USING AutoCAD® FOR INJECTION PROFILE ANALYSIS AND WATERFLOOD SURVEILLANCE

James S. McLaughlin
Cardinal Surveys Company

ABSTRACT

This paper discusses the use of AutoCAD, a popular PC CAD (Computer Aided Design/Drafting) application package, for calculation and analysis of water flood injection profile data. By heavily utilizing the customizing capability of the AutoCAD program, calculational accuracy and repeatability are enhanced. Additionally, the well log analyst is able to more readily verify and validate assumptions during the interactive data analysis phase.

The theory and application of profile analysis will be discussed: included are example calculations. Additionally, AutoCAD customizing techniques and programming examples will be discussed. Finally, the automated use of AutoCAD to facilitate multiple well presentations (historical and intra field) will be presented.

AUTOCAD - SUMMARY OF FEATURES

What Is AutoCAD?

The AutoCAD design package is a general purpose Computer-Aided Design/Drafting (CAD) application for the computer. CAD applications are known for their speed and ease for drawing preparation and modification. AutoCAD brings this sophisticated technology to the desk top personal computer (PC) user. As the leading PC CAD application package, AutoCAD enjoys the largest installed base among all PC CAD applications.

How AutoCAD Is Used

AutoCAD is used in a wide variety of situations. Any drawing normally created by hand can be created by AutoCAD. Applications for which AutoCAD is being used include architectural and mechanical design, proposals and presentations, flow-charts, musical scores, art, and just about any other type of line drawing imaginable.

The AutoCAD Data Base

Since AutoCAD is vector based, entity data are preserved. For example, drawings can be created where dimensional values are true to scale. They may then be reduced to hard copy format in any convenient scale, while internally retaining actual dimensional integrity to a high degree of accuracy. This allows the information contained in the drawing file (the drawing database) to be accessed for scientific and technical analysis and reporting. AutoCAD provides several ways to access information in the drawing database.

Customizing AutoCAD

AutoCAD allows for extensive customizing. Third party and end user developed routines may be added to the AutoCAD environment in a seamless fashion, thereby providing a user friendly environment with power and flexibility. By adding to the basic package, AutoCAD can be transformed into a powerful and productive tool to meet any design objective. Manual design calculations and redundant tasks are thereby automated and stream lined.

AutoCAD can be customized in a variety of ways. Most modern PC applications support some sort of macro programming. These range from storing simple key-stroke sequences to robust programming languages. AutoCAD is no exception, and supports a range of options (Figure 1). Since the AutoCAD drawing session is most often augmented by either a mouse or digitizing tablet to facilitate user interaction and input, AutoCAD also supports extensive screen and tablet menu customizing.

AutoCAD command and key-stroke sequences may be stored and reused. In the drafting environment, these are known as Script Files. A script file may be created by a simple ASCII text editor, or may even be created by other programs. By using other programs to create the script file, important parameters may be varied to create custom results each time the script file is created and executed.

AutoCAD additionally provides an implementation of the LISP programming language embedded within the AutoCAD application. This is known as AutoLISP®, and allows users and developers to write macro programs and functions in a very powerful high level language that is well suited to graphics applications. Since AutoLISP is embedded, all data in the drawing database are conveniently available.

AutoCAD also provides a DOS (PC-DOS® or MS-DOS®) Shell. The shell command allows the user to execute various programs while remaining in the editing environment. The programs include normal DOS utility programs as well as custom applications. Information can be passed between AutoCAD and DOS shell programs in a variety of ways. Shell programs can also be launched in the form of command definitions that appear transparent to the user. Custom applications can be written in just about any programming language that is supported on PC platforms. Commercially available applications including word processors, databases and spreadsheet programs can be executed from AutoCAD's DOS shell as well.

The most recently added AutoCAD customizing feature is the option for linking third party and end user developed "C" routines to the AutoCAD program kernel. In essence, this permits additional commands that are immediately available (versus DOS Shell) and that execute rapidly (versus AutoLISP, which is an interpretive language).

Hardware Platforms For AutoCAD Use

CAD drafting platforms are normally configured for a specific use. For tracer profile logs, the preferred platform falls into the high end of hardware configurations because of the amount of well log data (and resulting file sizes) and the required hard copy quality. The substantial man-power requirements for drafting of well logs also dictate high quality, ergonomically designed drafting stations.

To achieve the necessary speed and power for well log drafting, the best of equipment currently available on the market is not wasted. For example, MS-DOS systems utilizing Intel® 386/486 processor equipped mother boards, large capacity, high speed disk drives, and high resolution color monitors are generally required. Note that the AutoCAD package requires math co-processor support. Additionally, manual digitizing of data requires large, high resolution digitizing tablets. Figure 2 shows a typical configuration.

Oil well logs present a special problem when it comes time to make a hard copy. While AutoCAD maintains essentially an infinite drawing data base to a very high precision internally, most hard copy devices and software device drivers do not allow long ("Y") axis plotting. The design and drafting world is generally oriented to "E" size drawings and smaller, yet the standard well log data format is much different (Figure 3). There are, however, several models of pen plotters, electrostatic plotters, and dot matrix printers that support roll or continuous media in acceptable lengths.

AUTOCAD AND INJECTION PROFILE ANALYSIS

Why Use AutoCAD To Draft Injection Profiles?

Computer generated well logs are certainly nothing new. However, most computer generated well logs are produced on highly specialized, dedicated systems. For the intended purpose, they generally do the job well. But they offer the well log analyst little flexibility to meet unusual situations.

By its nature, the injection profile log defies rigid standardization of analysis and drafting techniques. Because of this, the transition from the manual drafting world to the world of computer automation requires retention of flexibility.

AutoCAD, on the other hand, offers total flexibility. Once in the editing environment, the analyst or draftsperson has complete freedom to do anything he chooses. By joining the flexible AutoCAD editing environment with AutoCAD's extensive customizing features, the analyst is able to tailor each well log presentation to allow for unique circumstances (Figure 4). Customizing of the AutoCAD environment automates the tedium of mundane, repetitive drafting requirements.

As a final benefit, the customer receives the finished AutoCAD drawing file on diskette. The drawing file can be conveniently stored (archived). If desired, the drawing can be reproduced on another AutoCAD system at a later point in time. Further editing may also be done, or portions of the finished injection profile drawing may be merged into other drawings.

The Injection Profile Log

The typical injection profile consists of a combination (composite) of several elements. Some method of obtaining rate data versus depth is combined with temperature logs, caliper logs (to measure well bore diameter versus depth and aid in rate calculations), natural gamma ray logs (for log depth control purposes), and casing collar logs. The rate data versus depth is used to calculate and present a profile of fluid loss versus depth. Additional information such as location of casing perforations, down hole equipment configuration (packers, bridge plugs, etc.), neutron porosity logs, etc., may also be presented in the injection profile composite drawing.

For the purposes of this discussion, it is assumed that radio active tracer methods are used for determining injection rate versus depth. Other methods, such as spinners or flow meters, can also be applied.

Tracer Tool Configuration

As mentioned above, the radio active tracer method is assumed. The normal tool configuration used for radio active tracer studies is as follows (Figure 5):

Ejector
Gamma Detector(s)
Casing Collar Locator (CCL)
Temperature

The ejector tool is a motorized tool that uses a moving piston to eject small, controlled volumes of liquid radio-isotope into the flow stream. The ejector tool is controlled by digital telemetry from electronic panels located at the surface.

The detector is a high sensitivity, sodium-iodide scintillation gama ray measuring instrument. It is capable of reading both naturally occurring radio-isotopes found adjacent to the well bore in the Earth's crust, and artificially induced, short half-life radio isotopes ejected by the ejector tool.

The temperature tool measures the temperature in the well bore as the tool is lowered through the well bore fluids. A platinum resistive thermal device (RTD) is used for this purpose. The casing collar locator tool senses changes in casing metal mass at casing collars via induction currents in an magnet-coil assembly.

The Fluid Loss Profile

The central part of the injection profile log is the fluid loss profile. The loss profile is augmented by other data, including the temperature log, the caliper log, the casing collar log, the natural gamma log, and other pertinent well data.

The loss profile is calculated from injection rate data versus depth. As mentioned above, for the purposes of this paper, the discussion will be limited to rate data obtained from radio active tracer techniques. Again, other instruments and techniques may be used, such as spinner or flowmeter surveys.

As the well logging industry has matured, several radio-active tracer methods have been proposed, with at least four methods normally utilized for practical tracer profile analysis[1]. These include the stationary velocity shot method, the intensity under the curve (Self) method, the peak elapsed travel time method, and the drop shot (Ford) method. Only the first three methods will be discussed here. Other methods have been proposed, such as the dual pulse method, but are not generally used due to practical limitations.

Once rate data are obtained, losses are calculated consistent with overall material balance assumptions. For the purposes of injection well data, it is assumed that fluid is injected at the surface and losses occur across the zone of interest, and that no fluid enters the well bore from the formation:

$$IF\ \ Q_i > Q_{i-1}\ then\ Q_i = Q_{i-1} \qquad (1)$$

Where Q_i is the volumetric flow rate at a given depth. This means that data points are rejected if calculations show a net increase in injection, which would constitute an increase in matter under the above assumptions. Note, however, that it is possible for a reservoir to exhibit cross flow behavior from a higher pressure zone even while the well is under injection. But when analyzing profile rate data, it is difficult to determine whether or not this is the case when the apparent anomalies in rate may be caused by fluctuations in surface injection, non-ideal flow behavior, or many other factors. The log analyst must therefore be involved iteratively with the data in order to estimate the most likely scenario.

The rate versus depth profile is used to calculate the percentage loss versus depth profile. First, the losses are calculated from the following equation:

$$Loss_i = 100\left(\frac{Q_i}{Q_{100}}\right) \qquad (2)$$

Where the percentage loss at a given depth is the ratio of the volumetric flow rate at the depth of interest to the 100 percent (surface) flow rate.

Once percentage loss versus depth is obtained, the loss profile is refined further in consideration of available information about the well bore configuration. If the well is cased and perforated, the loss profile <u>must</u> be assigned to the perforated interval. Assigning the loss profile is a complex process of collating the loss profile versus depth data with reference to known well bore exits.

Failure to consider the perforations will necessarily result in an incorrect understanding of how the injection fluid is exiting the well bore and moving out into the reservoir. The available data may also provide sufficient evidence to conclude that there are unreported perforations or possibly mechanical damage resulting in fluid profile changes.

A further comment is in order with regard to the rate data. These data are statistically independent events, and as such, preclude statistical analysis procedures for the purpose of eliminating statistically significant errors. In other words, it is impossible to determine whether differences in measured rate values result from measurement error or from actual fluctuations in injection rate or even interzonal reservoir instabilities. The data integrity would be improved with continuous recording of the surface injection, but this is not the common practice.

Calculational Methods - Stationary Velocities

The stationary velocity method (velocity shot method) is a tracer method where the ejected radio active tracer slug moves past the stationary (non-moving) gamma ray detector (or past two detectors) while radiation intensity is recorded in time drive (time elapsed since ejection). Figure 6 is a tool string schematic showing the radiation slug flow path. An example field-recorded time-based gamma curve is also shown in Figure 6. In these examples, only one detector is operated. When the radioactive material arrives at a point adjacent to the gamma detector, the tool response causes a deflection of the recorded curve to the right.

The next figure (Figure 7), shows the same curve as depicted in Figure 6, with lines of intersection added. These lines represent the best "eye-ball" fit through the pre-reaction base line and the post-arrival recorded detector response. The intersection point of these two lines is deemed the first arrival reaction time, as indicated. The first arrival time represents the leading edge of the ejected slug, and is generally representative of the maximum flow rate in the central region of the well bore.

