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Equipment for deployment of canisters with spent nuclear fuel and bentonite buffer in horisontal holes

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FOREWORD

This document is a co-operation project between Swedish Nuclear Waste Management Company (SKB) and Teollisuuden Voima Oy (TVO).
The Swedish-Finnish co-operative study has been carried out by V.Henttonen and M.Suikki at JP-Engineering. The contact persons have been C.Svemar at SKB and J-P.Salo at TVO.

ABSTRACT

This study presents the predesign of equipment for the deployment of canisters in long horizontal holes. The canisters are placed in the centre of the hole and are surrounded by a bentonite buffer. In this study the canisters are assumed to have a diameter of 1.6 m and a length of 5.9 m, including the hemispherical ends. Their total weight is 60 tonnes. The bentonite buffer after homogenization is 400 mm thick, making a total package diameter of 2.4 m. The deployment system consists of four wagons for handling the canisters and the bentonite blocks. To ensure safe emplacement, every part is installed separately in its final position. This also makes it possible to use small clearances between the canisters and the bentonite blocks and between the blocks and the rock wall. With small clearances, backfilling can be avoided. Another basic design idea is that the wagons are equipped with wheels, which are in direct contact with the rock walls. Thus, rails, which have to be removed as the deployment progresses, are unnecessary. To minimize the time taken for deploying one canister, the wagons are designed so that only three trips from the service area to the deposit area are needed. Due to the radiation in the vicinity of the canisters, the wagons have to be teleoperated.

CONTENTS

1 INTRODUCTION

This study is based on a predesign of the nuclear waste canister deployment system. It presents the principles of operation and describes in detail the machines used in the system. The predesign was carried out taking into account the high demand for reliability in operating the machines and the prevailing radiation level around the canisters.

The nuclear waste, encapsulated in copper/steel canisters, is deployed in fullface bored drifts. The diameter of the drift is 2400 mm and that of the canister is 1600 mm. The length of the canister is 5900 mm and its ends are hemispherical. The canister weighs 60 tonnes. The space between the canister and the drift is filled with bentonite blocks. Six blocks of a length of 1000 mm form a circle around the canister. There are also concave end blocks, which are placed between the canisters. The outer diameter of the endblocks is 1600 mm, so that they form a continuation of the cylindrical part of the canister. There are three endblocks per canister end. The whole length of the canister plus the endblocks is 6000 mm. Thus, 2 x 3 end blocks and 6 x 6 surrounding sideblocks are needed to cover one canister (see Fig.1).

The canisters are deployed in a row in the drift. The length of one drift might be up to 4500 m. At the mouth of the drift there is a service area, where the deployment wagons are normally situated. The loading of the canisters and the bentonite blocks takes place in the service area.

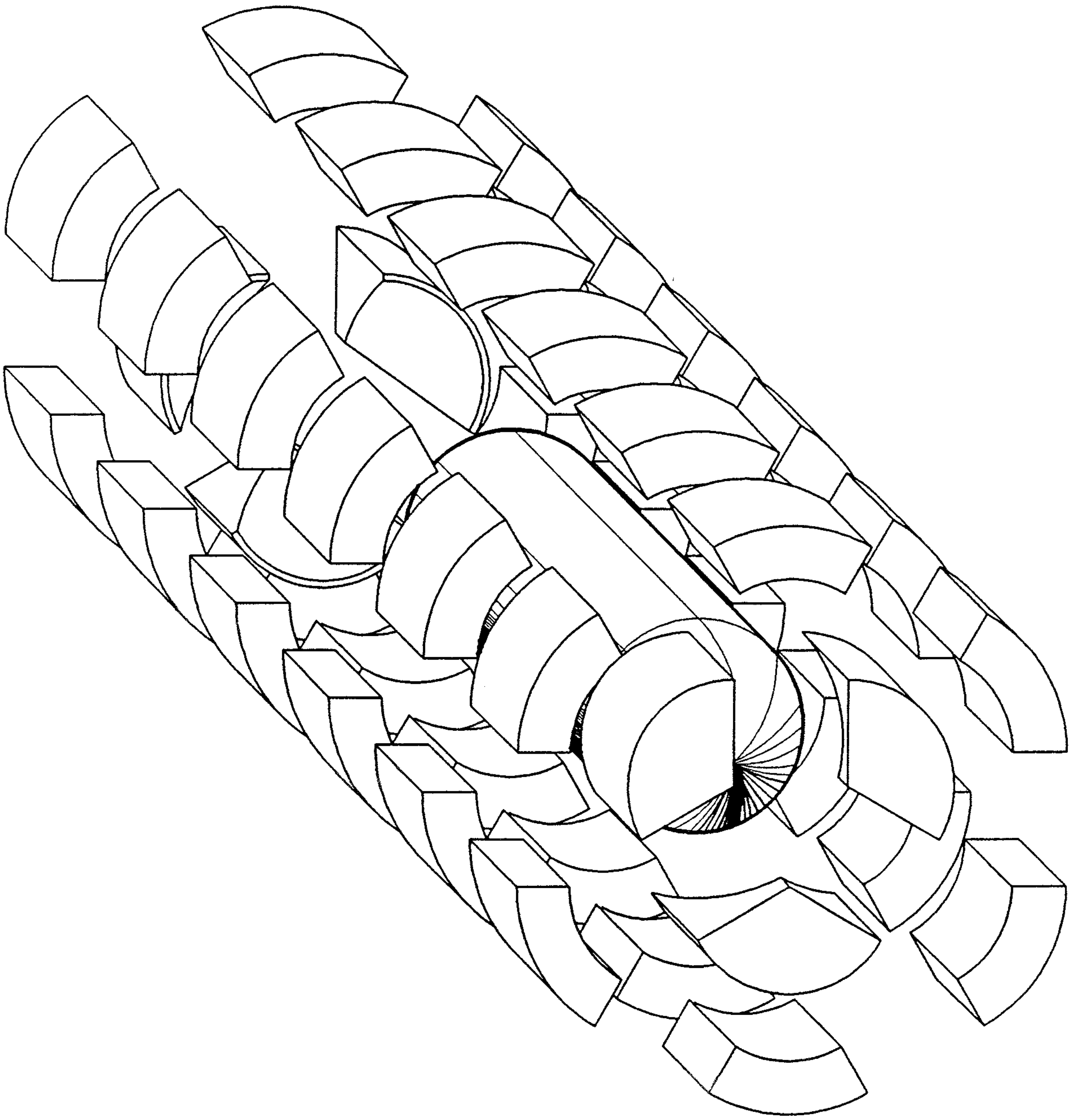


Figure 1   The canister and the blocks

2 PRINCIPLE OF DEPLOYMENT

The deployment of the canisters and emplacement of the bentonite buffer is carried out in the following four phases:

Phase 1: The Bentonite Wagon 1 (BW1) installs the bottom block and the lower sideblocks (Fig.2a). These three blocks form a sufficient support for the three endblocks, which are installed at the next stage (Fig.2b,2c). BW1 then places the upper side blocks and the top block around the endblocks. Finally BW1 installs the second bottom block, two lower sideblocks and the remaining three bottom blocks (Fig.2d). Before installing the bottom blocks the floor is filled with a certain amount of bentonite to ensure the correct positioning of the canister in the drift.

Phase 2: The Canister Wagon (CW) brings the canister to the disposal area and deploys it on the bottom blocks (Fig.2e).

Phase 3: The Bentonite Wagon 2 (BW2) installs the remaining eighteen surrounding sideblocks between the canister and the drift, leaving the end of the canister uncovered (Fig.2f).

Phase 4: BW1 backfills the remaining part of the drift in the same order as described in Phase 1 (Fig.2g).

If the deployment is continuous, Phases 4 and 1 can be carried out consecutively. Thus there are actually only three phases, which means that only three trips to the disposal area are needed to deploy one canister.

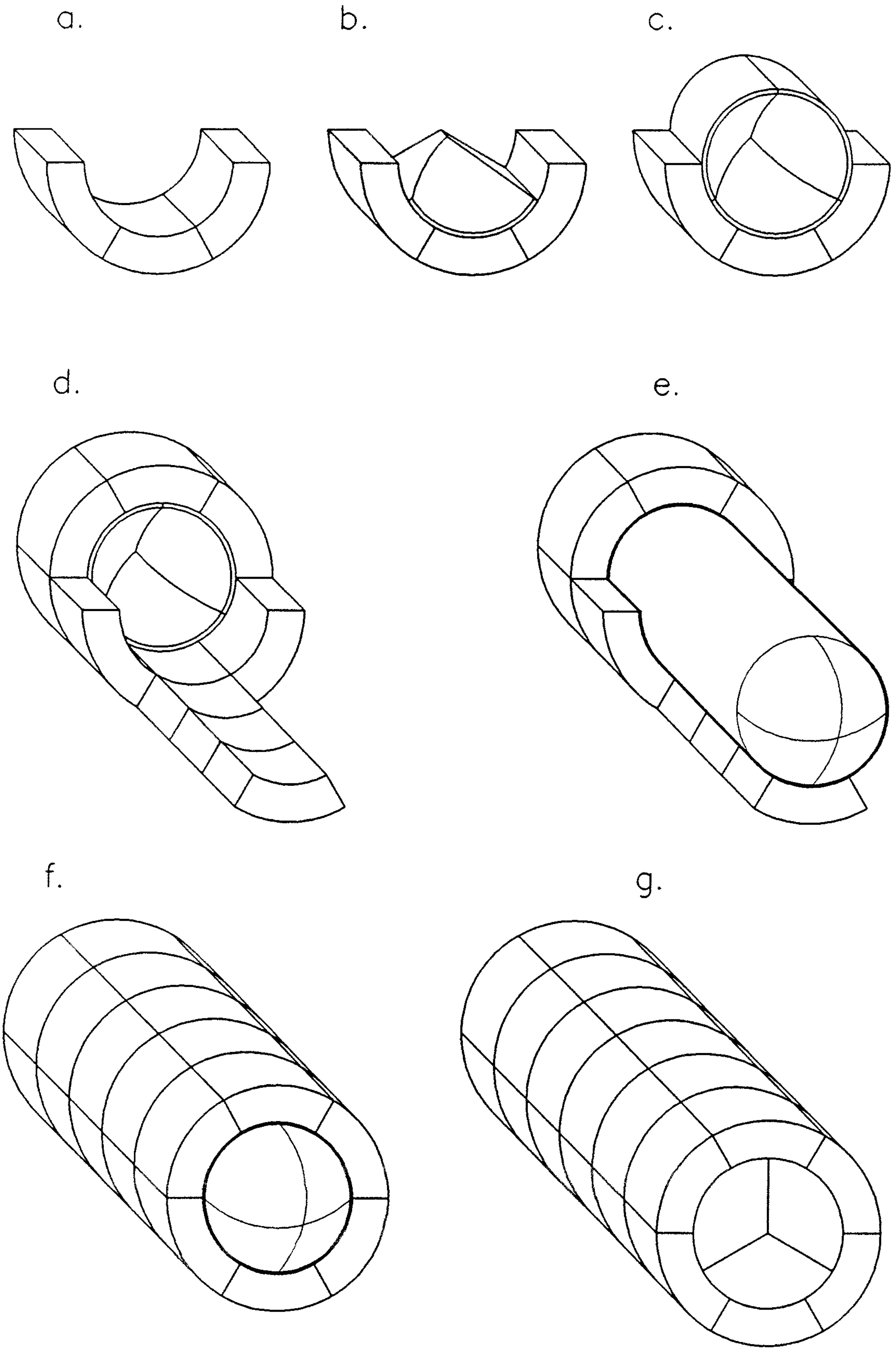


Figure 2 The phases of deployment

3 DEPLOYMENT DRIFT

The deployment drifts are constructed by tunnel boring techniques. The drift's diameter is 2400 mm and its length might be up to 4500 m. The maximum inclination of the drift is 2 % and the minimum radius of drift bend 50 m.

The tolerances of the drift's diameter is +0... -20 mm, due to elastic displacement of the walls. The surface structure of the rock wall is mainly determined by the size of minerals in the rock. However, the cutting also makes tracks, which might be up to 10...15 mm deeper than the inner lining of the wall.

Because of the limited space, the wheel size of the deployment wagons is relatively small, and suspensions compensating wheel movement are short. There are, therefore, some requirements concerning the bottom quarter of the drift. The drift should to be more elliptical than shown in Figure 3. In the deposition area, the shape of the drift must be more circular. All loose material must be removed and holes or cracks larger than 100 mm must be filled, for example, with concrete.

The bend radius of the drift affects the length and manoeuverability of the deposit wagons. Although the wagons are constructed to operate in drifts with a bend radius of 50 m, a larger radius would be favorable.

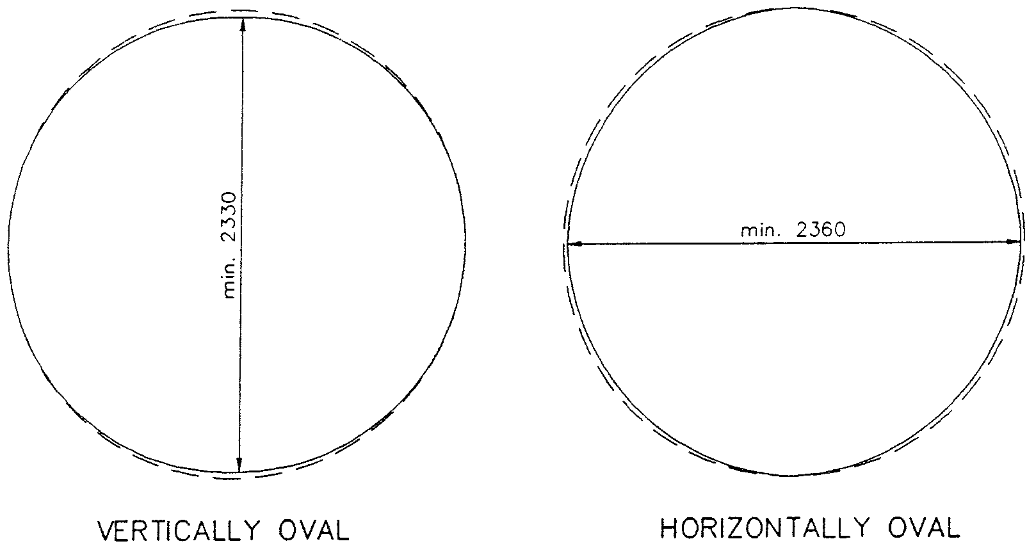


Figure 3 Permitted ellipticities of the drift

4 BENTONITE BLOCKS

The primary purpose of the bentonite blocks is to decrease the hydraulic conductivity in the immediate surroundings of the canister. There are two kinds of blocks: sideblocks and endblocks. Sideblocks fill the space between the canister and drift wall and endblocks the space between the canisters.

In order to make the manufacture and manipulation of the sideblocks easier, the dimensions of the blocks are limited (see Fig.5). The sideblock covers a 60° sector and its length is 1000 mm, excluding the projection for fitting. Its inner radius is 800 mm, which is the same as the radius of the canister. To ensure successful installation the outer radius is restricted to 1185 mm, while the radius of the drift is 1200 mm. This gives some flexibility, remembering the possible elastic displacement of the drift. Figure 4 shows respectively the alignment of sideblocks around the canister when the drift has the nominal diameter and when it has "shrunk" the maximum 20 mm.

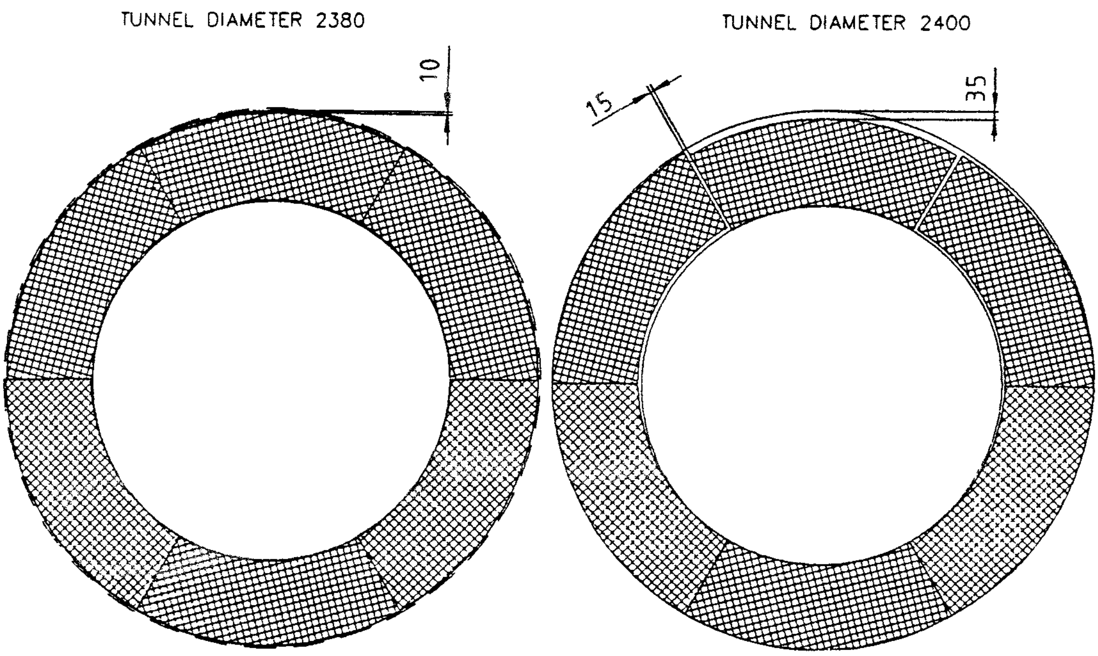


Figure 4 Alignment of sideblocks

At one end of the block there is a fitting groove and at the other a corresponding projection. This helps in accurate installation of consecutive blocks.

