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.
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 8⅞”), 185, 200 (9¼” to 11”), 260 (12” to 14½”) & 320 (14¾” 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 mm²/s (~35 second Marsh funnel), the flow rate is approximately 0.61 to 0.87 m³/min for a new tool and about 0.89 to 1.33 m³/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.

TARGET WOB = 1.1 to 4.5 kdaN

Lengths & weights in example estimated only. Detailed drill string & BHA design to achieve target WOB is the responsibility of the client.

Stabilizer

Under gauge, roller reamer recommended. Spiral stabilizer more prone to getting hooked on ledges.

X-Over

Fully pressure balanced stroke sub

Upper part

Telescopic joint (only items below this joint apply WOB)

eg: Smiths HE 6½” Hydra-Stroke AEBB fully pressure balanced, or equivalent NOT A THRUSTER.

Lower part

Pony collar or Collar

Genie 185 integral jet sub & check valve system

Genie 185

Genie 185 bit

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 – 204°C standard & 260°C 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.

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.

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

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.

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.

Continued drilling 650 m surface holes with 14¾" 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. 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 M/Hr Vs 2 M/Hr tricone. Hammer life increased to 40 hours.

**FIG. 12 – QUARRY TEST 8½” PROTOTYPES**

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 Fig. 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**

Australian Geothermal Conference 2010

SDS Corporation Ltd commissions an independent technical review of the design. The engineering and technology is validated.
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 (9¾” 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.

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.

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

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.
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.

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, FIE Aust, CPEng MEng Sc 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 SDS in 2006.

References
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