Edition (Continued)

Well Number	Observation	Depth ft	Static Time hr	BHST °F	BHCT °F	Circulating Time, hr	Circulating Rate, BPM	Temp. Gradient A °F/100 ft	Temp. Gradient B °F/100 ft	Mud Type
		9,308		196.0	153.0	3.00	5.60	1.300	1.246	w
8-2	45	14,013		260.0	242.0			1.320	1.285	
		12,310		239.0	191.0	3.00	8.00	1.332	1.292	w
2-0	2	13,875	26.5	260.0	217.0	4.00	6.70	1.333	1.297	w
6-1	20	17,700		312.0	311.0			1.339	1.311	
19-2	61	11,100	12.0	224.0	215.0			1.342	1.297	w
5-0	6	7,215	23.0	172.0	148.0	2.50	7.60	1.344	1.275	w
		9,160		199.0	152.0	3.00	9.50	1.354	1.299	w
6-1	19	20,580	20.0	354.0	344.0		6.00	1.356	1.331	w
		11,450	23.8	232.0	197.0	2.25	5.60	1.371	1.328	w
8-2	44	15,007	28.0	281.0	243.0		7.50	1.373	1.339	w
1-3	66	19,370	76.0	343.0	290.0			1.384	1.358	w
22-2	65	9,000	24.3	200.0	228.0			1.389	1.333	
2-2	33	9,896		213.0				1.395	1.344	
6-0	76	11,933	242.0	226.0				1.399	1.358	
		13,037		260.0	211.0		6.40	1.419	1.381	w
		16,300		315.0	292.0	4.00	3.30	1.472	1.442	w
		15,000		296.0	254.0	4.00	6.20	1.473	1.440	w
2-2	32	15,375	34.5	309.0	222.0	3.50	11.30	1.522	1.489	w
3-0	4	9,440		223.0	203.0			1.568	1.515	
		14,965		313.0	2910	4.00	4.00	1.590	1.557	w
		13,148	36.0	287.0	205.0	3.00	12.30	1.612	1.574	w
		11,440	32.0	262.0	209.0			1.635	1.591	w
		8,030		207.0	147.0	4.00	6.00	1.644	1.582	w
3-0	3	11,340	32.5	262.0	210.0	2.50		1.649	1.605	w
6-2	40	12,515	25.0	289.0	235.0		7.75	1.710	1.67	w
21-2	64	12,900	24.3	300.0	250.0			1.744	1.705	na
1-2	30	8,395	7.0	223.0	199.0		5.00	1.763	1.703	w
		15,520		350.0	295.0	4.00	5.30	1.772	1.740	w
		13,736	14.0	320.0				1.784	1.747	na
13-2	53	12,929	19.0	307.0	288.0		10.00	1.794	1.756	w
6-2	41	8,494		288.0	224.0			1.801	1.742	
		15,120	49.5	350.0	298.0		6.00	1.819	1.786	na
1-2	29	6,776		202.0				1.874	1.800	
12-2	52	8,532	17.0	235.0	222.0		6.00	1.875	1.817	w
		10,500	24.0	280.0	226.0	3.50	8.50	1.952	1.905	na
	72	12,400	44.5	321.0	231.0			1.984	1.944	
1-0	1	14,665	14.5	369.0	332.0	2.08	4.00	2.005	1.971	w

APPENDIX D—1974 DATA SET
(41 DATA POINTS)

$$\text{Temperature Gradient A} = \frac{(\text{BHST} - 75°\text{F}) \times 100}{\text{Depth}}$$

where

Temperature Gradient A = temperature gradient, °F/100 ft,

BHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

Depth = true vertical depth, ft.

$$\text{Temperature Gradient B} = \frac{(\text{BHST} - 80°\text{F}) \times 100}{\text{Depth}}$$

where

Temperature Gradient B = temperature gradient, °F/100 ft,

BHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

Depth = true vertical depth, ft.

Table D-1—41 Data Points Used to Prepare Temperature Correlations from the 1969–74 Data Set

Observation	Well Number	Depth ft	Static Time hr	BHST °F	BHCT °F	Circulation Time, hr	Circulation Rate, BPM	Temperature Gradient A °F/100 ft	Temperature Gradient B °F/100 ft	Mud Type
15	3-1	17,210	33.0	218	189		6.80	0.8309	0.8019	w
67	2-3	18,510	29.0	229	190			0.8320	0.8050	n
		17,310	33.0	227	189	3.00	6.80	0.8781	0.8492	w
12	1-1	11,920	16.5	185	166	3.00	9.65	0.9228	0.8809	w
42	7-2	16,088	32.0	234	202		9.10	0.9883	0.9572	w
8	7-0	11,735	20.0	194	179		7.80	1.0141	0.9715	w
34	3-2	10,525	19.0	190	149		11.30	1.0926	1.0451	w
50	11-2	9,881	13.5	183	138		9.50	1.0930	1.0424	w
13	2-1	13,540	32.5	223	177	3.00	10.00	1.0931	1.0561	w
38	5-2	11,456	28.0	202	156		8.50	1.1086	1.0649	w
36	4-2	12,000	32.0	211	192		2.80	1.1333	1.0917	w
		13,083	42.0	229	149	3.50	4.30	1.1771	1.1389	w
22	8-1	17,400	26.0	292	270		3.80	1.2471	1.2184	w
48	10-2	17,164	40.5	290	236		9.00	1.2526	1.2235	w
7	6-0	16,988		288	261		5.70	1.2538	1.2244	w
		9,308		196	153	3.00	5.60	1.2999	1.2462	w
		12,310		239	191	3.00	8.00	1.3323	1.2916	w
2	2-0	13,875	26.5	260	217	4.00	6.70	1.3333	1.2973	w
6	5-0	7,215	23.0	172	148	2.50	7.60	1.3444	1.2751	w
		9,160		199	152	3.00	9.50	1.3537	1.2991	w
19	6-1	20,580	20.0	354	344		6.00	1.3557	1.3314	w
		11,450	23.8	232	197	2.25	5.60	1.3712	1.3275	w
44	8-2	15,007	28.0	281	243		7.50	1.3727	1.3394	w
		13,037		260	211		6.40	1.4190	1.3807	w
		16,300		315	292	4.00	3.30	1.4724	1.4417	w
		15,000		296	254	4.00	6.20	1.4733	1.4400	w
32	2-2	15,375	34.5	309	222	3.50	11.30	1.5220	1.4894	w
		14,965		313	291	4.00	4.00	1.5904	1.5570	w
		13,148	36.0	287	205	3.00	12.30	1.6124	1.5744	w
		11,440	32.5	262	209			1.6346	1.5909	w
		8,030		207	147	4.00	6.00	1.6438	1.5816	w
3	3-0	11,340	32.5	262	210	2.50		1.6490	1.6049	w
40	6-2	12,515	25.0	289	235		7.75	1.7099	1.6699	w
30	1-2	8,395	7.0	223	199		5.00	1.7630	1.7034	w
		15,520		350	295	4.00	5.30	1.7719	1.7397	w
53	13-2	12,929	19.0	307	288		10.00	1.7944	1.7557	w
52	12-2	8,532	17.0	235	222		6	1.8753	1.8167	w
		10,500	24.0	280	226	3.50	8.50	1.9524	1.9048	nl
1	1-0	14,665	14.5	369	332	2.08	4.00	2.0048	1.9707	w
		12,294		325	250	4.00	4.70	2.0335	1.9928	w
28	1-2	7,905	10.0	236	155		5.00	2.0367	1.9734	w

Note: Temperature Gradient A = (BHST – 75°F) x 100/Depth

Temperature Gradient B = (BHST – °F) x 100/Depth

(Calculated for comparison with 1984 Data Set)

nl = data not listed in API records but believed to be water mud.

APPENDIX E—1984 DATA SET

Temperature Gradient Calculation Method for 1984 Data Set

$$\text{Temperature Gradient} = \frac{(\text{BHST} - 80°\text{F}) \times 100}{\text{Depth}}$$

where

Temperature Gradient = temperature gradient, °F/100 ft,

BHST = the static temperature, °F, measured by the temperature recording device prior to the start of circulation,

Depth = true vertical depth, ft.

Table E-1—1984 Data Set

Well Number	Depth, ft	Static Time hr	BHST ft	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
168	10,184		120	12.6	98		91.0	0.393	w
130	11,040	33.0	130	16.0	107	270.0	97.0	0.453	w
89	2,065	10.0	90	2.0	86	75.0	86.0	0.484	w
18	3,150		96		92		92.0	0.508	w
69	8,739		132		95		78.0	0.595	w
161	13,486		168	31.0	159	238.0	151.0	0.653	w
100	14,997		180	41.0	164	233.0	160.0	0.667	w
169	6,424		126	6.0	119		109.0	0.716	w
91	12,547		176	22.0	152	360.0	134.0	0.765	w
98	5,870		130	15.0	113	120.0	108.0	0.852	w
81	5,550		128	12.0	114	107.0	108.0	0.865	na
90	18,000		238	16.0	216	360.0	211.0	0.878	o
93	5,250	10.5	128	9.0	119	90.0	101.0	0.914	w
115	13,196		201	23.0	181	437.0	162.0	0.917	w
131	19,185		274	17.0	266	270.0	217.0	1.011	w
140	13,000	24.0	212	17.0	182	182.0	165.0	1.015	w
92	13,049	19.0	214	31.0	188	270.0	174.0	1.027	w
113	12,258	38.5	206	17.0	181	354.0	158.0	1.028	w
79	12,029	27.5	204		168		149.0	1.031	w
55	11,385	14.5	198	25.0	192	942.0	178.0	1.036	w
70	20,620	33.0	294	50.0	265	1,073.0	251.0	1.038	o
132	13,153	23.0	218	33.0	200	570.0	184.0	1.049	o
134	12,246	17.0	215	22.0	189	132.0	189.0	1.102	w
84	24,840	65.0	355	55.0	326	443.0	322.0	1.107	o
72	19,750	35.5	300	41.0	268	333.0	251.0	1.114	o
136	10,235	20.0	195			225.0	145.0	1.124	w
160	13,195		229	53.0	213	238.0	209.0	1.129	w
158	19,446		301	62.0	262		245.0	1.136	o
176	19,499		305	38.0	299		295.0	1.154	na
138	12,996		230	21.0	182	360.0	170.0	1.154	w
128	18,594		297	27.0	287	480.0	269.0	1.167	na
20	13,700		240		202		193.0	1.168	w
157	7,100		163	12.0	151	300.0	122.0	1.169	w
12	14,280		247		217		200.0	1.169	w
163	7,695		171	42.0	134	70.0	125.0	1.183	w
88	1,097	3.80	93	3.0	91	85.0	90.0	1.185	w
21	13,452		241		204		189	1.197	w
171	22,660		354	120.0	338	270.0		1.209	o
11	15,323		267		233		221.0	1.220	w
73	18,092		301	34.0	279	1,050.0	259.0	1.222	na
44	7,420		171			540.0		1.226	w
166	6,238		158	17.0	142	135.0	119.0	1.250	w
42	6,760		166	8.0	134	450.0	130.0	1.272	na
105	17,992	33.5	309	56.0	263	552.0	246.0	1.273	na
133	14,496		265	26.0	224		211.0	1.276	w
14	12,900		245		274		258.0	1.279	o
37	16,482		291				269.0	1.280	o
151	16,053	25.0	286	19.0	275		242.0	1.283	o
68	19,516		331		308	3,570.0	290.0	1.286	w
75	15,614		281		247	215.0	228.0	1.287	w
153	8,302	26.0	187	10.0	156	140.0	124.0	1.289	w

Table E-1—1984 Data Set (Continued)

Well Number	Depth, ft	Static Time hr	BHST ft	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
121	9,557		204	20.0	174	117.0	159.0	1.297	w
148	16,796	15.0	298	40.0	260	235.0	245.0	1.298	w
7	10,233	16.5	213	19.0	196	284.0	167.0	1.300	w
129	12,990	36.0	249	19.0	217	1,072.0	209.0	1.301	w
174	12,660		245	10.0	238	150.0	217.0	1.303	na
101	21,458	58.7	360	32.0	333	429.0	315.0	1.305	o
15	11,800		234		213		187.0	1.305	w
139	11,540	24.0	231	43.0	191	239.0	162.0	1.308	w
137	11,450	36.0	230	29.0	200		159.0	1.310	w
6	11,170	31.0	228	17.2	181	570.0	175.0	1.325	w
142	15,004	38.0	279	45.0	265	1,546.0	255.0	1.326	w
82	13,280	12.0	257	19.0	227	435.0	221.0	1.333	w
13	14,682		276		254			1.335	w
156	13,516	21.8	261	20.0	235		213.0	1.339	w
95	15,572	27.0	289	25.0	249	270.0	235.0	1.342	w
165	18,912		334	22.0	264	355.0	260.0	1.343	w
154	11,969	28.0	241	41.0	186	136.0	182.0	1.345	o
111	21,758	26.0	373	48.0	343	567.0	326.0	1.347	w
126	20,768	58.8	360	32.0	333	429.0	315.0	1.348	o
149	14,588	11.0	277	38.0	246	255.0	232.0	1.350	o
16	17,500		317		279		263.0	1.354	o
107	19,770		348	36.0	315	360.0	294.0	1.356	w
124	19,770		348	36.0	315	360.0	294.0	1.356	w
50	10,830	27.3	227	21.0	203	240.0	189.0	1.357	w
36	17,808		322		281		269.0	1.359	o
162	20,960		365	49.0	342		334.0	1.360	w
173	22,700		392	40.0	363		342.0	1.374	w
19	20,889		368		346		311.0	1.379	o
59	13,256		263		234		215.0	1.381	w
71	20,835		371	6.0	355	710.0	279.0	1.397	w
167	18,929	74.0	345	57.0	316		289.0	1.400	o
52	9,204		209	19.0	173	240.0	159.0	1.402	o
104	11,630	35.0	245	22.0	223	180.0	206.0	1.419	w
125	11,630		245			180.0	207.0	1.419	na
76	8,097	14.5	195	22.0	170	150.0	125.0	1.420	w
143	12,437	24.0	257	19.0	208		187.0	1.423	o
109	15,921	18.5	307	44.0	283	225.0	266.0	1.426	o
49	8,937		208	11.0	182	120.0	156.0	1.432	w
114	20,961		381	29.0	331	381.0	300.0	1.436	w
123	20,961		381	29.0	331	381.0	300.0	1.436	w
175	18,864		352				300.0	1.442	na
135	10,250	28.0	228	31.0		316.0	158.0	1.444	w
155	15,928		310	41.0	277		264.0	1.444	o
48	9,550		218	14.0	196	285.0	180.0	1.445	o
144	14,999		298	164.0	218	280.0	210.0	1.453	o
17	14,295		288		258		230.0	1.453	o
57	15,490		306	44.0	262	195.0	244.0	1.459	o
30	10,000		226	10.6	186	270.0	173.0	1.460	w
33	13,991		285	40.0	253	289.0	240.0	1.465	o
38	19,352		364		349		329.0	1.468	o
8	11,787	10.0	254	10.4	238	300.0	223.0	1.476	w

Table E-1—1984 Data Set (Continued)

Well Number	Depth, ft	Static Time hr	BHST ft	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
116	7,886	20.0	197	23.0	157	180.0	169.0	1.484	o
58	7,750	28.0	195	14.0	182	375.0	152.0	1.484	w
147	14,365	48.0	294	56.0	247	335.0	218.0	1.490	o
80	16,718	40.6	330	52.0	265	2,010.0	265.0	1.495	o
29	10,400		236	25.0	205	360.0	183.0	1.500	o
112	17,245	24.0	340	194.0	299	1,026.0	291.0	1.508	o
32	10,010		231	23.0		146.0	178.0	1.508	o
41	10,050		233	28.0	196	170.0	184.0	1.522	o
117	8,465	27.5	209	33.0				1.524	o
119	13,910	22.2	293	43.0	284	415.0	240.0	1.531	o
118	18,716	48.0	369	47.0	357	303.0	346.0	1.544	o
127	13,710		297	29.0	254		235.0	1.583	na
45	9,055		224	21.0	195	260.0	174.0	1.590	w
22	13,800		300	23.0	267		245.0	1.594	w
122	24,985		484	72.0	431	480.0	423.0	1.617	o
10	13,700		302	22.8	272	555.0	227.0	1.620	w
146	18,885	138.0	388	33.0	346		309.0	1.631	o
172	13,447		300	32.0	293	160.0	283.0	1.636	w
3	12,200		280	42.0	235	213.0	220.0	1.639	o
120	11,816	31.0	275	38.0	249	234.0	233.0	1.650	o
2	9,919		244	17.5	198	360.0	175.0	1.653	w
24	13,684		307	24.0	264	480.0	228.0	1.659	w
145	18,649	23.0	390	55.0	332		314.0	1.662	w
25	13,966		313		239	595.0	212.0	1.668	w
141	11,445	24.0	271	46.0	235	240.0	200.0	1.669	o
150	19,729	25.5	416	45.0	388		376.0	1.703	o
43	11,315	30.0	273	21.0	244	330.0	188.0	1.706	o
64	9,300		239	11.0	209	240.0	192.0	1.710	o
63	10,810		265	13.0	239	240.0	223.0	1.711	o
83	17,500		380		341	157.0	323.0	1.714	na
39	10,700		264	18.0	240	270.0	221.0	1.720	o
31	12,100		289	26.0	250	345.0	231.0	1.727	o
77	11,100	18.5	272	32.0	246	240.0	227.0	1.730	o
46	14,400		330		297	300.0	286.0	1.736	o
85	11,250	34.5	276	19.0	246	120.0	227.0	1.742	o
74	10,075		256	18.0	218	300.0	188.0	1.747	o
1	16136		363	44.6	339	270.0	325.0	1.754	o
56	10,200		260	21.0	233	285.0	191.0	1.765	o
5	14,616		340	23.0	295	294.0	274.0	1.779	o
66	11,700		290	18.0	262	255.0	233.0	1.795	o
23	15,023		350		324	330.0	308.0	1.797	o
99	9,755		256	22.0	218	120.0	202.0	1.804	o
96	10,130		263	15.0	232	240.0	211.0	1.807	o
51	12,490		306	21.0	275	240.0	251.0	1.809	o
87	12,599		308	16.3		200.0	243.0	1.810	o
97	11,049	8.3	280	16.0	261		239.0	1.810	o
102	10,512	36.0	271	20.0	237	210.0	217.0	1.817	o
78	12,364	35.5	305	19.0	277	300.0	245.0	1.822	o
94	18,200		412		372	541.3	317.0	1.824	o
61	12,400	30.0	307	26.0	269	240.0	253.0	1.831	o
54	12,222		304	24.0	265	240.0	238.0	1.833	o

Table E-1—1984 Data Set (Continued)

Well Number	Depth, ft	Static Time hr	BHST ft	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
34	13,094	35.0	320	27.0	261	490.0	218.0	1.833	o
53	11,100		285	23.0	242	240.0	212.0	1.847	o
4	13,000		321	30.9	295	214.0	267.0	1.854	o
26	15,774	29.0	376	33.0	340	303.0	326.0	1.877	o
60	16,496		390	58.0	356	233.0	335.0	1.879	o
47	14,834		359	69.0	291	1,240.0	289.0	1.881	o
40	10,717		283	18.0	256	240.0	231.0	1.894	o
62	11,108		292	22.0	254	240.0	238.0	1.909	o
28	17,712		419	42.0	364	600.0	322.0	1.914	o
27	11,682		305	14.4	270	210.0	237.0	1.926	o
65	11,100		294	15.0	267	270.0	241.0	1.928	o
9	13,564		346	27.8	315	370.0		1.961	o
106	13,100	36.0	338	22.0	275	360.0	225.0	1.969	o
152	15,219	35.5	381	39.0	348	300.0	331.0	1.978	o
35	11,900		320		287	210.0	269.0	2.017	o
164	12,951	44.5	342	21.0	274	280.0	229.0	2.023	o
103	17,565		438		384		361.0	2.038	o
110	18,205	48.0	457	38.0	402	180.0	383.0	2.071	o
86	1,298	4.0	138	4.0	112	75.0	100.0	4.468	w
108	1,206	9.0	136			75.0	116.0	4.643	w
67	1,435		148	4.0	87	105.0	71.0	4.739	w
159	1,374		147			182.0	96.0	4.876	w

APPENDIX F—LIST OF DRILLING FLUID TEMPERATURE DATA FROM THE 1984 DATA SET

Table F-1—Master List of Drilling Fluid (Mud) Inlet and Outlet Temperatures From the 1984 Data Set

