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DAEDALEAN ASSOCIATES, Incorporated

TECHNICAL REPORT

THE RESULTS OF THE DEVELOPMENT AND FIELD
DEMONSTRATION PROGRAM ON CAVITATION
DESCALING TECHNIQUES FOR PIPES AND TUBES
USED IN GEOTHERMAL ENERGY PLANTS

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THE RESULTS OF THE DEVELOPMENT AND FIELD
DEMONSTRATION PROGRAM ON CAVITATION
DESCALING TECHNIQUES FOR PIPES AND TUBES
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1.0 INTRODUCTION

1.1 Background

The conversion of geothermal energy into usable electrical power has become increasingly important to the overall national energy needs. A major area of technical interest which has resulted from the initial development of geothermal power plants is the scale formation developed in the facility pipes and related components. This scale formation is due to the concentration of minerals in the geothermal water and steam. The current state-of-technology utilized for descaling consists of a combination of sandblasting, water blasting, acid soaking and scraping. These cleaning methods, used individually or collectively, do not provide an acceptable descaling operation due to excessive facility downtime and cost.

DAEDALEAN ASSOCIATES, Incorporated (DAI) under contract to the Division of Geothermal Energy (DOE) has completed a feasibility program (Phase I) on cavitation descaling techniques for pipes and tubes used in geothermal plants. The engineering studies conducted under this program established the technical feasibility of utilizing this technique for

field applications. The program was accomplished under DOE contract number E(49-18)2289. A program summary is included in DAI technical report number JC-7651-001-FR, dated 28 February 1977. An explanation of the principle of cavitation phenomena, from which this cleaning technology evolved, is given in Appendix A of this report.

1.2 Problem Definition

The current state-of-technology for removing geothermal scale from pipe and system components requires lengthy periods of facility shutdown and extensive disassembly of the pipes and components. These descaling techniques also produce a deterioration of the base metal, which, in turn, reduces the usable life expectancy of pipes, fittings, valves and other system components. The objective of the Phase I program was to verify the technical feasibility for utilizing cavitation to remove scale from the interior surfaces of geothermal pipe and to generate the necessary engineering data for optimizing the design parameters of a field operational cleaning system. The results of the Phase I program indicated that: 1) the cavitating technique removes geothermal scale more rapidly than existing cleaning methods, 2) the cavitating technique does not damage the geothermal pipe and 3) the operating parameters are such that it is feasible to build a field operational system (Reference: DAI Technical Report Number JC-7651-001-FR).

1.3 Program Objectives

Due to the proven feasibility of utilizing the cavitation phenomena as an effective geothermal cleaning and descaling technique, DAI, under contract to DOE, has completed a design and development program which provides a working cavitation system (CONCAVER) for field applications. The ultimate objective of the program was to utilize this CONCAVER cleaning system in an actual cleaning demonstration at an operating geothermal facility.

The purpose of the program described in this report was to develop and demonstrate a field operational cleaning system utilizing the design parameters established during the initial feasibility study. The system, as designed, consisted of: 1) a trailer mounted high pressure water pumping system, 2) a hand-held cleaning gun, 3) a cleaning head for ten inch diameter pipe, 4) a cleaning head winching system and 5) all associated hardware and hose necessary for system connections.

This report discusses, in detail, the design and testing of the cleaning system, the laboratory evaluation of the complete system and the field demonstration.

2.0 CONCAVER SYSTEM DESIGN

2.1 High Pressure Water Pumping System

Using the engineering data generated under Phase I of this program, a trailer mounted high pressure water pumping system was designed. The operating characteristics of the system are variable through a range of 40 gpm at 5,000 psi (the maximum flow capability) to 12 gpm at 20,000 psi (the maximum pressure capability). The overall size and configuration of the pumping system is shown in Figure 1. A photograph of the actual equipment is shown in Figure 2. The pumping system is powered by a diesel engine which delivers 175 horsepower at 1,800 rpm. The complete drive system consists of the diesel engine, a five speed transmission and a speed reducer. This drive train allows the water pump to be operated through the entire required speed range (220 rpm to 560 rpm) while operating the diesel engine at 1,800 rpm. A schematic of the drive system is shown in Figure 3.