The side blocks are also provided with two holes of 50 mm diameter. The holes are used when gripping the block by the manipulators of BW1 or BW2. Without the holes, there would be difficulties in gripping and therefore also in handling a rather slippery bentonite block.

The endblocks are designed to be concave, so that they fit the end of the canister. They form a 120° sector, so that three endblocks cover one end of the canister. The outside radius of the endblock is 800 mm, i.e. the same as that of the canisters. There are two ø 50 mm holes for gripping. The distance between the holes is the same as the distance between the holes in the sideblock. This enables handling with the same manipulator in BW1. All the dimensions of the endblock are shown in Figure 6.

The dimensional tolerance for both of the block types is according to the manufacturer ± 1 mm, which can be considered adequate.

The weight of the sideblock is about 875 kg and that of the endblock about 435 kg.

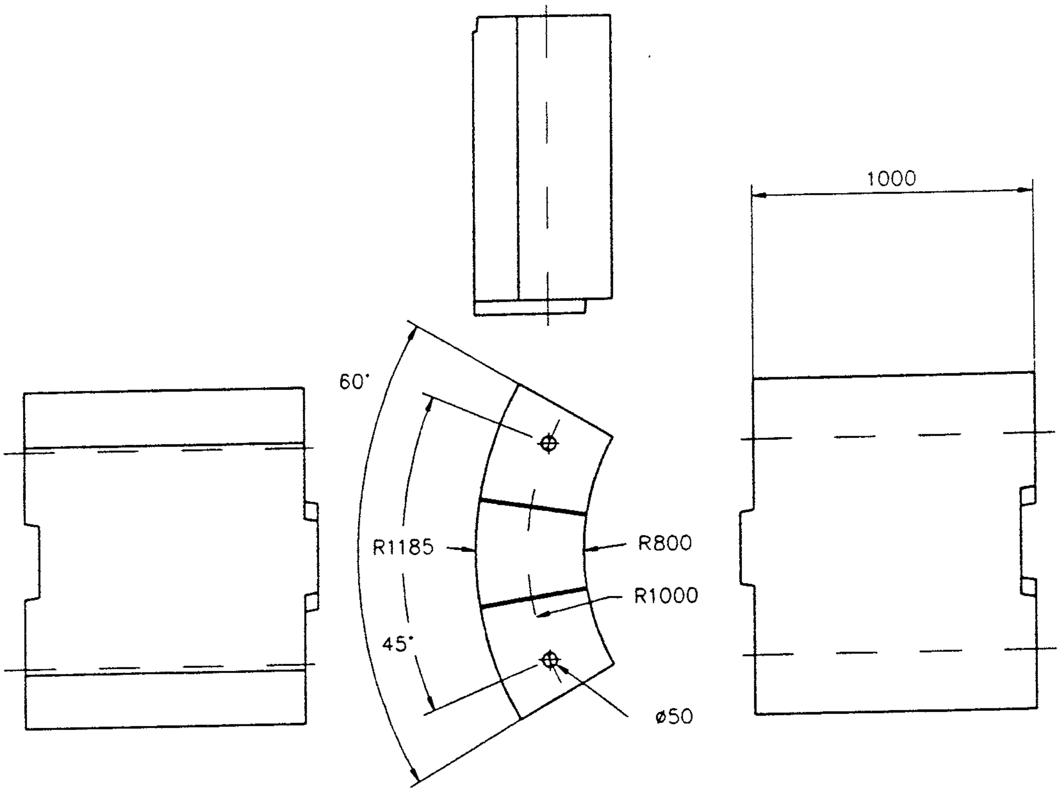


Figure 5   The dimensions of the sideblock

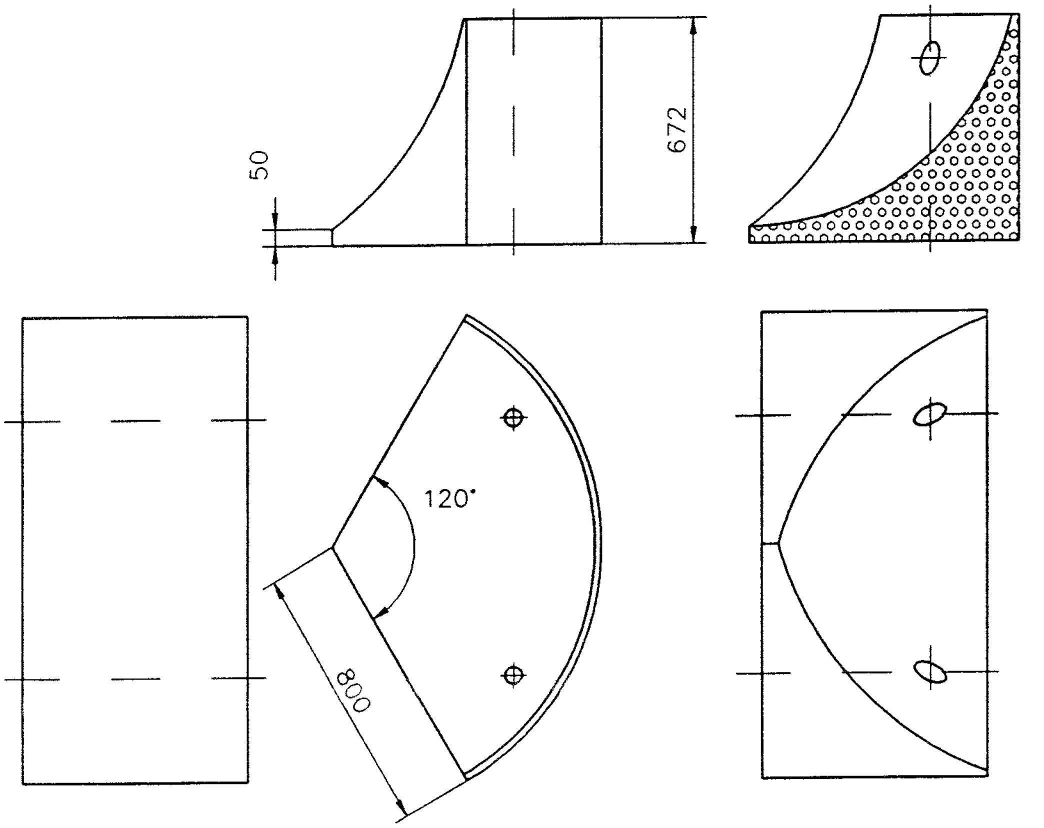


Figure 6   The dimensions of the endblock

5 BENTONITE WAGON 1 AND 3

In continuous deployment, as described above, Bentonite Wagon 1 (BW1) first installs the endblocks and the remaining sideblocks around the end of the canister deployed earlier. Then BW1 prepares the deployment of the next canister by placing the blocks for the end of the canister and by placing the bottom blocks. The bottom blocks form a bentonite "bed" onto which the canister can be lowered in the next phase. BW1 fills the bottom of the drift with bentonite so, that the centerline of the canister will coincide with the centerline of the drift. Altogether, the BW1 must have the capacity to handle and carry 6 endblocks and 18 sideblocks.

However, because the minimum bend radius of the drift (50 m) limits the length of one wagon, BW1 is divided into two wagons, BW1 and BW3 (Fig.7). BW1 incorporates the block manipulation options, while BW3 mainly provides storage for the sideblocks. Only BW3 is equipped with driving wheels.

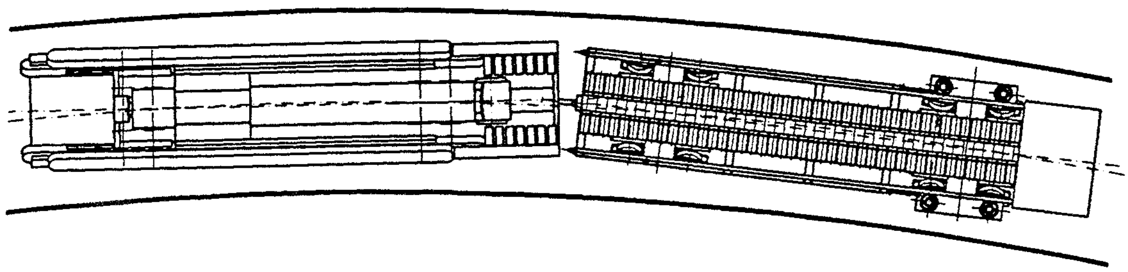


Figure 7 The combination of BW1 and BW3

5.1 Bentonite Wagon 1

5.1.1 Loading

In the service area, BW1 is loaded with the necessary number of endblocks and sideblocks. The endblocks lie in the upper conveyor (Fig.8). When loading the endblocks, the final operation must be taken into consideration. This means that the three first endblocks have to be placed with the concave end ahead and the remaining three with the flat end ahead. The sideblocks are loaded onto BW3. The roll conveyor of BW3 transports the sideblocks to the short roll conveyor of BW1. BW1 is equipped with a tipper, which lowers three blocks from the roll conveyor onto another conveyor, one at a time. This conveyor is situated below the endblock conveyor. In total there are six endblocks on the upper conveyor, three sideblocks on the lower conveyor and two on the short roll conveyor. The remaining sideblocks needed are stored in BW3.

5.1.2 Conveyors

BW1 has three independently functioning conveyors.

The endblock conveyor is in the upper part of the wagon. It is a V -shaped chain conveyor driven by hydraulic motors. The conveyor chains are equipped with plastic shield plates to minimize wear of the endblocks during transportation (Fig.9). The endblock conveyor also has a system for making a space between the first and the second block. The space between the blocks is necessary when the manipulator comes to take the first block away. In the front part of the conveyor there is a hoisting device, which can lift the five last blocks above the conveyor. The first block can be moved forward, while the others remain in place.

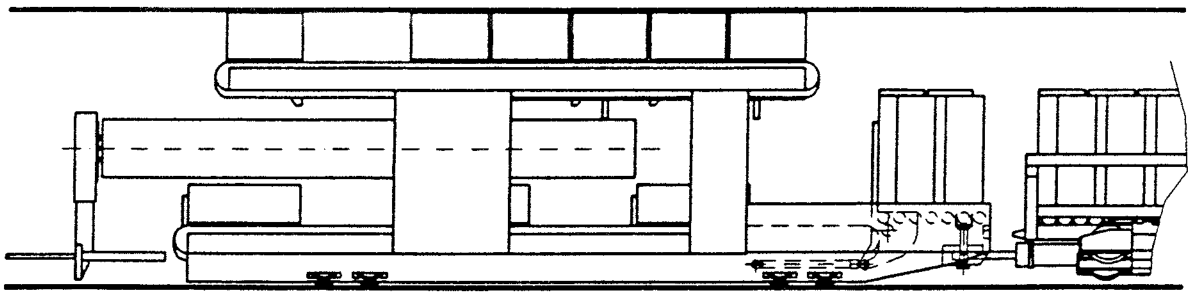


Figure 8 The Bentonite Wagon 1

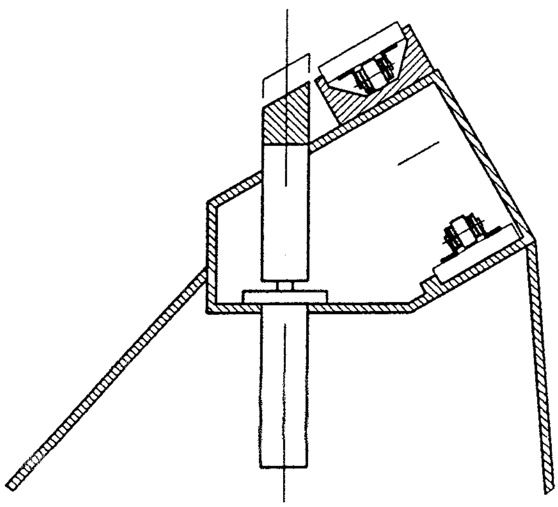


Figure 9 The endblock conveyor

The back conveyor serves as a magazine of two blocks during transportation and operates as an extension of BW3's conveyor. It is a roll conveyor driven by a hydraulic motor with gear.

The sideblock conveyor, which is situated in the lowest part of the wagon, moves sideblocks from the tipper to the manipulator. It is a chain conveyor rather similar to the endblock conveyor. However, the space between the blocks is effected in a different way. The tipper is lowered after the previous sideblocks on the conveyor have been moved sufficiently forward. There is no need for any hoisting device in this conveyor.

The tipping mechanism is a simple steel frame, rotated by a hydraulic cylinder. It turns the sideblock from the transporting position to the deposition position and lowers it onto the sideblock conveyor.

5.1.3 Manipulator

The manipulator, which is situated between the block conveyors, has a tubular frame (Figs 10 and 11). The frame is supported and mounted on guides on the wagon chassis. The manipulator is moved longitudinally by a hydraulic motor and gear with help of a rack and pinion.
At the end of the frame tube there are bearings for rotating the arm of the manipulator. The arm can be rotated $\pm$ 180° by a hydraulic motor equipped with a brake and cyclo-type gear, which are also placed inside the tube. The necessary accuracy of rotation is achieved by the cyclo-type gear, which has a very small or even zero rotating clearance. The arm has two hydraulic cylinders with a rod diameter of 45 mm. The distance between the cylinders is equal to the distance between the holes of the blocks.