Well Number	Depth ft	Static Time hr	BHST °F	Circulating Time, min	Initial Mud In Temp. °F	Final Mud In Temp. °F	Initial Mud Out Temp. °F	Final Mud Out Temp. °F	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
168	10,184		120.0		86.0	82.0	65.0	87.0	91.0	0.393	w
130	11,040	33.0	130.0	270.0	70.0	68.0	78.0	84.0	97.0	0.453	w
89	2,065	10.0	90.0	75.0	89.0	92.0	94.0	97.0	86.0	0.484	w
161	13,486		168.0	238.0	74.0	77.0	82.0	90.0	151.0	0.653	w
100	14,997		180.0	233.0	88.0	78.0	67.0	74.0	160.0	0.667	w
169	6,424		126.0		111.0	126.0	108.0	118.0	109.0	0.716	w
91	12,547		176.0	360.0	89.0	102.0	76.0	106.0	134.0	0.765	w
98	5,870		130.0	120.0		116.0		116.0	108.0	0.852	w
81	5,550		128.0	107.0	95.0	95.0	94.0	102.0	108.0	0.865	na
90	18,000		238.0	360.0	62.0	70.0	74.0	80.0	211.0	0.878	o
93	5,250	10.5	128.0	90.0	85.0	88.0	92.0	96.0	101.0	0.914	w
115	13,196		201.0	437.0	106.0				162.0	0.917	w
131	19,185		274.0	270.0	86.0	131.0	76.0	137.0	217.0	1.011	w
140	13,000	24.0	212.0	182.0	90.0	120.0	115.0		165.0	1.015	w
92	13,049	19.0	214.0	270.0	98.0	98.0	120.0	132.0	174.0	1.027	w
113	12,258	38.5	206.0	354.0	80.0	130.0	90.0	140.0	158.0	1.028	w
79	12,029	27.5	204.0		80.0	115.0	100.0	134.0	149.0	1.031	w
55	11,385	14.5	198.0	942.0		122.0		148.0	178.0	1.036	w
70	20,620	33.0	294.0	1,073.0	62.0	72.0	65.0	84.0	251.0	1.038	o
132	13,153	23.0	218.0	570.0		109.0		113.0	184.0	1.049	o
134	12,246	17.0	215.0	132.0	95.0	102.0	82.0	110.0	189.0	1.102	w
84	24,840	65.0	355.0	443.0	74.0	84.0	62.0	93.0	322.0	1.107	o
72	19,750	35.5	300.0	333.0	60.0	88.0	84.0	99.0	251.0	1.114	o
136	10,235	20.0	195.0	225.0	100.0	115.0	102.0	138.0	145.0	1.124	w
160	13,195		229.0	238.0	89.0	90.0	82.0	92.0	209.0	1.129	w
158	19,446		301.0		92.0	125.0	98.0	127.0	245.0	1.136	o
138	12,996		230.0	360.0	120.0	120.0	100.0	130.0	170.0	1.154	w
157	7,100		163.0	300.0		122.0		125.0	122.0	1.169	w
171	22,660		354.0	270.0		97.0		150.0		1.209	o
73	18,092		301.0	1,050.0	60.0	93.0	79.0	103.0	259.0	1.222	na
166	6,238		158.0	135.0		120.0		128.0	119.0	1.250	w
42	6,760		166.0	450.0		122.0		134.0	130.0	1.272	w
105	17,992	33.5	309.0	552.0	70.0	98.0	74.0	106.0	246.0	1.273	na
133	14,496		265.0		110.0	121.0	108.0	129.0	211.0	1.276	w
151	16,053	25.0	286.0			102.0		115.0	242.0	1.283	o
68	19,516		331.0	3,570.0	70.0	105.0	120.0	125.0	290.0	1.286	w
75	15,614		281.0	215.0	78.0	88.0	103.0	110.0	228.0	1.287	w
153	8,302	26.0	187.0	140.0	131.0	131.0	142.0	142.0	124.0	1.289	w
121	9,557		204.0	117.0		116.0		126.0	159.0	1.297	w
148	16,796	15.0	298.0	235.0	75.0	120.0	110.0	135.0	245.0	1.298	w
129	12,990	36.0	249.0	1,072.0		124.0		136.0	209.0	1.301	w
101	21,458	58.7	360.0	429.0		145.0		148.0	315.0	1.305	o
139	11,540	24.0	231.0	239.0	90.0	110.0	93.0	108.0	162.0	1.308	w
137	11,450	36.0	230.0		80.0	142.0	80.0	128.0	159.0	1.310	w
142	15,004	38.0	279.0	1,546.0	55.0	76.0	72.0	86.0	255.0	1.326	w
82	13,280	12.0	257.0	435.0		99.0		102.0	221.0	1.333	w
156	13,516	21.8	261.0		80.0	86.0	85.0	96.0	213.0	1.339	w
95	15,572	27.0	289.0	270.0	89.0	101.0	83.0	108.0	235.0	1.342	w

Table F-1—Master List of Drilling Fluid (Mud) Inlet and Outlet Temperatures From the 1984 Data Set (Continued)

Well Number	Depth ft	Static Time hr	BHST °F	Circulating Time, min	Initial Mud In Temp. °F	Final Mud In Temp. °F	Initial Mud Out Temp. °F	Final Mud Out Temp. °F	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
165	18,912		334.0	355.0	96.0	140.0	132.0	154.0	260.0	1.343	w
154	11,969	28.0	241.0	136.0		88.0		94.0	182.0	1.345	o
111	21,758	26.0	373.0	567.0	86.0	110.0	90.0	120.0	326.0	1.347	w
126	20,768	58.8	360.0	429.0		145.0		148.0	315.0	1.348	o
149	14,588	11.0	277.0	255.0	80.0	85.0	89.0	94.0	232.0	1.350	o
107	19,770		348.0	360.0	82.0	150.0	90.0	165.0	294.0	1.356	w
124	19,770		348.0	360.0	82.0	150.0	90.0	165.0	294.0	1.356	w
162	20,960		365.0		97.0	114.0	108.0	120.0	334.0	1.360	w
173	22,700		392.0		102.0	146.0	124.0	154.0	342.0	1.374	w
71	20,835		371.0	710.0	78.0	140.0	78.0	169.0	279.0	1.397	w
52	9,204		209.0	240.0		124.0		128.0	159.0	1.402	o
104	11,630	35.0	245.0	180.0	95.0	105.0			206.0	1.419	w
76	8,097	14.5	195.0	150.0	95.0	120.0	115.0	136.0	125.0	1.420	w
143	12,437	24.0	257.0		75.0	105.0	80.0	98.0	187.0	1.423	w
109	15,921	18.5	307.0	225.0	106.0	116.0	80.0	130.0	266.0	1.426	o
49	8,937		208.0	120.0		117.0		122.0	156.0	1.432	w
114	20,961		381.0	381.0	90.0	153.0	85.0	130.0	300.0	1.436	w
123	20,961		381.0	381.0	90.0	153.0	85.0	130.0	300.0	1.436	w
135	10,250	28.0	228.0	316.0	141.0	146.0	152.0	155.0	158.0	1.444	w
155	15,928		310.0			120.0		140.0	264.0	1.444	o
48	9,550		218.0	285.0		99.0		111.0	180.0	1.445	o
144	14,999		298.0	280.0	96.0	104.0	135.0	137.0	210.0	1.453	o
30	10,000		226.0	270.0		85.0		140.0	173.0	1.460	w
116	7,886	20.0	197.0	180.0	121.0	143.0	108.0	158.0	169.0	1.484	o
58	7,750	28.0	195.0	375.0	85.0	100.0	87.0	114.0	152.0	1.484	w
147	14,365	48.0	294.0	335.0	78.0	89.0	80.0	83.0	218.0	1.490	o
80	16,718	40.6	330.0	2,010.0		94.0		150.0	265.0	1.495	o
112	17,245	24.0	340.0	1,026.0				112.0	291.0	1.508	o
41	10,050		233.0	170.0	70.0	93.0	93.0	103.0	184.0	1.522	o
117	8,465	27.5	209.0			110.0				1.524	o
119	13,910	22.2	293.0	415.0		123.0		135.0	240.0	1.531	o
118	18,716	48.0	369.0	303.0		115.0		122.0	346.0	1.544	o
22	13,800		300.0			86.0		112.0	245.0	1.594	w
122	24,985		484.0	480.0	104.0	137.0	112.0	155.0	423.0	1.617	o
146	18,885	138.0	388.0			128.0		148.0	309.0	1.631	o
172	13,447		300.0	160.0	76.0	81.0	76.0	93.0	283.0	1.636	w
3	12,200		280.0	213.0					220.0	1.639	o
120	11,816	31.0	275.0	234.0	119.0	126.0	139.0	139.0	233.0	1.650	o
2	9,919		244.0	360.0		118.0		151.0	175.0	1.653	w
24	13,684		307.0	480.0	130.0	142.0	141.0	151.0	228.0	1.659	w
145	18,649	23.0	390.0		81.0	118.0	100.0	160.0	314.0	1.662	w
25	13,966		313.0	595.0	132.0	131.0	150.0	154.0	212.0	1.668	w
141	11,445	24.0	271.0	240.0	88.0	125.0	90.0	112.0	200.0	1.669	o
150	19,729	25.5	416.0		85.0	117.0	112.0	98.0	376.0	1.703	o
64	9,300		239.0	240.0		110.0		150.0	192.0	1.710	o
63	10,810		265.0	240.0		100.0		150.0	223.0	1.711	o
83	17,500		380.0	157.0	78.0	110.0	110.0	129.0	323.0	1.714	na
46	14,400		330.0	300.0		116.0		130.0	286.0	1.736	o
85	11,250	34.5	276.0	120.0		90.0		138.0	227.0	1.742	o
1	16,136		363.0	270.0		100.0		120.0	325.0	1.754	o
56	10,200		260.0	285.0		100.0		150.0	191.0	1.765	o

Table F-1—Master List of Drilling Fluid (Mud) Inlet and Outlet Temperatures From the 1984 Data Set (Continued)

Well Number	Depth ft	Static Time hr	BHST °F	Circulating Time, min	Initial Mud In Temp. °F	Final Mud In Temp. °F	Initial Mud Out Temp. °F	Final Mud Out Temp. °F	BHCT °F	Temp. Gradient °F/100 ft	Mud Type
5	14,616		340.0	294.0	92.0	130.0	116.0	142.0	274.0	1.779	o
99	9,755		256.0	120.0		98.0		130.0	202.0	1.804	o
96	10,130		263.0	240.0		140.0			211.0	1.807	o
102	10,512	36.0	271.0	210.0		95.0		135.0	217.0	1.817	o
61	12,400	30.0	307.0	240.0		80.0		160.0	253.0	1.831	o
54	12,222		304.0	240.0		115.0		150.0	238.0	1.833	o
34	13,094	35.0	320.0	490.0		80.0		135.0	218.0	1.833	o
53	11,100		285.0	240.0		80.0		125.0	212.0	1.847	o
4	13,000		321.0	214.0	110.0	110.0	125.0	130.0	267.0	1.854	o
60	16,496		390.0	233.0	101.0	120.0	143.0	146.0	335.0	1.879	o
47	14,834		359.0	1,240.0		80.0		120.0	289.0	1.881	o
40	10,717		283.0	240.0		80.0		125.0	231.0	1.894	o
62	11,108		292.0	240.0		110.0		125.0	238.0	1.909	o
65	11,100		294.0	270.0		100.0		150.0	241.0	1.928	o
152	15,219	35.5	381.0	300.0	111.0	120.0	117.0	130.0	331.0	1.978	o
35	11,900		320.0	210.0		100.0		122.0	269.0	2.017	o
164	12,951	44.5	342.0	280.0	131.0	196.0	129.0	193.0	229.0	2.023	o
103	17,565		438.0		128.0	128.0	120.0	162.0	361.0	2.038	o
110	18,205	48.0	457.0	180.0				150.0	383.0	2.071	o
86	1,298	4.0	138.0	75.0	102.0	104.0	102.0	104.0	100.0	4.468	w
108	1,206	9.0	136.0	75.0	110.0	115.0	115.0	118.0	116.0	4.643	w
159	1,374		147.0	182.0		88.0		104.0	96.0	4.876	w

APPENDIX G—1974–84 COMBINED MASTER DATA SET

Criteria used to eliminate data in the preparation of the selected master data set from the master data set

The criteria used to eliminate data for the 1974–84 Combined Master Data Set are listed below:

a. Offshore wells where the water depth is greater than 250 feet.
b. Offshore wells where the water depth is less than 250 feet IF the water depth was greater than 5 percent of the total well depth.
c. Data from up-hole temperature recording devices where circulation was a deeper depth and multiple subs were placed higher in the well.
d. Temperature Gradients greater than 2.1°F/100 ft.
e. No BHCT listed.
f. Duplicate data sets.

Table G-1—1974–84 Combined Master Data Set

Well Number	Depth ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
18	3,150		96.0		92.0		92.0	0.508	w
161	13,486		168.0	31.0	159.0	238.0	151.0	0.653	w
169	6,424		126.0	6.0	119.0		109.0	0.716	w
91	12,547		176.0	22.0	152.0	360.0	134.0	0.765	w
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
98	5,870		130.0	15.0	113.0	120.0	108.0	0.852	w
81	5,550		128.0	12.0	114.0	107.0	108.0	0.865	na
1-1	11,920	16.50	187.0				167.0	0.898	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
93	5,250	10.50	128.0	9.0	119.0	90.0	101.0	0.914	w
115	13,196		201.0	23.0	181.0	437.0	162.0	0.917	w
7-2	16,088	32.00	234.0				202.0	0.957	w
	18,336	19.00	256.0			420.0	213.0	0.960	o
7-0	11,735	20.00	194.0				179.0	0.971	w
14-2	15,731	18.75	232.5				205.0	0.973	w
	17,882	25.00	258.0				207.0	0.995	w
131	19,185		274.0	17.0	266.0	270.0	217.0	1.011	w
3-3	22,225	55.00	307.0				265.0	1.021	w
92	13,049	19.00	214.0	31.0	188.0	270.0	174.0	1.027	w
113	12,258	38.50	206.0	17.0	181.0	354.0	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
10-1	19,385	15.50	281.0				286.0	1.037	w
11-2	9,881	13.50	183.0				138.0	1.042	w
3-2	10,525	19.00	190.0				149.0	1.045	w
132	13,153	23.00	218.0	33.0	200.0	570.0	184.0	1.049	o
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.0	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
10-1	18,920		280.0				262.0	1.057	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
134	12,246	17.00	215.0	22.0	189.0	132.0	189.0	1.102	w
84	24,840	65.00	355.0	55.0	326.0	443.0	322.0	1.107	o
4-0	22,725	47.50	333.0				286.0	1.113	w
72	19,750	35.50	300.0	41.0	268.0	333.0	251.0	1.114	o

Table G-1—1974–84 Combined Master Data Set (Continued)

Well Number	Depth ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
160	13,195		229.0	53.0	213.0	238.0	209.0	1.129	w
158	19,446		301.0	62.0	262.0		245.0	1.136	o
20-2	13,995	21.50	240.0				190.0	1.143	w
8-0	13,025	42.00	229.0				149.0	1.444	w
176	19,499		305.0	38.0	299.0		295.0	1.154	na
138	12,996		230.0	21.0	182.0	360.0	170.0	1.154	w
128	18,594		297.0	27.0	287.0	480.0	269.0	1.167	na
20	13,700		240.0		202.0		193.0	1.168	w
157	7,100		163.0	12.0	151.0	300.0	122.0	1.169	w
12	14,280		247.0		217.0		200.0	1.169	w
163	7,695		171.0	42.0	134.0	70.0	125.0	1.183	w
88	1,097	3.75	93.0	3.0	91.0	85.0	90.0	1.185	w
21	13,452		241.0		204.0		189.0	1.197	w
15-2	17,930	14.25	294.5				265.0	1.199	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
11	15,323		267.0		233.0		221.0	1.220	w
73	18,092		301.0	34.0	279.0	1,050.0	259.0	1.222	na
10-2	17,164	40.50	290.0				236.0	1.223	w
6-0	16,988		288.0				261.0	1.224	w
18-2	18,240	13.00	308.0				290.0	1.250	w
166	6,238		158.0	17.0	142.0	135.0	119.0	1.250	w
105	17,992	33.50	309.0	56.0	263.0	552.0	246.0	1.273	na
5-0	7,215	23.00	172.0				148.0	1.275	w
133	14,496		265.0	26.0	224.0		211.0	1.276	w
14	12,900		245.0		274.0		258.0	1.279	o
	7,215	23.00	172.0			150.0	148.0	1.280	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
68	19,516		331.0		308.0	3,570.0	290.0	1.286	w
75	15,614		281.0		247.0	215.0	228.0	1.287	w
153	8,302	26.00	187.0	10.0	156.0	140.0	124.0	1.289	w
19-2	11,100	12.00	224.0				215.0	1.297	w
121	9,557		204.0	20.0	174.0	117.0	159.0	1.297	w
148	16,796	15.00	298.0	40.0	260.0	235.0	245.0	1.298	w
7	10,233	16.50	213.0	19.0	196.0	284.0	167.0	1.300	w
129	12,990	36.00	249.0	19.0	217.0	1,072.0	209.0	1.301	w
174	12,660		245.0	10.0	238.0	150.0	217.0	1.303	na
101	21,458	58.67	360.0	32.0	333.0	429.0	315.0	1.305	o
15	11,800		234.0		213.0		187.0	1.305	w
139	11,540	24.00	231.0	43.0	191.0	239.0	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.0	175.0	1.325	w
6-1	20,580	20.00	354.0				344.0	1.331	w
82	13,280	12.00	257.0	19.0	227.0	435.0	221.0	1.333	w
8-2	15,007	28.00	281.0				243.0	1.339	w
156	13,516	21.75	261.0	20.0	235.0		213.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.0	235.0	1.342	w
165	18,912		334.0	22.0	264.0	355.0	260.0	1.343	w
154	11,969	28.00	241.0	41.0	186.0	136.0	182.0	1.345	o
111	21,758	26.00	373.0	48.0	343.0	567.0	326.0	1.347	w
126	20,768	58.75	360.0	32.0	333.0	429.0	315.0	1.348	o
149	14,588	11.00	277.0	38.0	246.0	255.0	232.0	1.350	o

Table G-1—1974–84 Combined Master Data Set (Continued)

Well Number	Depth ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
16	17,500		317.0		279.0		263.0	1.354	o
107	19,770		348.0	36.0	315.0	360.0	294.0	1.356	w
50	10,830	27.33	227.0	21.0	203.0	240.0	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
36	17,808		322.0		281.0		269.0	1.359	o
162	20,960		365.0	49.0	342.0		334.0	1.360	w
173	22,700		392.0	40.0	363.0		342.0	1.374	w
19	20,889		368.0		346.0		311.0	1.379	o
59	13,256		263.0				215.0	1.381	w
71	20,835		371.0	6.0	355.0	710.0	279.0	1.397	w
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
52	9,204		209.0	19.0	173.0	240.0	159.0	1.402	o
104	11,630	35.00	245.0	22.0	223.0	180.0	206.0	1.419	w
125	11,630		245.0			180.0	207.0	1.419	na
76	8,097	14.50	195.0	22.0	170.0	150.0	125.0	1.420	w
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
109	15,921	18.50	307.0	44.0	283.0	225.0	266.0	1.426	o
49	8,937		208.0	11.0	182.0	120.0	156.0	1.432	w
114	20,961		381.0	29.0	331.0	381.0	300.0	1.436	w
175	18,864		352.0				300.0	1.442	na
135	10,250	28.00	228.0	31.0		316.0	158.0	1.444	w
155	15,928		310.0	41.0	277.0		264.0	1.444	o
48	9,550		218.0	14.0	196.0	285.0	180.0	1.445	o
144	14,999		298.0	164.0	218.0	280.0	210.0	1.453	o
17	14,295		288.0		258.0		230.0	1.455	o
57	15,490		306.0	44.0	262.0	195.0	244.0	1.459	o
30	10,000		226.0	10.6	186.0	270.0	173.0	1.450	w
33	13,991		285.0	40.0	253.0	289.0	240.0	1.465	o
38	19,352		364.0		349.0		329.0	1.468	o
8	11,787	10.00	254.0	10.4	238.0	300.0	223.0	1.476	w
116	7,886	20.00	197.0	23.0	157.0	180.0	169.0	1.484	o
58	7,750	28.00	195.0	14.0	182.0	375.0	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
147	14,365	48.00	294.0	56.0	247.0	335.0	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.0	265.0	1.495	o
29	10,400		236.0	25.0	205.0	360.0	183.0	1.500	o
112	17,245	24.00	340.0	194.0	299.0	1,026.0	291.0	1.508	o
32	10,010		231.0	23.0		146.0	178.0	1.508	o
41	10,050		233.0	28.0	196.0	170.0	184.0	1.522	o
119	13,910	22.15	293.0	43.0	284.0	415.0	240.0	1.531	o
118	18,716	48.00	369.0	47.0	357.0	303.0	346.0	1.544	o
127	13,710		297.0	29.0	254.0		235.0	1.583	na
45	9,055		224.0	21.0	195.0	260.0	174.0	1.590	w
3-0	11,440	32.50	262.0				209.0	1.591	w
22	13,800		300.0	23.0	267.0		245.0	1.594	w
122	24,985		484.0	72.0	431.0	480.0	423.0	1.617	o
	19,850		401.0			240.0	351.0	1.620	o
10	13,700		302.0	22.8	272.0	555.0	227.0	1.620	w
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
172	13,447		300.0	32.0	293.0	160.0	283.0	1.636	w
3	12,200		280.0	42.0	235.0	213.0	220.0	1.639	o