An AutoLISP routine is provided to aid the analyst in measuring the first arrival reaction time. The AutoLISP routine automatically calibrates the digitizing tablet, and prompts the user for the slug number. The analyst can then pick time zero and the slug arrival reaction time. The digitized distance is automatically converted to time based on the input time scale value. The AutoLISP routine records the slug number and reaction time in a file for later use. Table I is a sample raw data file that results.

The next step is to enter a set of FoxBase programs that first import the raw data file discussed in the paragraph above. The FoxBase programs are executed from an AutoCAD DOS shell command that is activate by an AutoLISP routine. The analyst uses these FoxBase routines for several purposes:

Verify Manual Data Entry (Check Print)
Enter Ejected Depths and Times
Enter Hole Size or Read Caliper Data
Calculate Volumetric Rates
Print Pre-glued Log Labels
Edit Data
Mark Data Points DNU (DO NO USE) As Required

This routine also allows the analyst to automatically calculate average hole sizes from digitized caliper log data. After completing the above steps as required, the analyst exits the FoxBase programs and is returned to the AutoCAD editing environment. The FoxBase routines create and update data files for use as discussed below.

Volumetric rates are calculated from the velocity reaction times. The reaction time is a function of the flow-stream linear velocity. The first arrival variant of the velocity shot method discussed above is more closely representative of the maximum flow stream velocity than the average velocity. The theoretical ratio of average to maximum velocity in turbulent, annular flow is approximately 0.88. First arrival velocities should theoretically be corrected by this factor or by experimentally determined correction factors. In practice, the ratio varies with Reynold's number and with other factors, but for the purpose of calculating percentages, can be assumed to be constant and therefore neglected. When comparing velocity rates calculated using the first arrival method with surface metered rates, this correction should be considered.

For a given linear flow stream velocity, the volumetric flow rate is given by:

$$Q_i = \frac{A_i \Delta L_i}{\Delta t_i} \qquad (3)$$

where the cross-sectional area between the logging sonde and the pipe wall is multiplied by the detector spacing and divided by the measured transit time (reaction time). Again, the reaction time is determined by an AutoLISP routine, and the volumetric flow rate is calculated by FoxBase programs.

The above procedures are easily applied to variants of the velocity shot method, such as dual gamma detectors or slug peak-to-peak reactions. The above discussion is illustrative of the simplest case. Single-detector velocities are the most practically efficient method, and practical experience has shown them to be generally as accurate as other methods. Dual-detector velocities take more time to run and analyze, and loose some depth resolution due to the overall greater sonde length. Peak-to-peak velocity determination (where the radio active slug is recorded until it completely passes the detector) is theoretically more representative of the average flow stream velocity, but it is practically difficult to determine peak times with precision because of tracer slug dispersal.

Calculational Methods - Intensities Method

The intensity method (tracer loss method) assumes that if a slug of tracer material is ejected into the flow stream, its intensity (as recorded) will decrease proportionally to the flow loss. Figure 8 is included as an example. Note that several runs are illustrated. In this method, only one slug is ejected, and multiple gamma detector passes through the slug are recorded versus depth. A representation of the volumetric flow rate at any measurement location is calculated from the following equation:

$$Q_i = Q_{100} \left(\frac{A_{gr}}{A_{100}} \right) \qquad (4)$$

where the A terms refer to area under the recorded slug curves. Q_{100} is the 100% flow rate above all zones of fluid loss.

As stated above, the tracer curve area is assumed to be proportional to the fluid flow rate. If the total injection rate is known (from another method or from surface meter readings), the curve areas can be prorated to the injection rate. The intensity method does not directly yield an absolute flow rate value, nor is a value necessary in order to calculate the percentage loss profile.

An AutoLISP routine is used to calculate the intensity curve area (by the trapezoidal rule), and insert this data into the drawing using AutoCAD's attribute feature. The attributes can then be subsequently extracted from the drawing to data files for later use as discussed below. The AutoLISP routine prompts the user for elapsed time since intensity slug ejection, run number (as recorded), and hole diameter. The slug depth is calculate from the intersection point of two lines sketched through the leading (rising) and trailing (falling) slug edges. The AutoLISP routine prompts the user for these two lines. Note that the tracer curve centroid is also calculated. Figure 9 shows a typical example.

The next step is to execute a compiled Microsoft® language routine to edit the tracer intensity data. This routine also allows the analyst to automatically calculate average hole sizes from digitized caliper log data. As in the case of the velocities routine, this program permits the analyst to exclude questionable data from the material balance and loss profile programs. The routine is executed from an AutoCAD DOS shell command, and the analyst is returned to the editing environment upon exiting.

Calculational Methods - Tracer Elapsed Time Method

The tracer elapsed time method uses the same tracer slug data as the intensity method discussed above. Each time the moving radio active slug is recorded, the time elapsed since ejection is noted. By triangulating the peak of the slug to identify the depth (again, Figure 9), the linear velocity is determined from the known distance and transit time. The formula for volumetric flow rate is the same as for the velocity shot method (Equation 3). Note that the peak movement more closely approximates average flow rate.

As in the velocity shot method, the slug peak lines are the best fit through the leading and trailing slug edges. An AutoLISP routine prompts the user for the slug curve, and the two best fit lines. The AutoLISP routine calculates the intersection point of the two lines and converts the intersection point to log depth. This information is also inserted into the drawing file data base using the AutoCAD drawing attribute feature. Alternately, the slug centroid may be used to locate the depth.

The same external editing routine discussed above for the intensity data is used for editing the elapsed time data (since it is essentially the same data set). This routine also performs the volumetric rate calculations, based on the slug position versus time. As before, the analyst can choose to exclude questionable data points from further calculation and analysis.

Calculational Methods - The Loss Profile

The above three sections discussed the methodology for obtaining rate data. The next step for the analyst is to execute a set of compiled Microsoft language routines to perform the following functions:

Analyze Rate Data Files:
- Determine 100% Rates
- Check For Inconsistencies
- Calculate Losses And Loss Intervals

Allocate Loss Profile To Well Configuration
- Perforations
- Open Hole Interval
- Mechanically Damaged Sections

Create AutoCAD Script Command File:
- Percentage Bar Chart
- Point-To-Point Rate Chart
- Rate Labels

These routines are launched by an AutoLISP routine which also executes the resulting script command file. The time required to calculate and display results is only a few minutes, depending on data set complexity and hardware configuration. The compiled routines also generate a print-out for the analyst to use in the process of scrutinizing the loss profile data. Additionally, the analyst has the option to plot draft copies of the log (or critical portions of the log) as often as necessary to aid in analyzing the loss profile data.

To illustrate, Figure 10 shows two loss profiles obtained from a typical set of intensity run data. Note some of the data are inconsistent. In this instance, the analyst chose to eliminate one data point (the curve area, 2.29 sq. in., seems to be too low). Assuming that an adequate explanation for the low rate is found, such as the slug shape being effected by well bore diameter (no caliper log was run), the analyst can exclude the data point from the profile calculation. The profile on the right side in the figure (Case 2) shows the result. Note that the excluded point is marked with an "X". Also, the profile results are changed substantially.

Each time the loss profile is updated, the AutoLISP routine erases all entities that make up the most current profile from the drawing. Other elements of the drawing are undisturbed. The analyst is therefore afforded the opportunity to make repeated iterations with the rate data until a satisfactory profile results. Again, it must be emphasized that all of this occurs automatically, essentially without operator intervention.

Figure 11 is an excerpt of the final injection profile log, where three rate methods are shown. All pertinent well configuration data is shown, along with the loss profiles, caliper and temperature logs. The intensity runs are also shown (dotted curves).

Data Entry

Data are entered into the well log data base either through the keyboard or through digitizing tablets. The AutoCAD screen and tablet menus have been extensively customized to provide the analyst with automated data entry routines. Further, the custom menus are so designed as to prompt the user for data in a logical sequence. The log analysis system is also capable of accepting digital data acquired in the field, via digital data acquisition equipment.

The Drawing Database and Information Exchange

The AutoCAD drawing data base readily lends itself to log drafting for a number of reasons. First, AutoCAD provides for placing of drawing entities on individual drawing layers. These may be thought of as transparent overlays, and allow for convenient grouping of drawing entities. An example would be to place all of the intensity data in one layer so that AutoCAD can easily and accurately locate the intensity data for export to the custom log drafting software. Judicious choice of layer and entity colors also reduces the analyst's workload. Table II lists layer names for a typical log. Note that many of the layer names are self descriptive.

AutoCAD's DXF (drawing interchange) is a file format that is defined for interchange of drawing data base information with external programs. The DXF utility is heavily used in injection profile log drafting for several purposes. The DXF file is an ASCII representation of the drawing data file. AutoCAD can create a DXF file for the entire drawing, or for user selected entities. In a similar fashion, AutoCAD can import DXF formatted files.

For example, the injection profile log drafting system uses the DXF format and utility for rescaling of temperature curves. To illustrate, assume that temperature logs are recorded in 2° Fahrenheit per inch in the field. After digitizing into the AutoCAD drawing, the temperature logs can be rescaled to any convenient scale. Figure 12 shows a set of temperatures recorded at 2° Fahrenheit per inch on the left, and rescaled to 1° degrees per inch on the right. Note that a scale shift is required after rescaling in order to fit within the two right-hand log tracks.

Of course, AutoLISP has direct access to the drawing data base. Figure 13 is an example AutoLISP routine that illustrates this. The purpose of this routine is to allow the log analyst to determine the reference log depth for any arbitrary place in the drawing. The routine is appropriately named "WHEREIS.LSP" (the DOS file extension is by AutoCAD convention). For example, if the analyst wants to know the exact depth at which a break in a temperature log occurs, he only has to place the screen cursor (cross-hairs) on the point of interest and activate WHEREIS by entering it as a command. The routine immediately returns the depth value. The convention for conversion of drawing coordinates to log grid coordinates is discussed below.

The Drawing Database - Conventions

The American Petroleum Institute (API) has established standards for log grids. The normal injection profile log is presented using a three track, five inch API grid. By convention, the grid is laid out where five inches equals 100 feet of well bore. Each track is 2.5 inches wide, with a 0.75 inch space between tracks one and two where the well bore schematic is drawn (Figure 14). The grid is 8.25 inches in total width. The grid shown in the figure includes an additional track that can be removed after use in the field.

The scale standard chosen for well log drawings in AutoCAD is one inch equals one inch (1 = 1) such that the API standard log grid is internally stored to scale. Also, the log drawing is oriented vertically. In order to translate data in the scale drawing to real values, a minimum of two items are required. First, the relationship of the drawing origin to actual log depth must be known. In the log drafting system, this relationship is arbitrarily established each time a log is begun. Second, the drawing coordinates for any point of interest must be known.

For example, assume that the analyst, after a initial look at the field recorded data, decides that 4500 feet should be equal to the ordinate ("Y") coordinate origin of the log drawing. In other words, the log orientation is such that the lowest point is 4500 feet, and the log depth decrease as the drawing Y axis increases. If it is desired to know where 3600 feet would be in the drawing according to the defined standard convention, then the depth difference is multiplied by 0.05 (5 inches per 100 feet per API):

$$(4500\ ft - 3600\ ft)\ 0.05\ \frac{in}{ft} = 45\ inches$$

and the point of interest is therefore 45 inches above the drawing origin. Table III shows a practical example. The first two columns in the table are temperature log data versus depth expressed in drawing standard coordinates. The next two columns are the same data, converted to actual data values. Note that in addition to the standard for log origin location, the temperature scale offset and span must be determined in order to make the necessary conversions shown in the table (as indicated).

Log Scales

A combination of AutoLISP and external (DOS shell) routines are provided to automate the drafting of the log data scale boxes (Figure 15). These routines simplify data entry by use of automated menus. Furthermore, some of the data required for labeling the data scales are automatically available as a consequence of digitizing the data curves. These scales are produced and placed in the log presentation drawing by the driver AutoLISP routine. No operator intervention is required.

