Automotive Products Group

Borg and Beck Company - Manufacturer of Automotive Clutches

The Borg and Beck Company was one of the main constituent companies of the large Automotive Products Group, whose headquarters and main manufacturing divisions were situated at Tachbrook Road, Leamington Spa, in Warwickshire. Other companies within the Group were the Lockheed Hydraulic Brake Company, Thompson Steering Joints, Purolator Filters Division, later relocated to Bolton, Automatic Gearbox Division, Lockheed Precision Products (Aviation Products) situated at Speke, Liverpool, Competitions Department (AP Racing) and the Spares and Service Division situated at Banbury. The main product divisions at Leamington were themselves supported by other manufacturing or process divisions, including a large Automatics machine shop and Central Process, whose function was to supply heat treated and surface treated components to the Group. Both of these latter divisions were also located at Leamington. In addition, several specialist companies were owned by the Group, including Hill and Jackson (Springs) Ltd., situated in West Bromwich.

The AP Group in its heyday also had manufacturing units and interests in Australia, New Zealand, South Africa and the USA. Somewhat later, production units in France and Italy were added to the company's manufacturing assets. Probably at its peak in about 1970, the AP Group had over eleven thousand employees worldwide. In addition to the main product divisions, the extensive Leamington site had large storage blocks, experimental and development workshops, including a Dynamometer Test House, laboratories, a large and well equipped tool room, a machine tool repair department, an equipment manufacturing department, an education department with apprentice training school, canteens and dining rooms, welfare and medical facilities and extensive playing fields and sports facilities. For many years the water tower and tall octagonal chimney were well known local landmarks. The extensive office blocks and well-tended gardens, incorporating ornamental water features that fronted onto Tachbrook Road, were particularly fine. Hardly anything of the above remains at Leamington and the former Banbury Service Division site has been completely redeveloped. "It is as though the wind has passed over it and it was never there".

Before we consider the Borg and Beck Company and its products, perhaps it would be apposite to explain the basic operation of a mechanical clutch. A clutch is a device that is installed in a power transmission system to enable the drive to be connected or disconnected at will. The actual take up of the drive can be instantaneous and rapid or smooth and progressive, depending on the clutch type and its application.

The first practical application of a mechanical clutch seems to have been incorporated in a number of very early machine tools designed by Marc Isambard Brunel, the father of the celebrated Victorian engineer, Isambard Kingdom Brunel. Marc Brunel, later knighted by Queen Victoria, was a very clever engineer who was, arguably, as talented as his more renowned son. Among Marc Brunel's major achievements was the design of the Portsmouth Ships' Block making machinery. These comprised a suite of twenty-two different machines to produce a complete range of ships' blocks virtually automatically. To operate the machines only a small number of unskilled operatives were required. Situated in Portsmouth Dockyard, these machines in 1805 constituted the world's first automated production line. The Block Mill building still exists at the dockyard, although devoid of all of its machinery. The Science Museum in London has a selection of the machines and a few more are held elsewhere.

The particular machine that featured a clutch was the morticing machine. It produced either single or multiple mortices in the block to receive the pulley or sheave. In practice the operator located the prepared block or blocks to the morticing machine, securing them in the machine vise. The operator engaged the cone clutch and the horizontal table automatically traversed the block/blocks under rapidly moving vertically mounted chisels, operating at up to 110-150 strokes per minute, to produce the mortice. At a pre-set point the automatic traverse was tripped and the operator disengaged the cone clutch and wound the table back to the starting position. The morticed blocks were removed from the vise to be replaced by a fresh set of blocks. The process was then repeated.

A heavy flywheel on the machine was continuously driven by pulley and flat belt drive from overhead line-shafting; a steam engine situated in the Block Mill supplying the primary power. The cone clutch engaged and disengaged the flywheel as required to start or stop the machine.

By 1808 the Portsmouth block making machines were producing 130,000 ships' blocks per year, a brilliantly successful installation that remained in occasional service until the mid 1950s. All the machines bristled with numerous, clever and innovative devices. The machines themselves, of almost artistic beauty, were manufactured by Henry Maudslay and Co. at his works in Margaret Street, Cavendish Square, London.

The Borg and Beck Company based at Leamington Spa produced an extensive range of mechanical clutches for a wide range of automotive and industrial applications. The rights to manufacture the Borg and Beck clutch were purchased and manufacture began at the Leamington site in1931.

A typical Borg and Beck automotive clutch installation comprises a Flywheel bolted rigidly to the end of the engine crankshaft. (Only exceptionally were flywheels supplied by Borg and Beck and this component was usually considered to be the customers interface). A Cover Assembly containing some form of spring element, either Helical Coil Thrust Springs or a Diaphragm Spring, which exerts a clamping load upon the Pressure Plate also contained within the cover assembly. Some form of positive drive is made between the pressure plate and the cover. This can be in the form of a number of equally spaced Lugs on the pressure plate periphery engaging matching slots in the cover. Provision is made for the axial movement of the pressure plate in the cover to permit clutch release. Alternatively, a connection between the pressure plate and cover could be effected by a series of equally spaced spring steel Drive Straps, either singly or laminated, riveted to the pressure plate at one end and to the cover at the other. The Cover Assembly is bolted as a unit to the Flywheel using six or more bolts, precision location between the two units usually being achieved using three equally-spaced dowels. In very rare instances special fitted-bolts were used. The cover assembly is single plane balanced and corrected as an individual unit. Balance correction is achieved either by material removal from the cast iron pressure plate as in the case of A/ AS Coil Spring type clutches or weight addition to the cover in the case of Diaphragm Spring DS and DST types.