Table G-1—1974–84 Combined Master Data Set (Continued)

Well Number	Depth ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
120	11,816	31.00	275.0	38.0	249.0	234.0	233.0	1.650	o
2	9,919		244.0	17.0	198.0	360.0	175.0	1.653	w
24	13,684		307.0	24.0	264.0	480.0	228.0	1.659	w
145	18,649	23.00	390.0	55.0	332.0		314.0	1.662	w
25	13,966		313.0		239.0	595.0	212.0	1.668	w
141	11,445	24.00	271.0	46.0	235.0	240.0	200.0	1.669	o
6-2	12,515	25.00	289.0				235.0	1.670	w
	18,179		384.0			225.0	292.0	1.672	o
1-2	8,395	7.00	223.0				199.0	1.703	w
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.0	188.0	1.706	o
64	9,300		239.0	11.0	209.0	240.0	192.0	1.710	o
63	10,810		265.0	13.0	239.0	240.0	223.0	1.711	o
83	17,500		380.0		341.0	157.0	323.0	1.714	na
39	10,700		264.0	18.0	240.0	270.0	221.0	1.720	o
31	12,100		289.0	26.0	250.0	345.0	231.0	1.727	o
77	11,100	18.50	272.0	32.0	246.0	240.0	227.0	1.730	o
46	14,400		330.0		297.0	300.0	286.0	1.736	o
85	11,250	34.50	276.0	19.0	246.0	120.0	227.0	1.742	o
74	10,075		256.0	18.0	218.0	300.0	188.0	1.747	o
	12,187		293.0			180.0	226.0	1.748	o
1	16,136		363.0	44.6	339.0	270.0	325.0	1.754	o
13-2	12,929	19.00	307.0				288.0	1.756	w
56	10,200		260.0	21.0	233.0	285.0	191.0	1.765	o
	16,035	68.00	364.0			240.0	285.0	1.771	o
5	14,616		340.0	23.0	295.0	294.0	274.0	1.779	o
66	11,700		290.0	18.0	262.0	255.0	233.0	1.795	o
23	15,023		350.0		324.0	330.0	308.0	1.797	o
99	9,755		256.0	22.0	218.0	120.0	202.0	1.804	o
96	10,130		263.0	15.0	232.0	240.0	211.0	1.807	o
51	12,490		306.0	21.0	275.0	240.0	251.0	1.809	o
87	12,599		308.0	16.3		200.0	243.0	1.810	o
97	11,049	8.25	280.0	16.0	261.0		239.0	1.810	o
102	10,512	36.00	271.0	20.0	237.0	210.0	217.0	1.817	o
12-2	8,532	17.00	235.0				222.0	1.817	w
78	12,364	35.50	305.0	19.0	277.0	300.0	245.0	1.822	o
94	18,200		412.0		372.0	541.0	317.0	1.824	o
61	12,400	30.00	307.0	26.0	269.0	240.0	253.0	1.831	o
54	12,222		304.0	24.0	265.0	240.0	238.0	1.833	o
34	13,094	35.00	320.0	27.0	261.0	490.0	218.0	1.833	o
53	11,100		285.0	23.0	242.0	240.0	212.0	1.847	o
4	13,000		321.0	30.9	295.0	214.0	267.0	1.854	o
26	15,774	29.00	376.0	33.0	340.0	303.0	326.0	1.877	o
60	16,496		390.0	58.0	356.0	233.0	335.0	1.879	o
47	14,834		359.0	69.0	291.0	1,240	289.0	1.881	o
40	10,717		283.0	18.0	256.0	240.0	231.0	1.894	o
	12,180		312.0			240.0	221.0	1.904	o
62	11,108		292.0	22.0	254.0	240.0	238.0	1.909	o
28	17,712		419.0	42.0	364.0	600.0	322.0	1.914	o
27	11,682		305.0	14.4	270.0	210.0	237.0	1.926	o

Table G-1—1974–84 Combined Master Data Set (Continued)

Well Number	Depth ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
65	11,100		294.0	15.0	267.0	270.0	241.0	1.928	o
	12,400	44.5	321.0			270.0	231.0	1.944	o
106	13,100	36.0	338.0	22.0	275.0	360.0	225.0	1.969	o
1-0	14,665	14.5	369.0				331.0	1.971	w
1-2	7,905	10.0	236.0				155.0	1.973	w
152	15,219	35.5	381.0	39.0	348.0	300.0	331.0	1.978	o
35	11,900		320.0		287.0	210.0	269.0	2.017	o
164	12,951	44.5	342.0	21.0	274.0	280.0	229.0	2.023	o
103	17,565		438.0		384.0		361.0	2.038	o
110	18,205	48.0	457.0	38.0	402.0	180.0	383.0	2.071	o

APPENDIX H—ELEVEN SUBSETS FROM 1974–84 COMBINED MASTER DATA SET

AllMuds1 Subset—102 records, all mud types, only data records which had static time information listed.

AllMuds2 Subset—95 records, all mud types, only data records with static times equal to or greater than 12 hours.

AllMuds3 Subset—66 records, all mud types, only data records with static times equal to or greater than 24 hours.

WaterMuds1 Subset—102 records, water muds only.

WaterMuds2 Subset—63 records, water muds only, only data records with static time information listed.

WaterMuds3 Subset—58 records, water muds only, only data records with static times equal to or greater than 12 hours.

WaterMuds4 Subset—35 records, water muds only, only data records with static times equal to or greater than 24 hours.

OilMuds1 Subset—88 records, oil muds only.

OilMuds2 Subset—38 records, oil muds only, only data records with static time information listed.

OilMuds3 Subset—36 records, oil muds only, only data records with static times equal to or greater than 12 hours.

OilMuds4 Subset—29 records, oil muds only, only data records with static times equal to or greater than 24 hours.

Table H-1—1974–84 AllMuds1 Subset—102 Records with Static Time Information Listed

Well Number	Depth, ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min.	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
1-1	11,920	16.50	187.0				167.0	0.898	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
93	5,250	10.50	128.0	9.0	119.0	90.00	101.0	0.914	w
7-2	16,088	32.00	234.0				202.0	0.957	w
	18,336	19.00	256.0			420.00	213.0	0.960	o
7-0	11,735	20.00	194.0				179.0	0.971	w
14-2	15,731	18.75	232.5				205.0	0.973	w
	17,882	25.00	258.0				207.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
92	13,049	19.00	214.0	31.0	188.0	270.00	174.0	1.027	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
10-1	19,385	15.50	281.0				286.0	1.037	w
11-2	9,881	13.50	183.0				138.0	1.042	w
3-2	10,525	19.00	190.0				149.0	1.045	w
132	13,153	23.00	218.0	33.0	200.0	570.00	184.0	1.049	o
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
134	12,246	17.00	215.0	22.0	189.0	132.00	189.0	1.102	w
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
4-0	22,725	47.50	333.0				286.0	1.113	w
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
20-2	13,995	21.50	240.0				190.0	1.143	w
8-0	13,025	42.00	229.0				149.0	1.144	w
88	1,097	3.75	93.0	3.0	91.0	85.00	90.0	1.185	w
15-2	17,930	14.25	294.5				265.0	1.199	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w

Table H-1—1974–84 AllMuds1 Subset—102 Records with Static Time Information Listed (Continued)

Well Number	Depth, ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min.	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
10-2	17,164	40.50	290.0				236.0	1.223	w
18-2	18,240	13.00	308.0				290.0	1.250	w
105	17,992	33.50	309.0	56.0	263.0	552.00	246.0	1.273	na
5-0	7,215	23.00	172.0				148.0	1.275	w
	7,215	23.00	172.0			150.00	148.0	1.280	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
19-2	11,100	12.00	224.0				215.0	1.297	w
148	16,796	15.00	298.0	40.0	260.0	235.00	245.0	1.298	w
7	10,233	16.50	213.0	19.0	196.0	284.00	167.0	1.300	w
129	12,990	36.00	249.0	19.0	217.0	1072.00	209.0	1.301	w
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
6-1	20,580	20.00	354.0				344.0	1.331	w
82	13,280	12.00	257.0	19.0	227.0	435.00	221.0	1.333	w
8-2	15,007	28.00	281.0				243.0	1.339	w
156	13,516	21.75	261.0	20.0	235.0		213.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
149	14,588	11.00	277.0	38.0	246.0	255.00	232.0	1.350	o
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
76	8,097	14.50	195.0	22.0	170.0	150.00	125.0	1.420	w
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
109	15,921	18.50	307.0	44.0	283.0	225.00	266.0	1.426	o
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
8	11,787	10.00	254.0	10.4	238.0	300.00	223.0	1.476	w
116	7,886	20.00	197.0	23.0	157.0	180.00	169.0	1.484	o
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.00	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.00	291.0	1.508	o
119	13,910	22.15	293.0	43.0	284.0	415.00	240.0	1.531	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
3-0	11,440	32.50	262.0				209.0	1.591	w
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
145	18,649	23.00	390.0	55.0	332.0		314.0	1.662	w
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
6-2	12,515	25.00	289.0				235.0	1.670	w
1-2	8,395	7.00	223.0				199.0	1.703	w
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
77	11,100	18.50	272.0	32.0	246.0	240.00	227.0	1.730	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o

Table H-1—1974–84 AllMuds1 Subset—102 Records with Static Time Information Listed (Continued)

Well Number	Depth, ft	Static Time hr.	BHST °F	Time Required to Pump 1 Workstring Volume, min.	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
13-2	12,929	19.00	307.0				288.0	1.756	w
	16,035	68.00	364.0			240.00	285.0	1.771	o
97	11,049	8.25	280.0	16.0	261.0		239.0	1.810	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
12-2	8,532	17.00	235.0				222.0	1.817	w
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
1-0	14,665	14.50	369.0				331.0	1.971	w
1-2	7,905	10.00	236.0				155.0	1.973	w
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

Table H-2—1974–84 Allmuds2 Subset—95 Records with Static Time Equal to or Greater than 12 Hours

Well Number	Depth ft	Static Time, hrs	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
1-1	11,920	16.50	187.0				167.0	0.898	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
7-2	16,088	32.00	234.0				202.0	0.957	w
	18,336	19.00	256.0			420.00	213.0	0.960	o
7-0	11,735	20.00	194.0				179.0	0.971	w
14-2	15,731	18.75	232.5				205.0	0.973	w
	17,882	25.00	258.0				207.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
92	13,049	19.00	214.0	31.0	188.0	270.00	174.0	1.027	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
10-1	19,385	15.50	281.0				286.0	1.037	w
11-2	9,881	13.50	183.0				138.0	1.042	w
3-2	10,525	19.00	190.0				149.0	1.045	w
132	13,153	23.00	218.0	33.0	200.0	570.00	184.0	1.049	o
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
134	12,246	17.00	215.0	22.0	189.0	132.00	189.0	1.102	w
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
4-0	22,725	47.50	333.0				286.0	1.113	w
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
20-2	13,995	21.50	240.0				190.0	1.143	w
8-0	13,025	42.00	229.0				149.0	1.144	w
15-2	17,930	14.25	294.5				265.0	1.199	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
10-2	17,164	40.50	290.0				236.0	1.223	w
18-2	18,240	13.00	308.0				290.0	1.25	w
105	17,992	33.50	309.0	56.0	263.0	552.00	246.0	1.273	na
5-0	7,215	23.00	172.0				148.0	1.275	w
	7,215	23.00	172.0			150.00	148.0	1.280	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
19-2	11,100	12.00	224.0				215.0	1.297	w
148	16,796	15.00	298.0	40.0	260.0	235.00	245.0	1.298	w
7	10,233	16.50	213.0	19.0	196.0	284.00	167.0	1.300	w
129	12,990	36.00	249.0	19.0	217.0	1,072.0	209.0	1.301	w
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
6-1	20,580	20.00	354.0				344.0	1.331	w
82	13,280	12.00	257.0	19.0	227.0	435.00	221.0	1.333	w
8-2	15,007	28.00	281.0				243.0	1.339	w
156	13,516	21.75	261.0	20.0	235.0		213.0	1.339	w

Table H-2—1974–84 Allmuds2 Subset—95 Records with Static Time Equal to or Greater than 12 Hours (Continued)

Well Number	Depth ft	Static Time, hrs	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
76	8,097	14.50	195.0	22.0	170.0	150.00	125.0	1.420	w
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
109	15,921	18.50	307.0	44.0	283.0	225.00	266.0	1.426	o
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
116	7,886	20.00	197.0	23.0	157.0	180.00	169.0	1.484	o
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.0	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.0	291.0	1.508	o
119	13,910	22.15	293.0	43.0	284.0	415.00	240.0	1.531	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
3-0	11,440	32.50	262.0				209.0	1.591	w
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
145	18,649	23.00	390.0	55.0	332.0		314.0	1.662	w
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
6-2	12,515	25.00	289.0				235.0	1.670	w
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
77	11,100	18.50	272.0	32.0	246.0	240.00	227.0	1.730	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o
13-2	12,929	19.00	307.0				288.0	1.756	w
	16,035	68.00	364.0			240.00	285.0	1.771	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
12-2	8,532	17.00	235.0				222.0	1.817	w
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
1-0	14,665	14.50	369.0				331.0	1.971	w
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

Table H-3—1974–84 Allmuds3 Subset—66 Records with Static Time Equal to or Greater than 24 Hours

Well Number	Depth ft	Static Time, hrs	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
7-2	16,088	32.00	234.0				202.0	0.957	w
	17,882	25.00	258.0				207.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
4-0	22,725	47.50	333.0				286.0	1.113	w
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
8-0	13,025	42.00	229.0				149.0	1.144	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
10-2	17,164	40.50	290.0				236.0	1.223	w
105	17,992	33.50	309.0	56.0	263.0	552.00	246.0	1.273	na
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
129	12,990	36.00	249.0	19.0	217.0	1,072.00	209.0	1.301	w
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
8-2	15,007	28.00	281.0				243.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.00	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.00	291.0	1.508	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
3-0	11,440	32.50	262.0				209.0	1.591	w
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
145	18,649	24.00	390.0	55.0	332.0		314.0	1.662	w
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o

Table H-3—1974–84 Allmuds3 Subset—66 Records with Static Time Equal to or Greater than 24 Hours (Continued)

Well Number	Depth ft	Static Time, hrs	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
6-2	12,515	25.00	289.0				235	1.670	w
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o
	16,035	68.00	364.0			240.00	285.0	1.771	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.0	338.0	22.0	275.0	360.00	225.0	1.969	o
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

Table H-4—1974–84 WaterMuds1 Subset—List of Records for Water Muds

Well Number	Depth ft	Static Time hrs	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
18	3,150		96.0		92.0		92.0	0.508	w
161	13486		168.0	31.0	159.0	238.00	151.0	0.653	w
169	6,424		126.0	6.0	119.0		109.0	0.716	w
91	12,547		176.0	22.0	152.0	360.00	134.0	0.765	w
3-1	17,210	33.0	218.0				189.0	0.802	w
2-3	18,510	29.0	229.0				190.0	0.805	w
98	5,870		130.0	15.0	113.0	120.00	108.0	0.852	w
1-1	11,920	16.50	187.0				167.0	0.898	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
93	5,250	10.50	128.0	9.0	119.0	90.00	101.0	0.914	w
115	13,196		201.0	23.0	181.0	437.00	162.0	0.917	w
7-2	16,088	32.00	234.0				202.0	0.957	w
7-0	11,735	20.00	194.0				179.0	0.971	w
14-2	15,731	18.75	232.5				205.0	0.973	w
	17,882	25.00	258.0				207.0	0.995	w
131	19,185		274.0	17.0	266.0	270.00	217.0	1.011	w
3-3	22,225	55.00	307.0				265.0	1.021	w
92	13,049	19.00	214.0	31.0	188.0	270.00	174.0	1.027	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
10-1	19,385	15.50	281.0				286.0	1.037	w
11-2	9,881	13.50	183.0				138.0	1.042	w
3-2	10,525	19.00	190.0				149.0	1.045	w
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
10-1	18,920		280.0				262.0	1.057	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
134	12,246	17.00	215.0	22.0	189.0	132.00	189.0	1.102	w
4-0	22,725	47.50	333.0				286.0	1.113	w
160	13,195		229.0	53.0	213.0	238.00	209.0	1.129	w
20-2	13,995	21.50	240.0				190.0	1.143	w
8-0	13,025	42.00	229.0				149.0	1.144	w
138	12,996		230.0	21.0	182.0	360.00	170.0	1.154	w
20	13,700		240.0		202.0		193.0	1.168	w
157	7,100		163.0	12.0	151.0	300.00	122.0	1.169	w
12	14,280		247.0		217.0		200.0	1.169	w
163	7,695		171.0	42.0	134.0	70.00	125.0	1.183	w
88	1,097	3.75	93.0	3.0	91.0	85.00	90.0	1.185	w
21	13,452		241.0		204.0		189.0	1.197	w
15-2	17,930	14.25	294.5				265.0	1.199	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
11	15,323		267.0		233.0		221.0	1.220	w
10-2	17,164	40.50	290.0				236.0	1.223	w
6-0	16,988		288.0				261.0	1.224	w
18-2	18,240	13.00	308.0				290.0	1.250	w
166	6,238		158.0	17.0	142.0	135.00	119.0	1.250	w

Table H-4—1974–84 WaterMuds1 Subset—List of Records for Water Muds (Continued)

Well Number	Depth ft	Static Time hrs	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
5-0	7,215	23.00	172.0				148.0	1.275	w
133	14,496		265.0	26.0	224.0		211.0	1.276	w
68	19,516		331.0		308.0	3,570.00	290.0	1.286	w
75	15,614		281.0		247.0	215.00	228.0	1.287	w
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
19-2	11,100	12.00	224.0				215.0	1.297	w
121	9,557		204.0	20.0	174.0	117.00	159.0	1.297	w
148	16,796	15.00	298.0	40.0	260.0	235.00	245.0	1.298	w
7	10,233	16.50	213.0	19.0	196.0	284.00	167.0	1.300	w
129	12,990	36.00	249.0	19.0	217.0	1,072.00	209.0	1.301	w
15	11,800		234.0		213.0		187.0	1.305	w
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
6-1	20,580	20.00	354.0				344.0	1.331	w
82	13,280	12.00	257.0	19.0	227.0	435.00	221.0	1.333	w
8-2	15,007	28.00	281.0				243.0	1.339	w
156	13,516	21.75	261.0	20.0	235.0		213.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
165	18,912		334.0	22.0	264.0	355.00	260.0	1.343	w
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
107	19,770		348.0	36.0	315.0	360.00	294.0	1.356	w
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
162	20,960		365.0	49.0	342.0		334.0	1.360	w
173	22,700		392.0	40.0	363.0		342.0	1.374	w
59	13,256		263.0		234.0		215.0	1.381	w
71	20,835		371.0	6.0	355.0	710.00	279.0	1.397	w
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
76	8,097	14.50	195.0	22.0	170.0	150.00	125.0	1.420	w
49	8,937		208.0	11.0	182.0	120.00	156.0	1.432	w
114	20,961		381.0	29.0	331.0	381.00	300.0	1.436	w
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
30	10,000		226.0	10.6	186.0	270.00	173.0	1.460	w
8	11,787	10.00	254.0	10.4	238.0	300.00	223.0	1.476	w
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
45	9,055		224.0	21.0	195.0	260.00	174.0	1.590	w
3-0	11,440	32.50	262.0				209.0	1.591	w
22	13,800		300.0	23.0	267.0		245.0	1.594	w
10	13,700		302.0	22.8	272.0	555.00	227.0	1.620	w
172	13,447		300.0	32.0	293.0	160.00	283.0	1.636	w
2	9,919		244.0	17.5	198.0	360.00	175.0	1.653	w
24	13,684		307.0	24.0	264.0	480.00	228.0	1.659	w
145	18,649	23.00	390.0	55.0	332.0		314.0	1.662	w
25	13,966		313.0		239.0	595.00	212.0	1.668	w
6-2	12,515	25.00	289.0				235.0	1.670	w
1-2	8,395	7.00	223.0				199.0	1.703	w
13-2	12,929	19.00	307.0				288.0	1.756	w
12-2	8,532	17.00	235.0				222.0	1.817	w
1-0	14,665	14.50	369.0				331.0	1.971	w
1-2	7,905	10.00	236.0				155.0	1.973	w