Log Assembly

The AutoCAD drawing generated through the process discussed above includes the log heading, data tables, data scales and the log presentation (see Figure 16). The complete log has additional data appended. Normally, all recorded data are spliced onto the end of the CAD produced portion of the log. This includes tracer runs, velocity shots, cross flow checks, and other pertinent data. The computer drafting system additionally provides laser printed, pre-glued, transparent labels (Figure 17) for the appended field data.

Digital Results

In addition to improved accuracy and quality, the computer drafting system provides the client with digital data generated during the drafting process. The final AutoCAD drawing file may be transferred to floppy disk along with various ASCII and spreadsheet compatible data files. The normal distribution includes the following files:

README.1ST	-	A file explaining the diskette contents.
XXXXXLOG.EXE	-	Self extracting AutoCAD drawing file. (drawing of the log presentation).
XXXXXHDG.CSV	-	Well log heading data in CSV format.
XXXXXHOL.CSV	-	List of well bore exits in CSV format. (perforations and/or open hole intervals).
XXXXXVEL.CSV	-	Velocity table in CSV format.
XXXXXVEL.PRN	-	Velocity table in ASCII format.
XXXXXINT.CSV	-	Intensity table in CSV format.
XXXXXINT.PRN	-	Intensity table in ASCII format.

XXXXXZER.CSV	-	Tracer elapsed time table in CSV format.
XXXXXZER.PRN	-	Tracer elapsed time table in ASCII format.
XXXXXTDS.CSV	-	Tubing drop shot table in CSV format.
XXXXXTDS.PRN	-	Tubing drop shot table in ASCII format.
XXXXXV1.CSV	-	Fluid loss profile - velocities.
XXXXXV2.CSV	-	Ditto, assigned to well bore exits.
XXXXXI1.CSV	-	Fluid loss profile - intensities.
XXXXXI2.CSV	-	Ditto, assigned to well bore exits.
XXXXXZ1.CSV	-	Fluid loss profile - tracer elapsed times.
XXXXXZ2.CSV	-	Ditto, assigned to well bore exits.

The "XXXXX" portion of the file name is a five digit well log file number, unique to each well log processed.

Files with the extension .PRN are ASCII files with exactly the same data and format as are found in the tabulated data section of the well log. CSV files are likewise the same data, but are formatted for import into most popular spreadsheet programs. CSV (comma-separated-value) formatted files may also be conveniently read by programming languages such as BASIC, and some data-base programs. To import into an appropriate application program, the keystroke/command sequence necessary for importing foreign format files must be determined.

The fluid loss profile files include data that correspond to the loss profiles shown on the log. XXXXXV1.CSV, XXXXXI1.CSV, and XXXXXZ1.CSV are files containing the loss profile data as calculated prior to any consideration of the well bore mechanical configuration (perforations and other points of fluid loss), and are included for information only. XXXXXV2.CSV, XXXXXI2.CSV, and XXXXXZ2.CSV contain loss profile data after assignment to known perforated or open intervals. Note that it is common practice in the industry to present loss profile data without considering the well bore configuration details. This practice is generally erroneous and misleading.

XXXXXLOG.EXE is a self-extracting archive file. What this means is that due to file size considerations, the original AutoCAD drawing file has been stored in a compressed format. The original file size may be several times that of XXXXXLOG.EXE. The user must first determine whether the target drive has sufficient space for a file several times as large as XXXXXLOG.EXE, and then copy XXXXXLOG.EXE to the target drive (preferably a hard disk). Next, log onto target drive and directory and enter XXXXXLOG (no extension) followed by return and the drawing file will automatically extract itself. At the completion of this process, where will be both XXXXXLOG.EXE and XXXXXLOG.DWG (a normal AutoCAD Release 10 drawing file).

For those not wishing to purchase AutoCAD, several utility programs for viewing AutoCAD drawing files are available. These applications do not support editing of AutoCAD drawing files, but some do allow both viewing and plotting of drawing files. These applications are generally less costly than the AutoCAD package.

Faxing Digital Logs

One additional benefit of CAD well log drafting is that the drawing file can be converted to Group III fax format. In AutoCAD, this is accomplished by first converting the drawing to a plot file format. Utility software packages are available with the capability to convert common raster plot file formats to Group III fax format, which can then be transmitted by means of a PC internal or external fax modem. The resulting fax transmission is faster (because a hard copy is not required) and clearer (the image is not pre-scanned).

MULTI-LOG COMPARISONS AND THE MACRO*LOG

Macro*Log - Purpose

Most injection profiles are run as a part of an overall larger objective to quantify reservoir performance under secondary flood. The reservoir engineer frequently must compare the effectiveness of several injection wells to evaluate factors such as the vertical efficiency and effectiveness of injection. The Macro*Log has been developed just for such multi-log comparisons. The Macro*Log is a plot of the essential parts of an injection profile log in a side-by-side format that is similar to a cross-section. Again, AutoCAD's customizing features are used to facilitate the drafting of the Macro*Log by automating the process.

Once a data base of injection profile logs (and other types of well logs) has been built, the Macro*Log can easily be constructed by using the digital well log data base. The analyst can select any number of logs, and present them in any desired sequence. Additional data such as primary log curves (gamma, neutron, and others), can also be displayed.

Macro*Log - Uses

The Macro*Log has been used to present several logs of the same well for side-by-side comparison of historical performance. This histogram allows the reservoir analyst an instant snap shot of the well's performance so that changes are readily identified. Figure 18 shows a typical example, where well logs run over a span of several years are displayed. Note that well performance changes may result from a variety of factors including mechanical damage (loss of cement bond, build-up of scale, plugging of perforations, fill in the well bore), from reservoir response (fill-up), or from remedial work overs to improve the well.

Another application is the multi-well comparison as shown in Figure 19. Here, the sub-sea topographical map is included in the presentation to show individual well locations. This 8 well presentation is useful when evaluation overall flood performance.

Macro*Log Routines And Procedures

Two procedures are currently available for automated Macro*Log generation. In one, data are entered into a spread sheet file and a script file is generated by a compiled language routine. The script file, when execute in AutoCAD, automatically creates the Macro*Log in a matter of minutes. In the other method, data already available from the well log drafting system (such as that distributed by diskette, see above) is automatically collated by a compile language routine to create an AutoCAD script file for generation of the Macro*Log.

If desired, the cross section can be selected during an interactive session inside AutoCAD using a map drawing that is first prepared for the field. This map is then used by an AutoLISP routine to select the cross section, at which time a compile language routine can be launched to prepare the AutoCAD script command file. This potentially allows the reservoir analyst the opportunity to rapidly make cross-section comparisons of even a very large field.

REFERENCES

1. Hill, A.D., and Solares, J. Ricardo, "Improved Analysis Methods for Radioactive Tracer Injection Logging," paper SPE 12140 presented at the 1983 SPE Annual Technical Conference and Exhibition, San Francisco.

Table I
Velocity Shots - Raw Data

```
1,102.272,1,3,8,5,1,2,15.5
2,91.2011,1,3,8,5,1,2,15.5
3,235.058,1,3,8,5,1,2,15.5
4,130.735,1,3,8,5,1,2,15.5
5,84.3753,1,3,8,5,1,2,15.5
6,59.5636,1,3,8,5,1,2,15.5
7,47.3747,1,3,8,5,1,2,15.5
8,25.3927,1,3,8,5,1,2,15.5
9,24.1156,1,3,8,5,1,2,15.5
10,23.5791,1,3,8,5,1,2,15.5
11,25.072,1,3,8,5,1,2,15.5
12,21.6613,1,3,8,5,1,2,15.5
13,20.6431,1,3,8,5,1,2,15.5
14,17.0294,1,3,8,5,1,2,15.5
15,18.3343,1,3,8,5,1,2,15.5
16,11.774,1,3,8,5,1,2,15.5
17,15.7853,1,3,8,5,1,2,15.5
18,15.9562,1,3,8,5,1,2,15.5
19,17.7546,1,3,8,5,1,2,15.5
20,3.00586,1,3,8,5,1,2,15.5
21,2.59364,1,3,8,5,1,2,15.5
```

KEY:

Run No, Reaction Time: Seconds, Tool Diameter: Inch, Tool Diameter: Fraction Numerator, Tool Diameter: Fraction Denominator, Casing Size: Inch, Casing Size: Fraction Numerator, Casing Size: Fraction Denominator, Casing Weight: LBS

Table II
AutoCAD Layer Names - Injection Profile Logs

LAYER NAME	LAYER NAME	LAYER NAME
0	GRID100	RTUN20
1	GRID50	RTUN21
AREAS	GRIDL10	RTUN22
BPDT	GRIDL100	RTUN23
BPDV	GRIDL2	RTUN24
CALIPER	GRIDL50	RTUN3
CCL	HATCHI	RTUN4
CIRCLEI	HATCHT	RTUN5
CIRCLET	HATCHV	RTUN6
CIRCLEV	HEADING	RTUN7
CSCOLOGO	HEADTXT	RTUN8
CSG	INT	RTUN9
CUTLINE	LAYOUT	SCALECAL
D-CAL	LOGO	SCALEGR
D-NEU	NEUTRON	SCALEINT
D-T1	PEAK	SCALETEMP
D-T2	PERFS	SCALETRA
D-T3	PKR	SCALEVEL
D-T4	RATELINEI	SERVICE
D-X1	RATELINET	STEVE
DEFPOINTS	RATELINEV	STVE
DEPTH100	RTUN1	TABLE
DEPTH50	RTUN10	TBG
DRAG	RTUN11	TEMP1
DRAG1	RTUN12	TEMP2
DRAGATT	RTUN13	TEXT
DRAGTXT	RTUN14	TIC4
EXESI	RTUN15	TOOL
EXEST	RTUN16	TRA
EXESV	RTUN17	VEL
GAMMA	RTUN18	XFLOW1
GR	RTUN19	
GRBASE	RTUN2	

X-Coord (in)	Y-Coord (in)	Temperature (Deg F)	Depth (ft)	X-Coord (in)	Y-Coord (in)	Temperature (Deg F)	Depth (ft)
2.61127	27.50000	125.06	3950.0	3.18940	15.83192	127.95	4183.4
2.62150	27.23202	125.11	3955.4	3.07590	15.55462	127.38	4188.9
2.65090	26.75112	125.25	3965.0	2.99370	15.19382	126.97	4196.1
2.68110	26.22642	125.41	3975.5	2.87790	14.80462	126.39	4203.9
2.71890	25.72582	125.59	3985.5	2.79560	14.45382	125.98	4210.9
2.74030	25.38262	125.70	3992.3	2.66340	14.09232	125.32	4218.2
2.79250	24.85422	125.96	4002.9	2.53740	13.72292	124.69	4225.5
2.84010	24.36572	126.20	4012.7	2.38890	13.38912	123.94	4232.2
2.87640	23.95692	126.38	4020.9	2.23220	13.06512	123.16	4238.7
2.90790	23.48012	126.54	4030.4	2.10110	12.76152	122.51	4244.8
2.92220	23.07292	126.61	4038.5	1.96490	12.40792	121.82	4251.8
2.95380	22.71192	126.77	4045.8	1.84810	12.08852	121.24	4258.2
2.98060	22.27502	126.90	4054.5	1.76620	11.70782	120.83	4265.8
3.01380	21.94602	127.07	4061.1	1.71090	11.28562	120.55	4274.3
3.04570	21.56312	127.23	4068.7	1.69310	10.89192	120.47	4282.2
3.10770	21.17472	127.54	4076.5	1.74910	10.50132	120.75	4290.0
3.13400	20.77172	127.67	4084.6	1.80350	10.08882	121.02	4298.2
3.17230	20.36692	127.86	4092.7	1.84220	9.65812	121.21	4306.8
3.15190	20.00912	127.76	4099.8	1.83470	9.24662	121.17	4315.1
3.12050	19.71902	127.60	4105.6	1.80450	8.87862	121.02	4322.4
3.02740	19.41602	127.14	4111.7	1.76100	8.46462	120.81	4330.7
2.92460	19.09292	126.62	4118.1	1.71300	8.09042	120.57	4338.2
2.81070	18.84552	126.05	4123.1	1.69610	7.63882	120.48	4347.2
2.69840	18.61812	125.49	4127.6	1.67540	7.17322	120.38	4356.5
2.60580	18.28512	125.03	4134.3	1.67430	6.73182	120.37	4365.4
2.63550	17.91412	125.18	4141.7	1.67190	6.24652	120.36	4375.1
2.76660	17.57672	125.83	4148.5	1.68440	5.83532	120.42	4383.3
2.90480	17.29932	126.52	4154.0	1.73620	5.45872	120.68	4390.8
3.05370	16.97012	127.27	4160.6	1.85690	5.02122	121.28	4399.6
3.17360	16.71042	127.87	4165.8	2.14400	4.15702	122.72	4416.9
3.26540	16.46022	128.33	4170.8	2.33431	3.67746	123.67	4426.5
3.28900	16.09912	128.45	4178.0	2.55630	3.33072	124.78	4433.4

Table III
AutoCAD© Data Conversion Example - Temperature Log Data

Drawing Depth Zero Reference: 4500 ft.
Temperature Zero: 112 °F.
Temperature Scale (Span): 5 °F.

