Engineering Standard

SAES-Q-004 30 November 2004
Installation of Piles and
Conductors for Offshore Structures

Saudi Aramco DeskTop Standards

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1 Scope

This standard presents the basis for installation of piles for use in offshore structures and coastal zones. This specification does not apply to onshore pile installation.

This standard describes the equipment, materials, personnel and procedures that shall be used to install offshore structure piles and conductors. The intent of this specification is to provide minimum installation requirements for offshore pile foundations, including anticipated problems and recommended remedial action that may be required in the event that pile installation does not proceed as expected.

The project specification for each individual job shall include penetrations of piles and conductors, lengths of concrete plugs or any other specific construction requirements to supplement the general requirements of this SAES.

Commentary:

A project specification is issued for most projects and gives requirements applicable for the site specific soil conditions, structure, pile types and loads.

In addition to the above information, the pile installation specification should also include project site geotechnical data, pile design drawings, pile capacities with applied safety factors, pile acceptance, driving criteria, and description of planned remedial action.

The sections on conductor/piles are included to provide installation guidance on these elements. Conductor/piles provide foundation support to the structure and are used for oil drilling and production purposes. The use of conductor/piles is not generally recommended because of inherent conflicts in design and construction of such dual use elements. Recommendations on installation of conductors on a structure are provided primarily to prevent damage to soil formations and reductions in the capacity of nearby foundations and support piles.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standard

SAES-M-005	*Design and Construction of Fixed Offshore Platforms*

Saudi Aramco Form and Data Sheet

3063-ENG	*Pile Driving Record*

3.2 Industry Codes and Standards

American Association of State Highway and Transportation Officials

AASHTO T26	*Standard Method of Test for Quality of Water to be Used in Concrete-HM-22*

American Society for Testing and Materials

ASTM C150	*Standard Specification for Portland Cement*
ASTM C494	*Standard Specification for Chemical Admixtures for Concrete*
ASTM C618	*Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzalan for Use as a Mineral Admixture in Concrete*

American Petroleum Institute

API RP10B	*Recommended Practice for Testing Oil-Well Cements*

4 Pile Marking and Installation Records

4.1 Pile Marking

Piles and added lengths of pile in excess of the water depth shall be marked with 12 mm wide stripes on 0.25 m centers. Stripes are to be painted with oil-based paint to cover at least 50% of the pile perimeter. Every fourth stripe shall be marked with the corresponding meter number, measured from the tip of the pile.

4.2 Pile Installation Records

A complete set of pile installation records shall be prepared by the contractor's site engineer. All records shall be made available to Saudi Aramco Representatives immediately upon request. Items that must be included in the records for each operation are listed in the following subsections.

Pile driving records shall be kept on Saudi Aramco Form 3063-ENG, "Pile Driving Record".

4.2.1 Driving

The following items shall be accurately recorded for each pile or conductor driven: date, time, overall pile length, length of added pile sections, cut-off lengths at piles, driving shoe (size and length), pile size (wall thickness and outside diameter), splice location, and splice details, interruptions during driving, total depth of penetration before and after drilling pilot holes, number of blows for every 0.25 meter (depending on marking system) of penetration, hammer type and size, operating air or steam pressure and volume, type and dimensions (diameter and thickness) of cushion block, and cushion packing details, overhang pile lengths, and depth to top of internal soil plug. Any unusual phenomena or difficulties encountered during driving shall also be recorded.

4.2.2 Drilling

The following records shall be kept for all drilling operations: date, time, bit size, centralizers spacing, hole penetration, pile tip penetration (if applicable), type, weight and viscosity of drilling fluid, and interruptions during drilling. Any unusual phenomena or difficulties related to the drilling program shall also be recorded. This includes drilled hole collapse, drill bit plugging, equipment breakdown, and withdrawal from drilled hole.

4.2.3 Insert Piles

Records required for insert piles installed in pre-drilled holes shall include: date, time, pile length, pile wall thickness and outside diameter, total depth of penetration, splice locations and details, interruptions during installation, over drill depth, internal grout plug length (top of grout to closure plate), and any unusual conditions observed during this portion of the installation operation.

4.2.4 Grouting

Contractor shall provide for all grouting operations: date, time, grout mix, setting time, and unit weight of grout samples, grouting pressure, ability to establish static head, volume change, compressive strength, seafloor leakage, interruptions or other problems encountered during grouting, time and number of each grout sample taken, and any unusual conditions observed during the grouting operation.

