Genie Impact Drills
Synopsis of a New Hard Rock Drilling Development

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Abstract

In 2004, a lean new Australian company was established to independently focus on the development and commercialisation of new drilling technology for the geothermal, petroleum & scientific industries. It began with assets including know-how, intellectual property, documentation and some equipment retained from pioneering work undertaken in the parent company between 1992 and 2002. It has produced a new commercial product, the Genie 185, a drilling liquid powered impact drill, the first in a range of new, high performance tools which offer higher Rates Of Penetration and simpler, lighter drill strings for hard formation drilling.

Purpose

To build a profitable commercial enterprise based on the development and provision of superior quality drilling services & products to the petroleum, geothermal and scientific industries.

Geothermal power market

Australian geothermal wells are being drilled to depths of around 4,500m but financial viability of hard fractured rock reservoirs is threatened by low Rates Of Penetration and problems associated with traditional rotary drilling systems in these environments.

Technology

High ROP, drilling liquid powered impact drilling systems for harder formations.

Product

Rented, on-site supported, fully serviced & equipped Genie impact drills and bit sales. .

Genie impact drill

Conceived and designed as a flexibly sized tool to create a range rather than a series of successive individually designed tools. The design is disciplined and imbedded in the drawings of the definitive, mid-range Genie 185 (for bits between 8-1/2" & 9-7/8"). See Fig. 1. There are fewer parts than in predecessor tools as well as enhanced bit alignment, new hard surface designs and treatments, corrosion protection, simple and secure jet nozzle mounting, longer tong grip zone and new assembly system for easy, fast and safe maintenance and set-up. A general mathematical model generates hydraulic & dynamic performance simulations which are used with a well model for application checks & set-up.

FIG. 1 – TALISMAN ENERGY INC WITH GENIE 185 ON NABORS RIG – BC, CANADA

General design & manufacturing

Part designs are geometrically and parametrically linked to each other and to a single scaling parameter which sets tool size. This saves repletion and improves drafting quality. The mid-range Genie 185 has a scaling parameter of 1. Each Genie model has an associated range of bit sizes. Bit head design geometry is linked to a second independent scaling parameter, the bit gauge diameter. A custom bit of any size between the specified minimum and maximum size can be produced. Design changes are more easily managed. Manufacturing is more flexible and simpler with improved quality and lead time as the result of feature commonality through the range.

Model selection & model number

The housing diameter in each Genie model is matched to BHA collar sizes whilst keeping the target bit gauge within range. The tool housing diameter in mm (rounded to nearest 5) provides the model number. The model number is not linked to any particular bit size and bit size ranges can overlap between some models.

Size & transport

Genie tools were designed with consideration for carrying in pick-ups and helicopters. They have an integral twin check valve. The Genie 185 is under 2m long, including the integral jet sub and is half the size and weight of predecessor tools.

Connecting threads

Genie tools have pin down API female top threads for protection during handling and for reduced length & mass. Genie bits are retained in a "pin up", splined drive sub (chuck) which screws into the Genie tool using a new design thread.

Model range

Current planned models include Genie130 (6" to 6⅞" bits), 160 (7½" to 8⅝"), 185, 200 (9⅜" to 11"), 260 (12" to 14¼") & 320 (14⅝" to 17½"). The 320 & 260 are next to be made. Smaller tools involve more manufacturing challenges and are expected to follow the bigger tools. A Genie 100 coring tool has been considered.

Hydraulics

The flow rate of fluid to power a new Genie tool over its operating range is generally lower than the flow rate used to clean the hole. The Genie tool therefore has an integral jet sub with a dual check valve. It enables jet nozzles to be fitted as may be required to provide for any additional flow rate at the same differential pressure. As a dynamic mechanism, the tool will be subject to gradual wear through its life at a rate depending on the amount of sand or other abrasive materials in the drilling fluid. It is important for economic reasons to keep the drilling fluid as free of cuttings as practically possible. Wear may be compensated for by increasing the pump rate. It is recommended that a working flow rate range be provided to maximise tool operating flexibility through its life. The Genie tool stops impact cycling when lifted off bottom and additional flow paths open within the tool to provide a more direct and lower flow resistant passage through the exhaust ports in the bit face. This enables higher flow rate bottoms-up circulation at lower differential pressure. It also facilitates passage of LCM. Fluid can become more abrasive under lost circulation control conditions.