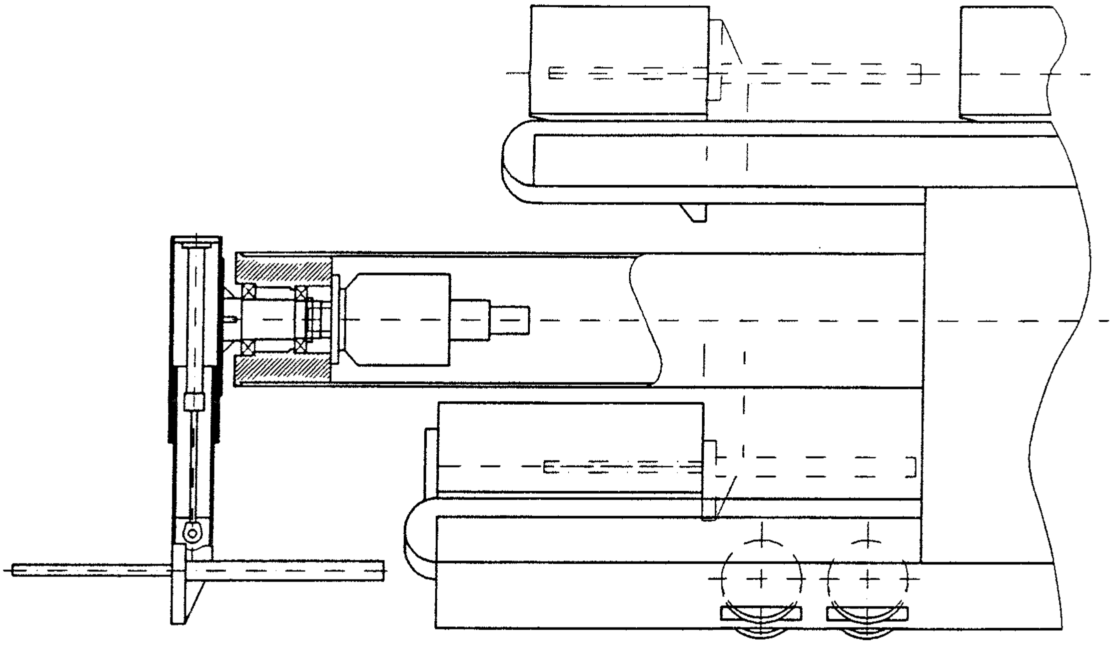


Figure 10 Side view of the manipulator

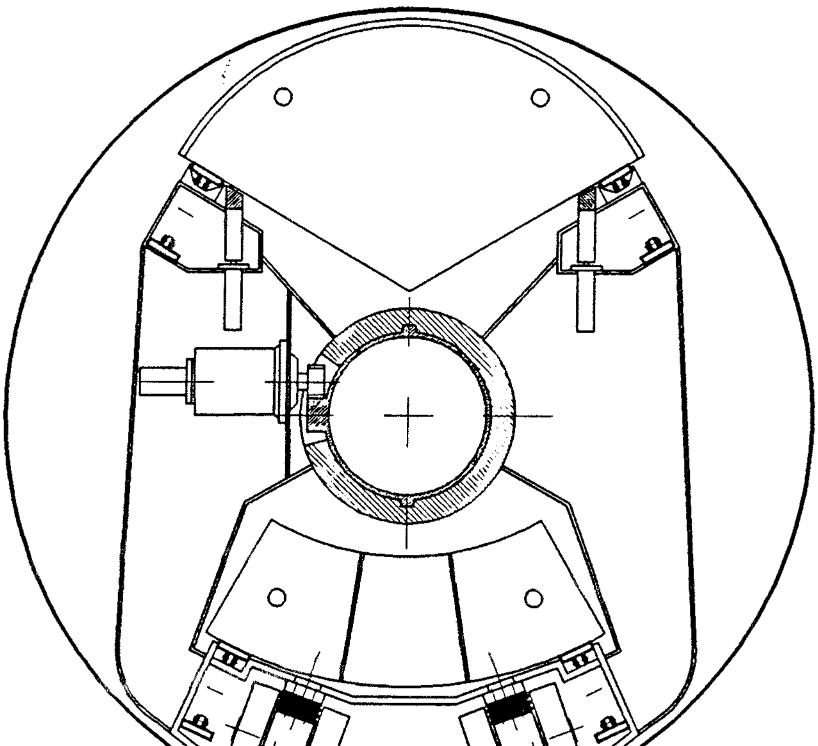


Figure 11 Front view of the manipulator

The rods can thus be inserted into the holes of the endblock or the sideblock. In order to carry the weight of the block, the front of the cylinder must be of a special structure, which carries the lateral load instead of the front sealings. Because the radial distances of the holes of the sideblock and the holes of the endblock from the drift centerline are different, the arm has to be of telescope structure. The rods are moved radially, depending on which type of block is being handled. The radial movement is obtained by a hydraulic cylinder.

The bentonite blocks are emplaced as follows. First the manipulator arm is rotated to the three o'clock position, then the manipulator is moved backwards to the rear position and the rods are pulled in. The arm can be rotated either upwards or downwards, depending on the kind of block being moved. After rotation, the manipulator arm is in place between the first and second block, which were brought to their places earlier by the conveyor. Next the arm is moved radially to the correct gripping position and the rods are inserted into the holes of the block. A short vertical movement lifts the block off the conveyor and the manipulator is able to move forward. When the arm is in front of the wagon, it can be rotated freely to the position for placing the block. Finally the manipulator places the block by pushing it forward to its final position. The rods can then be pulled out of the block. The plate at the front of the cylinders prevents the block from moving backwards.

5.1.4 Wheel construction

The BW1 has 8 pairs of rubbercoated wheels to carry the load. The wheels are steerable and suspended, but have no driving or braking mechanisms.

The axles of wheels (see 1 in Fig 12) are connected to a tube (2), which is pivoted on a shaft (3). The shaft is fixed to the wagon chassis. When steering, the tube is rotated around the shaft by a hydraulic cylinder.

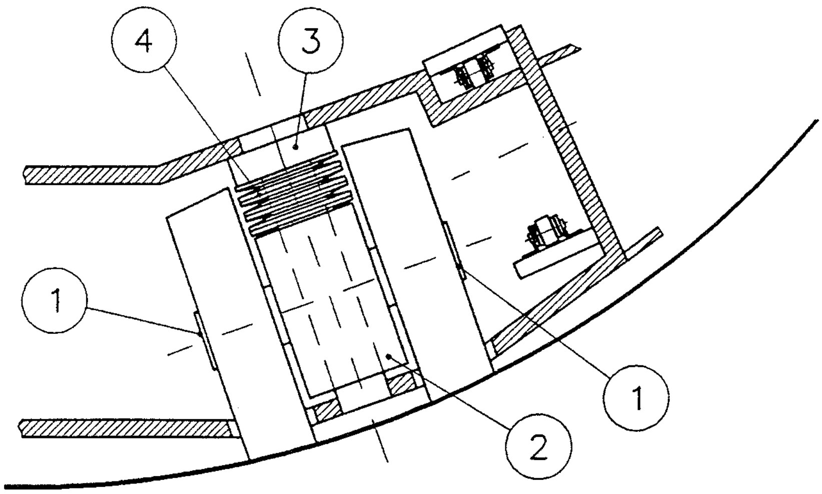


Figure 12 The construction of the wheel pair

The tube can also slide along the shaft, enabling the suspension to function. If the wheel meets roughness of the drift surface, this tends to compress the disc spring set (4) between the tube and shaft end (3).

5.2 Bentonite Wagon 3 (BW3)

BW3 has two main functions. It stores the necessary number of sideblocks and feeds them to BW1, as well as producing all the driving force for the wagon combination (BW1+BW3).The BW3 consists of chassis, bogies, roll conveyor, connection shaft and the power unit at the back of the wagon (Fig 13).

In the service area BW3 is connected to BW1. The wagons are pulled together to join their roll conveyors. The wagons are loaded as described above.

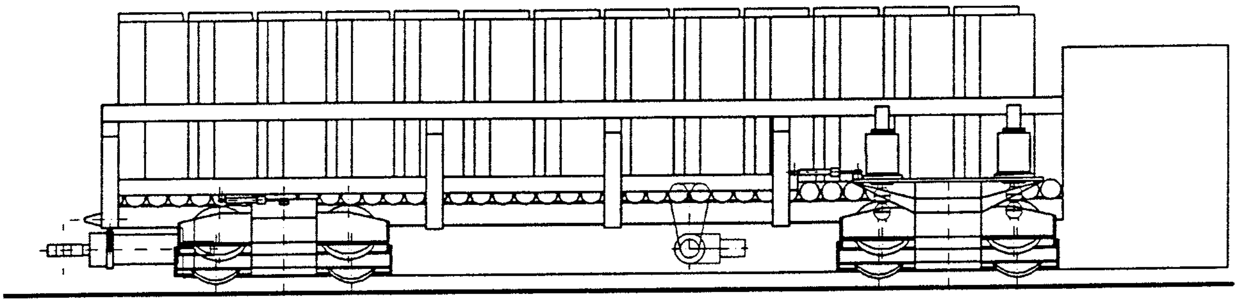


Figure 13 The Bentonite Wagon 3

Before the wagon combination is driven into the deployment drift, BW3 pushes BW1 300 mm forward to make space between the wagons. This space is needed for the wagons to be able to operate in the bends of the drift (see Fig 7).

The wagons are pulled together again in the deposition area. BW3 starts to feed the sideblocks to BW1 and prevents any movements of BW1 caused by the handling of blocks.

5.2.1 Bogies

BW3 has two bogies each having four separate bogie units and 8 rubbercoated wheels.

The rear bogie is equipped with hydraulic motors, gears and brakes. Four wheels function as driving wheels. The driving mechanism is located on the rear bogie. Because the power unit is relatively heavy, the center of gravity is always at the backend of the BW3, whether the wagon is empty or not. This ensures adequate friction and driving force.

Both of the bogies are steerable and suspended. The bogie construction is specified later in Chapter 6.

5.2.2. Roll conveyor

The bentonite blocks lie on a roll conveyor (Fig 14), the rolls of which are pivoted to the middle beam of the wagon chassis. Inside the beam there are chain wheels fixed to the roll axles and chains between the axles. The conveyor is powered by a hydraulic motor and gear. The side rails in the wagon chassis support the blocks during transportation.

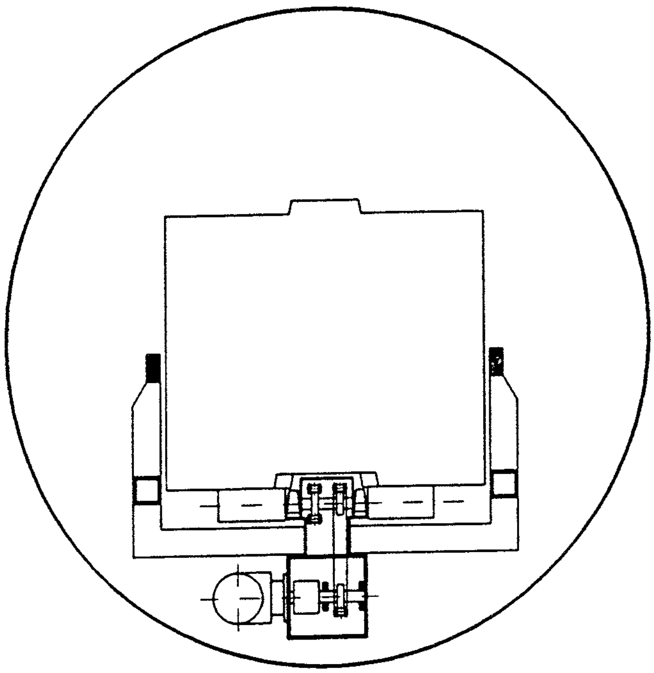


Figure 14 The conveyor of BW3

5.2.3. Connection of wagons

Because of the operations between BW1 and BW3, the connection shaft must be able to extend 300 mm. Thus instead of a rigid shaft a hydraulic cylinder is used as the connecting shaft. The cylinder end is pivoted to the wagon chassis and the front of the cylinder is supported by springs which center the rod for connection. The advantage of this flexible supporting structure still allows movements of cylinder when driving.

The rod end of the cylinder is connected to BW1 by a simple clamping mechanism. In BW1 a hydraulic cylinder pushes an axle through the rod end (Fig 15), which also allows rotation in other directions.

In the deposition area the wagons are pulled together by the cylinder. Then the two conical pins in BW3 are inserted into the conical holes in BW1. The purpose of this connection is to join together the mass of the wagons and thus stabilize the effects of movements of the manipulator in BW1. Accurate coupling of the conveyors is also ensured by pins.

When connecting the connection shaft, BW1 is also coupled to the electric and hydraulic systems of BW3.

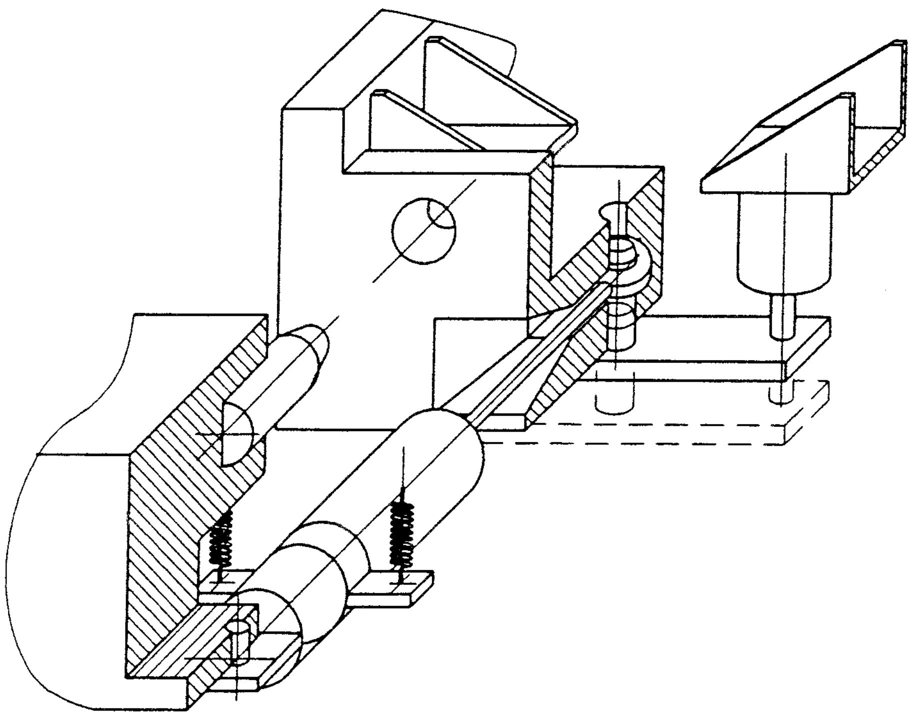


Figure 15 The clamping device

5.2.4.Power unit

In the rear of the BW3 there is a power unit, consisting of hydraulic power pack, electrical control system and onboard video camera transmitter.

The hydraulic power pack produces the necessary fluid and pressure for the motors and cylinders of the wagon combination. The driving motor of the power pack is an electric or a combustion motor depending on which system is chosen (see Chapter 11).

5.3 Steering of the wagon combination

The wagon combination is so long that the end of the combination tends to take a short cut in the drift bends. This may cause dangerous tilting, which can be prevented by making all the wheels steerable. The steering control of every wheel is in this case separate and automatic. The automatic control keeps the combination straight in every situation.

6 CANISTER WAGON

The task of the Canister Wagon is to transport the canister and deploy it on the bottom bentonite blocks. During transport the canister lies on the chassis. Before deployment the canister is moved onto the forks, which lower the canister to its final position.

To enable transportation in the drift, the bogies must be turnable. If the minimum radius of the drift bend is 50 m, the forks must also be turnable.

There is no need for an additional driving unit to move the Canister Wagon. The driving wheels are located in the centre of the chassis itself.

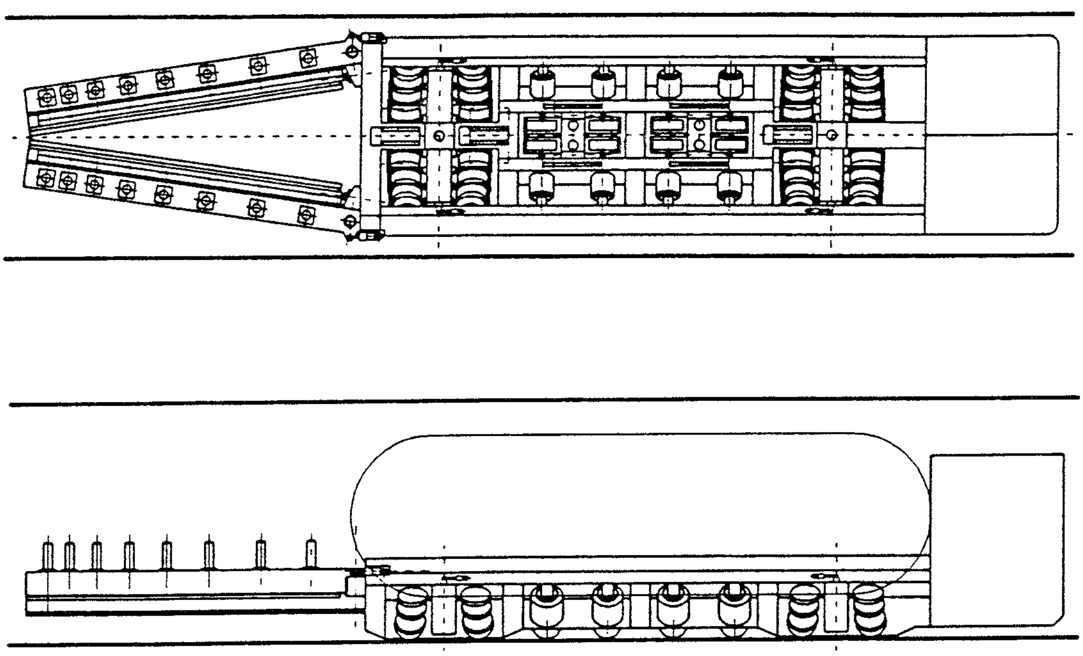


Figure 16 The Canister Wagon

6.1 Bogie construction

The bogie consists of a turnable support beam and separate suspended bogie units connected to the beam (see Fig.17). The beam is turned around the fulcrum of the wagon chassis by two hydraulic cylinders. The beam is designed to follow the shape of the drift in order to divide the carrying load on as many wheels as possible.

