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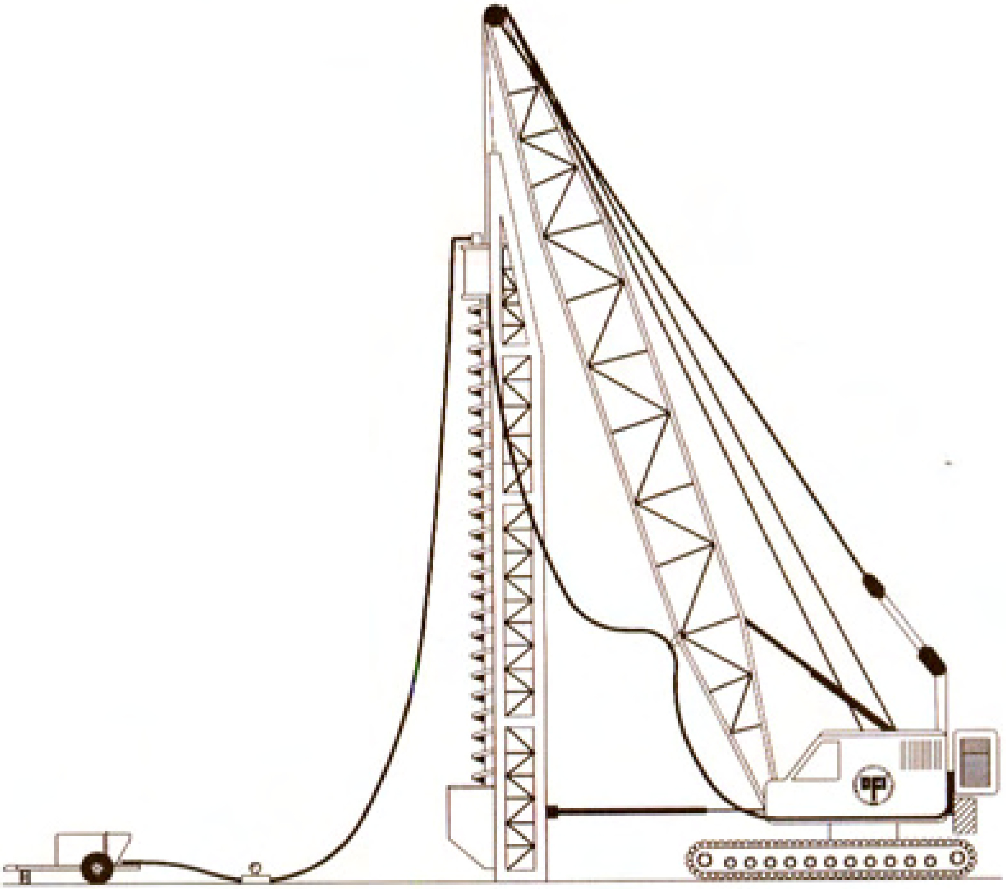
Specialty Seminar



Augered Cast-In-Place Piles

Friday, November 6, 1998 ~ Houston, Texas

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PILE INSTALLATION RECORDER TESTS FOR ACIP/CFA PILES

Garland Likins, George Piscsalko, Chris Cole

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University of Houston tests - Spring 1998

by Garland Likins[1], George Piscsalko[2], and Chris Cole[3]

INTRODUCTION

The Texas Department of Transportation, now considering using Augered Cast-In-Place (ACIP) Piles (also known as Continuous-Flight-Auger or CFA Piles) in their foundations, awarded a research project to Professor Mike O'Neill at the University of Houston (UH) to study the advantages and potential difficulties with ACIP/CFA piles. ACIP/CFA piles were installed on three sites for UH; they had extra instrumentation and additional measurements by UH staff during installation which are beyond the scope of this paper. Independent visual logging of the pile was done by an experienced inspection firm.

The main advantages of ACIP/CFA piles are their speed of installation and their economy. Potential savings are substantial. Disadvantages include an unknown structural condition of the shaft. Inspection is critical, but many simultaneous observations make accurate inspection difficult. Because of resulting uncertainty, many engineers have avoided ACIP/CFA piles in the past.

Pile Dynamics Inc. (PDI) developed the Pile Installation Recorder™ (PIR) to monitor ACIP/CFA pile installation. A schematic of the system is shown in Figure 1. The PIR is normally permanently installed so that every pile installed is inspected. These PIR measurements automatically document the augering and grouting processes and result in a graphic display of the grout volume pumped versus auger depth profile. The actual grout installed compared with the theoretical volume of the shaft is called the grout ratio. Ideally, the auger withdrawal rate should be just less than the displayed maximum withdrawal rate which results in the minimum objective grout ratio and optimal economy. If the operator observes a low grout ratio at any depth, the operator can simply redrill and regrout the hole while the grout is still fluid. PIR results are printed for a permanent record. Such inspection provides engineers with assurance that grout volume versus length was adequate, thus alleviating concerns about structural integrity, and allowing the engineer to specify ACIP/CFA piles with confidence.

Using a preliminary version PIR, PDI conducted tests on nine augercast piles for UH as part of the UH research project on augercast piles. The PIR included a magnetic flow meter to precisely measure the delivered grout volume, a pressure transducer to measure line pressure, and a depth sensor on the leads to measure auger depth. Several findings clearly demonstrate the potential value of such automated documentation.

CALIBRATION OF GROUT VOLUME

Before installing any piles, the grout pump was calibrated in the standard way for the visual inspection. A couple strokes after the pump was started, the grout was directed into a 55 gallon barrel until the barrel was nearly filled. Since only 12 counted pump strokes were used, the test precision was low. The barrel was not on level ground and a difference of several inches in grout level relative to the top was observed, complicating the calibration calculation. The pump calibration was calculated by the Inspector as 0.56 ft^3 per pump stroke (actual volume may vary

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depending on the distance required to seat the balls in the valve assembly which can vary based on pressure, grout consistency, pump RPM, etc.).

The PIR determines grout volume with a magnetic flow meter. The meter manufacturer specifies the indicated volume to be accurate to within ±0.25% for conditions of large volume and constant flow. Since ACIP/CFA piles have pulsed flow, the magnetic flow meter accuracy was checked under pulsed conditions and the calibration confirmed to an estimated ±2% (accuracy limited by our volume measurements). We are convinced the flow meter pulsed calibration is probably better than ±2%. However, even an accuracy of ±2% is probably acceptable for ACIP/CFA construction control purposes.

RESULTS FROM UH TEST

The test pile and its 4 reaction piles were monitored at the UH campus site. Reaction Pile 1 was monitored to the final auger depth to 40 feet. The volume calculated from counted pump strokes was 9% higher than the pile volume determined by the PIR for the top 25 ft (visual determination of the 25 ft depth by the less accurate visual method probably did not match exactly the depth from the PIR, so the visual pump count over this distance was slightly affected so the distribution is slightly affected as shown in Figure 2a). The Inspector observed 164 total pump strokes (19 initial to fill the lines and develop a grout head around the outside of the auger, plus 145 counted toward the shaft volume) compared with the actual mechanical pump count of 178.

When augering Reaction Pile 2 the drilling went beyond the 40 ft desired depth to an actual depth of 41.2 ft. The PIR accurately determines depth and excess lengths and therefore extra costs can be avoided. The volume from 169 counted pump strokes by the Inspector is significantly less than the grout volume measured by the PIR or the mechanical counter. The Inspector's total count of 169 pump strokes is only 93% of the 182 strokes from the mechanical pump counter (182 strokes at 0.56 ft^3 each compares to within 2.5% of the total volume obtained by the PIR).

The grout volume needs to be corrected for the auger volume. Since the grout line contained ball valves, and a check valve installed by PDI, the 3.14 ft^3 volume of the auger (3" diameter, 64 ft from top of hose to auger tip) must be filled prior to grout being pumped into the ground. Adjustments were made to PIR volumes to account for this initial volume for all piles. The Inspector typically discounted the first 18 pump strokes (10.08 ft^3) to allow for a buildup of grout head around the auger. The attached Figure 2b shows generally good agreement between the Inspector's and PIR volumes; the volume at the toe for the PIR includes the full pumped volume for the toe interval and is not adjusted for the grout head around the auger. Thus, it contains this extra (desirable) volume for the grout head buildup as compared with the visual counted stroke method which discounted grout head buildup.

During installation of Reaction Pile 3 the grout line ruptured and was replaced twice. The first line rupture was attributed to a weak hose, while the second rupture was then attributed to high pressures in the line due to a plug setting up in the hoses and auger caused by the approximate 2 hour delay. The pile was re-drilled to 40.9 ft and then re-grouted. In reviewing the data collected, the pump stroke volume based on Inspector counts consistently over predicted the actual volume of grout installed in the pile at each interval as measured by the PIR as shown in the attached Figure 3a (again as in all volume comparison plots in this paper, the PIR toe volume was not corrected for grout head pumping). The 100.8 ft^3 total volume from mechanical pump count of 180 compared with a total volume of 98 ft^3 based on 175 strokes from the Inspector's field records, while the total PIR volume was 83.3 ft^3 (83% of the volume from mechanical count based on 0.56 ft^3 per stroke). Actual grout pump volume per stroke depends on the engine speed, grout consistency, and pressure head, so the per stroke calibration may vary. The high grouting pressures and grout line ruptures probably affected the pump and certainly delayed grout placement and thus the pump was less effective for this older grout than for the previous two reaction piles, or during calibration where the grout was fresh.

Reaction Pile 4 was installed to 39.8 feet depth. As with the previous pile, the Inspector's counted pump stroke volume overpredicted the volume of grout determined by the PIR in most increments. Actually the Inspector's count of 169 strokes is low compared with the mechanical count of 182. The PIR total volume was 80% of the mechanical count total volume based on the assumed calibration, a ratio consistent with that of reaction pile 3. Due to the grout line rupture interruptions on pile 3, the grout was old, and is the probable cause for the low volumes measured. The differences in interval volumes in the attached Figure 3b show inaccuracy in visual depth determination. The difficulty of judging depth visually is illustrated here. Slight errors, compounded by counts by interval, introduce distortions into the visual volume profile. The PIR with automatic simultaneous sensing of both depth and volume provides a more reliable profile.

During installation of the reaction piles, the foreman determined the stopping depth based on markings on the leads spaced 5 ft apart. On Test Pile 1, the operator relied on the PDI depth sensor to determine when the pile had reached its desired depth. The augering phase for Test Pile 1 was slower than for the reaction piles; slow augering can result in extra soil being brought to the ground surface. The soils are reported as stiff to very stiff clay at the UH site.

The PIR volume for the toe interval is not corrected for the grout head pumping as is the Inspector's volume. A slow withdrawal was noted by the Inspector between 40 and 45 ft depth during grouting. The PIR recorded withdrawal rate noted a 39 second interval from 44 to 42 ft depth (3 to 4 times longer than normal), resulting in extra grout injected at this depth. It is noted however that the auger withdrawal rate was increased at the 14 ft depth, and thus the grout volumes are lower above this depth.

For Test Pile 1, a new batch of grout was brought to site. The Inspector's counted pump stroke volume again over predicted the measured PIR grout volume as shown in the Figure 4a for each depth interval, and the ratio is about constant. The 129.9 ft^3 total volume from the mechanical pump count of 232 compared with a total volume of 126.6 ft^3 based on 226 strokes from the Inspector's field records, while the total PIR volume was 107.7 ft^3 (again 83% of the volume from mechanical count based on the assumed calibration). Overall the PIR volume (corrected for auger filling) of 104.54 ft^3 has a grout ratio of 1.18 compared with the theoretical volume for a shaft of this length.

All five UH piles were installed on March 17. The correlation between the total grout determined by the PIR and pump stroke counts for the first two piles at this site was very good. For the last three piles, the pump efficiency was affected by the high pressure rupture and residual old grout still in the pump/hopper for reaction piles 3 and 4, and by the pump speed/pressures for the test pile (see Figure 9). The pump calibration should have been reduced to 83% of 0.56, or 0.465 ft^3 per stroke for the last three piles at the UH site.

If calibrated pump strokes are used to record the volume, the abrupt change in pump stroke volume demonstrates that the grout pump should be calibrated more than once (preferably periodically during the production process to spot check and confirm consistent pump performance). Significant variations may reflect need for pump maintenance. Such periodic calibration procedures have been observed on other projects. When PIR and counted stroke volume differed on other projects, re-calibration verified the PIR accuracy and the pump was repaired before continuing. As a result of these tests, a subsequent addition to the PIR display during pumping is the net volume per pump stroke. If the efficiency changes during a project, then the contractor is immediately aware of this change in per stroke volume. If the change is major, then corrective action can be taken to assure a quality pile is still produced.