4.2.5 Distribution

All records described above shall be signed by the Saudi Aramco Representative only to indicate concurrence with data presented and not to indicate approval. Four copies of records for each pile and conductor shall be forwarded immediately following installation to the responsible Saudi Aramco Construction Engineer.

5 Pile Installation Planning

5.1 Procedures used to install piles to achieve the specified design capacity shall be selected on the basis of the results from the geotechnical site investigation performed at the site, pile drivability analyses, and pre-installation planning.

All piles shall be installed by driving into existing undisturbed soil, except where sound rock strata greater than three (3) pile diameters thick is located within 12 m of the seafloor, or where pile refusal occurs above terminal penetration.

Jetting will NOT be permitted either on the inside or on the outside of any pile.

Pile installation procedures that are acceptable for use in Saudi Aramco operating areas are listed in Table 1. Alternative installation procedures will be subject to review and approval by Supervisor, Civil Engineering Unit, CSD.

Table 1 – Accepted Pile Installation Procedures

	Procedure	Application Conditions
a)	Driven Piles	All locations, where soil conditions consist of soft to very stiff clay and loose to dense sand with weakly cemented layers and with thin layers of very weak, weathered or highly fractured rock.
b)	Drill Out Soil Plug and Redrive Piles	Locations where strong soils, such as stiff and cemented clay, cemented sand and rock, have caused driven piles to refuse at penetrations above the terminal penetration.
c)	Predrilled Pilot Hole and Redrive Pile	Locations where strong soils, such as stiff and cemented clay, cemented sand and rock, have caused driven piles to refuse at penetrations above the terminal penetration and insitu soil will remain stable during and after drilling the pilot hole.
d)	Driven Piles with Internal Grout Plugs	At locations with soil conditions similar to those listed for driven piles, and where the internal soil plug resistance is not adequate to develop the full end bearing capacity of the soil strata below the tip of the pile, such as shallow penetration piles, piles where the soil plug has been removed, and where pilot holes have been drilled.
e)	Driven Main Piles with Drilled and Grouted Insert Piles	Locations with soils conditions consisting of highly cemented clay, cemented sand, and weak to strong rock. Also to be used where premature refusal occurs well above the required driven pile penetration. Main pile shall accommodate lateral loads and grouted insert shall provide axial resistance.

5.2 Geotechnical Site Investigation

The geotechnical site investigation to be used in the planning effort shall be in accordance with the requirements set forth in Saudi Aramco Engineering Standard SAES-M-005. The boring/piezocone penetrometer (PCPT) performed for the investigation should be located within the confines of the platform piles.

6 Driven Pile Installation

6.1 Pile Driving

6.1.1 Stabbing of piles and pre-driving

Contractor shall stab all piles or pile sections in all corner legs of the platform and predrive by putting the hammer weight on each pile. The sequence of stabbing should attempt to follow a diagonal pattern to reduce sideways drift. The expected penetration under pile weight plus hammer weight shall be analyzed prior to installation as part of the pre-installation planning work effort.

For tripod platforms it may be necessary to predrive only two piles to prevent interference of the batter piles.

6.1.2 Driving Sequence of Piles

If the platform jacket is not level after setting and predriving, the Contractor shall first drive the pile or initial section of the pile at the lowest corner of the jacket. Then the jacket shall be leveled and the top of the jacket leg shall be attached to the driven pile or pile section with a temporary welded connection. The remaining piles shall then be driven to design penetration. Finally, (if required) the first pile shall be spliced and redriven. During driving, every effort should be made to maintain the jacket top at the specified elevation.

6.1.3 Driving Sequence of Well Conductors

Well conductors on multi-well platforms shall be driven to design penetration beginning in the center of the group and working toward to the outside.

6.1.4 Test Pile

The first pile to be driven to design penetration or refusal shall be considered as the test pile. The test pile is used to prove pile capacity and setup at the site. Dynamic measurements and CAPWAP type analysis are performed on the pile after at least 12 hours of setup. Saudi Aramco Representative shall approve the DMS/CAPWAP report. Based on the driving characteristics of the test pile the Contractor and Saudi Aramco Representative shall re-evaluate the splicing schedule, the soil stratigraphy, and pile design parameters.

Contractor shall revise the lengths of additional pile sections if so instructed by the Saudi Aramco Construction Engineer in order to reduce the risk of pile refusal before design penetration has been achieved due to driving interruptions.

