A TELECONTROLLED APPARATUS FOR MEASURING ROAD PAVEMENT DENSITY

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SUMMARY

This apparatus is not in contact with the pavement, but measures the gamma radiation re-emitted by the material. Thesmall truck is telecontrolled from a tender. The use of radioactive material in an outdoor environment with traffic on nearby lanes and construction plant and labour in the vicinity requires reliable safety procedures. Infra red provides a suitable communications link. The tender driver can control the truck's progress up to a distance of 50m. Capacity is 2km in four hours. The flexibility of the apparatus and its on-site data processing capability make it ideal for quick controls on disseminated jobsites.

1. INTRODUCTION AND BACKGROUND TO PAVEMENT DENSITY MEASUREMENT

The GM PV (Variable Depth Gamma Densimeter) measures the density of road pavements. It is the latest version in a long line of monitoring equipment developed by our Design Centre for, and jointly with the Ponts et Chaussées and the French public works ministry organisation METAL.

This non-destructive method has entirely replaced core sampling with diamond auger. Pavement density is a primordial parameter largely governing the lifespan of a road under given traffic and weather conditions, and is the basis for compaction quality control. High precision in measurement is thus important. While coring and laboratory testing meet the precision criteria, sampling points are too few for any valid statistical representation, and there are two further serious disadvantages: it inevitably damages the pavement and, worse, results may not be available for several days or even a week, which is unacceptable for a job progressing a more than a kilometre per day.

Around the seventies, non-destructive radiation methods were current in mechanical engineering. We designed and built the PSM GDF 30, an apparatus for measuring wearing course thickness mounted on a minitractor driven by an operator. It could produce a continuous log of relative densities referred to a fixed point by one of the sensors. Counts were recorded on cassette and fed into a computer to obtain the results the next day. An analogue recording gave the operator a real-time idea of the density and density uniformity over the whole job. This was the forerunner of the GM PV.

2. GM PV DESIGN CRITERIA

Around 1985, despite continual servicing and replacement of the measurement electronics, it was becoming increasingly difficult to maintain the PSM GDF 30 models, and minitractors could not be found. It was a time of high enthusiasm for industrial robotics generated by the automobile industry. Public works engineers started to show interest, as well as the international community in the profession. These two factors incited us to build a density measurement robot.

2.1. Main Problems to be Solved

Obviously, this situation was not our only guide in preparing our new apparatus. It had to operate in all weathers (except when the road is covered with a film of water). It had to withstand splashes from passing vehicles since only one lane is closed for compaction work. Operating temperature range is -10°C to +50°C.

Compaction quality control involves measuring density on the hot mix (surface temperature is not more than 100°C during the measurements).

The minitractor drivers were exposed to the weather and the lack of comfort on this type of vehicle. The slow speed of travel (20 m/min) meant that the apparatus had to be carried to and from the job in a light van.

