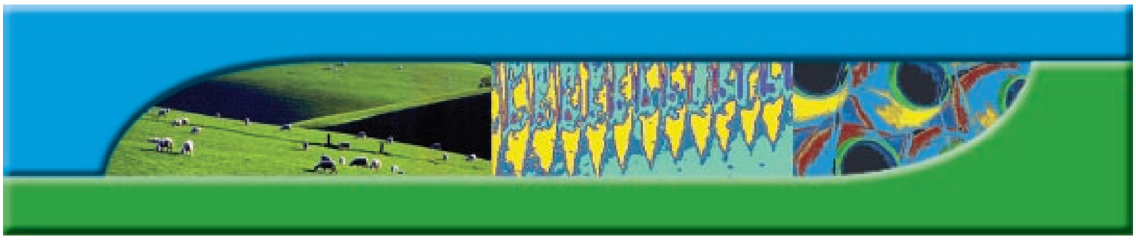
WOOLS OF NEW ZEALAND™

Carpet Technical Information



Carpet Manufacture

Broadloom tufting

WRONZ
WOOL REASEARCH ORGANISATION OF NEW ZEALAND (INC.)

www.woolsnz.com

BROADLOOM TUFTING. Part 1.

SUMMARY

The principles of tufting are outlined, with special reference to tufting wool carpets.

Guidance is given on engineering wool carpets to particular constructions, including advice on how to avoid or correct possible faults. Machine control systems may be used as aids to quality.

The available systems for producing patterned tufted carpets are surveyed with an indication of the design styles each can produce.

Conditions of use

This publication is currently under review and will be replaced by a new version in due course.

CONTENTS

Note. Section 5 continues in Broadloom Tufting - Part 2

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1 INTRODUCTION

Carpet tufting, having been commercialised in the USA in the 1940s, is a relatively young industry and is, therefore, evolving more rapidly than the older carpet weaving techniques. It was introduced as a rapid and economical means of converting yarn into simple styles of carpet. Numerous systems for creating patterned tufted carpets have since been introduced, most of them having particular limitations that stimulate the designers' skills. The most recent ones have patterning scope similar to that of some weaving looms. One system for introducing pattern, developed in parallel with tufting, is printing and basic information about printing of wool carpet is given in reference 1.

Tufting of wool carpets on a world scale began in the 1970s and the tufted carpet industry, which was originally targeted largely at volume products, moved significantly up-market following this lead.

Because wool carpets tend to be in the upper price brackets, it is essential to produce quality products. A commitment from both management and production personnel to quality (including aesthetic quality) is necessary if wool tufting is to be commercially successful. Well-maintained machinery of appropriate standard and suitable yarn are essential. Yarn selection is a key aspect, since the styling of wool tufted carpets is based as often on texture as on pattern. Speciality yarns are widely used to create textures such as frisé, pinpoint and tweed.

This publication introduces the principles of tufting and describes the patterning mechanisms available. Because this is an area of continually changing technology it is not possible to encompass all recent innovations in this document.

Information on wool yarns for tufted carpets may be obtained from Reference 2. Reference 3 deals with backing materials. The back-coating and laminating processes carried out post-tufting are outlined in reference 4.

2 PRINCIPLES OF TUFTING

2.1 Tufting Mechanism

Figure 1 shows an overall view of a tufting machine and Figure 2 schematically illustrates the main elements controlling the action of a cut-pile tufting machine. Tufts of yarn are inserted into a primary backing fabric by means of vertically reciprocating needles operating rather like sewing needles. There are several hundred threaded needles mounted on a bar across the width of the machine and a corresponding number of hooks (loopers) on another bar.

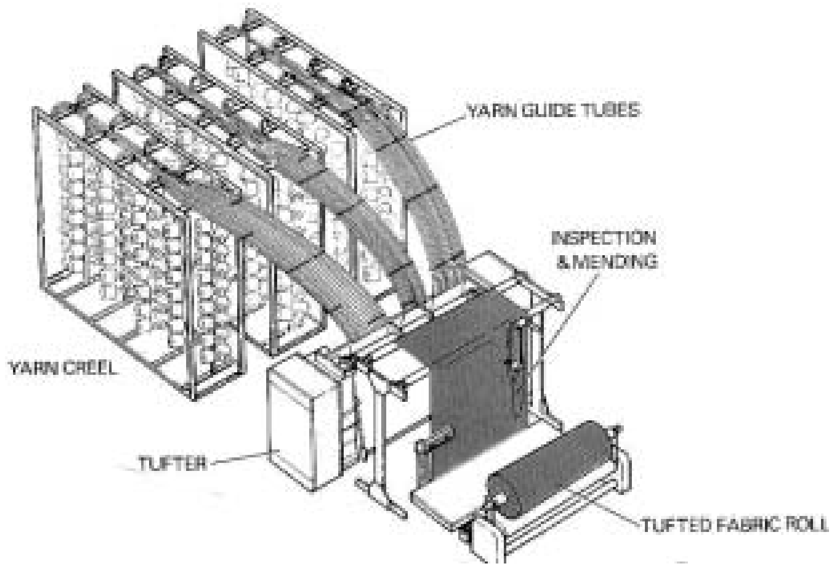

Figure 1 Perspective view of a tufting machine with its supply and take-off systems

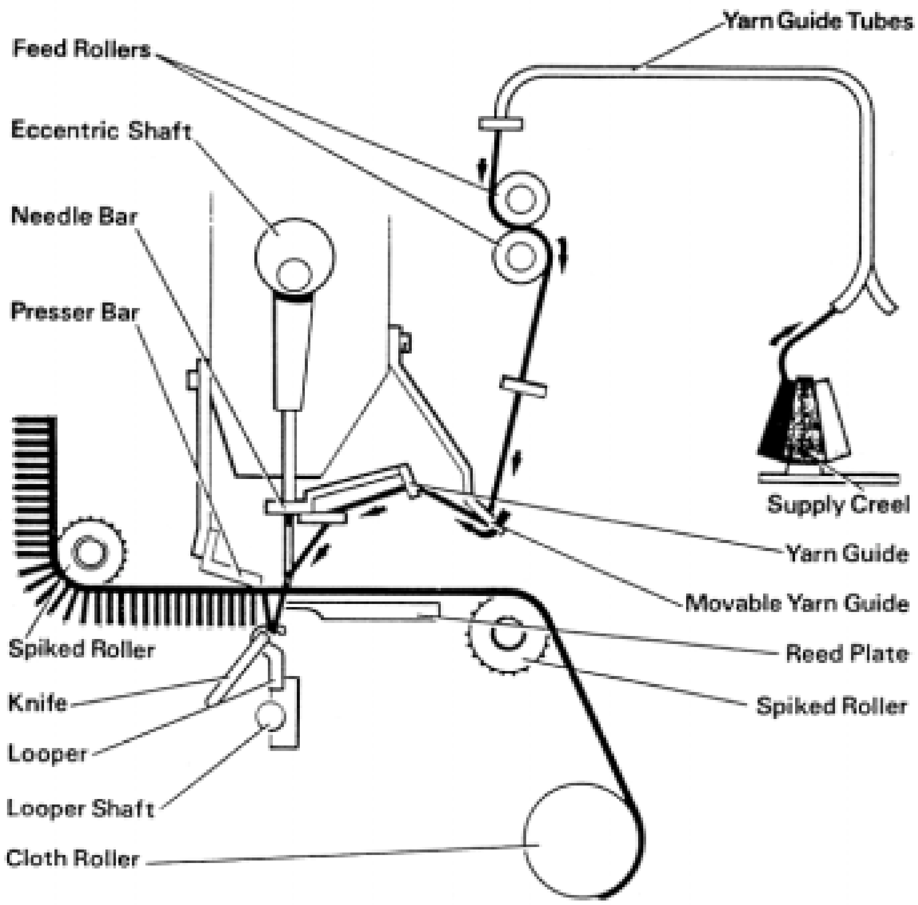

Figure 2 Schematic diagram of a cut-pile tufting machine

The yarn is fed from a *supply creel* (which may be a single-end creel, a magazine creel or a beam), and enters the ends of the *guide tubes* which lead all the individual yarns in the creel to the top of the tufting machine (collector board).

As the yarns emerge from the tubes, the sheet of yarn is fed through guide bars (one or two sets) to the yarn *feed rollers* (one or two sets) which are positively driven. It is then directed through a *movable yarn guide* (adjustable jerker bar). A further *yarn guide* (threader plate) which is attached to the *needle bar* moves up and down with the needle bar during insertion and withdrawal of the needles.

Finally the yarn is presented to its respective needle.

The row of needles is given a vertical reciprocating motion by means of an *eccentric shaft,* the needles passing through the open ended slats of a *reed plate.*

This causes the needle to pierce the backing fabric being drawn from the *cloth roller* by the *spiked metal intake roller.* The latter roller is driven by a similarly constructed *spiked take-off roller,* which draws the primary backing cloth through the machine.

On insertion of the needle into the backing fabric a *looper* is actuated by the *looper shaft* and moves forward to pass between the yarn and the needle, forming a loop on the looper as the needle rises. A *presser foot* prevents the primary backing from rising as the needles withdraw and the needle bar returns to the top dead centre position.