The high pressure water pump selected for this application is a triplex plunger pump having a fixed displacement and an operating pressure range of 20,000 psi. As a safety feature the pump is rated at 80,000 psi burst pressure. The pump is driven by an oil lubricated, automotive type crankshaft and connecting rods. The pump is equipped with three water lubricated ceramic plungers sealed by chevron packings. Each of three cylinders is protected by a

suction line filter. The pump design is shown in Figure 4.

Figure 5 is a general layout of the system plumbing. The plumbing is arranged for connection to an external water supply having a capacity of 40 gpm at a minimum of 20 psi. The reservoir has a capacity of 80 gallons and is rated for inlet water pressures of up to 100 psi. The supply water is fed, by system reservoir pressure, to a suction manifold, through individual cylinder filters and into the pump cylinders. The discharge from the pump (high pressure) is fed from each individual cylinder into the discharge manifold and from there to the cleaning device being utilized. To prevent pump damage due to line blockage or low water supply the system is equipped with high and low pressure and low water shutoff systems. Pressure gauges are installed for readout of pump suction and discharge pressures and reservoir pressure. An additional safety device is a throttle control which automatically returns the diesel engine to an idle condition when high pressure water is not being supplied.

The trailer is equipped with lights and a braking system which conform to I.C.C. requirements for interstate highway travel. A fuel tank, air compressor, battery (12 volt) and tool box are mounted on the trailer.

The trailer mounted high pressure water pumping system was designed to be a completely self-sustained assembly.

The only external requirement for system operation is an available water supply.

2.2 Cleaning Head and Gun

Design of the actual cleaning devices consisted of a cleaning head for descaling of pipe interiors and a hand-held cleaning gun for descaling of components and pipe sections removed from the system.

Figure 6 is a schematic illustration of the cleaning head. The cleaning head was designed for cleaning of ten-inch diameter pipe only. The body of the assembly is centered in the pipe by six guide wheels located on the circumference of the body. The rotating head is powered by a variable speed air motor. The rotating head is fitted with two adjustable nozzle holders capable of varying the angle of attack and also capable of holding any nozzle configuration required. High pressure water is fed from the feed hose through a rotating seal assembly to the rotating head. The assembly is fitted with quick disconnect water and air couplings for ease of installation. The assembly is propelled through the pipe by a hand winch and pull cable fastened to the rotating head by a universal swivel joint. A full flow bypass valve, foot actuated, is utilized for activation of the cavitating nozzles.

The hand-held gun is illustrated in Figure 7. The purpose of this unit is to provide a hand-held cleaning assembly

for descaling of pipe sections and components which have been removed from the facility. The gun design is for one-man operation. Two hand grips are provided for proper direction of the cavitating flow. The hand grip on the body is equipped with the activating trigger while the second hand grip is located on the barrel assembly and is adjustable for ease of operation. The activating trigger controls a full flow bypass valve and is spring loaded to the bypass position for operator safety. The barrel assembly is a replaceable screw-in unit and depending on the descaling operation, may be varied from six to thirty inches in length. Each barrel assembly is equipped with a nozzle adaptor capable of holding any nozzle configuration. The barrel is also fitted with a retaining cup which is adjustable for maintaining the required nozzle stand-off distance and also maintains a flooded area around the cavitating nozzle jet.

2.3 Associate and Support Equipment

The associate and support equipment selected for integration of the total system consisted of hoses, quick-disconnect fittings, air compressor, hand winch and cable, flange cap, water pump and tool box.

Three types of hose were required for system operation. The feed hose for supplying the high pressure pump is a one inch diameter water hose rated at 150 psi operating pressure. The hose selected for drain purposes is a two inch diameter

collapsible hose. The high pressure hose utilized for connecting the cleaning device to the high pressure pump is a 1/2 inch diameter wire reinforced hose. The hose construction is four spiral wire, one braided wire reinforced rubber tube rated at 20,000 psi operating pressure. The hose length is 50 feet and each end is fitted with swedge fittings having 1/2 inch male pipe thread ends.