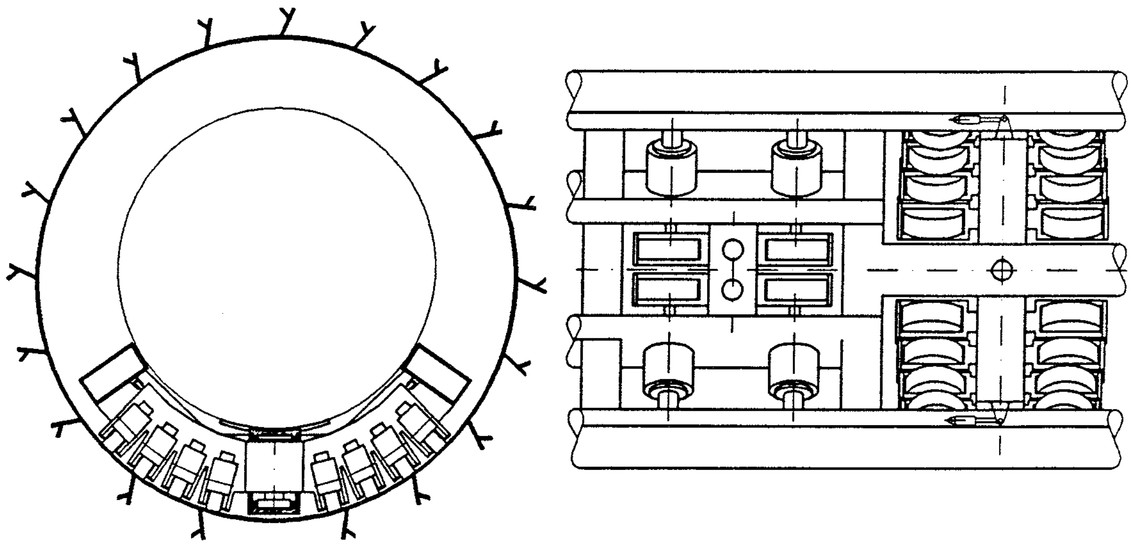


Figure 17 The bogie construction

The load per wheel is estimated to be 2.6 tonnes when the drift is circular. If the maximum load is limited to 3.5 tonnes, some ellipticity of the drift is allowed (see Fig.3). In an elliptical drift the load per wheel is not equal.

The stiffness of the beam and its behavior in an elliptical drift was also examined in FEM -calculations (see App.5). They show that the displacements are so small that they are easily compensated by the suspension.

By varying the length of the bogie unit the effect of ring-shaped roughnesses in the drift is decreased, as the wheels do not meet the roughness at the same moment.

6.1.1 Suspension

The purpose of the suspension is firstly to divide the load equally between all wheels and secondly to compensate the roughness of the drifts walls.

The structure is shown in Figure 18. The two wheels are pivoted to the ends of the bogie unit. The bogie unit is connected to the support beam by a pivot which is allowed to move vertically in relation to the support beam. The two sets of disc springs are placed between the support beam and the bogie unit on both sides of the pivot. In normal operation both sets of disc springs are compressed equally and proportionally to the carrying load. Thus, the bogie unit moves only vertically. When a roughness causes one of the wheels to rise, the bogie unit rotates around the

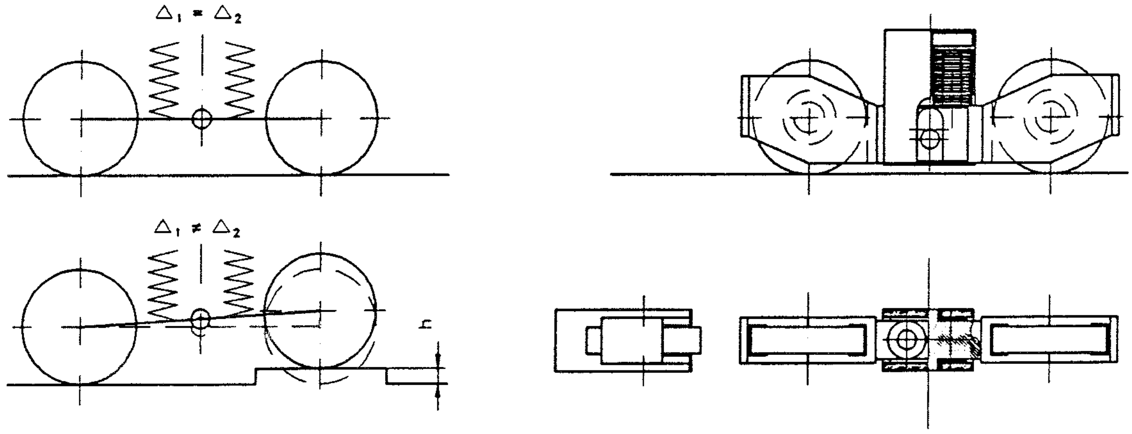


Figure 18 The operation principle and the basic structure of the suspended bogie unit

other wheel causing both spring sets to compress more (unequally).

The maximum vertical movement of the bogie unit is limited to 28 mm. Normally, with a full load, the spring sets are compressed 15 - 20 mm. The remaining permitted compression will be adequate to compensate the roughnesses (movement of wheel h > compression Δ_2).

6.1.2 Wheel

An appropriate wheel could be made by casting a polyurethane band on a steel frame (Fig.19). The coating is designed to be rather thick in order to minimize the surface pressure between the wheel and the drift wall. The polyurethane is for the most part sunk in steel frame. The frame supports the band by the sides and prevents it from brakeing as a result of the lateral shear forces.

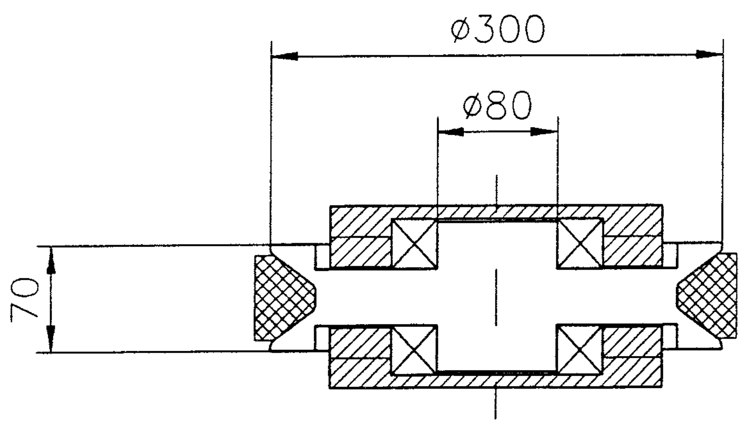


Figure 19 The polyurethane coated wheel

6.2 Driving wheels

The driving system includes four bogie units situated in the central area of the chassis. The basic construction of the driving bogie units is the same as described above, except that the two sets of disc springs are replaced by a hydraulic cylinder (Fig.20).

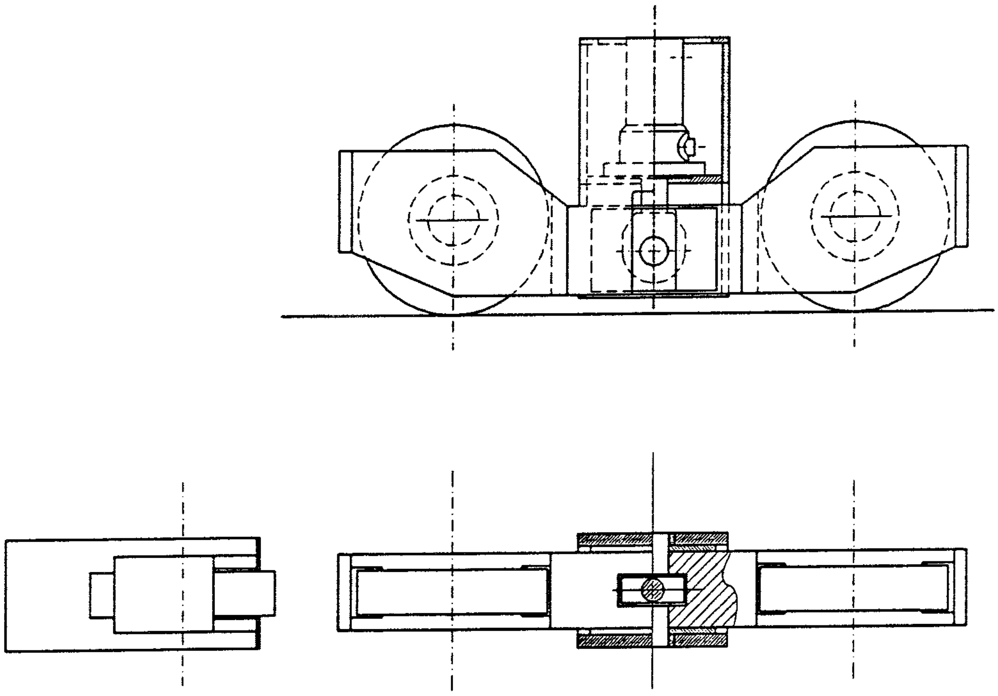


Figure 20 The bogie unit of the driving wheels

Each driving wheel is equipped with a planetary gear, brake and hydraulic motor. The motor unit is fixed to the chassis, and the torque is transferred to the wheel via a cardan shaft, which is necessary in order to allow the bogie unit suspension to function. The driving arrangement is presented in Figure 21.

By using a hydraulic cylinder it is possible to keep the constant force between the wheels and the drift wall i.e., the friction force is adequate in every situation. The functioning of the hydraulic suspension is presented in Figure 22.

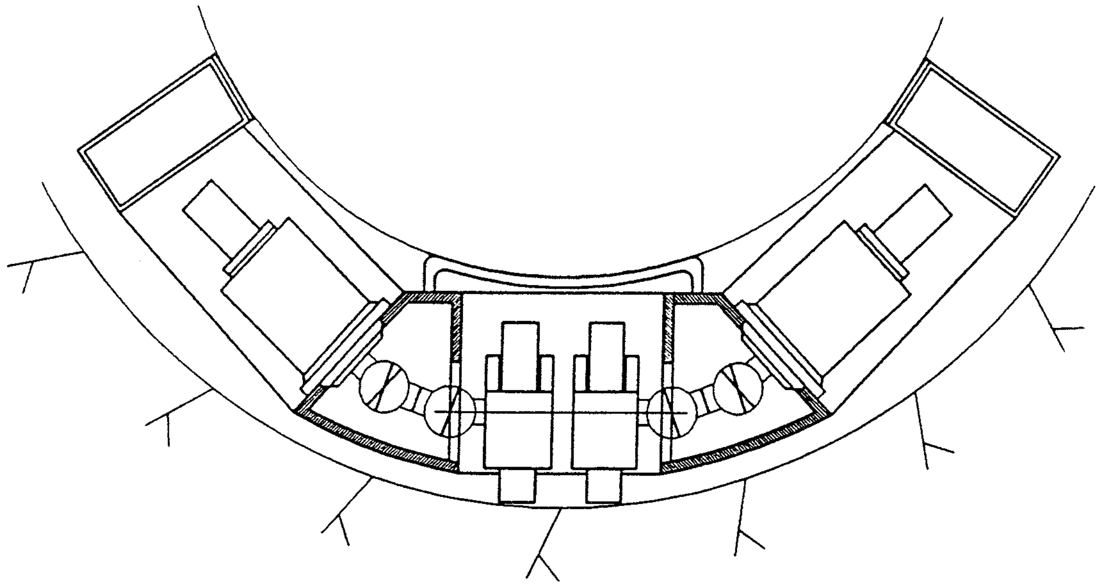


Figure 21 Driving arrangement

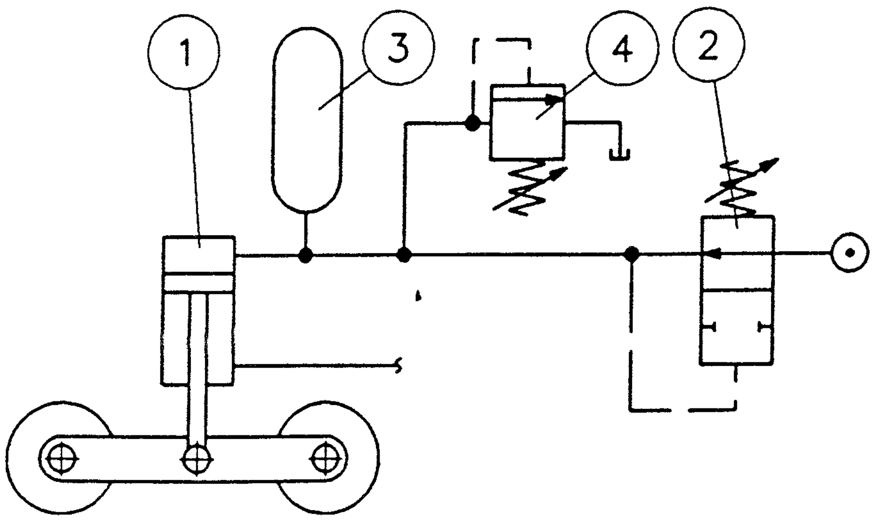


Figure 22 Hydraulic suspension system

The oil flows to the hydraulic cylinder (1) through a sequence valve (2) until the adjusted pressure (= force in the wheels) is reached. The pressure closes the valve. If a wheel meets a roughness it tends to move the piston of the cylinder and causes a pressure shock. The shock is compensated by a hydraulic accumulator (3).

If the pressure remains for any longer period of time at a level which is higher than the adjusted level, the oil flows through a pressure relief valve (4) and the pressure returns to correct level. This might happen when the shape of the drift changes.

The adjusted pressure depends on whether the canister is on the wagon or not.

6.3 Forks

Before the wagon arrives at the deposition area, the forks are opened so that they can be pushed onto both sides of the blocks. The rest of the turn is completed at the deposition place, and the forks are thus parallel to the drift. The drift walls support the forks. The canister is

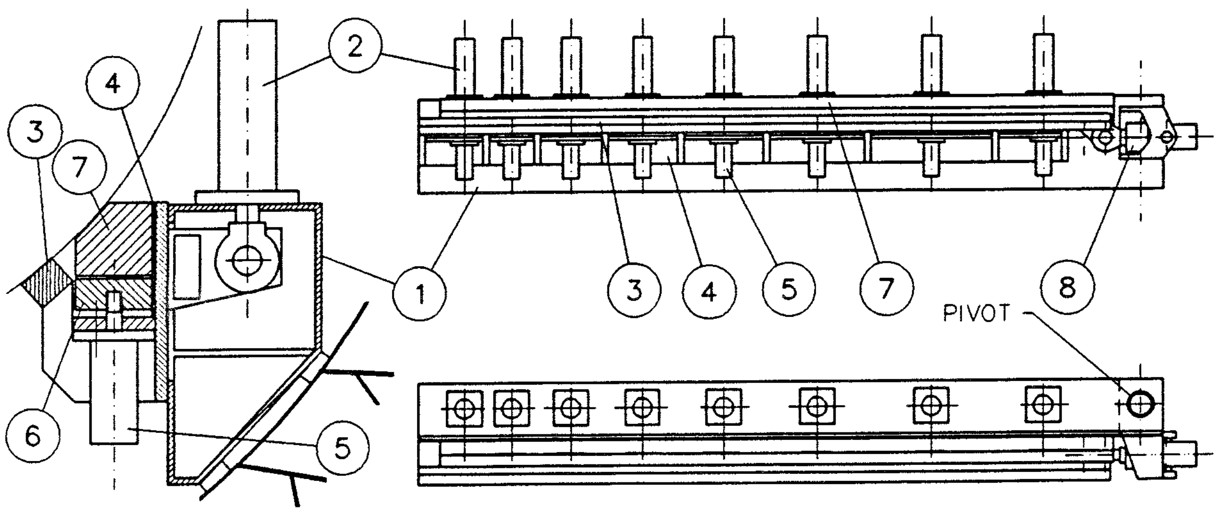


Figure 23 The construction of forks

transported to the conveyor of the forks. Finally the conveyor is lowered and the canister is positioned on the bottom blocks.

The forks are pivoted on the wagon chassis. The fork (see Fig.23) itself consists of a hollow section beam (1) and a conveyor, which can be lowered by hydraulic cylinders (2). Normally the canister lies on the rail (3), which is a part of the conveyor frame (4). The principle of the conveyor is as follows: The cylinders (5) , which are fixed to the conveyor frame, lift part (6) and also part (7). The canister is then supported by part (7) instead of the rail (3). The cylinder (8) pushes part (7) along part (6) and moves the canister forward. The cylinders (5) and cylinder (8) return, so that the canister lies on the rail (3) again. This sequence of operations is repeated until the canister is moved step by step to its final position. The cylinders (2) then lower the conveyor, and the canister is placed on the bentonite blocks. The basic principle of the conveyor is also shown in Figure 24.

