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CLEANING CLASSICAL PERSIAN CARPETS WITH SILK AND PRECIOUS METAL THREAD: CONSERVATION AND ETHICAL CONSIDERATIONS

Keywords: Persian carpet, ethics, textile conservation, metal thread, carbon dioxide cleaning

ABSTRACT

Three important historical Persian carpets were recently discovered in very poor condition. The main damage included extensive colour fading, oxidized metal threads, dust and material loss, caused in part by adverse exhibition conditions. A previous major intervention in the Medallion carpet raised important questions about the extent of the new intervention. This paper describes the ethical considerations involved in selecting an appropriate treatment. Given the high technical quality and precious materials of the carpets, various cleaning experiments were performed to evaluate the best method. Liquid and supercritical carbon dioxide cleaning was tested, for the first time, on samples from these carpets to determine its suitability for knotted-pile carpets. The three carpets were then submitted to suction-table wet-cleaning, as a large CO_2 apparatus was not available to conduct the carpets' cleaning. Treatment resulted in an overall improvement in the carpets' condition. After considerable debate, it was decided that the carpets should be sewn to a backing support with compatible materials. Stitch consolidation offered structural stability, necessary for future display.

RÉSUMÉ

Trois tapis persans anciens d'importance historique ont été récemment découverts dans un très mauvais état de conservation. Les principales dégradations incluaient une décoloration importante, une oxydation des fils métalliques, un empoussièrement et une perte de matériau, en partie dus à de mauvaises conditions d'exposition. Une précédente intervention importante sur le tapis Médaillon soulevait des questions es-

INTRODUCTION

Characterization of the carpets

Three historical Persian carpets were recently identified in northern Portugal, at the Palace of the Dukes of Bragança in Guimarães (Santos 2010). Acquired in the 1950s as part of the refurbishment programme of the palace, they were not recognised as important carpets belonging to the so-called 'Salting' group until 2007. Two of them are prayer rugs which are documented (Mills 1999), while the third is an entirely new addition to the corpus (80 niche and 27 medallion carpets, in total). Named after the collector George Salting, this group is distinguished by the presence of a silk foundation, fine wool pile, high knot density, brilliant colours, wide palette, and embellishments in precious metal thread.

The prayer rugs, known by the names of their previous owners, *Benguiat* (PD77; 178 × 106 cm) and *Duff* (PD78; 160 × 107 cm), respectively, have similar designs: a large niche in the centre, decorated spandrels, and cartouche borders with Koranic inscriptions (Figures 1 and 2). The *Benguiat* rug has a red ground with a symmetrical arabesque design and coloured patches filling the spandrels, also with religious inscriptions (Figure 1). By contrast, the field of the *Duff* rug is filled with interlocking hexagons with large-scale motifs (Figure 2).

The newly-discovered Medallion carpet (PD76; 244 × 170 cm) has a red ground with a blue medallion in the centre and green quarter-medallions in the corners. The entire field is decorated with scrolling arabesques interspersed with flowers and Chinese cloud scrolls woven in metal thread. In the border, ten rectangular cartouches containing poetic phrases in Persian alternate with eight-lobed medallions, on a beige ground (Figure 3).

In terms of their structure, the Guimarães carpets are quite similar, with silk warps and wefts (three passes), asymmetrical wool knots (open-to-the-left), and metal threads applied in tapestry technique (Figure 4). The *Benguiat* and *Duff* rugs have standard knot counts (ca. 7550 and 7000 knots/dm^2, respectively), while the Medallion carpet is extremely dense (ca. 11,155 knots/dm^2). The metal threads were made using a distinctive technique involving a hand-cut silver lamina of fine gauge covered with a gold coating, twisted around a silk core.

sentielles quant à l'étendue de la nouvelle intervention. Cet article décrit les considérations déontologiques prises en compte dans la sélection du traitement approprié. Étant donné la grande qualité technique et la préciosité des matériaux des tapis, plusieurs essais de nettoyage ont été réalisés en vue de déterminer la meilleure méthode. Le nettoyage au dioxyde de carbone liquide et supercritique a été testé pour la première fois sur des échantillons provenant de ces tapis afin de déterminer s'il convenait pour des tapis à points noués. Ces trois tapis ont ensuite été soumis à un nettoyage en phase humide sur une table aspirante, puisqu'un gros appareil au CO_2 n'était pas disponible pour nettoyer les tapis. Le traitement a entraîné une amélioration globale de l'état des tapis. Après des débats considérables, il a été décidé que les tapis seraient cousus sur un support constitué de matériaux compatibles. Une consolidation par points de couture a permis d'obtenir la stabilité structurelle indispensable pour leur future exposition.