Table H-5—1974–84 WaterMuds2 Subset—63 Records with Static Time Information Listed

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
1-1	11,920	16.50	187.0				167.0	0.898	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
93	5,250	10.50	128.0	9.0	119.0	90.00	101.0	0.914	w
7-2	16,088	32.00	234.0				202.0	0.957	w
7-0	11,735	20.00	194.0				179.0	0.971	w
14-2	15,731	18.75	232.5				205.0	0.973	w
	17,882	25.00	258.0				207.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
92	13,049	19.00	214.0	31.0	188.0	270.00	174.0	1.027	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
10-1	19,385	15.50	281.0				286.0	1.037	w
11-2	9,881	13.50	183.0				138.0	1.042	w
3-2	10,525	19.00	190.0				149.0	1.045	w
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
134	12,246	17.00	215.0	22.0	189.0	132.00	189.0	1.102	w
4-0	22,725	47.50	333.0				286.0	1.113	w
20-2	13,995	21.50	240.0				190.0	1.143	w
8-0	13,025	42.00	229.0				149.0	1.144	w
88	1,097	3.75	93.0	3.0	91.0	85.00	90.0	1.185	w
15-2	17,930	14.25	294.5				265.0	1.199	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
10-2	17,164	40.50	290.0				236.0	1.223	w
18-2	18,240	13.00	308.0				290.0	1.250	w
5-0	7,215	23.00	172.0				148.0	1.275	w
153	8,302	26.00	187.0	10.0	156.0	140.0	124.0	1.289	w
19-2	11,100	12.00	224.0				215.0	1.297	w
148	16,796	15.00	298.0	40.0	260.0	235.00	245.0	1.298	w
7	10,233	16.50	213.0	19.0	196.0	284.00	167.0	1.300	w
129	12,990	36.00	249.0	19.0	217.0	1,072.00	209.0	1.301	w
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
6-1	20,580	20.00	354.0				344.0	1.331	w
82	13,280	12.00	257.0	19.0	227.0	435.00	221.0	1.333	w
8-2	15,007	28.00	281.0				243.0	1.339	w
156	13,516	21.75	261.0	20.0	235.0		213.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
76	8,097	14.50	195.0	22.0	170.0	150.00	125.0	1.420	w

Table H-5—1974–84 WaterMuds2 Subset—63 Records with Static Time Information Listed (Continued)

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
8	11,787	10.00	254.0	10.4	238.0	300.00	223.0	1.476	w
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
3-0	11,440	32.50	262.0				209.0	1.591	w
145	18,649	23.00	390.0	55.0	332.0		314.0	1.662	w
6-2	12,515	25.00	289.0				235.0	1.670	w
1-2	8,395	7.00	223.0				199.0	1.703	w
13-2	12,929	19.00	307.0				288.0	1.756	w
12-2	8,532	17.00	235.0				222.0	1.817	w
1-0	14,665	14.50	369.0				331.0	1.971	w
1-2	7,905	10.00	236.0				155.0	1.973	w

Table H-6 1974–84 WaterMuds3 Subset—58 Records with Static Time Equal to or Greater than 12 Hours

Well Number	Depth ft	Static Time hr	BHST, °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
1-1	11,920	16.50	187.0				167.0	0.898	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
7-2	16,088	32.00	234.0				202.0	0.957	w
7-0	11,735	20.00	194.0				179.0	0.971	w
14-2	15,731	18.75	232.5				205.0	0.973	w
	17,882	25.00	258.0				207.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
92	13,049	19.00	214.0	31.0	188.0	270.00	174.0	1.027	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
10-1	19,385	15.50	281.0				286.0	1.037	w
11-2	9,881	13.50	183.0				138.0	1.042	w
3-2	10,525	19.00	190.0				149.0	1.045	w
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
134	12,246	17.00	215.0	22.0	189.0	132.00	189.0	1.102	w
4-0	22,725	47.50	333.0				286.0	1.113	w
20-2	13,995	21.50	240.0				190.0	1.143	w
8-0	13,025	42.00	229.0				149.0	1.144	w
15-2	17,930	14.25	294.5				265.0	1.199	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
10-2	17,164	40.50	290.0				236.0	1.223	w
18-2	18,240	13.00	308.0				290.0	1.250	w
5-0	7,215	23.00	172.0				148.0	1.275	w
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
19-2	11,100	12.00	224.0				215.0	1.297	w
148	16,796	15.00	298.0	40.0	260.0	235.00	245.0	1.298	w
7	10,233	16.50	213.0	19.0	196.0	284.00	167.0	1.300	w
129	12,990	36.00	249.0	19.0	217.0	1,072.00	209.0	1.301	w
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
6-1	20,580	20.00	354.0				344.0	1.331	w
82	13,280	12.00	257.0	19.0	227.0	435.00	221.0	1.333	w
8-2	15,007	28.00	281.0				243.0	1.339	w
156	13,516	21.75	261.0	20.0	235.0		213.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
50	10830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19370	76.00	343.0				290.0	1.358	w
104	11630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w

Table H-6 1974–84 WaterMuds3 Subset—58 Records with Static Time Equal to or Greater than 12 Hours (Continued)

Well Number	Depth ft	Static Time hr	BHST, °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
76	8097	14.50	195.0	22.0	170.0	150.00	125.0	1.420	w
135	10250	28.00	228.0	31.0		316.00	158.0	1.444	w
58	7750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15375	34.50	309.0				217.0	1.489	w
3-0	11440	32.50	262.0				209.0	1.591	w
145	18649	23.00	390.0	55.0	332.0		314.0	1.662	w
6-2	12515	25.00	289.0				235.0	1.670	w
13-2	12929	19.00	307.0				288.0	1.756	w
12-2	8532	17.00	235.0				222.0	1.817	w
1-0	14665	14.50	369.0				331.0	1.971	w

Table H-7—1974–84 WaterMuds4 Subset—35 Records with Static Time Equal to or Greater than 24 Hours

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
7-2	16,088	32.00	234.0				202.0	0.957	w
	17,882	25.00	258.0				270.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
113	12,258	38.50	206.0	17.0	181.0	354.0	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
4-0	22,725	47.50	333.0				286.0	1.113	w
8-0	13,025	42.00	229.0				149.0	1.144	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
10-2	17,164	40.50	290.0				236.0	1.223	w
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
129	12,990	36.00	249.0	19.0	217.0	1,072.00	209.0	1.301	w
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
8-2	15,007	28.00	281.0				243.0	1.339	w
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
3-0	11,440	32.50	262.0				209.0	1.591	w
6-2	12,515	25.00	289.0				235.0	1.670	w

Table H-8—1974–84 OilMuds1 Subset—List of Records for Oil Muds

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
	18,336	19.00	256.0			420.00	213.0	0.960	o
132	13,153	23.00	218.0	33.0	200.0	570.00	184.0	1.049	o
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
158	19,446		301.0	62.0	262.0		245.0	1.136	o
14	12,900		245.0		274.0		258.0	1.279	o
	7,215	23.00	172.0			150.00	148.0	1.280	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
149	14,588	11.00	277.0	38.0	246.0	255.00	232.0	1.350	o
16	17,500		317.0		279.0		263.0	1.354	o
36	17,808		322.0		281.0		269.0	1.359	o
19	20,889		368.0		346.0		311.0	1.379	o
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
52	9,204		209.0	19.0	173.0	240.00	159.0	1.402	o
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
109	15,921	18.50	307.0	44.0	283.0	225.00	266.0	1.426	o
155	15,928		310.0	41.0	277.0		264.0	1.444	o
48	9,550		218.0	14.0	196.0	285.00	180.0	1.445	o
144	14,999		298.0	164.0	218.0	280.00	210.0	1.453	o
17	14,295		288.0		258.0		230.0	1.455	o
57	15,490		306.0	44.0	262.0	195.00	244.0	1.459	o
33	13,991		285.0	40.0	253.0	289.00	240.0	1.465	o
38	19,352		364.0		349.0		329.0	1.468	o
116	7,886	20.00	197.0	23.0	157.0	180.00	169.0	1.484	o
147	14,365	48.00	294.0	56.0	247.0	335.0	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.0	265.0	1.495	o
29	10,400		236.0	25.0	205.0	360.00	183.0	1.500	o
112	17,245	24.00	340.0	194.0	299.0	1,026.0	291.0	1.508	o
32	10,010		231.0	23.0		146.00	178.0	1.508	o
41	10,050		233.0	28.0	196.0	170.00	184.0	1.522	o
119	13,910	22.15	293.0	43.0	284.0	415.00	240.0	1.531	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
122	24,985		484.0	72.0	431.0	480.00	423.0	1.617	o
	19,850		401.0			240.00	351.0	1.620	o
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
3	12,200		280.0	42.0	235.0	213.00	220.0	1.639	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
	18,179		384.0			225.00	292.0	1.672	o
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
64	9,300		239.0	11.0	209.0	240.00	192.0	1.710	o
63	10,810		265.0	13.0	239.0	240.00	223.0	1.711	o
39	10,700		264.0	18.0	240.0	270.00	221.0	1.720	o
31	12,100		289.0	26.0	250.0	345.00	231.0	1.727	o
77	11,100	18.50	272.0	32.0	246.0	240.00	227.0	1.730	o
46	14,400		330.0		297.0	300.00	286.0	1.736	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o

Table H-8—1974–84 OilMuds1 Subset—List of Records for Oil Muds (Continued)

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
74	10,075		256.0	18.0	218.0	300.00	188.0	1.747	o
	12,187		293.0			180.00	226.0	1.748	o
1	16,136		363.0	44.6	339.0	270.00	325.0	1.754	o
56	10,200		260.0	21.0	233.0	285.00	191.0	1.765	o
	16,035	68.00	364.0			240.00	285.0	1.771	o
5	14,616		340.0	23.0	295.0	294.00	274.0	1.779	o
66	11,700		290.0	18.0	262.0	255.00	233.0	1.795	o
23	15,023		350.0		324.0	330.00	308.0	1.797	o
99	9,755		256.0	22.0	218.0	120.00	202.0	1.804	o
96	10,130		263.0	15.0	232.0	240.00	211.0	1.807	o
51	12,490		306.0	21.0	275.0	240.00	251.0	1.809	o
87	12,599		308.0	16.3		200.00	243.0	1.810	o
97	11,049	8.25	280.0	16.0	261.0		239.0	1.810	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
94	18,200		412.0		372.0	541.30	317.0	1.824	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
54	12,222		304.0	24.0	265.0	240.00	238.0	1.833	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
53	11,100		285.0	23.0	242.0	240.00	212.0	1.847	o
4	13,000		321.0	30.9	295.0	214.00	267.0	1.854	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
60	16,496		390.0	58.0	356.0	233.00	335.0	1.879	o
47	14,834		359.0	69.0	291.0	1,240.00	289.0	1.881	o
40	10,717		283.0	18.0	256.0	240.00	231.0	1.894	o
	12,180		312.0			240.00	221.0	1.904	o
62	11,108		292.0	22.0	254.0	240.00	238.0	1.909	o
28	17,712		419.0	42.0	364.0	600.00	322.0	1.914	o
27	11,682		305.0	14.4	270.0	210.00	237.0	1.926	o
65	11,100		294.0	15.0	267.0	270.00	241.0	1.928	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
35	11,900		320.0		287.0	210.00	269.0	2.017	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
103	17,565		438.0		384.0		361.0	2.038	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

Table H-9—1974–84 OilMuds2 Subset—38 Records with Static Time Information Listed

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump1 Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
	18,336	19.00	256.0			420.00	213.0	0.960	o
132	13,153	23.00	218.0	33.0	200.0	570.00	184.0	1.049	o
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
	7,215	23.00	172.0			150.00	148.0	1.280	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
149	14,588	11.00	277.0	38.0	246.0	255.00	232.0	1.350	o
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
109	15,921	18.50	307.0	44.0	283.0	225.00	266.0	1.426	o
116	7,886	20.00	197.0	23.0	157.0	180.00	169.0	1.484	o
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.00	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.00	291.0	1.508	o
119	13,910	22.15	293.0	43.0	284.0	415.00	240.0	1.531	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
77	11,100	18.50	272.0	32.0	246.0	240.00	227.0	1.730	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o
	16,035	68.00	364.0			240.00	285.0	1.771	o
97	11,049	8.25	280.0	16.0	261.0		239.0	1.810	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

Table H-10—1974–84 OilMuds3 Subset—36 Records with Static Time Equal to or Greater than 12 Hours

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1 Workstring Volume, min	BHSqT F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
	18,336	19.00	256.0			420.00	213.0	0.960	o
132	13,153	23.00	218.0	33.0	200.0	570.00	184.0	1.049	o
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
	7,215	23.00	172.0			150.00	148.0	1.280	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
109	15,921	18.50	307.0	44.0	283.0	225.00	266.0	1.426	o
116	7,886	20.00	197.0	23.0	157.0	180.00	169.0	1.484	o
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.00	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.00	291.0	1.508	o
119	13,910	22.15	293.0	43.0	284.0	415.00	240.0	1.531	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
77	11,100	18.50	272.0	32.0	246.0	240.00	227.0	1.730	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o
	16,035	68.00	364.0			240.00	285.0	1.771	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

Table H-11—1974-84 OilMuds4 Subset—29 Records with Static Time Equal to or Greater Than 24 Hours

Well Number	Depth ft	Static Time hr	BHST °F	Time Required to Pump 1Workstring Volume, min	BHSqT °F	Circulating Time, min	BHCT °F	Temperature Gradient °F/100 ft	Mud Type
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.00	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.00	291.0	1.508	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o
	16,035	68.00	364.0			240.00	285.0	1.771	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

APPENDIX I—LIST OF DATA AND CORRELATION EQUATIONS USED TO DEVELOP PROPOSED UPDATES FOR CASING AND SQUEEZE-CEMENTING TEMPERATURES

Mathematical correlations developed from 1974–84 Allmuds3 Subset to predict Casing and Squeeze-Cementing Temperature.

Casing-Cementing Temperatures

$$BHCT = \frac{80\text{ F} + (-10.0915) + [6.061 \times (Depth \times TG \times 0.001)]}{1 + (-1.5052 \times Depth \times 0.00001)}$$

where

BHCT = bottom-hole circulating temperature, °F,

TG = temperature gradient, °F/100 ft,

Depth = true vertical depth, ft.

Note: This equation was accepted for use at depths deeper than 10,000 feet.

Squeeze-Cementing Temperatures

$$BHSqT = \frac{80\text{ F} + (-8.2021) + [7.6495 \times (Depth \times TG \times 0.001)]}{1 + (-0.8068 \times Depth \times 0.00001)}$$

where

BHSqT = bottom-hole squeeze temperature, °F,

TG = temperature gradient, °F/100 ft,

Depth = true vertical depth, ft.

Table I-1—1974–84 Allmuds3 Subset—66 Records with Static Time Equal to or Greater than 24 Hours

Well Number	Depth ft	Static Time hrs	BHST F	Time Required to Pump 1Workstring Volume, min.	BHSqT F	Circulating Time, min.	BHCT F	Temperature Gradient F/100 ft.	Mud Type
3-1	17,210	33.00	218.0				189.0	0.802	w
2-3	18,510	29.00	229.0				190.0	0.805	w
4-1	18,380	36.80	245.0				196.0	0.898	w
9-1	22,800	35.00	287.0				240.0	0.908	w
7-2	16,088	32.00	234.0				202.0	0.957	w
	17,882	25.00	258.0				207.0	0.995	w
3-3	22,225	55.00	307.0				265.0	1.021	w
113	12,258	38.50	206.0	17.0	181.0	354.00	158.0	1.028	w
79	12,029	27.50	204.0		168.0		149.0	1.031	w
16-2	14,000	36.00	227.3				200.0	1.050	w
	21,853	34.00	310.0				290.0	1.052	w
2-0	13,875	26.50	226.0				190.0	1.052	w
2-1	13,540	32.50	223.0				177.0	1.056	w
5-2	11,456	28.00	202.0				156.0	1.065	w
4-2	12,000	32.00	211.0				192.0	1.092	w
84	24,840	65.00	355.0	55.0	326.0	443.00	322.0	1.107	o
4-0	22,725	47.50	333.0				286.0	1.113	w
72	19,750	35.50	300.0	41.0	268.0	333.00	251.0	1.114	o
8-0	13,025	42.00	229.0				149.0	1.144	w
17-2	10,245	35.00	204.0				160.0	1.210	w
8-1	17,400	26.00	292.0				270.0	1.218	w
10-2	17,164	40.50	290.0				236.0	1.223	w
105	17,992	33.50	309.0	56.0	263.0	552.00	246.0	1.273	na
151	16,053	25.00	286.0	19.0	275.0		242.0	1.283	o
153	8,302	26.00	187.0	10.0	156.0	140.00	124.0	1.289	w
129	12,990	36.00	249.0	19.0	217.0	1,072.00	209.0	1.301	w
101	21,458	58.67	360.0	32.0	333.0	429.00	315.0	1.305	o
139	11,540	24.00	231.0	43.0	191.0	239.00	162.0	1.308	w
6	11,170	31.00	228.0	17.2	181.0	570.00	175.0	1.325	w
8-2	15,007	28.00	281.0				243.0	1.339	w

Table I-1—1974–84 Allmuds3 Subset—66 Records with Static Time Equal to or Greater than 24 Hours (Continued)

Well Number	Depth ft	Static Time hrs	BHST F	Time Required to Pump 1Workstring Volume, min.	BHSqT F	Circulating Time, min.	BHCT F	Temperature Gradient F/100 ft.	Mud Type
95	15,572	27.00	289.0	25.0	249.0	270.00	235.0	1.342	w
154	11,969	28.00	241.0	41.0	186.0	136.00	182.0	1.345	o
111	21,758	26.00	373.0	48.0	343.0	567.00	326.0	1.347	w
126	20,768	58.75	360.0	32.0	333.0	429.00	315.0	1.348	o
50	10,830	27.33	227.0	21.0	203.0	240.00	189.0	1.357	w
1-3	19,370	76.00	343.0				290.0	1.358	w
167	18,929	74.00	345.0	57.0	316.0		289.0	1.400	o
104	11,630	35.00	245.0	22.0	223.0	180.00	206.0	1.419	w
143	12,437	24.00	257.0	19.0	208.0		187.0	1.423	o
135	10,250	28.00	228.0	31.0		316.00	158.0	1.444	w
58	7,750	28.00	195.0	14.0	182.0	375.00	152.0	1.484	w
2-2	15,375	34.50	309.0				217.0	1.489	w
147	14,365	48.00	294.0	56.0	247.0	335.00	218.0	1.490	o
80	16,718	40.60	330.0	52.0	265.0	2,010.00	265.0	1.495	o
112	17,245	24.00	340.0	194.0	299.0	1,026.00	291.0	1.508	o
118	18,716	48.00	369.0	47.0	357.0	303.00	346.0	1.544	o
3-0	1,1440	32.50	262.0				209.0	1.591	w
146	18,885	138.00	388.0	33.0	346.0		309.0	1.631	o
120	11,816	31.00	275.0	38.0	249.0	234.00	233.0	1.650	o
145	18,649	24.00	390.0	55.0	332.0		314.0	1.662	w
141	11,445	24.00	271.0	46.0	235.0	240.00	200.0	1.669	o
6-2	12,515	25.00	289.0				235.0	1.670	w
150	19,729	25.50	416.0	45.0	388.0		376.0	1.703	o
43	11,315	30.00	273.0	21.0	244.0	330.00	188.0	1.706	o
85	11,250	34.50	276.0	19.0	246.0	120.00	227.0	1.742	o
	16,035	68.00	364.0			240.00	285.0	1.771	o
102	10,512	36.00	271.0	20.0	237.0	210.00	217.0	1.817	o
78	12,364	35.50	305.0	19.0	277.0	300.00	245.0	1.822	o
61	12,400	30.00	307.0	26.0	269.0	240.00	253.0	1.831	o
34	13,094	35.00	320.0	27.0	261.0	490.00	218.0	1.833	o
26	15,774	29.00	376.0	33.0	340.0	303.00	326.0	1.877	o
	12,400	44.50	321.0			270.00	231.0	1.944	o
106	13,100	36.00	338.0	22.0	275.0	360.00	225.0	1.969	o
152	15,219	35.50	381.0	39.0	348.0	300.00	331.0	1.978	o
164	12,951	44.50	342.0	21.0	274.0	280.00	229.0	2.023	o
110	18,205	48.00	457.0	38.0	402.0	180.00	383.0	2.071	o