Differential pressure & flow rate

The flow rate to run the tool from low to high power, and the resulting differential pressure, depend on the fluid. As an example and using a drilling fluid of 1.05 SG with a Newtonian kinematic viscosity of 5.55 mm^2/s (~35 second Marsh funnel), the flow rate is approximately 0.61 to 0.87 m^3/min for a new tool and about 0.89 to 1.33 m^3/min for a half-worn tool. The corresponding range of differential pressure is about 6.21 to 11.03 MPa. This is much lower than 12.76 to 17.24 MPa of the predecessor tools.

Weight On Bit (WOB)

A low WOB of 1.1 to 4.5 kdaN is required for the Genie 185 with an 8½" (215.9 mm) drill bit. The WOB for a rotary drilling system of the same size may exceed 20 tonnes for hard formations. WOB outside the Genie limits will cause a reduction in impact energy delivered to the bit face, a loss of ROP and an increase in drill string torque.

Bottom Hole Assembly (BHA)

A for ease of control, the lower BHA is isolated from the rest of the drill string by a fully pressure-balanced heave compensator type stroke sub. The applied WOB is thus limited to the weight of the items below it. See Fig. 2 for an example.

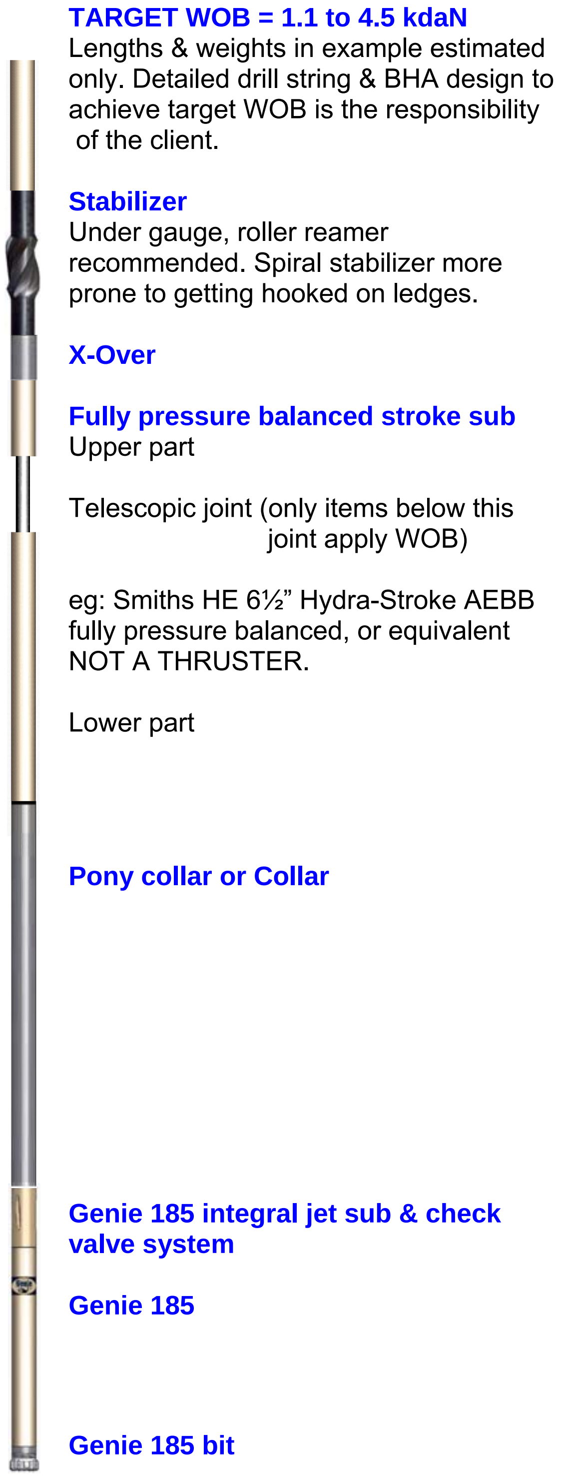

FIG. 2 – GENIE 185 BOTTOM HOLE ASSEMBLY

Project status

Approaching sign-off on the Genie 185 tool with its hard surfacing developments.