6.1.5 Insurance Piling

Unless specified otherwise, the Contractor shall have available at the site a minimum 9 m long section of piling in addition to the design length of piling. This extra length shall be available for each pile to cover the possibility of having to drive piles deeper than the design penetration. The purpose of insurance piling is to allow pile driving to continue while additional pile material is brought to the site.

6.1.6 Closure Plates (Steel or Rubber Diaphragm)

Closure devices are used on the lower end of the jacket columns and pile sleeves to provide buoyancy. They should be designed to avoid

interference with the installation of the piles.

Closure devices shall NOT be removed by punching them off with the piles. Diaphragm rupturing tools can be used to remove the closure plates.

6.1.7 Stabbing Guides

Add-on pile sections should be provided with guides to facilitate stabbing and aligning them with the already installed pile sections. Fit up between the pile and the guides should be tight and uniform.

Guides should be designed to support the full weight of the add-on pile section prior to welding the pile sections together.

6.1.8 Lifting Eyes and Weld-on Lugs

Lifting eyes and weld-on lugs used for pile handling shall be designed to accommodate stresses associated with initial pile pickup, stabbing and impact loads as may occur during the handling of the pile.

Where lifting eyes and weld-on-lugs are used to support the initial pile section from the top of the jacket, each eye or lug should be capable of resisting the entire hanging weight.

In all cases, the padeyes should be designed to resist all possible out-of-plane bending loads.

Where lifting eyes and/or weld-on-lugs are on lengths of pile that will remain in service, they should be removed by torch cutting 6 mm from the pile steel surface and subsequently be ground smooth to prevent damage to internal jacket leg elements such as packers during pile driving.

6.2 Pile Driving Equipment

Contractor shall supply all equipment and experienced personnel for driving piles in accordance with plans and specifications.

All pile driving equipment shall be in good operating condition when brought to the work site and shall be approved by the Saudi Aramco Representative at the site.

6.2.1 Pile Hammers

Contractor shall select suitable pile hammers to drive the piles to the

design penetration, based on the drivability analyses performed as part of the pre-installation planning.

If not specified by Saudi Aramco, the Contractor shall submit the hammer characteristics (size designation, ram weight, anvil weight, fall height, etc.), cushion block characteristics (material type, coefficient of restitutions, etc.) and proposed splice schedule to Saudi Aramco. These data shall be submitted to Saudi Aramco at least 60 calendar days prior to the commencement of installation.

6.2.2 Pile Hammer Guides

Pile hammer guides shall provide a close fit to the pile wall and must hold the hammer properly in line with the pile.

6.2.3 Boilers and Air Compressors

Boilers or air compressors shall be capable of continuously supplying a volume of steam or compressed air equal to at least 125% of the hammer manufacturer's, recommended volume, and pressure requirements. Easily accessible calibrated gauges shall be provided on the work vessel deck for verification of the pressure. Adequate safety relief valves should be provided on the boilers. All hoses should be inspected frequently for leakage and replaced if necessary.

6.2.4 Cushion Block Material

Contractor shall supply cushion blocks made of micarta, wire rope or bongossi wood, in accordance with the pile hammer manufacturer's recommendations. Cushion block materials other than those listed above shall be approved by Saudi Aramco Representative prior to the commencement of construction.

6.3 Pile Installation Monitoring

All pile installations shall be monitored with dynamic pile monitoring (DMS) equipment, operated by trained personnel and analyzed by engineers, all approved by Supervisor, Civil Engineering Unit, CSD.

6.3.1 The choice of the DMS system to be used will be made by the Supervisor, Civil Engineering Unit, CSD, based on the results of the pile drivability analyses, pile driving experience in the area, experience with a specific pile hammer, confidence in the site investigation data and assigned soil parameters, and expected installation problems identified during the pre-installation planning effort.

Saudi Aramco will provide the monitoring equipment and personnel, unless otherwise specified.

Contractor shall provide assistance where necessary to install the monitoring equipment on the piles, jacket and work vessel.

6.3.2 Dynamic Pile Monitoring (DMS)

6.3.2.1 A list of all dynamic monitoring equipment shall be submitted to Consulting Services Department for review and approval at least three months prior to use in the field.

Dynamic pile monitoring equipment shall provide real time force - time curve, wave velocity, stresses in the pile, hammer energy, ram impact velocity, hammer and system efficiency, cushion stiffness, cushion coefficient of restitution, and soil resistance to driving (SRD). These data shall be recorded and submitted to Saudi Aramco Representative within three hours after the end of pile driving for each platform.