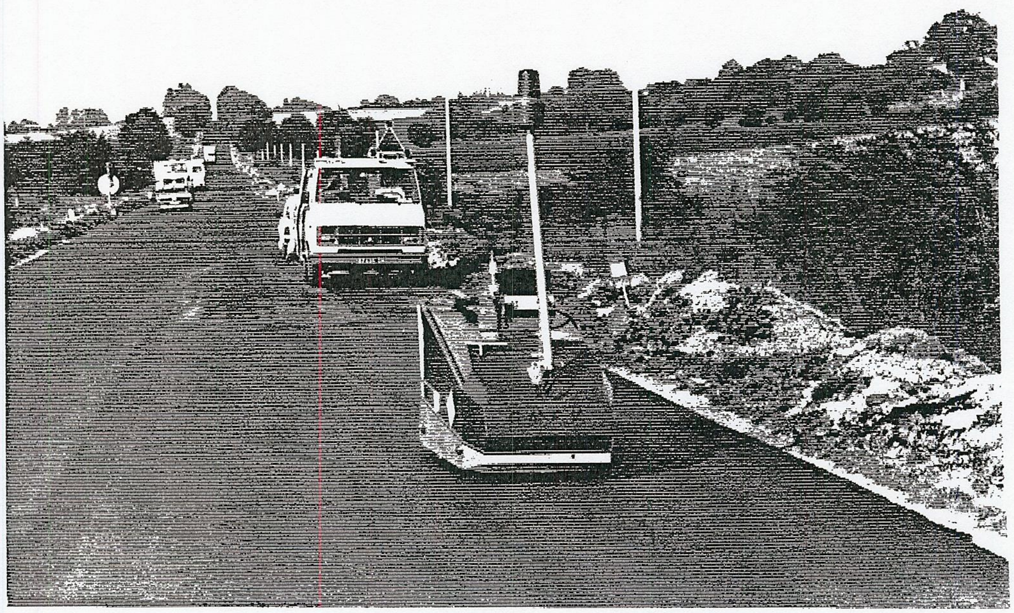

Fig. 1 - GM PV Working on Site

The Engineer ordering the controls and the contractor want results immediately to amend the work procedures if necessary. Controls are accepted more easily if they follow on quickly after construction.

2.2. GM PV Specification

Unlike the PSM GDF 30, the GM PV is not just a measuring apparatus, it is a complete jobsite system comprising a telecontrolled self-contained sensor unit and a tender housing the operator's station and computer.

2.2.1. Sensor

The sensor is the most important component which gives the unit its name. It consists of a container with a Ce137 source which can move through a passage from the storage position to the working position. The radiation emerges from the guide tube and impinges on the layer to be tested. After diffusion, a photomultiplier counts the gamma radiation from the layer, while a second multiplier checks the radiation diffusing in the air gap between the emitter and the surface. The two counts are carefully combined to determine the density of the layer, whose thickness ranges from 2.5cm to 7cm. A monthly calibration and daily checking of proper operation are of course necessary.

Because the layers are so thin, a 10mm gap is necessary between the layer surface and the air gap monitor. Therefore, the sensor must be raised when not in use to confer adequate mobility on the apparatus.

2.2.2. Truck

It was decided to mount the densimeter on a self-propelled truck. The 300kg weight is reasonable in terms of what the tender van can transport.

The standard speed for pavement monitoring is 18 km/hr, a compromise between measurement precision, caesium source activity and daily work rate. A slower speed (5 km/hr) is available for special measurements and manoeuvring the truck in congested places (as when parking it in a shed).

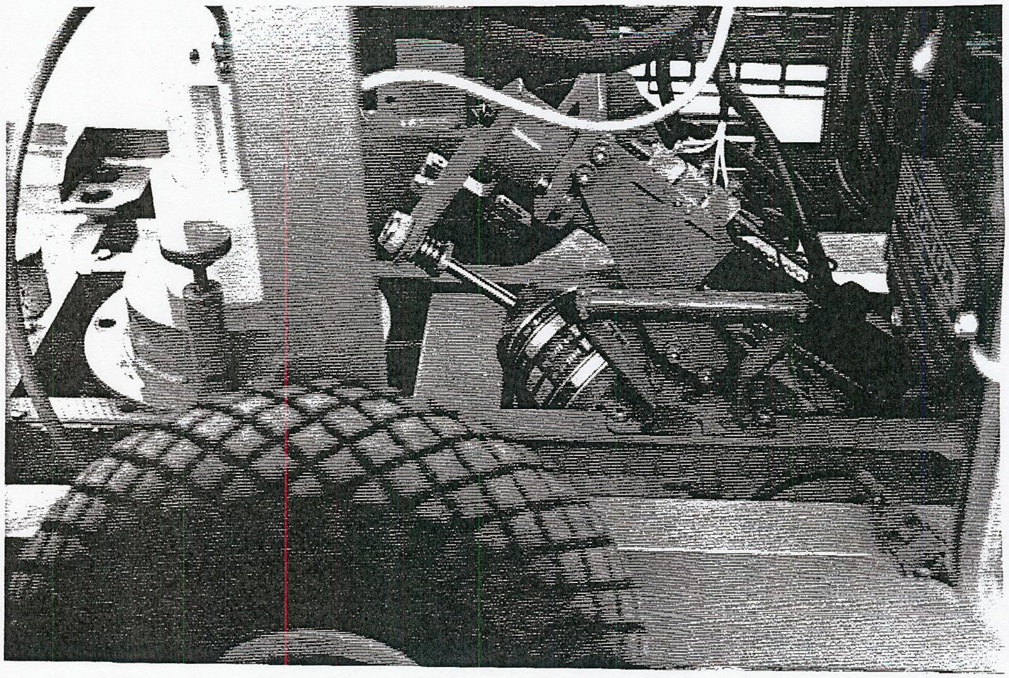

Fig. 2 - Container, Photomultipliers and Electricity Generator

The specifically innovative robotics feature as compared with earlier models lies in the fact that the truck is entirely self-contained, its power source being a small 2kW 220V a.c. electricity generator with a 10-litre fuel tank, sufficient for a day's operation. Effectors for driving and safety are controlled by a programmable automatic system with an on-board processor for data acquisition and control of the communications link with the tender.