RESULTS FROM BAYTOWN TEST

One week after finishing the UH site, the reaction piles were installed on March 23. The PIR arrived on March 24 and monitored the Test Pile (Test Pile 2) at the Baytown site. The operator relied on the PIR depth sensor to accurately stop at the desired drilling depth. During drilling, extra time (37 seconds for a 2 ft interval compared with more typical rate of 15 seconds for a 2 ft interval) was taken at about 40 ft depth (a nearby boring shows 41 ft of low N-value sand overlying hard clay), increasing the soil brought to the surface and lowering productivity. As shown in Figure 4b, the distribution of grout pumped was similar for both PIR and visual counting methods; the difficulty of determining depth visually accounts for much of the relatively minor differences observed. The PIR toe segment volume in Figure 4b was adjusted for the initially unfilled hose plus auger for the 40-50 ft interval. There was also a slow auger withdrawal at 18 to 14 ft, resulting in a large over pumping of grout during this interval. The average grout ratio for this Test Pile 2 was then 1.52 (adjusted PIR volume of 134.52 ft^3 compared with a theoretical volume of 88.35 ft^3).

The 162.4 ft^3 total volume from the mechanical pump count of 290 compared with a total volume of 162.96 ft^3 based on 291 strokes from the Inspector's field records, while the total PIR volume was 145.71 ft^3. The mechanical counter volume based on the assumed pump stroke calibration was 11% larger than the PIR volume. The pump pressure was very low for this pile for the first 34 ft (Figure 10), reflecting low pump RPM's and also the loose sandy soils.

RESULTS FROM ROSENBERG TEST

All reaction piles were installed on April 7. At the Rosenberg site, the PIR monitored only the final two reaction piles (soils were 10 ft of clay, over 10 ft of N-value 25 sand, over 50+ N-value sand). Reaction Pile 3 was drilled to 28.8 feet and the drill rate was very consistent and relatively fast. The total volume was 79.53 ft^3 from both the mechanical pump count and the Inspector's field records which both recorded 142 pump strokes, while the total PIR volume was 72.33 ft^3. The mechanical counter volume based on the assumed pump stroke calibration was 10% larger than the PIR volume. In reviewing this data, the calculated pump stroke volume method are in similar ratio throughout compared with the PIR volume as shown in Figure 5a.

Reaction Pile 4 was drilled to a depth of 26.3 feet. In reviewing the grouting data the volumes obtained by both traditional pump stroke volume and by the PIR are in generally good agreement for this pile (after initial volumes are accounted for) as shown in Figure 5b. The visual depth determination at 25 ft caused a minor difference for the bottom two intervals. The 81.76 ft^3 total volume from the mechanical pump count of 146 compared with a total volume of 81.20 ft^3 based on 145 strokes from the Inspector's field records, while the total PIR volume was 70.31 ft^3. The mechanical counter volume based on the assumed pump stroke calibration was 16% larger than the PIR volume.

Test Pile 3 was monitored to a depth of 31.0 feet. During the augering phase, the auger rate was very slow at the 14, 15 and 18 ft depths. In reviewing the grouting data in Figure 6, the calculated volume based on pump stroke counts was similar in distribution to the grout volume determined by the PIR, although the distribution for the bottom two depth increments was again affected by the inaccuracy of visual depth determination at 25 ft. The 98.56 ft^3 total volume from the mechanical pump count of 176 compared with a total volume of 100.80 ft^3 based on 180 strokes from the Inspector's field records, while the total PIR volume was 93.94 ft^3. The mechanical counter volume based on the assumed pump stroke calibration was 5% larger than the PIR volume.

Plots of the grout line pressure for several pump cycles are given for different depths for Reaction Pile 3 in Figure 7 and for Reaction Pile 4 in Figure 8. These pressures were sensed by a pressure transducer located near the magnetic flow meter. Comparisons show that the shapes and pressures are quite different for the two piles and even at different depths. For Pile 3 for the 24.5 ft depth, note that the pressures are increasing throughout even these 5 cycles. For Pile 4, there is obviously a changing situation as the pressures generated from one piston cycle are quite different from those of the second piston on this two cylinder pump. The pressures were measured at the tip of the auger (Figure 11) for Reaction Pile 1 at UH. Tip pressure measurement is possible as a specialty test, but perhaps not yet necessary for production monitoring.

Plots of the peak grout line pressures recorded near the magnetic flow meter located near the crane are shown for selected piles in Figures 9 and 10. In Figure 9, reaction pile 2 at UH represents the condition before the line rupture and corresponding to the calibration of the pump strokes. The lower pressures for Test Pile 1 at UH are due to a slower operating speed of the pump (lower RPM). The low pressures for Baytown Test Pile 2 are a combination of pump speed and loose soils (the pump speed was increased at the 16 ft depth. The grout line pressures for the more dense soils at Rosenberg are similar to those for the UH site with clay. Such variability in grout line pressures from site to site and pile to pile casts doubt on the counted pump stroke (mechanical or visual inspection) method's ability to consistently determine an accurate volume. The pump pressure variability may not directly translate to volume variability. Other factors such as soil stiffness, pump speed, ball valve operation, and grout consistency also are factors in the actual volume delivered per pump stroke. The visual inspector cannot be expected to account for all these variables, and it is not practical to calibrate the pump for every pile. The PIR with its magnetic flow meter automatically adapts and determines an accurate volume regardless of these external conditions.

SUMMARY OF TYPICAL CURRENT PRACTICE

These piles were all installed using current practice of installation and Inspection. The operator relied on the foreman and the Inspector. The data recorded by the PIR during these tests suggests several potential problems with non-monitored ACIP/CFA installations since except for the depth in a couple cases, the PIR information was not made available to the piling crew during pile installation. The data collected from only these nine piles on three test sites suggests nonuniformity in operation. Of course, larger projects with more piles will probably result in more uniformity as the contractor gets into a "routine".

For these tests, the grout volume based on the traditional method of counting pump strokes has some uncertainty due to the changing volume per pump stroke due to changing conditions. Pump calibration accuracy and consistency are critical if volumes are to be calculated from this method. The minimum and maximum line pressures for all piles were monitored automatically by the PIR and reveal that the pressures are quite different from pile to pile or at different depths on the same pile. It should not be surprising that the volume pumped per stroke is also a variable, and also that it is different from the calibration at zero head of concrete. It is concluded that due to the variable consistency of the grout, and condition or operating speed of the pump, the grout volume per pump stroke is not constant and can in fact be quite variable. Periodic pump stoke volume calibrations should be required (if a volume per pump stroke is to be used to calculate volumes based on counted pump strokes), but are often neglected.

The precision of estimating auger depth is about ± one ft. Most piles were drilled beyond their intended depth as the operator was relying on the Inspector determining when the drill was at the appropriate depth based on marks every 5 ft on the leads. These errors affect not only the total length (and cost), but also the accuracy of the grout volume recorded for each depth increment. The depth and stroke count uncertainties limit the accuracy of the visual increment volume.

There are multiple observations (time, depth, pressure, pump count, etc) to be made and recorded by a single observer in a brief installation time. Visual recording is a very difficult task and highly experienced inspectors are therefore a necessity. Time constraints and project pressures result in unintentional recorded errors. There are recorded differences in the total number of pump strokes counted mechanically and by the visual Inspector. Visual observation of counted strokes or depth can be biased by the count of the preceding depth increment, or even the minimum stroke count required per increment. Errors are possible due to recording the wrong numbers or having the hand written number read incorrectly. Several hand written entries were difficult to read.

EXAMPLE OF IMPROVED PRACTICE THROUGH AUTOMATIC MONITORING

The PIR was used on another recent project (soils are soft clays over harder layers) where the PIR was installed in the rig for the operator's continuous inspection (Figure 12). Several hundred piles were installed on this site with automated PIR inspection on each. The enclosed graphs show the uniformity achieved through knowledge of the actual and suggested withdrawal rate. The minimum required grout ratio was 1.20 while the actual minimum installed ratio was 1.25 for any segment (maximum ratio was 1.36, excluding the toe segment which in this plot was not corrected for the initial auger volume). The 14 inch diameter auger and 49.9 ft depth required 77 pump stokes at an average volume of 0.95 ft^3 per stroke. The augering phase took 4 minutes and 30 seconds and grouting took 2 minutes 29 seconds. The total cycle time (including moving to the next location was 11 minutes 46 seconds. Such timing information can be invaluable in scheduling and improving productivity. The typical enclosed printout satisfied the inspection authorities.

SUMMARY OF IMPROVEMENT OF PRACTICE THROUGH AUTOMATIC MONITORING

The PIR will improve the current inspection process and the operator (or foreman) could observe the PIR display to more effectively and efficiently control the installation (Figure 13). This will result in more uniform shafts and reduced potential for defects. Following minimal instruction, crane operators with little ACIP/CFA experience can follow the PIR display and still produce quality piles. The overall ACIP/CFA pile quality will improve as automated documentation systems are employed. The data collected and printed by the PIR will verify proper installation. Engineers and building officials will appreciate the accuracy of recording and therefore be less skeptical of shaft integrity, leading to an increased acceptance of ACIP/CFA piles.

The PDI depth sensor clearly determines auger depth very accurately to a precision never before possible with conventional visual inspection procedures, so the tendency to increase the pile depth is reduced and costs are saved. When obtaining grout volume using the PDI magnetic flow meter system, the volume pumped is measured very precisely regardless of pump operating condition. Further this volume can be related exactly to the auger depth. A reliable grout volume pumped is obtained as a function of measured auger depth for the entire shaft length. By comparing this grout volume with the required grout volume, the grout ratio is obtained instantaneously. If the grout ratio for any depth increment is too low, the pile is then simply redrilled and regrouted while the grout is still fluid and anomalous piles are eliminated. The operator's actual withdrawal rate and the calculated maximum auger withdrawal rate to produce the minimum acceptable grout ratio are both displayed, guiding the operator to install an acceptable shaft.

As a result of these tests, further improvements in the PIR automated data collection and reporting process have already been made. The calculated pump stroke volume is continuously displayed during installation. The only entry now required by the field operator is entry of the pile name; all other data collection functions can be now handled completely automatically. In fact, if a desired pile installation sequence is preplanned, it can be entered in a file and the PIR can follow this sequence and prompt the crew so that no field entry is then required.

It is envisioned that the ACIP/CFA operator will observe the PIR during installation to improve the ACIP/CFA pile. The operator can use the displayed torque (optional addition to the basic PIR used in these tests) to optimize the crane power and reduce drilling time and prevent stalling the rig. The drilling rate display and elapsed time prompt the operator to minimize the drilling time and soil spoils. The depth of drilling will be known with better accuracy and excess lengths eliminated. The grout volume ratio will be known during installation and the withdrawal rate guide will produce more uniform shafts. The PIR volume per stroke can be monitored continuously, to detect major variations and pump malfunctions. Optimized grouting results in grout savings and optimal installation times, making ACIP/CFA piles even more economic than is currently the case. Productivity and quality should both increase.

The reliability of ACIP/CFA piles can be improved by thorough and automatic PIR monitoring and the risks reduced. PIR results are printed in the field during installation to complete the necessary documentation. Alternately, the records which are stored on memory cards can be conveniently summarized in the office. Summarized documentation can automatically assist in the billing process.

As engineers become more confident in ACIP/CFA installation procedures through complete and accurate documentation, ACIP/CFA piles will be more readily accepted and approved. Every pile becomes a well inspected pile.