Sandwiched and clamped between the Flywheel and Cover Assembly pressure plate is the Driven Plate. The driven plate comprises an internally splined forged Hub which engages upon an externally splined Shaft projecting from the Gearbox, on which the driven plate is permitted some degree of axial movement. A bearing bush in the centre of the flywheel supports the outer end of the gearbox splined shaft. In its simplest form the driven plate has a rigid steel Disc attached to the hub. Riveted to both faces of the disc is the Friction Facing Material which engages upon the surfaces of the flywheel and the pressure plate. However, most automotive driven plates were far more complex than the one described, employing a selection of Damper Springs to even out torsional inequalities and Crimped Cushioned Segments with feet attached to the disc adaptor and the crimped portion attached to the facing material, in order to assist in the smooth take up of the drive. The crimped cushion segment does have one other subtle but important design feature in that it ensures the driven plate releases away from the flywheel friction face rather than from the pressure plate friction face. This obviates wear in the expensive flywheel component and transfers it to the cheaper and more expendable pressure plate. Friction facing material varies considerably in composition and included moulded and woven asbestos, asbestos alternatives and sintered or ceramic pads or segments. The Driven Plate is single-plane balanced and corrected as an individual unit. Correction is achieved by the addition of either clip type weights to the segment feet or washers secured over the stops pins.

To complete the Borg and Beck package a Release Bearing Plate or Release Bearing is frequently, although not always supplied. The above description is of a single dry plate clutch. There were many clutch variations including multi-plate and PTO (Power Take Off) types, the latter for tractors and special clutches for military vehicles, helicopters, etc.

Brief reference has already been made to the A, and AS type clutches. These were helical coil spring cover assemblies with either lug drive between the pressure plate and cover (A Type) or strap drive between the pressure plate and cover (AS Type). The cover was a steel pressing with complex convolutions for added strength. The cover was pierced in several places for ventilation and heat dissipation purposes. Borg and Beck purchased all of its pressed steel covers, of whatever type A/AS DS/DST, from outside suppliers. A /AS Types were made in a range of sizes from about 6.5"pressure plate diameter up to about 20" pressure plate diameter.

The A Type series of clutches were durable units and were supplied for many years to the motor industry for a wide range of automotive and commercial vehicle applications.

However, the A/AS series of clutches suffered from a number of inherent limitations. Thrust springs have a fairly linear load/ deflection curve and produce, by modern standards, high release loads at the foot pedal. Additionally, as the driven plate begins to wears in service, its thickness decreases, which results in a corresponding loss of clamp load in the coil spring cover assembly. A -types also have a considerable number of components and are therefore more costly to manufacture and time consuming to assemble and adjust. They have considerable friction in their release mechanisms. A-type clutches are bulky and heavy for their driveline capacity. Their service life is much shorter than a DS/DST Type clutch. By comparison the DS/DST Type clutches suffer from none of the above mentioned disadvantages.

In the early 1960s a new type of automotive clutch was launched by the US motor industry. It was the diaphragm spring clutch and at a stroke it virtually eliminated most of the inherent weaknesses of the coil spring clutch. One of the first companies to market the diaphragm spring clutch was the Dana Corporation.

In the new design a single diaphragm spring replaced the numerous coil springs, levers, eyebolts, eyebolt nuts, pins, struts, split pins, etc, and consequently was a much more compact unit with greater driveline capacity. It was also much easier, quicker and cheaper to make.

The engineering characteristics of a diaphragm spring are such that as the driven plate thickness reduces due to wear in service, the clamping force applied by the diaphragm actually increases, the exact opposite of the coil spring type. Further wear of the driven plate results in increased load until peak clamp load is achieved. Continued driven plate wear results in a progressive reduction in clamp load until the fully worn in condition is arrived at and the driven plate is too thin to transmit drive and consequently starts to slip. The service life of a diaphragm spring clutch can be in the order of three times that of a coil spring type, often in excess of 100,000miles. Additionally, release loads at the foot pedal are considerably lower and the release travel shorter than the coil spring type. The clutch has a lower overall height profile and easier to balance and correct. The net effect of the above is considerable, making for smaller and neater vehicle installations, improved service life and reliability and hence greater customer satisfaction.

