2. COMPONENT DETAILS

2.1 Drillstring Options

Figure 2 indicates the two configurations of the drillstrings under study; and Table 1 provides the major dimensions for these strings designed to drill a 311 mm (12-1/4 in) borehole to 4 km depth. It is suggested that use be made of drilling string connections or couplings based on the new Integral Joint Connections (IJC) premium casing designs (Klementich et al. 1993).

Table 1. Drillstring pipe sizes selected for study; (a) Dual-wall, (b) multi flow path.

(a) DUAL-WALL DRILLSTRING

Quantity	Outer Pipe	Inner Pipe
Outer Dia.: (in.)	9-5/8	7.0
Wall Thickness: (in.)	0.750	0.640
Unit Mass: (lb/ft)	71.8	44.0
Steel Area: (sq in.)	20.9	12.78

Total String Mass: 1.5 X 10E+6 lb,

(b) MULTIPLE FLOW PATH DRILLSTRING

Quantity	Outer Pipe	Inner Pipe
Outer Dia.: (in.)	7-5/8	2-7/8
Wall Thickness: (in.)	0.500	0.360
Unit Mass: (lb/ft)	39.0	10.4
Steel Area: (sq in.)	11.19	3.20

Total String Mass: 6.5 X 10E+5 lb,

Note: Hi Press Tubes are 1.0 in. OD Std, with 20 KSI Rating.

As an example of the type of analyses included within this study, Figure 3 shows the calculation results for the potential optimization of a dual-wall drillstring, with outer pipe diameter of 200 mm (9-5/8 in), for nitrogen (air) drilling. The dashed curves of bottom hole pressure vs flow rate indicate the flow necessary to lift cuttings and some inflow of

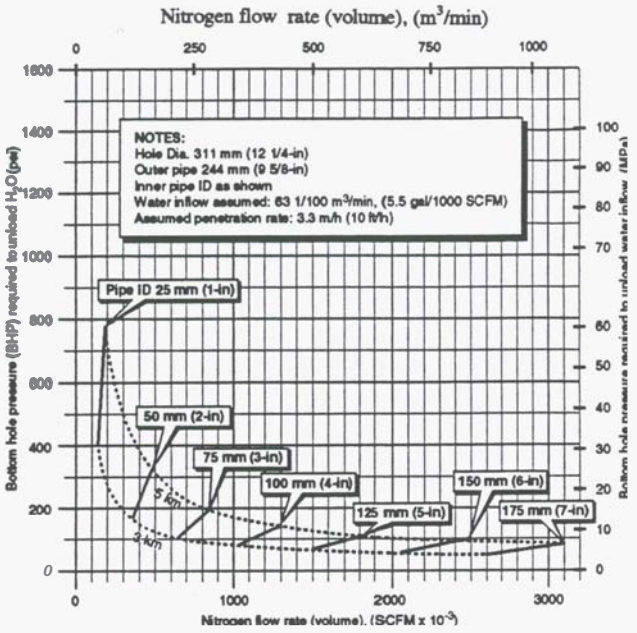

Fig. 3. Optimization analysis for dual-wall drillstring; nitrogen flow - pressure drop necessary to clean hole.

water and are parameterized for various inner pipe diameters. The trade-off of reduced pressure on the reservoir and flow volume (compressor capacity and cost) and the pressure requirements to clean and unload the hole are illustrated. It seems that an optimum diameter for the reverse circulation pipe ID is between 50 and 75 mm. Further analyses for these multi-flow-path strings should be undertaken, especially thermal and heat transfer simulations for the MultiCon system relative to cooling of BHA and provisions for special downhole sensors. Further study of use of treatment fluids in the annulus would be very desirable.

2.2 Percussion Hammer Drills

There have been innovative hammer development projects in Australia, Canada, China, Germany, Japan, Russia, and recently, two in the USA of interest for potential application to the AGDS design.

The two in the USA are illustrated in Figures 4 and 5. An air (nitrogen) tool (Bui 1995) has the valuable features of downhole indexing and can therefore be steered or "navigated".