Table 1: Total Volume Pumped as recorded by Device

Pile name	PIR cu.ft.	Mechanical Counter cu.ft.	Ratio [ ]	Visual Inspector cu.ft.	Ratio [ ]
RP2 UH	104.64	101.92	0.97	94.64	0.90
RP3 UH	83.34	100.80	1.21	98.00	1.18
RP4 UH	81.72	101.92	1.25	94.64	1.16
TP1 UH	107.68	129.92	1.21	126.56	1.18
TP2 Baytown	145.71	162.40	1.11	162.96	1.12
RP3 Rosenberg	72.33	79.52	1.10	79.52	1.10
RP4 Rosenberg	70.31	81.76	1.16	81.20	1.15
TP3 Rosenberg	93.94	98.56	1.05	100.80	1.07

Notes:

Mechanical counter and Visual Inspector volumes from stroke counts multipled by 0.56 cu.ft. assumed calibration

"Ratio" is refered to PIR volume

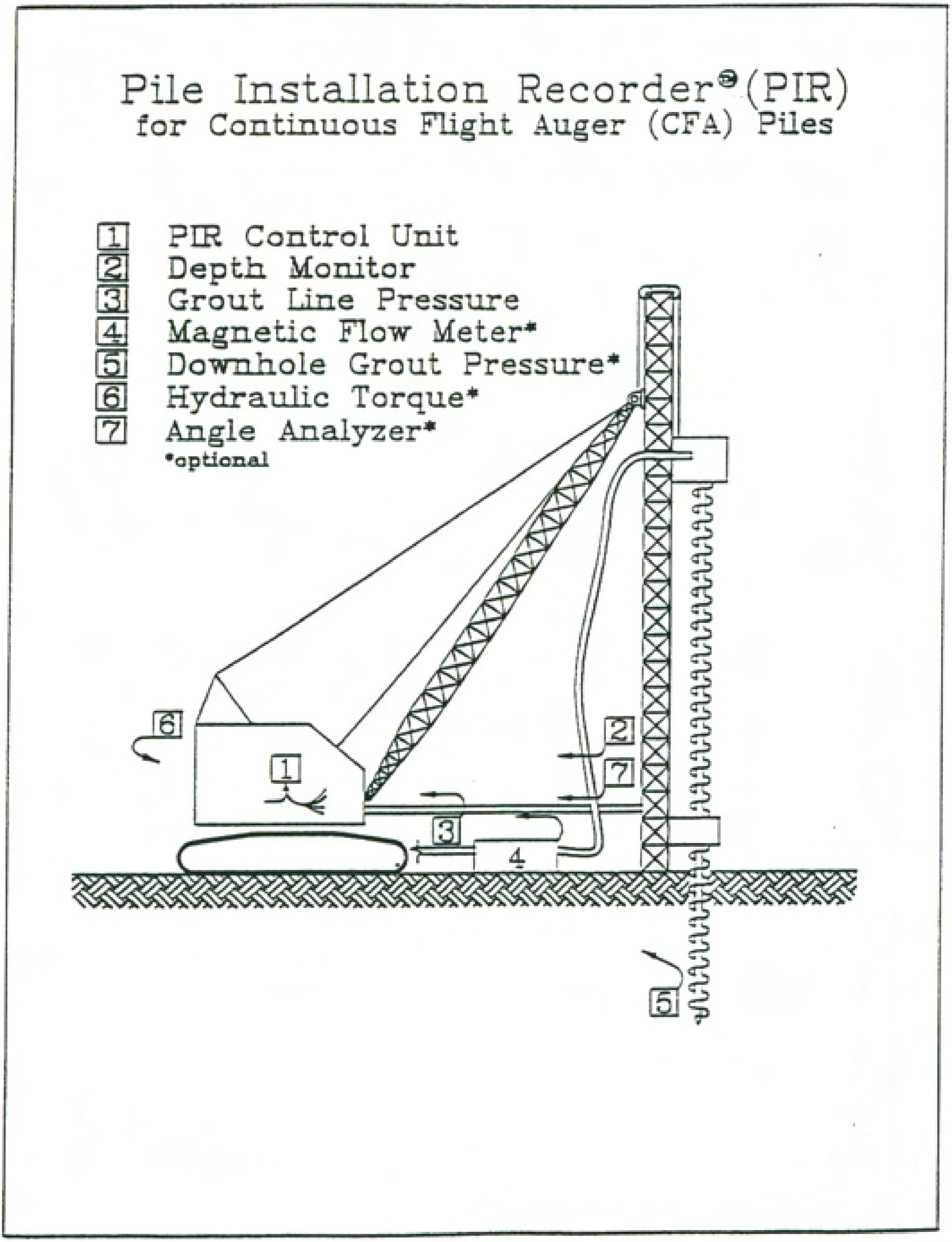
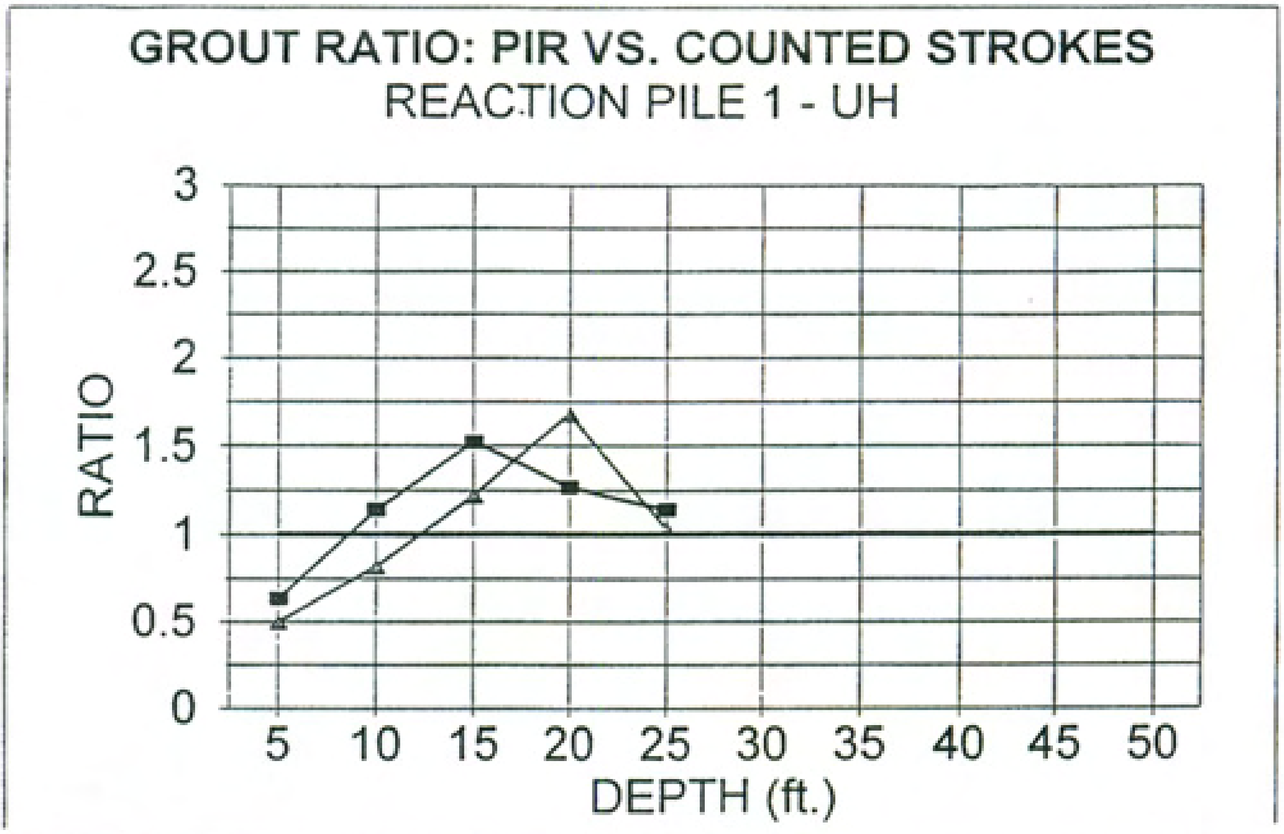