The quick-disconnect couplings are commercially available 60,000 psi screw-type assemblies. All couplings are fitted with 1/2 inch female pipe threads for assembly to the high pressure hose.

The air compressor utilized for operation of the cleaning head air motor is a portable 1/2 horsepower (electric motor) unit with a regulated air supply for operating pressure of 0 through 120 psi.

The hand winch used for pulling the cleaning head through the pipe is a ratchet type assembly rated at 1,000 pounds. The winch was fitted with 1/8 inch wire rope and mounted on a modified flange for set up on the facility clean out ports.

An engine powered 3 horsepower water pump was used for supplying water at 40 psi to the high pressure water pump reservoir.

3.0 CONCAVER SYSTEM EQUIPMENT

3.1 Fabricated Items

In-house fabrication consisted of cleaning head, hand-held cleaning gun, 10 inch flange cap and hand winch mounting adaptor.

The fabrication of the cleaning head consisted of in-house machining of the rotating head, nozzle holders, body and gear box. The guide wheels, air motor, rotating seal assembly, gears and quick-disconnect couplings were purchased items.

The hand-held cleaning gun contained a purchased bypass valve-handle assembly, which was modified in-house, and two purchased quick disconnect couplings. All other gun components (barrel, water retainer and nozzle holder) were manufactured in-house.

A 10 inch flange cap and valve assembly, see Figure 8, was machined and assembled in-house. The ball valve was a purchased assembly.

A winch mounting bracket was fabricated for mounting the hand winch on the facility clean out port.

3.2 Purchased Items

The high pressure water pumping system consisted of subassemblies and components purchased and assembled in accordance with DAI specifications and requirements. The complete system was trailer mounted in compliance with I.C.C.

regulations for highway transport. The fluid end of the high pressure pump was modified at DAI to insure satisfactory field performance. Flow and pressure parameters were demonstrated at the five specified pump speeds (RPM) and all automatic and safety systems were checked for proper operation prior to start of the overall system evaluation.

Other system support equipment such as hose, fittings, air compressor and hand winch are commercially available items which were purchased and modified as required for the system application.

3.3 Assembly and Operation

Once all purchased items had been received and modified and all in-house fabrication was completed, the system was assembled to ensure proper fit and function of the individual components and the overall system. The system was then operated at 12,000 psi with the cleaning head rotating at approximately 20 rpm. While operating at the above conditions, the rotating seal assembly in the cleaning head and all hose and fittings were visually inspected for leakage. The system was shut down and two leaking connections were repaired and the pressure test repeated. No leakage was observed during the test re-run.

4.0 LABORATORY EVALUATION

4.1 Maneuverability of Cleaning Head

The initial equipment evaluation consisted of a demonstration of the cleaning head maneuverability in a section of 10 inch diameter pipe. The general test layout is shown in Figure 9. For this demonstration, two elbows and approximately 30 feet of ten inch diameter pipe were purchased and weld assembled into the configuration shown in Figure 9. The hand winch was secured to an open pipe end and connected to the cleaning head using a 1/8 inch wire rope. A high pressure hose and air hose were connected to the cleaning head. Since the test pipe section was open at each end and the welded pipe joints were not water tight, the cleaning head was not subjected to high pressure water during this demonstration; however, the rotating head was operated using the system air compressor. During the initial efforts to pull the cleaning assembly through the test pipe, difficulties were encountered in the first elbow. An investigation revealed that the pull cable was riding on the inside diameter of the elbow causing the rear portion of the cleaning head to cock and bind in the elbow. To correct this difficulty, two spacers were fabricated and installed on the pull cable as shown in Figure 10. The purpose of the spacers was to position the cable toward the center line of the elbow radius and prevent cocking of the cleaning head. After installation of the

spacers, the cleaning head traveled through the test pipe in both directions without difficulty.

