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PART I
ANALYSIS
of
TECHNICAL SPECIFICATIONS
for

DEEP WELL DRILLING, COMPLETION, AND TESTING
PARADOX VALLEY UNIT
COLORADO RIVER BASIN SALINITY CONTROL PROJECT

PREPARED FOR

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE

UNDER

P. O. NO. 3-PG-40-10000

BR-301

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I. INTRODUCTION

As set out in the purchase order and in the background data provided, the purpose of this analysis was to evaluate the following areas:

1. Review the design of the well for completion and operation.
2. Provide comments/recommendations relative to the adequacy of the specication to produce the successful completion of the well.
3. Provide comments/recommendations relative to the method of payment to the contractor for the construction of the well.

Comments relative to the overall design of the well are addressed in Section III - Conclusion and Recommendations along with a proposed payment method. A detailed analysis of the adequacy of the specifications including an analysis of design details, are provided in Section II.

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II. ANALYSIS

An analysis relative to the adequacy of the specifications to produce the successfull completion of the well can best be achieved by providing detailed comments and recommendations on the same format as the Specification.

Section 1.1 GENERAL

1.1.1 The Requirement

The requirement must clearly state all objectives of the project in a format to answer the questions - What, Where and When. These were only fragmentarily addressed in the current specification.

The capacity of the well (900 GPM), design service life (? years), location of the work, anticipated start of construction date and required completion date (if applicable) must be given.

1.1.2 Description of Work

The description of work is incomplete. In a lump sum contract each distinct phase must be listed along with the general requirements, namely:

a. Detailed Engineering of the well
b. Acquisition of long lead time materials
c. Selection of the rig, service contractors, procurement of short lead time materials
d. Preparation of the location
e. Drilling of the well listing the general requirements and any unusual features, such as cores, non damaging muds, etc.
f. Completion
g. Hydrofracturing tests
h. Injection tests
i. Final surface facilities hook up

Note: Paragraph 1.1.2.b is in error; 13-3/8" O.D. T&C casing cannot be run inside 16" O.D. casing. For 13-3/8" O.D. casing, 18-5/8" O.D. or more commonly 20" O.D. casing is required. As a result, 30" O.D. conductor is usually set in wells with a 9-5/8" x 13-3/8" x 20" casing program. With 18-5/8" casing, a 26" O.D. conductor is adequate.

Paragraph 1.1.2.d - If a well with a 900 GPM injection capacity is required, it is not logical to test it at only 200 GPM. A full volume injection test is strongly recommended.

1.2.2 Reference Specifications and Standards

"Standard Commercial Quality" materials are completely inadequate for a 15,000' deep disposal well. Detailed material specifications with an appropriate QA/QC program are mandatory for a successful completion.

1.3.8 Water for Construction Purposes

Details concerning potential sources of water for construction purposes should be provided to expedite the bidding and recude the effects of this variable in the bid.

A separate paragraph must be used to address the specifics of the brine for the injection test. Details on the location of the source, chemical analysis, concentrations of particulates, degree of filtration required, leakage, spill tolerance, etc. must be provided.

1.4.4 Hazardous Gas Conditions

Specifics regarding the location and amount (pressure, volume and concentration) of H_2S gas must be provided. The problems from H_2S can be anywhere from acute to insignificant and can therefore increase the cost greatly or none at all.

Section 2.1 DRILLING PROGRAM

General Comments
Turnkey well specifications are extremely difficult to generate and can often contain great pitfalls. For example, if a specific casing string design were specified and that string were to fail during the construction of the well who shall be financially responsible for the repair or redrill operation? It would be extremely difficult to prove, either way, that 1) the design was not defective or 2) that the casing was not improperly installed. Since such a question involves millions of dollars in a well of this type it could, and likely would, lead to lengthy litigation before the Board of Contract Appeals. As a result fixed specific designs must be avoided in turnkey contracts. However, on the other hand, lack of specifications could lead to premature failures shortly after the well is accepted. The solution to the problem lies in developing rigid performance specifications with verification of material acceptability through a thorough user, Bureau of Reclamation in this case, Quality Assurance program.

The drilling program, as contained in the specification, suffers from another problem - great specificity in some areas, with completely inadequate details or specifications in others. For example, great details are provided in paragraph 2.1.6. Completion concerning the manipulation of the tubing string, but no specifics are provided on what constitutes an acceptable packer and seal element test. The pressure nor the acceptable leakage rate are specified. Similarily, neither are there any specifications in paragraph 2.1.4 Drilling and Casing Details of what constitutes "a uniform, true hole".

Some specific problem areas are:

2.1.1 General
"Cemented to surface" is not an adequate specification. Specifics relative to the strength of the cement, degree of fill up, bonding, etc., must be provided.

2.1.4 Drilling and casing Details

a. Paradox Salt Formation

Specifications such as "uniform, true hole", and "best drilling practices" cannot be enforced because they are totally subjective. If a specification on the hole is truly required it must be specified in terms of the holes geometry - size, deviation, etc.