Within three hours after driving, conduct an analysis on a high quality representative hammer blow to obtain soil resistance to driving (SRD). The SRD shall be performed using force/velocity signal matching techniques with results reported in metric units. Closed form real time solutions will not be accepted. The SRD analysis and results shall be provided to Saudi Aramco representatives. The SRD force/signal matching results shall include:

- Shaft friction versus depth
- End bearing at analyzed penetration
- Extreme compressive stress vs. depth
- Extreme tension stress vs. depth
- Maximum velocity vs. depth
- Maximum displacement vs. depth
- Comparisons of driving results with soil conditions
- Computed factors of safety using SRD and appropriate setup
- Comparison of required FS and computed FS.
- Recommendations on pile acceptance

Commentary:

The SRD for piles in compression shall be taken as the sum of shaft resistance and end bearing.

The SRD for piles in tension shall be taken as 0.67 x shaft resistance after the bottom three pile diameters of shaft resistance has first been removed. The bottom three diameters of shaft friction is subtracted to avoid confusing end bearing and shaft resistance at the tip. The 0.67 multiplier models an assumed distribution of shaft friction of 2/3 on the outside of the shaft, and 1/3 on the plug side (inside) of the shaft.

6.3.2.2 The minimum complement of personnel that will be associated with dynamic pile monitoring includes:

6.3.2.2.1 Senior Geotechnical Engineer with a minimum of 10 years of related experience in offshore operating environments, to provide field data gathering, interpretation capability, and recommendation on accepting or rejecting the pile as needed.

6.3.2.2.2 Electro/Mechanical Technician or Engineer with a minimum of 5 years experience in offshore operating environments, to assist the Geotechnical Engineer, instrument piles and maintain equipment.

6.3.2.2.3 A resume of all Dynamic Monitoring personnel with above qualification will be submitted to Supervisor, Civil Engineering Unit, CSD for review and approval, at least three months prior to mobilization.

6.4 Pile Driving Requirements

Pile driving should proceed continuously or with as little interruption as possible to reduce increases in driving resistance during delays. Setup tests with DMS monitoring/analysis shall be planned on at least one pile per structure to demonstrate adequate capacity at or near final penetration.

Suitable complete backup pile hammers should be supplied and readily available, especially when driving through soil layers that will develop increased driving resistance (setup) during delay periods.

6.4.1 Terminal Penetration

Terminal pile penetration is the penetration achieved at the completion of

pile driving operations. At terminal penetration the capacity of the pile and the penetration of the pile shall be checked against design requirements to determine acceptance.

Piles shall be driven to the design penetration, and a minimum resistance specified for the site, or to refusal.

Design penetration shall be based on the static axial pile capacity and lateral load requirements for each site, calculated in accordance with the procedures presented in SAES-M-005.

Calculated static axial capacity may be revised based upon data measured during monitoring of pile driving. Any resulting revision in required pile penetration shall be approved by the Supervisor, Civil Engineering Unit, Consulting Services Department, Saudi Aramco, Dhahran.

In the event that the pile refuses at a penetration less than the design penetration and the calculated static axial capacity is less than the design requirements, remedial action shall be taken to provide the design pile capacity requirements.

6.4.2 Driven Pile Refusal

Pile driving refusal with properly operating hammer is defined as the point where pile driving resistance exceeds either 300 blows per 30 cm for at least 150 cm or 800 blows per 30 cm of penetration. (This definition applies when the weight of the pile does not exceed four times the weight of the hammer ram. If the pile weight exceeds this, the above blow counts are increased proportionally, but in no case shall they exceed 800 blows for 152 mm of penetration.)

If there has been a delay in pile driving operation for one hour or longer, the above refusal criteria shall not apply until the pile has been advanced at least 25 cm or the hammer has been operated at the manufacturer's rated speed for at least 15 minutes, following the resumption of pile driving.

Minimum acceptable pile hammer efficiency at refusal shall be 90% for steam and diesel pile hammers.

Driving should be terminated, however, when driving stresses become more than 90% of the yield stress.

6.4.3 Minimum Driving Resistance

Minimum final driving resistance for driven piles shall be specified for each individual job.

Minimum final driving criteria should be based on the results of dynamic analyses such as wave equation, the data of geotechnical investigation, past experience in the area and/or pile load tests.