Hydraulic hammers of new, innovative designs are under development by NOVATEK, Inc. (Pixton and

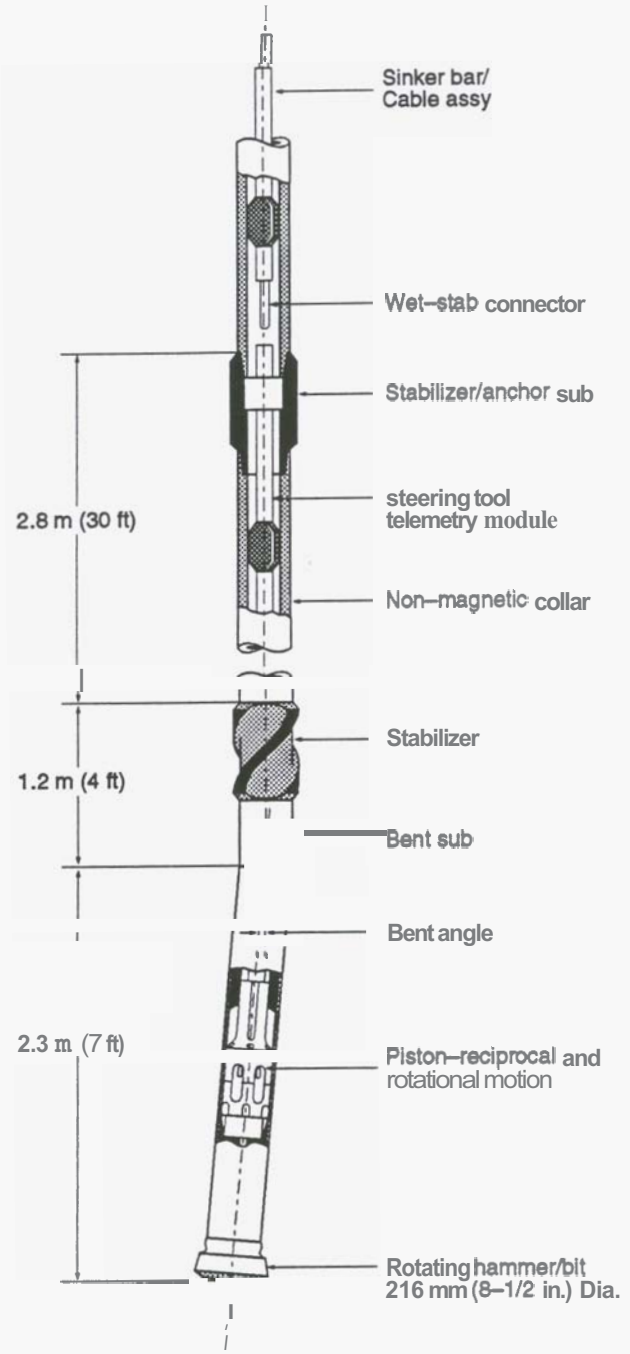

Fig. 4. Steerable percussion air hammer with downhole indexing (Smith Int'l., Inc.).

Hall 1995) with tools of 216 mm (8-1/2 in) and 311 mm (12-1/4 in), the latter specifically designed and developed for high-temperature, geothermal drilling applications; Figure 5.

Table 2 is a summary of the desirable features and the estimated performance characteristics for the AGDS hammer tools.

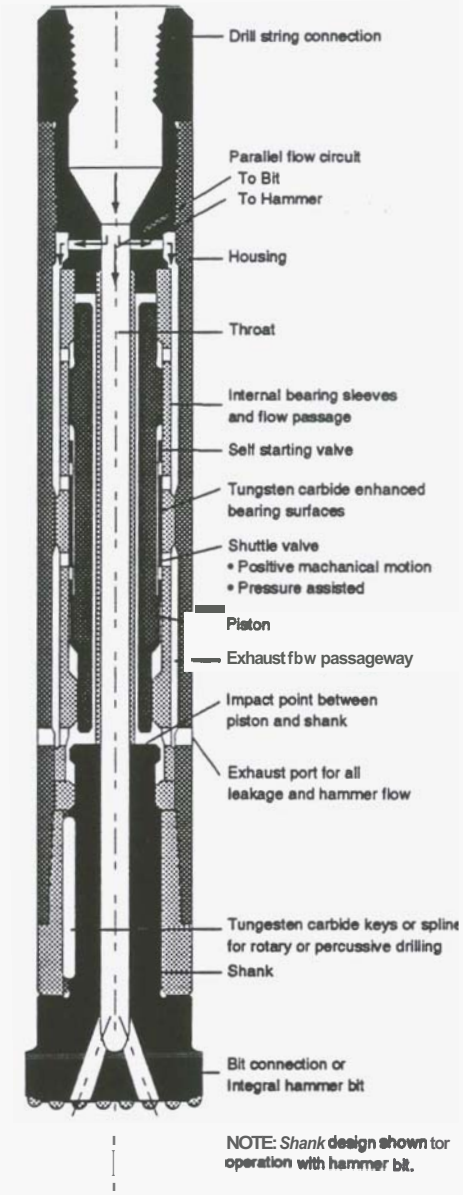

Fig. 5. Hydraulic geothermal hammer with parallel flow and high power features (Novatek Corp.).