The diaphragm spring manufactured by Borg and Beck was a carbon steel component, blanked as a simple disc from Sheffield steel strip. Window apertures were then pierced and the periphery of the spring and windows were coined in a coining press. The spring was then radially slit to produce the spring fingers; a battery of power presses, suitably equipped with automatic indexing tables, performed this operation. After slitting the springs were surface ground on both faces to the specified thickness. This operation was accomplished predominantly on Lumsden horizontal table, vertical spindle grinding machines. The final operation before hardening and tempering was the forming of the cone angle and this in combination with the thickness gave the required load characteristics to the diaphragm. The spring was then hardened and tempered. At least six different hardening/tempering methods were developed over the years by the company and it was something of a quasi - scientific “black art” to obtain the desired engineering loads from the spring. The final operation was shot-peening on the concave side of the spring. Shot peening is a recognised method of improving the fatigue strength characteristics on highly stressed engineering components used in the motor and allied industries. Small particles of steel shot, of a prescribed grade, are fired at the component producing a very fine orange peel effect upon the treated surface. Machines supplied by the Wheelabrator Corporation performed this function. Occasionally some springs, depending on the specification, were subjected to an additional final finger forming operation, performed at the tips of the fingers. This necessitated localised reheating of the diaphragm and pressing in a suitably tooled press to achieve the desired form. The completed spring was then identified by applying a specific paint colour to one or more of the diaphragm fingers. The completed spring was then dipped in a self-hardening preservation oil.

Eventually, very late in the day, Borg and Beck followed their competitors' lead and opted to manufacture diaphragm springs from Chrome Vanadium Steel, in place of the Carbon Steel they had traditionally used. This gave improved control of the load characteristics of the diaphragm spring, but necessitated a massive injection of capital for new automated heat treatment facilities. This new equipment was manufactured in Germany by the Aichelin Company.

The other major component in the cover assembly was the pressure plate. Pressure plates were made from Grade 14 cast iron for the vast majority of applications, although some very special racing clutches demanded higher quality spheroidal or nodular iron to permit higher engine speeds. Pressure plate castings came into Borg and Beck from several outside suppliers. The A/AS type pressure plates were a more complex casting than the later DS/DST types and required additional machines and machining time to complete. By comparison the DS/DST pressure plates were simplicity itself.

Borg and Beck had about twenty-six pressure plate machining lines, some dedicated to particular types of pressure plates and others more universal. Initial turning, facing and boring operations were carried out on Vertimax vertical spindle production lathes. The final machining operation was on the pressure plate friction face and this was mostly accomplished on twin spindle Wyvomatic machines, manufactured by Wyvern Machine Tools of Leicester. Surface finish was critical on the friction face and damage due to careless handling had to be prevented wherever possible. The various pressure plate machining operations made extensive use of carbide index-able inserted tip turning tools, operating at optimum cutting speeds and feeds. The Swedish Sandvic Company was a prominent supplier of carbide tipped tooling, extensively used throughout Borg and Beck and indeed AP. When all the machining operations had been completed the finished pressure plate was dipped in a dewatering oil to prevent corrosion.

Normally, cast iron is commercially machined at high rates without the need for cutting fluids or coolants. However, to suppress cast iron dust released from the various machining operations, cutting fluid or coolant was used. Nevertheless, despite its use the pressure plate lines were dirty and dust laden areas, to be avoided if at all possible. The lines became somewhat worse after a decision was subsequently taken to dispense with coolant altogether! I bet that person never worked on the pressure plate lines!

The first stage in the assembly of a DS (Diaphragm Spring) or DST (Diaphragm Spring Tab) Cover Assembly was actually a sub – assembly, requiring the drive straps to be riveted into the cover pressing. Usually, but not exclusively, there were three sets of straps per sub-assembly, each set usually comprising a lamination of two or more straps. This operation was usually performed on a 15Ton Mills hydraulic press.

In the main build of Diaphragm Spring Cover Assemblies, of both the DS and DST types, male operatives were employed on one of six moving belt conveyor assembly tracks.
In the DS type the diaphragm spring was retained within the steel cover pressing using hardened steel shouldered rivets or soft rivets with hardened sleeves, the shanks of the rivets passing through the windows in the diaphragm and the tails of the rivets into the cover, sandwiching the diaphragm between two open-ended and tagged fulcrum rings. The tags of the rings were positioned as near diametrically opposite each other as possible and

secured into the diaphragm windows. Positioning the fulcrum rings in this manner assisted the subsequent balancing operation. Where hardened sleeves were used an additional annular flanged section ring was introduced into the build. This gave added support to the fulcrum rings.

The diaphragm to cover retaining rivets were closed using 60Ton Mills hydraulic presses, equipped with SP 1156 air bed sliding bases, onto which were mounted the riveting fixtures. The sliding base arrangement permitted doubled-sided press operation.

To complete the cover assembly main build the pressure plate was riveted into the cover and spring sub-assembly. Firstly the pressure plate was located to the riveting fixture, friction face down and the fulcrum lands greased with Keenomax grease. Many different ideas were experimented with to dispense a thin layer of grease quickly and efficiently to the pressure plate lands. There was one method that could never be outperformed and that was the “cardboard box”, with the base smeared with grease! For management this was an anathema, as it did not look very professional. However, despite our best efforts nothing better or quicker was ever found.