6.4.4 Cushion Blocks

Prior to commencing driving, the cushion block shall be inspected by the contractor and Saudi Aramco Construction Engineer and replaced if required to ensure that the pile can be driven to design penetration without interruptions caused by failure of the cushion blocks.

Acceptable ranges for cushion stiffness shall be specified for locations where pile refusal is expected. The cushion block or hammer shall be changed when measured cushion stiffness is outside the acceptable range.

6.4.5 Pile Splices

Any splice made to a pile extending more than 5 m into clay layers at penetrations of more than 15 m below the seafloor will probably experience sufficient increases in driving resistance (set-up) to make the continuation of driving difficult. Therefore, splice locations shall be chosen to minimize the possibility of refusal due to the increase in driving resistance.

6.4.6 Grout Plug

When the soil plug is drilled out of the pile and the pile re-driven or a predrilled hole is used to facilitate driving, a grout plug must be placed to develop end bearing of the pile. The pile should first be cleaned out as described in Paragraph 7.2.7 and the grout plug placed in accordance with Paragraph 9.3.7. The length of the grout plug shall be specified for each specific job.

7 Drilling

7.1 Drilling Equipment and Personnel

The Contractor shall supply all equipment, materials and experienced personnel required to drill soil plug from inside piles, drill pilot holes, and drill holes or pre-drill holes for insert or grouted piles. Before arriving at the site, all

equipment shall be approved by Saudi Aramco Representative and shall be in good operating condition.

7.1.1 Drill Rig

The drill rig shall be either a rotary type, power swivel or turbo drill. The rated torque for these units shall not be less than 8100 N.m. (6000 ft. lbs).

7.1.2 Support Equipment

The support equipment to accompany the drill rig shall include the following:

(1) As a minimum, a supply of drill pipe that is at least 125 mm diameter to drill to design penetration, including pup joints and cross-over subs with a 100% reserve.

(2) An adequate supply of drill collars to provide bit manufacturer's recommended weight to drill bit and bumper subs for use from floating barge.

(3) Stabilizers of appropriate size and number to keep drill string aligned in hole.

(4) Two roller type bits with jets of each size required.

(5) Positive displacement pump(s) capable of providing at least 1100 liters per minute to the bit together with suction and discharge hoses.

(6) Small tools and spare parts for rig and pump repairs to maintain equipment in good working order.

(7) Air lift equipment for removing cuttings.

7.1.3 Additional Equipment

The following additional equipment shall be provided if drilling mud is used:

(1) One active mud tank of at least 7600 liters capacity.

(2) One mud storage tank of at least 2300 liters capacity.

(3) Mud return collector and pump for flow equal to at least 1100 liters per minute.

7.1.4 Specifications

The Contractor shall provide Saudi Aramco with equipment specifications for review at least 30 calendar days prior to mobilization.

All drilling equipment and drilling equipment specifications are subject to Saudi Aramco Approval.

7.1.5 Assembly and Testing

All drilling equipment shall be mobilized at the job site in time to allow testing at least one day prior to earliest need.

7.1.6 Personnel

Experienced drillers and helpers shall be supplied by the Contractor for each shift to drill and handle equipment. One drilling supervisor shall be supplied for overall control of drilling procedures.

7.2 Drilling Procedures

7.2.1 Purpose

Drilling in conjunction with offshore pile installation may be done for one of the following reasons:

(1) Drilling out soil plug from inside pile prior to re-driving.

(2) Drilling out soil plug from inside pile and pre-drilling pilot hole to near the terminal pile penetration prior to re-driving.

(3) Drilling out soil plug from inside pile and pre-drilling holes for grouted insert piles below driven pile section.

(4) Drilling holes for grouted piles.

All piles installed in drilled holes shall be grouted into place.

7.2.2 Removal of Soil Plug

The soil plug can be removed from a pile using a bit with a diameter slightly less than the inside diameter of the pile.

Drilling to remove a soil plug should stop one pile diameter or at least 1.5 m above the tip of the pile, whichever is greater.

7.2.3 Pre-drilled Pilot Holes

A predrilled pilot hole to assist driving shall stop two pile diameters or 2 m above terminal penetration whichever is greater. The diameter of the pre-drilled hole shall be less than 75% of the outside diameter of the pile when mostly in clay and, less than 50% of the outside diameter of the pile when mostly in sand.

Predrilled pilot holes of diameter up to 95% of the pile diameter may be used to drive piles into competent rock layers.