In the case illustrated (Figure 2), successive loops are picked up by the looper and moved along the blade of the looper by the forward movement of the primary backing. This causes a build-up of loops (usually 3 or 4) towards the shank of the looper. These loops are then severed by the action of a cutting blade (*knife*) which presses up against the shank of the looper. The reciprocating action of the knife against the looper is similar to that of a pair of scissors.

A loop-pile carpet is made by a similar action but the looper has no yarn retaining hook and its direction is reversed. Thus, when the looper moves on its back stroke the yarn loop is released. The forward movement of the backing fabric also helps to clear the loop from the looper.

The sequences of loop- and cut-pile tufting actions are shown in Figures 3 and 4 respectively.

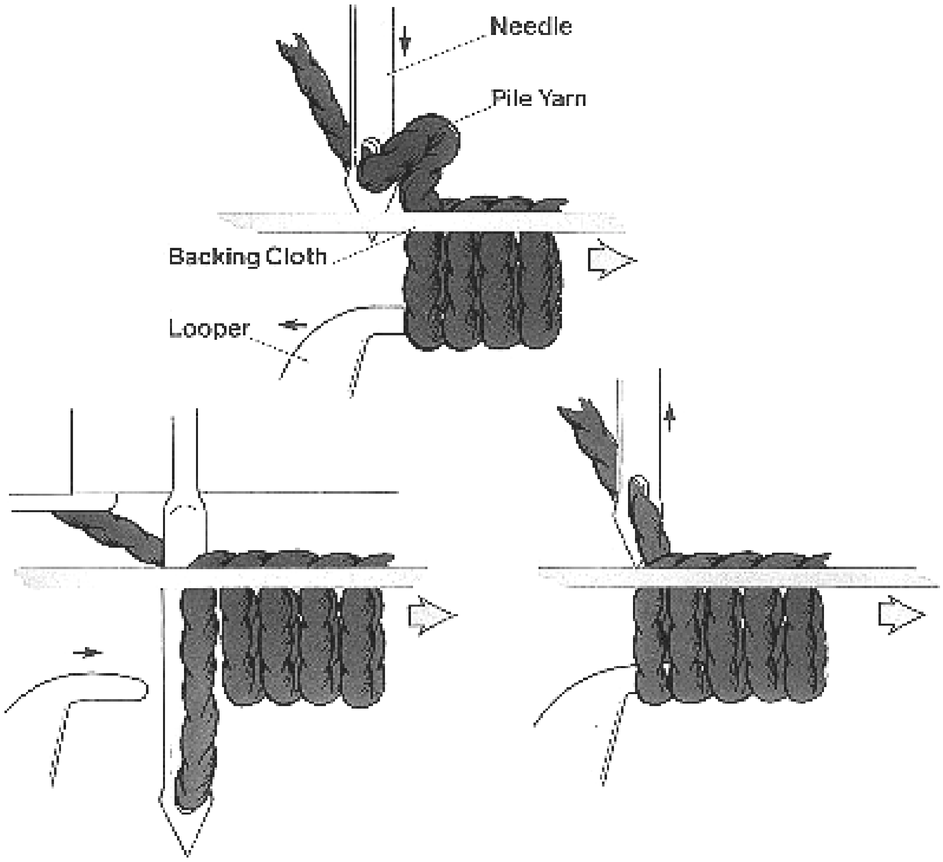

Figure 3 Loop pile tufting sequence

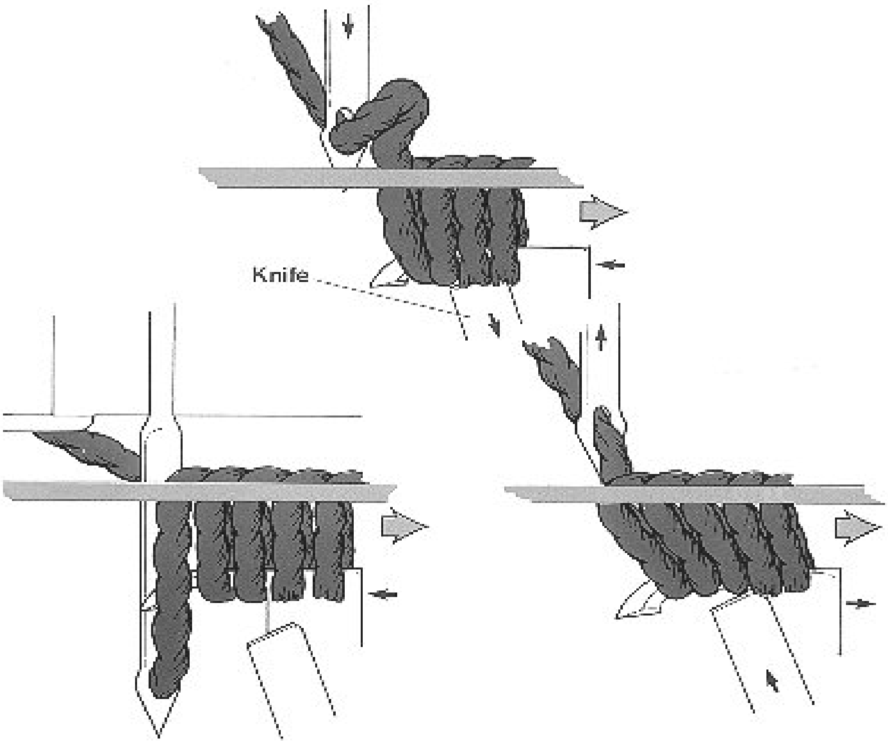

Figure. 4 Cut-pile tufting sequence

2.2 Geometry of Tufting Elements and Requirements for Yarn Twist

Tufting machines are described as having left or right hand take-off, depending on the relative position of the loopers and needles (tufting elements). Right hand take-off means the looper, when viewed from behind, takes the yarn from the right side of the needle. Similarly, left hand take-off means the yarn is taken from the left hand side of the needle.

Yarn twist direction should be selected according to the *hand* of the machine if tufting is to proceed smoothly: the twist causes yarn formed into a loop to turn and it is desirable for it to turn onto the looper rather than off it. Loop-pile loopers face the direction of travel of the formed carpet, whereas cut-pile loopers face in the opposite direction. Therefore, cut-pile and loop-pile machines of the same hand require yarns of different twist direction. This situation is clarified in Figure 5.

Most commonly, tufting machines have right hand take-off so cut-pile machines require Z-twist yarns, whereas loop-pile machines require S-twist yarns. However, for good reasons many manufacturers specify machines with left hand take-off so twist direction should not be selected without knowledge of the configuration of the tufting elements.

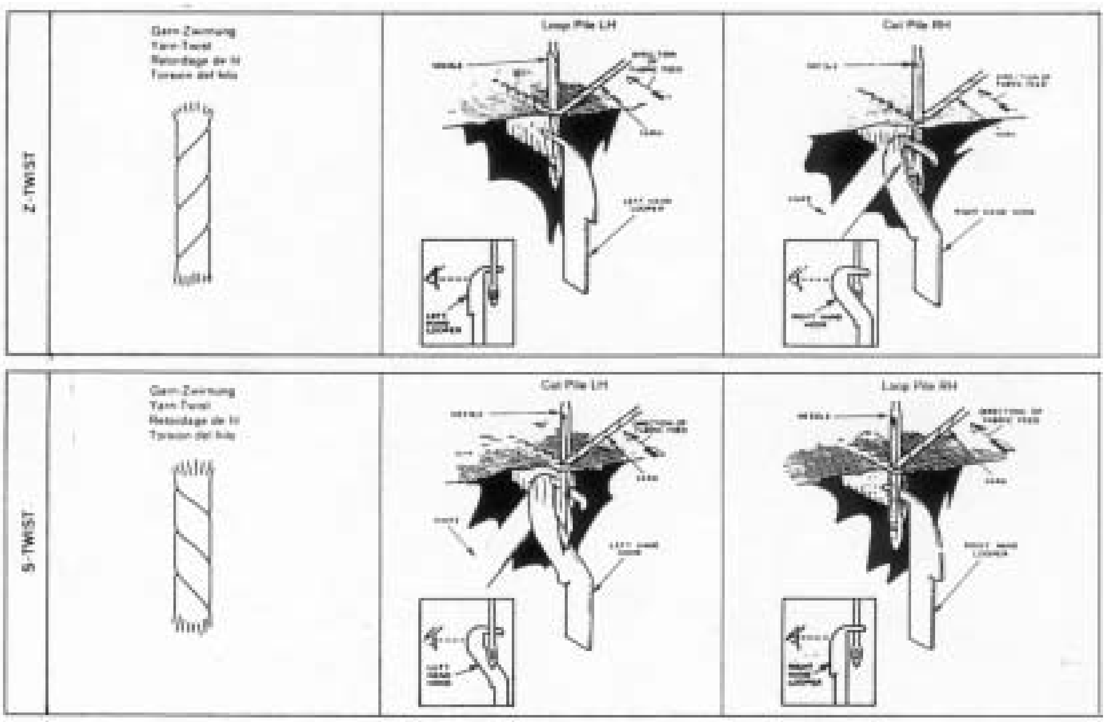

Figure 5 Geometry of tufting elements and requirements for yarn twist direction

2.3 Gauge Parts

As tufting machines were originally developed in the USA, they are commonly specified in imperial units so the gauge of a machine is expressed as the spacing of needles in fractions of an inch. The tufting elements (ie needles, loopers and knives) are commonly known as gauge parts.