The pressure plate’s fulcrum lands were kept in contact with the concave belleville portion of the diaphragm by the use of three equally spaced clips. Three sets of laminated drive straps, together with their respective clips were riveted to the pressure plate lugs thus securing the drive between the pressure plate and the cover pressing, and completing the assembly. The pressure plate to strap riveting operation was accomplished using 30 Ton Mills hydraulic presses, similarly tooled to the diaphragm riveting operation above. Again, doubled-sided press operation was utilised.

The DS Cover Assembly was made over a long period of time in a range of sizes from 6.5”-18” diameter; the larger sizes for commercial applications.

The DST (Diaphragm Spring Tab) Cover Assembly was a development of the DS type and completely dispensed with rivets to secure the diaphragm spring into the cover pressing. Instead, the DST clutch had integral projecting tabs in the cover pressing which passed through the diaphragm windows and were then formed, in a two-stage pressing operation, to retain the diaphragm spring. Welded closed- type fulcrum rings were used in place of the open-ended variety, to sandwich the diaphragm spring into the cover.

The first stage in the DST tab forming operation was to deflect the projecting tabs through about forty-five degrees. To prevent the fulcrum rings “threepenny-bitting” (developing flats) during this first stage tab forming operation, a back- up support ring was incorporated into the press tool. At the completion of the first stage forming operation the operator had to manually index the cover assembly round by about 30 degrees to remove it from the top press tool. It had been envisaged that the indexing of the back-up support ring would be accomplished automatically as a function of the tool; however, this was not carried forward.

Automatic indexing of the back-up support ring was subsequently accommodated in the tooling of the French Automated Cover Assembly line (see later note). A Mills 60T hydraulic press was used with double-sided operation.

In the second stage operation the partly finished cover assembly was located on a second press tool to complete the tab forming operation. This resulted in the tabs being fully deformed through a total angle of about 118 degrees from the initial raw pressing condition. No fulcrum ring back- up support was required. After a considerable amount of development work with the tab forming press tools and increasing confidence in the DST clutch in general, it became possible to dispense with the initial forming operation and complete it all on a single-stage press tool, utilising a 60T Mills hydraulic press. Whilst this single-stage tool produced a generally satisfactory DST clutch, it was probably not quite as good as a similar clutch produced by the original two- stage tool method.

The pressure plate was then riveted into the cover and spring sub-assembly in a similar manner to the DS type, although no clips were used on DST types.

Mills hydraulic presses, manufactured by John Mills and Co. of Railway Foundry, Llanidloes, were extensively used throughout the Borg and Beck assembly areas. They were real workhorse machines that produced millions of units over the years, with very little trouble indeed. Excellent machines!

Although possibly not quite the first company to introduce the rivet- less diaphragm spring clutch - that honour may have actually belonged to a French competitor Valeo - AP Borg and Beck was amongst the leaders and perhaps quite rightly received the Queens Award to Industry for its DST design. Unfortunately, as is probably the case with most of these awards, the actual people who designed the DT Clutch, along with those who developed it, production engineered it, made the tools for it and generally made it work, hardly received a look in. It is rather like the design of the Spitfire being credited to one man, R J Mitchel, but not many will be aware that the very distinctive shape of the Spitfire's elliptical wing was down to the chief aerodynamicist of Supermarine, Beverly Shenstone. His name hardly trips off the tongue, does it?

After completion of the cover assembly build all units, irrespective of whether they were DS or DST types, were single-plane balanced on Hofmann EVD 50 or 100 vertical spindle balancing machines. Hofmann balancing machines were manufactured in Pfungstadt/Darmstadt, Germany, a recognised centre of balancing technology. Borg and Beck used an in- house method of balance resolution called a Light Box, which took the magnitude of imbalance and its position on the cover assembly and displayed the necessary correction pictorially to the operator, using a matrix of small illuminated lamps. Many operators became very proficient at balance correction and frequently did not resort to “plugging the light box” to read the correction. Correction of imbalance was achieved by the addition of a range of weights, “pop” riveted or occasionally squeeze riveted, to the cover at the appropriate positions indicated by the light box.

In the author’s opinion, Borg and Beck clutch design never really fully appreciated that a good balance correction system needed to be an integral part of product design, not merely an adjunct. All too frequently it was a case that at the eleventh hour someone from the DO would say, “here is the balance limit and how do we (you) achieve it”? Industrial Engineering usually did, but it was not always easy. The author frequently did his own balance force-diagrams just to see if the balance limit could be achieved, given the disposition and range of weights available! The fairly standard balance limit for an average Cover Assembly was in the order of 0,5 oz inches in old money.

Functional testing of DS/DST Cover Assemblies included measuring finger-tip dimensional runout at a specific height, with the cover assembly clamped on an adaptor plate, simulating a new condition driven plate. Manual levers were employed to deflect the spring fingers as necessary. This was a somewhat crude, time consuming and not very satisfactory method. It was only after some years and several expensive and largely abortive attempts that a reasonably satisfactory solution was found.