Figure 1: Schematic of PIR System



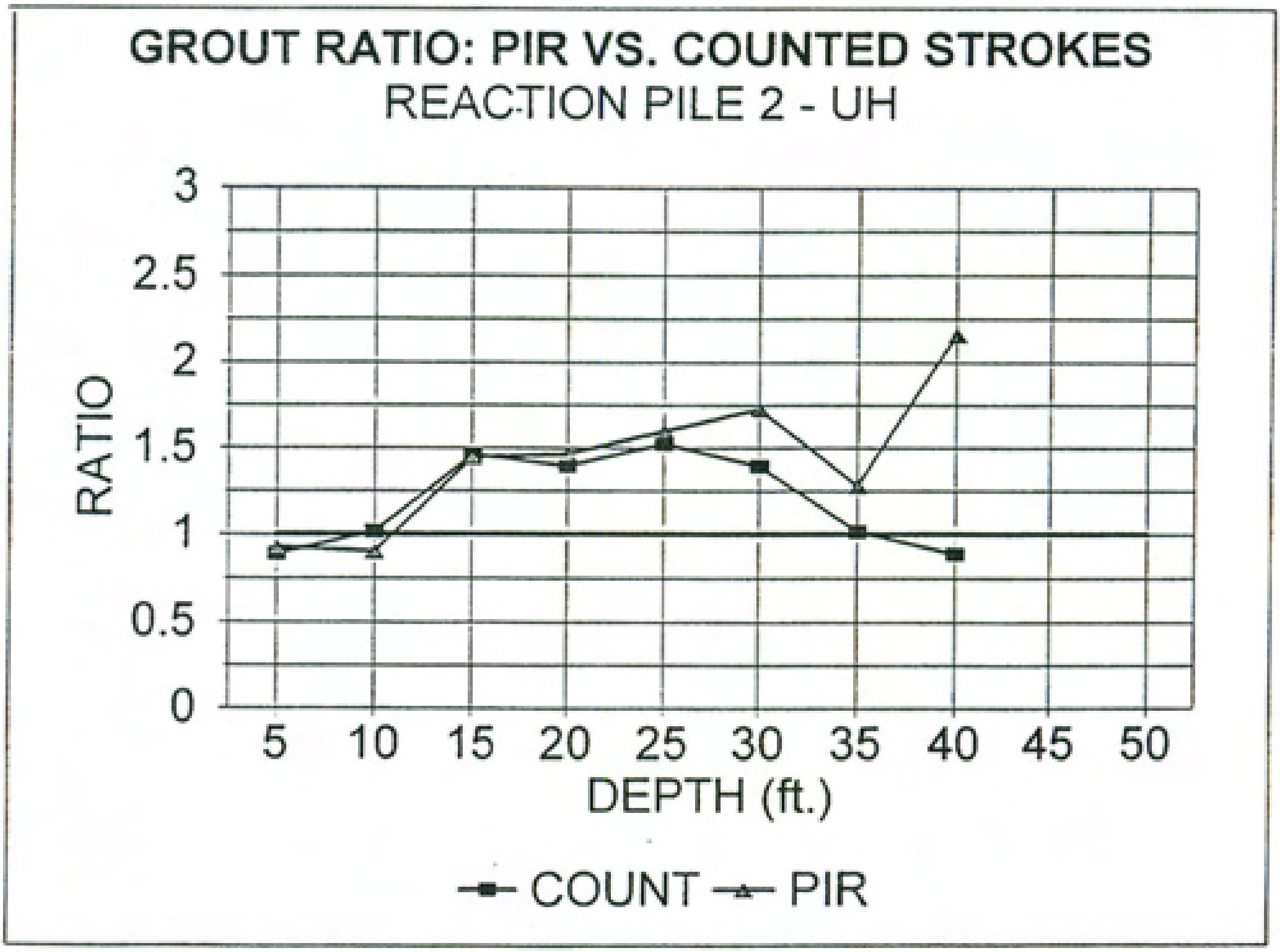


Figure 2: Grout Ratio versus Depth

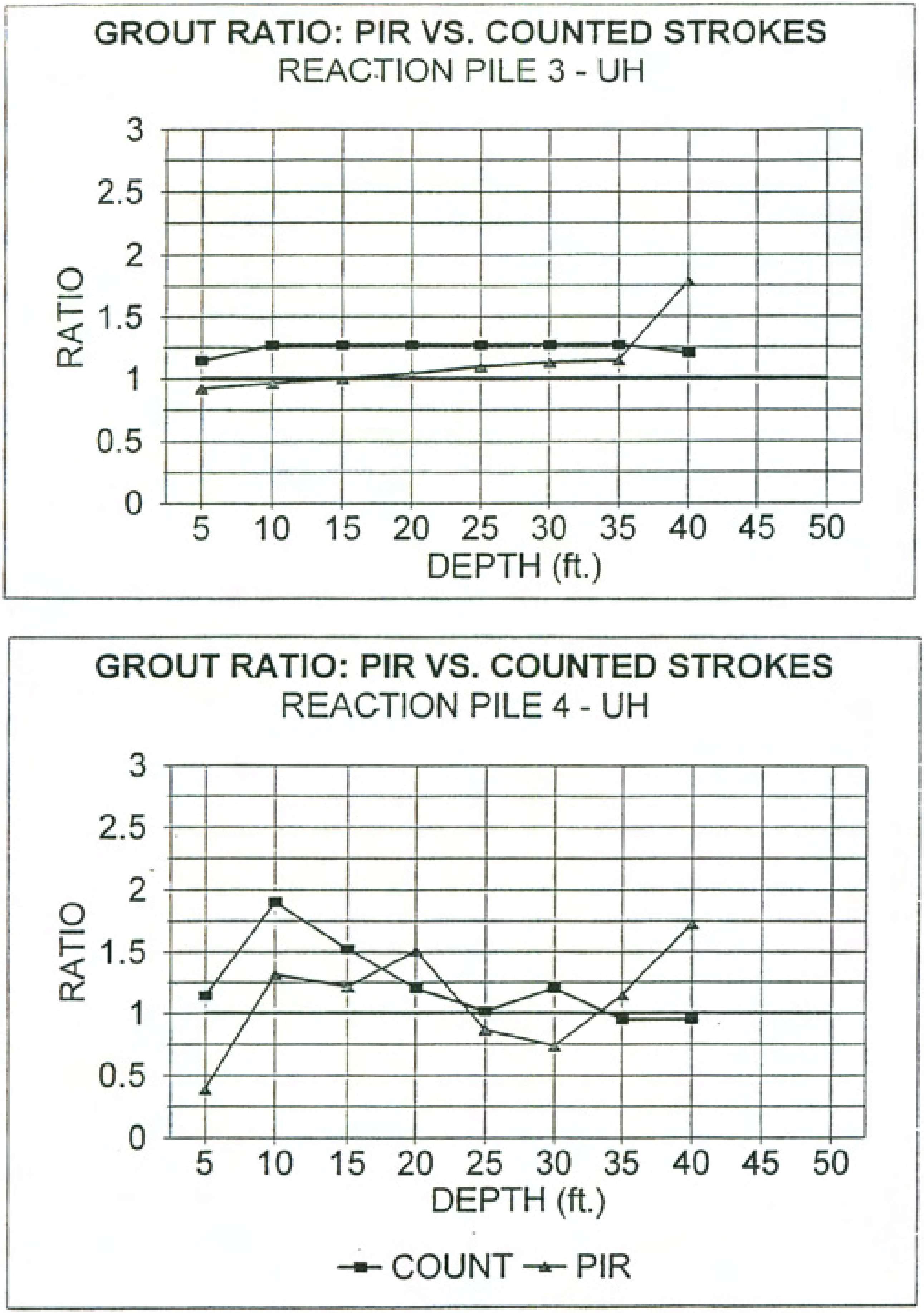


Figure 3: Grout Ratio versus Depth

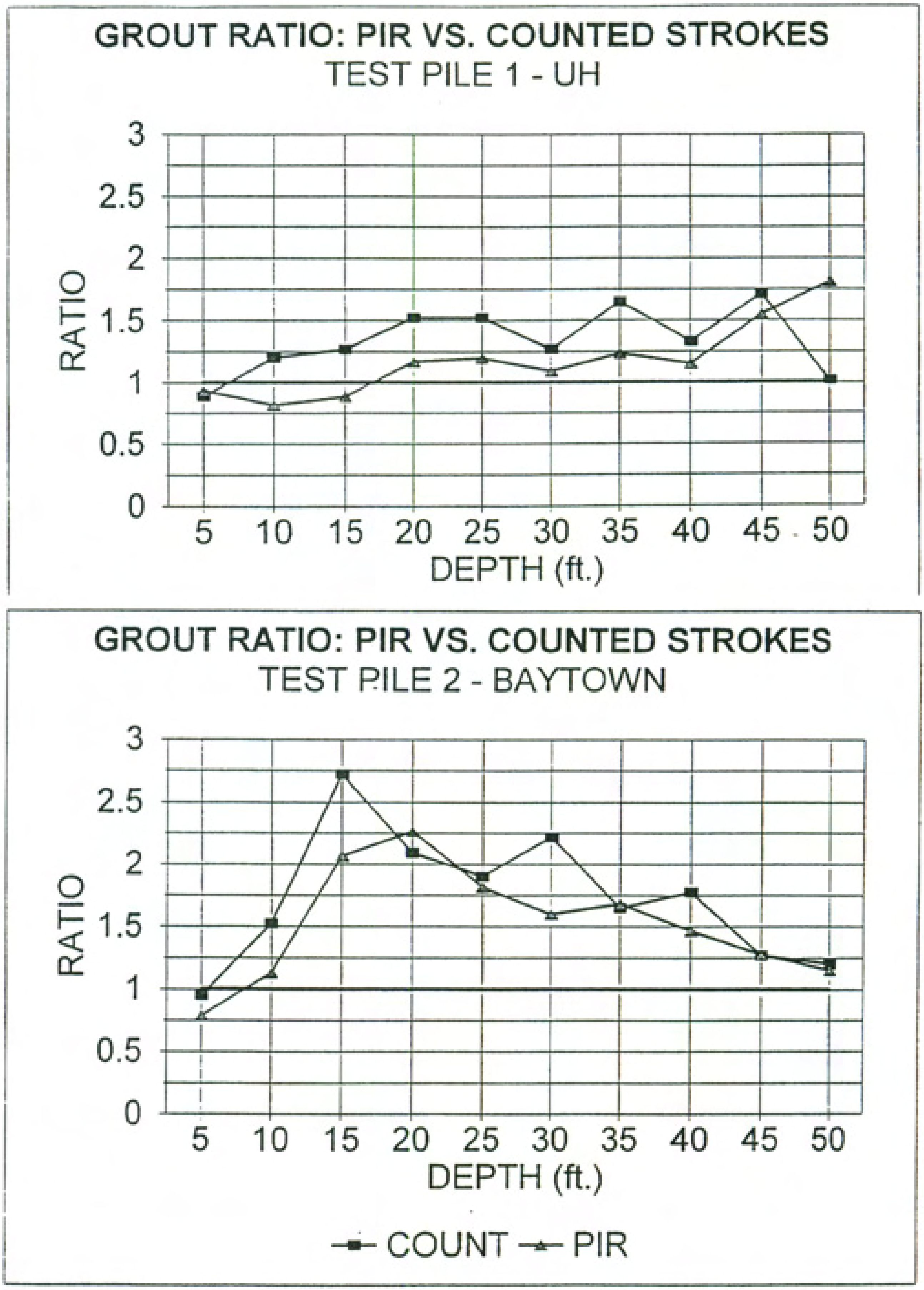
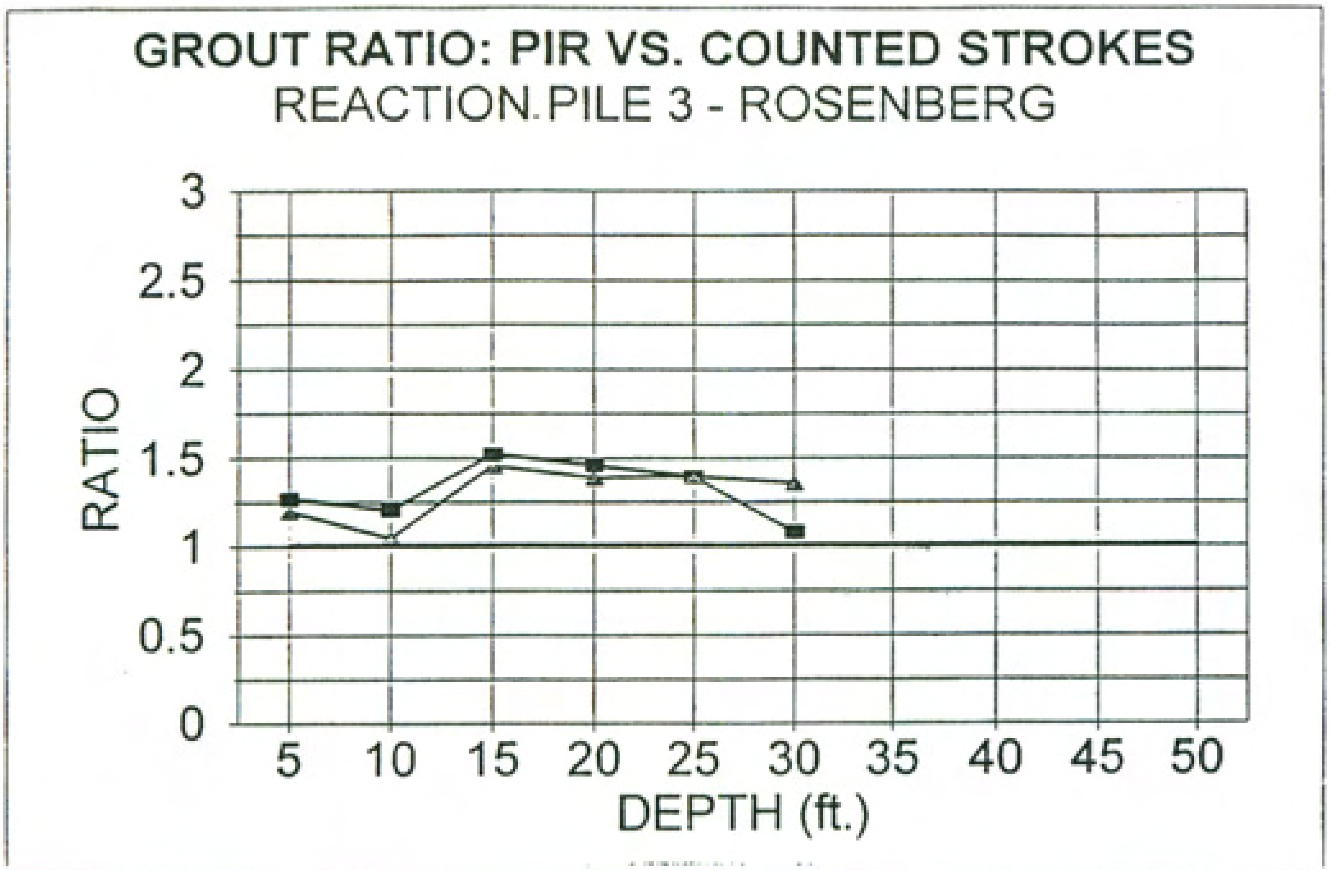