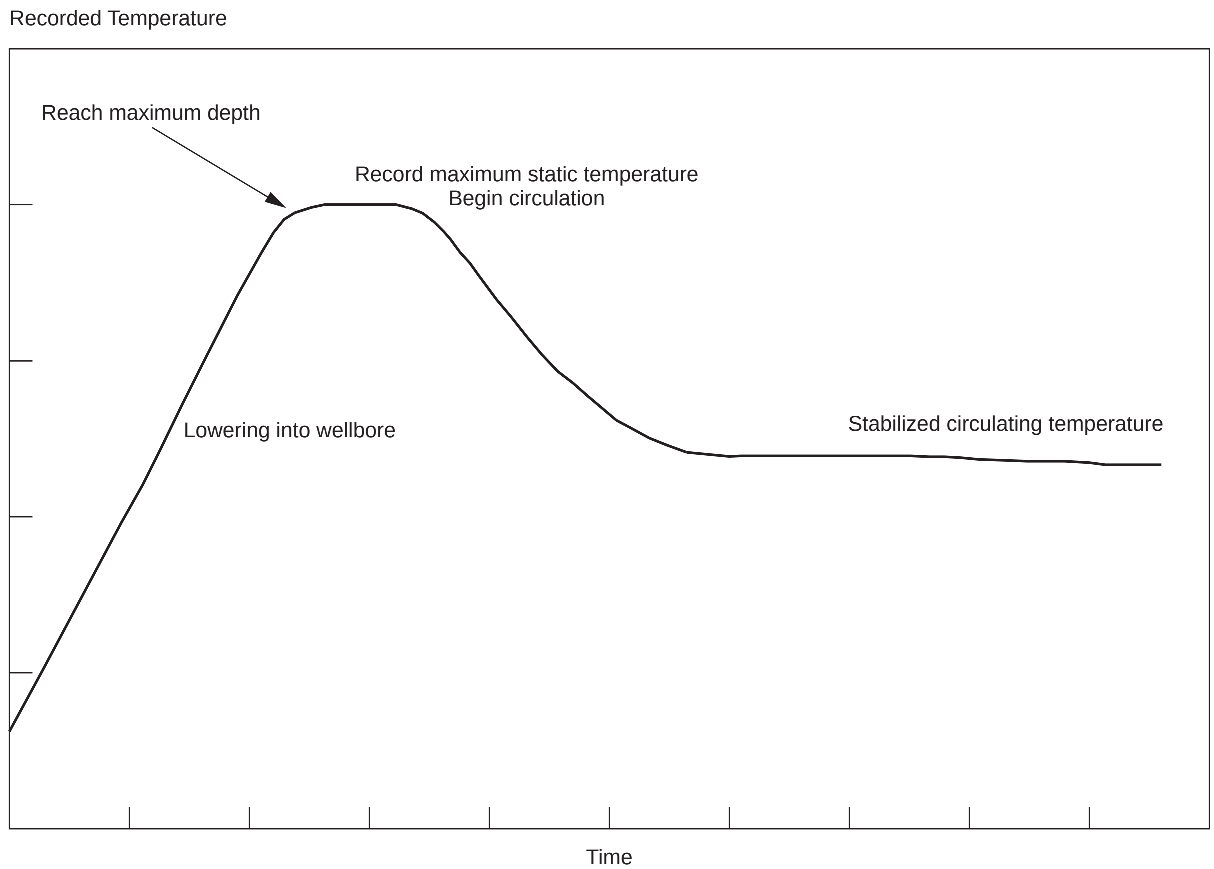

Figure 1—Illustration of Temperature Profile Recorded by the Temperature Measuring Devices