RESUMEN

Se han descubierto recientemente tres tapetes persas antiguos en condiciones muy deficientes. Entre los daños más graves se incluyen grande decoloración, hilos metálicos oxidados, polvo y pérdida de material, debidos en parte a las condiciones adversas de la exposición. Una de las principales intervenciones realizadas anteriormente en el tapete del Medallón despertó importantes dudas sobre el alcance de la nueva intervención. Este artículo describe las consideraciones éticas relacionadas con la elección del tratamiento más adecuado. Dada la elevada calidad técnica y los materiales preciosos de las alfombras, se realizaron varios experimentos de limpieza para valorar el método más apropiado. Por primera vez se hicieron pruebas en muestras de dichas alfombras con métodos de limpieza en dióxido de carbono líquido y supercrítico para determinar su idoneidad en alfombras de nudos. Las tres alfombras se sometieron luego a una limpieza en húmedo con succión, ya que no se disponía de un aparato de CO_2 de grandes dimensiones para llevar a cabo la limpieza de los tapetes. El tratamiento resultó en una mejora general de la condición de las alfombras. Después de un largo debate, se decidió que los tapetes debían ser cosidos a un soporte con materiales compatibles. La consolidación por puntos de costura ofrece una estabilidad estructural que era necesaria para su futura exposición.

Figure 1
Benguiat prayer niche carpet (PD77), before conservation (photography by Jorge Oliveira, LCRJF-IMC)

Figure 2
Duff niche carpet (PD78), before conservation (photography by Jorge Oliveira, LCRJF-IMC)

Figure 3
Medallion carpet (PD76), before conservation (photography by Luis Piorro, LCRJF-IMC)

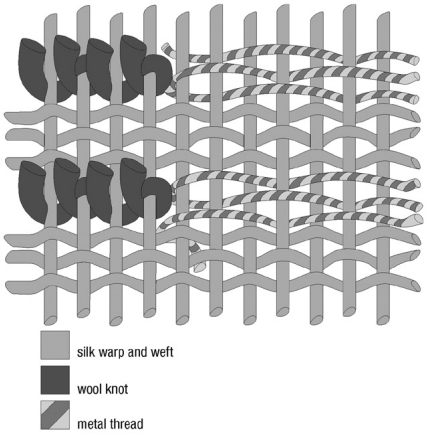

Figure 4
Woven structure of the carpets, showing warps, wefts, knotted-pile and metal thread

All of the colours, now severely faded, were obtained with natural dyes typical of Persian carpets. The reds and pinks were obtained with lac-dye. A luteolin-based dye, possibly weld, was identified in the yellows, and also appears with indigo in the greens and with alizarin in the oranges, respectively. The browns as well as beige colours were obtained with natural wool, with the exception of the browns in the Medallion carpet, in which ellagic acid (indicating the presence of tannins) was identified. All of the colours were applied to the textile fibres using alum, with the

exception of the browns in the Medallion carpet (iron), beiges (natural wool), and indigo (no mordant) (Santos 2010).

Condition of the carpets

Since their acquisition in the 1950s, the three carpets were exhibited beneath a window, in direct sunlight and uncontrolled environmental conditions. This encouraged extensive colour fading (ca. 32 percent)[1] and fibre degradation. The carpets are also very fragile and reveal considerable material loss, especially in the longitudinal and transversal axes, probably from having been folded for a long period prior to being purchased for display in Portugal.

Although the high knot density has contributed positively to their structural integrity, a considerable loss of fibres and knots was observed (around 4-5 percent of the total original area of each carpet).

In addition, the carpets had acquired an overall dust layer, especially in the knotted-pile surface. Widespread oxidation of the metal threads and the presence of an external dark-grey layer composed of silver corrosion products were also observed (Santos 2010).

