

Rope Automatic People Mover Systems

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For the past 17 years POMA/OTIS has installed nineteen-roped Automatic People Mover (APM) systems worldwide and also assisted POMA with installation and service of three incline elevators. This presentation will concentrate on the latest three US APM systems, which are, Detroit Airport, Minneapolis Airport Concourse, and Huntsville Hospital

These three systems as well as many of our others consist of a main drive system, electronic computerize control system, station equipment, support sheaves, tensioning system, a variety of vehicles or cabs, and finally the rope itself. The track, or guideway, for these systems are either elevated or underground and vary in the number of curves, both horizontal and vertical. The curves can be present at a variety of locations along the length of guideway and are restricted to a minimum horizontal radius of 200 ft and a minimum vertical radius of 300 feet. The guideway is protected from the general public at station locations by station doors, and the remainder of the guideway by fencing placed along the guideway.

The ropes on the three systems consist of a JOTA rope with the Detroit rope being 6 strands, 25 wire/strand, with filler wire, 38 mm diameter, and compacted construction. Both the Huntsville and Minneapolis Concourse ropes are 6 strands, 19 wires/strand, seale, 25 mm and 28 mm diameter respectively, and compacted construction. The rope is connected at the vehicle, except for Minneapolis, which is clamped, and routed through the entire guideway, drive assembly, return sheave assembly, tensioning system, and then reattached back at the vehicle. The number of rope bends is kept to a minimum and subject to machine frame, return sheave frame and tensioning frame designs.

The drive systems can be located in the middle or ends of the guideway alignment. The three systems, Detroit, Minneapolis, and Huntsville use a General Electric AC drive for propulsion. The machine itself sets in a machine frame, which uses a gearbox and an idler sheave. The idler sheave diameter is determined by system speed, frame design, and the type of rope used. The idler sheave diameter varies from 144 inches at Detroit, to 60 inches at Huntsville, to 90 inches at Minneapolis. Electrical power to the drive system, and the total APM system, originates from a 480 volt, 3-phase source.

The electronic computerized control is a redundant system for safety and reliability reasons. The system is based on the General Electric Genius Bus system. There is basically a master computer system, which controls the entire APM system. This master computer is then linked, via a fiber optic network, to local computers at the APM stations, the APM drive room, APM maintenance area, and each individual vehicle or cab. The local computers control all local functions in these areas with the status information being communicated to the master computer via the fiber optic link. The link to the vehicles is accomplished by the combination of the fiber optic network and a

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wireless local area network (WLAN) system. Each APM system, due to the computerized control, has the capability to operate in any of the four modes of operation.

Single Shuttle Mode: A single train, or tram, which operates in between all stations on a particular time schedule.

Double Shuttle Mode: two trains, which operate between all stations in a coordinated manner on a particular time schedule.

Demand Mode Single Shuttle: A single train, or tram, which operate between all stations only when requested by the riding personnel.

Demand Mode Double Shuttle: two trains, which operate between all stations in a coordinated manner only when requested by the riding personnel.

Each station is equipped with station doors, emergency egress doors, station displays, demand buttons, and an emergency call box. The station door operation is all automatic and is controlled from the computerized control system. There are light curtains and safety edges located in the open door areas to sense obstructions. The curtains and safety edges are linked to the computerized control to provide safe unloading and loading of the tram vehicles. Station displays are interactive and display next tram arrival time, tram next destination, APM system status and local time. The emergency egress doors are located between the station doors or in some cases at the end of the station platforms. The exact location is subject to local authority approval. The demand buttons are located on the door frame with the appropriate signage. The emergency call boxes are located in the station platform area and consist of an emergency stop button and a phone, which is link to central control and security.

The number of sheaves and their location depends on the track alignment. The diameter of the sheaves varies between 9.5 inches to 12 inches and is limited to a load value of 300 lbs. Once an alignment is finalized POMA/Otis uses the above criteria along with rope type, and systems speed to locate the support sheaves so it can limit rope and the Becorit liner wear on the support sheaves.