Where pilot holes are used the axial pile capacity shall be re-evaluated to account for the reduction in insitu soil stress caused by the drilling. In all cases the driven pile skin friction and end bearing unit values in disturbed zone shall be reduced by at least 25%. In addition, the unit skin friction values shall be reduced by 25% along the length of the already driven pile for a distance of at least five (5) pile diameters above the pile tip.

7.2.4 Anchor Piles

For anchor piles subject to lateral loads only, the diameter of the predrilled hole may be increased to the outside diameter of the anchor pile.

7.2.5 Predrilled Hole for Insert or Grouted Piles

Predrilled holes for grouted insert piles or grouted piles should provide at least a 76 mm clear space around the pile to be grouted to the full design penetration.

7.2.6 Drilling Fluid

Seawater with an air assist can be used as drilling fluid to remove drill cuttings in stable clays, rock and sand layers of limited thickness. Drilling mud shall be used to pre-drill holes in unstable clays and sand deposits greater than 4.5 m thick. Specifications for drilling mud are given below:

Soil	Mud Weight kg per m^3	Viscosity, m^2/sec
Clay	1140 to 1200	55 to 60
Sand	1140 to 1200	80 to 100

Drilling mud supply should be adequate to maintain continuous and speedy drilling operation.

7.2.7 Stabilizers

Stabilizers shall be employed at 9 m intervals along the drill string to provide a straight and true hole.

7.2.8 Cleaning the Hole

7.2.8.1 Internal Grout Plug - After drilling out the internal soil plug and re-driving the pile to an acceptable penetration and prior to installing the grout plug, all loose soil shall be removed from the inside of the pile.

7.2.8.2 Pilot Hole - After drilling the pilot hole and re-driving the pile to an acceptable penetration, all loose soil shall be removed from inside the pile prior to placing the grout plug.

7.2.8.3 Insert or Grouted Piles - Drilled hole shall be washed for at least 15 minutes after reaching design penetration, so as to remove all loose soil and drilling mud from the hole.

7.2.9 Detailed Drilling Procedure

Contractor shall provide Saudi Aramco with a detailed drilling procedure for approval prior to commencing drilling. The procedure shall include equipment descriptions and all techniques to be used, as well as the drilling fluid program to be followed.

8 Insert or Grouted Piles

8.1 Size and Length

Insert or grouted piles shall be of the size and length indicated in the Pile Installation Specification and drawings for a specific job.

8.2 Centralizers

Piles shall be equipped with centralizers at 6 m to 9 m intervals to ensure proper alignment in the predrilled hole, so that a uniform grout envelope can form around the entire pile.

8.3 Pile Placement

Piles shall be placed in the predrilled holes and should advance into the hole under self weight plus the weight of a pile hammer, if necessary. No blows shall be applied to any pile to be grouted. The tip of pile shall be 30 cm above bottom of predrilled hole.

9 Grouting

Contractor shall provide all equipment, materials and experienced personnel required to grout structure piles in jacket sleeves, structure piles to insert piles and structure or insert piles to foundation formations. All equipment shall be in good operating

condition when it is brought to the job site and shall be approved by the Saudi Aramco Construction Engineer at the site.

9.1 Grouting Equipment and Personnel

9.1.1 Grouting Equipment

The following minimum support equipment shall be supplied by the contractor for grouting operations.

9.1.1.1 Bulk Cement

(1) One air operated grout surge tank unit with mixing hopper.

(2) Three 31 m^3 conical bottom pneumatic cement silos ("P" tanks) or equivalent.

(3) Two pump skids each equipped with diesel or turbine powered positive displacement cementing pumps and a 5.7 m^3 tank calibrated to determine discharge rate. Minimum pump capacity shall be 1100 liter/min at 10.3 MPa discharge pressure.

(4) Two centrifugal pumps each capable of moving sea water at 1100 liter/min to cementing tanks.

(5) Two air compressors each capable of discharging 190 liter/min at 345 KPa minimum.

(6) Flexible cementing hose in sufficient quantity to allow hook-up from cementing equipment to any jacket leg without moving work barge, including adequate allowance for normal hose losses.

(7) A suitable system of slips and elevators for handling grout pipes for insert and grouted piles.

9.1.1.2 Bagged cement

(1) Mixing hopper and tank with circulation, mixing and transfer pumps.

(2) Two pump skids each equipped with diesel or turbine-powered positive displacement cementing pumps and a 5.7 m^3 tank calibrated to determine discharge rate.