The "antique interventions" (early 20th century?) involving linen fabric patches had also caused surface deformations (Figure 5). Partial supports had been applied to the back of the prayer carpets with numerous heterogeneous stitches, hiding major areas of material loss (mostly in the longitudinal axis). In the Medallion carpet, an invasive full support (tabby weave) was applied with numerous coloured stitches outlining the decorative motifs (Figure 6). The coloured stitches had faded severely on the front side resulting in a beige appearance, severely impairing visual appreciation of the design.

In conclusion, the three carpets were in very poor condition and could not be exhibited without being submitted to conservation treatment.

Figure 5
Medallion carpet, deformations caused by textile support (detail)

Figure 6
Medallion carpet, back side showing full support (detail)

Ethical issues

Given the advanced state of their degradation, observing main damages and old restorations, any intervention proposed had to contribute positively to their preservation. All the treatment phases were extensively debated in an interdisciplinary team, taking into account the fundamental principles of the Code of Ethics adopted by the European Confederation of Conservator-Restorers' Organization (ECCO) in 2003. Firstly, the importance of maintaining or removing the "antique" restorations was addressed, as these previous interventions reflected technical knowledge, and therefore had historical value. The total support applied to the Medallion carpet revealed a strong concern for reinforcing the structure, and its removal could result in irreversible material loss, especially in the most fragile areas along the longitudinal axis. Indeed, treatment should "respect the aesthetic, historic and spiritual significance and the physical integrity of the cultural heritage" (Article 5). Hence, if maintaining the historical value of this carpet was the priority, this "antique" restoration could not be removed. However, the total support

was in very bad condition, displaying numerous yellowish stains due to its acidic state and causing severe deformations, which were liable to provoke further damage. Removing the lining would make it easier to reduce surface deformations and would also facilitate the removal of dust during cleaning. Moreover, fading of the coloured stitches on the front had a significant impact on visual appreciation. Hence, removal of the support was considered. Nevertheless, photographic documentation and preservation of the textile supports throughout the removal process were considered essential.

Another major aspect raised during the discussion was to "limit the treatment to only that which is necessary" (Article 8). The question of using "materials and procedures which (...) will not harm the cultural heritage, the environment or people" was debated extensively. Cleaning is an important step in any conservation treatment and may even be essential for long-term preservation. However, it is an irreversible stage that should be well evaluated and documented. Owing to the high knot density of the 'Salting' carpets, mechanical cleaning could only have a superficial effect and was not sufficient to remove all dust present. Hence, wet-cleaning was discussed, but full immersion would almost certainly contribute to mechanical damage and further material loss. Therefore, the use of a suction table was also considered. This approach would ensure that "even the smallest and most fragile elements of the fibres" were maintained (Maes 1998). However, the presence of metal threads posed an additional challenge as water could cause the silk core to swell (about 30 percent), inducing extra tension in the metal threads which could cause the metal lamina to split (Johansen 2009). This problem might be avoided with carbon dioxide cleaning (a "green technology", not "harmful to the cultural heritage, the environment or people") which "had good results with historic textiles in limiting disintegration" (Sousa 2005 and 2007).

The principle of minimum intervention was thoroughly discussed for the stitch consolidation, as the carpets were very fragile and application of a full support was regarded necessary. However, attention was drawn to the importance of using a material (silk) compatible with those of the carpets (protein-based fibres), in contrast to the previous interventions (cellulosic fibres). Several hand stitches were selected to attach the textile supports in order to respect the minimum intervention principle.

Given these considerations, it was decided by the interdisciplinary team that treatment would involve mechanical cleaning, removal of previous supports, cleaning tests using full aqueous immersion, and a suction table, as well as carbon dioxide cleaning, and finally, stitch consolidation.

EXPERIMENTAL AND CONSERVATION TREATMENT

Removal of previous interventions

Careful removal of previous interventions was undertaken using scissors and tweezers. The process was photographed and documented, and all material removed was preserved.

Mechanical cleaning

Mechanical cleaning was conducted on the front and back with a Muntz vacuum cleaner. After several tests concerning vacuum time and intensity, the carpets were cleaned using the following conditions: ca. 6 min./dm^2 on the front and 3 min./dm^2 on the back, with medium intensity (circa 1 mBar), using a rubber nozzle. The nozzle was kept at a 1 cm distance from the textile surface which was covered with a polyester diamond mesh (6-8 holes/cm), to prevent further damage.