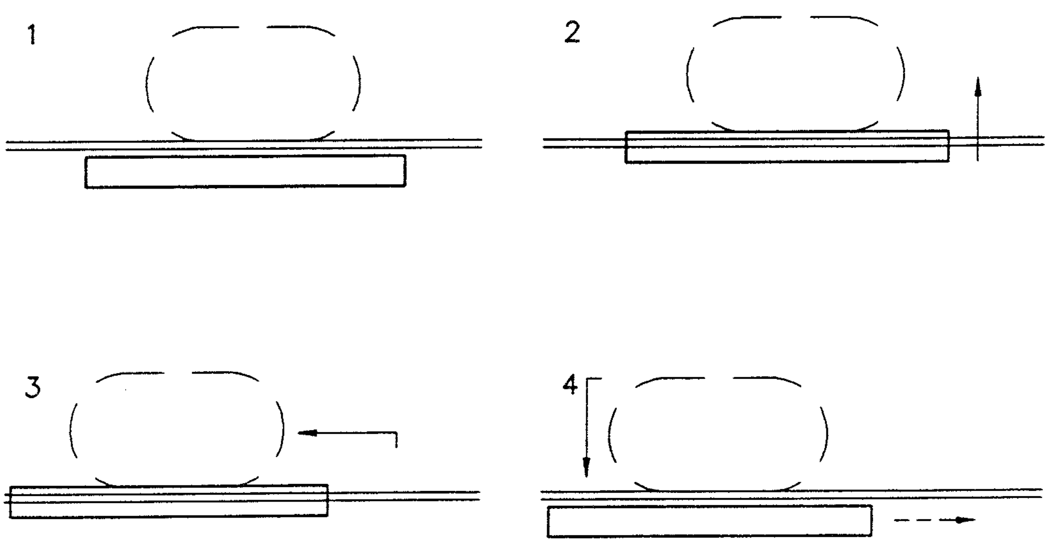


Figure 24 Operation of the conveyor

The obvious benefit of this type of conveyor is the very low surface pressure between the conveyor and the canister (calculated to be less than 5 N/mm^2). It also takes up very little space and because it is completely hydraulic, the energy is easily transferred from the chassis to the forks, even though the fork is turnable.

6.4 Chassis construction

The chassis of the canister wagon consists of longitudinal hollow section beams which are connected to each other. The canister is moved by the same kind of conveyor as in the forks described above. The conveyor units are placed in the chassis near the bogies, in order to transfer the loads to the ground via the wheels as directly as possible. This minimizes the effect of loads on the chassis structure. When the conveyor is making its return movement the canister lies on the support areas of the chassis, which are also situated near the bogies. The situation of the conveyor units and the support areas are shown in Figure 25.

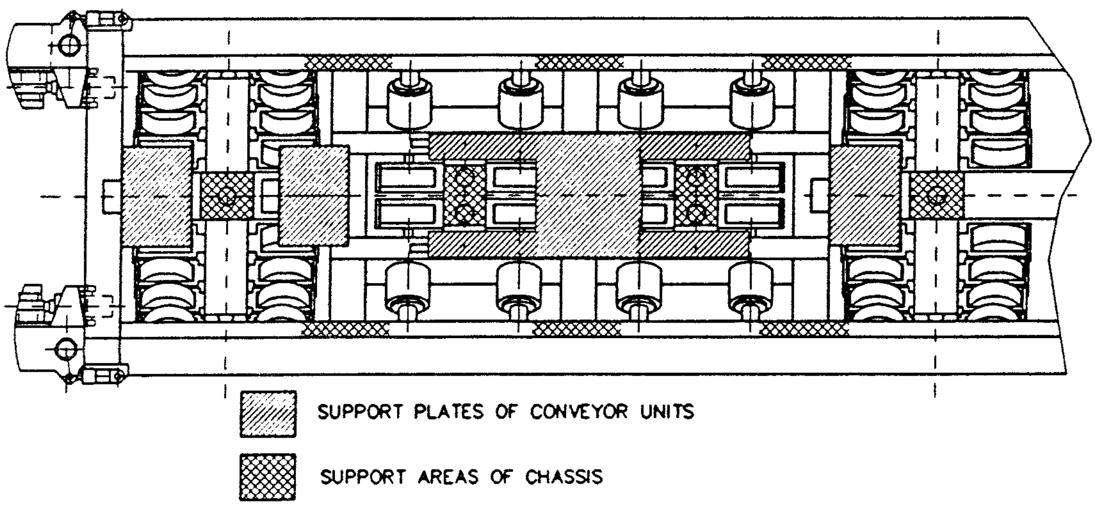


Figure 25 The conveyor units and support areas in the chassis

The conveyor units include a supporting plate, which is moved longitudinally by a hydraulic cylinder and a frame part with the gliding plates, as a support plate. The frame part is moved vertically by hydraulic jacks (Figs. 26 and 27).

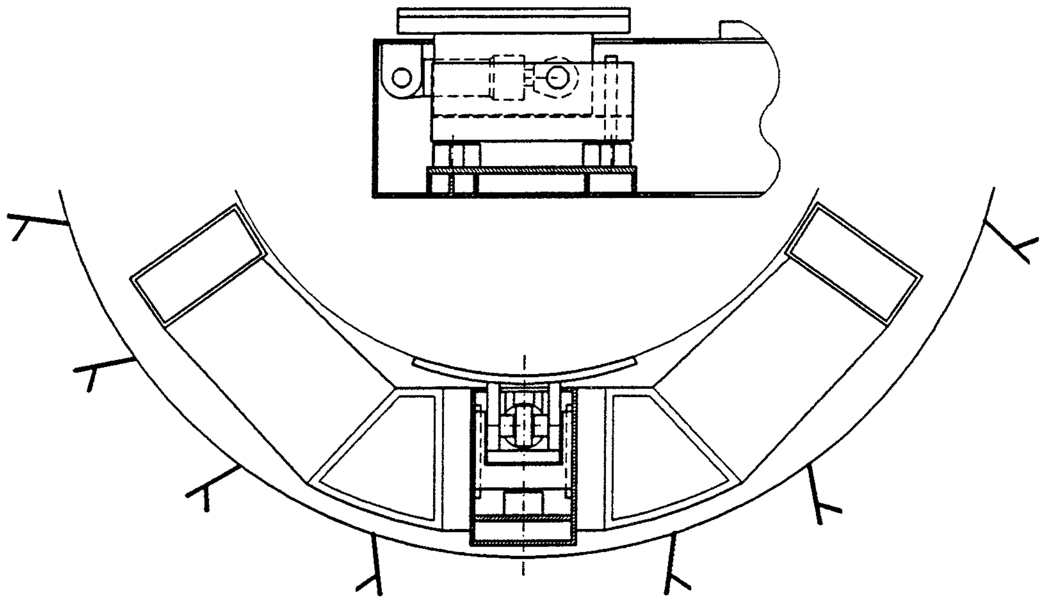


Figure 26 The conveyor unit at the ends of the chassis

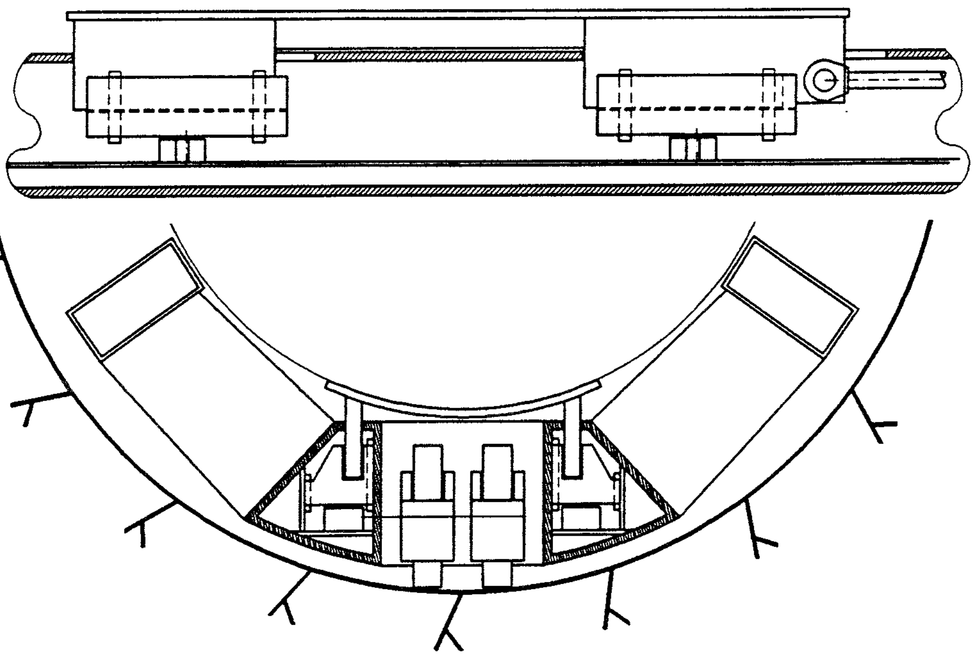


Figure 27 The conveyor unit in the centre of the chassis

During transportation in the drift, the canister lies on the support areas of the chassis. Unevenesses of the drift walls may cause some dynamic effect, which increases the load. In the bogie area the load is transferred through the top flange of the chassis beam and spherical thrust bearing directly to the bogie beam (Fig.28). The central part of the bogie beam may be solid. The load causes no bending of the chassis beam. The load carrying capacity of the bearing is about 63 tonnes.

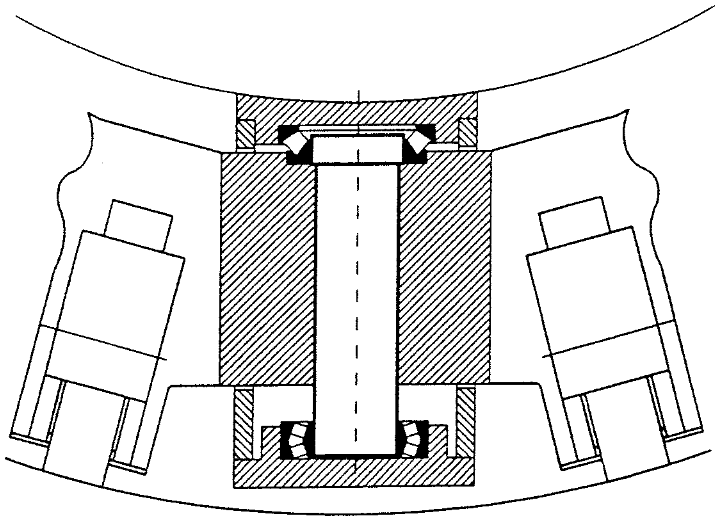


Figure 28 The pivot of the bogie beam

The most demanding load situation arises when the conveyor units beside the pivot of the bogie lift the canister. This causes bending of the chassis beam. The beam has openings both on the top flange for the conveyor units and on the sides for the bogie. The chassis structure was analyzed by the FEM method. The stress level remains under 300 N/mm². The model and the results are presented in Appendices 6 and 7.

In other areas of the wagon chassis the loads are relatively small. The construction principle of the whole canister wagon is shown in Figure 16 and in Appendix 3.

7 BENTONITE WAGON 2

Bentonite Wagon 2 (BW2) installs the remaining sideblocks (18 pcs) around the canister. Due to the limited length of one wagon, it also operates together with BW3, in the same way as BW1. It therefore has the same kind of connection units as BW1, and needs no driving mechanism of its own.

The chassis of BW2 consists of two parts, which to move on guides on each other. The rear part incorporates a roll conveyor, tipper, telescope hydraulic cylinder and clamping devices. In the front part there is a manipulator, which handles and instals the blocks. It rotates ± 120° around the tunnel centerline and has a reach of 4 m. The front part of the chassis is able to move longitudinally in relation to the rear part, which consists of a fork structure. The front part moves between the forks. When driving, the chassis parts are pulled together in order to minimize the length of the wagon.

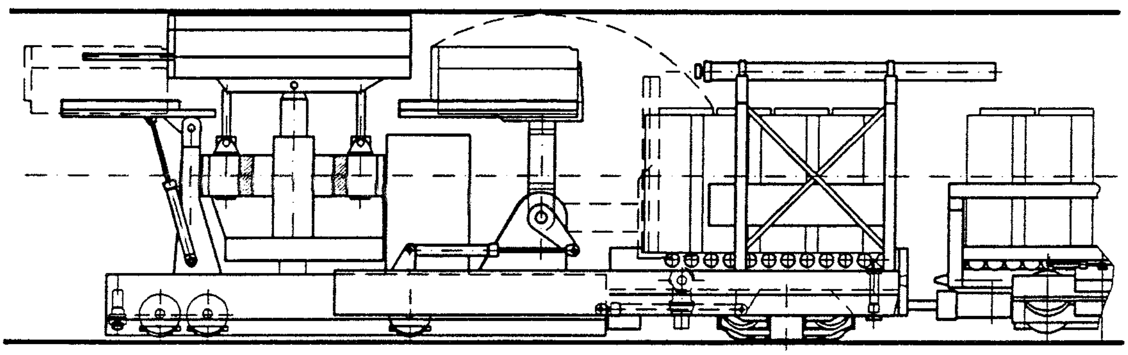


Figure 29 The Bentonite Wagon 2

7.1 Loading

In the service area BW2 and BW3 are pulled together. The sideblocks are lowered to the roll conveyor of BW3. The conveyor transfers five of the blocks to the roll conveyor of BW2. The first of these are lifted by a tipper, located at the end of the roll conveyor. Finally there are 13 sideblocks in BW3 and 5 in BW2, one of them in the tipper.

7.2 Manipulator

Because of the required reach of 4 m and the limited space available, the manipulator is of three part telescope structure (see 1, Fig.30). At the end of the telescope there is an end plate (2) and two hydraulic cylinders (3), as in the manipulator of the BW1, for carrying the bentonite sideblock. The outer beam of the telescope is fixed to a support beam (4) with two hydraulic cylinders (5) and linear guided beams (6). On the opposite side of the support beam there is a counterweight (7), which decreases the need for torque to rotate the manipulator. On the side of the support beam between the telescope and the mass there is a fixed plane (8) for sideblocks. The support beam (4) is pivoted to two support structures (9,10) in the front part of the chassis. The axis of rotation coincides with the centerline of the drift (and the canister). The manipulator is rotated by a hydraulic motor and cyclo -type gear. The motor, gear and brake are situated inside the rear support structure (9). On the front support structure (10) a turnable plane (11) is pivoted, which can be rotated 90° by the hydraulic cylinders.

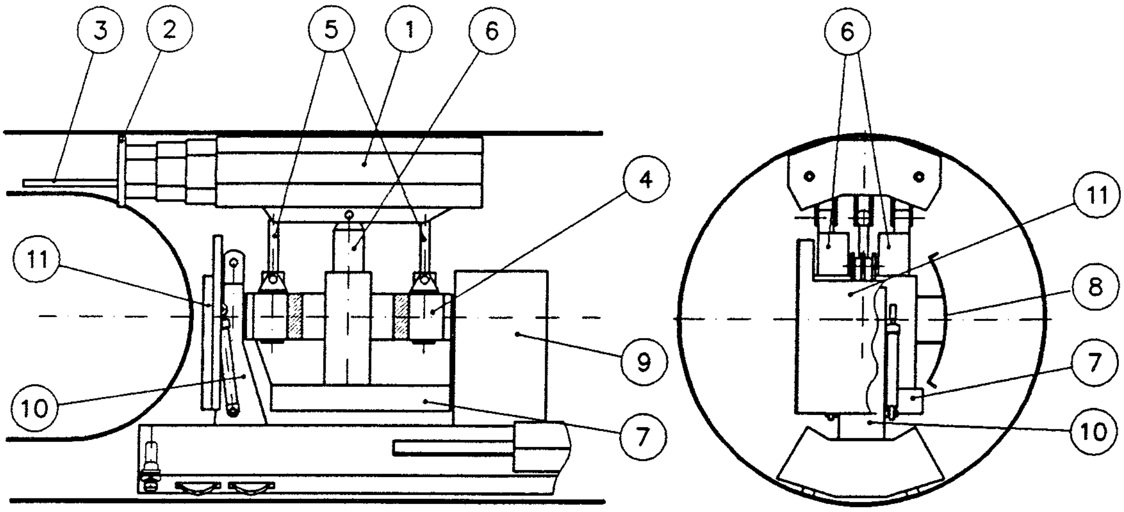


Figure 30 The manipulator of Bentonite Wagon 2

In the deposition area the front plane is turned in the first stage to the horizontal position and the manipulator rotated to the three o'clock position. The rods of the cylinders at the endplate of the telescope are pulled in. The tipper, the side plane of the manipulator and the front plane then form one continuous plane. The sideblock is pushed from the tipper to the front plane by a hydraulic telescope cylinder, which is placed above the roll conveyor. At the next stage, the manipulator is rotated and lowered to the gripping position (Fig.31). The rods are pushed into the holes of the sideblock and the manipulator lifts the block from the front plane. The front plane is turned down and the front part of the chassis is pushed close to the canister. Before installation of the sideblock, the chassis is fixed to the wall of the drift in order to prevent the operation of the front wheel suspension. This support is obtained by hydraulic jacks, which are situated at the very front of the chassis.