2.2.3. Infra Red Telecontrol

The self-propelled truck is autonomous in taking the measurements, but it must be guided, for two reasons. A straight course is unfeasible on a road job, while setting out guide markers is laborious and quite costly over a distance of 1km; furthermore, it requires a guidance system on the truck with a pre-programmed course.

Some control procedures involve a zig-zag course, meaning that a new trajectory is required for each jobsite; there can be no question of preparing a 'flight plan' for each one!

Radiation counts and position (curvilinear coordinates) must be sent continuously to the tender so that densities can be calculated and filed. Other control information also travels over the same link.

Communications are two-way, the tender sending guidance information to the truck. This permanent exchange of information over the half-duplex link is controlled jointly by the truck processor and the microcomputer in the tender.

2.2.4. Tender

The purpose of the tender is to (i) transport the truck to the job without inconvenience or danger for the user, and in compliance with safety standards on transport and radiation protection, and (ii) to act as control, data recording and processing centre.

In addition to the infra red transmission/reception equipment, it houses the operator's station for guiding the truck, a portable microcomputer for data acquisition and processing. Coded environmental event data is keyed in by the operator and recorded simultaneously with the instrumental data, to provide a commentary on the subsequent output.

A printer connected to the microcomputer provides listing of as-recorded data when required and reports containing statistically analysed data on homogeneous zones can be handed directly to the site engineer.

3. TECHNICAL DESCRIPTION AND PERFORMANCE

The above description from the functional specification gives rise to technological functions in the automation chain. In terms of its architect-ure, the apparatus can be considered as a teleoperated system with much reduced movement capabilities since it works in a two-dimensional universe. The simple, reliable communications link is ideally suited to the purposes for which it was designed, and it could in fact be extended to other applications.

3.1. Automation

The flow chart shows the organisation of the uatomatic parts of the system. Remember that a human controller forms an integral part of all teleoperators.

The infra red transmitter/receiver provides the communications link over a distance of 5-50m. The operator drives the truck in direct sight. His controls are FORWARD/REVERSE/STOP and a LEFT/RIGHT self-centering pulsed steering control operating a single drive/steering wheel on the centreline of the truck.

The microcomputer in the tender is a 640k RAM portable PC with 20Mb hard disk storage. It controls truck movements, receives the intrumental data and tests the infra red link interface.

The pulses from the two photomultipliers are handled by a counter whose integration period can be pre-selected between 4 sec and 100 sec. The processor has been specifically developed for controlling the automatic functions and data acquisition on the truck. The distance travelled is summated, or subtracted if the truck is reveresed. It supervises the commands from the programmable automatic system in the measurement mode