Table 2. Hydraulic Percussion Hammer Specifications and Features.

HYDRAULIC PERCUSSION HAMMER
Design Goals & Preliminary Specifications (KTB)*

ITEM	APPROX. VALUE
Bit Dia.:	311 mm (12 1/4 in)
TCI (Cutter) Dia.:	10 to 12 mm
No. of TCI	35
Stroke Energy:	2 to 4 KJ
Tool Length	2 m
Tool Dia.:	197 mm
Tool Mass:	700 kg
Tool & Bit Life:	> 100 hours (MTBF)**

* Source: A. Sperber (1994)
** Mean Time Between Failures

DESIRABLE FEATURES OF

PERCUSSION HAMMER

- Air/Hydraulic Operation
- Variable Impact Frequency
- Parallel By-Pass Flow
- Self Starting Valve
- Anti-Clogging & Self-Cleaning
- Few Moving Parts
- No HT Seals
- Use with HEAVY Mud
- Operating Depth to 4 km
- 400°C Temperature Rating

2.3 Other BHA Components

The sketch in Figure 6 shows the conceptual design for the BHA proposed for the AGDS BHA. It will be necessary, for example, to have a thruster (often termed a "bumper sub") to control the force on the percussion tools. One such design concept is shown in Figure 7. This design needs to be developed for both hydraulic and air (nitrogen) service.

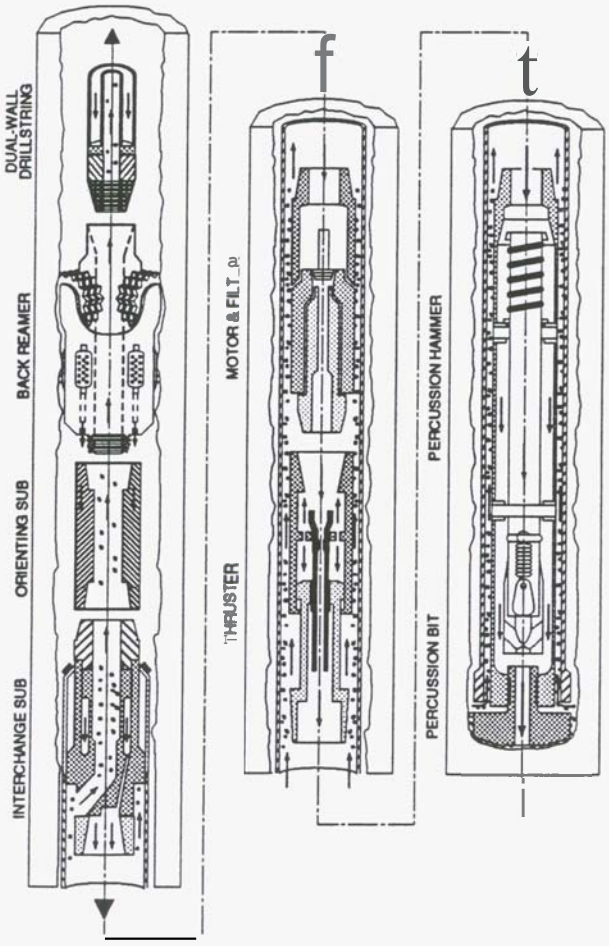

Fig. 6. Conceptual design for BHA elements.

2.4 Unique Nitrogen Source

The use of nitrogen, in place of air, has several advantages for geothermal drilling. The primary benefit is the great reduction in corrosion, very important if the goal of drilling 400°C reservoirs is to be effectively achieved. Figures 8 and 9 give the layout of a new nitrogen source, where the nitrogen is derived from the exhaust manifold of a diesel engine. Figure 9 gives the performance of several models of this source (Baugh 1994).