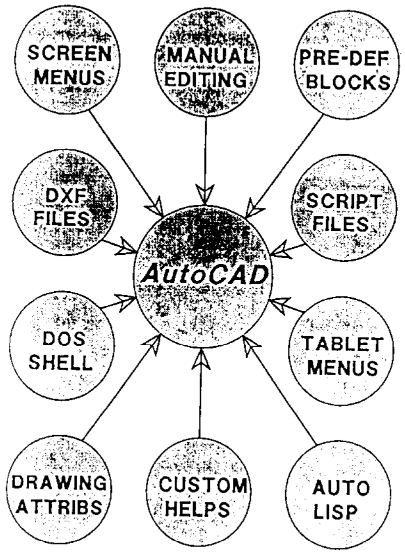


Figure 1 - AutoCAD© customizing options

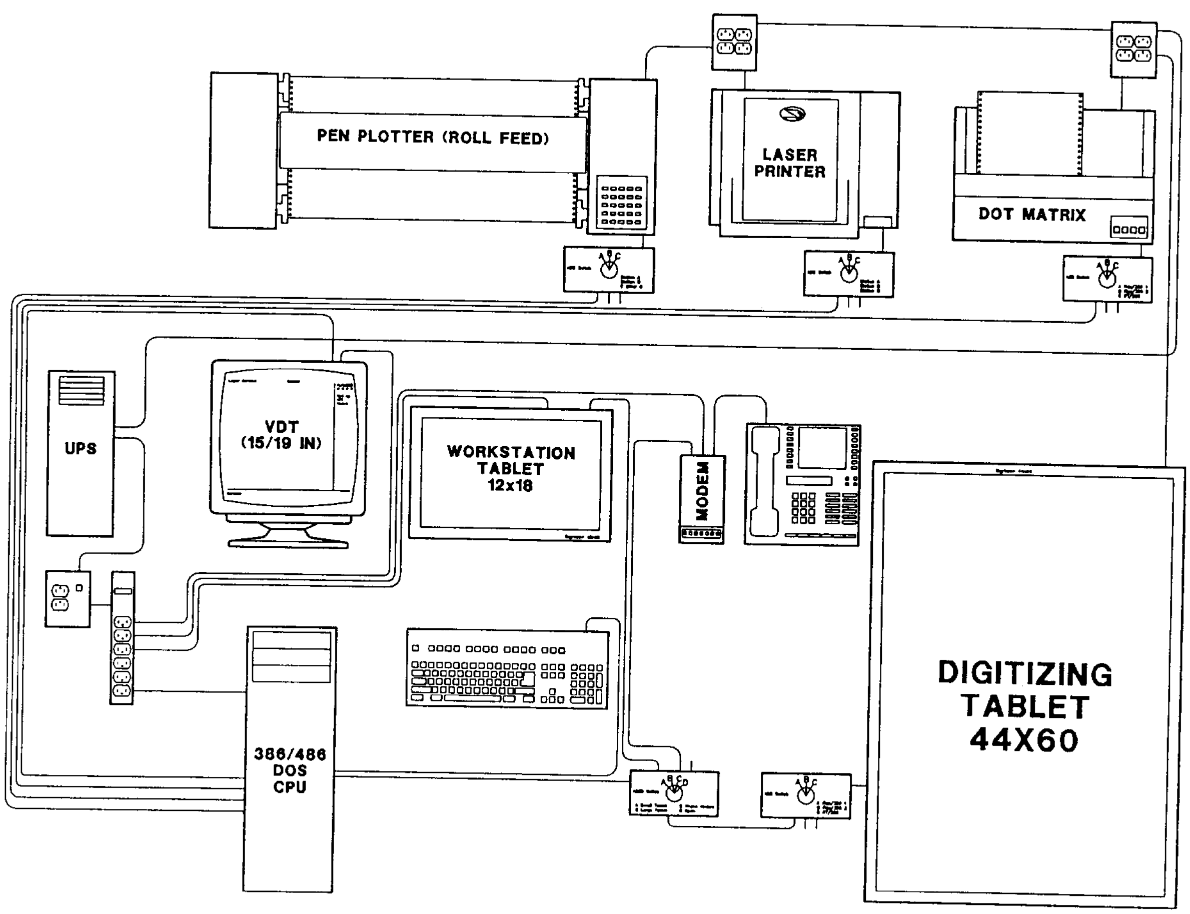
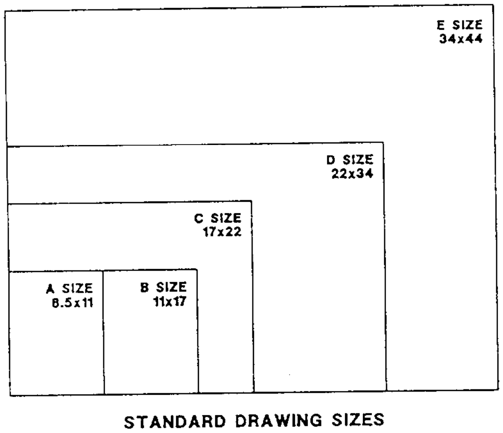