4.2 Scale Removal

After successful completion of the maneuverability demonstration, the complete system was assembled to evaluate the scale removing capability of the equipment. Pipe sections with accumulations of geothermal scale, furnished by the Union Oil Company, were used for this evaluation. These samples were 10 inch diameter sections of straight pipe approximately 18 to 22 inches in length. The scaled sections of pipe were set up between two pieces of clean pipe as shown in Figure 11. The cleaning head was positioned in one section of clean pipe and connected to the hand winch located at the opposite end of the pipe assembly. After the cleaning head was positioned in the pipe, the test assembly was sealed and filled with water. Air and water pressure were supplied to the cleaning head and it was winched through the pipe sample. After each test run, the pipe sample was disassembled and the scaled pipe visually inspected. This type of test was conducted at nozzle pressures of 2,000 psi through 10,000 psi. Test results indicated satisfactory descaling capabilities at any pressure between 3,000 psi and 10,000 psi. The established cleaning rate demonstrated during these test runs was a maximum of 90 square inches per second. The limiting factor in the establishment of cleaning rates was the speed at which the cleaning head could be

winched through the short pipe section.

Two pipe samples furnished by the Union Oil Company are shown in Figure 12. One sample shows the scale buildup typical of the pipe sections received while the other sample shows the result of the descaling evaluation. As shown in this photograph all scale was removed down to the base metal of the sample pipe section. This result was duplicated during all descaling operations at nozzle pressures of 3,000 psi or greater.

5.0 FIELD DEMONSTRATION

5.1 Size Selection

The site selected for the demonstration of the CONCAVER descaling technique was the San Diego Gas and Electric Company operated Geothermal Loop Experimental Facility (GLEF) located at Niland, California. Initial contact was made with Mr. William O. Jacobson of the San Diego Gas and Electric Company in July of 1977. A visit was made by DAI personnel to the GLEF in October 1977 at which time preliminary discussions were held with Mr. Jacobson and photographs were taken of the proposed areas to be cleaned. A test plan was prepared for the demonstration and submitted to cognizant government personnel and Mr. Jacobson. The sections of pipe proposed for the demonstration were the reinjection pipe from the fourth stage flash tank and the pipe section connecting the third and fourth stage flash tanks. A copy of the test plan is included as Appendix B of this report.

5.2 Demonstration Setup

Scheduling of the demonstration was timed to coincide with the normal facility shutdown and cleaning operation beginning in early January of 1978. The high pressure water pumping system and all associated equipment were packaged and shipped by commercial carrier in late December. The CONCAVER equipment and DAI personnel arrived at the GLEF on 6 January 1978. The equipment was unpacked, set up and

operated to insure that no damage had occurred during the cross-country trip. Operation of the high pressure water pump and all associated equipment was satisfactory. Since the facility had been shutdown on 6 January, the required disassembly of the facility was delayed until 7 January to allow the pipes and components to cool.

5.3 Field Demonstration

The field demonstration was conducted in accordance with the Field Test Plan given in Appendix B of this report with the following exceptions:

1. The extent of flow loop disassembly for the demonstration is identified in Figure 13 as (A) control valve, (B) spool, (C) spool, and (D) venturi. Figure 14 shows the extent of disassembly required for the complete demonstration.
2. The pipe section connecting the fourth stage flash tank to the reinjection pump (Ref: Figure 2B of Appendix B) was not cleaned since the scale formation was of a soft nature and was easily removed with commercial water blasting techniques.
3. The actual cleaning operation demonstrated to cognizant government personnel and geothermal facility operational and service personnel was of the venturi. This sample was chosen for the demonstration as it was removed from the facility plumbing and the before

and after results were more readily visible.

The area selected for the demonstration was the brine line (10 inch diameter) connecting the third and fourth stage flash tanks as shown in Figure 15. Although the nature of scale buildup between cleaning cycles is unpredictable, this piping normally produces the hardest and most difficult scale to remove. A visual examination of the pipe interior prior to cleaning revealed a very hard scale buildup varying between 1/8 to 1/2 inch thick.

The procedure utilized for each cleaning operation consisted of: 1) feed pull cable through pipe section and mount hand winch; 2) secure cleaned spool to pipe entrance; 3) connect cleaning mole to pull cable and position in spool; 4) cap spool end and flood pipe section with water; 5) adjust nozzle pressure and rotating speed; and 6) pull cleaning mole through pipe. Cleaning was accomplished in the sequence listed below with call outs as referenced in Figure 16.