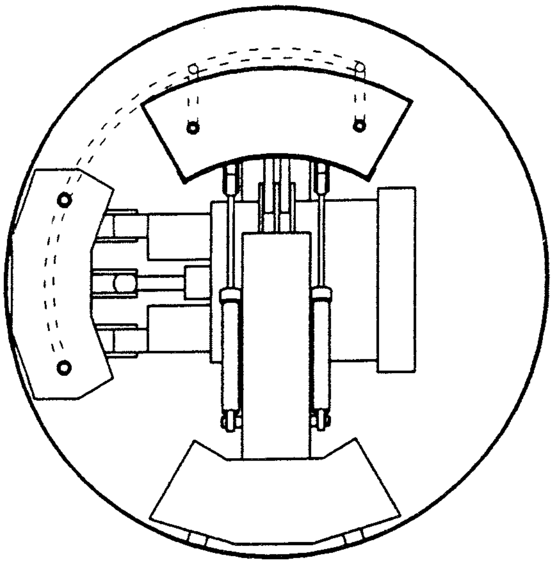


Figure 31 Gripping of the sideblock

To accomplish the emplacement of the blocks, the telescope extends and slides the sideblock along the canister surface. When the desired distance has been reached the manipulator rotates the block to the correct position. Finally, the telescope makes an additional move to push the fitting groove of the block onto the fitting projection of the block installed earlier. The cylinder rods are pulled out of the holes, while the endplate prevents the backward movement of the sideblock.

For the installation of the next sideblock, the manipulator is moved to the initial position, the front part of the chassis is pulled backwards and the front plane rotated to the upper position.

7.2.1 Telescope construction

Because the space needed by the manipulator has to be minimized, a threepart telescope structure has been chosen. The telescope consists of an outer fixed beam, three movable hollow beams and an end plate with two hydraulic cylinders, as in the manipulator of BW1. The initial length of the telescope is 1750 mm. By moving each of the inner beams 1350 mm, a reach of 4050 mm is achieved.

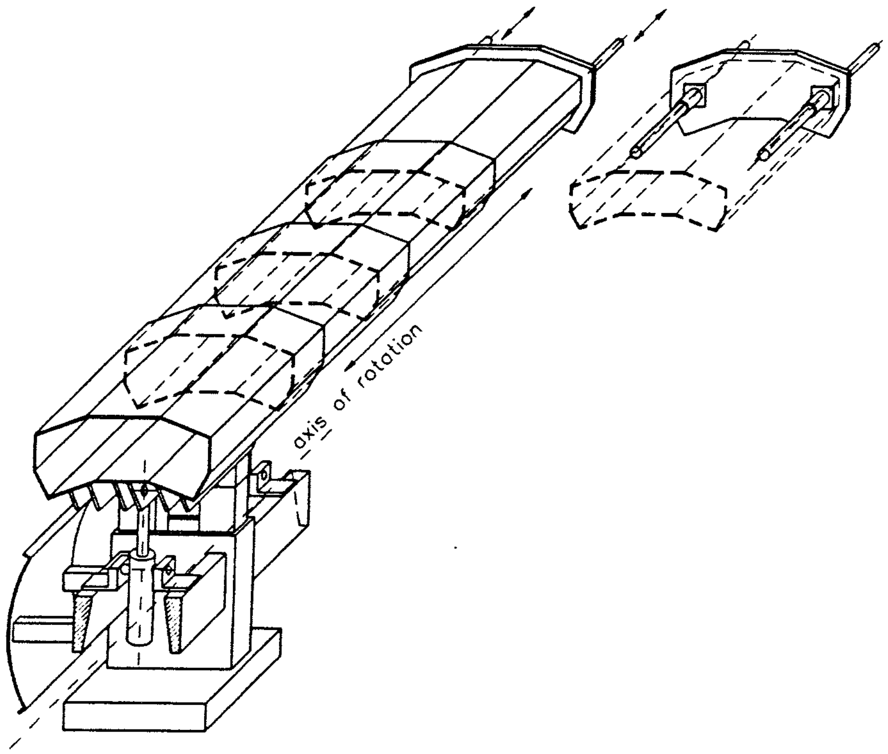


Figure 32 The construction of the telescope

The extension of the telescope is effected by the following wire system (Fig.33). The hydraulic winch (1), which is connected to the outer, fixed beam (2) pulls a wire (3),

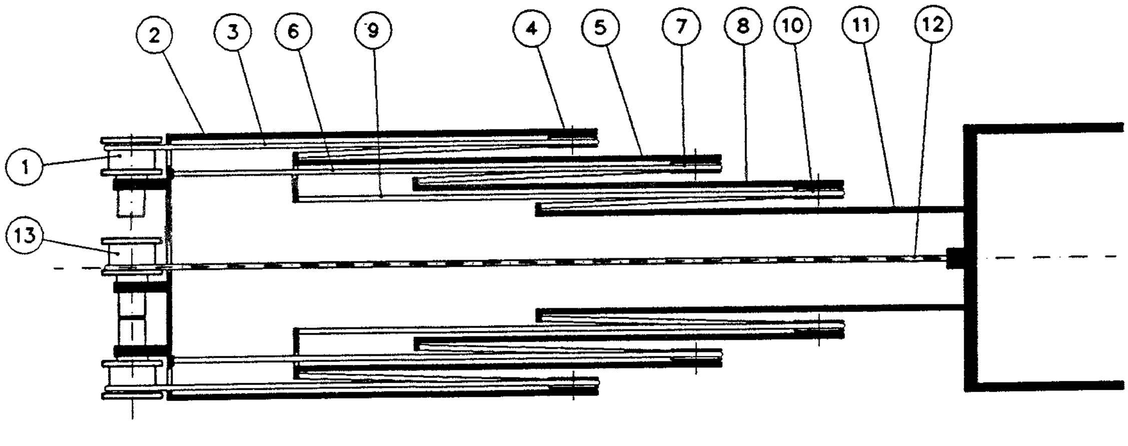


Figure 33 The wire system of the telescope

which goes from the winch to the wire wheel (4). This wheel is connected to the other end of the outer beam. Another end of the wire goes to the back end of the outer movable beam (5). There are also three other wires. One of them (6) goes from the end of the outer beam via a wire wheel (7), which is connected to the end of outer movable beam, to the end of the centre movable beam (8). Another (9) goes from the end of the outer movable beam (5) via a wire wheel (10) to the end of the inner beam (11). The last of the wires (12) simply connects the endplate and another hydraulic winch (13). When the wire (3) is pulled it forces the outer movable beam to move forward, which further forces the next beam to move and so on. Thus, by pulling the wire (3) a certain amount, every beam moves the same amount. By pulling the wire 1350 mm, an extension of 4 m is achieved. The back stroke is obtained by pulling the wire (12) by the winch (13) and letting the wire (3) move freely.

This system has some benefits. It needs relatively little space and is light. The weight is mainly concentrated at the near end of the telescope. Thus, the system has little effect on the displacements of the telescope.

To ensure the operation of the telescope, the wire system (3,6,9) could be built on both sides of the telescope.

To ensure that the structure is rigid the telescope should take up as much as possible of the space available between the canister and the drift wall. According to FEM studies the construction can be considered relatively rigid. The telescope was examined in three situations: installation of the top sideblock, installation of the lower sideblock and when the block is rotated to the three o'clock position. In all of these cases it was assumed that the canister does not support the block at all. The displacement at the far end was calculated to be less than 20 mm. The stress level remains under 185 N/mm². The displacements are shown in detail in appendices 6-8.

In order to achive the calculated rigidity, no clearance is allowed in the linear guiding system of the telescope. This means that the gliding shoes must be adjustable (Fig.34).

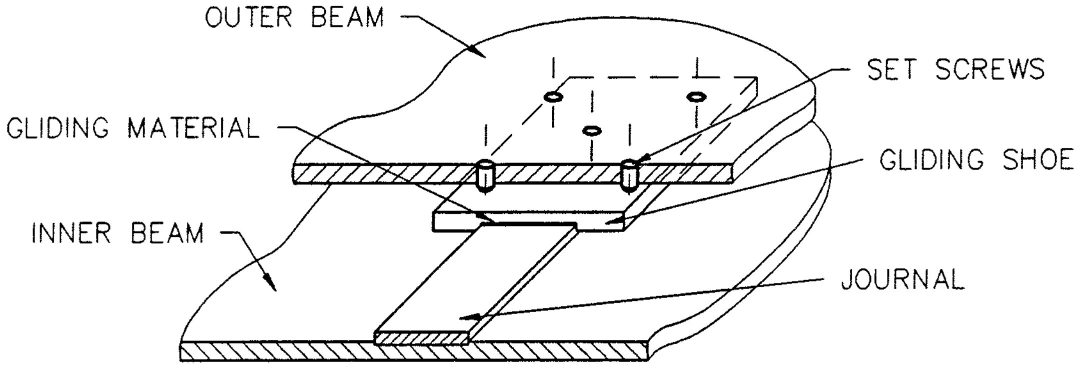


Figure 34 The principal of linear guiding of the telescope

The gliding shoe is a kind of a floating part between the beams. It is compressed against the journal with set screws. The set screws are sunk in the gliding shoe to prevent movement of the shoe. The maximum surface pressure, including the precompression, is calculated to be less than 10 N/mm². The location of the linear guides is shown in Figure 35. Because the length of one beam is 1750 mm and the maximum stroke per one beam 1350 mm, the overlap of two beams is a minimum of 400 mm.

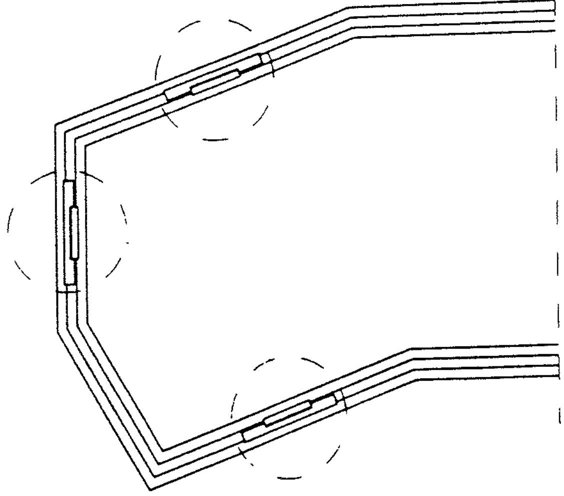


Figure 35 The location of the linear guides between the telescope section beams

7.2.2 Manipulator moving system

To facilitate the installation of the sideblock, the manipulator has several degrees of freedom (Fig.36).

In order to emplace all the blocks, the telescope must turn ± 120° around the axis, which coincides with the centerline of the drift. The axis of rotation can be adjusted by moving the front bearing of the rotational shaft vertically. This is necessary if the centerline of the drift and the axis of rotation are not parallel. It can also be used to compensate the displacement of the telescope.

The radial movement of the telescope is carried out by two hydraulic cylinders on both sides of the linear guide. This construction allows the rotation of the telescope around the pivot point of the guide, which is useful when installing the lower sideblocks.

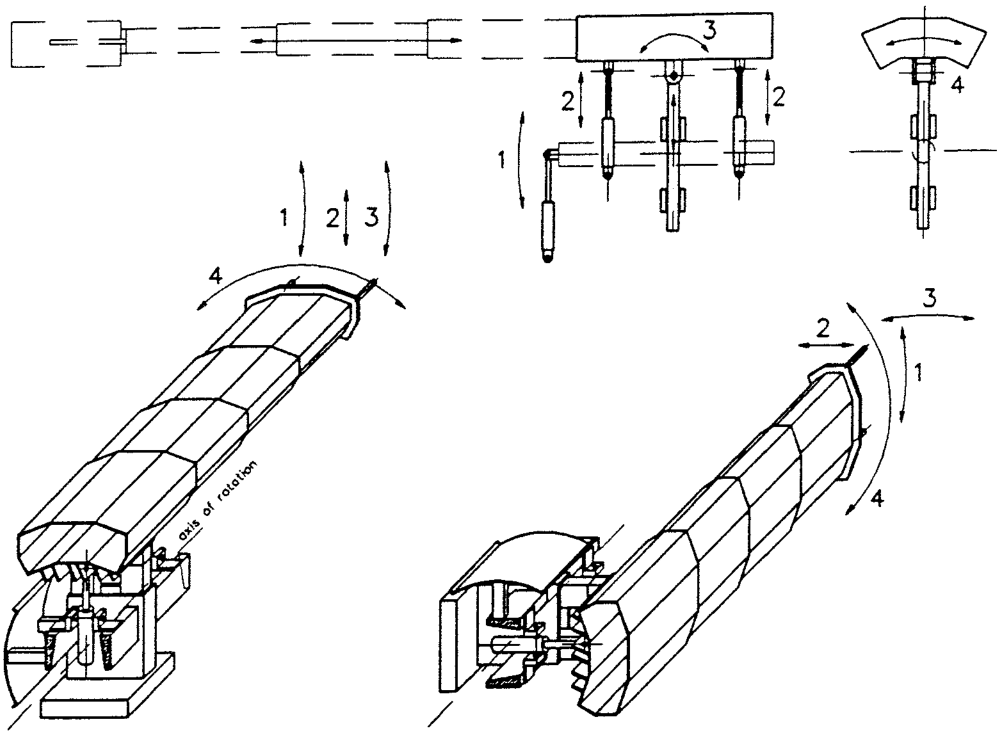


Figure 36 The manipulator moving system

7.3 Chassis

In order to rotate the plane in front of the manipulator the wagon must be a certain distance away from the canister. However, to minimize the reach of the telescope the manipulator should be as near the canister as possible. Instead of moving the whole wagon combination (BW2+BW3) between the installations of every block, the chassis of BW2 is divided into two parts. There is a linear guide between the parts (Fig.37) and the front part is moved by a hydraulic cylinder.

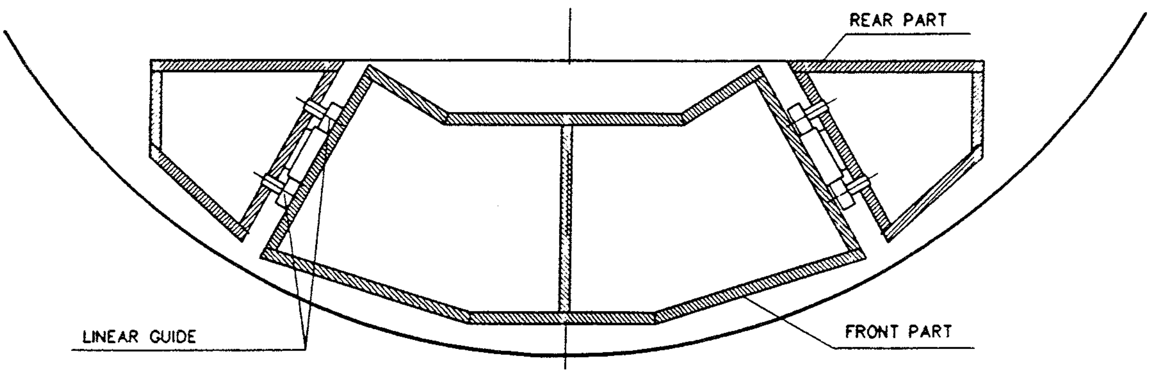


Figure 37 Front view of the chassis

7.4 Wheels

The rear part of the chassis is provided with the same bogie construction as in Canister Wagon or in Bentonite Wagon 3.

The wheels in the front part of the chassis are similar to the wheels in Bentonite Wagon 1 (see Chapter 5. Section 1.4), with the exeption that one wheel unit has only one wheel.

7.5 Conveyor

A short roll conveyor equipped with a hydraulic motor in the rear part of the wagon transfers sideblocks one at a time to the tipper. The tipper rotates the block 90° to the upper position.

In the deposition area when the wagons are pulled together, the conveyor functions as an extension of BW3's roll conveyor.

8 SERVICE AREA

For most of the time, the wagons are situated in an exchange unit in the service area. The exchange unit includes a horizontally movable platform with places for BW1, BW2 and CW. Behind the movable platform there is a fixed place for BW3. The wagon is moved to the end of the deployment drift. In the case of bentonite wagons (BW1 or BW2) the BW3 is coupled on (Fig.38). The bentonite wagons and the Canister Wagon are loaded by a crane.