The specific casing design must be left up to the contract, however, a minimum acceptable pipe program can be given. Specifically in this specification the 30" O.D. conductor should be API 5L 30" O.D., 1.00" wall grade B line pipe. The 20" surface casing must be at least 20" 106.5# K-55 BTC. The intermediate casing string must be at least 13-3/8" 72# C-95 BTC, with ovality limitations.

The existing 9-5/8" production casing string design is completely inadequate. Furthermore, the grade designation is nonsensical. An analysis of the 9-5/8" casing at the nominal service life condition and a preliminary alternate design are presented in Appendix A.

The use of a stage cementing technique on this well will lead to early failure of the 9-5/8" casing string.

b. Disposal Formations

Step 1. A maximally rigid, not minimum size, core barrel shall be used.

Step 4. The correct hole size is 8-1/2" not 8-3/8". Special drift 9-5/8" casing, commonly available, is of course required.

c. Short Term Injection Test

The objectives, not specific procedures, should be clearly stated.

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2.1.6 Completion

As with the short term injection test, the objectives to be accomplished in the completion, not specific procedures, shall be clearly stated. The procedures as written contain a hodgepodge of information that is inconsistent and often incorrect. Specifically the problem areas are:

The 9-5/8" production casing must be cemented to surface immediately after it is run, not after the injection test, otherwise an early failure due to plastic salt flow will occur.

The procedure relative to the "safety sub" is completely nonsensical, entirely too specific and presumptuous. No previous mention of a safety sub in the hole has been made. Nor is there a description or a specification given for the polished bore assembly. The use of duplex materials in this well should be reevaluated.

A 7" tubing string design using 29# and 38# N-80 LTC casing is completely incorrect for this application.

Consideration should be given to the use of plastic coated API X-line casing. This combination has proven successful in a DOE geopressured/geothermal source well.

The remaining completion procedures are entirely too detailed for specific equipment which may or may not be used in the completion.

Performance specifications for the tree must be given, not a specific manufactures designation. Furthermore, the use of a "wrap around bushing" for sealing the 7" x 9-5/8" annulus is not advisable. In critical wells, suspension and sealing of the tubing string must be accomplished by one device, i.e.: a mandrel type hanger.

2.1.7 Two Week Injectivity Test

a. General

Specifications regarding the minimum/maximum injection rate, permissible suspended solids in the injection fluid, type and location of instrumentation, etc. must be provided.

III. CONCLUSION AND RECOMMENDATION

The technical specifications contained in Deep Well Drilling, Completion and Testing, Paradox Valley Unit, Colorado River Basin Salinity Control Project, are insufficient and will not guarantee a successful well or injection test. Moreover, the proposed drilling/completion plan will likely result in a premature well failure due to plastic salt movement and subsequent casing deformation, i.e.: "casing collapse".

It is possible, but extremely difficult and very costly, to drill nearly 15,000' of massive, laterally loaded, salt beds, equip the well for permanent injection and expect a useful life of twenty plus (20+) years. At minimum, the salt section must be divided into two, preferably three, essentially equal intervals. This would necessitate a three or four string casing program, plus the conductor and the injection tubing. For example, - 42" conductor, 30" surface casing at 500'; 20" first protective casing at 5,000'; 14" second protective casing at 10,000'; 9-5/8" production casing at 14,800'; 7" injection tubing string. Such a casing program is necessary to prevent excessive hole enlargement, thereby assure complete circumferential cement fill up, to prevent asymmetric lateral salt loading, and thus prevent "casing collapse".

It would be more logical to drill a well "off structure" where only approximately 500' (plus or minus) of salt would be encountered. An adequate seal would still be achieved and the well cost would be far less. Furthermore, in case of a salt collapse, a cost effective recompletion could be accomplished.

Generally a least cost well can be obtained by an operator on a daywork contract basis. This however, presumes the presence of three critical items. First, an expert engineering staff to design the well, i.e.: a competent staff group, second, an expert operating group to construct the well, i.e.: a competent line group and third, experienced/competent management familiar with high technology drilling and completion engineering and operations. Many oil companies do not even have such a structure. Consequently often cost overruns or even junked holes result.

It is doubtful that the Bureau of Reclamation has within it's organization the required deep drilling expertise. Nor would it be cost effective to staff up for one well.

As a result, in this particular situation, it would be best to issue several, (at least two), separate contracts. The first would be for the planning of the well, preparation of the specifications (bid package), evaluation of the bids and technical surveillance during the construction phase. The second would be for the actual construction of the well, performing the injection test and final completion

To assure a competent well a detailed hierarchical user (Bureau of Reclamation) quality assurance plan would have to be developed and implemented. In a hierarchical quality assuance program the performance required in the Project is assured by verifying that all aspects of each individual component to each assembly system, etc., from design to manufacture, to installation, meet the required specifications.