2.3.1 Gauge Part Assemblies

Originally, the various gauge parts were attached individually to their respective bars. With the trend towards finer gauge cut pile machines, better precision was required to achieve the necessary accuracy of interaction so several machinery manufacturers developed *modular gauge parts* and other systems for improved accuracy. Very fine gauge tufting would not have been feasible without such developments. Carpets made using modular gauge parts have enhanced uniformity of appearance, so their application was extended to loop-pile tufting and medium gauge machinery.

Examples of available systems are illustrated in figures 6 - 8.

Pre-cast Modules

Cobble has available moulded modules for needles, loopers, knives and reed fingers, as illustrated in Figure 6a.

In this system, each unit contains a specified number of needles, etc.- for example, on 1/10 gauge, the modules are 1.2 inches long and contain 12 needles.

One disadvantage of this system is that if a needle breaks it is necessary to replace the entire module and return it to the manufacturer for repair or replacement.

Semi-modular Gauge Parts

Cobble's system illustrated in Figure 6b is a modular system of loopers and knives offering the same accuracy as the conventional moulded gauge parts. This system has a 2.5 inch looper block module combined with a knife block module which will hold up to 12 knives. Loopers or knives can be removed individually or as complete module units.

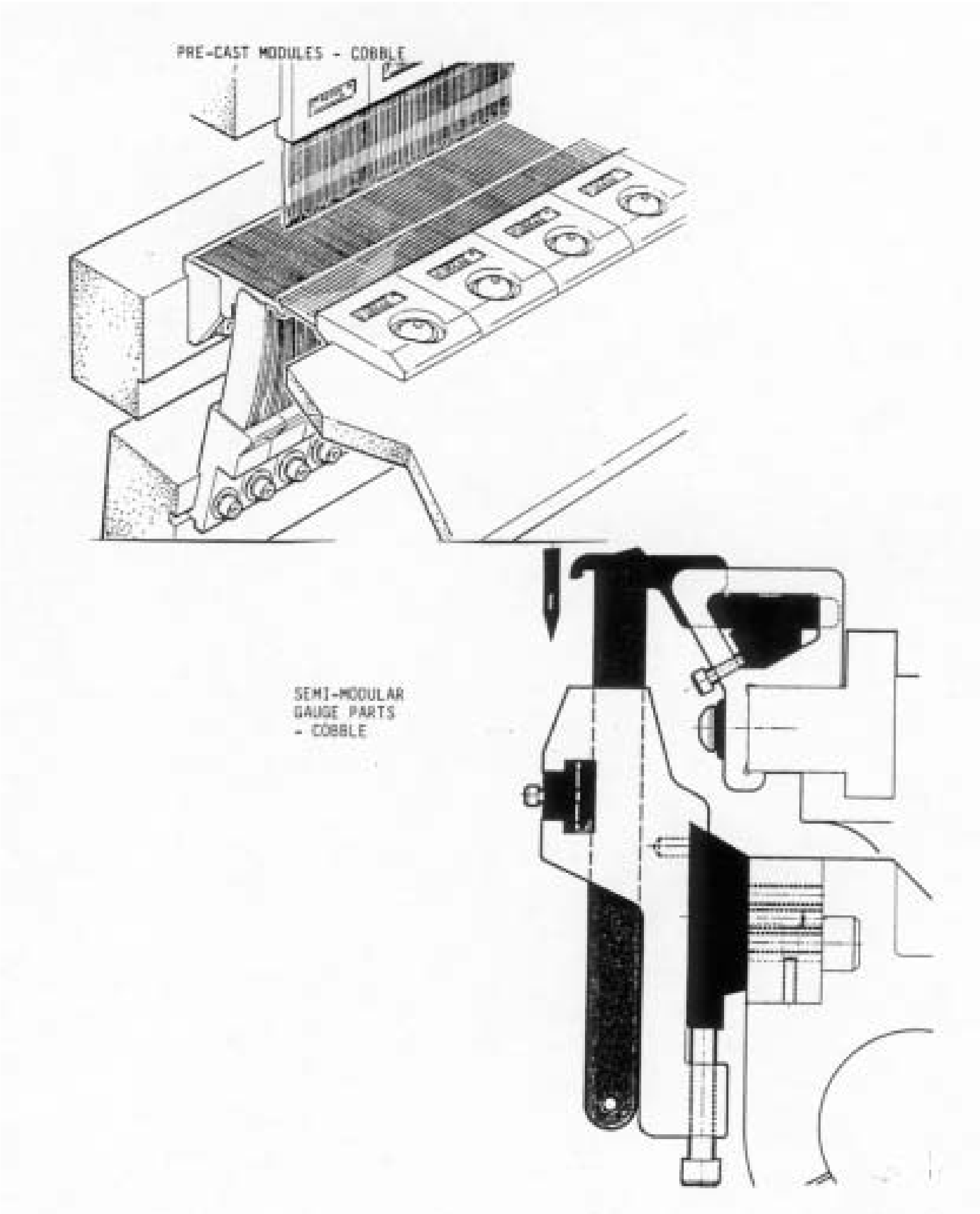

Figure 6 Cobble's pre-cast modules and semi-modular gauge parts

Accu-Gauge System

Tuftco's Accu-Gauge system, illustrated in Figure 7, uses a machined looper bar combined with modular knife blocks which allow replacement of individual loopers or knives.

A specially engineered needlebar system has high precision, short needle segments (modules) fixed to a continuous back-up needlebar. Each needle has its own set screw which allows it to be removed individually or adjusted for pitch. The looper bar uses a continuous, machined bar which has an insert milled to the individual gauge desired.

The knife bar system has a continuous keyway across the width of the machine, ensuring a uniform and accurate compound setting of the angle on the knife block and blades. The individual knives in the knife block module are held in place by steel balls which are forced in contact with the knife when a set screw is tightened.

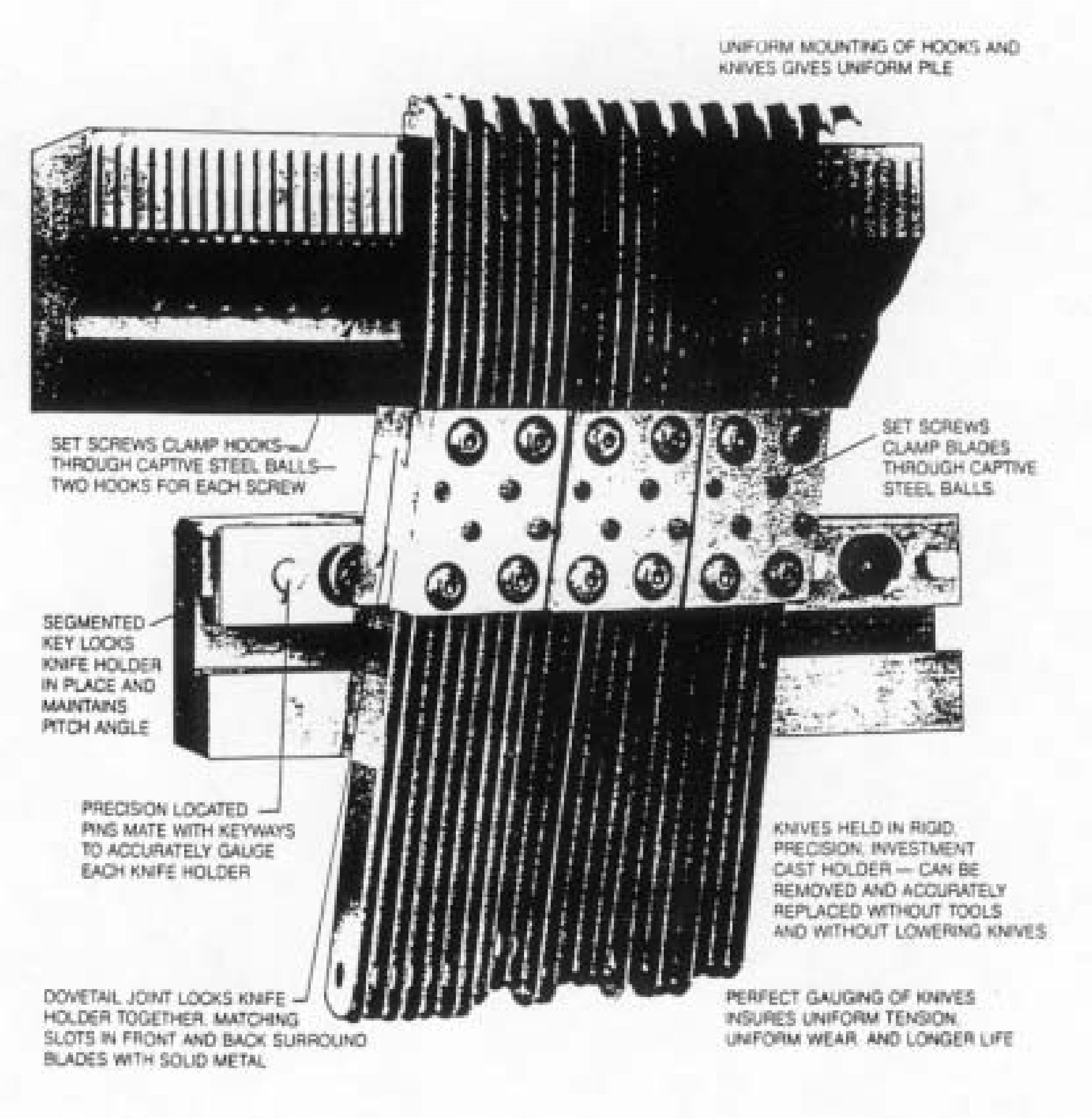

Figure 7 Tuftco's Accu-Gauge system

Advanced Cutting System II

Card Monroe Corporation's system (shown in Figure 8) provides the flexibility for changing individual knives and loopers as well as replacing complete blocks of knives and loopers.