Minimum pump capacity shall be 1100 liter/min at 10.3 MPa discharge pressure.

(3) Dry storage for calculated cement quantity required for the structure plus adequate reserve.

(4) Two centrifugal pumps capable of moving sea water at 1100 liter/min to cement mixing unit.

(5) Flexible cementing hoses in sufficient quantity to allow hook-up from cementing equipment to any jacket leg without moving work barge, including adequate allowance for normal hose losses.

(6) A suitable system of slips and elevators for handling grout pipes for insert or grouted piles.

9.1.2 Equipment Specifications

A detailed Specification for all equipments, including horse power, capacity, layout and hook-up on barge shall be given to Saudi Aramco Representative at least 30 calendar days before the equipment is required.

9.1.3 Assembly and Testing

All cementing equipment shall be mobilized in time to allow hook-up and testing at least one day prior to grouting. Saudi Aramco approval to proceed will be contingent upon proof testing of the equipment.

9.1.4 Personnel

Competent and experienced equipment operators shall be provided by the contractor to perform grouting in a continuous operation. An experienced supervisor shall be provided by contractor for each working shift.

9.2 Materials

9.2.1 Cementitious Material

The cement used for grouting shall be ASTM C150, type V (Sulfate resistant Portland cement) with 30% Fly ash. Fly ash shall comply with ASTM C618.

9.2.2 Grout Mix

The grout mix shall have high fluidity to ensure flow during grouting process. Chemical admixtures complying with ASTM C494 can be used to achieve the required fluidity of the grout mix. The maximum water to cementitious ratio (water/ cement + Fly ash) shall not exceed 45%. The mixing water shall be from oils, acid, organic matter of other deleterious substances and shall have total dissolved solids (TDS) less than 500 ppm as per AASHTO T26. The minimum compressive strength of the grout mix shall be 17.2 MPa (2500 psi). Contractor shall conduct trial mixes to meet the specified requirement prior to commencing the grout application.

9.2.3 Lost Circulation Material

To install a plug in jacket leg annulus or to control lost circulation in fissured limestone or coral formations, Gel flake, pea gravel or other approved lost circulation material may be added to the cement slurry if required and with approval by the Saudi Aramco Construction Engineer.

9.2.4 Quantities

When ordering materials, the contractor shall consider that grout seals are normally imperfect, that grout loss can occur in the formation and at the seafloor.

9.3 Grouting Procedures

9.3.1 Purpose

Grouting in conjunction with offshore pile installation may be done for thee following reasons:

(1) To fill the annulus between a pile and the jacket leg or a skirt pile and the sleeve.

(2) To fill the annulus between insert piles and the foundation formation and between the insert pile and initial pile section.

(3) To fill the annulus between pile and the foundation formation.

(4) To provide a grout plug in a re-driven pile for end bearing.

9.3.2 Driving During Grouting

Driving of other piles in the same structure is not permitted during grouting or within 24 hours after completion of grouting.

9.3.3 Sampling

Grout samples shall be collected by the Contractor for testing by Saudi Aramco at the beginning of each operation and at intermediate points as directed by the Saudi Aramco construction engineer. In addition, a sample shall be taken of grout overflowing from the annulus of the pile when grouting an insert pile.

Samples of overflowing grout shall be taken at the end of the grouting operation. The molds used for strength test specimens shall be prepared as outlined in Section 6 of API RP10B "Recommended Practice for Testing Oil-Well Cements."

9.3.4 Filling Pile-Jacket Annulus

The annulus between pile and jacket leg should be filled with grout where it is required by SAES-M-005 after the pile has been installed to grade and is completely shimmed and welded to the jacket. Sealer plates should be omitted until after grouting. The grouting procedure shall be as follows:

(1) Try to establish circulation by pumping seawater through the lower grout line.

(2) If circulation can be established and the returns are approximately equal to pumped quantity, pump 0.14 m^3 slug of grout followed by a sufficient volume of water to clear hoses and grout lines plus 300 liters. Slurry used for grout plug should be monitored to ensure a minimum weight of 1860 kg/m^3.

(3) If partial or no circulation is obtained, add lost circulation material to cement slurry, pump slug as in Step 2, allow sample to set two hours, and try to establish circulation using seawater. If water level in leg holds for 5 minutes proceed with Step 5. If water level will not hold, use divers to place bagged cement around jacket leg to seal obvious flow channels, then repeat Step 3.