1. Pipe section number 1 with cleaning mole traveling from E to A.
2. Pipe section number 2 with cleaning mole traveling from F to B.
3. Pipe section number 3 with cleaning mole traveling from C to G.
4. Pipe section number 4 with cleaning mole traveling from D to H.

The schedule for the complete field demonstration was as shown in Table I.

DATE	OPERATION SEQUENCE
1-6	Set up and check out equipment
1-7	Clean 10 inch diameter spool Set up and clean pipe section 3 Set up to clean pipe section 1
1-8	Start cleaning of pipe section 1
1-9	Finish pipe section 1 Set up and start cleaning pipe section 2
1-10	Finish pipe section 2
1-11	Demonstration for government and industry personnel (Venturi)
1-12	Set up and clean pipe section 4
1-13	Package and ship equipment to DAI

TABLE I - DEMONSTRATION SCHEDULE (reference Figure 16 for pipe section designation)

All cleaning accomplished during the field demonstration was performed at nozzle pressures of 8000 psi or less. The cleaning rates established during the demonstration varied from 60 - 90 square inches per second. Specific pressures and cleaning rates for the individual pipe sections is given in Figure 17 of this report. The established cleaning rates were determined while cleaning straight pipe sections only,

as some difficulties were encountered as the cleaning head transversed elbows and irregular sections of pipe making it impossible to establish cleaning rates in these areas. These difficulties were caused by (1) excessive weld burn through, (2) misalignment of pipe ends during butt weld operation and (3) varying pipe inside diameters due to use of different schedule pipe during facility modifications and/or repairs. The cleaning head was reduced in overall length and diameter to increase the maneuverability through elbows and irregular pipe sections. These modifications made it possible for the cleaning head to travel the entire pipe length.

A portion of the actual pipes cleaned during this demonstration are shown in Figures 18, 19 and 20. Photographs of the cleaning head prior to being inserted into the scaled pipe and after insertion into the scaled pipe are given in Figures 21 and 22 respectively. The scale removed from a vertical section of pipe is shown in Figure 23.

The demonstration for cognizant government and industry personnel was given on 11 January 1978. As previously stated in this report, the demonstration consisted of descaling an eight foot venturi section. The scale buildup in the venturi section was visually inspected prior to the descaling operation by the visiting personnel. The procedure listed below was utilized for the descaling demonstration.

1. One end flange of the venturi section was scaled with

a ten inch diameter wooden tapered plug.

2. The venturi section was placed in a vertical position with the plugged end down.
3. The venturi section was filled with water.
4. The cleaning head, with nozzles rotating was lowered into the venturi (reference, Figure 24).
5. Pressure was applied to the cleaning head nozzles, 7000 psi, and the cleaning head was lowered into the venturi. Since the travel was vertical from top to bottom, it was not necessary to pull the cleaning head through the venturi.
6. The cleaning head was lowered into the venturi until it reached the reduced diameter portion of the venturi at which time the nozzle pressure and rotation was stopped and the unit removed from the venturi.
7. The water and scale were drained from the venturi section and it was opened for visual inspection (reference, Figures 25 and 26).

The visual inspection of the venturi section after cleaning, revealed all scale had been removed in the test area.

5.4 Additional Cleaning Effort

After completion of the proposed field demonstration, it was requested that the DAI field team clean the vertical

section of brine line connecting the third stage flash tank to the injection pump. This pipe section had been previously cleaned using conventional water blasting at 9500 psi. The soft scale had been removed; however, a hard scale approximately 3/8 inch thick had not been affected by the water blasting. After modifying the cleaning mole diameter necessitated by interior pipe irregularities, the CONCAVER system removed the scale from approximately 50% of the pipe interior using a pressure of 9500 psi. The remaining 50% of the pipe was cleaned using a nozzle pressure of only 7500 psi. This additional demonstration offered a field comparison of conventional water blasting and the CONCAVER system, indicating the advanced cleaning capability of the CONCAVER system.