Knives can be set accurately to give a consistent compound angle across the width of the tufting machine. The interlocking looper and knife system also assures uniformity of looper height as well as knife setting. It is also possible to pre-set the knife and looper components, thus reducing installation time when changing gauge parts.

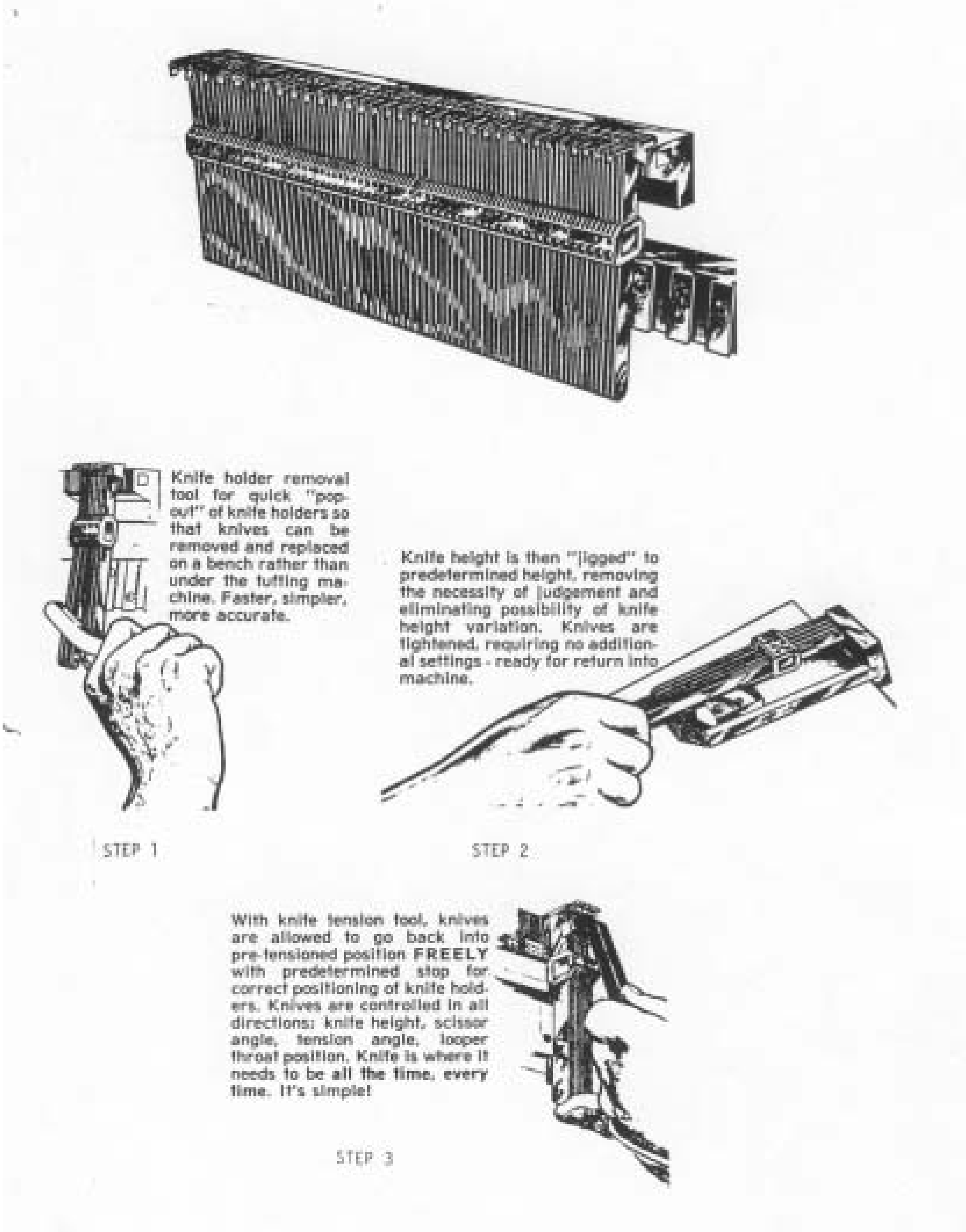

Figure 8 Advanced Cutting System II - Card Monroe Corporation

2.3.2 Tufting Needles

Studies have been conducted at the Wool Research Organisation of New Zealand[5] on the principle cause of stoppages when tufting wool yarns. This research showed the cause to be yarn failures resulting from joints or yarn faults jamming in the needle eye as the needle was withdrawn. Needles were, therefore, designed with eyes that caused minimum deflection to the path of the yarn during the upstroke[6], whereas earlier needles had often been designed to minimise damage to the yarn during the downstroke. Manufacturing of WRONZ-Eye (Eisbar) needles is now licensed to Groz-Beckert KG and they are the principal type of needle used for tufting wool. Other designs of needle (and other manufacturers' needles) may be more appropriate for the coarser tufting gauges.

The design of WRONZ-Eye needles, showing the relatively straight yarn path, is illustrated in Figure 9.

Table 1 lists the designations of Eisbär needles appropriate for the different gauges of tufting machine, together with cautious guidance on relevant yarn linear densities (many manufacturers find it possible to use heavier yarns than those listed).

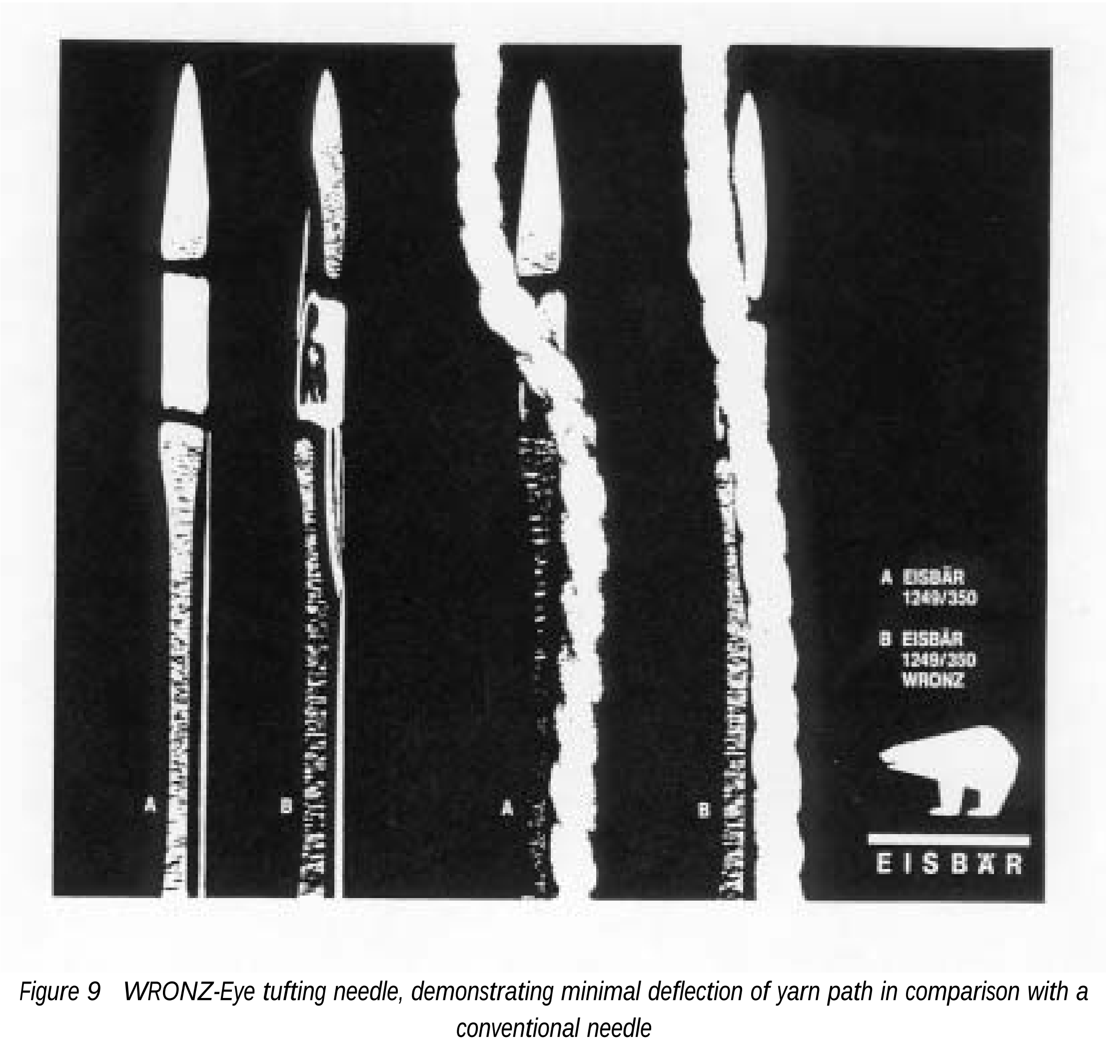

Figure 9 WRONZ-Eye tufting needle, demonstrating minimal deflection of yarn path in comparison with a conventional needle