(4) An alternate procedure for setting grout plug is to run a 25 mm (1 inch) grout pipe inside the annulus between jacket and pile and pump a grout plug consisting of 0.14 m^3 plus volume needed for grout lines followed by sufficient volume of water to clear hose and grout lines plus 300 liters. Check water level as in Step 3.

(5) Allow four hours for plug to harden, then fill remainder of annulus using upper grout line. Grouting should be continued until returns at the jacket leg are 1860 kg/m³ grout.

(6) Fill any empty space that occurs from grout settling with hand-mixed grout within 24 hours and install sealer plates.

9.3.5 Insert Piles

Grouting insert piles to foundation formation and initial pile section shall be done after the insert pile with centralizers is placed in the predrilled hole. Two pressure heads and a 3 inch grout pipe shall be provided by fabricator for contractor's use. The stepwise grouting procedure of insert piles shall be as follows:

(1) Run grout pipe to 1 m above the tip of the pile. The length of grout plug will be specified in pile installation specification for individual projects or shown on the drawings.

(2) Connect pressure head and weld to cover top of insert pile.

(3) Hook-up lines to pressure head and pump seawater until all air in insert is displaced through exhaust valve, then close exhaust valve.

(4) Pump 0.4 m³ to 0.6 m³ low density grout, 1280 kg/m³ to serve as a scouring medium ahead of structural grout.

(5) Pump grout at minimum density of 1860 kg/m³ until grout uncontaminated with drilling fluid flows over top of initial pile section. Use maximum practical pumping rate to insure scouring of predrilled hole wall. Samples shall be taken at the mix tank during pumping to determine density and hardening time of the grout.

(6) After good returns are obtained pump a volume of seawater sufficient to displace grout from hoses and pipe plus 1 m inside diameter of the insert pile. The amount of water required for flushing shall be determined accurately to ensure a grout plug of sufficient length is provided as specified.

(7) Discontinue pumping and simultaneously close the line valve to maintain pressure inside the insert pile.

(8) Maintain pressure for four hours or until grout hardens.

(9) Relieve pressure through exhaust valve, remove pressure head and grout pipe.

9.3.6 Grouting of piles to the formation and jacket leg

Grouting of piles to the foundation formation and jacket leg shall be done after the pile, with centralizers, is placed in the predrilled hole. The stepwise grouting procedure shall be as follows:

(1) Run the grout pipe to the tip of the pile.

(2) Connect the grout lines and pump 0.4 m^3 to 0.6 m^3 of low density grout, 1280 kg/m^3, to serve as a scouring medium ahead of further pumping of structural grout.

(3) Station the diver at the seabed, then pump grout at minimum density of 1860 kg/m^3 until good returns show at sea floor and pile up around jacket leg.

(4) Grout the annulus between pile and jacket as outlined in Paragraph 9.3.4. Inflatable grout seals are required to allow lowering of insert piles with projecting centralizer plates.

9.3.7 Placing Grout Plug

Placing a grout plug in a driven pile shall follow the stepwise procedure given below:

(1) Run the grout line to the top of the soil plug.

(2) Connect the grout lines and pump a quantity of grout adequate to fill all grout lines and to provide the required length of grout plug in the pile plus 0.3 m^3 and lift grout line.

(3) Wait four hours, then measure top elevation of the grout plug. If not adequate, repeat Steps 1 and 2.

10 Conductors and Conductor/Piles

10.1 Conductors are used as part of the oil drilling and/or production operations and are not used to provide axial or lateral foundation support to the structure. Conductor/piles serve a dual use and are depended upon and designed to provide axial or lateral foundation support in addition to serving oil production and drilling functions. The use of conductor/piles is generally not recommended except for minimum structures.

10.2 Conductor/piles shall be installed using the techniques given in this standard for piles. All requirements for grout should be met detailed procedures and materials used for installing conductor/piles should be approved at least two months prior to installation by Supervisor, Civil Engineering Unit, CSD.

10.3 Conductors can be installed by driving or drilling or a combination of both. During conductor installation operations - driving, drilling, drilling out, or grouting - caution must be exercised to prevent damaging, eroding, washing out, or reducing the strength of foundation support soils. Foundation support soils are generally within a depth of 150 m of the mudline. Foundation support soils are soft, loose and unconsolidated sediments that cannot resist high pump pressures, high pump volumes, or fast drill rates. Drill bit advance rates should be recorded and should not be faster than 3 minutes per meter.

Revision Summary

30 November, 2004 Major revision.