Relevance to Geothermal projects

- ✓ SUITABLE for HARD formations (metalliferous mining origins)
- ✓ HIGH TEMPERATURE RATING – 204C standard & 260C high temp. version
- ✓ HIGH ROP – up to 3 times offset rotary
- ✓ LOW WOB (1.1 to 4.5 kdaN for 8½" hole)
- ✓ LOW rotational speed (typically 25 rpm)
- ✓ LOW DRILL STRING STRESS
- ✓ LIGHT BHA – faster trips with less rig power
- ✓ API top thread & housing suits collar size
- ✓ LOW VIBRATION
- ✓ NO SEALED BEARINGS
- ✓ SIMPLE – only 3 moving parts plus bit
- ✓ ONE PART CUSTOMISED to mud
- ✓ DIRECTIONALLY STABLE
- ✓ EASY TO USE – manual or auto drill
- ✓ LOWER OFF–BOTTOM CIRCULATION PRESSURE
- ✓ RELIABLE – has always started on bottom
- ✓ RISK MANAGEMENT – no fishing & no bits lost on bottom (since 1993 start)
- ✓ AVAILABLE – designed & manufactured in Australia & based in Adelaide
- ✓ COST EFFECTIVE – cheaper drill string, no mud motor, less string wear, light & compact for transport, integral check valve & jet sub, potential to complete drilling in less than 50% of rotary drilling time for early production.

Abbreviated development chronology

1992 A system was conceived by Fred Moir, founder of S.D.S. Pty Ltd to drill 5¼" blast holes of 20 m depth in hard metalliferous mines using coaxial drill rods and a down-hole hammer powered by clean, high pressure, recirculated water. He sought the benefits of top-hole hydraulic hammers, down-hole air hammers and a benign, dustless drilling fluid. Used water returned to the surface in drill rods for re-use. A controlled portion was exhausted through the bit for hole cleaning. Malcolm McInnes was contracted to undertake system R&D. Trialled in underground mines with Western Mining and Pasminco with speed and dust suppression advantages.

1993 Performance diminished with depth due to "water hammer" vibration, the result of uneven cyclic flow resistance. Novel down-hole hydraulic accumulator systems had limited success. Managing the effect was replaced with managing the cause. A new concept impact drill (see Fig. 3) with progressive, staged pistons, cyclic flow resistance levelling, anti-cavitation impact faces and a new constant-exhaust bit was invented and designed by Malcolm McInnes who then won a $500,000 competitive Government R&D grant and completed the project to budget. Extensive mathematical system modelling was undertaken.

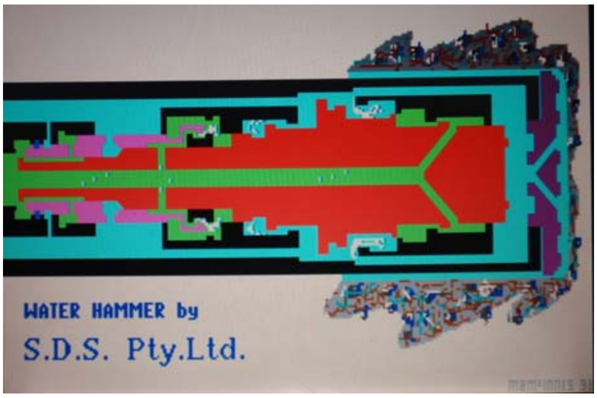

FIG. 3 – 1993 HYDRAULIC PERCUSSIVE DRILL

The compact new, patented design provided smoother, more powerful operation (see Fig 4) independently of depth. Recirculation through drill rods was abandoned for hole cleaning.

FIG. 4 – WATER HAMMER PROTOTYPE TESTING WITH GRANITE & UNDERGROUND

1994 Further underground testing with Mt.Isa Mines. Total distance drilled 1000m.

1995 Attracted to petroleum industry with more suitable pump & fluid infrastructure and more commercial potential. Developed tool coatings for contaminated fluids. Sub project to accommodate denser drilling fluids put on hold. Mixed results in oil field trial with partner Santos. Partly related to control & instrumentation issues and a packer.