Other functional tests determined whether various release loads and pressure plate lift and runout, at specified release travels, complied with engineering specifications. Additional testing determined whether clamp loads at various dimensions met the engineering specifications. All these were 100% production checks.

Eventually, "state of the art” computer controlled test rigs were developed that could perform all of these functional tests within a cycle of thirty seconds or so; providing full sets of spring load/ defection/ lift curves and test results if necessary. They were expensive machines made by George Kingsbury and Wickman – Automation, requiring the operator to merely load and unload the component and press the start button. The author of this paper spent a great deal of time dealing with test rigs and functional testing at AP. One of main problems with all testing is correlation of results. The clutch design and engineering departments always based their calculations on data provided by test rigs in the development and experimental departments, quite remote from the rigours of the production shops. There were nearly always some slight differences between the development and production test rigs and sometimes, more disconcertingly, between the production test rigs themselves! The reasons for these discrepancies were probably well known, but never fully resolved or reconciled. For example, a fairly small linear positional error of .001” (.025mm) on a steep diaphragm spring load/ deflection curve might result in a big discrepancy in load! The production test rigs, wherever possible, mirrored the experimental/development rigs, especially in the use of the best available load cells from the USA. In addition, expensive high quality Heidenhain linear- transducers and encoders were used throughout.

At the centre of all Driven Plates was the Hub. This was a forged steel component which may or may not have an integral circular flange. The vast majority of hubs produced for cars and light vehicles had flanges. These high volume components were machined using a system called Phased Groups.

The machining sequence of the hub was as follows;

A hole was drilled and reamed in the centre of the hub on 21A, 23A or 28A Pollard Vertical Drilling Machines equipped with a multiple drilling spindles and powered three station rotary tables.

An internal spline was machined in the hub using a Matrix Horizontal Hydraulic Broaching Machine, the previously drilled and reamed hole being the pilot for the broach. The broach entered the reamed round hole and was drawn hydraulically through the rigidly held hub, progressively cutting as it went, until the final splined form was achieved at the end of the stroke. There were many sizes and varieties of splines, each necessitating a dedicated broach. Broaches were expensive items, being over a metre in length and made of high quality high-speed steel, precision ground to very high standards of dimensional accuracy and form. Copious amounts of lubricant are required to achieve good surface finish and promote extended broach life. The broaching operation gave very little trouble and was an efficient and accurate machining process. Many millions of hubs were broached in this manner at AP. The Coventry Gauge and Tool Company made the Matrix Broaching Machine under licence from the American Rockwell Corporation. Borg and Beck had numerous Matrix Broaching Machines.

The broached hub was then further machined on a Herbert Auto Junior, No 2A or 3A Automatic Lathe. The machining operation consisted of turning and chamfering the outside diameter of the flange, facing both sides of the hub flange and turning any spigot or location diameters on the hub boss, as specified on the drawing. For this machining operation the hub was mounted on a special externally splined mandrel secured to the lathe spindle. The component was secured in place on the mandrel by use of a suitably adapted Herbert Air Chuck. Machining was performed by multiple turning tools located on the cross slides and possibly two stations of the four station self-indexing turret. The machines were totally automatic and the only operator intervention required was to load and unload the component. Occasionally, the turning tool carbide inserts had to be indexed round to present a new cutting edge, or replaced completely when fully worn by the tool-setter. Many millions of Hubs were machined on Auto Juniors. The Auto Junior automatic lathe was a venerable machine, widely used in the British Motor Industry and Borg and Beck had many of them. They were constantly being reconditioned on a rota basis by the Machine Tool Repair (MTR) Department. Many of them must have been forty, fifty or sixty years old. However, as engineering specifications started to get more stringent and dimensional tolerances became tighter, the Auto Junior began to show its limitations and AP should have invested in new plant accordingly. They did not.

The next operation on the hub was to pierce the windows and stop pin cut-outs in the flange. This was a very quick operation and consisted of placing the fully machined hub on a press tool, located on the bed of a large power press. The press was operated and all the windows and cut-outs were pierced at one hit. The windows in the hub flange were necessary to provide locations for the torsional damper springs fitted in the completed driven plate assembly. There were many different window patterns, necessitating numerous dedicated press tools. Because the window piercing operation introduced some slight distortion into the hub flange a secondary planishing operation was required. This merely consisted of placing the hub on a simple tool in a power press and giving the hub a secondary blow. This produced a more or less reasonably flat flange, hopefully with little total indicated runout (TIR) when checked off a splined mandrel. The writer always considered these two operations the most dehumanising and soul destroying in Borg and Beck. They should have been automated or perhaps robotically controlled.