The tensioning system is located at one end of the guideway. The location of the tensioning system is usually the farthest from the drive machine area and is part of the return rope assembly. The tensioning is accomplished by moving one of the return sheaves, which is mounted on a separate frame, using an electric motor and ball screw. The actual tension is measured using load cells which is linked to the local computerized control via a serial link. If tensioning is required then the system will begin tensioning only when the tram is stop in a desired station. The tram will not continue until the tensioning process is completed.

There are a variety of cab and chassis designs for the three APM systems. On two systems the cab is constructed with fiberglass and sits on a steel chassis. The Huntsville cab is constructed with lightweight steel and sits on a steel chassis. The Detroit system incorporates the Otis Patented HovAir system, where the vehicle is elevated off the track surface with the use of airpads and an on board blower system. The Huntsville system incorporates rubber tire wheels

and the Minneapolis Concourse system uses a steel wheels. The interiors and styling vary with project and will be describe below. Each vehicle has public vehicle doors, emergency access doors, interior displays, emergency phone system, fire extinguisher, seating, and a variety of handrails and handholds.

The track design varies from concrete to steel, with the running surface constructed of either flat concrete, steel beams, or train rail. The alignments that are available are; single lane with a center bypass, single lane with off center bypass or two independent lanes. The vehicle guidance also varies between systems. Detroit uses side mounted guidance wheels, which pinch a steel beam, mounted on one side of the track. Huntsville incorporates a pinch guidance system, which uses guidance wheels, mounted on both sides of the vehicle moving along steel beams mounted on both sides of the track. The Minneapolis Concourse uses flanged wheels mounted on one side of the vehicle, which rides on an ARA 90 train rail. The Detroit and Minneapolis systems incorporates a separate end of track maintenance areas while the Huntsville system incorporates in station maintenance area. The Detroit guideway is constructed of concrete and is elevated while Minneapolis and Huntsville guideways are steel construction and are also elevated.

Detroit Midfield Terminal APM



The Detroit APM system is 4000 feet in length and is located inside the new Midfield Terminal at the Detroit Airport. The system was handed over in February of 2002 and is capable of handling 3,872 people per hour per direction. The maximum speed of the system is 30 mph and operates approximately 17 hours per day. The line sheaves (support sheaves) diameters that are used are 12 and 10 inches, with approximately 186 sheaves per rope. There are two roping systems on an alignment that has single lane with a center bypass. The track is flat for the 4000 feet (See figure 1).

This system is used to transport airline passengers between gates in the mile long Midfield Terminal which is a main hub for Northwest Airlines.

There are 3 stations. Two stations are at each end of the track with the platforms on one side. The center station is located between the two guideways at center bypass. This results in two platforms. For the entire system the total number of station platforms is four (4). At each

platform there are eight (8) station doors resulting in a total of thirty two (32) station doors. Each station door width is eighty four (84) inches.

The drive machines are located at the end of the West Station beyond the maintenance area. The drive machine base horsepower is 700hp at 1800 rpm with a gear box ratio 26.662 resulting in a drive sheave speed of approximately 70rpm. The drive sheave wrap angle is 223 degrees with a maximum drive sheave torque at AW2, 117,080 ft-lbs. The rope breaking strength is 200,300 lbs with the nominal rope tension of 33,000lbs. The idler sheave diameter is 144 inches with a D/d ratio of 96. The acceleration rate is 0.075 g. There is also drip lubrication on each roping system.

The Detroit system consists of 2 trains, one per roping system, with each train consisting of two vehicles resulting in a fleet size of 4 vehicles. The train length is 112 feet with a vehicle floor area of approximately 407 sq feet. There are 6 seats per vehicle with a normal vehicle capacity, using a passenger density of 180 lbs, of 114 people. A fully loaded vehicle, AW2 loading, has the capacity of 171 people. The empty vehicle weight is 32,400 lbs. Each vehicle has cooling with two air conditioners per vehicle. The cab is constructed of fiberglass and sets on a steel chassis.

As indicated earlier this system incorporates the Otis HovAir system, which results in having three high efficiency centrifugal blowers, two active and one standby. The blower assemblies are located in the middle of the chassis under the cab of the vehicle and are set into a noise reducing enclosure mounted in the chassis. The blowers are control by 10HP, 3600rpm, and 215T frame motor. The motors have electric brakes and are connected to the blower units with three (3) V belts.