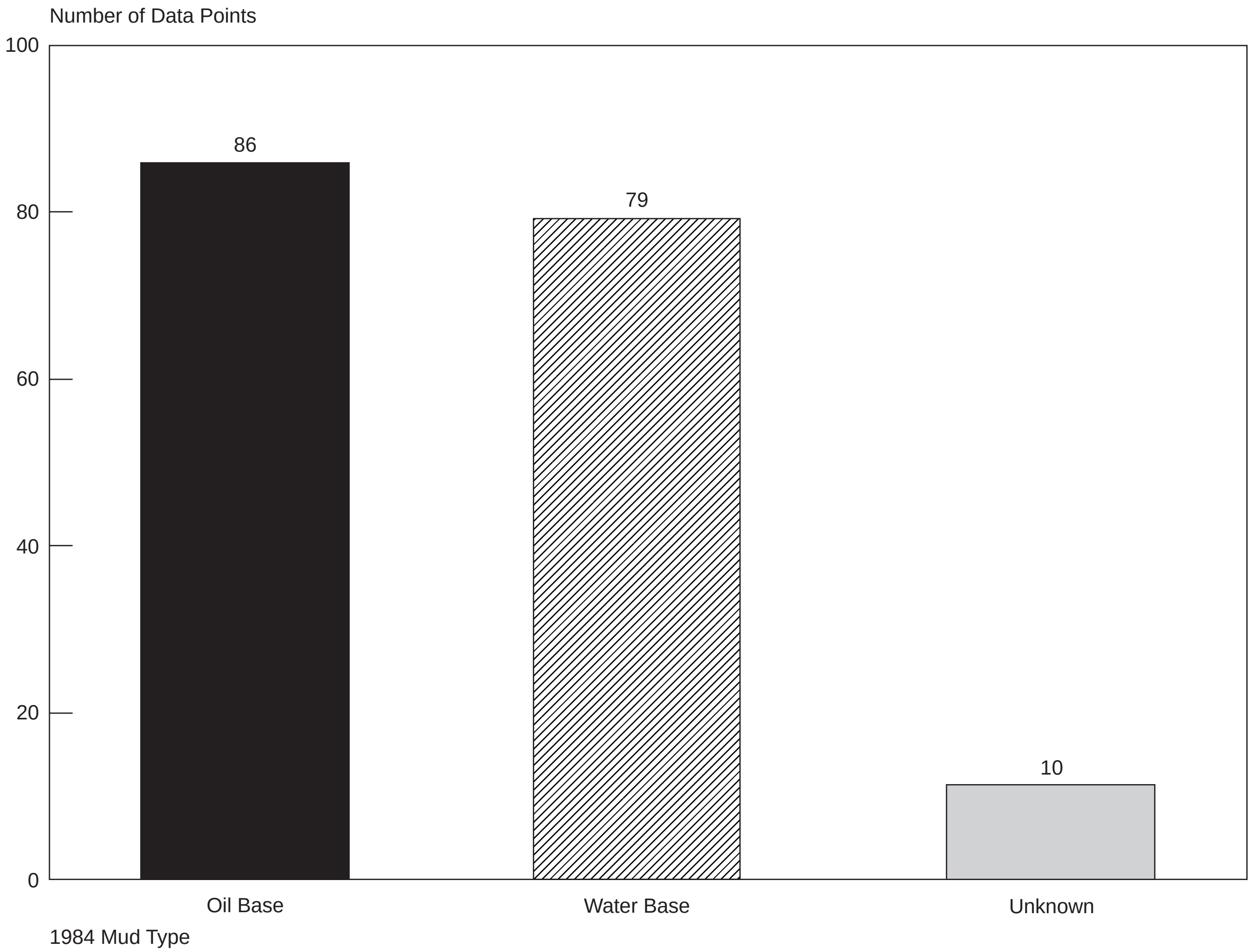

Figure 2—Drilling Fluid Type Distribution for the 1984 Data Set

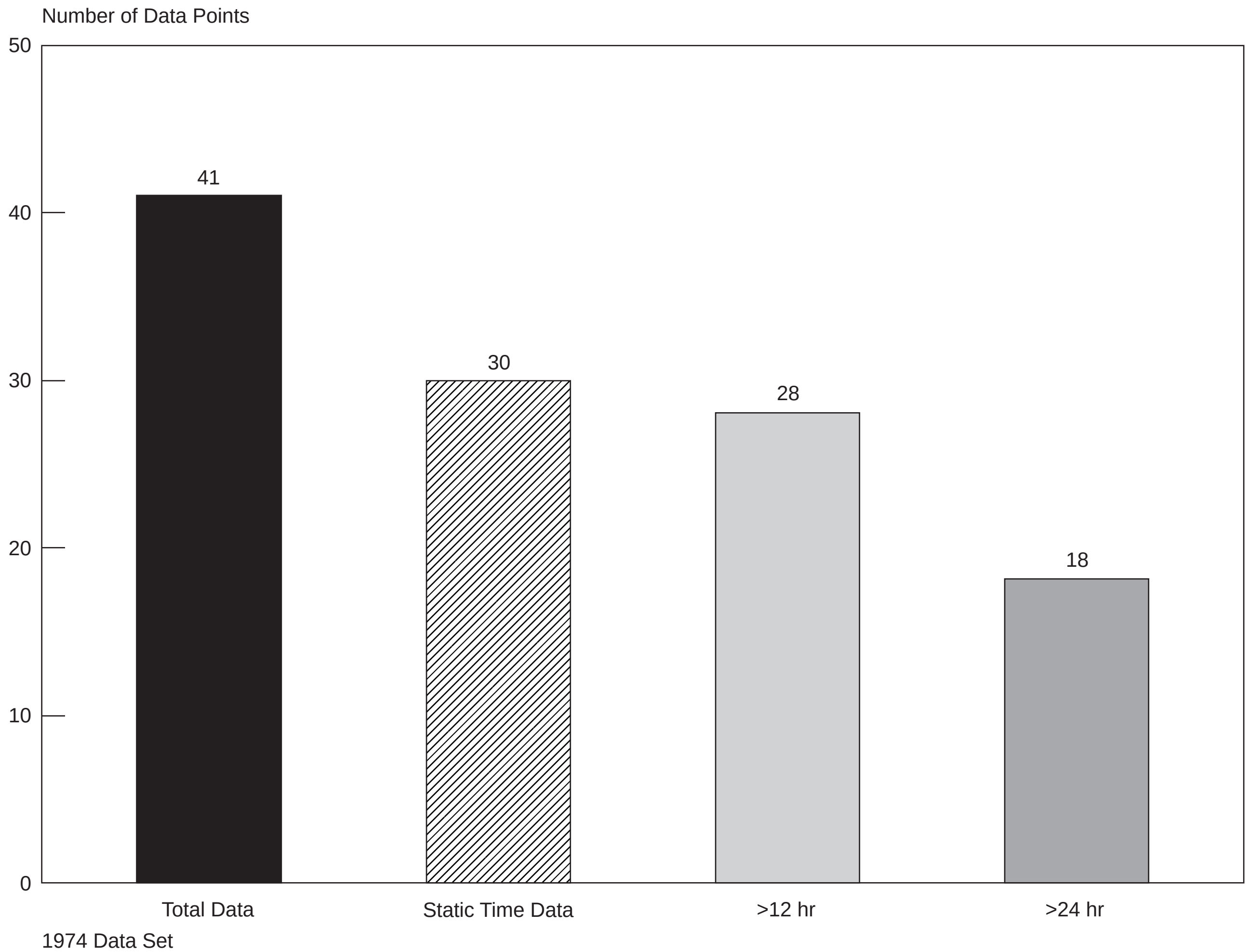

Figure 3—Static Time Distribution for Water Base Muds in the 1974 Data Set

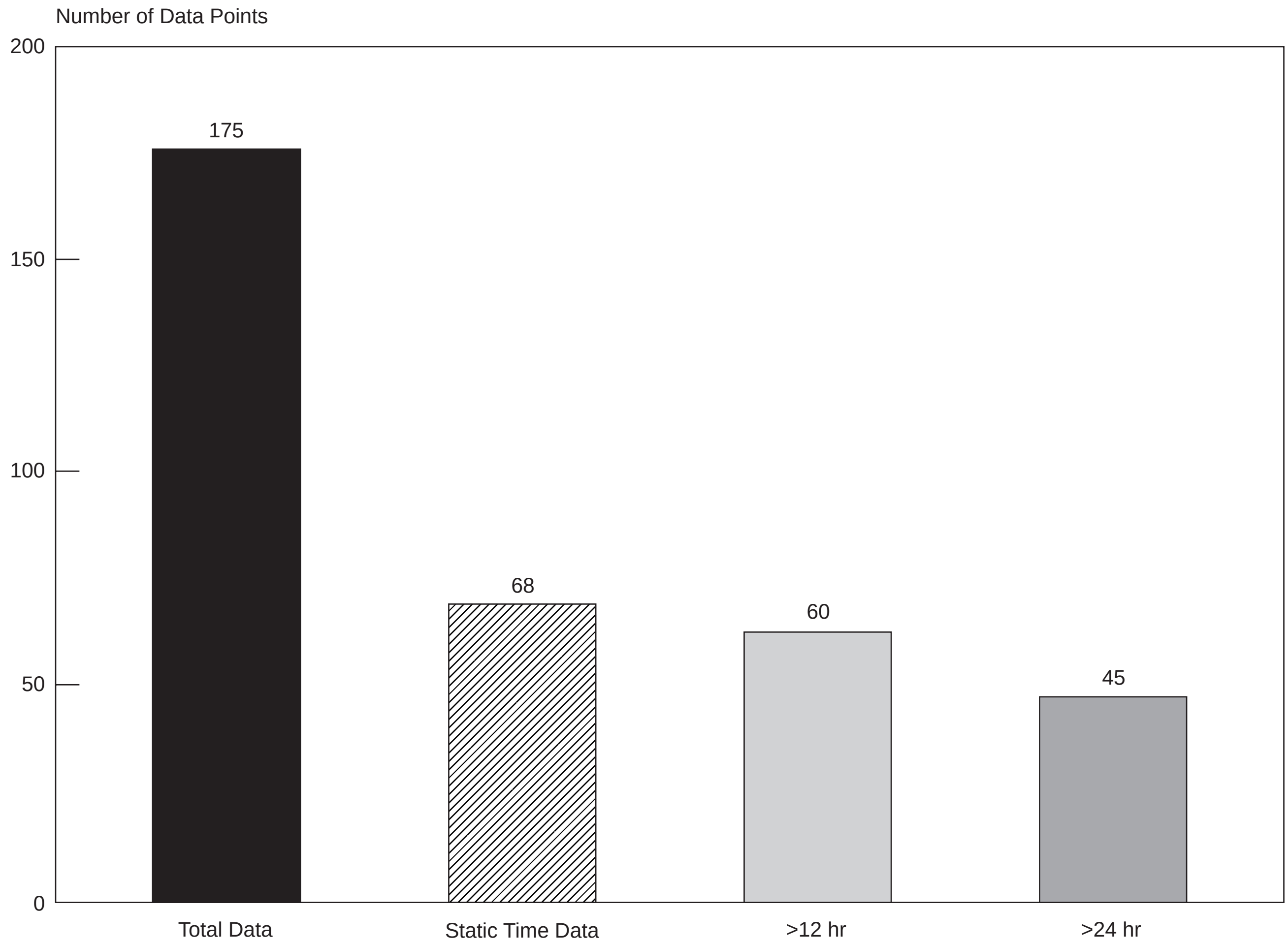

Figure 4—Static Time Distribution for All Data in the 1984 Data Set

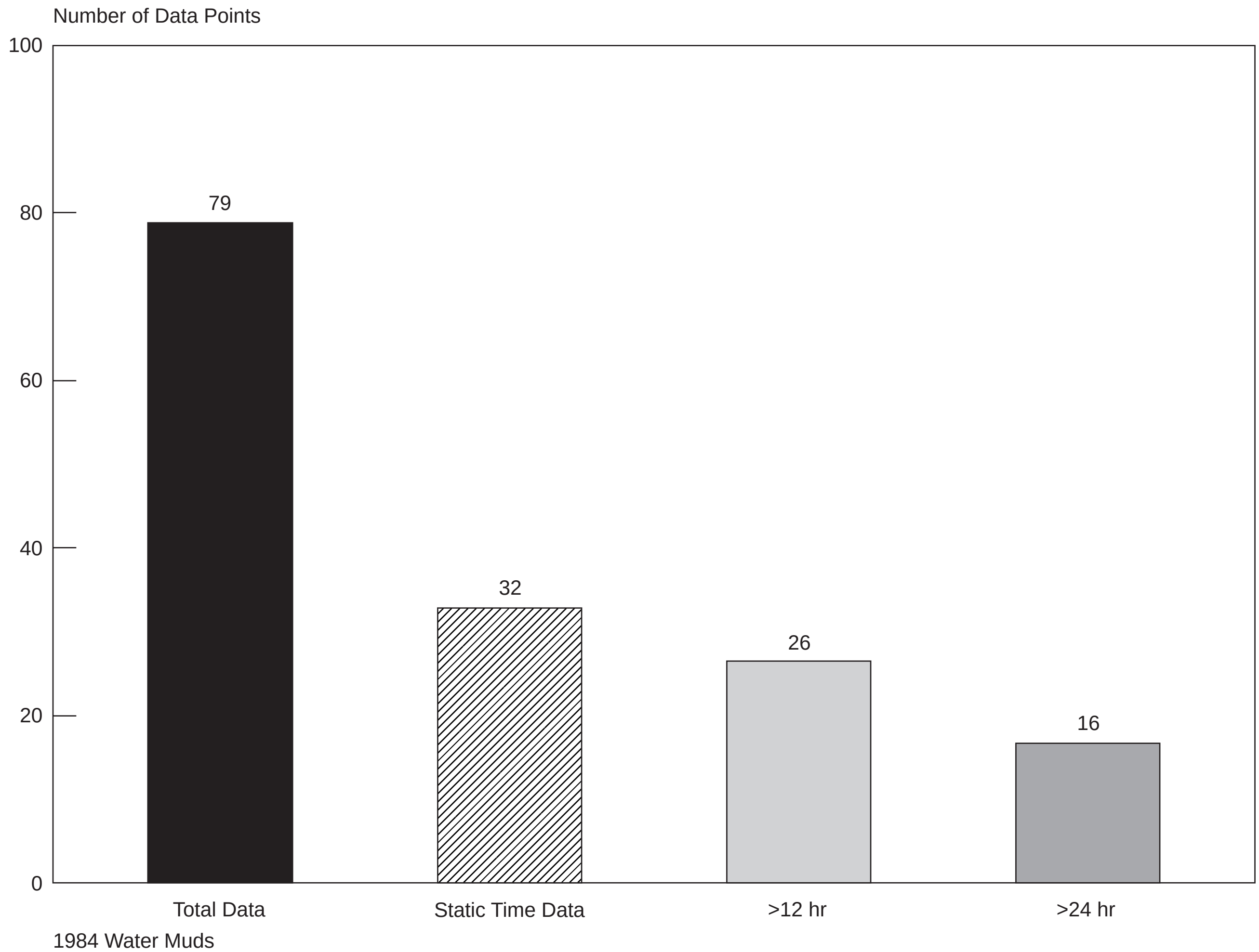

Figure 5—Static Time Distribution for Water Base Muds in the 1984 Data Set

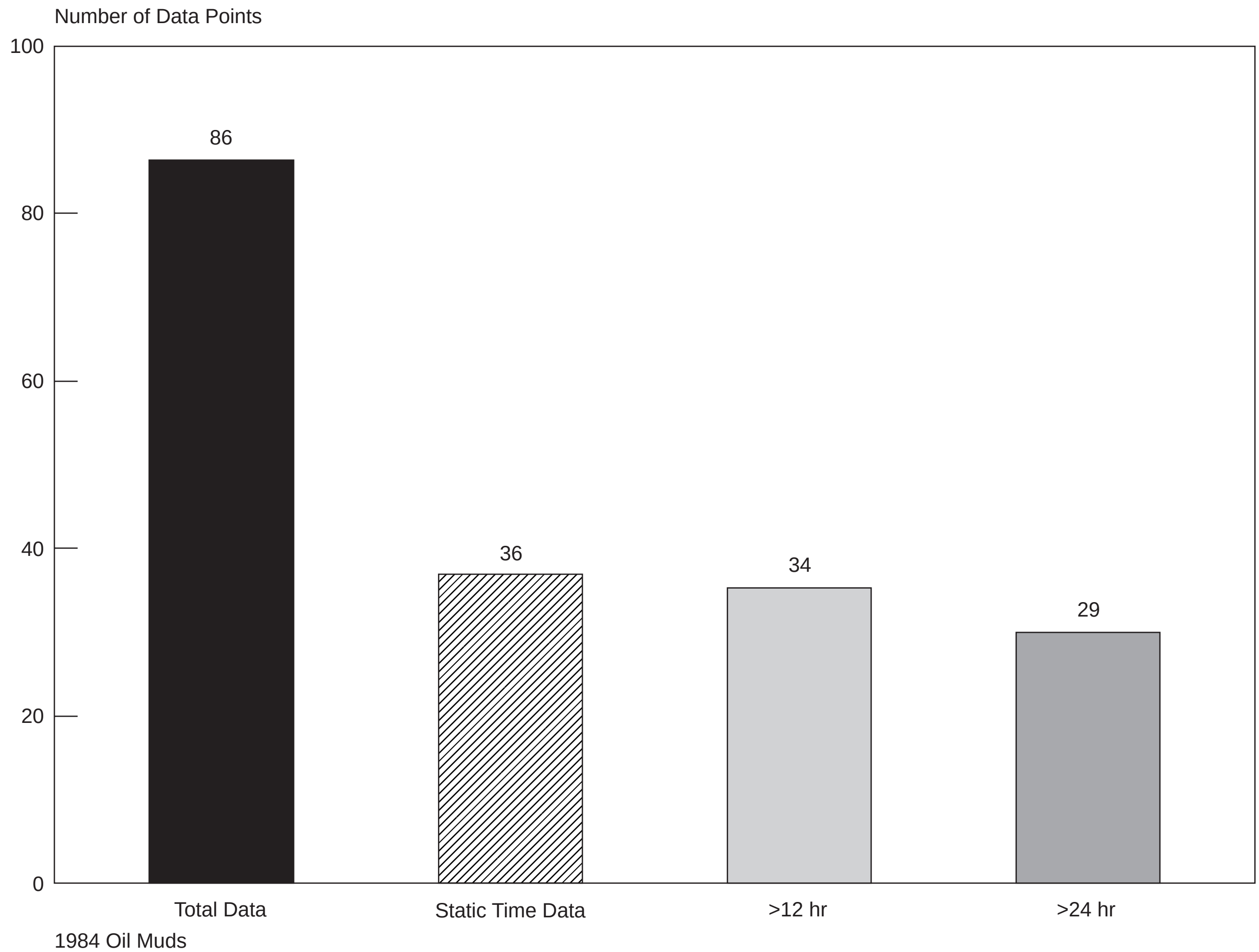

Figure 6—Static Time Distribution for Oil Base Muds in the 1984 Data Set

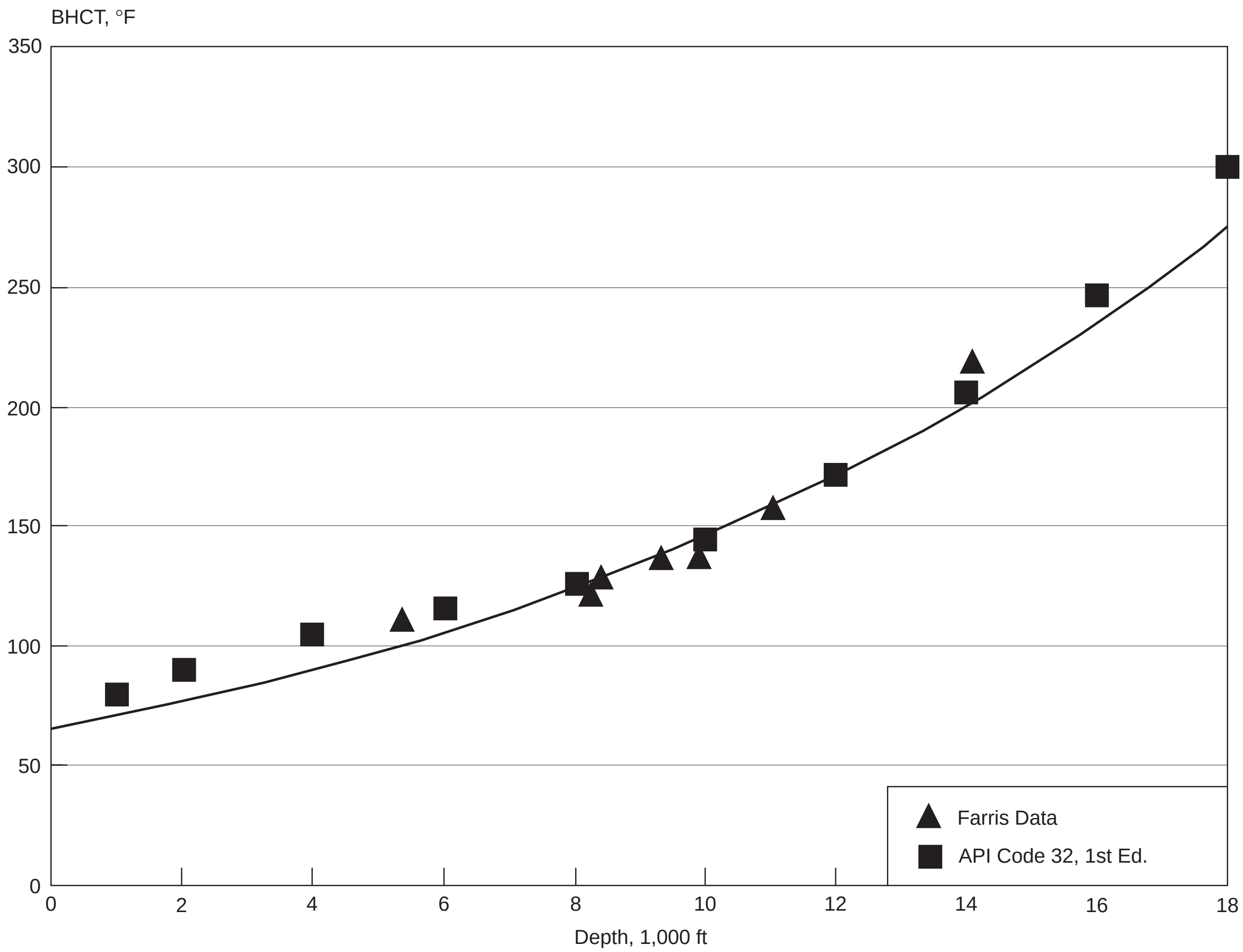

Figure 7—Comparison of API Code 32 Casing-Cementing Temperatures with Predicted Temperatures from a Correlation Developed from the 1984 Data Set

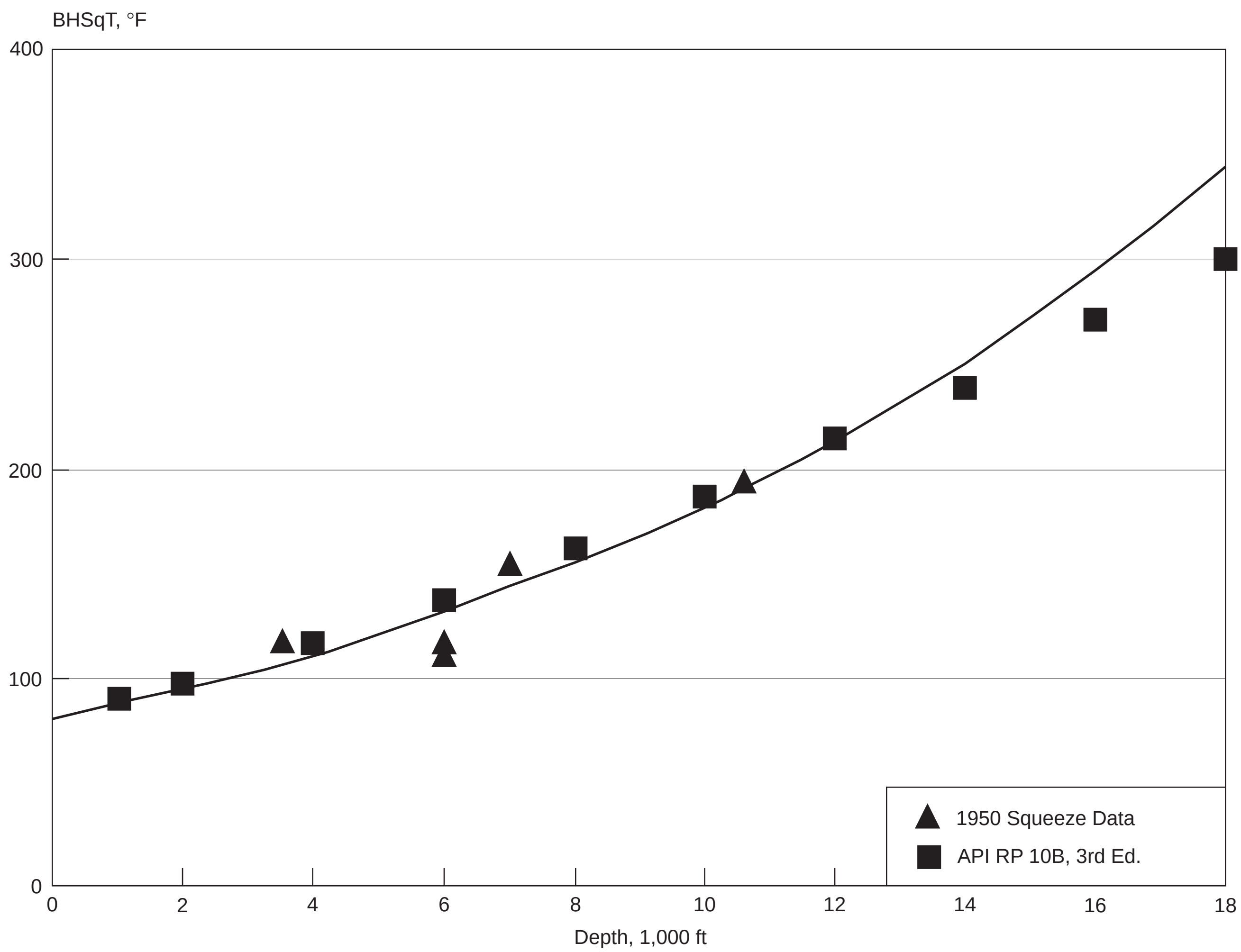

Figure 8—Comparison of API RP 10B Squeeze-Cementing Temperatures with Predicted Temperatures from a Correlation Developed from the 1953 Squeeze Data Set

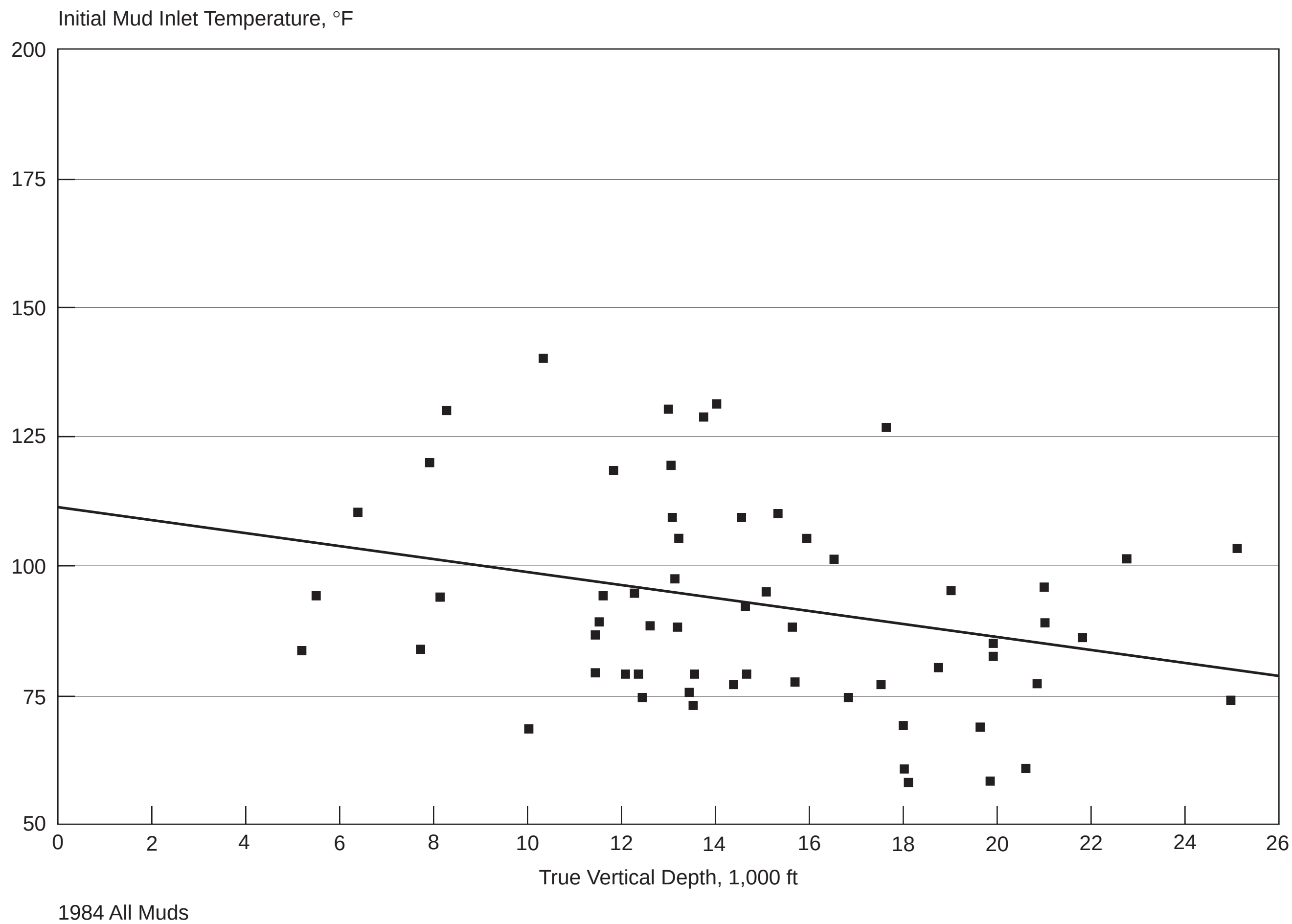

Figure 9—Plot of Initial Mud Inlet Temperatures
versus Depth for All Mud Types in the 1984 Data Set

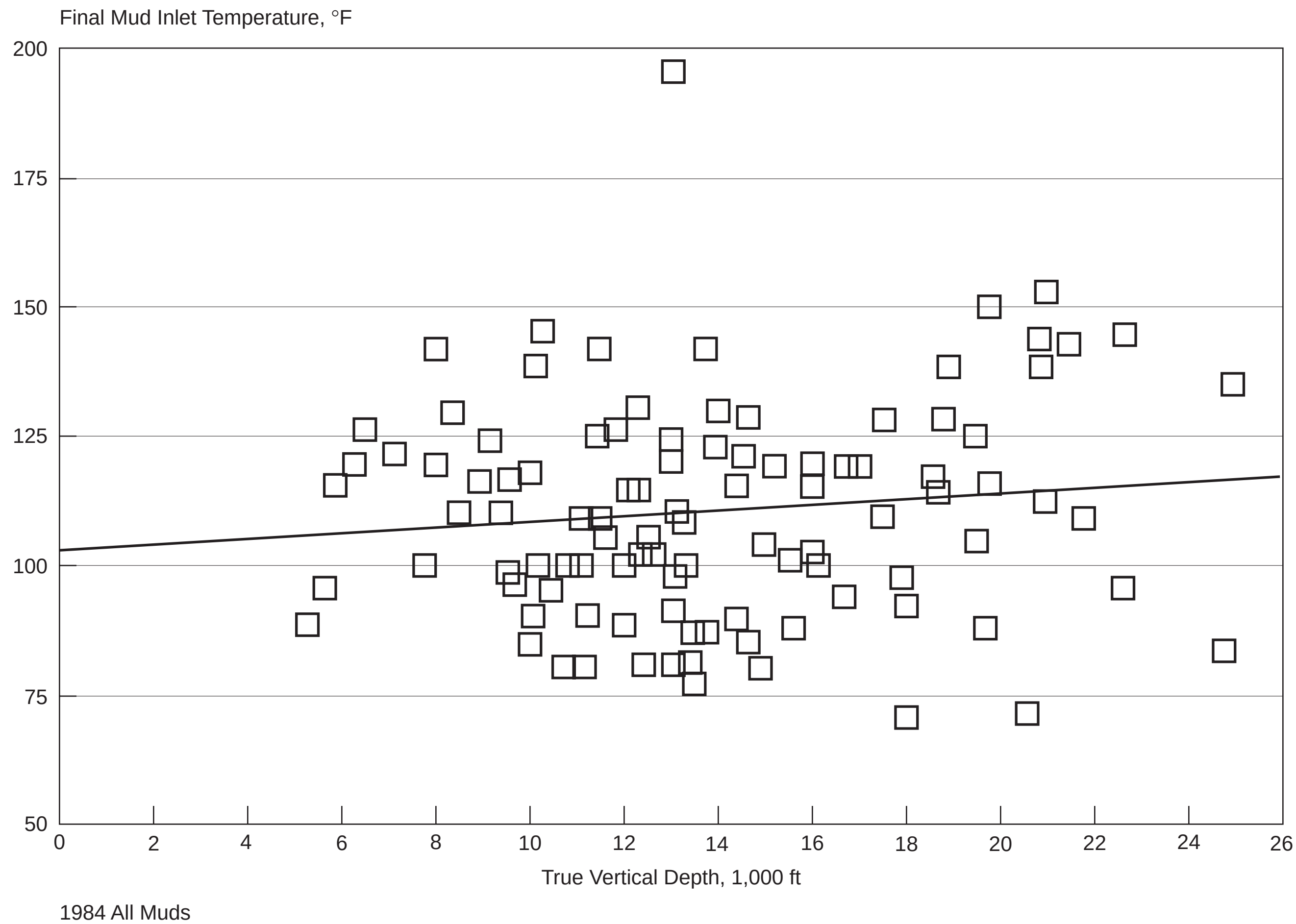

Figure 10—Plot of Final Mud Inlet Temperatures versus Depth for All Mud Types in the 1984 Data Set

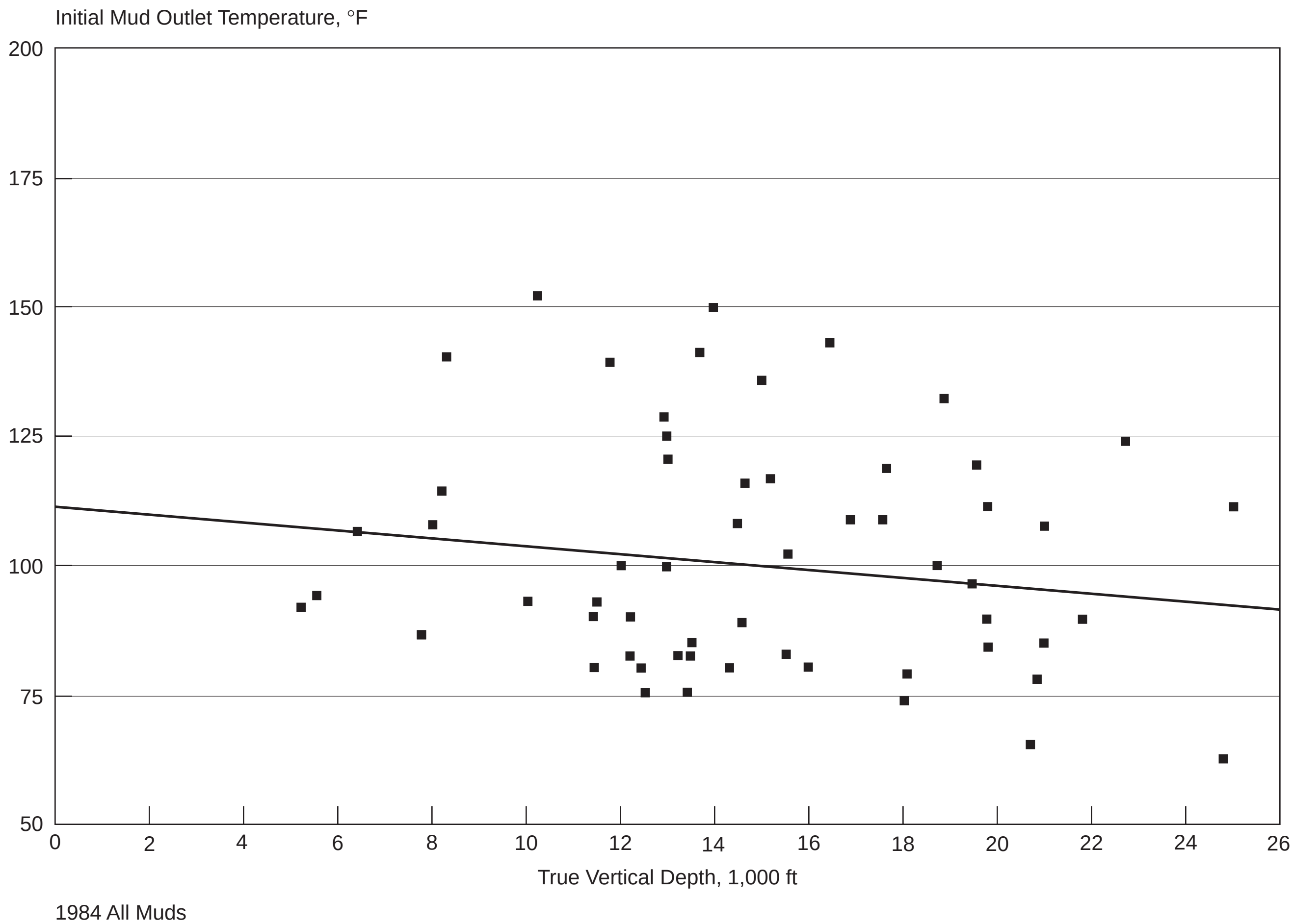

Figure 11—Plot of Initial Mud Outlet Temperatures versus Depth for All Mud Types in the 1984 Data Set