Towards the end of the writer's tenure at AP, Borg & Beck did start to stir itself and invested in a fully automated machine to produce hub windows using CNC Laser Cutting Technology. The investment was very considerable. In theory this was a good move as it eliminated at a stroke numerous very expensive window piercing press tools, the associated distortions inherent in the piercing operation and obviate the need to do a secondary planishing operation. Additionally, any new window patterns not yet dreamed up by the design office could be easily and quickly accommodated by pressing a few buttons on the computer console. Production lead times would also be significantly reduced as no press tools needed to be designed and manufactured. There could also be an extra bonus of induced hardness to the windows whilst they were actually being cut! That was the theory. Like many theoretical things the practical application may be somewhat different! The immediate question of course was speed of operation. What was being achieved in a fraction of a second using a power press would take considerably longer with a Laser. There were other problems and the author of this paper does not know whether they were resolved or not. However, the author well remembers one sceptical production engineer in the office suggesting that one day someone would suggest using a power press and press tool to do the job!

We have digressed somewhat! The above completed the hub machining operations. However, two further operations were required to complete the hub. The first of these was the induction hardening of the windows. This consisted of placing the hub on a fixture equipped with induction heating coils that entered each of the hub windows. The heating coils were energised and the inner periphery of each of the windows rapidly reached red heat. On reaching the correct temperature the hub was automatically vertically quenched in water or oil. This process created a hard and durable working surface against which the helically coiled damper springs reacted. Unhardened windows would have fretted away very rapidly under the constant action of the damper coil springs. The induction hardening machines were supplied by Wild-Barfield and Borg and Beck had several of these.

The final operation to the hub was the application of a protective coating, probably one of the phosphate treatments. This was carried out in the Central Process Department.

Another important component that required machining was the friction facing material, attached to the driven plate disc or segments. Although the author of this paper thinks that a limited amount of friction material may have been made at the Service Division at Banbury, the vast majority of facings were bought in. One of the major suppliers of friction material for both Borg and Beck and Lockheed Brakes was Ferodo Ltd., based at Chapel-en-le-Frith, Derbyshire. With regard to Borg and Beck, the facings were supplied in the form of bored discs of varying diameters and thicknesses. Friction material also varied widely in its composition, some being woven asbestos, some moulded asbestos, etc. Eventually, when the health hazards of asbestos became an increasing problem, alternative non-asbestos friction materials were introduced.

Before a consignment of facings could be used they had to be drilled and countersunk to the prescribed fixing pattern of a particular driven Plate. There were many fixing patterns, depending on the diameter of the driven plate and other considerations. The drilling and countersinking of all facings was done in the Facing Drilling Section, which in 1968 when the author started his employment with AP was roughly in the centre of the Borg and Beck shop. This ensured that everyone in the plant got their fair share of asbestos dust!

The author remembers late one afternoon, in perhaps 1969/70, visiting the Facing Drilling Section shortly after the workers had left and was appalled to see a work station operated by a middle aged woman heaped with asbestos drill chips, and an airline positioned nearby to ensure its atomisation. Airlines at this time were provided so the operators could blow asbestos dust from the drilling fixture component location points. The dangers to human health of asbestos dust had been well known for a very long time, but largely dismissed by successive Governments. Together with a supine Factory Inspectorate and weak and ineffective legislation nothing had changed over many years. This really was an appalling state of affairs.

The drilling of high volume facings was achieved using fully-automated multi-headed drilling spindles attached to Pollard Vertical Drilling Machines. Small quantity facings were drilled manually, but still using multi-headed drilling spindles on Pollard or Herbert Vertical Drilling Machines.

However, this cavalier attitude towards asbestos was soon to drastically change. In the early 1970s new stringent Health and Safety Directives concerning the use and processing of asbestos and asbestos based products came into effect and the company had to change its ways of operation, not only in Borg and Beck but also in the Lockheed Brakes Division. Brakes of course drilled linings for drum type brake shoes in much the same carefree manner as Borg and Beck did for clutch facings!

To the company's credit, a new self-contained and enclosed facing drilling section was created away from the main workshop areas and this became a model of cleanliness and best practice. All drilling machines, jigs, fixtures, work benches, handling and stacking areas, etc, had powerful exhaust extraction ducted to a state of the art air filter unit and bagging chamber. The air in the facing drilling section was changed several times an hour and constant monitoring proved that it was the cleanest working atmosphere by far in the factory. And of course there were no more airlines! However, the author never spent more time than was absolutely necessary in the facing drilling section. An asbestos monitoring expert from the Ferodo laboratories once remarked, rather tellingly, that the real danger was from asbestos particles that you could not see, not the ones you could! Not all asbestos related problems, however, were associated with the facing drilling section as we shall see.

The first stage in the manufacture of a typical high volume driven plate was the sub-assembly of the crimped segments to the disc-adaptor. A disc-adaptor was placed on a fixture together with a set of crimped segments, the latter locating off fixture pins projecting through the holes to be subsequently used for the facing rivets. The feet of the segments were then riveted to the disc adaptor using flat headed Bifurcated rivets supplied by the Bifurcated and Tubular Rivet Company (Bif) of Aylesbury, Bucks. The power operated riveting machines were also of Bifurcated manufacture and were actuated by foot pedal control. The rivets were hopper fed down a track to the pockets, where one rivet was held preparatory to the machine being actuated. When the machine was tripped, the punch, driven by the machine crank mechanism, rapidly descended taking the rivet held in the pocket into the aligned segment and disc-adaptor holes forming the tail of the rivet against a specially profiled anvil/pin and against the disc-adaptor face.