TABLE I *EISBAR NEEDLES RECOMMENDED FOR VARIOUS TUFTING MACHINE GAUGES WITH LIMITING YARN SIZE AND EXAMPLES OF PRACTICABLE YARNS*

GAUGE	NEEDLE (EISBAR)	MAXIMUM COUNT (TEX)	TYPICAL COUNTS (TEX)
CUT PILE			
5/64	1209 SWB/WZ	250	R 165/2
1/10	1209 SWB/CD	285	R 250/2 or R 280/1
1/10	1397 SWB/WZ	400	R 410/2
1/10	1299 SWB/WZ	510	R 520/2
1/8	1256,1382 SWB/WZ	510	R 520/2 or 3
5/32	1249,1246 SWB/WZ	770	R 620/2 or 3
3/16	1246 SWB/WZ	770	R620/2 or 3
3/16	1252 SWB	1000	R 900/1 or R 780/3
5/16	1244 SWB	1550	R 620/2 or 3
5/16	1470B, 1473	2500	R 2500/1
3/8 or 5/8	1470B, 1473	4000	R 3900/1
LOOP PILE			
5/64	1256 SWB/WZ	500	R 500/2 or 1
1/10	1249 SWB/WZ	620	R 620/2 or 1
1/8	1256 SWB/WZ	520	R 500/2 or 1
9/64 or 5/32	1249 SWB/WZ	770	R 620/2 or 1
3/16, 1/4, 5/16	1346 SWB/WZ	1400	R 1000/1 or R 1250/2
5/16, 3/8	1370/530	2500	R 2100/1 or R 1250/2
15/32, 1/2, 5/8	1370/530	5000	R 3500/1 or 2

NOTE: *WZ = WRONZ Eye*
SW = Swollen eye
B = Bias Point
CD = Sidelong Located Point Groove

WRONZ Eye needles and modular gauge parts, together with improved yarn technology such as spliced joints, have had synergetic effects on the efficiency of production of wool tufted carpets, especially in the finer gauges. Although the WRONZ studies showed waxing of tufting yarns (as knitting and sewing yarns are waxed) contribute to good tufting efficiency, experience has indicated that the lubricant applied to the primary backing fabric is adequate to facilitate tufting.

2.4 Tufting Speeds

Machines specifically designed for high speed tufting are available. For example, Cobble's ST91 Sprint machine operates at up to 2000 rpm on loop pile and up to 1800 rpm on cut pile. Such machines are used in the production of large volumes of synthetic filament products diversified by printing or piece dyeing, principally in the USA. The main factors that have enabled such speeds to be achieved are:

- improved rigidity of the machine frame, eliminating vibration
- use of modular gauge parts to improve accuracy and uniformity of settings
- modified needle stroke mechanism

- improved yarn feed system
- variable speed drive, offering smooth acceleration and deceleration, coupled with stopping at the top of the needle stroke

Wool is not generally considered appropriate in the market area for which high speed machines are largely used. However, some of the technical facilities leading to high speed tufting have proved advantageous in tufting wool yarns. The overall approach to tufting wool yarns is to operate the machine in such a manner as to apply as little stress as possible, leading to fewer stoppages and consequent faults, and creating a quality product with good surface appearance. For plain wool carpets this means speeds of 600-750 rpm on modern machinery and 300-500 rpm for crossover patterned styles (see 5 - Patterning Mechanisms).

2.5. Ancillary Equipment

2.5.1 Yarn Supply

Most tufting machines are fed from cones mounted in a yarn creel at the front of the machine. One cone is required for each tufting needle. The number of cones in the creel and the space available will govern whether the creel is single, double or even treble storey construction. The yarns are led through tubes to the collecting board of the tufting machine.

Most creels are magazine creels with two cone positions for every running end, enabling the tail of each running cone to be joined (by latex or splice) to the leading end of the reserve cone. Therefore, minimal time elapses when one package runs empty and the reserve is brought into use.

Alternatively, the yarn may be pre-wound from packages onto beams, which are then positioned for tufting on racks. This saves space in the tufting area and some companies believe the yarn supply to the tufting machine is advantageously smooth and uniform. Use of yarn beams is, however, limited to carpet constructions where the yarn take-up is the same on every end.

2.5.2 Inspection and Mending

Inspection of the tufted fabric is normally carried out on an inspection frame (with dancing rollers to create a reservoir of fabric) in line with tufting. Visual inspection is sometimes supplemented by the use of sophisticated fault detectors (see 3.2 Quality Control). At the inspection stage, gaps created by yarn breakages are filled using a mending gun (single-end pneumatic tufting machine). This is guided by hand, aided by a suspension unit and spiked rollers driving the gun along the tuft row.

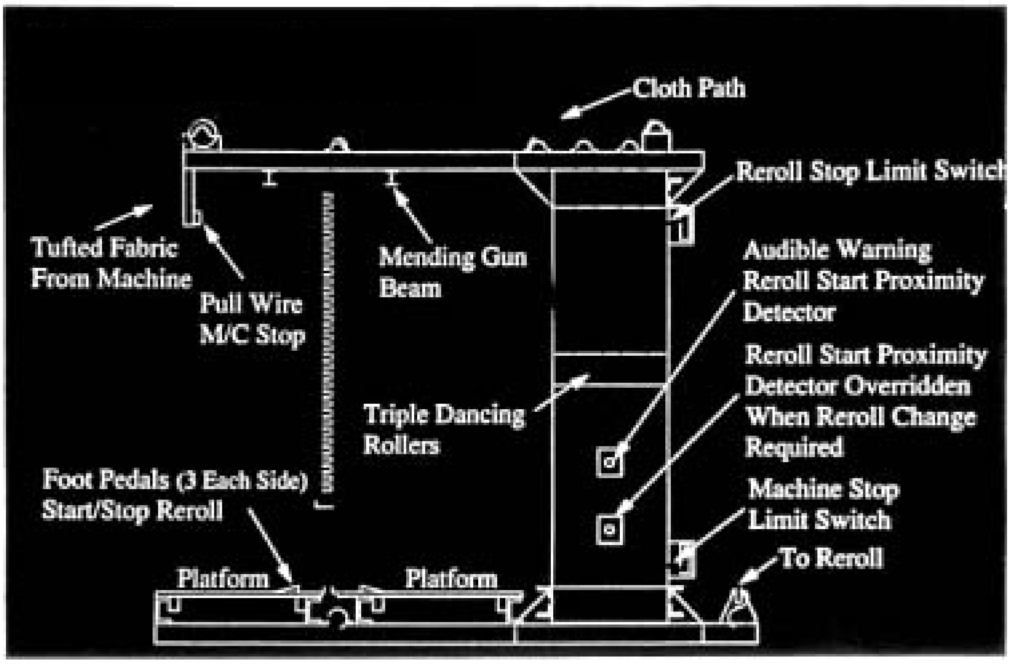

Figure 10 A modern burling frame for inspection and mending

3 CONTROL OF QUALITY

3.1 Tufting to Specification

Variables controlling the construction of tufted carpet are yarn count, gauge of machine, stitch length and pile height. If all these variables are converted to the same units (eg, per metre), the total pile weight of the carpet can be calculated:

Total pile Weight = gauge × stitch rate × pull out × yarn linear density

Gauge = number of needles per metre bar width

Stitch rate = number of tufts or loops per metre length of carpet

Pull-out = metres of yarn supplied per tuft or loop (2 × pile height, plus allowance for yarn in backing and back stitch, typically 5mm for medium gauge)

Yarn linear density = g/m (tex/1000)

Example:
1/8" gauge carpet tufted from 560 tex yarn at 10 stitches per inch to 7 mm pile height.

Gauge = 315 needles per metre

Stitch rate = 394 per metre

pull-out = 7mm x 2 + 5mm back stitch, divided by 1000 to convert to metres

Yarn linear density = 0.56 g/metre

Total pile weight = $315 \times 394 \times (7 \times 2 + 5)/1000 \times 0.56 = 1320$ g/m^2

Such calculations are a necessary preliminary to designing a carpet and providing an element of its cost (cost of pile).

Estimating yarn pull-out for a stitch is more complex in the case of patterned carpets. There may be long and variable back stitches, or short loops buried in the pile so the designer must base his/her estimates on knowledge of the design proposed coupled with past experience.

The following short sections indicate how the variables are controlled, with useful conversions from imperial units (as used for machine gauge) to metric.