Wet-cleaning

Several wet-cleaning tests were performed on two carpet fragments (circa 8 × 2 cm and 2 g each). Both were submitted to three baths at room temperature, each for 5-10 minutes: i) 100% distilled water; ii) solution 0.5% saponin/distilled water (v/v) or 0.01% Lissapol N/H_2O (v/v); iii) 100% distilled water. The samples were sponged with a natural sponge, and then thoroughly rinsed with distilled water. The pH, colour and weight variations of the fragments were measured, as reported previously (Sousa 2005) (Table 1).

Table 1

Results obtained for the different cleaning processes; each is evaluated according to their harmfulness and efficiency, following Sousa (2005 and 2007). Vacuum and suction-table cleaning was applied to all three carpets. CO_2 cleaning was tested only in carpet fragments, as a large CO_2 apparatus was not available to clean the three carpets

	Harmfulness			Efficiency		
Cleaning	Δ weight (%) [$weight_{final}$ - $weight_{initial}$]	Metal threads losses[1]	Color bleeding[2]	Amount of dirt particles extracted[3]	ΔL* (L_{final}-$L_{initial}$)[4]	ΔpH (pH_{final}-$pH_{initial}$)
Vacuum	<1	1	-	3	Variation within experimental error	-
Wet-cleaning	10	2-3	2	1		~1
Suction-table	4	1-2			2	
Liquid and supercritical CO_2	2	1	1	2	Variation within experimental error	

[1] Metal thread losses were evaluated by comparing the same textile area before and after the cleaning: 1 –preserved completely intact; 2 – at least 50% intact; 3 – less than 50% intact.

[2] Color bleeding observed during cleaning, namely in the rinsing baths: 1 – transparent solvent; 2 – yellow solvent.

[3] Extraction of dirt particles was evaluated by comparing the same textile area, before and after cleaning, by optical microscopy. However, due to the tridimensional structure of the knotted-pile surface, it was not possible to obtain good microscopic photographs for quantification. Nevertheless, a qualitative analysis was estimated: 1 – more than 70% of dirt particles removed; 2 – circa 50% removed; 3 – less than 30% removed.

[4] Luminosity variation (Lab* system) was obtained by comparing the same textile area, before and after cleaning, using a *Datacolor* colorimeter.

Suction-table wet-cleaning

Three different fragments (circa 8 × 2 cm and 2 g each) were submitted to wet-cleaning using a suction table, 1.5 m long × 1.2 m wide, based on the technique described by Maes (1998). The results obtained were evaluated as for the wet-cleaning reported above.

Afterwards, the three carpets were also submitted to wet-cleaning using a suction table. As the carpets were longer than the suction table, it was necessary to clean sections of the carpets separately. Each section was washed for three hours under the following conditions: gentle humidification with four water aerosol sprays during 0.5 hour; application of 0.05% Saponin/water solution (v/v) for circa 10 minutes; followed by the Saponin solution extraction; application of six distilled water rinses, each followed by extraction. A Melinex cover was used to promote suction exclusively in the carpet area. After the last water bath, extraction was performed with acid-free absorbent paper and Melinex film above the carpet. This paper was replaced 2-3 times. During this last stage, suction was applied at maximum power, for a total of circa 5 minutes. The total time of the cleaning process was circa 6 hours for each prayer carpet and 12 hours for the Medallion carpet. Afterwards, the carpets were left to dry in controlled environmental conditions (T=18-20°C and HR=60-70%), without suction. Complete drying was achieved after 12 hours.

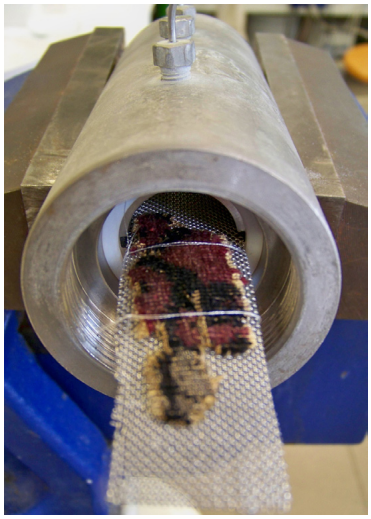

Figure 7
Insertion of a selected fragment on the CO_2 cell (detail)