One of the perennial problems that occurred with the disc-adaptor and segments sub-assembly was the inadvertent riveting of two segments to the disc adaptor. This was quite difficult to spot as the segments were relatively thin and sometimes stuck together as a result of a previous preservation treatment operation. A double segment, if incorporated in a finished assembly, resulted in excessive runout in the driven plate and ensuing "clutch drag" in the vehicle. The problem was eventually solved by the incorporation of a pre-set load cell in the riveting machine anvil assembly. An abnormally high riveting load recorded by the load cell tripped out the riveting machine and the operator immediately knew there was a faulty assembly with a double segment.

High volume automotive Driven Plates were assembled using powered moving belt conveyors in much the same manner as that for the cover assemblies, the main difference being female labour was employed throughout to perform the various operations. The first operation was to secure two facings to the disc and segments sub assembly. This was a riveting operation involving setting countersunk rivets through the pre-drilled facings and securing them to the segments. The rivets used were of the countersunk head semi-tubular type or variations of these, supplied by the Bifurcated and Tubular Rivet Company and to a lesser extent by the S&D Rivet Company of Leicester. The riveting machines used were of Bifurcated manufacture. Rivets were hopper fed down a track to the pockets where one rivet was held preparatory to the machine being actuated. The machine was actuated by placing the facing and segment rivet hole over a sprung loaded anvil pin and depressing a trigger type lever arrangement. This tripped the machine allowing the punch, driven by the machine crank mechanism, to rapidly descend taking the rivet held in the pocket into the facing and segment hole and forming the tail of the rivet over a specially profiled anvil and pin against the segment face. All this took a split second. Bifurcated always supplied the punches, pockets and anvils. AP attempted to make these particular tools in house but the outcome was not entirely satisfactory, the form of the anvil and pin being particularly critical. So AP left it to Bif to make them, albeit rather expensively!

The girls were extremely dextrous and very fast with their facing riveting. They could have done it their sleep and probably did! The Bifurcated Company always maintained that our girls were the fastest users of their machines and the clutches on the riveting machines were almost continuously engaged, so fast were they being used. Absolutely zillions of rivets must have been set by these girls. It has been hinted at previously that there was another problem with asbestos dust and this concerned the riveting operation. Every time the punch descended to set a rivet, a minute puff of asbestos dust was released from the facing. Eventually exhaust extraction was fitted on each of the facing riveting machines, the point of extraction being made near the anvil pin.

The next operations consisted of loosely assembling all the other elements of the driven plate including the correct sequence of coil damper springs into the hub, positioning of the hub into the disc adaptor, the location of any friction washers to the hub boss, the positioning of the stops pin and finally the location of the retainer plate to complete the loose assembly.

Some driven plates could be considerably more complex than that outlined above, with special friction elements etc. The loose build assembly was then located to a stop pin riveting fixture on a Mills Hydraulic Press. The press was actuated to close the stop pins to retain the whole assembly. To finish the splines of the hub were lightly wiped through with Keenomax grease using a spoke brush. The assembly was now complete.

The driven plate was then single plane balanced and corrected by adding balance weights at appropriate position.

The finished driven plates were then subjected to certain functional checks

These included:

A check for runout of the assembly when mounted on a splined mandrel and rotating between two plates a pre-set distance apart.(Set to Nominal Clamped Thickness+ Release Movement) This was to ensure the assembly did not “drag” when installed in the vehicle. This was a 100% check frequently necessitating manual correction

Test Rigs were also used to check the hysteresis (mechanical friction) within the driven plate to ensure the prescribed engineering limits were being met. This was achieved by clamping the driven plates between two plates to simulate the vehicle condition and subjecting the assembly to angular torsional movement and taking readings of friction on the wind up and return. Later computer controlled machines did this fully automatically, producing graphs and test figures.

A further rig measured the crimp deflection of the segments when subjected to prescribed loads.

Unlike the Diaphragm Spring Cover Assemblies where 100% checking of engineering test specifications was the order of the day, Driven Plates were only sample checked.

Automated Assembly

When AP Borg and Beck received a large order for its 180/190mm DST Cover Assemblies and matching Driven Plates, from the French Renault Company, a decision was taken by management to automate as far as possible the build of these units. Many studies were carried out of both linear and rotary table type assembly concepts. In many ways the questions that needed to be answered were much the same that probably confronted Marc Brunel when considering his own pioneering Ships’ Block manufacturing machines, some two centuries previously. They could be summarised as; the type of products to be assembled (DS/DST); the size range of the products to be assembled; was it to be totally automated manufacture or varying degrees of it and the amount of technical sophistication? In the final analysis most of the questions were answered by budgetary constraints and what was technically feasible, practicable and sensible.