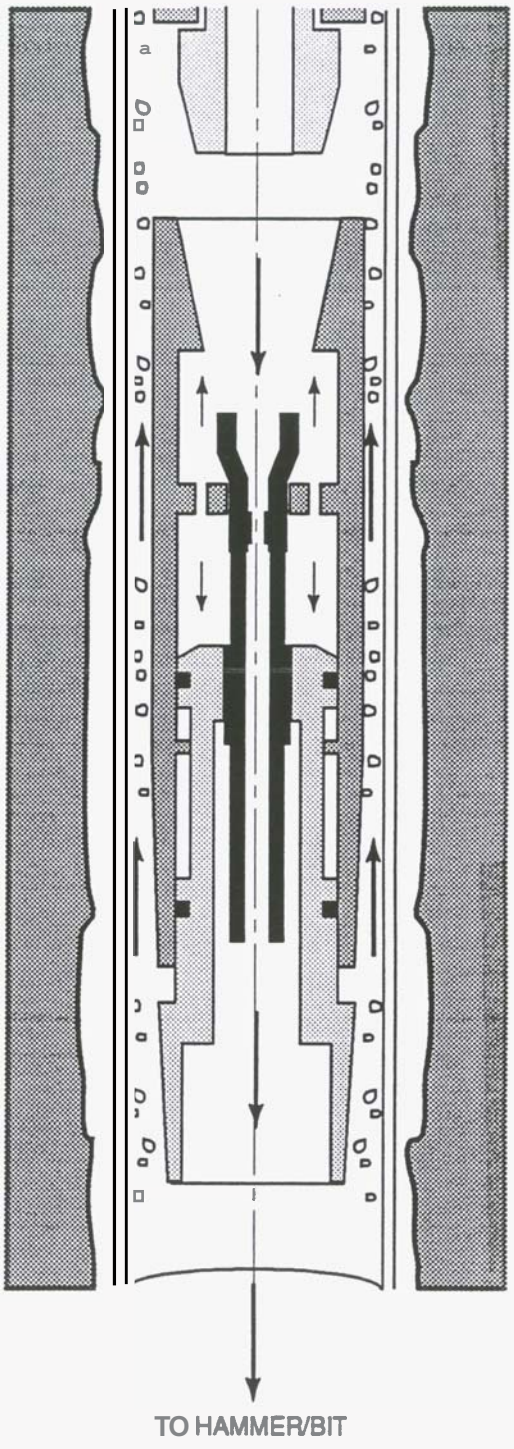

Fig. 7. Conceptual design of thruster.

3. CONCLUSIONS

The past two years have seen the formation of a 'design team' that has provided serious critique, input, literature, and many helpful contacts. The concepts for the AGDS system have progressed to a more mature state, and is on the verge of a feasibility design. Commercial sources for some of the elements suitable to be applied and research and development projects, for the needed percussion hammers especially, are underway.

The potential sponsors for any further AGDS development have as yet not been identified. But it seems that a continued volunteer effort might offer progress that can be of interest to potential funding sources. Perhaps an evaluation of the various subcomponents can be sustained as they each might have more immediate use in current drilling projects.

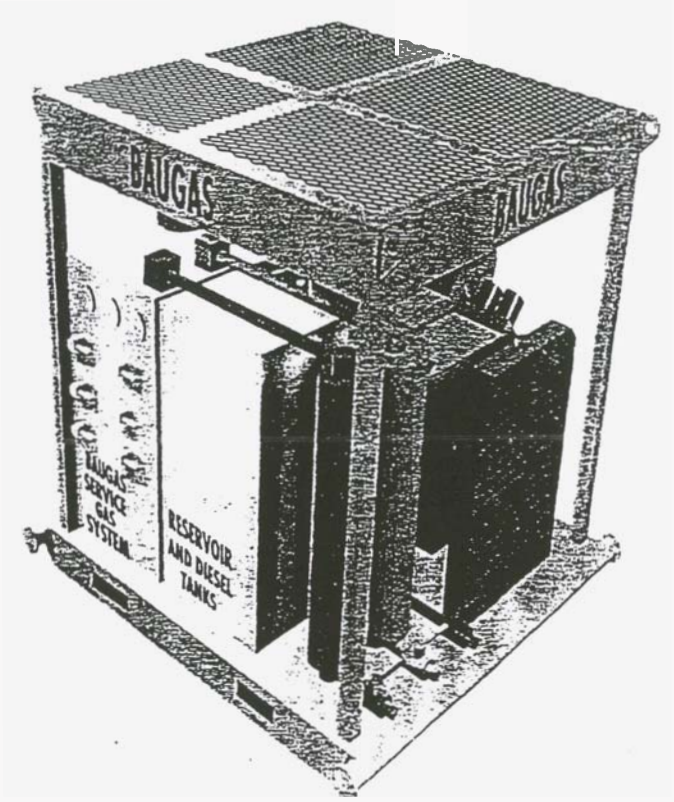

Fig. 8. Diesel exhaust nitrogen source unit (Baugas Co.).