6.0 DISCUSSION OF RESULTS

The following specific conclusions and recommendations are summarized as a result of the field demonstration of the CONCAVER descaling technique.

6.1 Conclusions

1. Although the scale buildup between shutdowns at the GLEF is not predictable, the area selected for the demonstration usually produces the most difficult scale to remove. The scale removal during the demonstration would normally have been removed using a combination of acid soaking and water blasting. This indicates that the CONCAVER technique produces results superior to those produced by conventional water blasting.
2. The cleaning rates established during the demonstration (60 to 90 square inches per second) are approximately ten times faster than the conventional water blasting capability. It is felt that these rates were not the maximum capability of the CONCAVER descaling technique. The upper limit of the measured cleaning rate (90 square inches per second) was accomplished while moving through the scaled pipe at the maximum design speed (three inches per second) of the cleaning head. A faster winching system would be required to achieve cleaning head speeds in excess of three inches per second in order to determine the actual maximum

cleaning rate for the CONCAVER cleaning technique.

3. Operating nozzle pressures employed during the demonstration (7000 to 8000 psi) was well below the original design pressure for the CONCAVER system; however, these pressures removed all scale encountered during the demonstration. Although the area cleaned during the demonstration was restricted to the third stage and fourth stage flash tank piping, it is felt that the above pressures would remove any scale encountered in the facility.

4. The additional cleaning operation described in section 5.4 of this report further demonstrates the superiority of the CONCAVER system to existing "state-of-technology" descaling methods employed in cleaning of geothermal facilities.

6.2. Recommendations

1. It is recommended that the overall results of the field demonstration be considered as conclusive evidence that utilization of the phenomena of cavitation is an effective geothermal cleaning and descaling technique and is superior to the methods currently employed by the industry.

2. Further development of cleaning equipment and associated hardware is required in order to fully utilize the CONCAVER system as an overall geothermal facility

cleaning tool.

3. Develop a series of fixed and movable nozzle assemblies which can be permanently installed in the facility pipes and components. This type cleaning assembly could be activated while facility was operational and would eliminate the necessity for shutdown and disassembly during descaling and cleaning operations.

4. Modify the existing cleaning head design and develop a hose feed system for cleaning of production wells. The cleaning head modification would consist of material changes necessary for operation in the environment (temperature) common to production wells. The overall design configuration would remain unchanged. The hose feed system is necessary due to the scale depths expected in a production well.

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FIGURE 1 SCHEMATIC REPRESENTATION OF PROTOTYPE CONCAVER FIELD UNIT FOR CLEANING PIPE AND SYSTEM COMPONENTS

**FIGURE 2 PHOTOGRAPHIC REPRESENTATION OF PROTOTYPE CONCAVER FIELD UNIT FOR
CLEANING PIPES AND SYSTEM COMPONENTS**

FIGURE 3 SCHEMATIC OF DRIVE SYSTEM FOR PROTOTYPE
CONCAVER FIELD UNIT INDICATING ENGINE
PARAMETERS, TRANSMISSION AND REDUCER
RATIOS AND PUMP CHARACTERISTICS

1. LUBRICATION	8. DISCHARGE MANIFOLD
2. PLUNGER PACKING	9. SUCTION MANIFOLD
3. PLUNGER	10. FILTER
4. SUCTION VALVE	11. EXTENSION ROD
5. DISCHARGE VALVE	12. EXTENSION ROD SEAL
6. SECTIONALIZE FLUID HEAD	13. CONNECTING ROD
7. VALVE COVER	14. CRANKSHAFT

Fluid Area

**FIGURE 4 SCHEMATIC OF HIGH PRESSURE WATER PUMP
FOR PROTOTYPE CONCAVER FIELD UNIT**

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FIGURE 5 WATER PUMPING SYSTEM SCHEMATIC FOR PROTOTYPE CONCAVER FIELD UNIT

FIGURE 6 CONCAVER CLEANING HEAD SHOWING NOZZLE LOCATIONS AND ROTATING HEAD POWERED BY AN AIR ACTUATED VARIABLE SPEED MOTOR