Figure 2 - CAD workstation



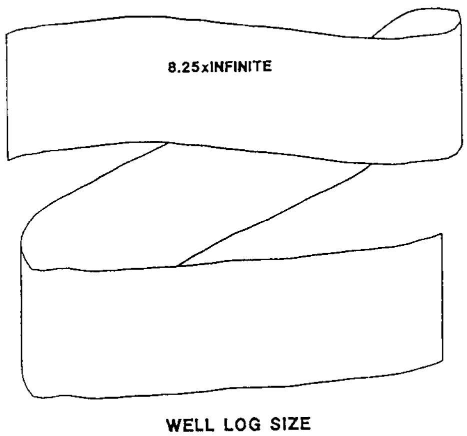


Figure 3 - Drafting formats

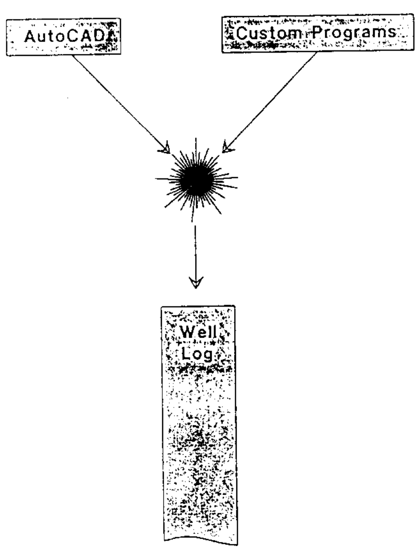


Figure 4 - Flexibility and structure

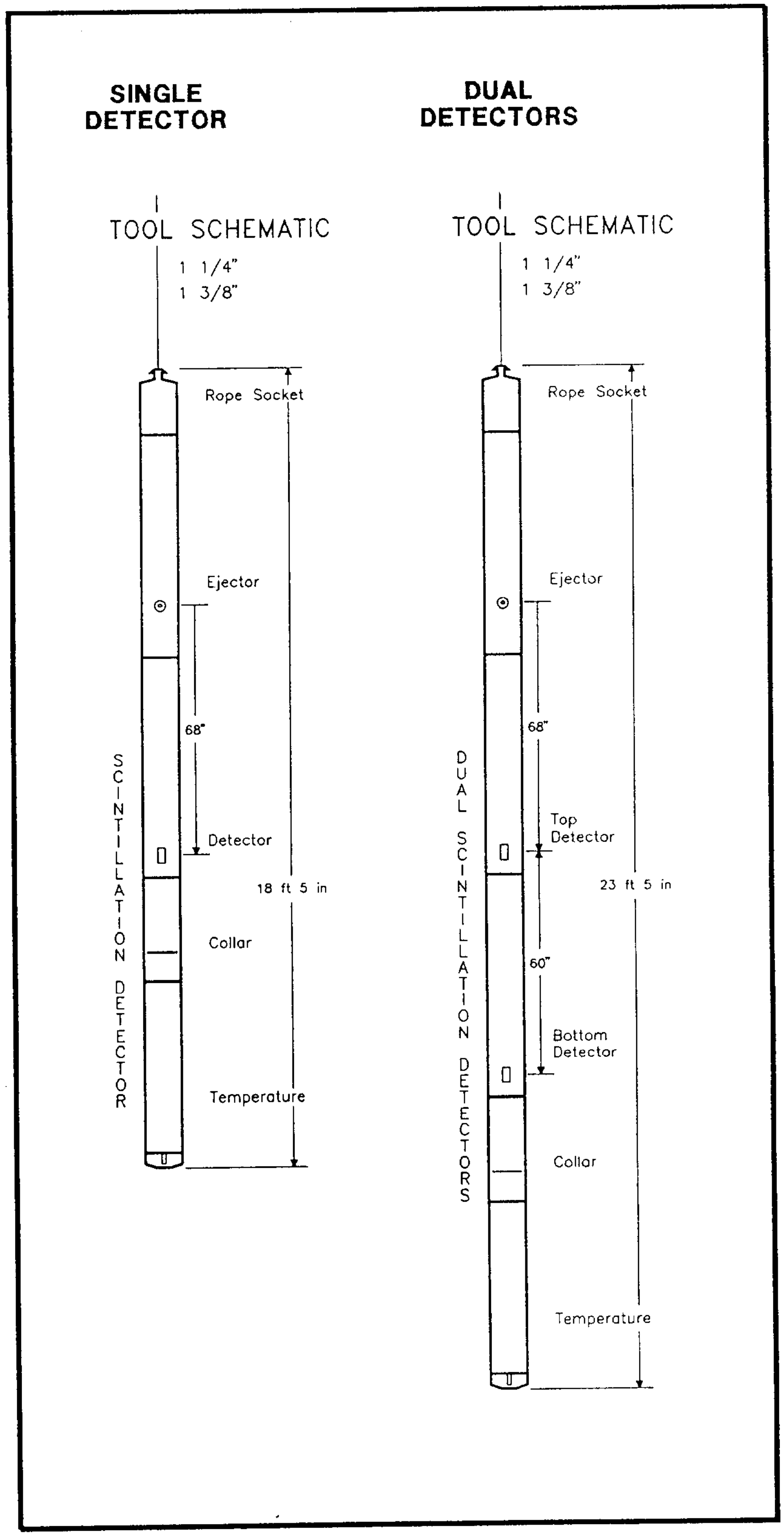


Figure 5 - Tool string schematics

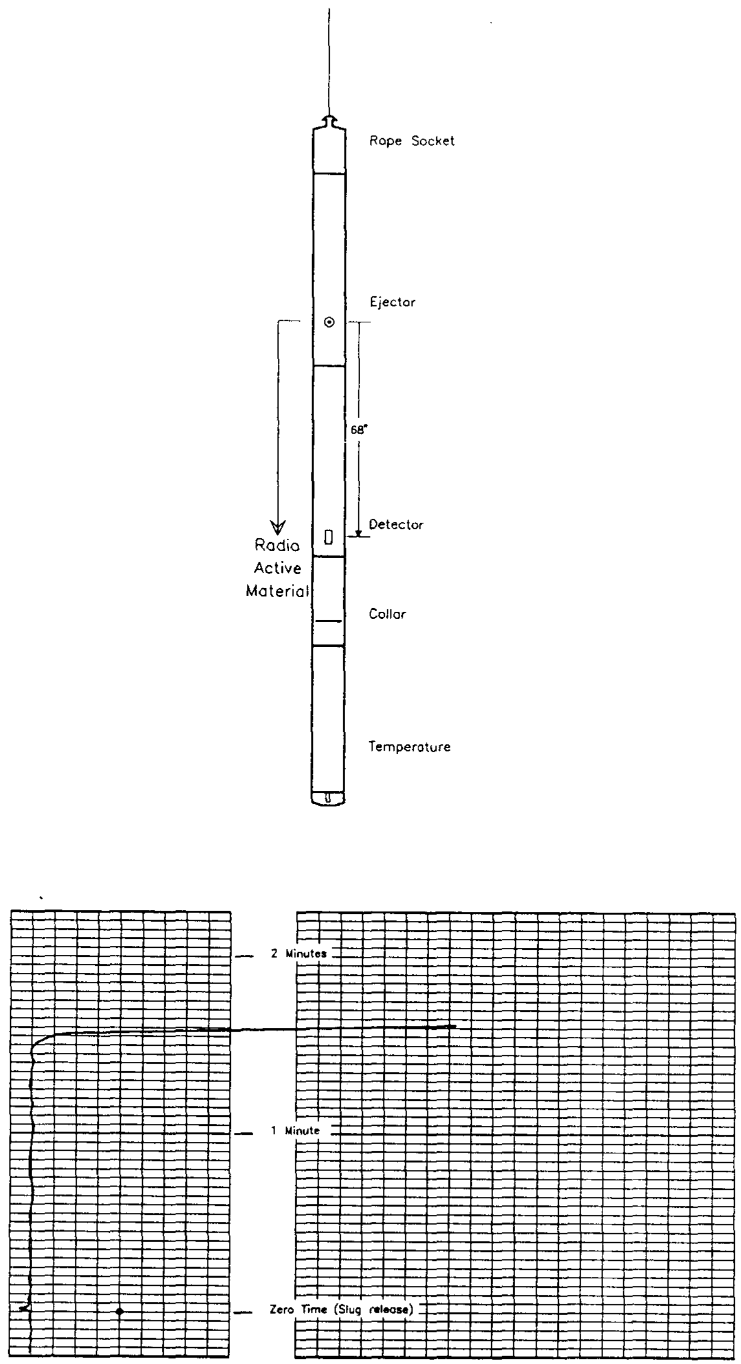


Figure 6 - Stationary velocity shot

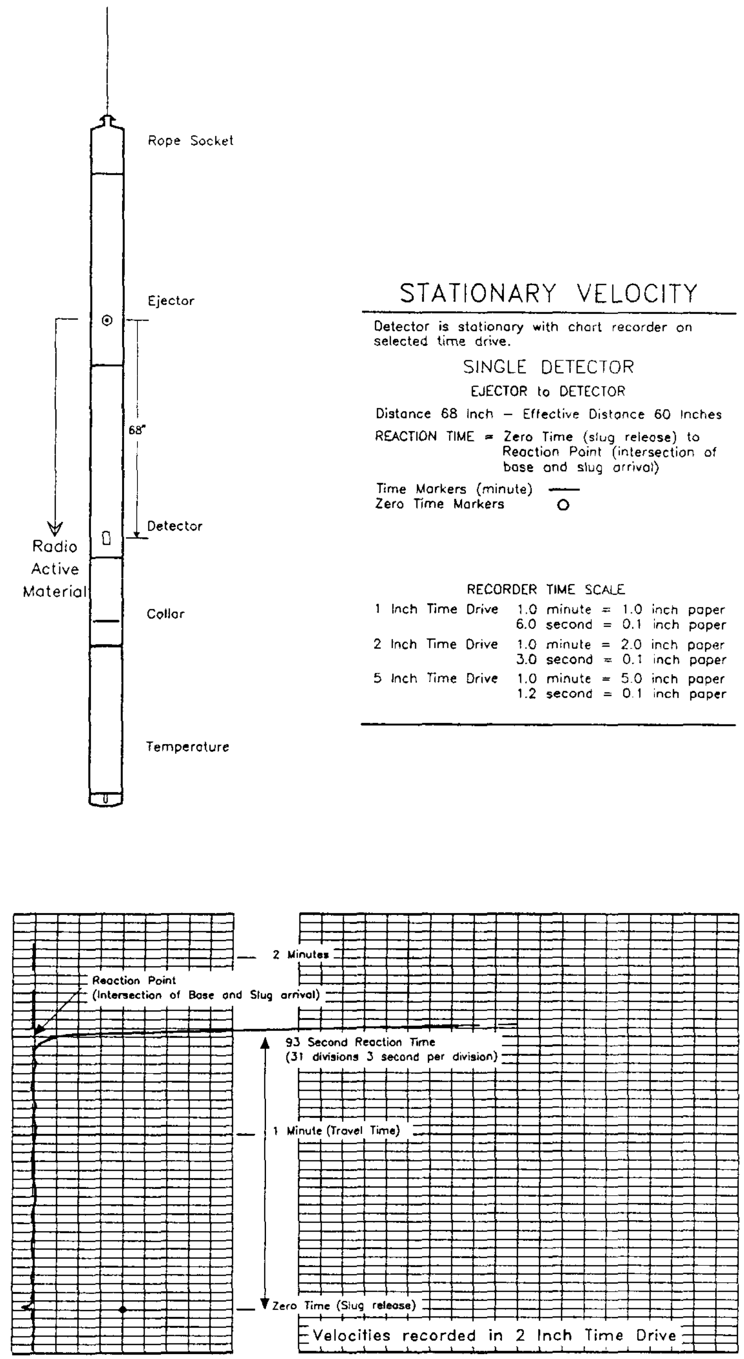


Figure 7 - Stationary velocity shot

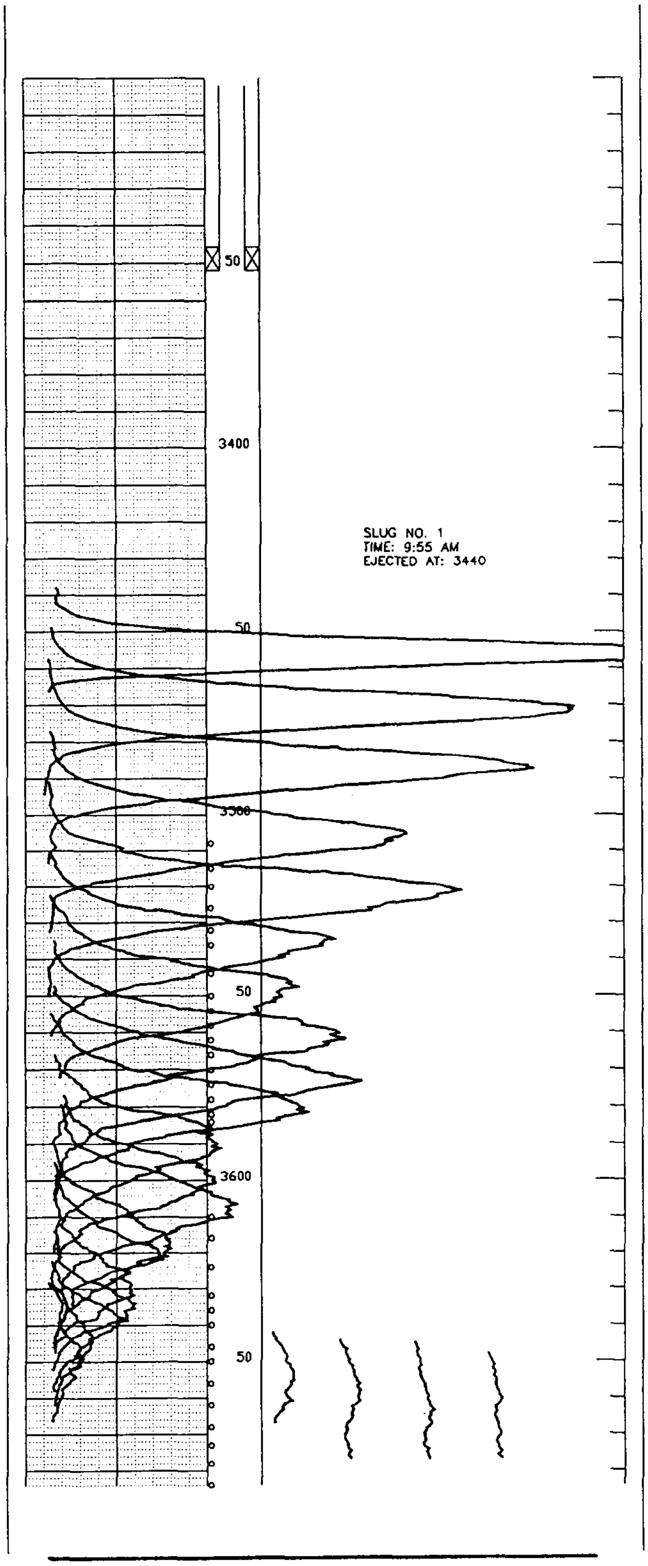


Figure 8 - Intensity (raw data)

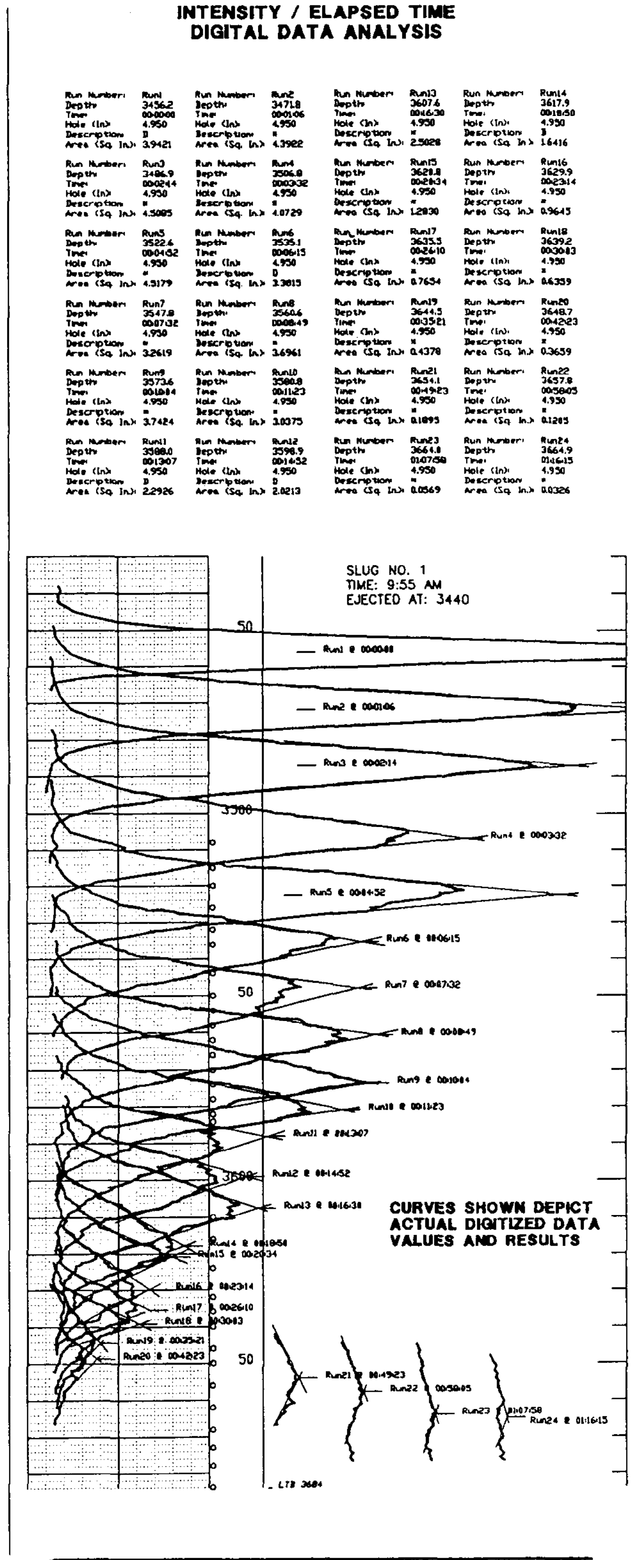


Figure 9 - Intensity (digital analysis)