Huntsville Hospital APM System



The Huntsville Hospital system is 1,573 feet in length and connects two Hospital complexes together, which is separated by two city blocks. There are two additional stops along the alignment, which service the Heart Center and Orthopedic Center. The system began public operation in March of 2002 and is capable of handling 694 people per hour per direction. The maximum speed of the system is 15 mph and operates around 14 hours per day. One of the two systems is always available on demand mode twenty-four hours a day for emergency service. The support sheave diameter is 9.5 inches, with approximately 130 sheaves per roping system. There are two roping systems on two totally independent guideways. There is an elevation change of 2 ½ feet along the entire 1,573 feet of guideway. The entire system is an outdoor environment located in northern Alabama (See Fig 2).

All hospital employees, patients, physicians, and hospital visitors use this system. It allows people to move from the two different hospitals, heart center, orthopedic center, and parking garages.

There are four (4) stations. Two stations are at the ends of the guideways with the loading and unloading platforms in between the two guideways. A third station, Heart Center, is located approximately 200 feet from the West end station and the fourth station, Orthopedic Center, is located approximately 1200 feet from the West station (or 1000 feet from the Heart Center Station). These stations are also located between the two guideways. In addition, the Orthopedic Center station has a separate loading platform on the North Side of guideway directly opposite the center station. This results in a total of nine loading and unloading platforms. At each platform there are two station doors, which results in a total of 18 station doors. All the stations are constructed so, if needed in the future, the customer will be able to add a second vehicle to system and all that will be required will be the installation of the additional station doors.

The drive machines are located at and under the center platforms at the Orthopedic Station (1200 feet from the West end station). The drive machine base horsepower is 125hp at 1800 rpm with a gearbox ratio 19.744 resulting in a drive sheave speed of approximately 84 rpm. The drive sheave wrap angle is 360 degrees with a maximum drive sheave torque at AW2, 15,086 ft-lbs. The rope breaking strength is 87,600 lbs with the nominal rope tension of 11,000lbs. The idler sheave diameter is 60 inches with a D/d ratio of 61. The acceleration rate is 0.06 g. There is also drip lubrication on each roping system.

The Huntsville Hospital system consists of 2 trains, one per roping system, with each train consisting of one vehicle resulting in a fleet size of 2 vehicles. As indicated, the system is capable of adding a vehicle per train. The train length is 30 feet with a vehicle floor area of approximately 118 sq feet. There are 3 seats per vehicle with a normal vehicle capacity, using a passenger density of 180 lbs, of 42 people. A fully loaded vehicle, AW2 loading, has the capacity of 63 people. The seats are located along one side of the vehicle between the operating doors so that a full size hospital bed can be moved into and out of the vehicle. The empty vehicle weight is 14,200 lbs. Each vehicle has heating and cooling with an air conditioner per vehicle. The vehicles ride on run flat rubber tires and the cab constructed of lightweight steel with the chassis being constructed of heavy gauge steel.

This system can operate in the before mention four operating modes plus an additional emergency mode. If required to move an emergency patient, the attending physician can call central control or the security room, and the operator will have the ability, by turning a keyed selector switch, to put the system into emergency mode. When selected, one tram, the south lane tram, will proceed (if not already there) to the next station. The riding public will be instructed, by the on board public address system, to exit the vehicle. Then the tram will proceed to the requested end (Hospital) station and wait for the emergency patient. Once on board the physician or attending nurse, uses the onboard push to talk phone to indicate to the control or security operator that they are ready for transport. The tram will proceed to the opposite end station with out stopping at any of the mid stations. The emergency service only operates between the two end stations, which is the two hospitals. Either lane is available for this service, but the South lane is the priority lane since this lane is the shortest travel distance between the two hospitals and therefore the fastest service.

Minneapolis Airport Concourse APM System



The Minneapolis Concourse system is 3000 feet in length and is located along the C Concourse at the Minneapolis Airport. The system was just handed over in May of 2004 and is capable of handling 1,592 people per hour per direction. The maximum speed of the system is 26 mph and operates approximately 17 hours per day. The line sheave (support sheaves) diameter is 9.5 inch with approximately 200 sheaves per rope. There are two roping systems on single lane with an off center bypass. There are two movable track switches locate in the bypass area. The track grade changes 13 feet from the East Station to the Regional end Station, which is approximately 1000 feet. The track is mainly flat for the remaining distance (See fig 3).

