Development of a Snowplough/Salt Spreading Vehicle for Ice and Snow Clearance of Motorways in England

R.J. Gould, U.K. Department of Transport, London

Reason for Development

In England Central Government has a direct responsibility for about 1336 miles (2150 km) of motorway and 5059 miles (8400 km) of all-purpose trunk roads which are shown in Figure 1. Remaining roads are the responsibility of Local Government.

Central Government delegates maintenance on an agency basis to local highway authorities; that is, the Agent Authority provides the staff, workforce, plant and material with the costs charged against Central Government funds. Generally, this arrangement applies to winter maintenance operations on trunk roads. There is, however, a departure for motorways since not all local authorities have large specialised salt-spreading vehicles with the capacity to cope with motorways.

Such specialised vehicles are therefore provided and maintained by the Department of Transport and operated by drivers from the Agent Authority.

From the mid-1960's, the Department started taking delivery of 6x6 vehicles with a gross vehicle weight (GVW) of 20 tons (20.32 tonnes) which were based on a highly specialised chassis built against a tight engineering specification. This was followed in the late 1960's by a larger, improved version of the same vehicle having a GVW of 22 tons (22.35 tonnes) built by the same chassis manufacturer. The builder brought in all parts of the vehicle from separate suppliers and acted as an assembler only.

This led to in-service problems because there was very little dealer back-up in the field, which resulted in the Department having to purchase and set up a spares organisation of its own.

In 1973 it was decided that the Department would confine itself to supply vehicles for motorway winter maintenance purposes only. This prompted engineering thinking toward a different design approach because the operational parameters of a snowplough/salt spreading vehicle for use only on motorways dictates different design requirements. In this case, maximum gradients are tied by motorway specification to only 1 in 20 (5%) for slip roads (entry and exit) and 1 in 25 (4%) on the main carriageways. Road construction is such that heavy drifting of snow is almost eliminated and the road surface is kept to a high standard in terms of friction coefficients and adhesion factors.

The fleet consists of some 227 6x6 vehicles with two vehicles covering each 15 miles (25 km) of motorway with some additionally held in emergency depots. Early vehicles are in need of replacement due to age and ever-increasing corrosion problems exacerbated by the mode of spreading salt. The bodies have twin spinners, one on each side of the vehicle, situated between the back of the cab and the front of the body, and this results in heavy salt contamination of the vehicle. The body has a conveyor belt that is driven mechanically by drive from the transfer box power take-off (PTO) through drive shafts, a reduction gear box and flexible couplings, etc., which means that to engage the conveyor belt drive the vehicle must be stationary. The spinners and plough lifting ram are hydraulically powered from a small pump directly driven off the engine timing chest.

The conveyor belt carries salt to two cross augers running in troughs at the front of the body where it is fed into chutes which direct the salt onto the spinners. This design makes it difficult to achieve low spread rates - this will be clarified later in the paper.

In 1974 vehicle development trials started with the object of selecting a suitable chassis/cab and body to meet the Department's future requirements. The intention was to find as near a manufacturer's standard chassis/cab as possible with a 6x4 configuration by subjecting several different makes to exacting performance and operational trials. In the spreader body market all salt spreading body manufacturers are specialists in the field and we decided to try six makes of body and fit these to five makes of chassis. The trials were competitive and each unit was judged on its own merits, that is, each chassis/cab and each body separately.

Design Requirements

Broad specifications were issued for chassis/cabs and bodies which allowed manufacturers wide

scope. The six bodies tested were all different in the method of operation - the only common factors being that of payload capacity and salt being spread from the rear. The main specification items for the chassis/cab and body were:

Chassis/cab

- 24 ton gross vehicle weight
- 6x4 configuration
- Power/weight ratio 8 BHP/ton
- Tractive effort 25,000 lb
- Chassis frame stiffness at front end to take standard sub-frame for snow plough mounting
- Diesel engine with automatic fan and PTO facility from crankshaft
- Conventional manual control gearbox
- Standard on/off highway tyres (cross-ply construction)
- Differential lock-up facility between and across axles
- Automatic chassis lubrication system with minimum number of points
- Cold starting aid
- Leading dimensions (overall height, length, etc.)
- Low centre of gravity
- Tilt cab to give quick access to engine compartment
- Minimum maintenance and good accessibility to those parts requiring maintenance
- Paint specification to give lasting protection against salt-induced corrosion
- Insulated earth return electrical wiring
- Additional sets of obligatory lamps above cab
- Heavy duty alternator (50 amp)
- Heavy duty batteries.

Body

- Payload capacity of 12 tons (12.192 tonnes) with spreading device at rear of body
- Hopper shaped body to give good salt flow, with a low centre of gravity
- Hydraulic operation of conveyor system, spinners and plough lift
- All controls operable from cab whilst vehicle is moving
- Salt spread to be constant in each setting regardless of vehicle speed (road-related spread)
- Capable of spreading salt to a width of 60 ft symmetrically and asymmetrically
- Spread rate from 1.16 oz/yard^2 (40 g/m^2) down to 0.29 oz/yard^2 (10 g/m^2)
- Minimum maintenance with good accessibility to those parts requiring maintenance
- Salt spreading sensor unit to give driver indication in the cab of spread or no spread
- Body and sub-frame construction to be free from pockets where salt poultices could form
- Good accessibility for washdown by high pressure water hose
- Steel mesh sieving screens over body angled at 35° to the horizontal
- Rapid off-load facility for unused salt.