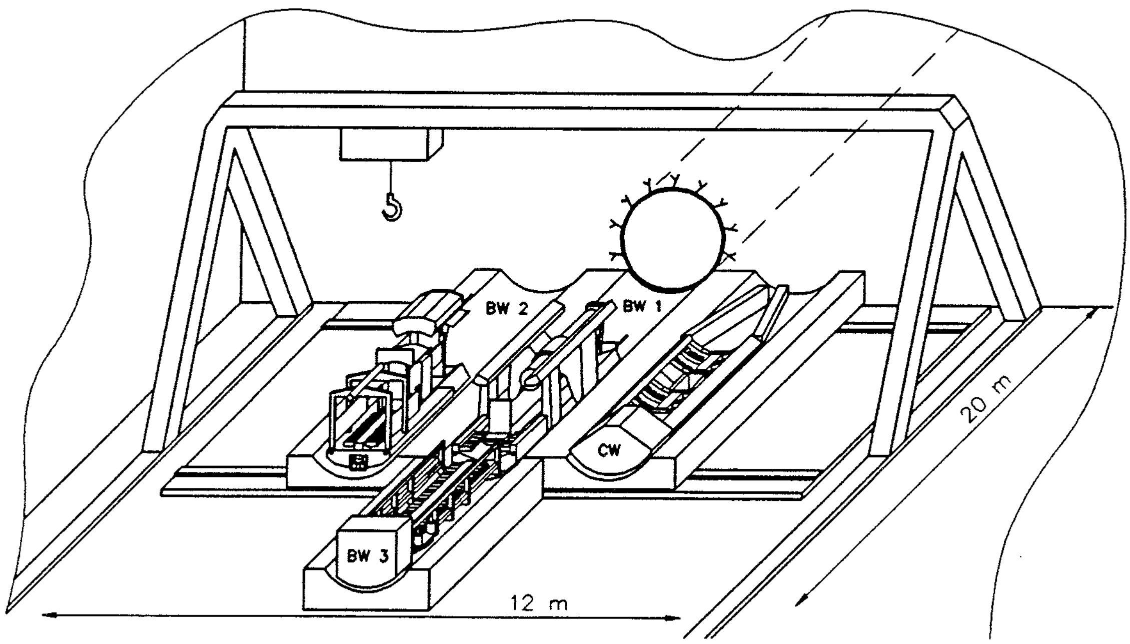


Figure 38 The service area

There is also an area for servicing the wagons. A radiation shielded control room could be also situated adjacent to the service area.

9 CYCLE TIME

The time taken for emplacing one canister depends mainly on the length of the deployment drift. The basic operation in the service and in the deposition areas always takes the same time, but the distance between the service area and the deposition place has an effect on the total cycle time. Appendix 9 shows representative cycle time estimations for three different cases.

10 CONTROL SYSTEM

The control of the wagons is semi automatic. Some of the functions have to be under the operator's control and some are fully automatic. Communication between the wagons and the control system is by cable. The wagons must be equipped with an adequate number of onboard cameras to handle the operator's functions.

The manipulators are mainly under the control of the operator. However, to facilitate positioning of the manipulators, they should be equipped with the necessary number of sensors. Some of the movements could be performed automatically.

To prevent tilting of the wagons all of the wheels must be steerable. It is very difficult for the operator to control every wheel, and for this reason the steering of the wagons must be automatic and adaptive. The system monitors the direction route of the drift and the tilting of the wagons, and steers every wheel independently. The operator only selects the driving direction and speed.

The handling of blocks on conveyors and in tippers may also be automatic.

11 ENERGY SUPPLY

Because of the heavy loads on the wagons, their energy consumption is high. The maximum power needed is estimated to be 100 kW, which includes the energy required for operations and the energy loss when converting the energy supplied to hydraulic energy.

The power units are situated in the canister wagon and in the Bentonite Wagon 3. The two alternatives, using a common energy supply or using separate systems, are presented below.

11.1 Electric system

The wagons use the same electric system for power supply.

In the case of short travel distances (<400 m) the wagons could be provided with cable wheels. The energy is transferred from the service area to the wagon by a cable, which reels out from the wheel when driving forward.

If the distance is longer, the dimensions of the cable wheel will be too big to fit into the drift. In the case of long distances, the installation of a fixed conduction rail is necessary (Fig.39). Only a short cable is then needed between the wagon and the conduction rail. As deployment progresses, the conduction rail must be disassembled.
It must therefore be built of short parts (for example 3 m), which are easily removable. The removing unit could be added to Bentonite Wagon 3.

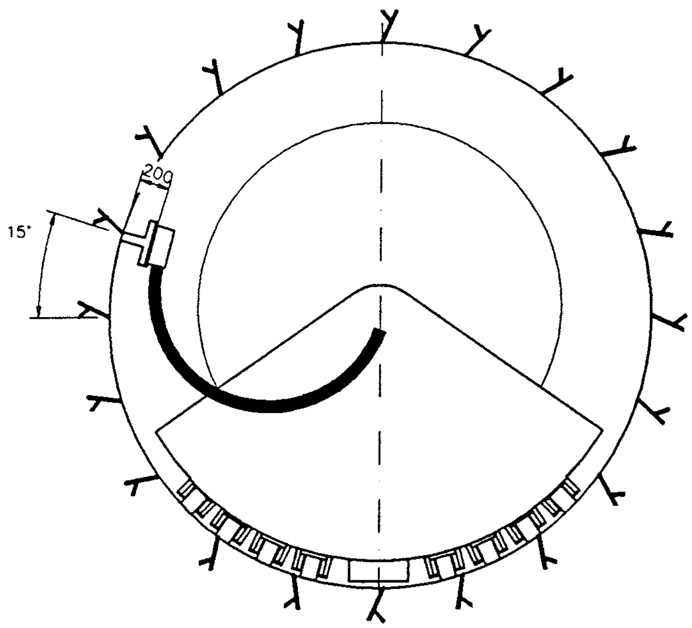


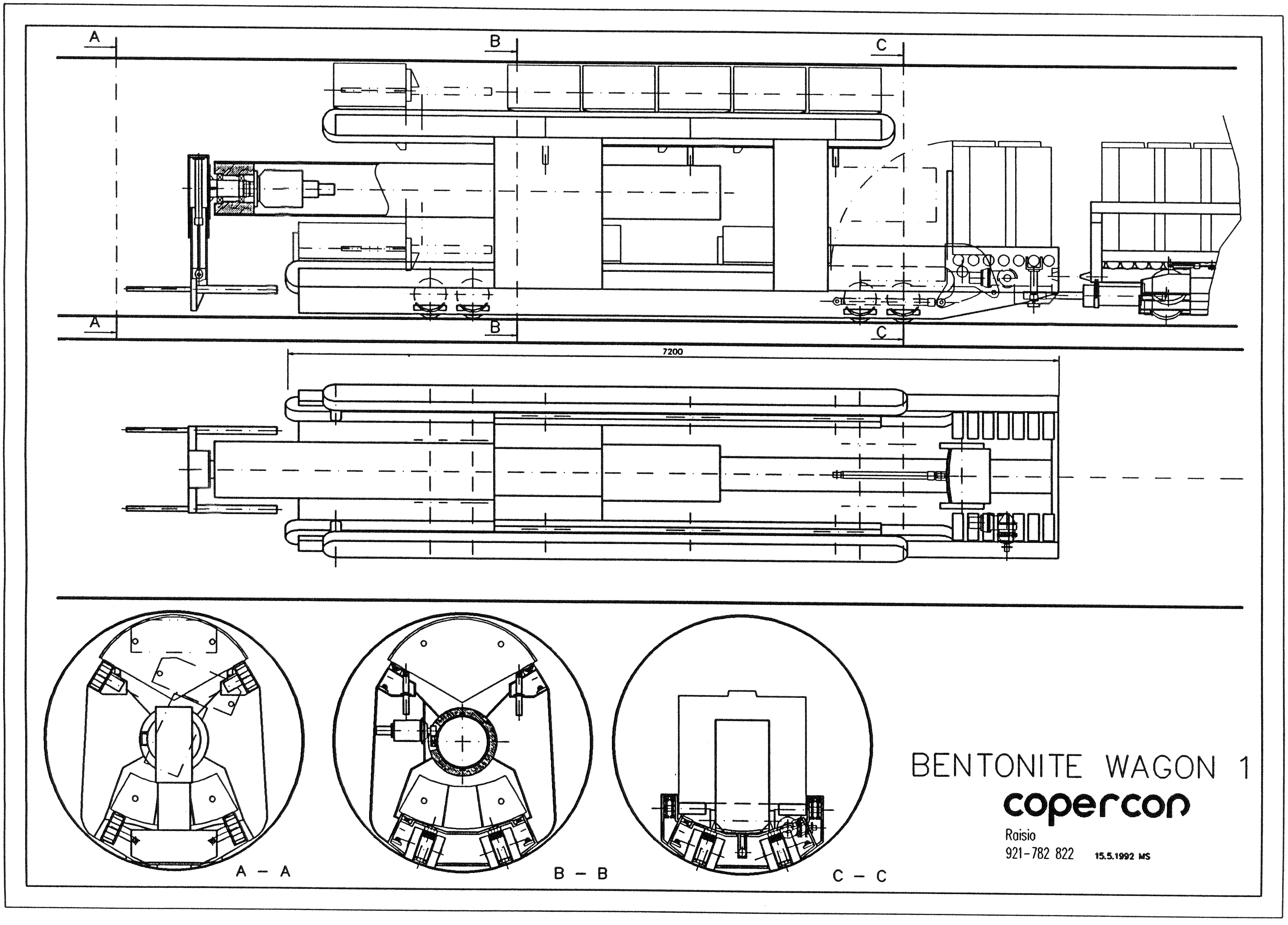
Figure 39 The conduction rail

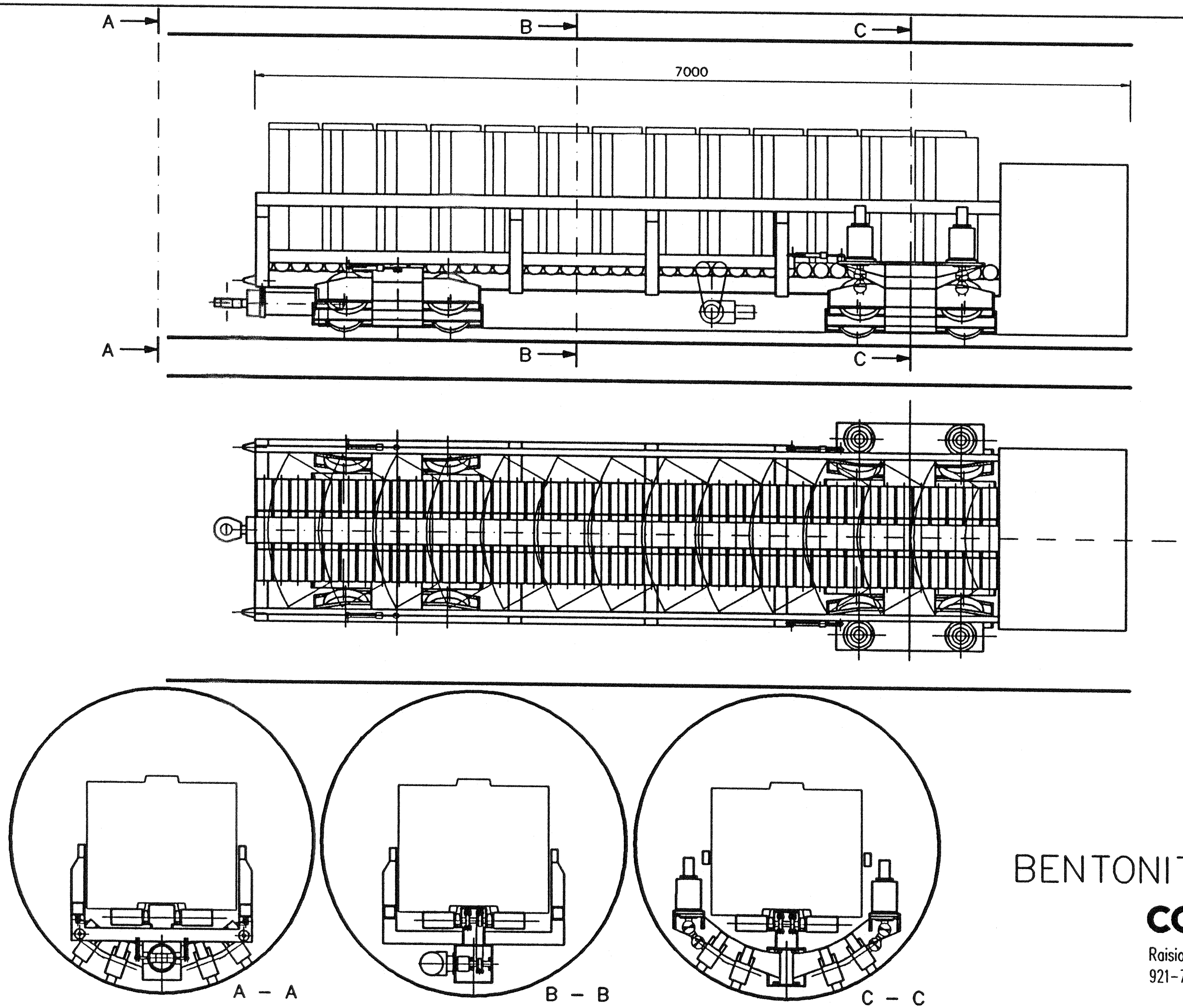
11.2 System of independent energy supplies

It is also possible for the power units of CW and BW3 to produce the energy needed themselves. In this case they have to be provided with energy sources of their own, for example with combustion engines.

If combustion engines are used, ventilation air must be supplied, and the air piping must be removable.

APPENDIX 1


A
B
C
7200
A — A
B — B
C — C
BENTONITE WAGON 1
copercon
Raisio
921-782 822
15.5.1992 MS