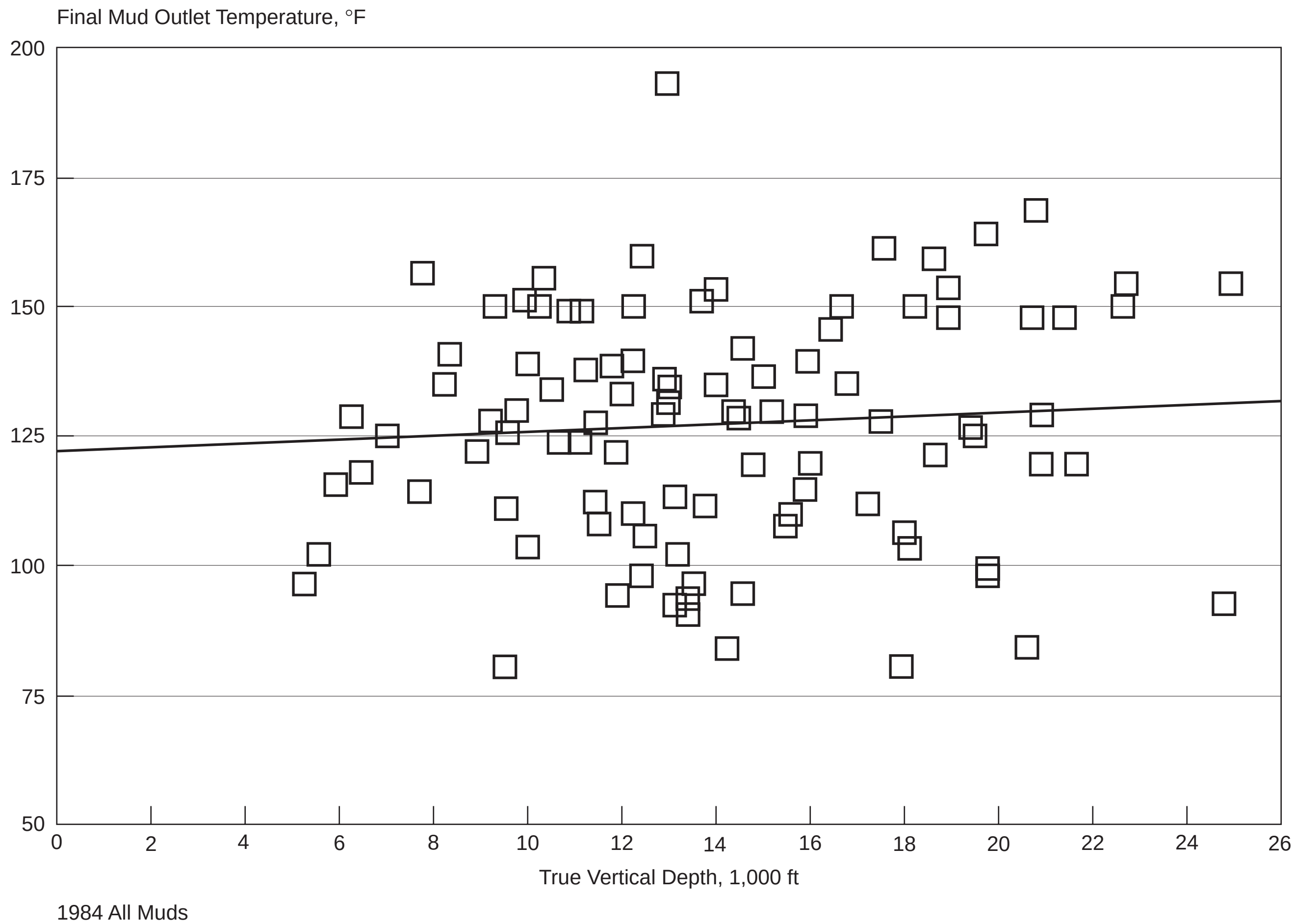

Figure 12—Plot of Final Mud Outlet Temperatures versus Depth for All Mud Types in the 1984 Data Set

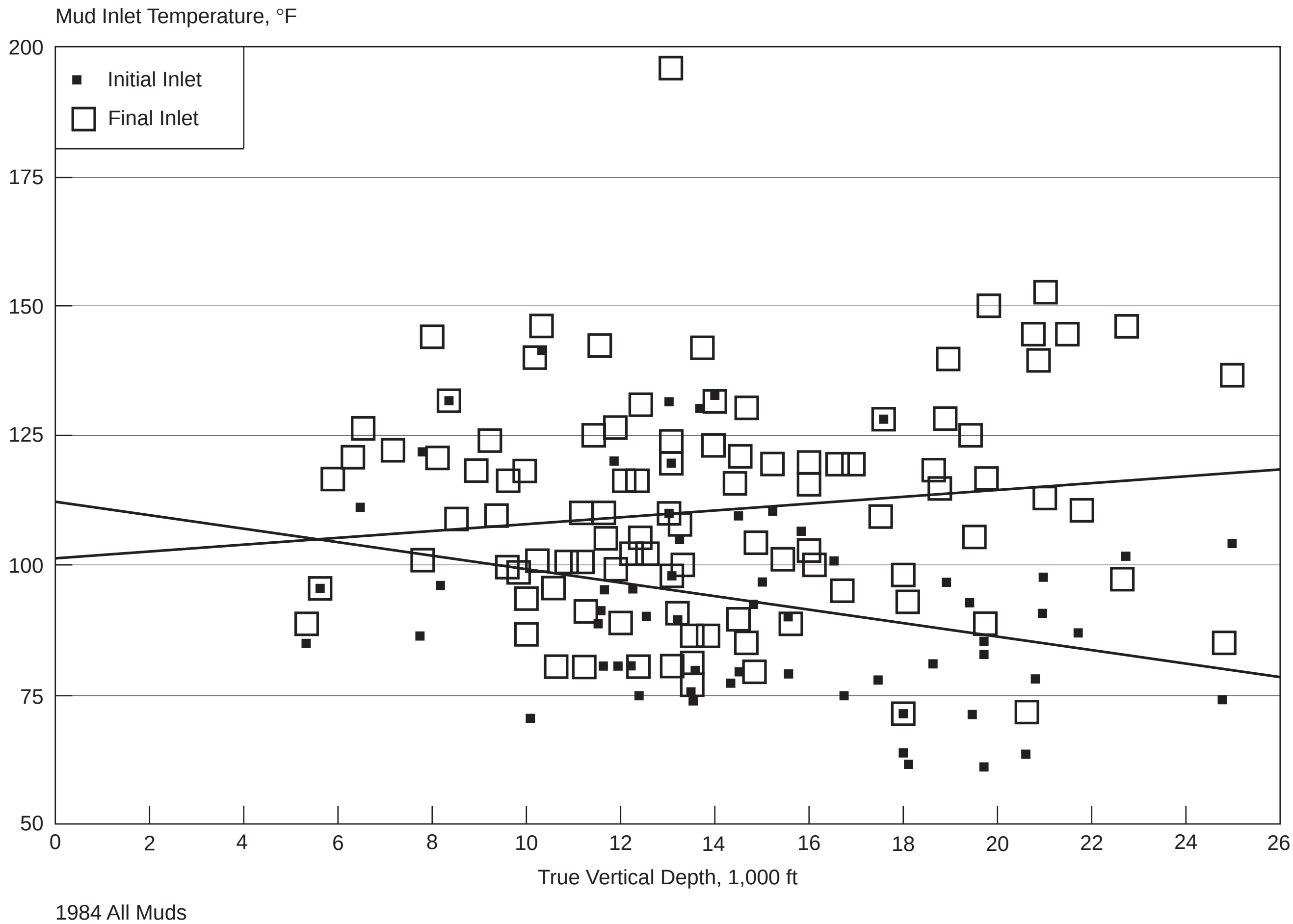

Figure 13—Plot of Initial and Final Mud Inlet Temperatures versus Depth for All Mud Types in the 1984 Data Set

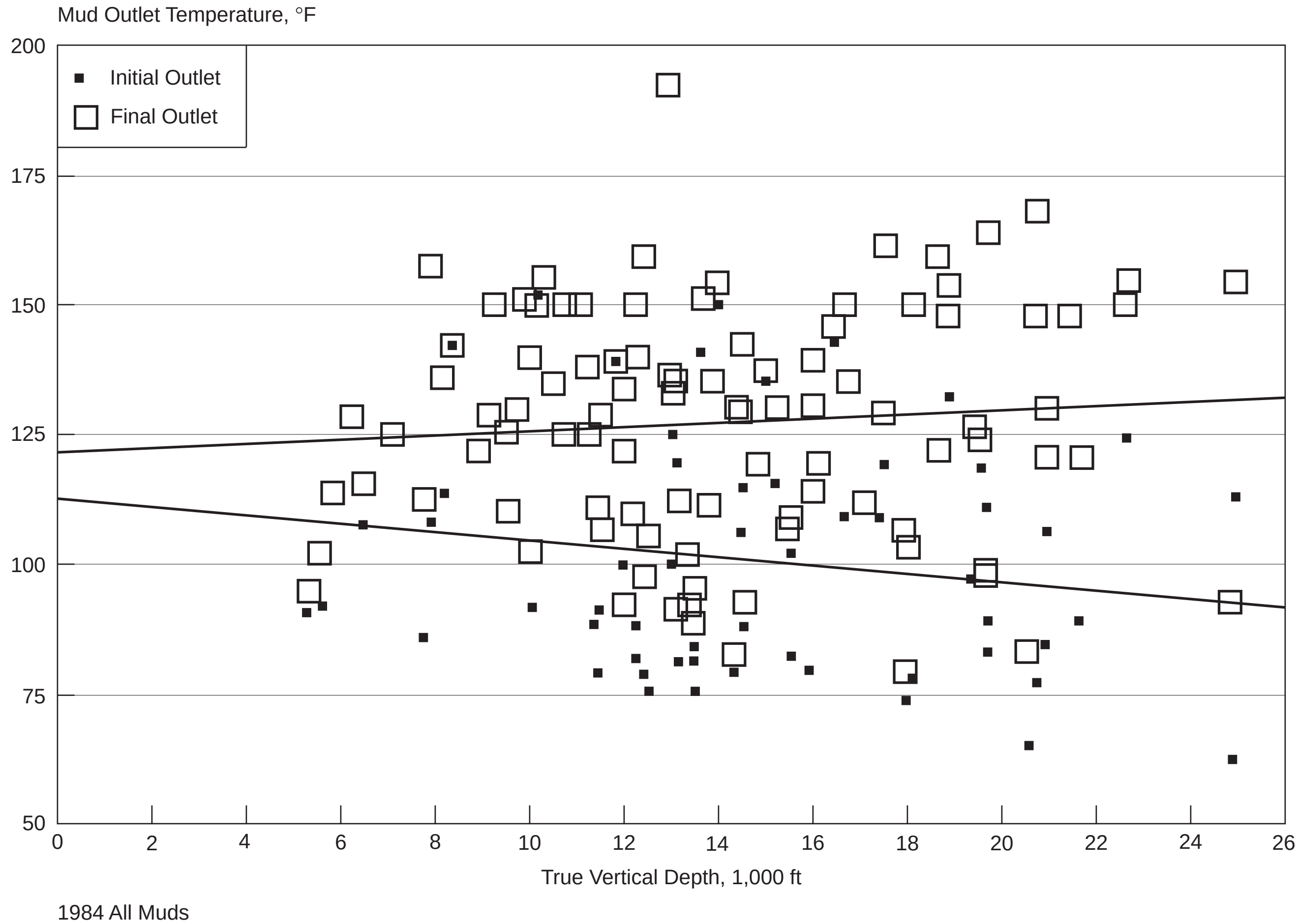

Figure 14—Plot of Initial and Final Mud Outlet Temperatures versus Depth for All Mud Types in the 1984 Data Set

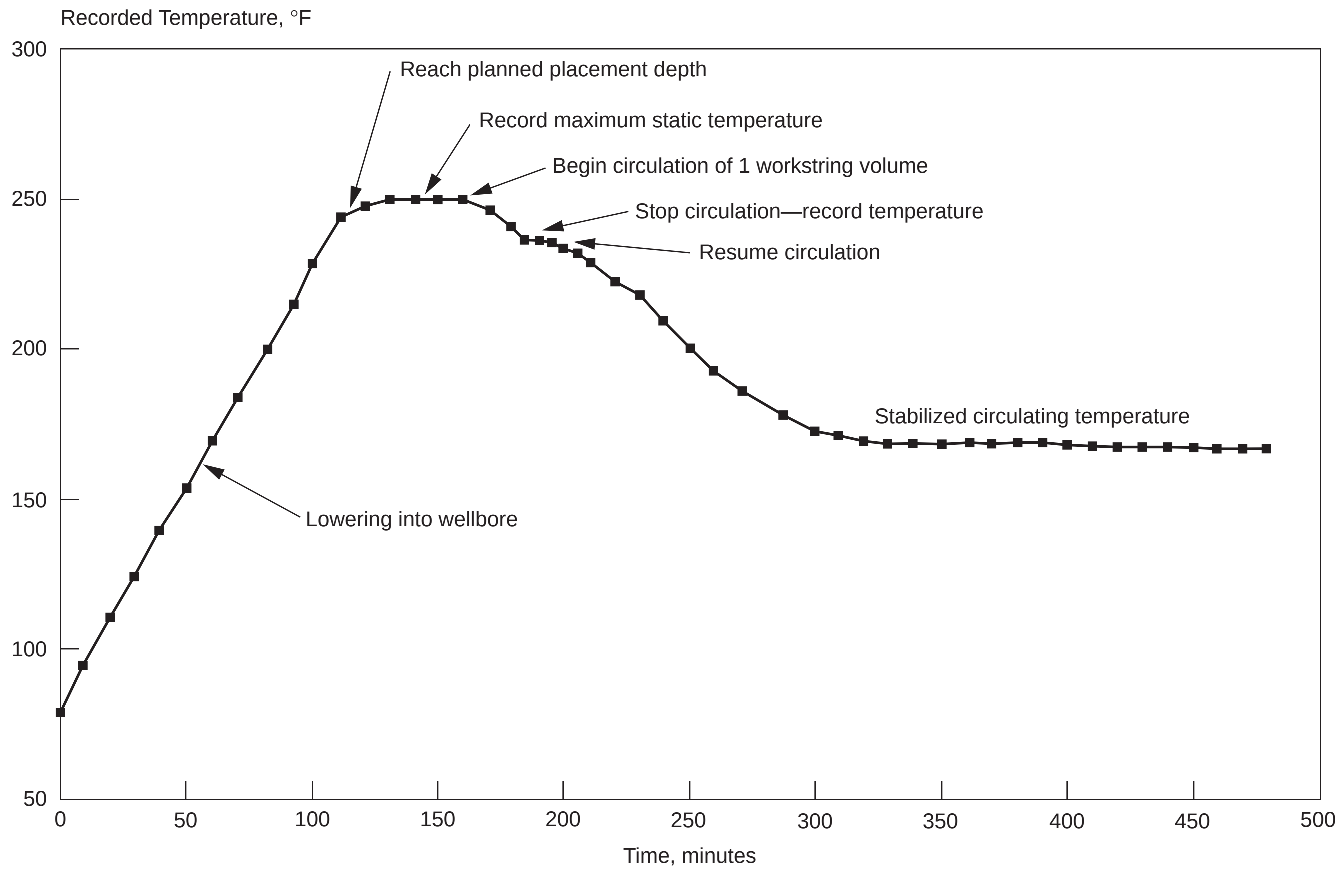

Figure 15—Illustration of Temperature Profile Recorded by the Temperature Measuring Device Showing How Squeeze Temperature Information was Collected in the 1984 Data Set

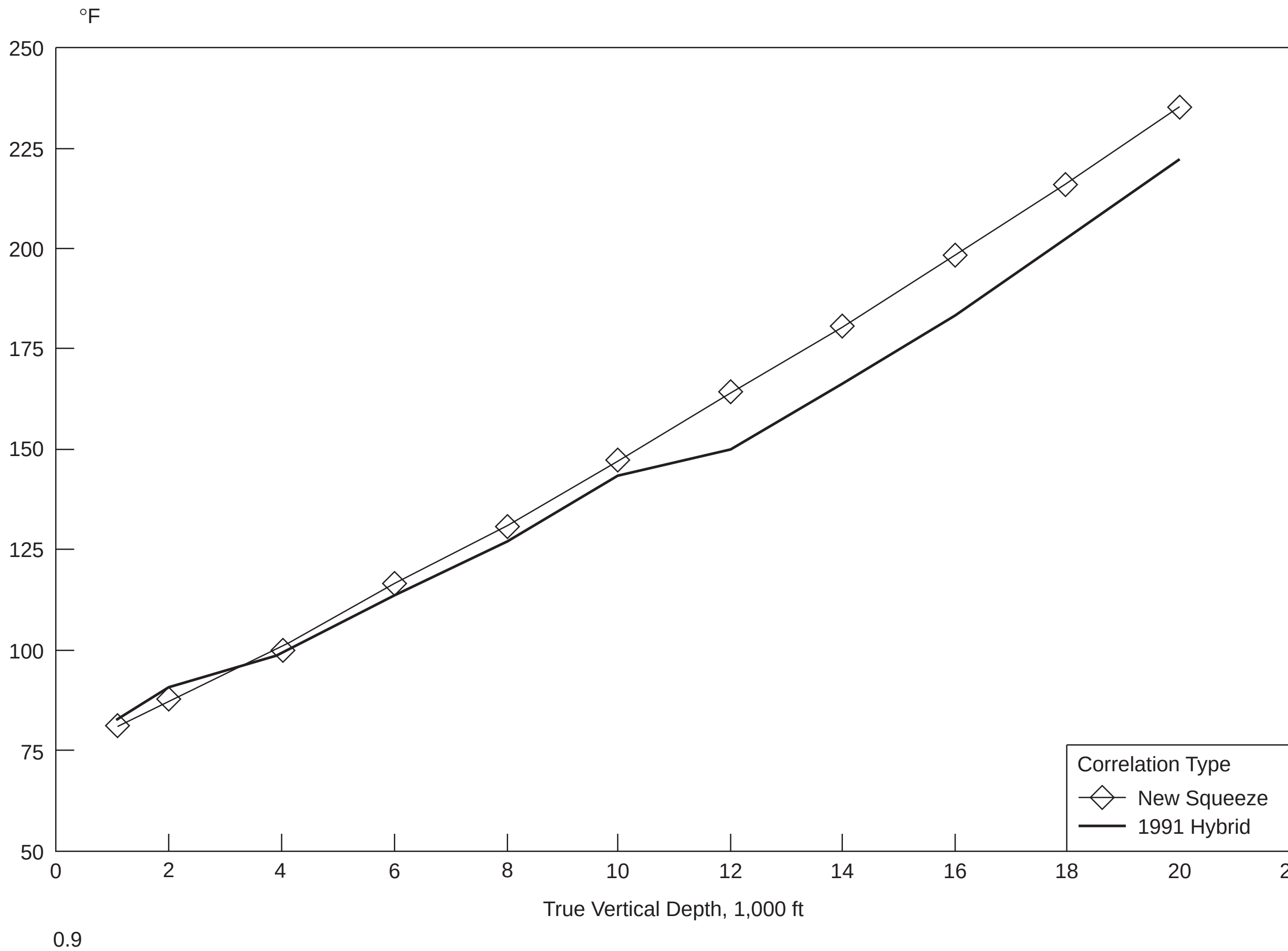

Figure 16—Comparison of Casing and Squeeze Temperatures with Depth for Proposed Updated Temperature Schedules—0.9°F/100 ft Temperature Gradient