3.1.1 Machine Gauge

Gauge is the equivalent of pitch on a weaving loom, but is expressed as the distance between the centres of needles in fractions of an inch. Thus, an 1/8 gauge machine has needles at 1/8 inch intervals along the needlebar.

The gauge of a machine can be changed. However, it is actually more satisfactory to buy a total machine of a different gauge because of the cost of conversion parts, labour and down time. The variable of gauge is, therefore, controlled by machine selection.

3.1.2 Stitch Rate

To measure the stitch rate, count the number of stitches per decimetre (or similar length in inches) along the warp length and average the result of measurements. Stitch rate is controlled by adjusting the speed of the primary backing fabric passing under the tufting needles. To reduce the stitch rate (increase the spacing between tufts) the speed of the backing fabric is increased; and to increase the stitch rate (reduce the spacing between tufts) the speed of the backing fabric is increased.

Once a carpet specification has been established, small adjustments in stitch rate may be used as the most convenient way of compensating for light or heavy yarn count in a delivery.

3.1.3 Pile Height

Pile height is measured from the surface of the primary backing fabric to the top of the tuft, using a gauge inserted between the rows of pile. It is determined principally by the height setting of the reed plate: in Figure 11 the pile height is essentially the distance (B) between the upper surface of the reed plate and the underside of the looper. From the point of view of quality, it is not desirable to adjust the pile height of a wool carpet by changing the tension of the pile yarn: rather the yarn pull-out should be adjusted to match the setting B.

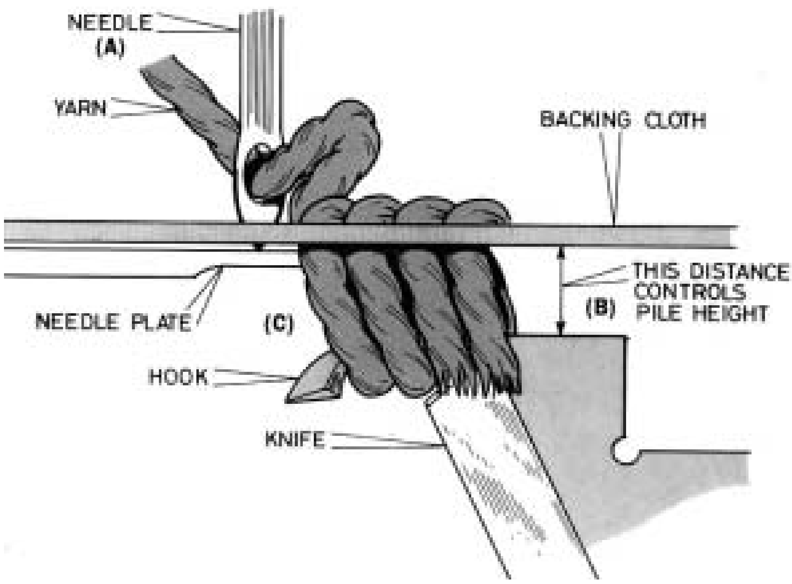

Figure 11 Setting to control pile height

Pile height, the second most common factor used to adjust the pile weight of a carpet, tends to be related to machine gauge. As finer gauge machines insert more tufts per square metre (more yarn), a lower pile height is required to achieve a particular pile weight.

Pile height is a similar value to pile thickness, but is not usually identical. Pile thickness, obtained using a micrometer attached to a weighted plate on the surface of a carpet, is a more precise measurement: the thickness of the carpet substrate from which the pile has been shorn is subtracted from the total thickness of the carpet.

3.1.4 Yarn Count

Yarn count must be selected when designing the carpet. It is not a variable that can be changed after the carpet has been specified. Guidance on the yarns that can be used for particular machine gauge/needle constructions is given in Table 1, Section 2.3.2.

Note: Wool yarns hold a variable amount of moisture, depending on atmospheric conditions, and account must be taken of this when checking deliveries of yarn. IWTO regulations for the trading of wool yarns specify standard allowances for moisture regain of dried yarns. For woollen spun carpet yarns the IWTO regain allowance is 17%, although different values are specified in some countries. When it is necessary to check the total pile weight accurately, a measured sample of the unbacked carpet is dried to constant weight; the weight of the polypropylene backing is subtracted (regain zero) and 17% added to the difference to obtain the weight of the pile at standard regain.

An approximate value of pile weight can be obtained by weighing a measured sample of carpet directly off the loom and assuming the regain approximates to 17%.

3.2 Quality Control

Once a carpet specification has been established, it is essential to be able to manufacture the carpet reliably and without faults. The general rules for achieving this are:

- Record the carpet specification and the machine settings used to obtain the construction
- Record the specifications of the materials used, viz yarn(s) and backing fabric
- Apply good housekeeping methods in the factory
- Avoid stoppages, which often cause faults
- Use a modern machine and set it for optimum performance
- Maintain the machine in good operating condition
- Check the result after tufting the first few metres and do not proceed with production until any faults have been identified and cleared: the list of faults and their origins in Section 3.3 provides guidance.

Supplementing these procedures, a number of technical devices are available to assist the manufacture of quality carpets consistent with efficiency of production. Efficiency and quality are positively correlated since stoppages that reduce efficiency also introduce faults.

3.2.1 Avoiding Stoppages

Creel design is important if local build-up of tension is to be avoided. Although a creel may be superficially simple, modern creels have improved reliability. Creels should be patrolled for obstructions to yarn passage and kept clean from swarf.

Yarn joints should be specified to be made at the spinner by splicing: knots and latex joints can jam at contact points and cause breaks. Hand-held splicers should be used as far as possible on the creel and yarn feed sheet. Note: a latex joint constitutes a fault in the carpet that can attract soil. The general *quality of yarn* (strength, extensibility, regularity, faults) is also important in avoiding stoppages.

Needles and yarns appropriate for the gauge of machine should be used. See Table I.

Special needle eyes that facilitate the passage of yarns should be used for wool: for fine and medium gauges this usually means WRONZ-Eye needles.

Machines with *controlled acceleration* alleviate yarn stress. Moderate speeds (600 rpm for plain carpet; 300 rpm for crossover) give fewer stoppages and better efficiency than higher speeds.

3.2.2 Machinery and Settings

To avoid irregular surfaces in both cut-pile and loop-pile carpets and lines of "J" tufts or "corn rows" in cut-pile carpets, it is essential to use a good standard of well-maintained, correctly-set machinery.

Stripes, the result of individual groups of tufting elements acting a little differently from the rest, can be largely eliminated by accurate setting of needles, loopers and knives in their respective bars. The availability of modular gauge parts has made a strongly positive contribution. It is still necessary to inspect gauge parts for wear and to replace worn components or modules as necessary. In particular, knives should be reground at regular intervals (every 1500m of carpet or less, depending on aspects such as use or not of loopers with tungsten inserts).

Knife grinding demands skill. Templates are available to mount groups of knives for grinding to the same angle but the knives must be mounted with care to achieve precise alignment.

To avoid irregular loop formation in both cut-pile and loop-pile tufting (and to avoid stressing the pile yarn) the loop length should be governed by feeding the required length of yarn (pull-off) and setting the reed space/looper spacing to correspond with this length. It is not satisfactory to set the spacing to a higher value than required and then rob the previously formed loop to the required length by restricting the yarn feed. The yarn should only just tighten on the jerker bar at each stroke of the needles.

Some "J" tufting in cut-pile constructions is inevitable since the loop of yarn is cut on one side of the looper and the length of the two legs of the tuft may be expected to differ by the thickness of the looper. "J" tufting may be minimised by controlling the number of loops held on the looper before cutting to that specified by the machine manufacturer: too many loops on the looper causes them to tighten as they reach the knives, accentuating

"J" tufting. For least "J" tufting, "all options" loopers should be used: these taper in cross-section towards the back of the looper, reducing the effective cross-section at the point where the loops are cut.

If the extent of "J" tufting is variable between needles, quite serious stripes ("corn rows") can result.

Tufts formed between the warp tapes of a woven primary backing fabric tend to lay at a different angle from those formed by stitching through the tapes. Stripes are created by the different aspect of the tuft ends. This effect is minimised, however, by selecting a backing fabric in which the number of warp ends per decimeter is not a close multiple of the number of needles per decimeter. Alternatively, special backing fabrics treated so as to avoid this effect, are available - see reference 3.

Modern tufting machines incorporate unroll and re-roll mechanisms for the fabric that provide exact alignment. The capacity of a roll is about 100 linear metres of tufted carpet.

3.2.3 Machine Control Devices

Stop Motions enhance both the quality and efficiency of tufting and contribute to the feasibility of multi-machine manning. They have assumed new importance as speeds have risen and pattern mechanisms become more complex.

In their simplest form, devices are available to detect end breaks. Cobble's Tuftstop system is based on a specially designed detector hook held upright when the yarn is running normally. If the end breaks, the detector hook swings down, interrupts a light beam and a photocell causes the machine to stop. The break is also indicated by audible and visible alarms. A counter records the number of breaks in a pre-set period.

If tight ends are a problem, a similar system can be fitted between the creel collector board and the yarn feed rollers. The increased tension caused by the tight end lifts the detector hook through the photo-cell light beam to stop the machine. A time delay device ensures temporary increases in tension do not cause unnecessary stops.