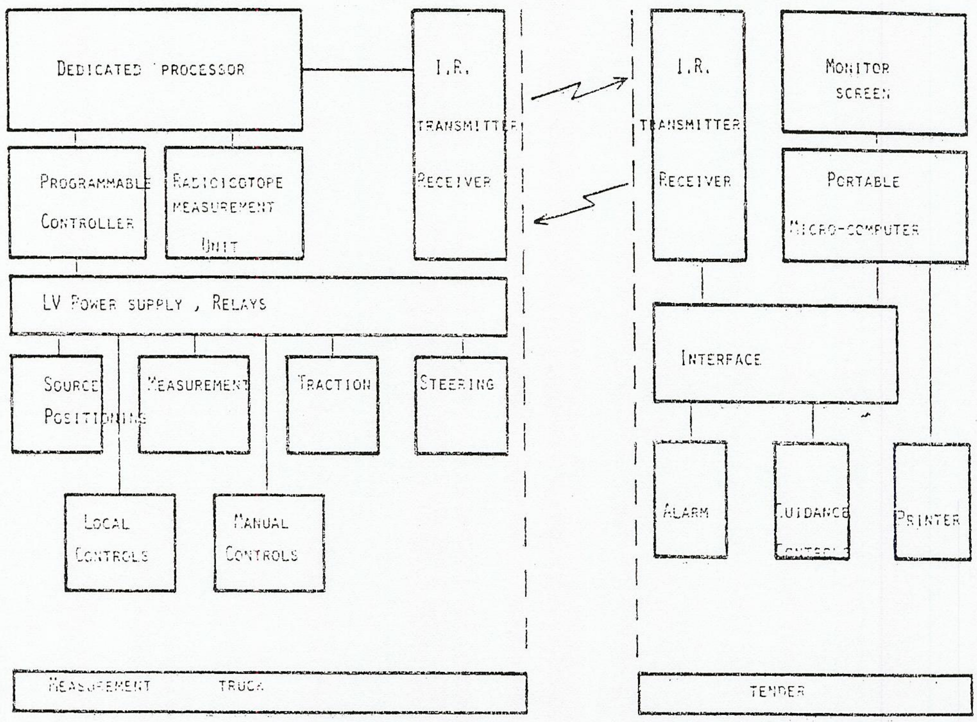

Fig. 3 - Automatic Control Chart

and controls communications with the transmitter/receiver. The processor cards are double Europe standard.

The programmable controller is the interface between the processor and the effectors. Truck-mounted driving controls enable the truck to be moved if the infra red link is unavailable. They are also used for parking and handling the truck.

The infra red transmitters/receivers are 2m above ground level so that passing workmen cannot block the line-of-sight. Only large plant like rollers and heavy trucks can cut the link and stop the measurement truck.

3.2. Measurement Truck

Only the physical parts of the truck are described, communications having been dealt with above. It is a fully modular design for convenient maintenance from two centres in France. Dimensions are: height 1.3m (mast lowered) or 2m (mast raised); length 2m (transport) or 2.4m (obstacle detector deployed); width 0.9m.

3.2.1. Preparation for Measurement

There are three selector positions: TRANSFER, JOBSITE, CALIBRATION. The caesium source operating system consists chiefly of a ram controlling the source movement and a fail-safe spring, held in the working position by an electromagnet.

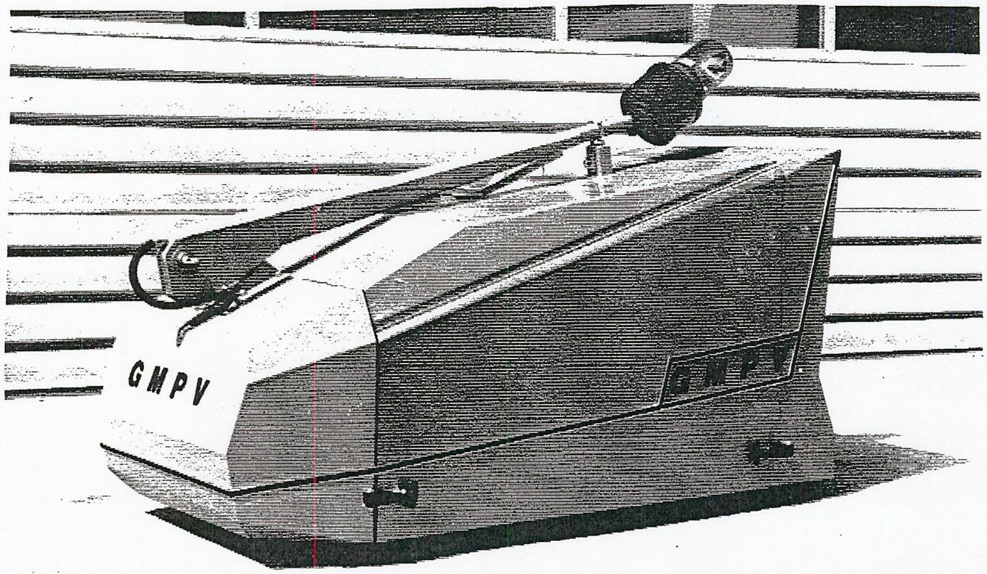

Fig. 4 - Measurement Truck with Mast Lowered

All these movements can only be controlled from the truck, but indicators tell the operator if the equipment is working correctly. Of course, automatic safety procedures are incorporated to withdraw the source if any link in the automatic chain develops a fault.

3.2.2. Truck in Measurement Mode

The traction system consists of a d.c. motor and reduction gearing driving a single wheel through a transmission chain. Speed control is by a conventional four-quadrant controller capable of power braking on slopes. The maximum slope is 7% at constant speed.