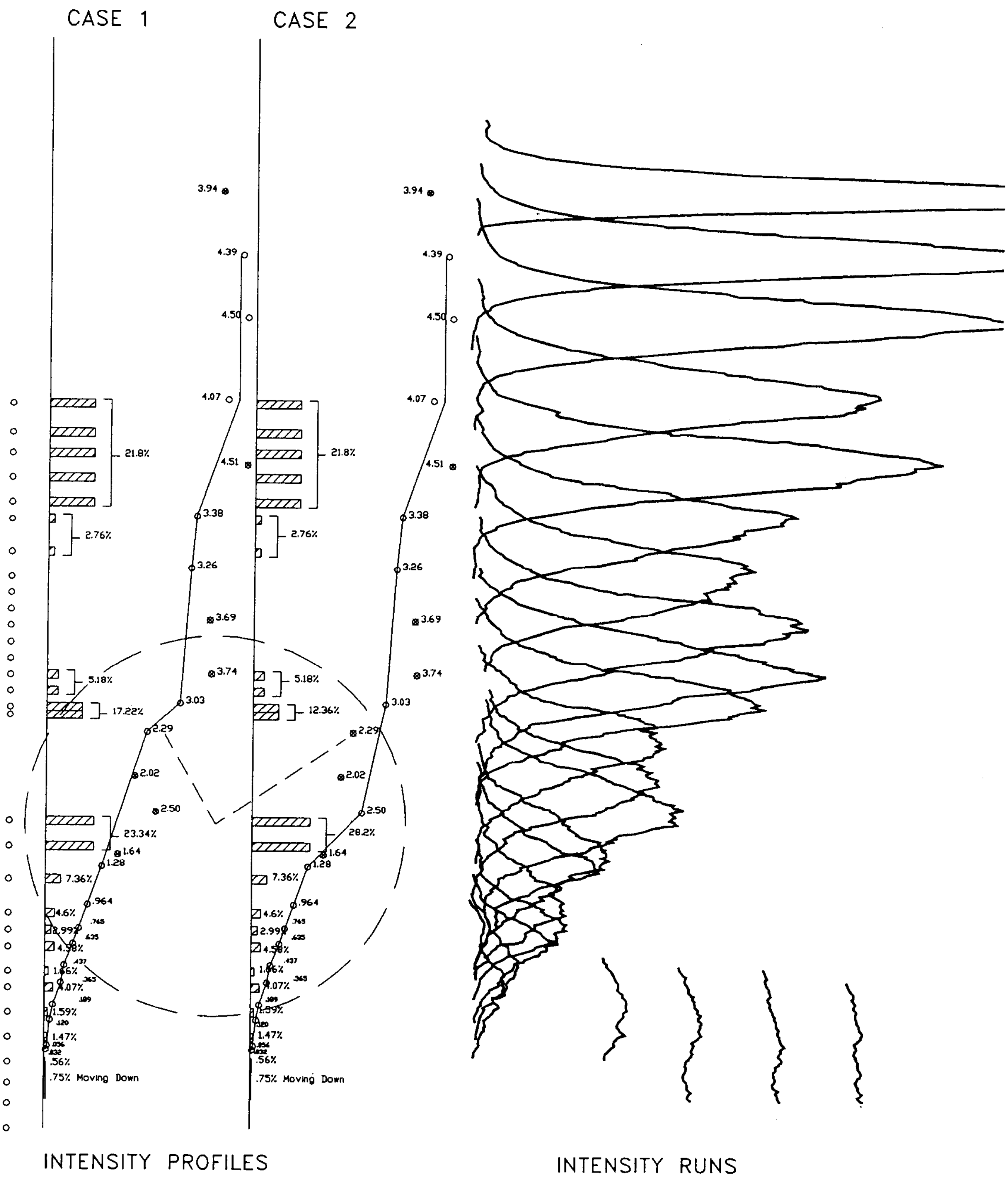


Figure 10 - Effects of data selection

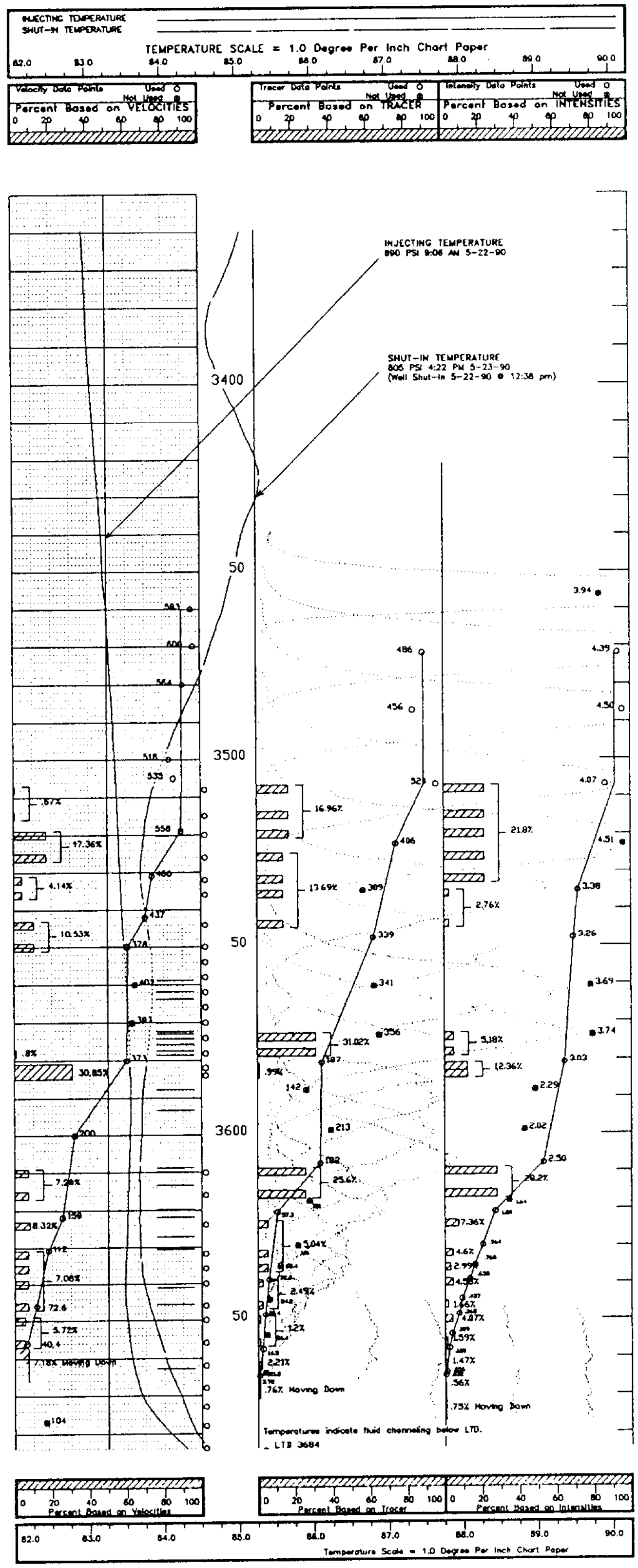


Figure 11 - Tracer profile (excerpt)

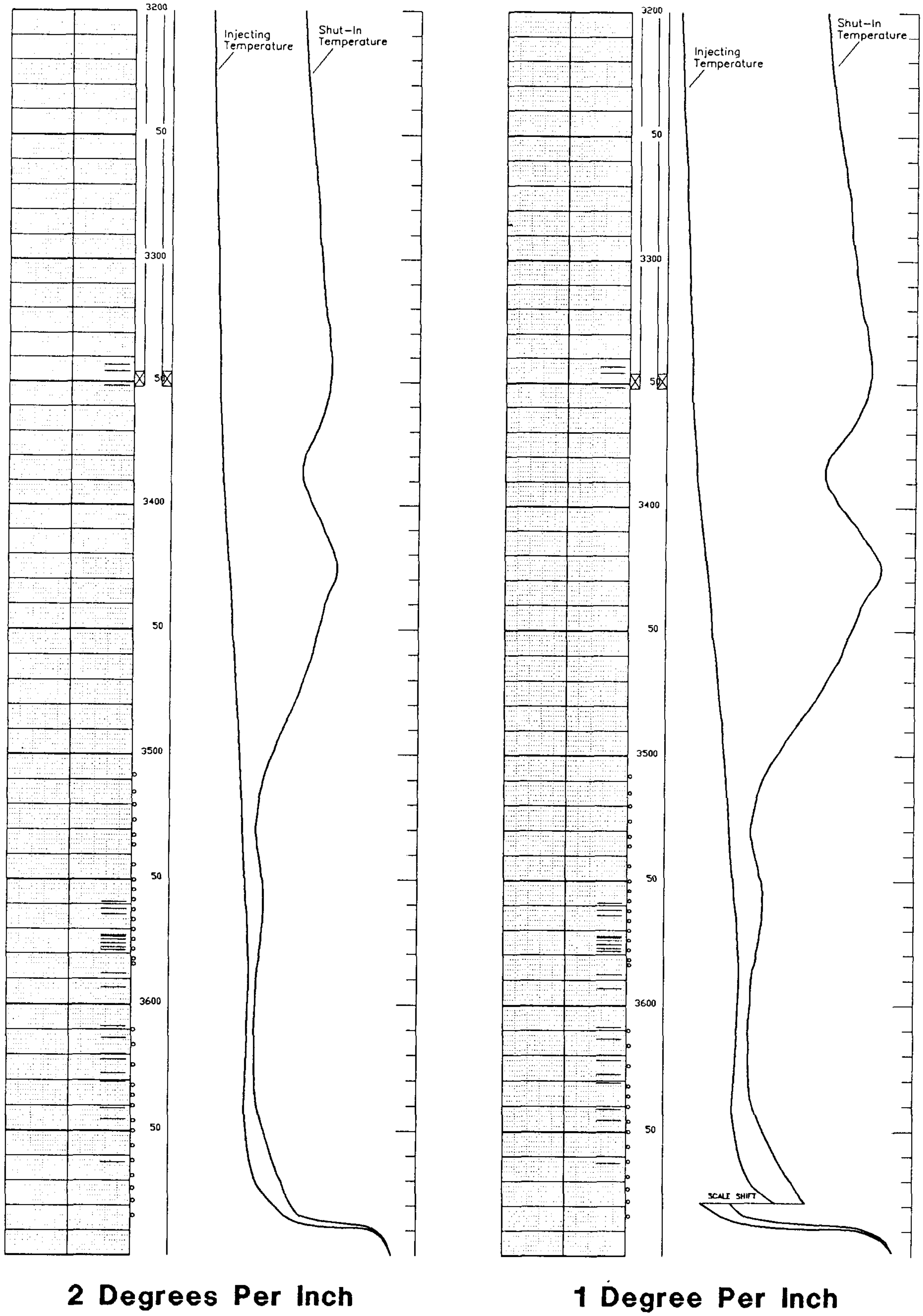


Figure 12 - Temperature rescale example

```
(defun c:whereis ()
 (activelog)    ;go get active log number into 'active'
 (setq genfile (strcat active "GEN.DAT"))
 (setq infile (open genfile "r"))
  (setq btmgrid (read-line infile))      ;read grid top value
  (setq btmgrid (read-line infile))      ;read grid bottom
 (close infile)
 (setq btmgrid (atof btmgrid))     ;convert to a real number
 (setq zerozero btmgrid)           ;set zerozero value
 ;Next, check to see if global variable "zerozero" is set:
 (if (= zerozero nil) (progn
   (prompt "Bottom Log Depth NOT defined") (terpri)
   (setq zerozero (getreal "Enter Log Bottom Depth: "))
 ));end if / progn
 (terpri)
 (graphscr)
 (princ "Pick depths of interest:")
   (setq depth 5)    ; not nil
   (while depth
    (print)
    (setq depth (getpoint "Pick a depth ... "))
    (if depth (progn
     (setq depth (- zerozero (/(* (cadr depth) 100.0) 5.0)))
     (prin1 depth)
    )); endif / progn
   ); end while
); end "whereis.lsp" function
```