Procedure and Selection of Equipment

The five makes of chassis/cab were chosen after advertising in the national press and by direct approach to manufacturers who were requested to quote a price against our specification. Originally nine manufacturers expressed an interest but only seven quoted.

The body advertisement attracted quotations from seven manufacturers and six were chosen. The imbalance of five makes of chassis/cab to six makes of body was corrected by purchasing two chassis/cabs of the same make.

Chassis/Cabs

It was arranged that proprietary vehicle equipment, which also required assessing, should be allocated to different manufacturers. Five makes of automatic chassis lubrication equipment were chosen to be assessed together with three makes of automatic engine cooling fans.

There was a considerable degree of variation between the chassis/cabs both in cost terms and design.

Only two vehicle manufacturers could offer differential locks across axles with one offering a limited slip differential as a solution. There was a wide variation in transmission ratios which were aimed at giving maximum tractive effort but which gave operating problems at 30-35 mph (48-56 km/h) in the wrong engine speed band. Top speed of the slowest vehicle was 48 mph (77 km/h) and the fastest was 70 mph (113 km/h). Rear bogie suspensions were offered in two and four-spring configurations.

Power/weight ratios varied from 7.5 BHP/ton (5.85 kW/tonne) to 12.3 BHP/Ton (9.03 kW/tonne).

Cab tilt operation varied from quick and simple to slow and cumbersome.

The power take-off from the engine crankshaft was a new departure for all manufacturers and this facility varied from easy to install to very difficult - one had a rectangular hole in the radiator to allow the drive shaft to pass through. It is a criticism of all engine manufacturers that not enough basic engine design work has been applied to give good PTO facilities from the engine. With a tilt cab the obvious place for power take-off is at the rear of the engine where the capability of extracting some 30 HP presents no great problems and the driven pump unit would be well guarded and readily accessible for maintenance, etc.

All makes were fitted with cold starting aids.

Chassis/cab weight varied from 14,538 lb (6608 kg) to 18,764 lb (8529 kg).

Wheel-bases varied from 186 in. (4.737 m) to 197 in. (5.022 m).

Bodies

Of the six bodies, one had an auger conveyor system, two had chain-driven single conveyor belts, two had single rubber conveyor belts and one had twin rubber conveyor belts.

Body design varied from low profile to high profile with the attendant low and high centres of gravity. It was noted that the auger body had its body design inhibited by the auger length which resulted in a high C of G. Some bodies had high-pressure hydraulic control valves in the cab. Others were remotely controlled through cables. The tilt cab presents problems for body controls as they either have to be disconnected behind the cab when tilting or routed around the cab hinge point.

There was a wide variation in the method of obtaining the road speed/belt speed constant ratio. One manufacturer's solution was to take drive off a rear road wheel by means of a small friction wheel which was held in contact with the inner tyre wall by a spring controlled arm; the wheel in turn powered a small hydraulic pump which gave a metering signal to the main pump.

The remaining five manufacturers all used the vehicle transmission propellor shaft as a drive source for either direct-acting hydraulic pumps or for metering devices to control the main hydraulic pump. Direct drive pumps had to deliver 15-20 HP and this presented problems because of the imposed side-loading on the propellor shaft and variable centre distances of the drive pullies. A metering device drive only absorbs fractional HP (about 1/3).

Two bodies had gas/hydraulic accumulators fitted to give pressure consistency at low engine speed, e.g. gear-changing periods.

Off-loading facilities varied from simple and rapid to difficult and slow.

Body weights ranged from 5152 lb (2342 kg) to 6800 lb (3091 kg).

Overall heights varied from 10.34 ft (3.15 m) to 11.75 ft (3.58 m).

Hydraulic pressures ranged from 1750 psi (123 kg/cm^2) to 3000 psi (211 kg/cm^2).

Performance Trials

A project sheet was compiled and issued to clearly define the work required. Testing facilities existed at Government Experimental and Developmental Establishments and these were used on a hired basis. Each complete vehicle was checked dimensionally and weighed and then taken on to a test track to carry out performance running to determine top speeds, fuel consumption, retardation and reliability mileage, etc. A large area in the centre of the test track (skid pan) was used to check draw bar pulls, to determine tractive effort and rolling resistance, and to also check turning circles.

Vehicle overturn angles (tilt angle) were checked on a special hydraulically operated tilt rig. The information derived from this test, i.e. the tilt platform and body roll angles, was used to calculate the true vertical centre of gravity for each vehicle.

To thoroughly investigate chassis and body robustness, the vehicles were driven over a suspension course which consisted of irregularly spaced 1-in. concrete sets. This was chosen to simulate driving over frozen rutted snow and was a very effective test of the vehicle's suspension system, body mounting brackets, all bolted-on assemblies and welded joints.