Liquid CO_2 and supercritical CO_2 cleaning

CO_2-assisted extractions were performed on one sample from the Medallion carpet (circa 2 × 6 cm and 1 g). The laboratory scale apparatus and methodology used are similar to a previous publication (Sousa 2007). The experiments were carried out in a 33 ml stainless steel cell, with the sample placed in a metallic net (Figure 7). Cleaning was performed in a two-step process. Firstly, the sample was cleaned with liquid CO_2 plus a co-solvent to promote the extraction of polar particles, strongly attached to the textile, with the massic composition: 98.13% CO_2+ 1.64% ethanol + 0.23% distilled water, at 25°C and 20 MPa for two hours, with a flow rate of 1.5 ml/min. At the end of the experiment, the sample was further cleaned with only liquid CO_2 (30 minutes, 1.5 ml/min) to remove traces of any co-solvent. Secondly, the same sample was further cleaned with supercritical $scCO_2$ at 40°C and 20MPa for 2 hours, at a flow of 1.5 ml/min. The physical damages and efficiency of the CO_2-assisted cleaning process were evaluated, as stated in Sousa (2005 and 2007), and compared with the previous wet-cleanings tests (Table 1).

Stitch consolidation

A new full support similar in texture and thickness to the carpets (silk tabby fabric) was selected to reinforce their structure. The textile supports were dyed with synthetic acid dyes to obtain a dark-red colour similar to the red ground of the carpets (L*=33±1.31, a*=9.37±0.65, b*=10.78±0.47). Dyeing the textile support was performed with 1.43% orange Telon M-GSN, 4.4% red Supralan S-RL and 2.9% blue Telon M-RLW acid dyes. The dye bath was kept at 85°C during 60 minutes, after an initial stage where the temperature was increased gradually from 50°C until 85°C (1°C/min.). Avolan UL75 and acetic acid (pH=4.5) were used as auxiliary products. After dyeing, the fabric was washed in water.

The silk support was attached to the carpets with selected consolidation stitches (Grim 1993). Tacking stitch was applied to secure the carpet's perimeter and major areas of material loss (Figure 8). When necessary, stab stitch was applied, near the latter areas, in order to enhance the stability of the structure. Self-couching stitch (to secure loose threads) and invisible darning stitch were applied to reinforce areas where metal thread was present and/or wool knots were particularly fragile or absent. Finally, the carpets were secured to the support fabric with half back stitch rows of appropriate spacing, parallel to the warp, using more stable areas to distribute forces.

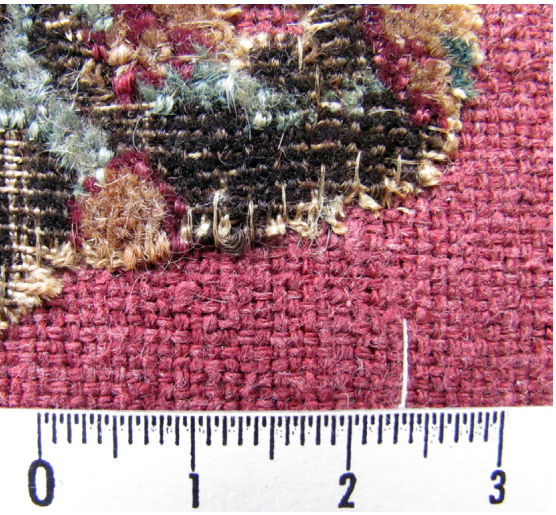

Figure 8
Securing the perimeter, with tacking stitch (detail)

RESULTS

Removal of previous interventions

Partial supports were removed from the prayer rugs without any noticeable material loss, as the stitches were very weak. As expected, removing the full support from the Medallion carpet enhanced appreciation of its brilliant colours and wide palette. The loosely-woven cellulosic textile had not been contributing to its stability, and a visible decrease in deformations and tensions was observed after its removal. By eliminating the stitches from the structure, the motifs became more clearly defined, and contrast between colours more intense.

Mechanical cleaning

With mechanical cleaning, the surface dirt particles were easily removed from the knotted-pile surface, without damaging the fibres. However, as expected, due to the high knot density, numerous dirt particles inside the tridimensional pile structure were not removed. Indeed, colorimetric measurements did not reveal any noticeable change in the final colour of the three carpets. As these dirt particles could have reacted chemically with the fibres, dyes and metallic threads, submitting the carpets to more "in-depth" cleaning was considered important.