Figure 4: Grout Ratio versus Depth



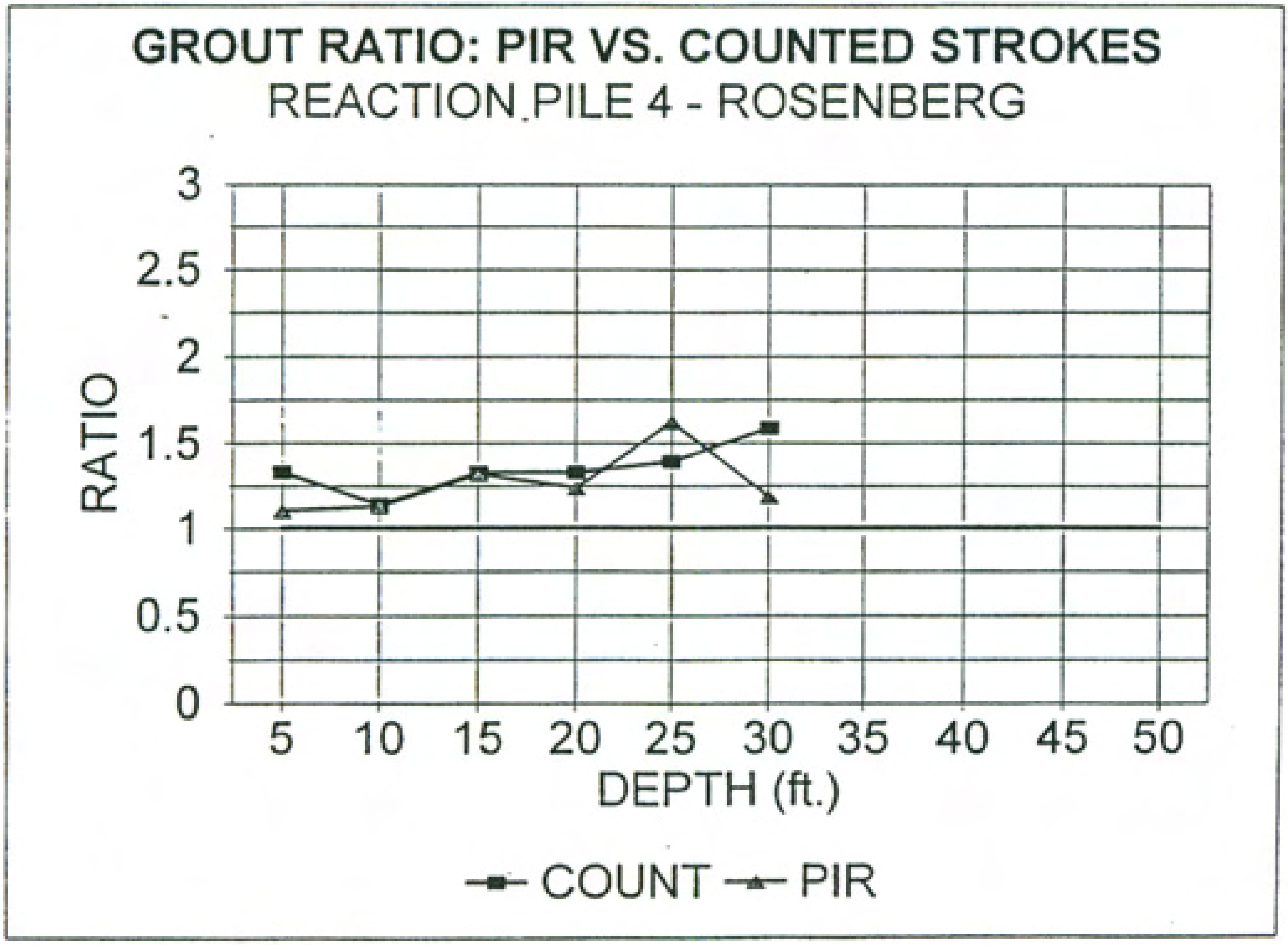


Figure 5: Grout Ratio versus Depth

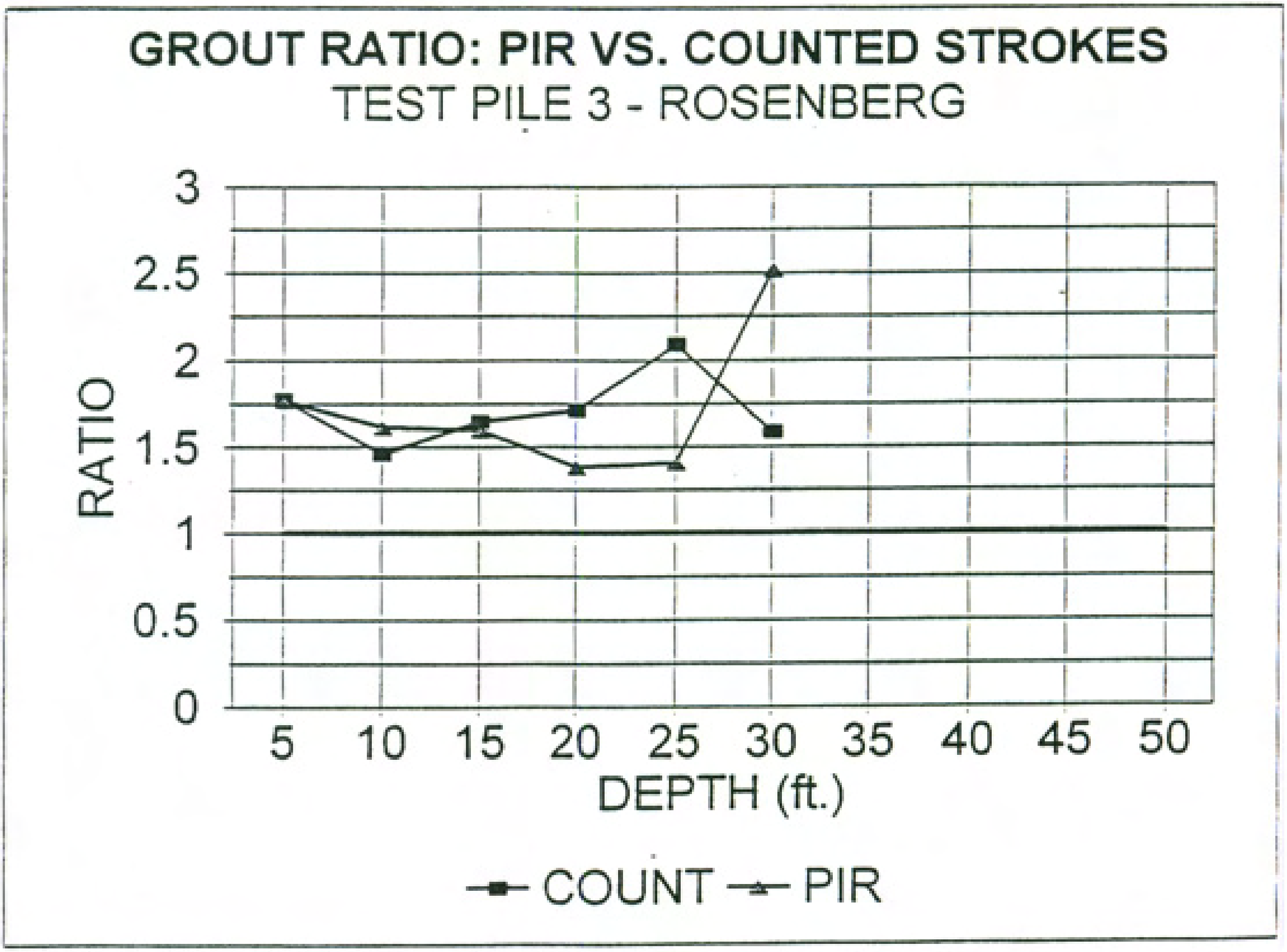
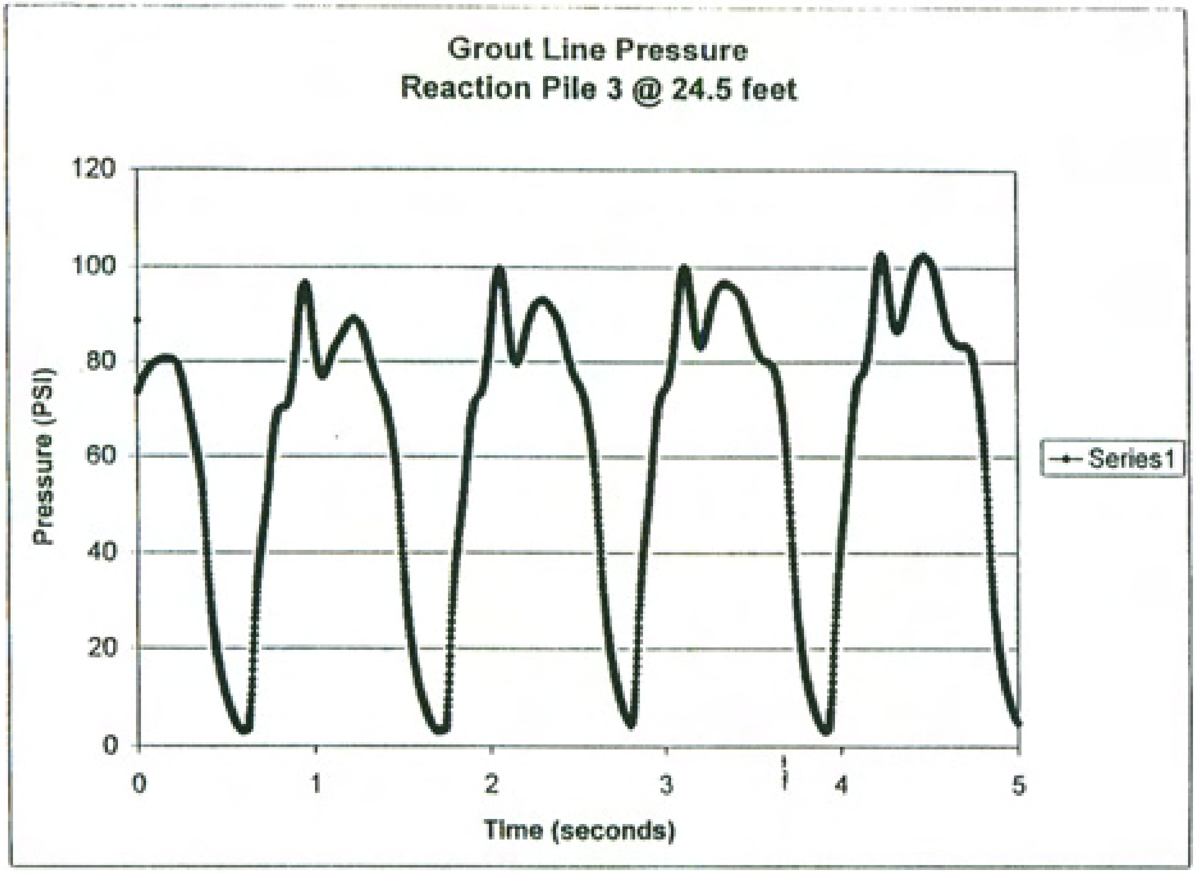


Figure 6: Grout Ratio versus Depth



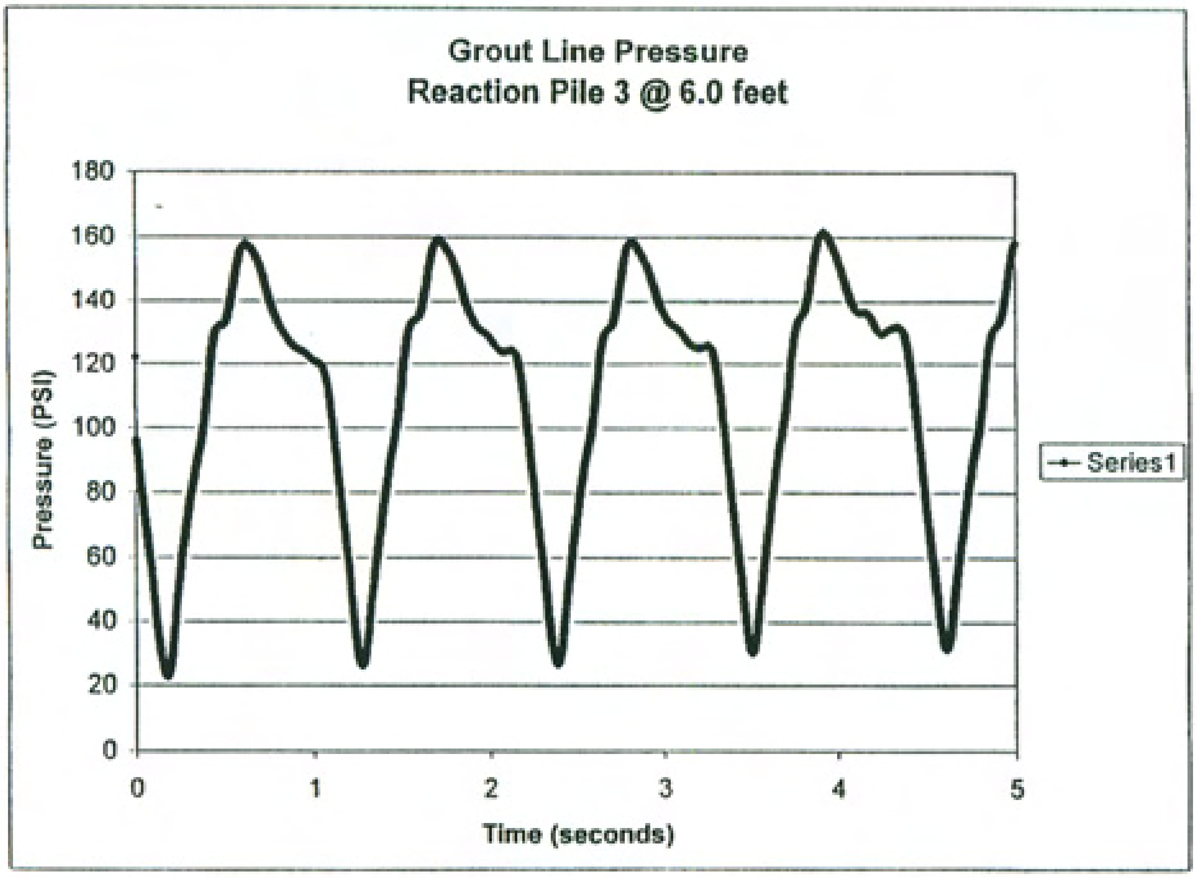
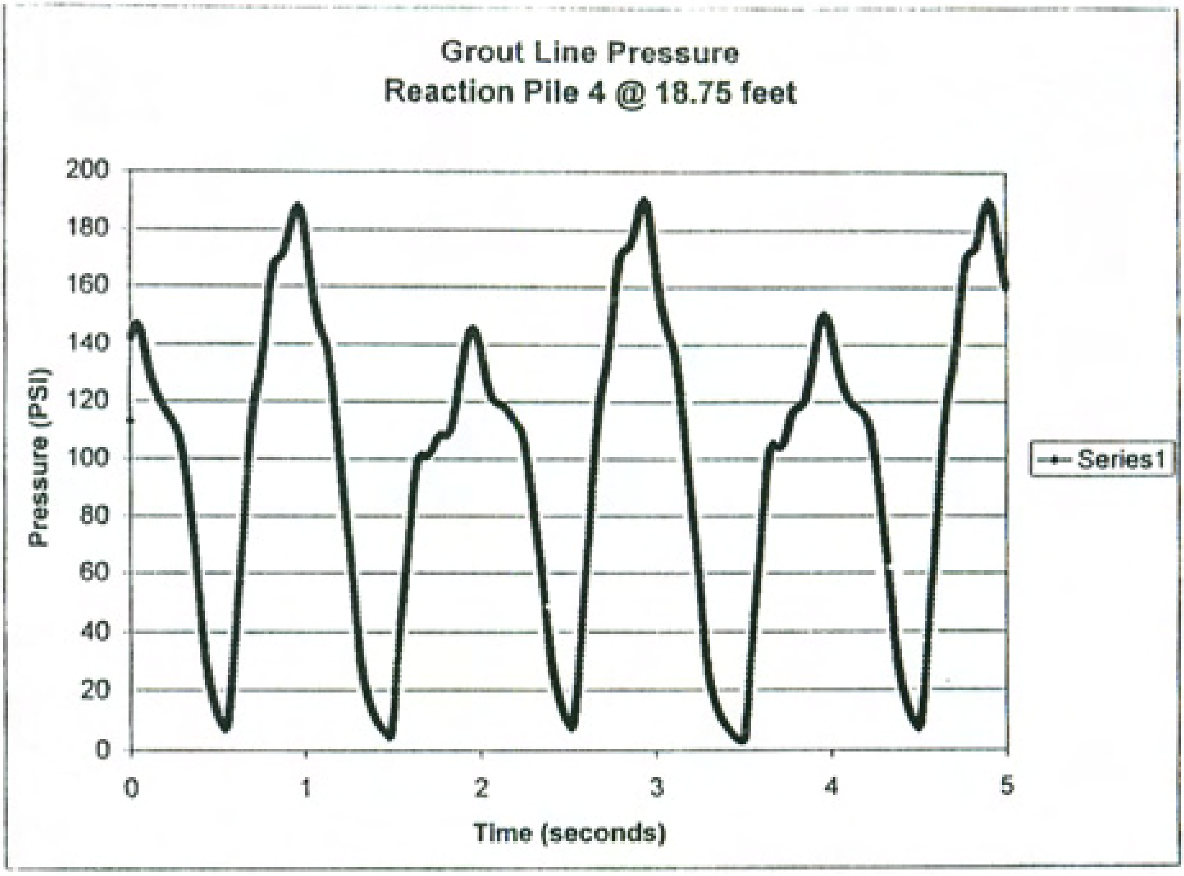