Figure 13 - AutoLISP© example (program listing) "WHEREIS.LSP"

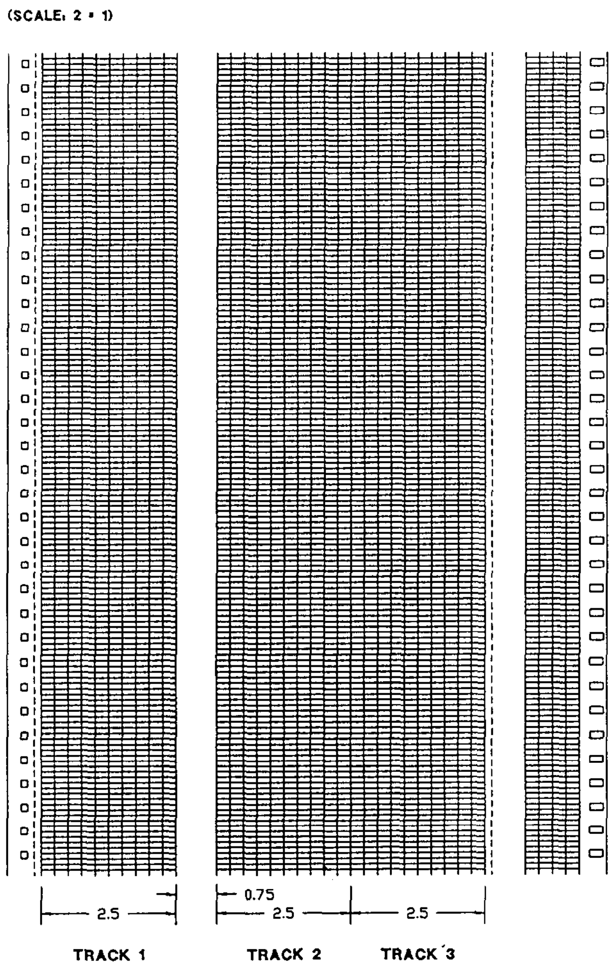


Figure 14 - API well log grid (5 in = 100 ft)