This system is used to transport airline passengers between the main concourse to gates in the C concourse and to the regional gates E & F.

There are 4 stations. Two stations are at each end of the track, Lindbergh Station on the West end and the Regional Station on the East end. There are two mid stations, West Station and East Stations, and they are located in the general area of the bypass. The West Station is used when the tram travels East to West and the East Station is used when the tram travels West to East. All the platforms for these stations are on the same side. Maintenance area is located at the end of the East end of the guideway past the Regional Station.

The drive machines are located under the East Station Area. The drive machine base horsepower is 400hp at 1800 rpm with a gear box ratio 17.424 resulting in a drive sheave speed of approximately 97rpm at full speed. The drive sheave wrap angle is 360 degrees with a maximum drive sheave torque, at AW2, 49,630 ft-lbs. The rope breaking strength is 125,000 lbs with the nominal rope tension of 22,000lbs. The idler sheave diameter is 90 inches with a D/d ratio of 82. The acceleration rate is 0.06 g. There is also drip lubrication on each roping system.

The Minneapolis Concourse system consists of 2 trains, one per roping system. Each train consists of two vehicles, resulting in a fleet size of 4 vehicles. The train length is 65 feet with a vehicle floor area of approximately 190 sq feet. There are 4 seats per vehicle with a normal vehicle capacity, using a passenger density of 180 lbs, of 47 people. A fully loaded vehicle, AW2 loading, has the capacity is 132 people. The empty vehicle weight is 23,500 lbs. Each vehicle has heating and cooling with two air conditioners per vehicle. The cabs are constructed of fiberglass and set on a steel chassis.

Due to the limited land availability at this location, along with a minimum capacity requirement for the tram system, required the use, for the first time, a detachable grip system and movable track switches.

The detachable grip required a hydraulic moveable clamp and frame assembly to be mounted on the vehicle. At each end stations, Lindbergh and Regional station, a rope lifting assembly had to be installed. When a train arrives at one of the end stations, while the tram is unloading and loading passenger, the train changes ropes. The cable lift assembly, located under the track at the station, lifts a "rope holding bracket" up closed to the cable clamp on the vehicle. The hydraulic cable clamp opens its clamps (pair of clamps per vehicle) allowing the rope to drop onto the holding bracket. It should be noted that there are two rope-lifting assemblies, one is at the Lindbergh station and the other is at the Regional station. Once the rope is on the holding bracket, then the bracket retracts the rope to a safe distance. Then the onboard cable clamp assembly moves to the opposite side of the vehicle with its clamp jaw still open. Once the cable clamp assembly has completed its move, the second rope lift assembly lifts the rope up to the cable clamp. The cable clamp jaws close on the rope and the rope lift assembly retracts. The same procedure is occurring at the same time on the other train which is at the opposite end station. The computerized control insures the both vehicles are stopped at their correct end stations, and they are braked before any cable clamp changes are made. Redundant load cells measure the clamp pressure on the rope with a calibrated analog input to the onboard vehicle computer. The resultant measured pressure is compared to the calculated required pressure and if not within a tolerable window both tram system will remain in station until the discrepancy can be dealt with.

There are two track switches located at the bypass, which are control with electric motor through the computerized control. These switches along with the detachable grip help to increase capacity and reduce the wait time at the station for the riding public.

Conclusion

Over the years POMA/Otis has incorporated ropes in a variety of lengths, tensions, and bends, and then installed them as a way to move people horizontally in all types of environments. The maximum travel distance using this roped system is about a mile and quarter (Sun City, South Africa) with the shortest distance being 650 ft (Mystic Center, Medford Mass.). At the Getty Center (Los Angeles, Calif.) we have a rope installation where 92% of the guideway is in a horizontal curve and the guideway transitions from level to a 7% grade back to a level. The length of the system is $\frac{3}{4}$ mile and the 7% grade is 90% of the alignment. The local Otis office maintains majority of these systems with support from our engineering group in Farmington Ct.

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