1996 Breakthrough field trial of 6" Water Hammer with Shell in Canadian Rockies foothills with water. Drilled in a pipe stand in an 8½" hole at ~4.5 times ROP of roller cone using manual and automatic drilling.

FIG. 5 – FRED MOIR & MALCOLM McINNES AT WATER HAMMER RUN, CANADA 1996.

Began development of Water Hammer for 12¼" bit to suit same commercial application (water).

FIG. 6 – CLUSTER WATER HAMMER

Developed and successfully trialled 32" hole cluster drilling tool based on 4 water hammers for J C McDermott & Sons. See Fig. 6. Potential for 26" conductors & sub-sea anchorages.
Manufacturing & drafting moved from SDS Pty Ltd in Adelaide to SDS Digger Tools in WA.

1997 New 12¼" hole size water hammer designed & made. Immediately worked in Canada. 30 hour running time with new hard coating technology and flock water.
Developed case-while-drilling systems for Ocean Drilling Program. Achieved fast, unsupported spudding on hard, smooth, 30° sloping granite. Quarry tested CWD insertion and retrieval of casing. Development progressed in offshore trials with the ODP and sea water drilling fluid.

FIG. 7 – FLUID HAMMER 260 WITH ODP

1998 Ran 12¼" tool off shore from jack-up rig through short hard layer with ARCO Indonesia (see Fig. 8). Tool put in at 1,350 m & drilled 11 hours at higher than offset ROP (up to 5 x). This was despite some damage incurred to the bit due to tungsten carbide inserts left in the hole by the preceding roller cone.

FIG. 8 – WATER HAMMER & ARCO INDONESIA

Continued drilling 650 m surface holes with 14¼" bits with Talisman Energy Inc at ROP consistently 2 to 3 times faster than conventional rock bits in hard formations. See Figs. 9 & 10. A major downturn in the international mining industry threatens the internally funded project.

FIG. 9 – WATER HAMMER – CHERT CUTTINGS

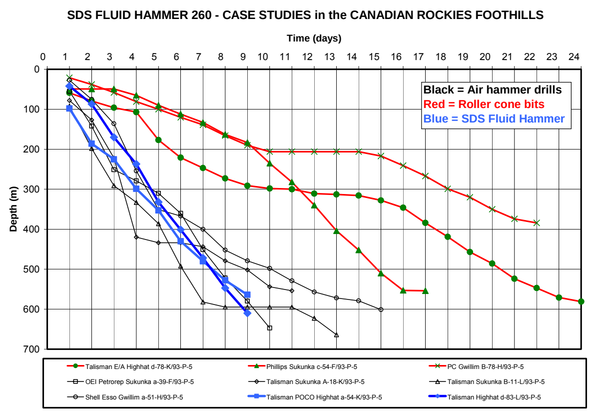

FIG. 10 – COMPARATIVE PERFORMANCE

Shoreline approach hole opening job at Statoil Mongstad refinery, Norway with 12¼" hole opening bit on slope rig run by Halliburton. Fig 11.

FIG. 11 – WATER HAMMER 260 & STATOIL

1999 Began development of new 8½" hole tool with fewer parts, new features and for range of drilling fluids (not completed), as new series base model. Performance testing undertaken in Orange Grove quarry, WA. See Fig. 12. Drilling with 12¼" tool with Northstar energy - Recorded continuous ROP 4-7 Mt/Hr Vs 2 Mt/Hr tricone. Hammer life increased to 40 hours.

FIG. 12 – QUARRY TEST 8½" PROTOTYPES

SDS Corporation Ltd commissions an independent technical review of the design. The engineering and technology is validated.

2000 Drilled with PDVSA in Venezuela at 4,355 m depth (2 to 3 x offset instantaneous ROP) with SDS water hammer 260 (12-1/4" bit). The fluid was a mineral oil of about 1.03 SG. WOB difficult to control. See Fg. 13.