Eventually, a linear type automated assembly line was adopted for the Cover Assembly and a combined linear and rotary table design for the Driven Plate Assembly. Both lines contained a certain amount of manual input. The Renault clutch order came with conditions. Half the automated plant would be built in the UK and the other half in France, with the special purpose machine division of Renault electing to make the Driven Plate Assembly line. The contract for the Cover Assembly line was awarded to John Brown Automation, a Division of Wickman Ltd., based at Binley, Coventry.

Although much of the initial project work was done in the industrial Engineering Department at Leamington, control of the Driven Plate Assembly line was eventually lost to the French and they assumed responsibility for their part of the project.

John Brown Automation in Coventry was a very competent company with considerable experience and expertise in building automated production lines. They produced a very good assembly line for Borg and Beck, incorporating some innovative features. The writer will not go into the technicalities of the line, other than to say it included both assembly and test equipment.

Although it should have been blindingly obvious from the start, when Renault first insisted on manufacturing half the plant in France, it still came as a bit of a surprise when it was discovered that the John Brown manufactured line was to be shipped to France to join the Renault built equipment. So it was really a French project after all! We felt at Leamington somewhat deflated and outmanoeuvred by all this and considered politics had played a very considerable part in the entire project, from start to finish. Perhaps, looking at it more dispassionately and with the benefit of hindsight, it made good sense to assemble in France nearer to the end user, although all the components parts used in both assemblies were still sourced from the UK.

The equipment worked well enough in France for ten or more years and with the closure of the French factory the plant ended up in Leamington, both the Cover Assembly and Driven Plate Assembly lines. The writer was responsible for the installation of the Cover Assembly line and a colleague for the Driven Plate line. The plant had been obviously well cared for and although well used, was still capable of making a significant contribution towards production. However, the writer felt general indifference towards its installation – it was just ten years too late and the shine had gone off it!

Licensing AP Technology and Know How.

Senior AP Management decided in their wisdom to adopt an active policy of licensing others to use its manufacturing technology and knowhow. To this end Borg and Beck licensed companies from the Soviet Union (as it was then), Japan, China and the Republic of South Korea to use its knowhow, patents and manufacturing methods. The author of this paper was quite deeply involved, from a production engineering aspect, with all the delegations that came to Leamington, from the countries mentioned above. The Soviet and Chinese delegations were quite large with many specialists in design, metallurgy, heat treatment, machining, etc.

The work was intense with a high degree of interpreter participation. Shop floor discussions on technical topics tested all of us considerably – the delegation specialists, the interpreters (mostly supplied by them) and AP staff. The Soviets were great, and we got along just fine. We had great fun trying to identify the spy! They always told the author when they had enough for the day, saying their heads were "spinning" with facts and they wanted to return to their hotel! In actual fact on many occasions the author's head was spinning too! One amusing comment is remembered from when the Soviet delegation was first shown one of the Phased Hub Machining Groups, which contained a three machine set- up with one operator. Although not particularly arduous the operator was fairly well occupied most of the time. This was an anathema to the Soviets and one engineer commented that the operator must be, "rushing around like a Squirrel". What a lovely description. Whether all this was a really a good deal for AP Borg and Beck the author is still undecided, but the stark fact is that all those countries mentioned above make clutches in high volume and Borg and Beck in Leamington no longer does!

To close this paper an inventory of the "workhorse machines" of the AP Borg and Beck Company is appended below. They collectively contributed to Borg and Beck's success over a considerable number of years. Well done to all those who designed, manufactured and maintained them!

Machine Shops;

Vertimax vertical Spindle Production Lathes; Wyvomatic twin spindle and Vertical spindle Finishing Lathes; Pollard Vertical Drilling Machines, 15A, 23A; 28A; Herbert No 2/2A Auto Junior and 3A Production Lathes; Cincinnati Production Milling Machines; Hofmann Balancing Machines; Coventry Gauge and Tool (Rockwell) Horizontal Broaching Machines; Lumsden Grinding Machine; Wild Barfield induction Hardening Machines; Power Presses by Cowlishaw - Walker, Bliss, Jones and Attwood (Worcester), SMT, etc.; Shot Peening Machines by Wheelabrator; Heat Treatment and many other rigs and special equipment designed and manufactured in house by EMD (Equipment Manufacturing Department); Swiss made Bruderer High Speed Cold Heading Machines.

Assembly Areas;

Mills Hydraulic Presses 6Ton,15T, 30T, 45T, 60T, 150T, 200T; Hofmann Balancing Machines; Bif Riveting Machines; Test Rigs by George Kingsbury (Gosport) Wickman Automation (Binley) and many test rigs designed and manufactured in house by EMD (Equipment Manufacturing Dept.)

And in conclusion, a tribute to all the many people who worked in AP Borg and Beck, from the Chief Engineer to the shop floor labourer - they made it a very successful and profitable company for many years. Almost all of it is now confined to history.

This Paper has been produced totally from memory and personal recollections, based on the company's activities spanning the years 1968 - 1997. No secondary sources of information whatsoever were used. I would particularly like to thank Michael Doody, Philip Braggs and David Dredge for reading the text, checking certain technical aspects and recommending, where appropriate, amendments. However, any errors of commission or omission are entirely the author's!

John Willock March 2020