

As the world-leader in concrete distributor booms up to 62 m vertical reach, Putzmeister has been working on computer controlled multi-articulating booms since 1986. To increase their efficiency, computer controlling has been introduced to guide the boom-tip in any desired direction, preferably horizontally. The FH 26 has been developed as a 5-arm hydraulically articulating and computer controlled **flexible handling system** to fill the gap between standard robotic equipment and the "master and slave systems", in the industry.



AEG



Competent Partners For Skywash.

Based on the PM-Technology the Skywash-system was developed and operated to the benefit of the customer by this consortium.

■ Putzmeister

Main contractor, system integrator, mechanical and hydraulic systems.

■ AEG

Robot control and software, electric system.

■ Fraunhofer Institute IPA-TEG

Scientific support.

■ Dornier

Three dimensional laser scanner.

■ Deutsche Lufthansa AG

Development partner and launching customer.



The assembly plant in Aichtal – 7 km south of Stuttgart airport is the birthplace of Skywash: Numerous daughter companies back up this plant in basic manufacture as well as sales and servicing worldwide.



Putzmeister Products and Services:

- PM-Concrete Pumps
- PM-Putzmeister Mortar Machines GmbH
- PM-Tunnelling Equipment
- PM-Industrial Pumps
- PM-Robotics
- PM-Consulting and Data Technology PCD
- PM-Academy
- PM-Marketing-Services



Putzmeister-Werk
Maschinenfabrik GmbH
Max-Eyth-Str. 10
D-72631 Aichtal
P.O. Box 2152
D-72629 Aichtal
(07127) 599-0
Telex 7266113
Fax (07127) 599-520

Skywash A Robot for Aircraft Washing.



The unique machine for clean and shining aircraft – making passengers feel comfortable and safe.



Image Quality.

The world's leading airlines recognize the importance of excellently washed and clean airplanes for their company culture and image. Passengers feel safer when they enter a spotless plane, knowing that airlines, which keep the surface in order, also care about all safety details.

For this and other reasons, airlines impose regular washing schedules on their planes, which ask for aircraft-surface cleaning. The lengths of intervals between the washes depend on many factors, e.g. long or short distance operation, pollution, paint.



Washing Aircraft.

Aircraft have to be washed at regular intervals due to optical and technical reasons prescribed by both manufacturer and airlines. The SW 33 Skywash performs the important tasks in washing a fleet of aircraft of sizes ranging from a B 737 to a B 747, or an A 320 to an A 340:

- To achieve better washing results with minimum manpower and shorter ground time.
- To wash at any airport outside or inside the hangars with minimum infrastructural requirements.
- To wash any type of aircrafts with sizes ranging from B 737 to B 747 according to specific customer requirements.
- To wash the maximum aircraft surface.

PM flexible handling system FH 26. In its Skywash figuration SW 33 mounted on Mercedes truck with Diesel EURO 2 low emission engine and sensor brush with specific handling system. The unit is completely self-contained, to utilize the very short aircraft ground-time effectively.

Convincing benefits with Skywash.

Deutsche Lufthansa approved.

In 1993 the SW 26 Skywash was tested successfully during 6 months by Deutsche Lufthansa at Frankfurt Airport on several aircraft B 747-400 and B 737-300. The suitability of the Skywash with realistic chances for positive optimizations has been proven. Based on their current practical experience Deutsche Lufthansa expect that an adequate return on investment with Skywash can be achieved. Based on the test results of the smaller SW 26 the configuration of SW 33

Skywash was developed. Lufthansa has decided to wash their aircrafts with two SW 33.

1. Today's problems.

Increasing the active flying time of aircrafts is the main key for improving business results of the international airline industry. So any ground-time has to be minimized. This especially reflects to the outside aircraft washing, as e.g. a total wash of a wide-body aircraft consumes up to 10 hours ground-time. The routing schemes seldom allow such a long time on ground. Airlines have to employ a large crew for aircraft cleaning. Their washing efficiency is quite often low due to irregular availability of the planes. Reasons may be unforeseen maintenance requirements, weather conditions or non-availability of hangar space. A washing event may have to be postponed, however some day finally it has to be performed. Partial washes may ease these problems, however they do not solve them. Skywash solves these problems. With two units working in parallel, a.m. ground-time can be reduced down to 3 hours with the help of two hand-washers for a B 747.

2. Benefits for the airline.

With two Skywash units working in parallel on one aircraft the following benefits can be obtained in comparison with manual washing:

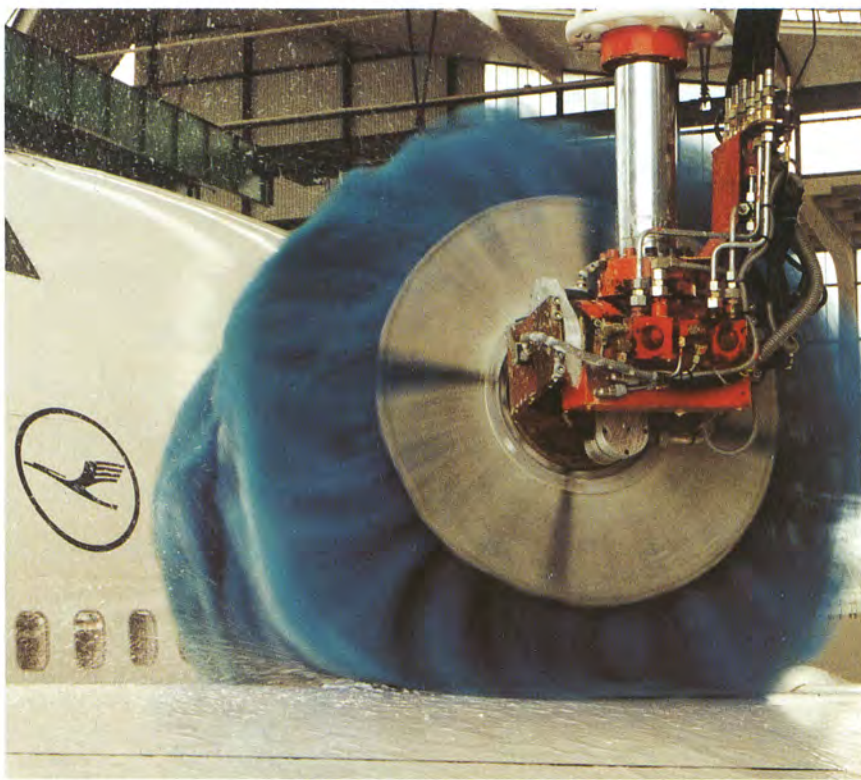
- Extremely reduced washing ground-time leads to higher aircraft availability and more flexibility in aircraft and washing scheduling.
- A robot control, which is operator initiated and monitored, guarantees a reliable and safe washing.
- Robot control avoids human errors.
- Superior washing results lead to increased cleaning intervals even with difficult paint (B 747/400).
- Only small areas of the lower parts of the aircrafts have to be washed manually.
- The flexibility of the system allows easy adaptation to washing concepts, aircraft types and washing areas.



Skywash on Mercedes Benz truck with reduced emissions permits operation in closed hangars.



The washing brush easily reaches the undersurface of the wing.



Telescopic control and adaption regulation of the sensor monitored washing brush.



The sensor washing brush adapts to the rounded fuselage by defined centrifugal forces pressing the brush to the surface.



Washing the top of the fuselage, the multi-section boom keeps away from the ceiling of the hangar.



The washing brush compensates for geometric deviations of more than 1 metre.

Technical Description.

Washing Brush System.

- All aeroplanes are only accurate to a certain extent.
- The washing brush measures the pressure applied onto the plane's surface structure.

Robot Control System.

- The system is applicable to all aircraft types.
- AEG Robot Control IRC 250 type manipulator.
- Operation in programmed task execution mode.
- High accuracy for the fast movements required.
- The washing area and special equipment such as antennas, can be programmed according to customer specifications.

Offline Programming.

- Teach-in is very time consuming and expensive.
- All movements of the manipulator are generated offline.
- Excellent simulation provided for operator's training.

EBK-Position Sensor System.

The position of Skywash in relation to the aircraft is never identical. Adjusting the memorized brush motion programme precisely on the real aircraft surface is achieved with the help of EBK and special software after the Skywash stands in a certain one by one metre area close to the aircraft.

- The Dornier laser camera measures space geometry three dimensionally. The sensor picks the 3-D-space geometry in front of the manipulator and transfers the data to the robot control which compares the actual position of the aircraft with a memorized digital model of the aircraft and calculates out of this position and orientation of the aircraft in the Skywash coordinates system. With this information the adaption of the washing programmes can be recalculated on to the actual position.

Truck.

Washing at any location must be possible.

- Standard on-road Mercedes Benz 5-axle-chassis MB 4838.
- Engine driven with Diesel EURO 2 with low emissions to permit operation in closed hangers.

Peripherals.

- Only minimum infrastructure needs to be provided.
- Autonomous system regarding energy and detergent.

- Manipulator performs fine adaption according to the pressure.
- Geometric deviations of more than 1 m can be compensated.

Collision Control System.

- Collisions of the manipulator with the plane could become very expensive.
- Redundant control of the movements by two computers.
- Software limiting switches to each articulation in reference to the positions are provided.

- Elaborated emergency stops.

Boom Structure SW 33.

- A B 747 has to be washed from four locations and a B 737 from two.
- Large multi-section manipulator boom with 33 m vertical reach and 30 m horizontal reach.
- High flexibility by 10 programmable axes.
- Operations under narrow geometric conditions.

Working Process.

Each of the two Skywash units takes position in the center between wing-tip and fuselage front or rear. To find the precise working position, a special laser camera (EBK), mounted at the front of Skywash acts as a navigation assistance. It focuses the plane and helps the operator to find the precise working position comfortable. At this position the ideal picture on the screen complies with the picture of the plane which the camera reads at that moment. After stabilizing

the Skywash with outriggers on the ground, the boom is folded out automatically, whilst the laser camera and the computer calculate the exact position and orientation of the aircraft relative to the Skywash unit. Moments later, the Putzmeister sensor washing brush at the boom-tip touches the surface of the plane and moves over it path by path with defined centrifugal force pressing the rotating brush fibers towards the surface, being continuously injected with jet-clean foam.

The washing path for the brush is approx. 2600 m on a Boeing 747-400, and approx. 600 m on a 737-300. This covers approx. 90% of the Jumbo. The rest of the surface is done manually and simultaneously to the robotized washing programme. Parallel use of 2 Skywash units at the aircraft reduces ground-time, especially with Wide-Bodyplanes.



The SW 33 has been developed and optimized in computer simulation to cover a high percentage of the B 747 and other large aircraft for perfect and quick washing operation. The washing

programmes of most common aircraft are programmed offline as well. They define the sequence of the brush washing path on the aircraft surface.



Operator interface.



Manipulator control panel.



EBK-position sensor system.



Task selection.



EBK pixel print.