FIG. 14 STEERING HYDRA 185. FIG. 13 PDVSA

First steering run using unfinished prototype Hydra 185 (8½") at Sperry-Sun Nisku test facility. The tool built a turn of 5° using a 1° bent sub and 9°using a 1.5° bent sub, in 18.3 m of concrete which it drilled at 100 m/hr (Fig. 14). Successfully demonstrated steering and operation in a well with Measurement While Drilling System (Hydra 185 not developed for fluid SG over about 1.05).

2001 May. Controlled surface benchmark testing of SDS Fluid Hammer 185 at TerraTek testing facility (see Fig. 15) in Salt Lake City, Utah, USA, separately and in conjunction with consortium lead by US Department of Energy. Facility simulates deep, overbalanced drilling with standard rock samples and drilling muds. Despite tool not being designed for 1.2 and 1.8 SG muds, Extensive testing confirmed the soundness of the concept, verified operating characteristics and inspired development to suit denser fluids and expand application versatility.

FIG. 15 – TERRATEK & FLUID HAMMER 185

Fluid Hammer 260 tool (12¼" bit) was trialled with PDVSA in well MCA-2X in Venezuela at 1,498 m. A new drilling technique had been developed in theory and was successfully used to control the tool and Weight On Bit for optimum ROP, a major breakthrough that also protected the bit. Worked despite failure of hook feed indicator. An instantaneous ROP 2 to 3 times off-set roller cone was demonstrated. Project investment and finance options were pursued for the board.

2002 June. Verification field tested prototype SDS Fluid Hammer 185 (9⅞" bit) with Talisman Energy Inc. & Precision Drilling. See Fig. 16. Used new design Bottom Hole Assembly. BHA provided required low Weight On Bit. Identified torque as a key WOB maximum & minimum indicator. System worked and overcame major hurdles in applying the technology commercially.

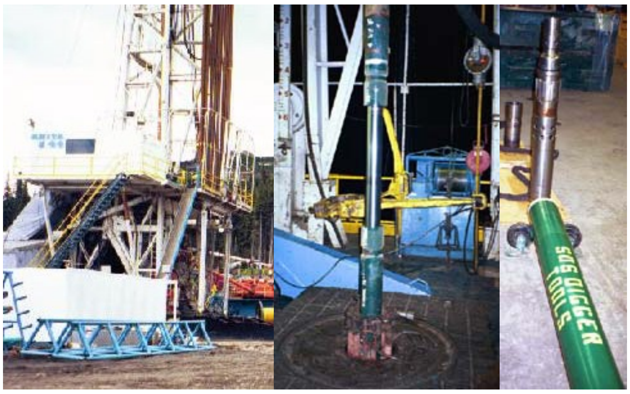

FIG. 16 – PROTOTYPE 185 & BHA. TALISMAN ENERGY INC & PRECISION DRILLING

Fluid Hammer project suspended.

2004 Project and its assets moved from SDS Digger Tools into new Adelaide based entity *IMPACT DRILLING INTERNATIONAL Pty Ltd.* to focus on development and commercialisation of the technology for the petroleum & geothermal industries. Genie project announced. New design, engineering, manufacturing and supply, testing, operations, quality systems, branding and funding to develop new range of tools for industry drilling fluids and with lower operating differential pressure to maximise versatility. Managed by Malcolm McInnes. Concurrently with new tool development, the company won a commercial contract with Integrated Ocean Drilling Program to use two 1997 design 260 tools with IODP Hard Rock Re-entry Systems (up to 15" bits) to insert casing with re-entry cones 30m into Atlantic Ocean floor, (1.5 to 2.5 km depth) north of the Azores, without a template. See Figures 17 & 18.

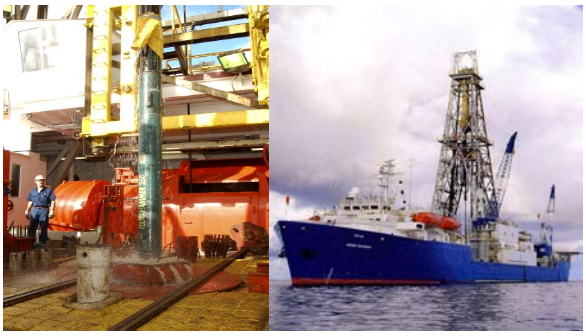

FIG. 17 – FLUID HAMMER 260 & CWD & IODP JOIDES RESOLUTION

2005 Successfully completed IODP job January, 2005. 2 tools ran a total of over 92 hrs in sea water without significant performance loss. The revenue supported the Genie project for the first 18 months. See Fig. 18.