DESIGN FEATURES

1. ONE MAN OPERATION
2. FULL FLOW BYPASS
3. VARIABLE NOZZLE SIZE
4. SELF FLOODING NOZZLE
5. PRESET NOZZLE SPACING

**FIGURE 7 CLEANING GUN DESIGN FOR USE WITH PROTOTYPE
CONCAVER FIELD UNIT**

**FIGURE 8 FLANGE CAP UTILIZED FOR SEALING PIPE ASSEMBLY
AND FEED THROUGH FOR HOSES**

**FIGURE 9 LABORATORY EVALUATION, SIMULATED SETUP FOR
MANEUVERABILITY EVALUATION OF CLEANING HEAD**

FIGURE 10 LAB EVALUATION: MODIFICATION TO CABLE LEAD IN FOR INCREASED MANEUVERABILITY

FIGURE 11 LABORATORY EVALUATION, SIMULATED SETUP FOR ACTUAL SCALE REMOVAL

FIGURE 12 LABORATORY EVALUATION, TEN INCH DIAMETER PIPE SECTIONS SHOWING THE EXTENT OF SCALE FORMATION AND THE RESULTS OF THE CONCAVER CLEANING SYSTEM

FIGURE 13 FLASH TANK PIPING BETWEEN 3rd STAGE AND 4th STAGE
FLASH TANKS IDENTIFYING THE SECTIONS OF PIPE TO BE
REMOVED FOR CLEANING DEMONSTRATION

FIGURE 14 FLASH TANK PIPING BETWEEN 3rd STAGE AND 4th STAGE FLASH TANKS
DISASSEMBLY REQUIRED FOR CLEANING DEMONSTRATION

FIGURE 15 FLASH TANK PIPING BETWEEN 3rd STAGE AND 4th STAGE FLASH TANKS
IDENTIFYING THE CLEANED SECTIONS OF PIPE

FIGURE 16 FLASH TANK PIPING BETWEEN 3rd STAGE AND 4th STAGE FLASH TANKS
CLEANING DEMONSTRATION SEQUENCE

FIGURE 17 FLASH TANK PIPING BETWEEN 3rd AND 4th STAGE FLASH TANKS
CLEANING DEMONSTRATION DATA PARAMETERS

**FIGURE 18 GEOTHERMAL LOOP EXPERIMENTAL FACILITY (GLEF)- ACTUAL PIPE SECTIONS
CLEANED DURING THE FIELD DEMONSTRATION**

**FIGURE 19 GEOTHERMAL LOOP EXPERIMENTAL FACILITY (GLEF)-ACTUAL PIPE SECTIONS
CLEANED DURING THE FIELD DEMONSTRATION**

**FIGURE 20 GEOTHERMAL LOOP EXPERIMENTAL FACILITY (GLEF) - ACTUAL PIPE SECTIONS
CLEANED DURING THE FIELD DEMONSTRATION**

FIGURE 21 CLEANING HEAD CONNECTED TO PULL CABLE AND PRESSURE HOSES PRIOR TO INSERTION INTO SCALED PIPE

**FIGURE 22 CLEANING HEAD, SPOOL AND FLANGE SET-UP FOR
CLEANING OPERATION DURING FIELD DEMONSTRATION**

FIGURE 23 FLANGE REMOVED FROM PIPE AFTER CLEANING OPERATION, SCALE ON
FLANGE CLEANED FROM VERTICAL SECTION OF PIPE

**FIGURE 24 FIELD DEMONSTRATION FOR COGNIZANT GOVERNMENT AND GEOTHERMAL PERSONNEL -
DESCALING OF VENTURI SECTION**

**FIGURE 25 FIELD DEMONSTRATION FOR COGNIZANT GOVERNMENT AND GEOTHERMAL PERSONNEL -
INSPECTION OF VENTURI SECTION AFTER DESCALING OPERATION**

**FIGURE 26 FIELD DEMONSTRATION FOR COGNIZANT GOVERNMENT AND GEOTHERMAL PERSONNEL -
INSPECTION OF VENTURI SECTION AFTER DESCALING OPERATION**