Figure 7: Grout Line Pressure versus Time



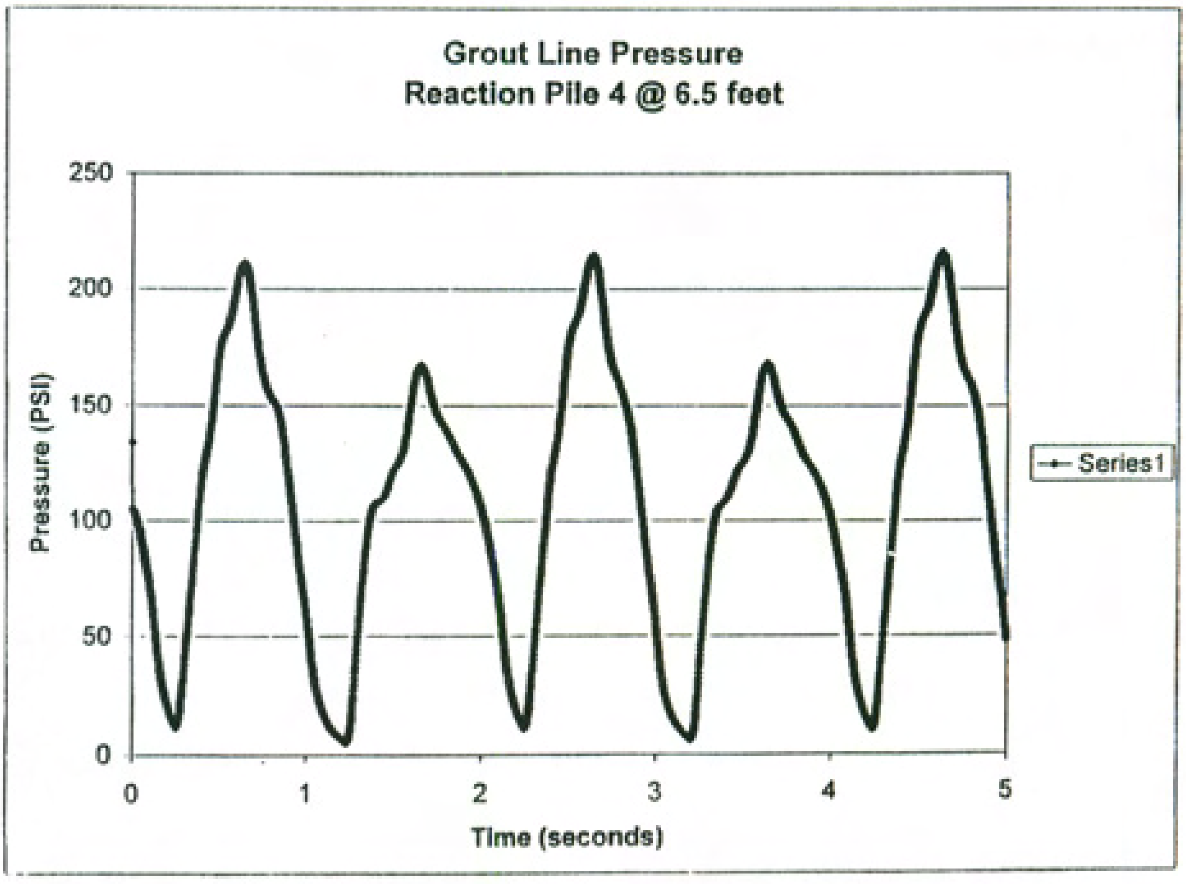
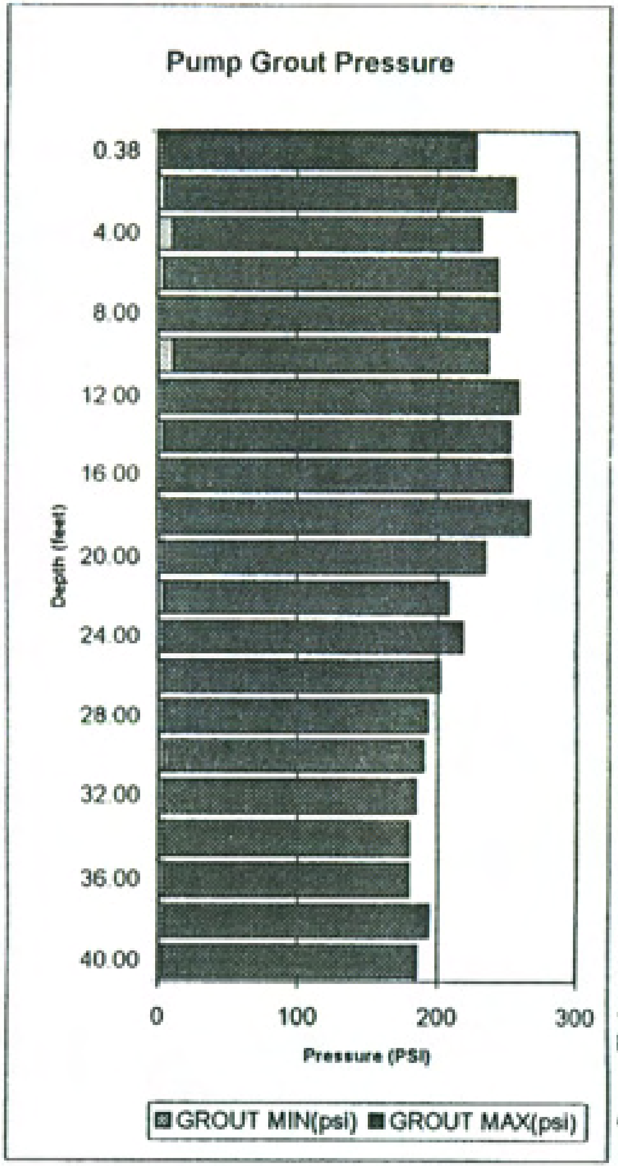
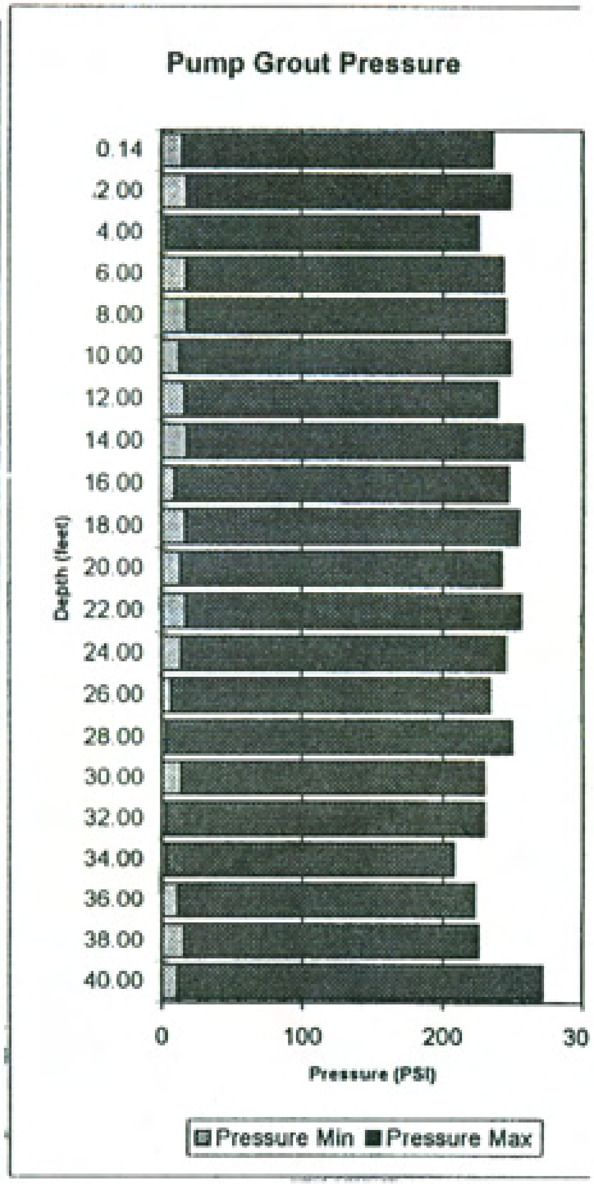


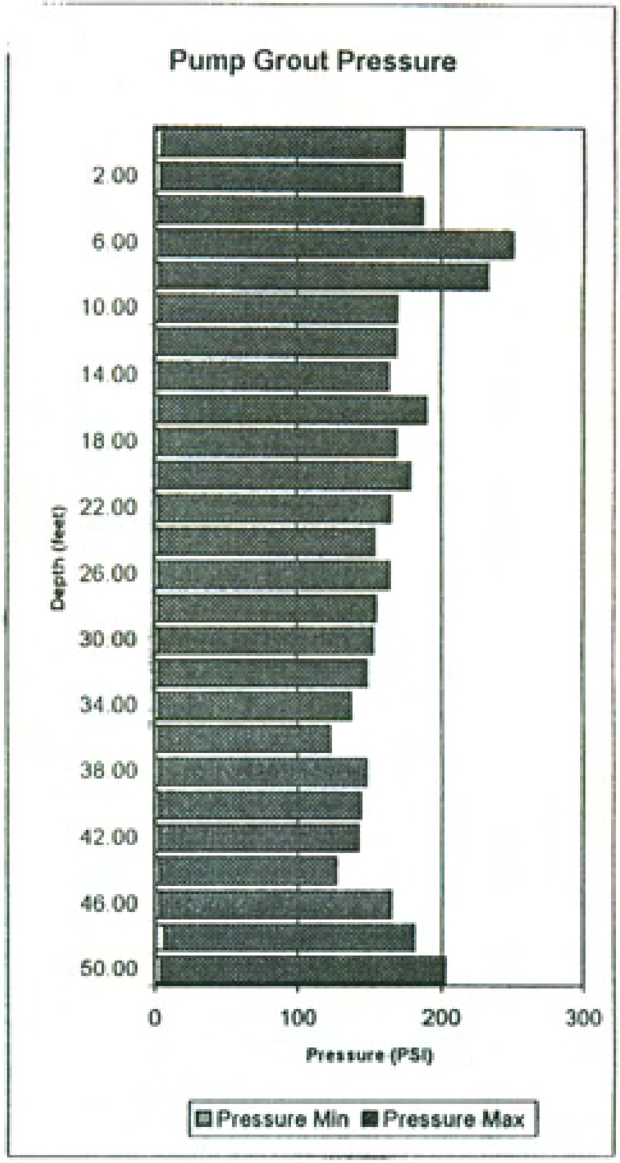
Figure 8: Grout Line Pressure versus Time