Steering uses an electric piston and link rod swivelling the traction system through an angle of 10° on either side of the centreline, giving a turning radius of 10m.

The truck is defended against obstacles by means of a rod-mounted sensors which stop the vehicle if it encounters a sudden depression or ridge more than 2-3cm high with respect to the monitored surface. Side contact sensors allow the truck to come within 15cm of obstacles.

3.2.3. Other Modules

Power supply and distribution modules power all the electric effectors and the electronics.

3.3. Tender

The functions of the tender vehicle have already been described; 95% of the components make use of parts that are commonplace in industry.

The real problem was to produce an ergonomically-designed control station that could be operated by one man. In addition to driving the

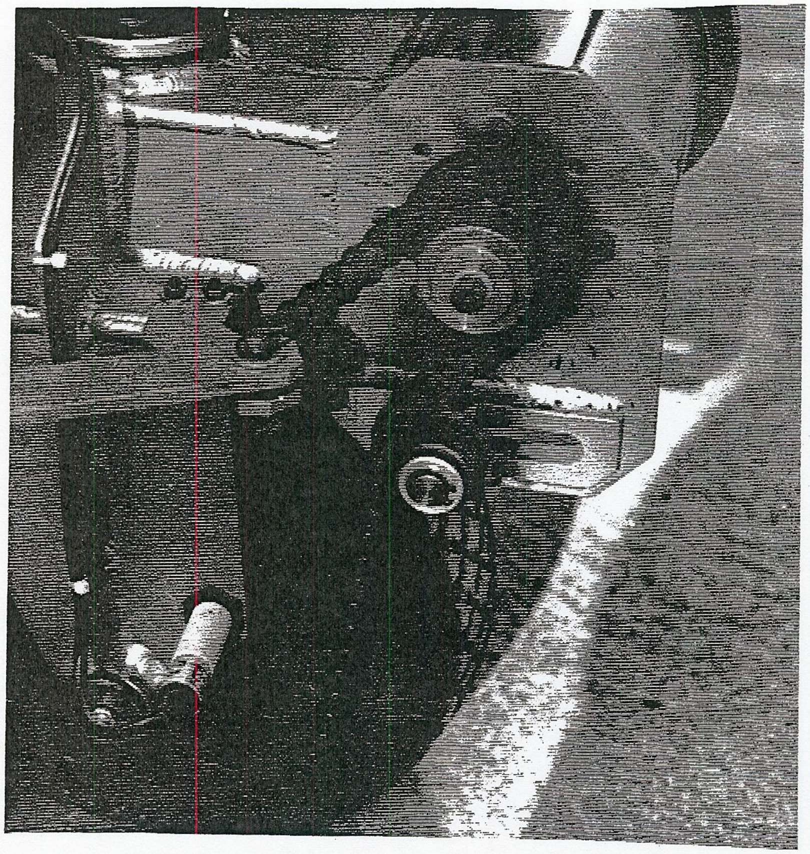

Fig. 5 - Traction-Steering Module

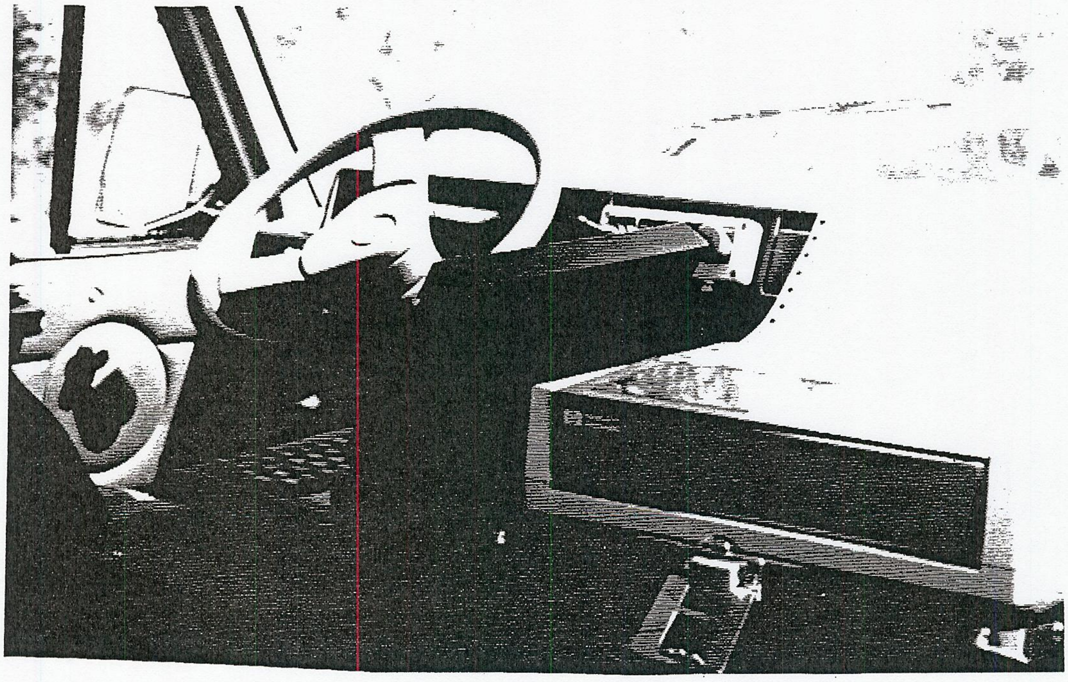

Fig. 6 - Operator's Station in Tender Vehicle

tender at reduced speed, he must also steer the truck, check density data on the microcomputer monitor screen and type-in comments. The station must accommodate men of different sizes and be readily adapted to different models of light vans suitable for transporting the measurement truck.

Loading equipment specific to the van is used to load and off-load the truck at the jobsite and the laboratory for calibration and maintenance.

The system normally operates within a radius of 100km on average, for jobs lasting a day and requiring 1-2km of density monitoring.

4. TYPICAL JOBSITE APPLICATION

The sequence of operations performed by the operator once he has arrived on site are described.

.Align tender with direction of truck travel (FORWARD). Switch on tender warning lights.

.Off-load measurement truck.

.Start truck generator and electronics (the photomultipliers need 15 minutes to warm up).

.Use controls on truck to move it to the minimum operating distance from the tender.

.Move radiation source to working position and check residual radiation around the apparatus. The system is ready to operate.

.The operator then drives the measurement truck from his control station. He can proceed continuously or in steps, if he prefers.

.He monitors densities and if no problems appear, he stops the truck, retracts radiation source and begins to collate the data so that he can hand the report to the site engineer.

.If no extra spot checks are required, he loads the truck into the tender and leaves the jobsite.

5. SAFETY

5.1. Radiation Protection