Tests to stop and restart the vehicle on a 1 in 4 (25%) gradient were carried out on a purpose-built test slope.

Salt spreading calibration trials were carried out on a disused aerodrome site. This was a painstaking exercise to determine the bodies' actual spread rates and their conformity to British Standard 1622, which is a standard drawn up by the British Standards Institution to guide manufacturers through set testing procedures.

All results from performance trials were recorded and tabulated. One of the widest variations was in the tilt angle test where the worst vehicle was 22.5° and the best, 27° which gave C of G heights of 6 ft 3.65 in. (1920 mm) and 5 ft 9.37 in. (1762 mm), respectively. Obviously the stability of the worst machine was unacceptable and modifications were carried out before continuing further trial work.

Operational Trials

The vehicles were tested over two winters (75/76 and 76/77) under actual operating conditions on the motorways. Selected sites were chosen in the North of England where weather conditions are generally more severe, and for the first winter six motorway compounds were used with the vehicles (one vehicle/compound) being moved around every three weeks to get as much operator comment and feedback as possible. Due to staff resources the number of compounds used was cut to three for the second winter with two vehicles per compound and a six-week turn-round period.

Defects were experienced on all equipment and all needed development work as the trials progressed. Obviously some needed more modification work than others but in every case the product was improved during the trial period.

Salt usage rates were carefully monitored and consistency of spread rates continually checked. This work was made more difficult because of the variation in salt conditions between motorway compounds - ranging from very wet to just moist.

All vehicles were fitted with 10-ft (3.03-m) angled blade snow ploughs built to the Department's own standard, and although ploughing work was not excessive, there was sufficient work done in ploughing snow to a depth of 3 ft (0.9 m) to establish beyond doubt the viability of a 6x4 vehicle being used in this role.

The Agent Authority drivers took some time to get used to rear spread bodies because they were accustomed to seeing the salt being spread from the

front spread machines. With the new vehicles they had to rely on the salt sensor unit which gives a spread/no spread signal in the cab. They also had to reverse the vehicle with more care as the overhanging rear spinner has a propensity to damage.

On completion of the operational trials each product was assessed by taking the following information into consideration:

Agent Authority drivers' comments

Agent Authority technical staff comments

Defects—incidence and rectification by manufacturers

Manufacturers' performance - supply of spare parts, etc.

Performance trial results

Department of Transport engineering and technical assessment.

From this exercise a chassis/cab and body, together with the most successful chassis automatic lubrication system, automatic fan unit and salt sensor, were chosen as being the best combination of equipment to meet the Department's future requirements.

The successful chassis/cab and body had not been tested as a combination so it was decided to purchase some pre-production prototypes before a final decision was made for a bulk production order.

Pre-Production Prototype Vehicles

In the interests of testing the new chassis/cab and body as a unit and to ensure that teething troubles could be eliminated before bulk production commenced, it was decided to purchase four units and make a fifth unit from the original trial prototype equipment.

The five vehicles have been thoroughly tested over the past winter. Teething troubles came up and were dealt with to such an extent that it has resulted in a snow plough/salt spreading vehicle having the capability of operating reliably at low ambient temperatures (down to -20°C) and being able to spread salt at very economical rates.

In the snow plough role the experience gained over the past winter has been invaluable. English winters are not normally renowned for severity and heavy snowfalls, but on this occasion the raw material for testing purposes was supplied in abundance and the prototypes dealt with the problem without trouble.

Conclusions

The complete testing programme over the past three winters has resulted in a development of equipment not only to suit the Department but also to improve the products being offered to local government, because each manufacturer who participated in the exercise gained valuable experience and was able to make improvements as the trials progressed.

The development aspect was a joint effort between the Department and Industry - advice was given freely to all concerned on how to overcome problems as they arose.

The greatest benefit arising out of the trials is the capability to spread salt at 0.29 oz/yard^2 (10 g/m^2) for the precautionary salting operation. This figure is unattainable with the existing 6x6 vehicles because of the cross auger system not being able to deal with such small quantities of salt coming through the discharge gate.

Main areas of cost benefit are:

Savings of about 30% on salt usage

Prime cost of chassis/cab 6x4 standard against 6x6 special - saving 40%

Servicing and maintenance costs reduced - assessed at about 20%

Operational efficiency increased - saving in staff time and vehicle down time.

From the engineering perspective an appreciable advance in the development of winter maintenance vehicles has been achieved, but to get the best return of capital out of the equipment it still comes down to the operator being properly trained to use the vehicle as it was intended by the engineer. We try to eliminate chance and take operations and decisions away from the driver but until we get the equivalent of an automatic pilot we have to accept the vagaries of human nature. In closing it is opportune to say that we are constantly criticised by the public for spreading salt on the highways, which does result in increased corrosion of vehicles, but being a simple engineer, I see it as a straight choice. The conscientious motorist can get to grips with corrosion by preventative maintenance but he cannot get to grips with a sudden lack of adhesion between tyre and road surfaces.

Figure 1. Plans for the trunk road system.