REACTION PILE 2

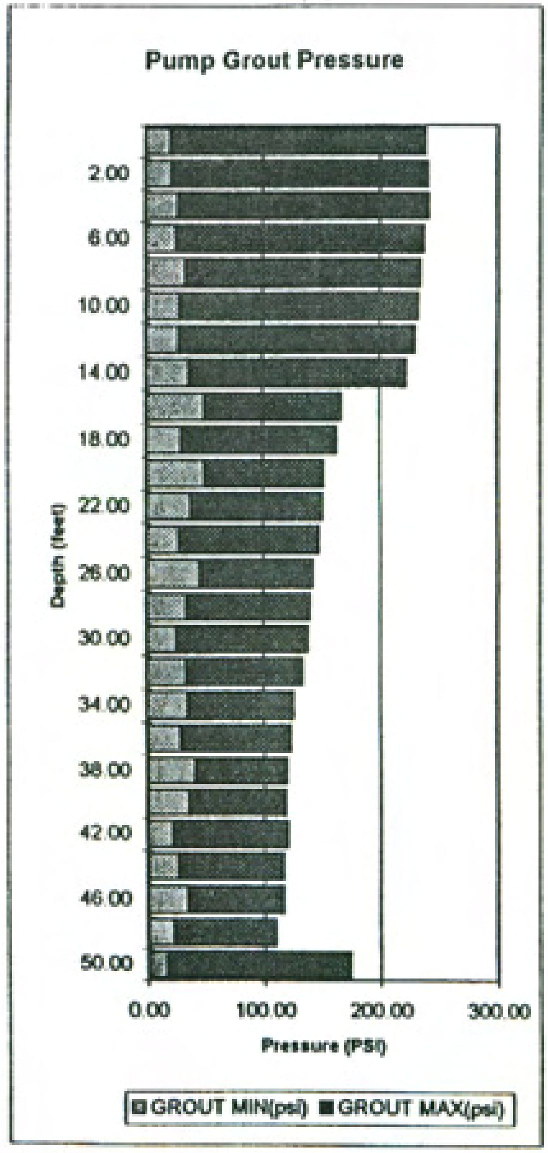


REACTION PILE 3

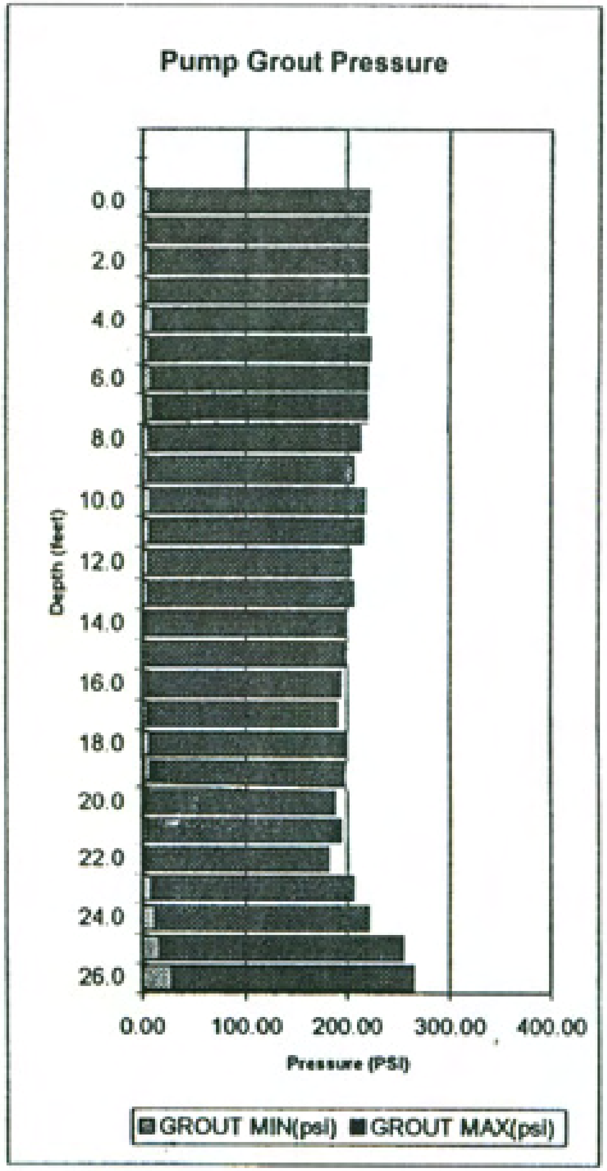


TEST PILE 1

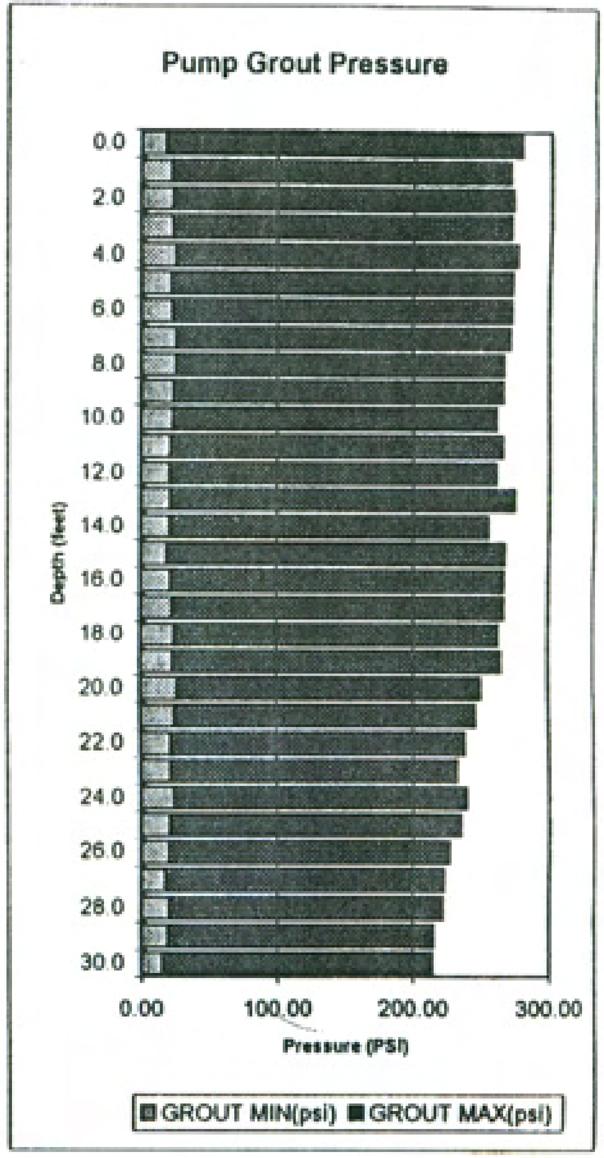
Figure 9: Grout Pressures at UH Site



TEST PILE 2



REACTION PILE 4 - ROSENBERG



TEST PILE 3 - ROSENBERG.