For optimum results, a payment schedule based on achieved milestones, of benefit to the user and contractor (for example successful pressure tests on each casing string recorded cores, injection test, etc.), needs to be implemented.

Drilling a deep disposal well is difficult. It is even more difficult to attempt such a venture on a fixed cost basis. Only with adequate planning and a hierarchical performance specification and quality program can success be assured.

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APPENDIX A

CASING ANALYSIS SUMMARY

APPENDIX A - CASING ANALYSIS SUMMARY

1.0 Designs Analyzed

1.1 9-5/8" Design Specified by the Bureau of Reclamation

Feet of Casing	Description	Interval
1,275	9-5/8" 53.50# P-110 LTC	0' - 1,275'
1,900	9-5/8" 47.0# P-110 LTC	1,275' - 3,175'
5,400	9-5/8" 47.0# C-95 LTC	3,175' - 8,575'
6,145	9-5/8" 53.50# C-95 LTC	8,575' - 14,720'
80	9-5/8" 53.50# C-75 LTC	14,720' - 14,800'

1.2 9-5/8" Design Proposed by OTS

Feet of Casing	Description	Interval
7,000	9-5/8" 47.0# C-95 LTC	0' - 7,000'
1,000	9-5/8" 53.50# C-95 LTC	7,000' - 8,000'
3,500	9-5/8" 53.50# P-110 LTC	8,000' - 11,500'
3,300	9-5/8" 59.20# P-110 LTC	11,500' - 14,800'

2.0 Service Conditions

Designs 1.1 and 1.2 were analyzed for the following anticipated service conditions:

2.1 Cement Condition (base case) - 2,800' of 16.2 PPG cement on bottom, 14.0 PPG cement above 12,000' to the surface; 10.0 PPG mud internal from the surface to 14,800' (total depth); 60° F at the surface, 240° F at total depth.

2.2 Collapse Case - 19.2 PPG lithostatic salt gradient external; internally evacuated to 1,100', 8.3 PPG fresh water packer fluid below 1,100' to total depth; presumed minimum internal Bottom Hole Pressure, 5,936 psi equivalent to the potentiometric surface of the Colorado River; differential collapse pressure at 14,800' equals 8,864 psi; 60° F at the surface, 120° F at 14,800'.

3.0 Results of the Analysis

TABLE I
MINIMUM DESIGN FACTORS
DESIGN 1.1

	Minimum Design Factors		
Service Condition	API Pressure	API Joint	VME
Cement Condition			
(Base Case)	1.87 C* at 14,800'	3.69 at 0'	2.67 at 14,800'
Collapse Case	0.72 C at 14,800'	3.69 at 0'	0.90 at 14,800'

TABLE II
MINIMUM DESIGN FACTORS
DESIGN 1.2

	Minimum Design Factors		
Service Condition	API Pressure	API Joint	VME
Cement Condition			
(Base Case)	2.82 C at 14,800'	2.59 at 0'	3.10 at 0'
Collapse Case	1.08 C at 14,800'	2.59 at 0'	1.42 at 14,800'

*C - Collapse

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DESCRIPTION

OF

CASING ANALYSIS TABULAR OUTPUT

DESCRIPTION OF CASING ANALYSIS TABULAR OUTPUT

The first page, at the extreme left lists the node number and depth. To the right spaced between the nodes is a complete description of the casing - weight per foot, outside diameter, nominal internal diameter, nominal wall thickness. nominal area of the pipe body, the minimum yield and ultimate strengths, a description of the connector and its axial tension efficiency, followed by the collapse and minimum internal yield pressure of the pipe body and the joint strength.

The second page of the output describes the cement condition, listing nodes and node depths, a differential pressure, axial force above and below the node, temperature (degrees F), fluid densities, axially adjusted collapse ratings above and below the node joint strength above and below the node, burst or collapse load capacity design factors, and joint strength design factor. A notation will be made whether floats are open or holding and another message appears if there is to be any axial adjustment in the ensuing load cases.

For each load case (one or more) three (3) pages of output are provided. The first page lists the same columnar output as for the cement condition. Messages consist of the depth to the top of the cement and one (1) of three (3) buckling messages - buckling cannot occur, buckling forces are present but are less than the critical buckling load and buckling will occur with a description of buckling parameters.

The second and third page of each load case lists stresses and von Mises design factors based upon nominal pipe and minimum pipe body properties. In columnar form the printout consists of the node number, node depths, internal and external pressure at each node, internal and external hoop stress above and below each node, axial stress above and below each node and maximum (either internal or external) and average (one half of the internal plus external) von Mises stress above and below each node. Corresponding design factors, the specified minimum yield strength divided by the von Mises equivalent stress, are presented at the right of the printout.

The above information provides a complete description of the force and stress state of the casing essential to a proper evaluation of the particular casing design.

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9-5/8" CASING ANALYSIS TABULAR OUTPUT