4. ACKNOWLEDGEMENTS

The authors thank the other members of our AGDS 'design team' for their continued interest, feedback, and many useful reviews of various aspects of this AGDS concept. Several commercial firms have graciously supplied performance information for their equipment or components. Of particular value has been the sharing of R & D results and plans for the percussion hammer projects.

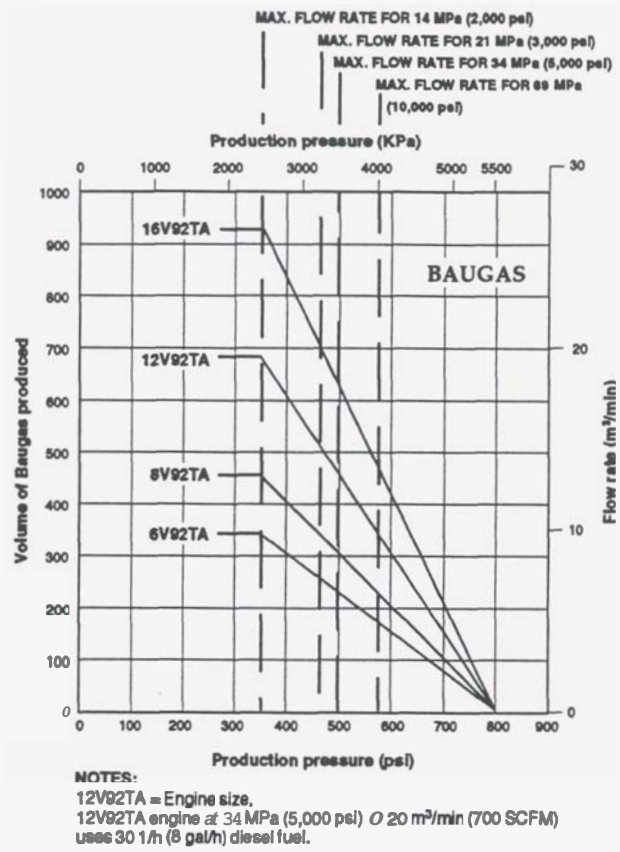

Fig. 9. Nitrogen source performance characteristics.

5. REFERENCES

Baugh, B.F. (1994) "Baugas Service Systems", Radoil Tool Co., Corporate Brochure, Houston, TX.

Bui, H.D. (1995) "Steerable Percussion Air-Drilling System", Smith Int'l., Inc., Corporate Report, April, 25 pp. 13.

Klementich, E.F., Morey, S.C., Payne, M.L., Asbill, W.T., Bouche, K.J.K. (1993) "Development and Acceptance Testing of a Flush Joint Casing Connection with Improved Properties", SPE No. 26320, 68 ATCE, October, Houston, TX USA, Drilling Vol. pp 31-59.

MultiCon (1994) Corporate Brochure, Telejet Technologies, Inc., Dallas, TX USA.

Pixton, D.S. and Hall, D.R. (1995) "Development of a New Generation, Mud-Driven Hammer System", Nat'l. Advanced Drilling and Excavation Technologies News, Vol. 3, No. 1, September, pp 3-5.

Rowley, J.C. (1993) "Geothermal Drilling: History and Technology Improvements", Proc. 15th New Zealand Geoth. Workshop, Auckland, NZ, November, pp 99-102.

Rowley, J.C. (1994) "Design Concept for An Advanced Geothermal System", ASME/ETCE Drilling Tech. Symposium Proc., PD-Vol. 55, January, New Orleans, LA USA, pp 239-247.

Rowley, J.C., Saito, S. and Long, R. (1995) "An Advanced Geothermal Drilling System: Component Options and Limitations", ASME/ETCE Drilling Tech. Symposium, PD-Vol 65, January, Houston, TX, pp 25-32.

Rowley, J.C., Saito, S. and Long, R. (1995) "An Advanced Geothermal Drilling System", Proceedings World Geothermal Congress 1995, May, Florence, Italy, pp 1379-1383.

Sperber, A. (1994) Personal communication.