Use of a radioactive source involves compliance with specific regulations on equipment and operating procedures, and protection in the event of an accident. A substantiated application must be made and approved by the regulatory authority (CEA in France) before the radioactive source can be procured.

This passes the automatic safety systems controlling the container. Special maintenance centres make the necessary tests and calibrations twice yearly.

Users wear radiation badges at all times when working with such equipment. The industrial health authorities, which regularly inspects the laboratories, can authorise or prohibit the use of equipment by virtue of industrial health legislation in France, and their terms of reference are not confined to radiation protection.

5.2. Jobsite Safety

5.2.1. Loss of Communications Link

Loss of the infra red communications link for more than 1.5 sec immediately stops the truck, after it has covered a distance of 50cm. An indicator enable the operator to see if the link is becoming weak, e.g. if the truck is too far ahead of the tender.

5.2.2. Guidance Malfunction

If the operator cannot control the truck, he has an emergency control which immediately cuts off the electricity supply; the truck stops and the radioactive source retracts into the container, to the storage position.

To recommence operations, he must repeat the whole starting procedure described above.

5.2.3. Safety Warnings

The truck is orange, and the communications mast carries at orange winking light at the top. The tender is painted white so that it is clearly seen at a distance, and has a row of flashing lights at the rear and regulation oblique red stripe pattern.

The tender carries a fire extinguisher suitable for the type of equipment in use.

Site safety is the responsibility of the site engineer, and so long as the operator complies with his requirements, he does not have to concern himself with any other problems.

CONCLUSION

The GM PV, a simple apparatus in terms of its automation, embodies solutions to the various problems relevant to the civil engineering and building industries. It highlights the more important problems of mobility and variety in jobsite environments, as well as safety, which is further aggravated in this case by the use of a radioactive source. The solution resides in the concept of a communications chain and independent safety systems in a multi-level hierarchy.

Acknowledgements

Acknowledgements are due to the French Ministry of Public Works, Housing, Development and Transport (MELAT) and Atomic Energy Commission (CEA).

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