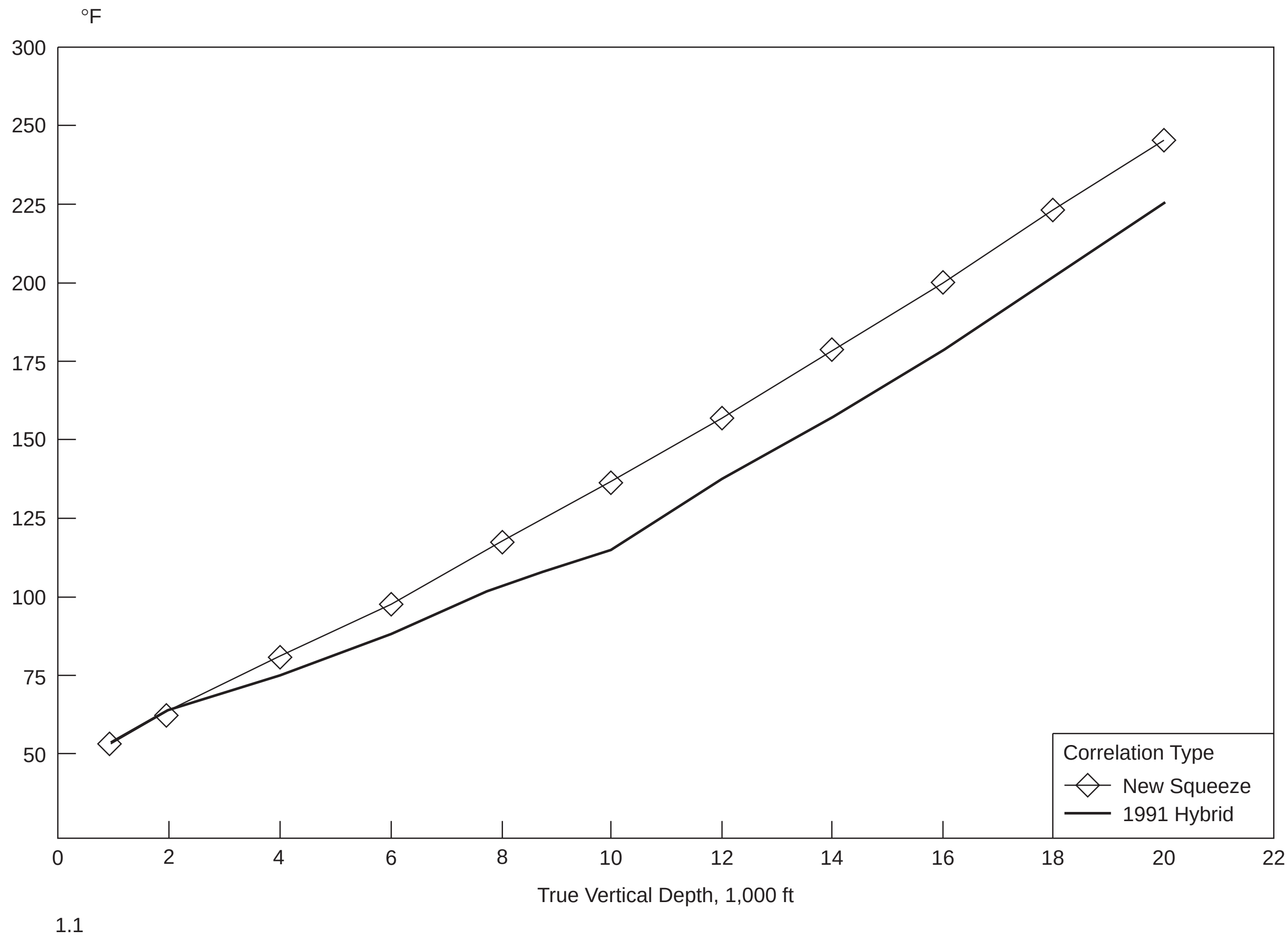

Figure 17—Comparison of Casing and Squeeze Temperatures with Depth for Proposed Updated Temperature Schedules—1.1°F/100 ft Temperature Gradient

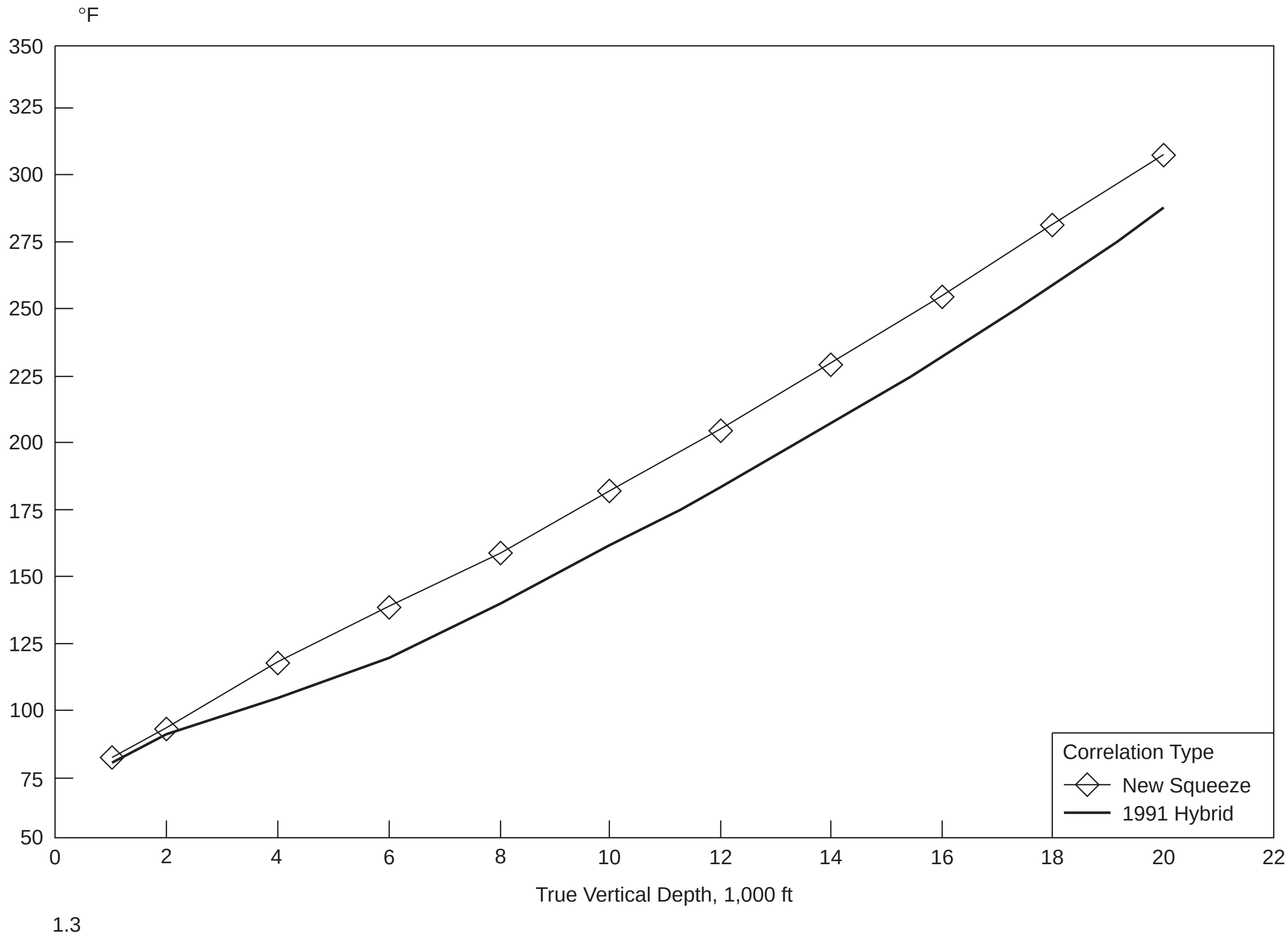

Figure 18—Comparison of Casing and Squeeze Temperatures with Depth for Proposed Updated Temperature Schedules—1.3°F/100 ft Temperature Gradient

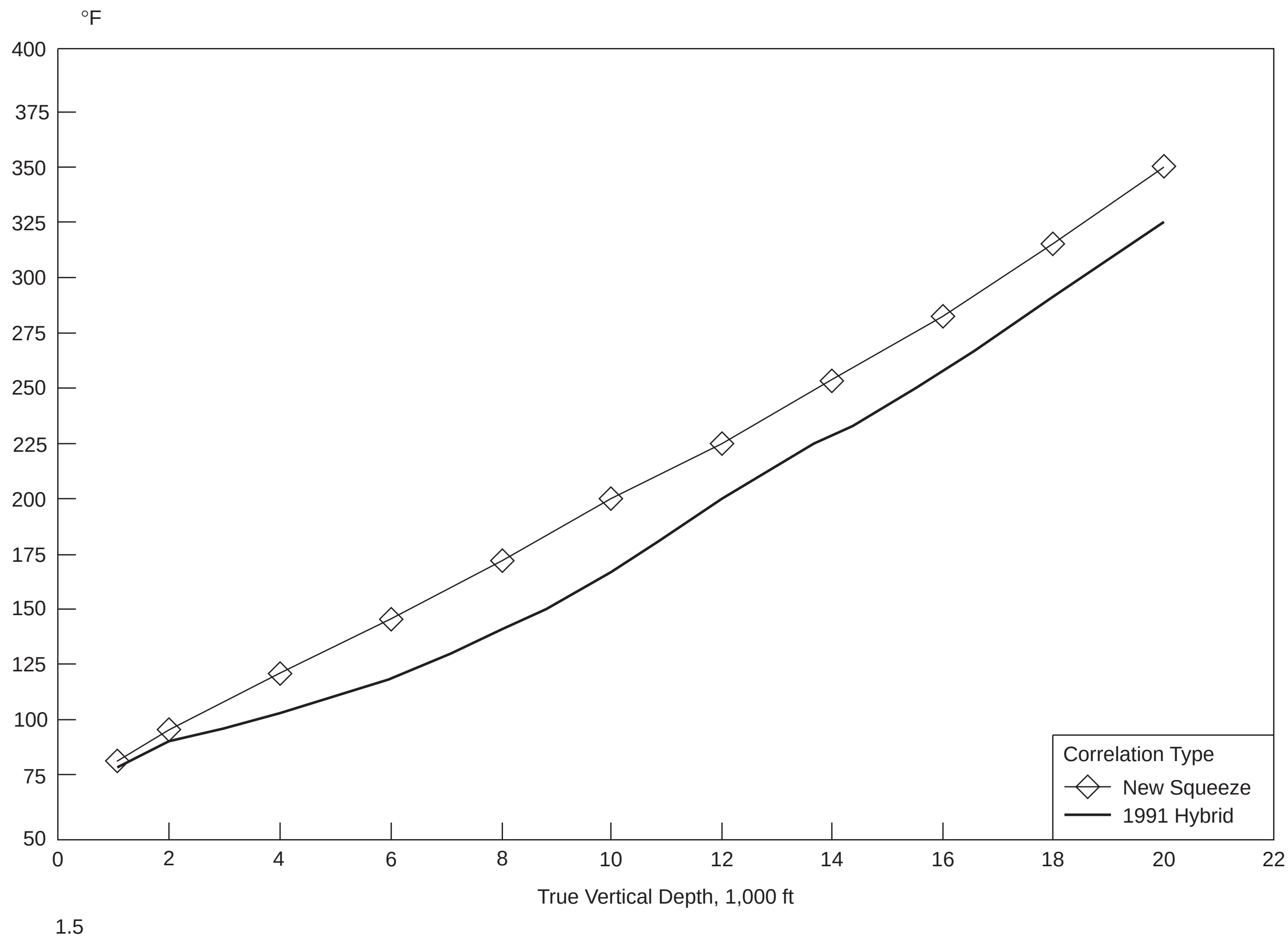

Figure 19—Comparison of Casing and Squeeze Temperatures with Depth for Proposed Updated Temperature Schedules—1.5°F/100 ft Temperature Gradient

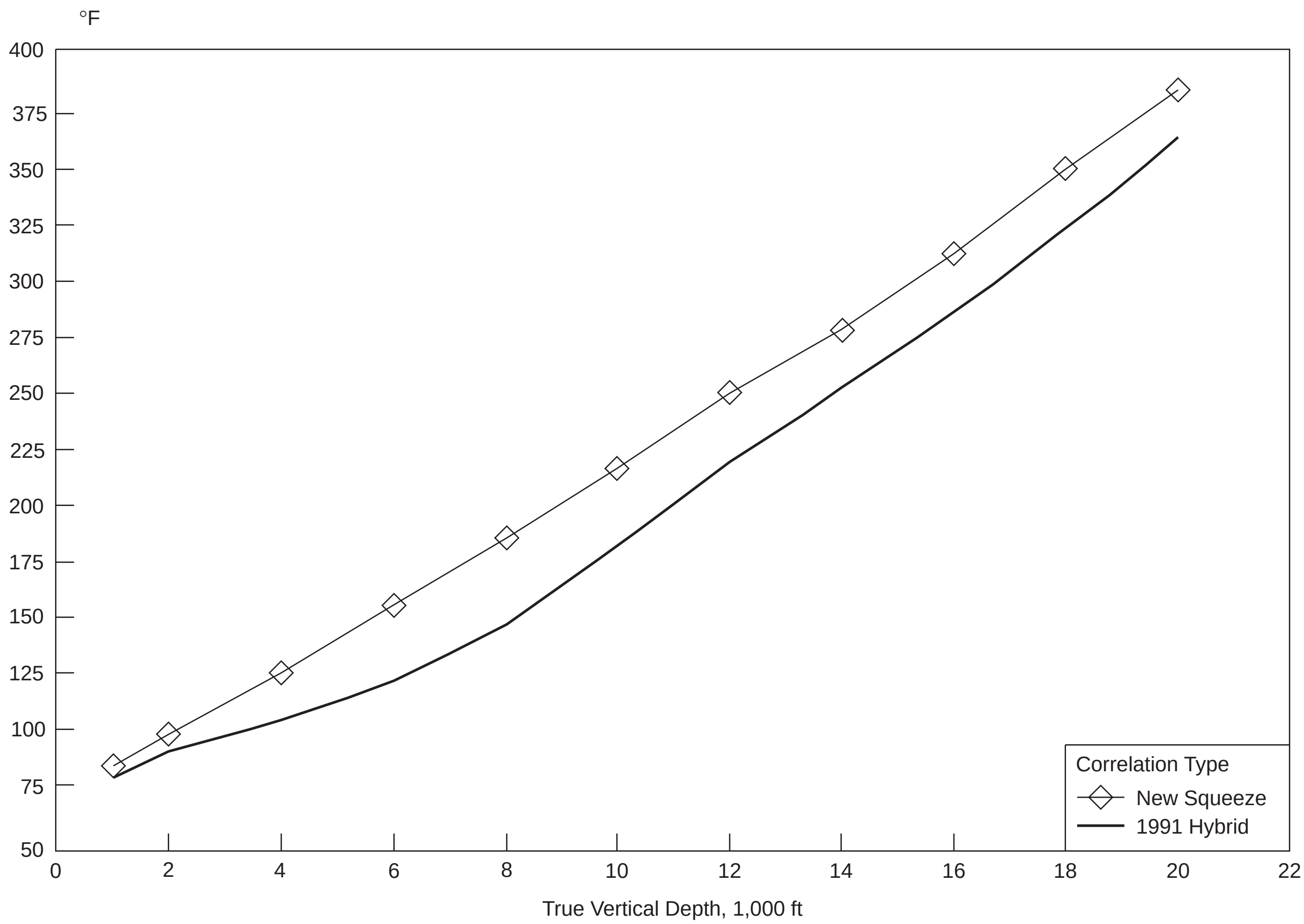

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Figure 20—Comparison of Casing and Squeeze Temperatures with Depth for Proposed Updated Temperature Schedules—1.7°F/100 ft Temperature Gradient

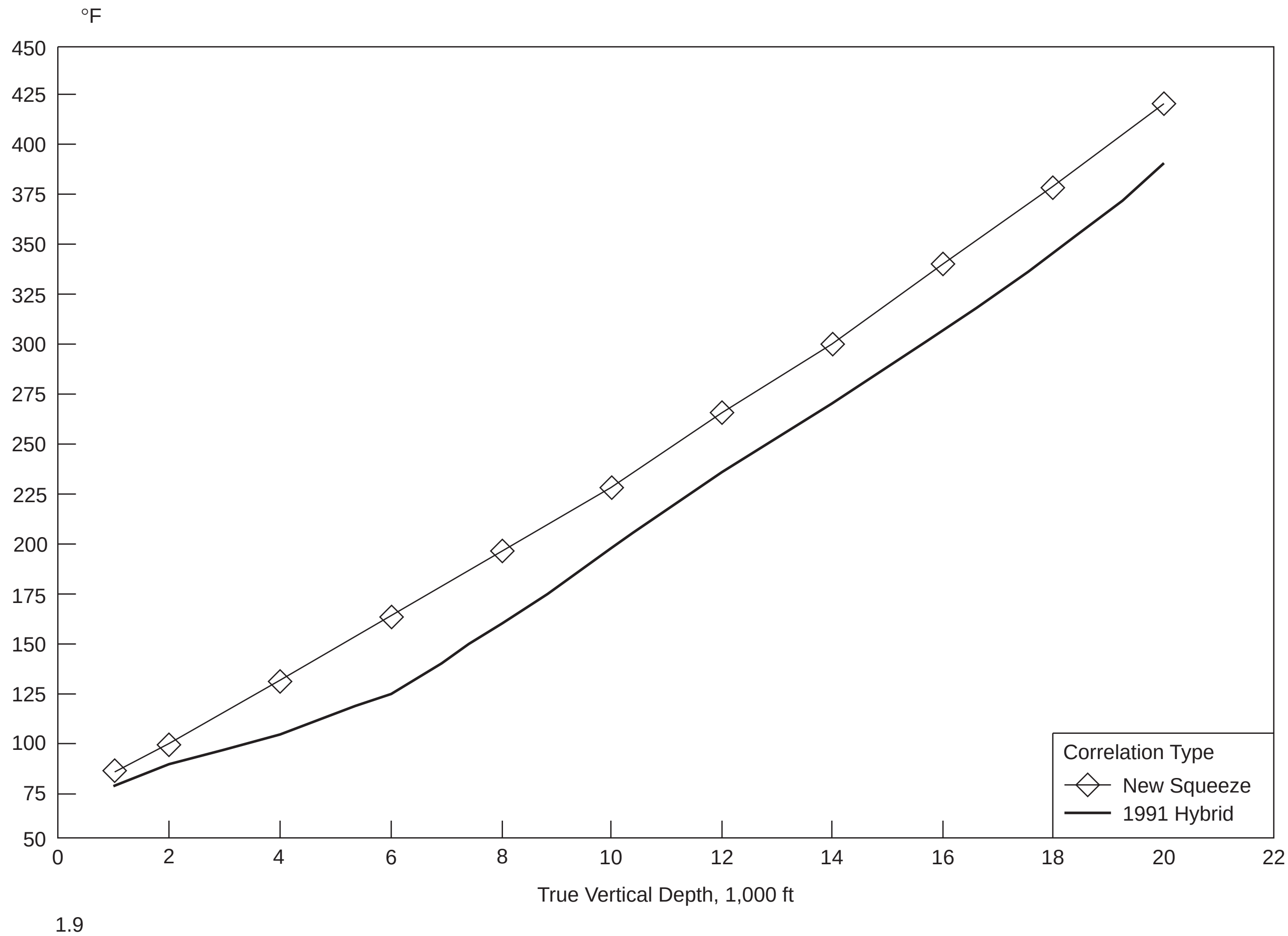

Figure 21—Comparison of Casing and Squeeze Temperatures with Depth for Proposed Updated Temperature Schedules—1.9°F/100 ft Temperature Gradient

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