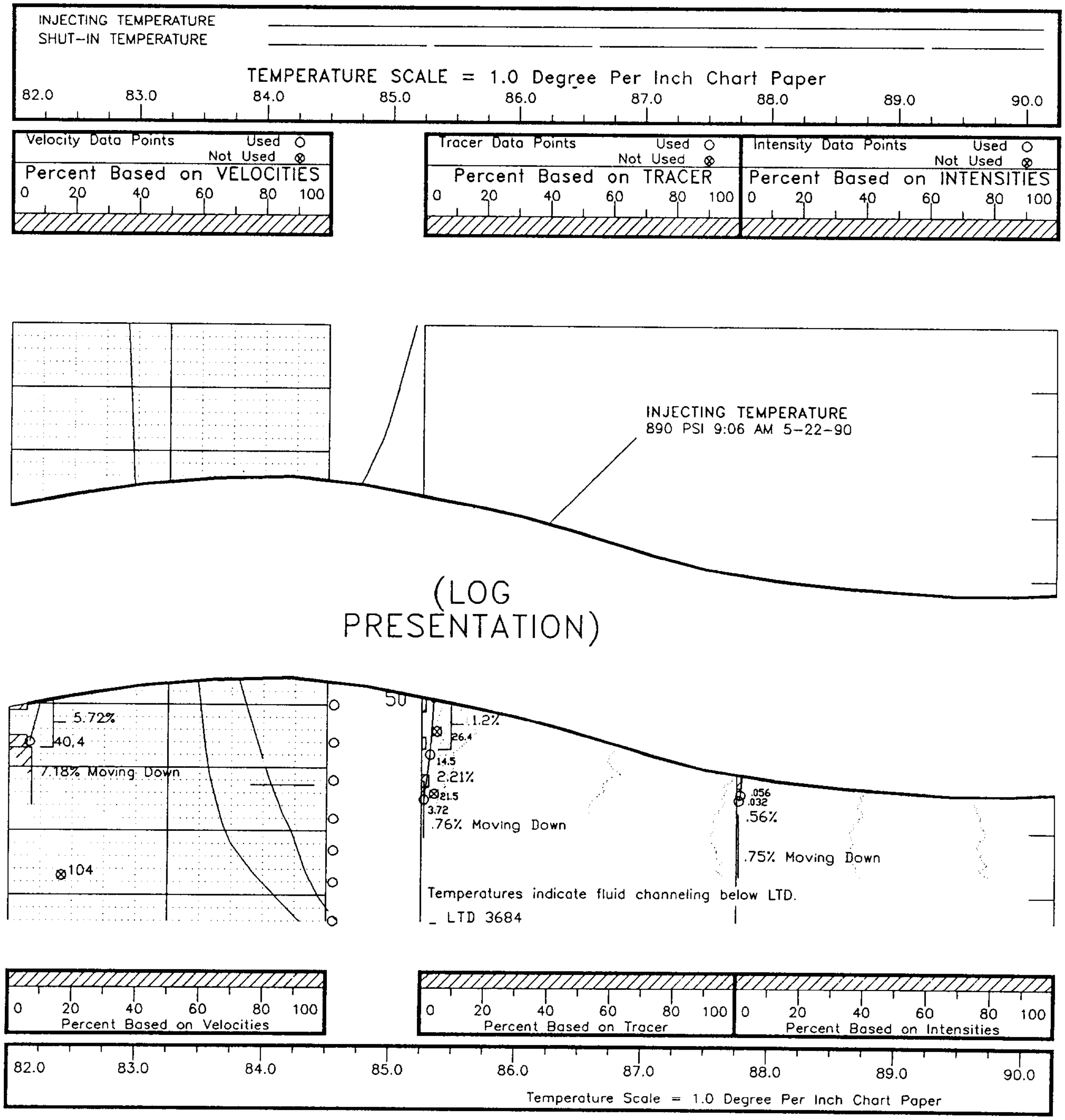


Figure 15 - Well log data scales

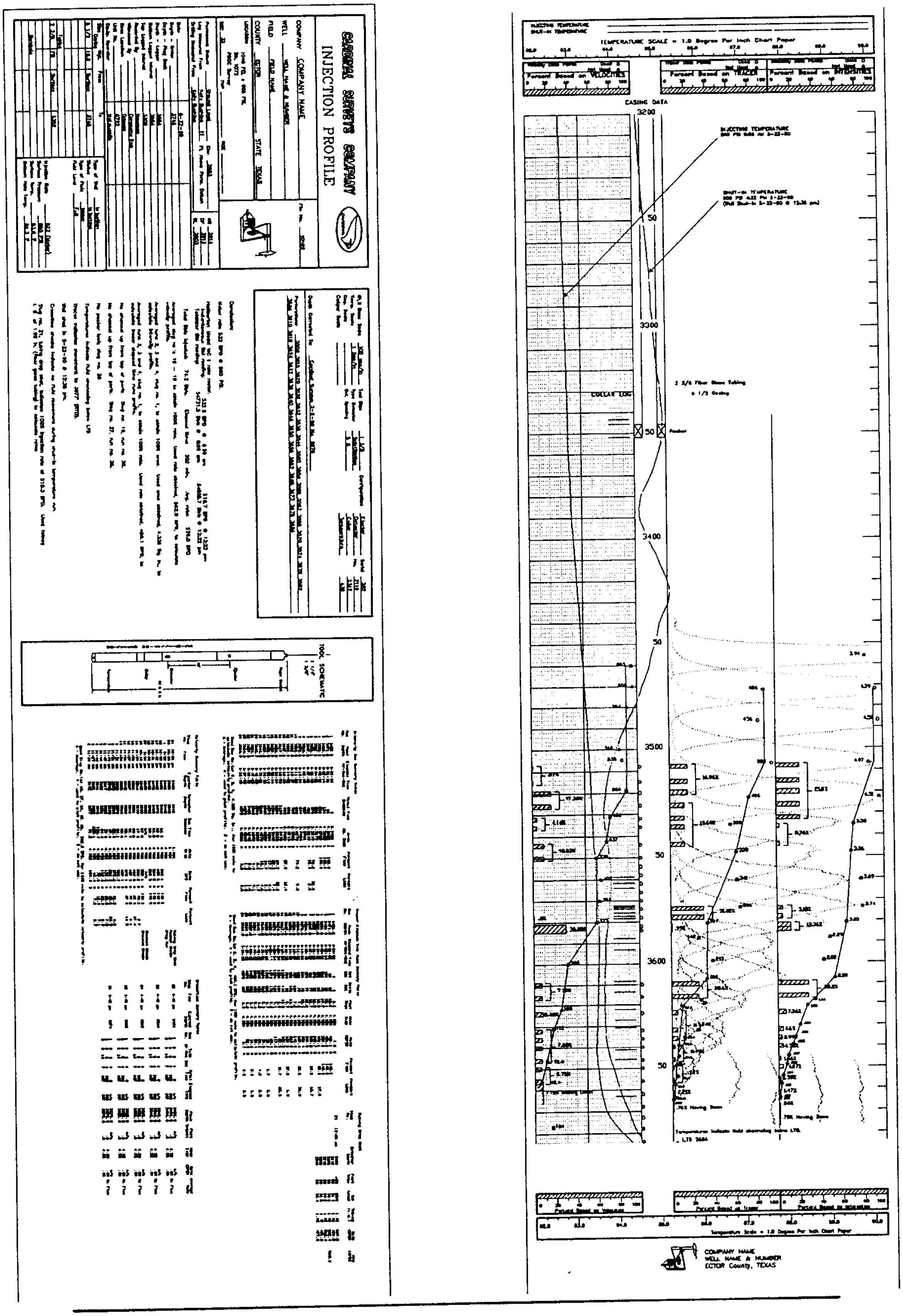


Figure 16 - Injection profile presentation

SLUG NO. 1
DRAG RUN

TIME	9:55:AM
EJECTED AT	3440' 0"
BOTTOM DETECTOR AT	3445' 0"
REACTION TIME (SEC)	N/A

SLUG NO. 2

TIME	11:14:AM
EJECTED AT	3672' 0"
BOTTOM DETECTOR AT	3677' 0"
REACTION TIME (SEC)	91.2

SLUG NO. 3

TIME	11:27:AM
EJECTED AT	3651' 0"
BOTTOM DETECTOR AT	3656' 0"
REACTION TIME (SEC)	235.1

SLUG NO. 4

TIME	11:40:AM
EJECTED AT	3641' 0"
BOTTOM DETECTOR AT	3646' 0"
REACTION TIME (SEC)	130.7

SLUG NO. 5

TIME	11:44:AM
EJECTED AT	3626' 0"
BOTTOM DETECTOR AT	3631' 0"
REACTION TIME (SEC)	84.4

SLUG NO. 6

TIME	11:47:AM
EJECTED AT	3617' 0"
BOTTOM DETECTOR AT	3622' 0"
REACTION TIME (SEC)	59.6

SLUG NO. 7

TIME	11:49:AM
EJECTED AT	3595' 0"
BOTTOM DETECTOR AT	3600' 0"
REACTION TIME (SEC)	47.4

SLUG NO. 8

TIME	11:51:AM
EJECTED AT	3575' 0"
BOTTOM DETECTOR AT	3580' 0"
REACTION TIME (SEC)	25.4

SLUG NO. 9

TIME	11:52:AM
EJECTED AT	3565' 0"
BOTTOM DETECTOR AT	3570' 0"
REACTION TIME (SEC)	24.1

SLUG NO. 10

TIME	11:54:AM
EJECTED AT	3555' 0"
BOTTOM DETECTOR AT	3560' 0"
REACTION TIME (SEC)	23.6

SLUG NO. 11

TIME	11:56:AM
EJECTED AT	3545' 0"
BOTTOM DETECTOR AT	3550' 0"
REACTION TIME (SEC)	25.1

SLUG NO. 12

TIME	11:57:AM
EJECTED AT	3537' 0"
BOTTOM DETECTOR AT	3542' 0"
REACTION TIME (SEC)	21.7

SLUG NO. 13

TIME	11:58:AM
EJECTED AT	3526' 0"
BOTTOM DETECTOR AT	3531' 0"
REACTION TIME (SEC)	20.6

SLUG NO. 14

TIME	11:59:AM
EJECTED AT	3514' 0"
BOTTOM DETECTOR AT	3519' 0"
REACTION TIME (SEC)	17.0

SLUG NO. 15

TIME	12:00:PM
EJECTED AT	3495' 0"
BOTTOM DETECTOR AT	3500' 0"
REACTION TIME (SEC)	18.3

SLUG NO. 16

TIME	12:01:PM
EJECTED AT	3475' 0"
BOTTOM DETECTOR AT	3480' 0"
REACTION TIME (SEC)	16.8

SLUG NO. 17

TIME	12:02:PM
EJECTED AT	3465' 0"
BOTTOM DETECTOR AT	3470' 0"
REACTION TIME (SEC)	15.8

SLUG NO. 18

TIME	12:03:PM
EJECTED AT	3455' 0"
BOTTOM DETECTOR AT	3460' 0"
REACTION TIME (SEC)	16.0

SLUG NO. 19
CHANNEL CHECK - UPWARD

TIME	12:10:PM
EJECTED AT	3500' 0"
BOTTOM DETECTOR AT	3505' 0"
REACTION TIME (SEC)	17.8

SLUG NO. 20
PACKER CHECK

TIME	12:19:PM
EJECTED AT	3335' 0"
BOTTOM DETECTOR AT	3340' 0"

SLUG NO. 21
TUBING DROP SHOT

TIME	12:26:PM
EJECTED AT	3000' 0"
BOTTOM DETECTOR AT	3005' 0"

SLUG NO. 22

TIME	4:45:PM
EJECTED AT	3490' 0"
BOTTOM DETECTOR AT	3495' 0"
REACTION TIME (SEC)	DNU

SLUG NO. 23

TIME	4:45:PM
EJECTED AT	3540' 0"
BOTTOM DETECTOR AT	3545' 0"
REACTION TIME (SEC)	DNU

SLUG NO. 24

TIME	4:45:PM
EJECTED AT	3595' 0"
BOTTOM DETECTOR AT	3600' 0"
REACTION TIME (SEC)	DNU

SLUG NO. 25

TIME	4:45:PM
EJECTED AT	3635' 0"
BOTTOM DETECTOR AT	3640' 0"
REACTION TIME (SEC)	DNU

SLUG NO. 26

TIME	4:45:PM
EJECTED AT	3670' 0"
BOTTOM DETECTOR AT	3675' 0"
REACTION TIME (SEC)	DNU

SLUG NO. 27
CHANNEL CHECK - UPWARD

TIME	5:04:PM
EJECTED AT	3500' 0"
BOTTOM DETECTOR AT	3505' 0"
REACTION TIME (SEC)	0.0

Figure 17 - Log labels

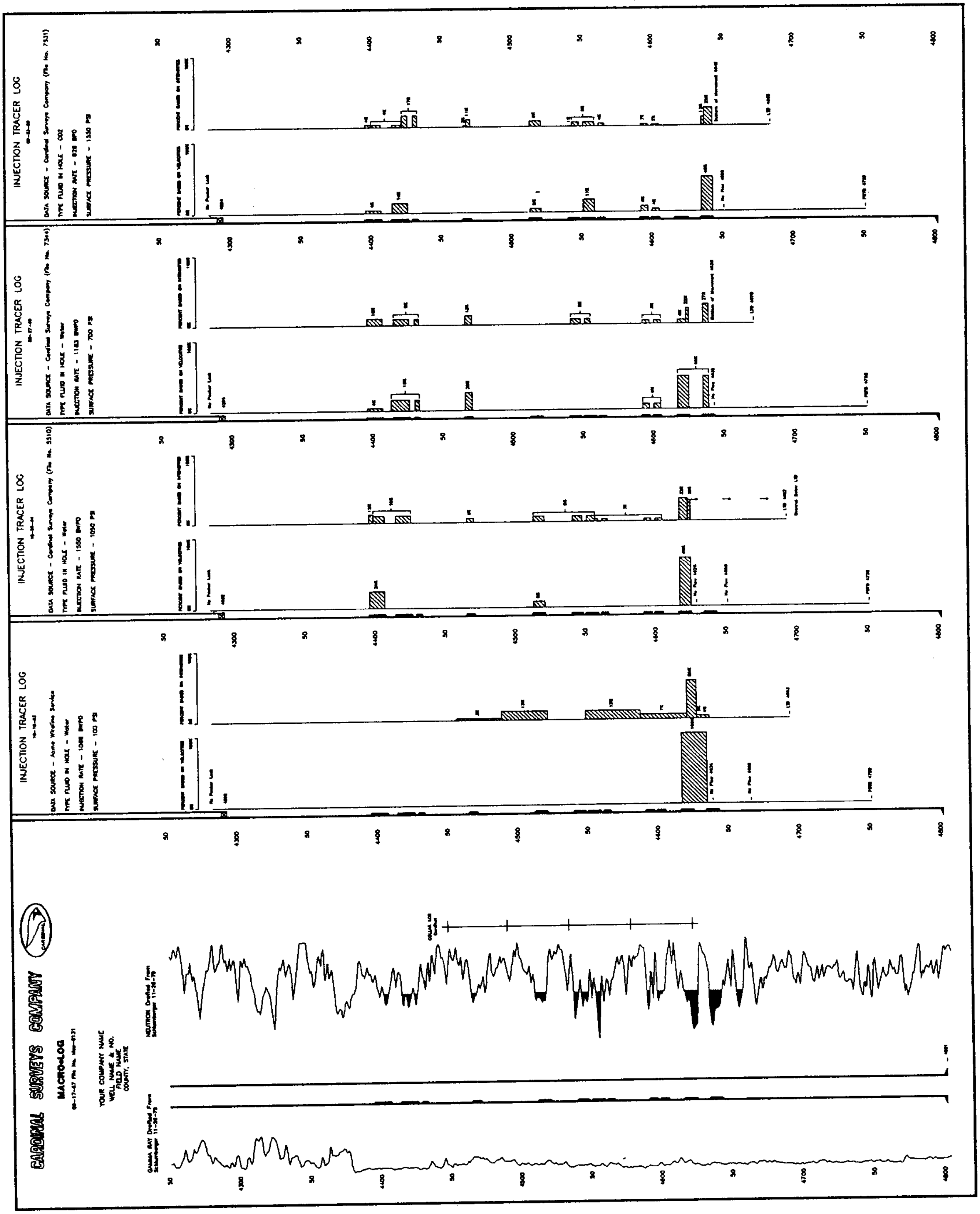


Figure 18 - Single well histogram

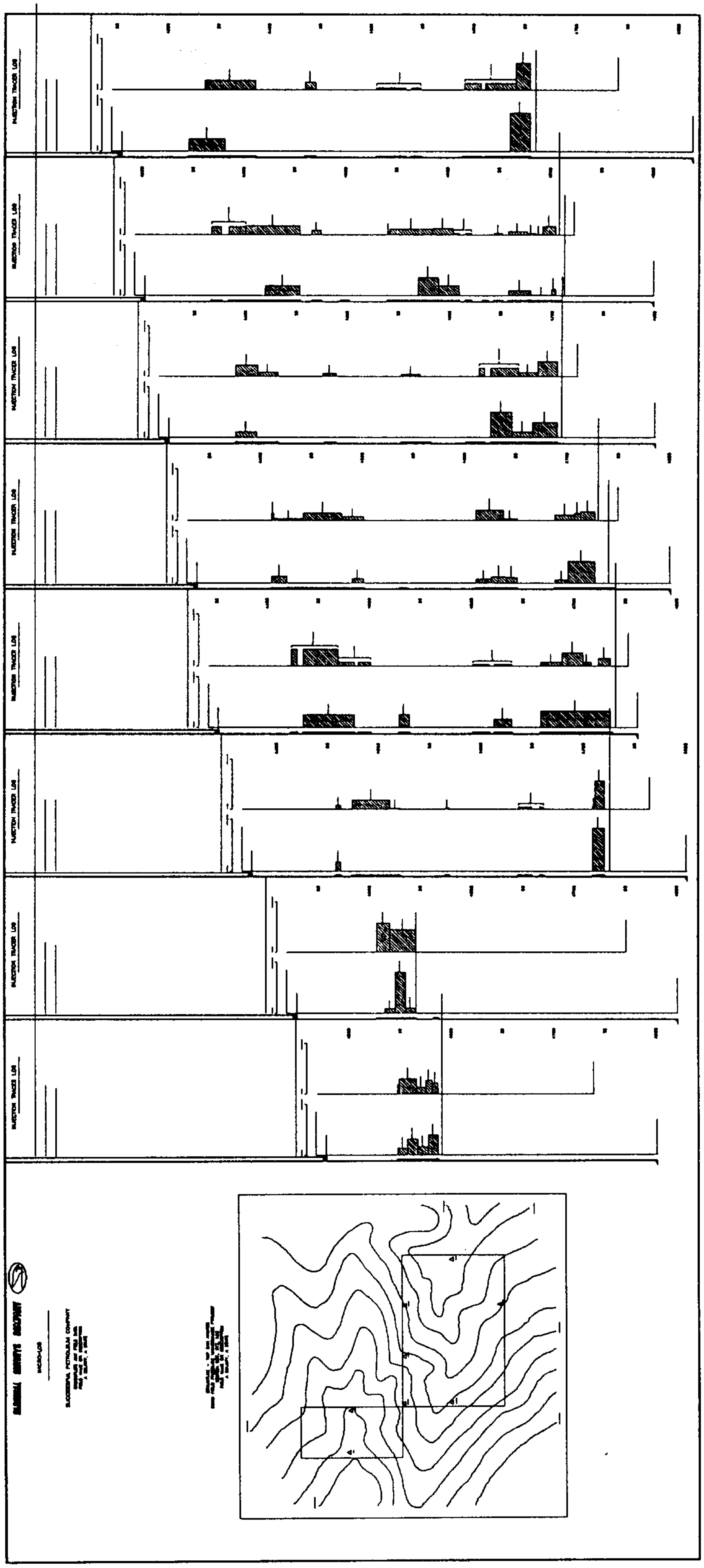


Figure 19 - Multi-well histogram (crossplot/structure map)