Figure 10: Grout Pressures at Baytown and Rosenberg

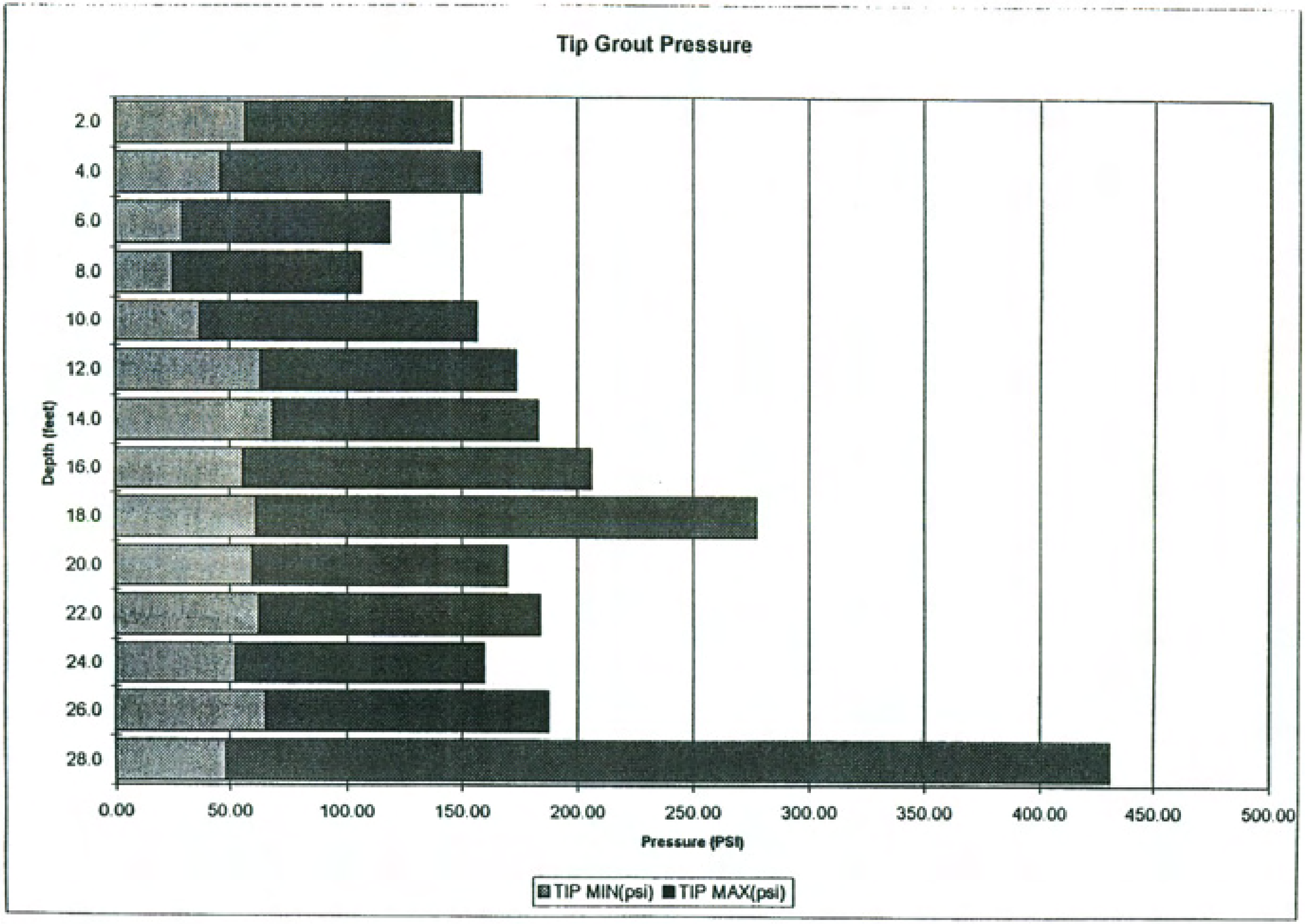
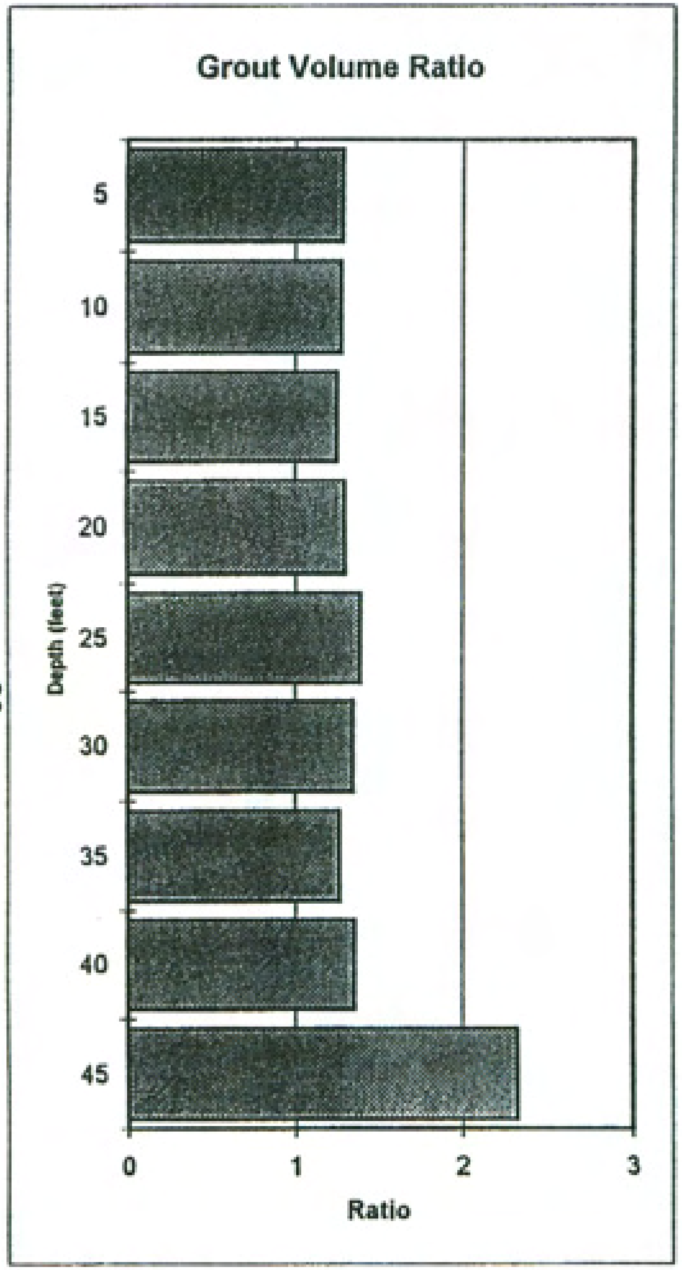
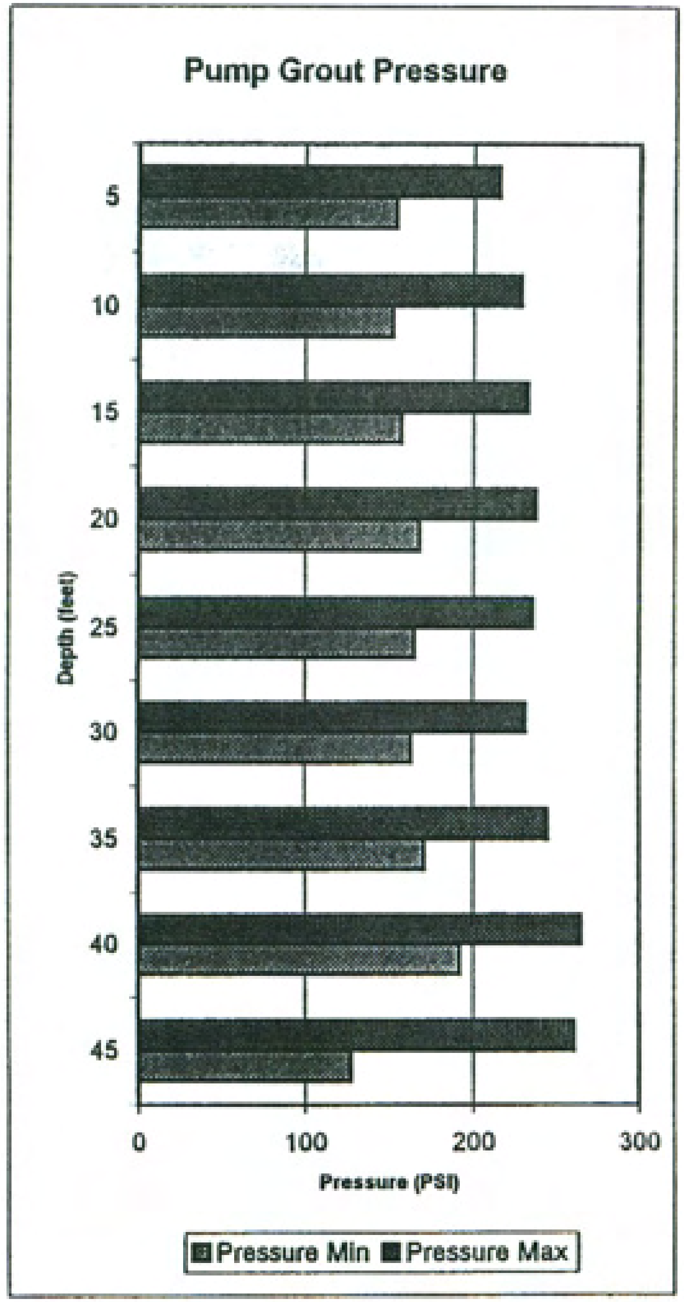


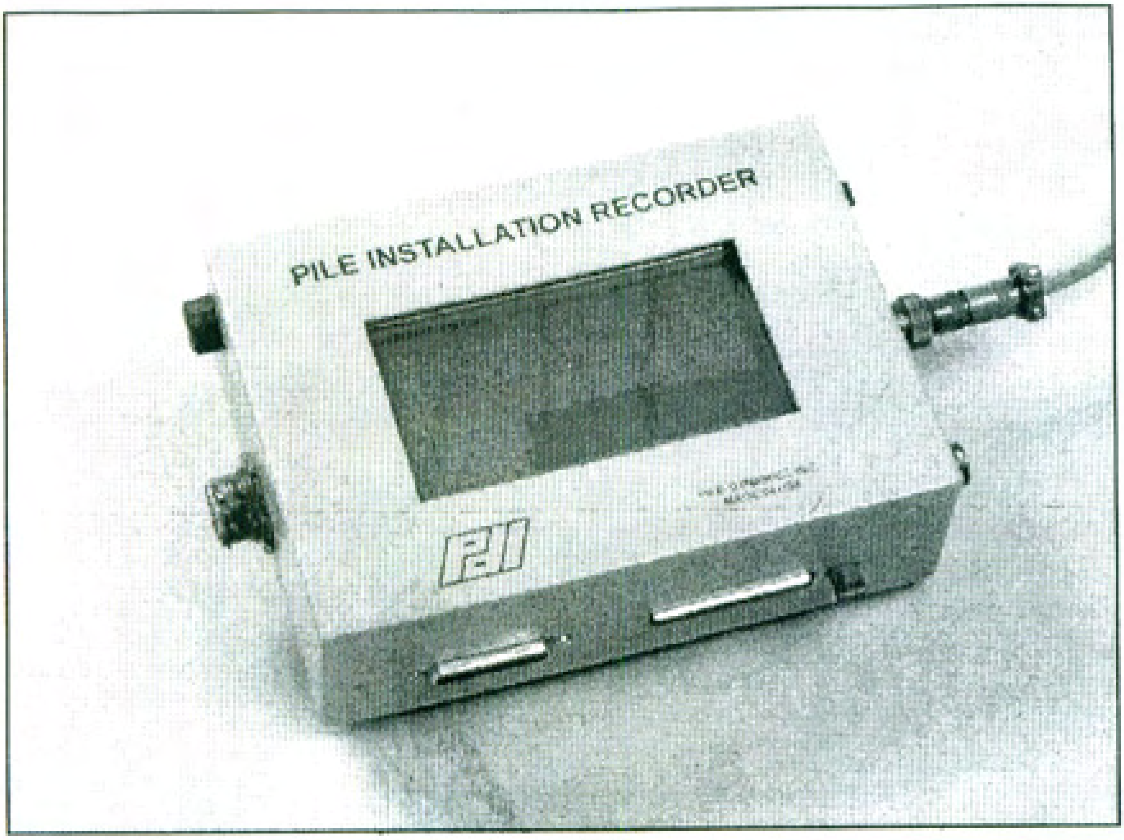
Figure 11: Pile Tip Pressure for Reaction Pile 1 at UH






```
Summary Information
  Shaft Name:        279
  Project Name:      CAM_MA
  Start Time:        1998-07-15_15:21
  Elapsed Time:      00:11:46
  Depth:             49.89 ft.
  Diameter:          14.02 in.
  Theor Volume:      53.46 ft3
  1.20x Theor Vol:   64.15 ft3
  Grout Volume:      73.21 ft3
  Grout Ratio:        1.37
  Pump Strokes:      77
  Auger Volume:       0.00
  Stroke Volume:      0.95 ft3
  Min Grout Pres: 127 PSI
Augering Data (1998-07-15_15:21)
  depth  time  interval  torque
     5  00:50     50        0
    10  01:09     19        0
    15  02:23     74        0
    20  02:50     27        0
    25  03:13     23        0
    30  03:28     15        0
    35  03:56     28        0
    40  04:12     16        0
    45  04:30     18        0
Grouting Data (1998-07-15_15:30)
  depth  volume  strks  grout  tip
    45   15.36    14    127    1
    40    7.27     8    192    0
    35    6.78     7    171    0
    30    7.24     7    163    0
    25    7.45     8    165    0
    20    6.96     7    168    0
    15    6.71     7    157    0
    10    6.85     7    152    0
     5    6.89     7    154    1
            (1998-07-15_15:33)
  grouting time: 149 sec.
```

Figure 12: Output for Integrated *PIR* System



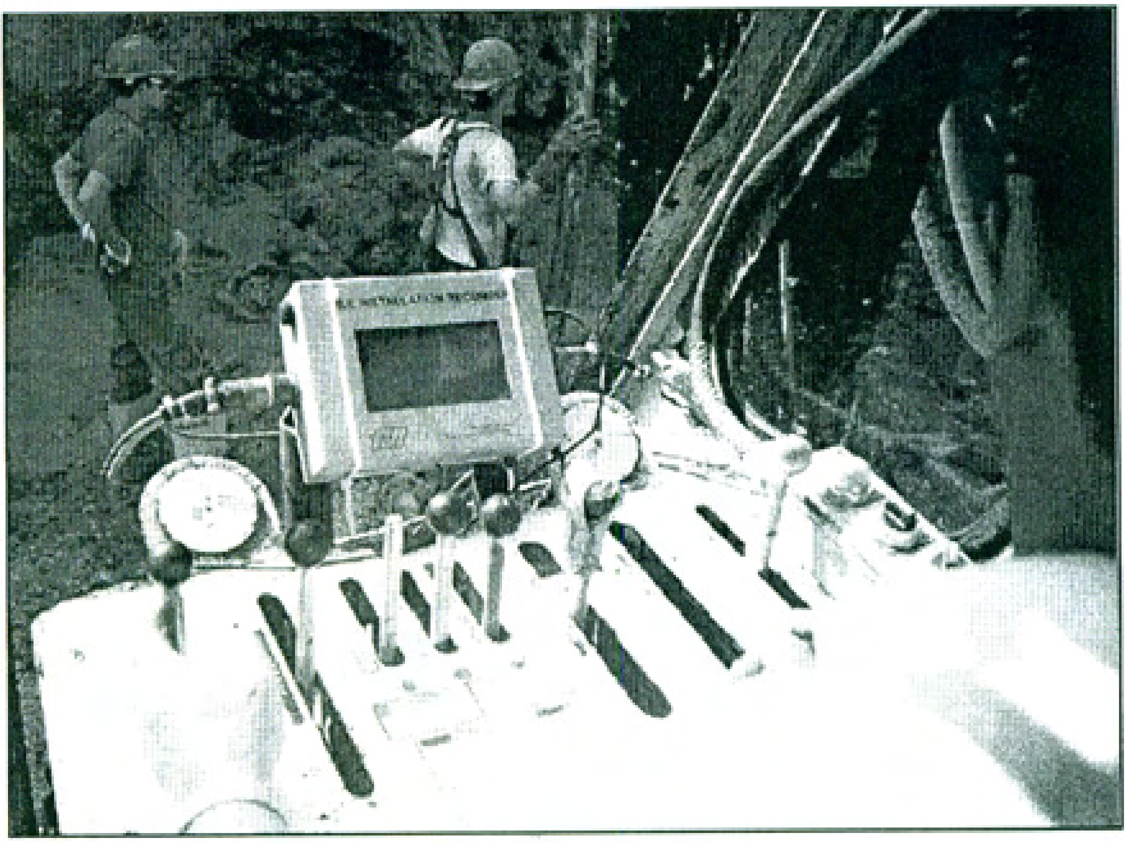


Figure 13: PIR screen and shown mounted in pile rig