The *Zieseniss FST* broken end detector is based on the use of drop wires: their FNT tight end detector runs each yarn through a loop in a spring which contacts a conducting plate when the tension becomes too high.

Sick Optik Elektronic System

A sophisticated system developed by Erwin Sick incorporates three devices for on-line quality control of tufting relating to problems of yarn tension, broken ends and missing yarns.

The *TC Tension Monitor* checks the tension of each individual thread between the creel and the feed rollers, thereby helping to avoid thread breakages and prevent defects in both cut and loop pile fabrics. The switching board consists of two steel strips isolated from each other, which contact under pressure and sense the tension of yarn running across the switching board. If the tension exceeds a pre-determined threshold, the machine stops with a variable time interval of 0.5 to 8 seconds.

The yarn tension monitor, up to 5.5 metres long, is divided into eight zones. Yarn threads passing in front of and behind the unit are checked separately. There are 16 different sections across the total length, each with a red flashing display for front and rear zones to indicate fault location.

The *Broken End Detector* monitors individual yarns through the use of an infra-red light barrier and can work at a scanning distance of up to 6 metres. When broken yarns and those hanging out of the yarn feed are detected, a function display located directly at the light barrier indicates the appropriate yarn end. If the needle eye is blocked because of a thick place in the yarn, causing a run in a loop pile fabric, the device reports the defect immediately.

The Broken End Detector is used in combination with the TB Blower System. This ensures that when a yarn breaks at a tufting needle or out of the creel and its tension decreases, it is blown into the detection range of the Broken End Detector, which reliably stops the machine. The blower system is mounted under the last yarn feed roller behind the yarn. A plastic blower pipe with perforated air nozzles is located in plastic slide bearings. It moves inside an aluminium mounting rail across the yarn, blowing a constant stream of air across the whole machine.

The third part of the Sick system is the *IMS Tufting Scanner* which monitors all yarns in the region of the needles. The scanner operates with laser light which has excellent optical properties and gives reliability and precision to the system. A concentrated beam enables the electronics to both register and indicate minute beam changes. Within approximately 3.5 milliseconds it can scan the entire width of the machine, allowing the immediate detection of missing yarns, two yarns in one needle, broken yarns from the creel, or yarn snags caused by knots.

The monitoring width is divided into one-metre zones, each equipped with a red fault indicator, enabling the operator to find a fault quickly in the zone indicated.

Yarn Feed Systems
The wide variety of single and double sliding-needle bar machines has led to the machinery manufacturers seeking a solution to the problem of undesirable "shift marks" on the surface of the carpet. These are created when the needle bar is shifted to create a pattern, the shifted backstitch robbing yarn from the face of the carpet and putting it on the carpet back.

All the tufting machinery makers have developed yarn tension compensation systems to increase the amount of yarn fed to the needles during shift of the needle bar.

Card Monroe's CP-2100 version of a Command Performance system and Tuftco's Encore system operate through the use of DC Servo motors controlled via a computer. The systems are such that when the shift pattern and desired pile height are entered into the computer control system, yarn feed rates are calculated to automatically compensate for "shift marks".
Cobble's Tomco variable yarn feed system operates on a different principle whereby the yarn is fed to the machine in a totally relaxed manner. Thus, because the yarn is under

little or no tension, the needle bar delivers the required amount of yarn to produce a level pile.

Centralised Machine Control System

The problem of achieving consistent quality during the tufting process as well as reliably repeating a particular construction has, in the past, been left to the practised eye of staff with knowledge of manufacturing processes, materials and machinery. However, these techniques are notoriously difficult to document and time consuming to implement and control.

As a consequence of recent demands to reduce set-up times whilst maintaining and improving the high standard demanded by the customer, machinery manufacturers have developed automated systems for controlling the three basic elements - pile height, stitch rate and yarn feed.

The available systems are:

- Encore - Tuftco
- Command Performance - Card Monroe Corporation
- Re-Call - Cobble
- Posituft - Posiva (UK)

Pile Height is controlled by movement of the bedplate in relation to the looper position. In Cobble's Re-call system, pile height is controlled by a motorised hydraulic clamping bedplate and an automatic recall system.

Stitch rate and yarn feed are controlled in most of the systems by adjusting yarn and cloth feed rolls through PIV drives or DC servo-motors.

Tuftco's Encore system uses an electronic encoder to read the revolutions of the main shaft and is the primary information source for the computer in controlling the speeds of motors for yarn and cloth feed. The computer takes measurements of the main shaft position 500 times per second. It then "adjusts" yarn feed and cloth feed motors to their appropriate relative speed for each product style setting.

All the systems mentioned are designed to give quick and accurate re-setting as qualities are changed on the tufting machine. The systems can be purchased as an integral part of a new machine or, in most cases, can be retro-fitted to existing machines.

3.3 Carpet Faults and their Correction

Visible faults in a carpet include:

- Stripes: tuft rows (or groups of adjacent tuft rows) clearly associated with particular yarn ends
- Streaks: intermittent stripes
- Bands: differentiated zones running across the weft direction

Faults not readily visible include incorrect stitch rate, gauge and pile height.

When starting to tuft a batch of carpet or when creeling up a new batch of yarn, the first length tufted should be checked for correct construction and visible faults. The bulk of the order should not be tufted unless the sample is satisfactory. If it is not satisfactory, the cause of the problem should be identified and corrected.

Most often (but not always) *streaks* arise from faults in the yarn or in dyeing. *Bands* are usually tufting faults, but can also be created when finishing the carpet.

It is not easy to differentiate between *real* colour faults and *apparent* colour faults (those arising from differences in texture). To be certain about real colour differences it is necessary to hand-card samples from the stripe or streak and the background area and measure the web on a sensitive colorimeter.

Guidance on apparent colour faults is as follows:

- Cut yarn ends look darker than the sides
- The coarser the wool, the darker the colour
- The straighter and more erect the tufts, the deeper the colour
- The bulkier the tufts, the lighter the colour
- Medullated wool looks lighter than normal wool
- The more random the fibre orientation (felting), the lighter the colour
- The better the twist set (tuft definition), the darker the colour
- Faults looking worse from the side are usually related to pile height variation

Detailed discussion of yarn faults is outside the scope of this publication. Recommendations for overcoming faults caused at tufting follow.

3.3.1 Faults in Loop-Pile Carpets

Chainstitching (Tagging): Needles either tag the previously formed loop or stitch through it. Carpets with high stitch density and long loops may be prone to this fault, especially if the twist is unbalanced.

- *Check loopers and needles are free from burred metal. Looper timing may have to be later than normal, with less forward movement. heck yarn pull-out matches yarn required, avoiding excessive yarn tension. n staggered needle bars, consider* *the type of reed fingers available: double straight fingers are better than "I" or "Y" configuration.*

Rough pile: A random textured appearance caused by variable yarn tension.

- *Check yarn tension, jerker bar setting, bed plate setting, top needle clearance and presser foot setting. On individual ends, check the yarn package for correct winding and check the path of the yarn to the needle for obstructions.*

Rough Backstitch: Loose or uneven yarn on the back of the carpet can result in problems of poor tuft bind and delamination of the secondary backing material.

- *Check the settings of the presser foot and bedplate; and looper timing and yarn tensions.*

Split Looping: Loopers may not pick up all the plies of the yarn, giving an uneven pile surface.

- *Check if the yarn twist is correct for the hand of machine (see 2.2). Check timing of needles and loopers.*

Stop Marks: Bands across the carpet may be associated with the yarn relaxing or by variations in feed of the primary backing fabric.

- *Generally, if the stop mark is visible on the back stitch, the problem is with the cloth feed. If the mark is not visible on the back of the carpet but is associated with a variation in pile height, the problems may be that the yarn is highly elastic. Alternatively, stop marks may be caused by excessive yarn tension, loose or woven yarn feed rollers, or the machine stopping at an inappropriate part of the cycle.*

3.3.2 Faults in Cut-Pile Carpets

Pull-down (drag): Yarns fail to cut and distort the carpet badly, probably distorting the tufting elements and causing a stoppage.

- *Check if the knife is sharp, knife/looper timing, position of knife to looper, and for excessive yarn tension.*

"J" tufting: This is caused by the tufts being cut on one side of the looper and is inevitable. "J" tufting can be minimised but not eliminated.

- *Use hollow ground or "all options" loopers to reduce the thickness of the looper at the point of cutting. Avoid high yarn tension so loops are not tight at the point of cutting. Check the looper/knife timing is correct and the number of loops held on the looper is as specified by the machine manufacturer. Heavy shearing can reduce "J" tufting but rarely eliminates it.*

Split looping: More of a problem than in loop pile as only part of the loop is cut if only one ply of the yarn is picked up by the looper.

- *Check the direction of yarn twist is appropriate for the hand of the machine. Check machine timings. For double sliding-needlebar machines, this problem can sometimes be overcome by wrapping the yarn round the needle on one of the two bars.*

Rough backstitch: As for loop pile.

Isolated stripes: This fault is usually owing to mal-setting of the tufting elements or to a yarn (or yarns) differing from the bulk.