FIG. 18 – IODP RE-ENTRY CONE ON FLUID HAMMER 260 & CWD INSERTED CASING

Designed & built in-house, impact drill dynamometer test rig for new Genie range R&D (see Fig. 19) with mud cooling, mixing, instrumentation, prime pump & twin HT400 pumps. Many components were reclaimed scrap.

FIG. 19 – IDI GENIE DYNAMOMETER TEST RIG

Successfully tested two different prototypes (see Fig 20) on water and standard muds 1.2 & 1.8 SG (as used in USA benchmark testing), without significant hydraulic vibration and at lower differential pressures. Different valves successfully used for different fluids. The parts supplier was late and the order incomplete. Enough parts provided for 2 complete Genie prototypes and one spare set of internals.

FIG. 20 – A PROTOTYPE GENIE 185

All part drawings parametrically linked and all drawings of the models in the product range linked to simplify and speed-up drafting, improve quality, simplify and standardise manufacturing, reduce lead times & costs. Check valve system redesigned for high solids mud. Safer, easier & faster assembly procedure and tools developed.

2006 SDS Corporation Limited sold to Sandvik Mining & Construction, Adelaide.
IMPACT DRILLING INTERNATIONAL Pty Ltd acquired by Fred Moir & minor shareholders.

2007 Prototype Genie 185 design & manufacturing completed. Business name changed to SPECIALISED DRILLING SERVICES AUSTRALIA Pty Ltd.

2008 Prototype Genie 185 tools run with field trial partner Talisman Energy Inc in Canadian Rockies foothills, 5 to 9 January 2008. Fig. 21.

The new Genie 185 system demonstrated:

- Directional stability. Deviation no more than ¾°
- Low rig mechanical & hydraulic vibration.
- High ROP, average 3 times offset tool ROP.
- Easy auto & manual drilling control.
- Reliable & predictable starting & operation.
- Automatically regulated, low WOB with lightweight BHA.
- Different but easy to learn to use.
- Can pass loss control material.

R&D program to increase durability. Prototypes did not employ hard overlays as used in predecessor tools. Accelerated wear was observed during lost circulation management due to increased sand level in drilling fluid. New design features, materials and pioneering manufacturing processes developed and incorporated into the Genie tools. A new dual check valve system was developed.

FIG. 21 – GENIE 185 TRIAL WELL, CANADA

2009 R&D and prototype manufacture of new hard overlaid tools completed in second half of year. New production systems developed for high volumes and low lead time. Additional field trial partners sought after follow-up drilling program delay in Canada due to financial crisis in USA. Local opportunity provided with contract won in late 2009.

2010 Tools mobilized to rig. Returned unused after anticipated hard formation was not encountered. Tools on stand-by for new project. Contract won for trial managed pressure drilling run in Asian project during last quarter of year. Development of below-the-hook lifting systems, maintenance procedures, manuals, drawings and other documentation continues.

Management

Chairman of the Board of Directors and principal shareholder is Mr Fred Moir. Fred is an international business leader with extensive drilling, service provision and manufacturing experience in the mining industry. Fred was founder of SDS Pty Ltd and instigated the original project to develop a water powered percussion drilling tool in 1992. Impact Drilling International Pty Ltd was established under his Chairmanship.
The business is managed by Malcolm McInnes, FIEAust. CPEng MESc BE ARMIT Mech Eng MAIE SPE with over 30 years experience in manufacturing, product development, R&D, marketing, sales & management and has run his own business since 1992. He is the designer and inventor of the Genie tools and inventor of the of the internationally patented SDS water/fluid hammer in 1993. Malcolm has 17 years experience in the drilling industry and became an employee and shareholder of SDSA in 2006.

References

McInnes, M.B. - Internal reports & photographs & company documents & photographs 1992 - 2010.

The Author acknowledges the contributions of all people involved in the project since its inception