Wet-cleaning and suction-table wet-cleaning tests

Wet-cleaning promoted a higher extraction of dirt particles than mechanical cleaning. An increase in the fibre flexibility was also observed due to re-hydration. A slight increase in pH was achieved (from pH circa 5 to a final pH around 6). However, wet-cleaning contributed to noticeable material loss (circa 10%). This problem was overcome by using a suction-table, and all the tests performed revealed a decrease of material loss (circa 4%). As humidification was gradual, it was possible to avoid extensive swelling of the fibres and disintegration of the metal laminas, in contrast to wet-cleaning (Johansen 2009). Contrary to mechanical cleaning, a noticeable change in the final colour of the three carpets was observed, with an increase in the luminosity (ΔL around 2) (Table 1).

Due to these positive observations, the three rugs were submitted to suction-table wet-cleaning. The fibres became more flexible, the colours more saturated, and contrasts more perceptible. However, some colour bleeding was observed, namely with the yellows of the silk foundation.

Liquid CO_2 and supercritical CO_2 cleaning

The above results for wet-cleaning were compared with CO_2 cleaning, which is a safe and efficient method for textiles. This was the first time this technique was applied to fragments of historical carpets, thus testing new parameters: knotted-pile structure and metal-wrapped threads. The results obtained revealed that CO_2 was able to penetrate the knotted-pile structure and remove some dirt particles. A significant cleaning effect was also noticed on the surface of the metal threads. The most important observation was that, contrary to wet-cleaning, the structure of the metal-wrapped threads was preserved completely intact and no significant material losses occurred (2%). Also no colour bleeding was observed (Table 1). An international proposal under the framework FP7 was submitted to build a large CO_2 apparatus. Unfortunately, this proposal was not approved and so the three carpets were submitted to the suction table cleaning.

Stitch consolidation

Tacking stitch was applied, with additional stitches near the areas of loss for proper stabilisation and distribution of forces. The level of intervention was the minimum necessary to achieve an acceptable guarantee of stability, in compliance with horizontal display and occasional rolling for storage and transportation. Hence, the carpets can now be returned to the exhibition gallery, although under restricted conditions: controlled environment and limited exhibition time.

CONCLUSIONS

The poor condition of the three Guimarães carpets, and their exceptional value, raised several conservation challenges. Achieving physical and chemical stability and increasing their visual aesthetic were the main goals. Given the advanced state of their degradation and main damages observed, all treatment phases took into account the ECCO Code of Ethics. Alternatives to traditional full-immersion wet-cleaning were considered, such as a suction table and CO_2 cleaning. The tests performed revealed that suction-table cleaning promoted extraction of dirt particles, pH increase, colour improvement, and preservation of the metal threads. Experiments with CO_2 cleaning resulted in no colour bleeding and only very minor material loss. This reinforces the importance of constructing a CO_2 laboratory-scale apparatus of sufficient size to clean objects with these characteristics and dimensions.

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further funding. We also thank Rui Miguel, Francisco Franco and José Machado (Universidade da Beira Interior, Covilhã) for dyeing the full supports for the carpets.

NOTES

[1] The percentage of fading was obtained by comparing the luminosity colourimetric values of the front and back sides of the carpets.

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MATERIALS AND EQUIPMENT LIST

Solvents
Sigma-Aldrich Química, S.A.
http://www.sigmaaldrich.com/portugal.html

Saponin
Dr. Alessandro Bizzarri S.A.S.
http://www.bizzarri-fi.biz

Polyester net
B. Sousa, Lda
http://www.bsousa.pt

Melinex film
Productos de Conservacion, S.A.
http://www.productosdeconservacion.com

Silk support
Joaquim Augusto Bispo, Lda
http://www.bispos.eu

Synthetic dyes
DyStar – Anilinas Têxteis Unipessoal, Lda
http://www.dystar.com

Lissapol N
Laborspirit, Lda
http://www.laborspirit.com

Muntz, vacuum cleaner
Productos de Conservacion, S.A.
http://www.productosdeconservacion.com

Feestol CT55E liquid vacuum cleaner
Feestol España
http://www.feestol.es

BM-Zwickau suction table
ILKAZELL Isoliertechnik GmbH Zwickau
http://www.directindustry.com