- *Check the quality of the tufting elements (freedom from burrs, sharpness of knives, alignment of needles) and their timing. Ensure the yarn path is not blocked or the yarn badly wound or snagging.*

- *Check the yarn for unlevel dyeing or twist setting, correct yarn count, correct and uniform twist level, and for the presence of oil, stains, incorrect fibre or inadequate blending (of mixture colours).*

Uneven spacing of tufts (also for loop pile): Gives a generally stripy effect.

- *Check the setting and quality (straightness) of the needles, and make sure the reed fingers are not bent. Ensure the warp spacing of the (woven) backing fabric is not a close multiple of the needle spacing, and the backing fabric is not creased. Check for the gauge, correct needle design (eg WRONZ-Eye), yarn passage obstruction, and generally poor yarn package winding. Such faults may be alleviated by using a sliding needle bar or backing shifter to break up the effect.*

Excessive damage to backing fabric:

- *Wrong type of backing fabric for carpet construction or fabric not correctly lubricated. Excessive tension on fabric or yarn. Worn or damaged needles, or incorrect machine timing.*

Tufts protruding from back of fabric:

- *Can be caused by excessive fabric tension, or yarn too bulky for needles and reed fingers. Also check machine timing and setting of tufting elements (eg cutting too early, bottom dead centre for needles too high) and for worn needles.*

Stop marks: As for loop pile

3.3.3 Faults in Patterned Carpets

In addition to the foregoing occurring in plain carpets, the following problems may be introduced when tufting patterned carpets from dyed yarn.

- Wrong yarn colour
- Wrong colour sequence on creel
- Wrong sequence on sliding needle bar
- Wrong scroll pattern
- Damaged scroll pattern
- Wrong pattern disc
- Crossover shift marks (corrected by yarn feed system, see 3.2.3)

4 STITCH PLACEMENT MECHANISMS

Various mechanisms are available for displacing stitches laterally by half, one or more gauge widths (Figure 12). These may be used to disrupt the linearity of the carpet surface (in the case of loop-pile carpets, the texture or style of the carpet is markedly changed), to increase the density of the carpet pile, or to introduce simple patterns (usually zig-zag effects).

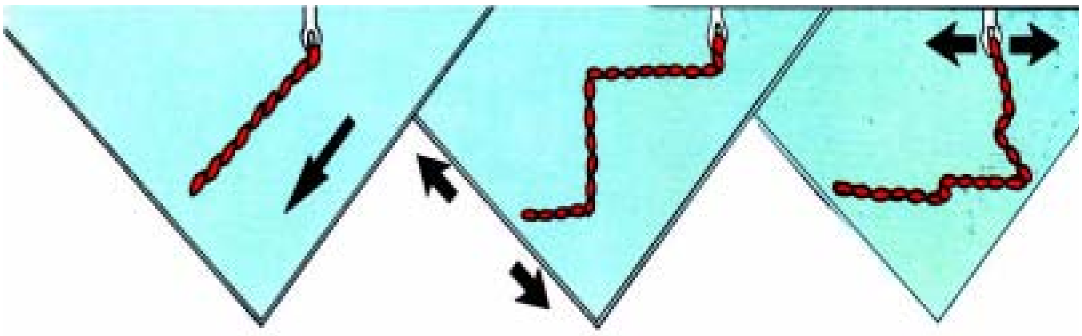

Figure 12 Methods of stitch placement: straight line (left), backing shifter mechanism (centre), sliding needle bar (right)

4.1 Sliding Needle Plate

This arrangement is used to produce zig-zag effects in loop pile fabrics only. The effects achieved are simple but precise.

Effectively, the sliding needle plate moves laterally across the machine precisely one gauge, or in multiples of one gauge, in a predetermined pattern controlled by a hardened cam mechanism. Because of the precise nature of its movement, the mechanism restricts the maximum speed of the tufting machine to 580 rpm.

4.2 Backing Shifter

Formerly known as the jute mover, the backing shifter is much faster than either the sliding needle plate or sliding needle bar. It is offered in three basic constructions:

- Front mover - fitted in front of the needles: best suited for low loop-pile and low cut-pile fabric.
- Rear mover - fitted after the needles: best suited for high cut-pile fabric.
- Front and rear mover - the most commonly fitted backing mover and the most positive of the three types.

The mechanism can be used for 1/2, 1 and 1.5 stitch movements, since no gauge part movement is involved.

Simply, the backing fabric is moved laterally in relation to the needles and loopers, causing an apparent sideways traverse of the yarn path in relation to the backing. Because the gauge parts are not moved laterally to each other, the backing cloth movement can be made over a greater part of the needle stroke cycle, thus allowing high speed operation.

4.3 Sliding Needle Bar

This mechanism is most commonly used on cut pile, but can also be used on loop pile.

The sliding needle bar moves laterally across the machine precisely in one gauge, or in multiples of one gauge, in a predetermined pattern controlled by either a mechanical or hydraulic actuating mechanism (see Patterning Mechanisms).

4.4 Double Density Tufting Attachments

The objective of these devices is to allow an apparently fine gauge carpet to be produced on a medium gauge machine. Further, the range of yarn counts that can be made into densely stitched pile is increased.

Double density effects are achieved by using a sliding needlebar and shifting it half a gauge width between stitches. At the beginning of the downstroke, the needles are slightly out of line with the loopers and penetrate the backing while still out of line. At this stage the needlebar is reversed, aligning the needles with their corresponding loopers but displacing the backing fabric to one side while the loop is formed. After withdrawing the needles from the backing fabric, the needlebar moves to displace the stitch in the opposite direction. The sequence is repeated to give a narrow zig-zag pile structure.

This action is illustrated in Figure 13. Different manufacturers achieve high density tufting in different ways.

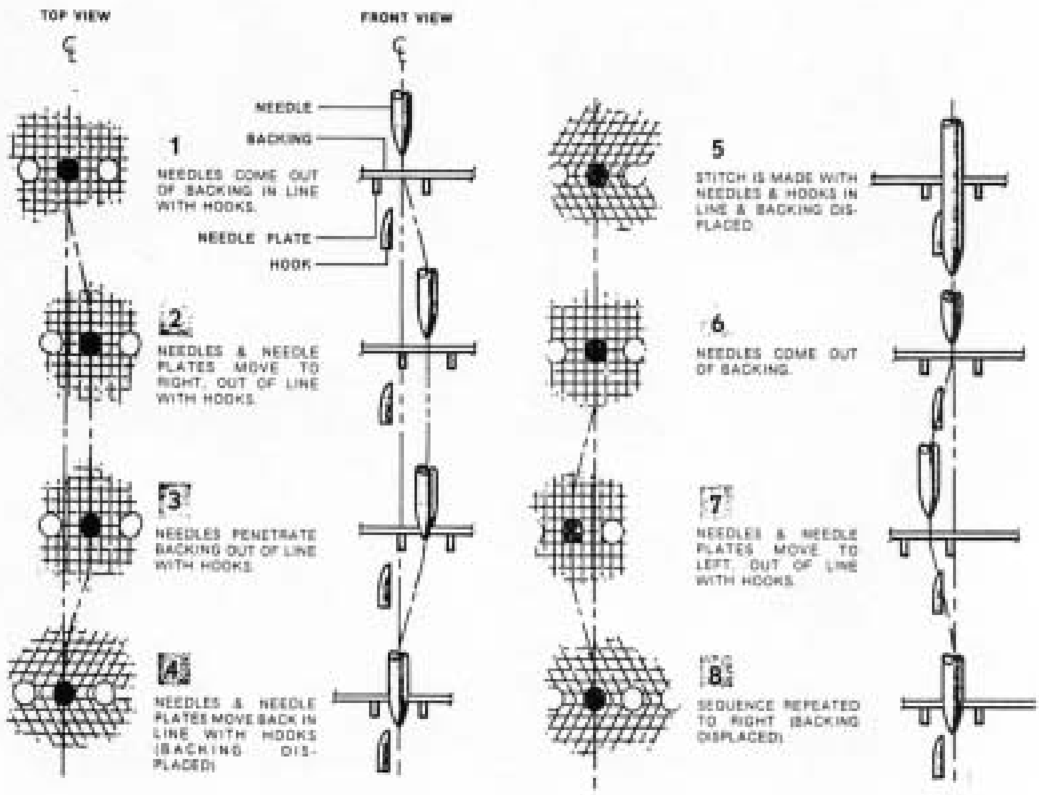

Figure 13 Double density tufting as performed by Cobble's Dual Stitch Placement System

Dual Stitch Placement System (DSP) - Cobble

The DSP attachment combines a sliding needle bar with a sliding needle plate, both actuated by a Super Shifter cam. The advantage of shifting the needlebar and needleplate together is that the needles are always situated midway between the reed dents and the needleplate. Because of this Cobble claims the system is not limited to coarse/medium gauge tufting and can be applied to finer gauges.

Positive Stitch Placement (PSP) - Card Monroe Corporation

The PSP system was the first double density system to be offered commercially and has been widely used on loop-pile carpets to give attractive non-linear textures (Level Textured Loop). In cut-pile constructions, high density fine effects are achieved on 3/16 and 5/32 gauge machines. PSP is based on a sliding needlebar actuated by a cam moving the needles between the reed fingers of the needleplate.

Stitch and Move (SAM) - Tuftco

The SAM system utilises a hydraulically actuated sliding needlebar for moving the needles between the reed dents.