BENTONITE WAGON 3

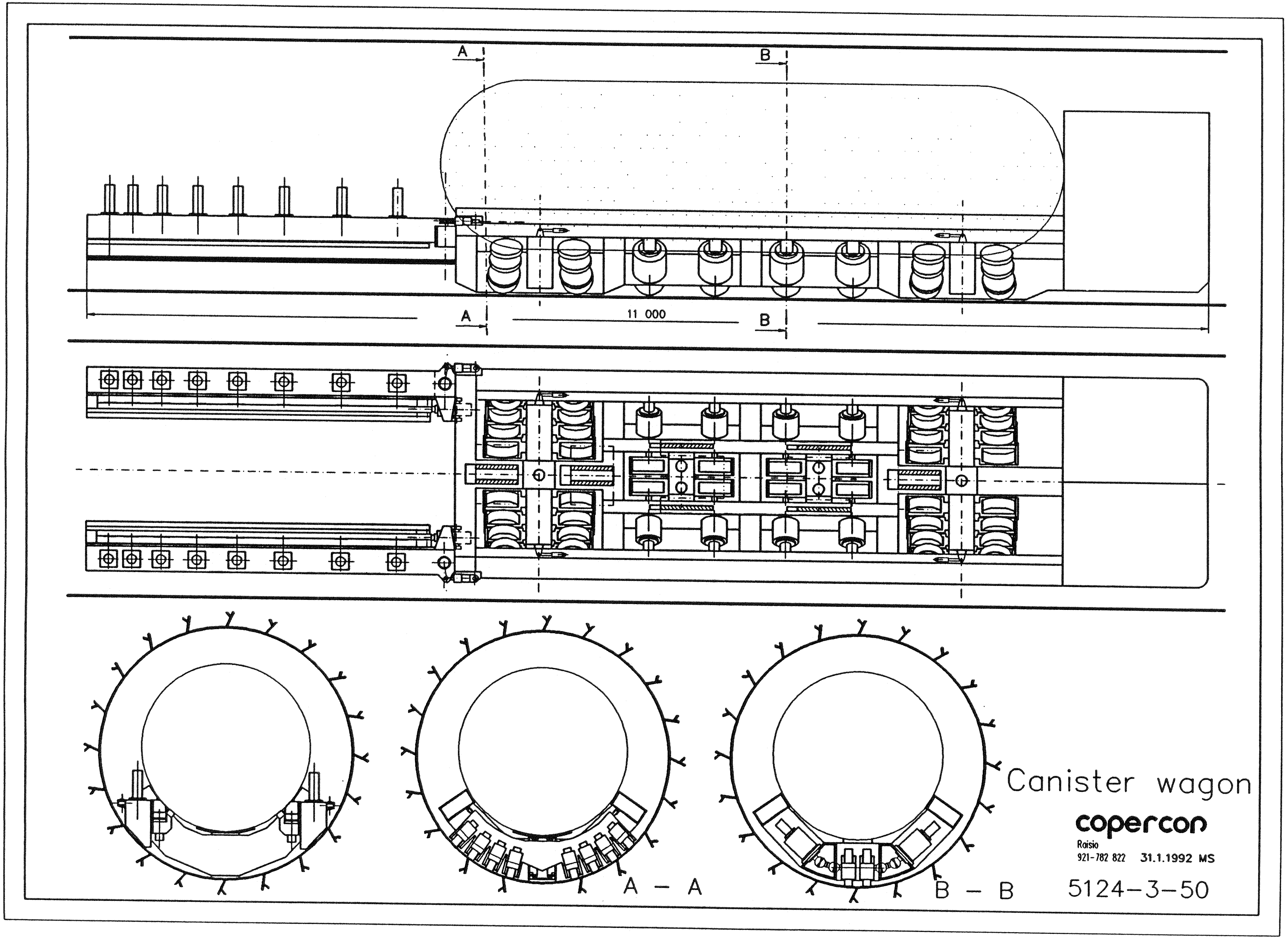
copercon

Raisio

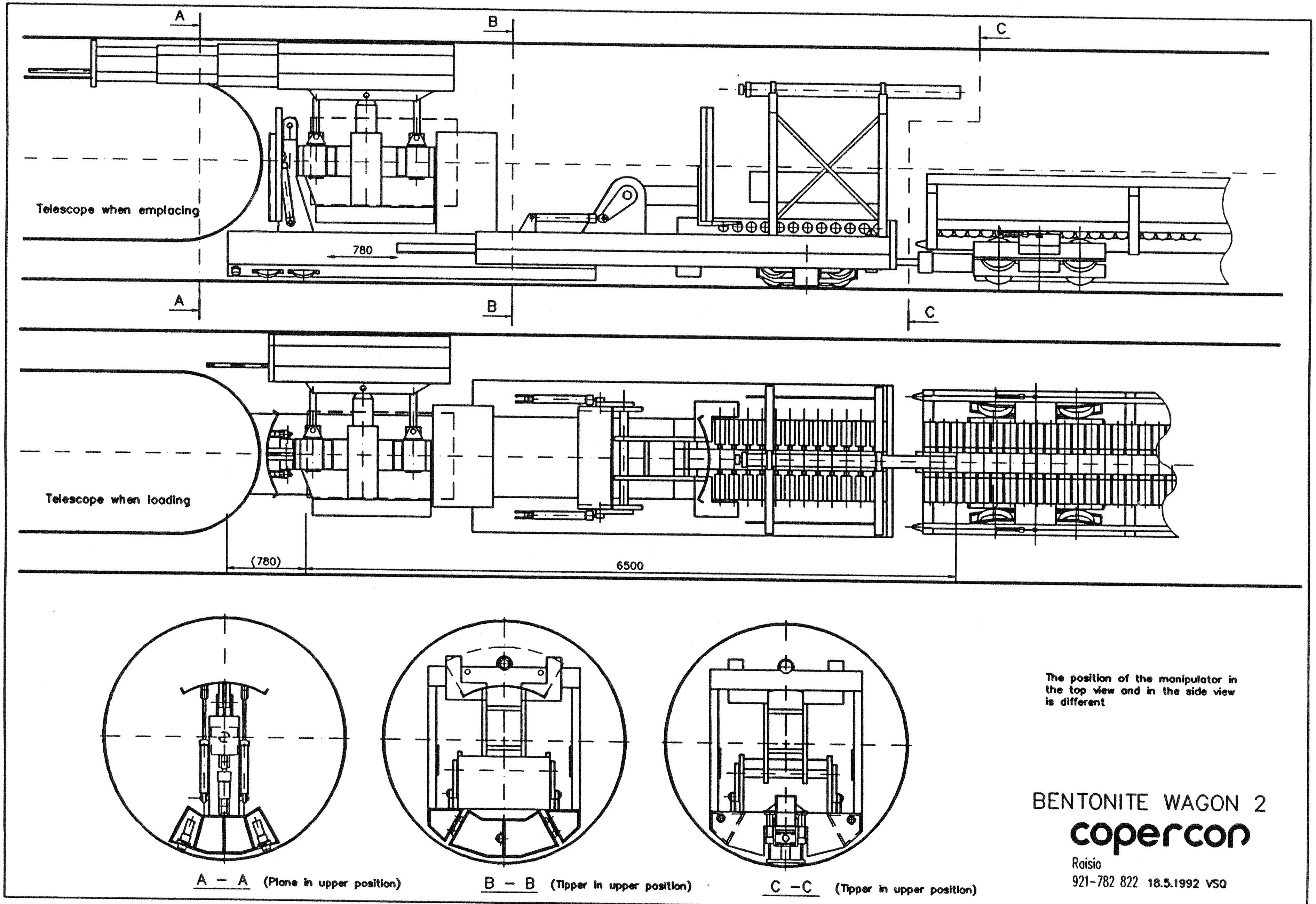
921-782 822 15.5.1992 MS

APPENDIX 2

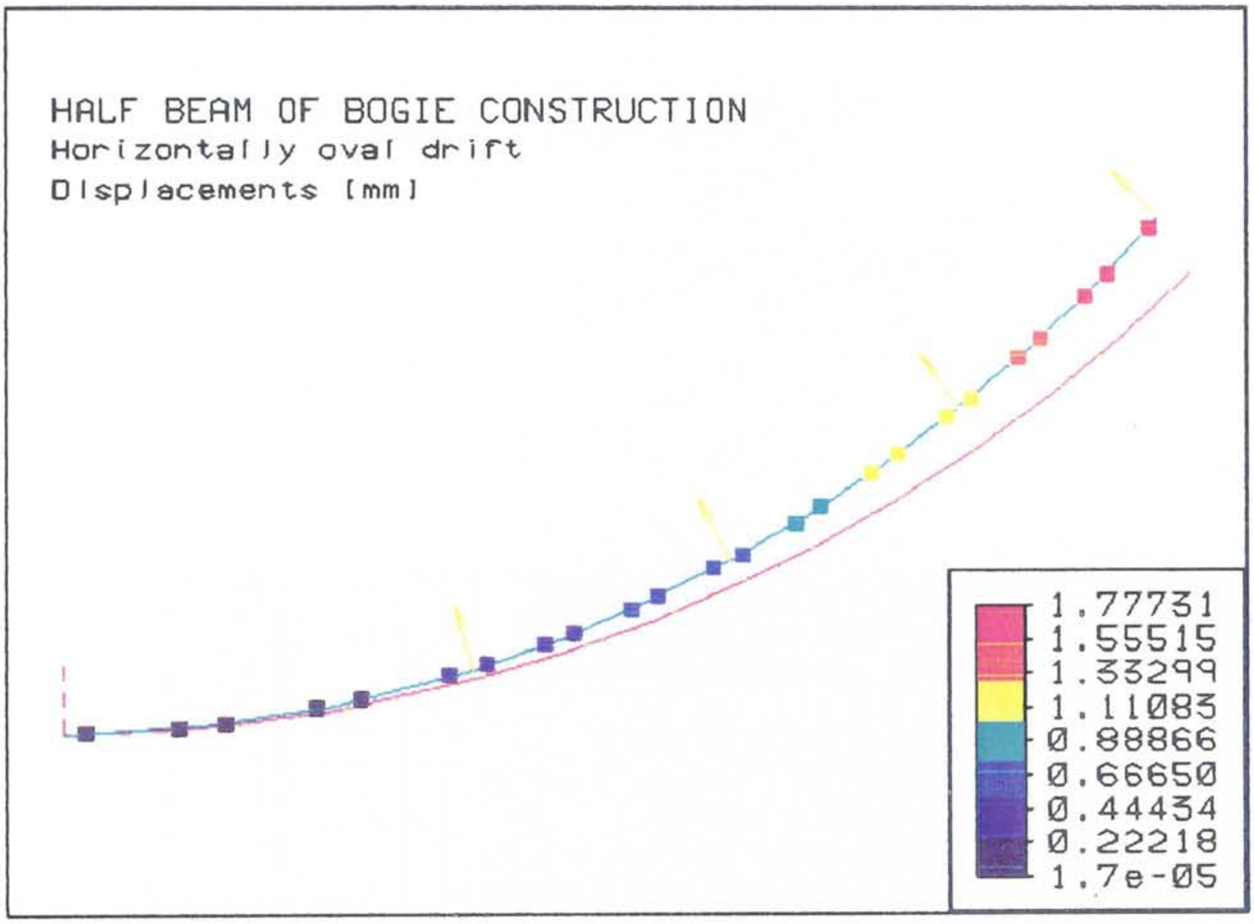
APPENDIX 3

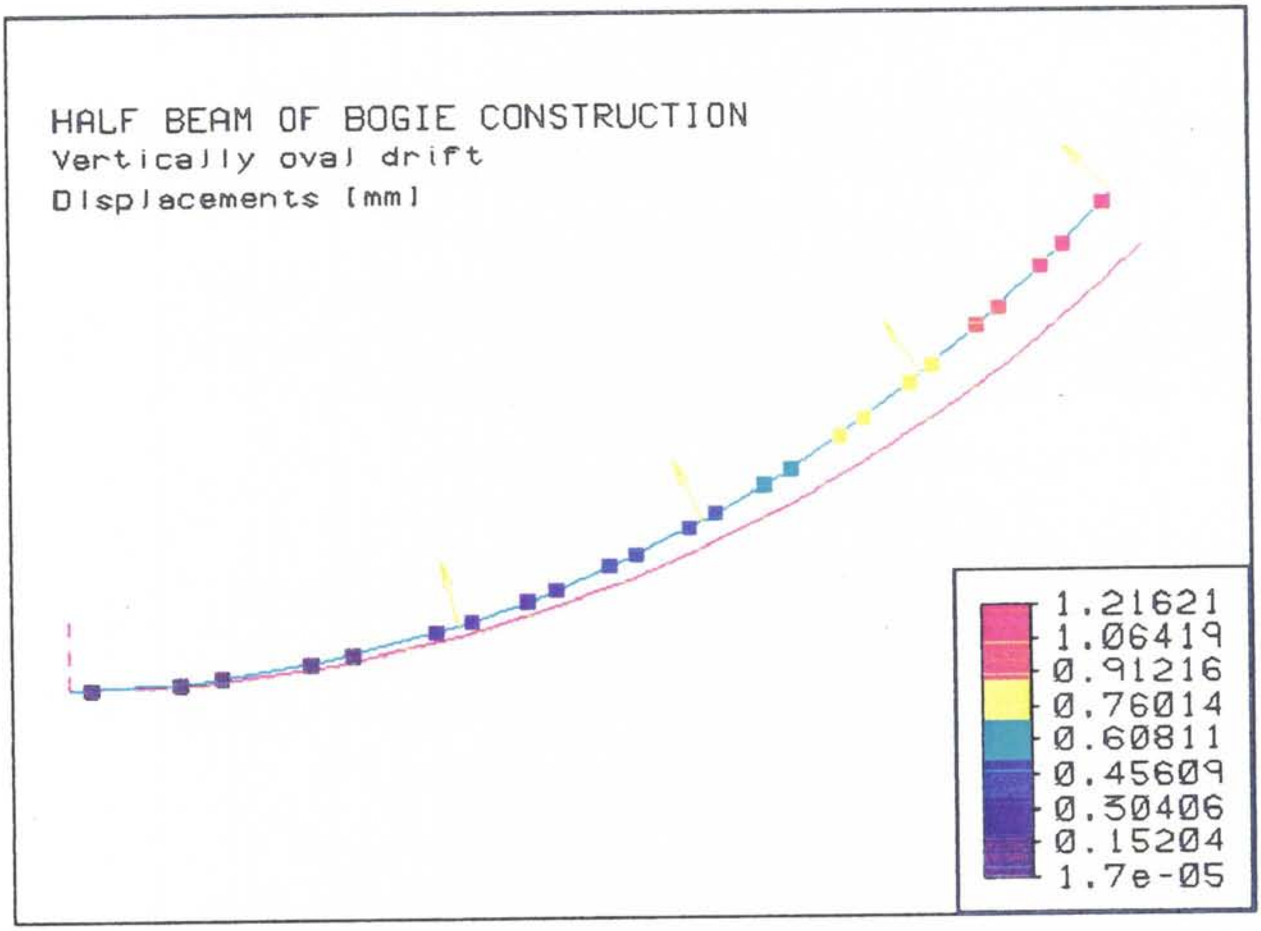

A
B
11 000
A – A
B – B
Canister wagon
copercon
Raisio
921-782 822 31.1.1992 MS
5124-3-50

APPENDIX 4



A
B
C
Telescope when emplacing
780
Telescope when loading
(780)
6500
The position of the manipulator in the top view and in the side view is different
A – A (Plane in upper position)
B – B (Tipper in upper position)
C – C (Tipper in upper position)
BENTONITE WAGON 2
copercon
Raisio
921-782 822 18.5.1992 VSQ


HALF BEAM OF BOGIE CONSTRUCTION
Horizontally oval drift
Displacements [mm]
1.77731
1.55515
1.33299
1.11083
0.88866
0.66650
0.44434
0.22218
1.7e-05


HALF BEAM OF BOGIE CONSTRUCTION
Vertically oval drift
Displacements [mm]
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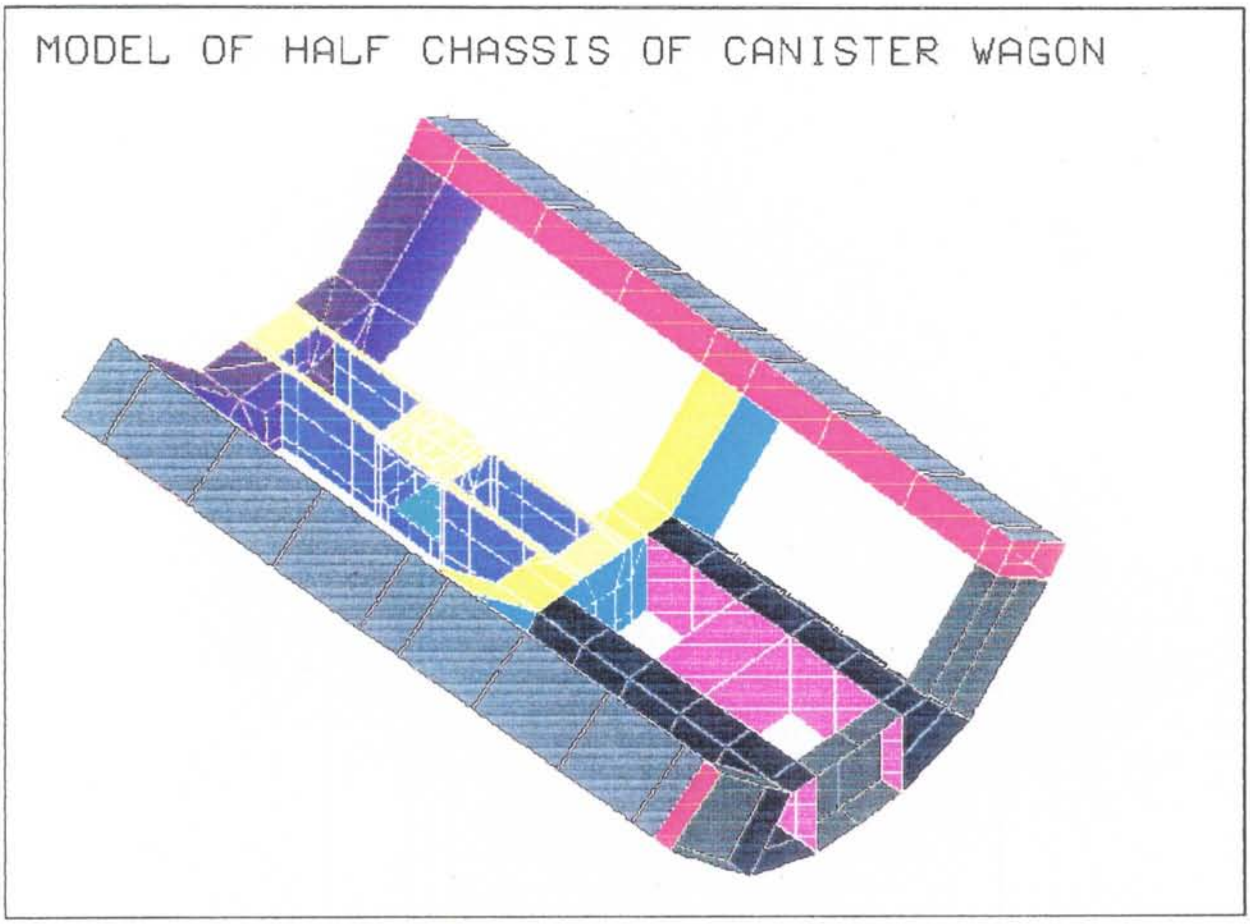
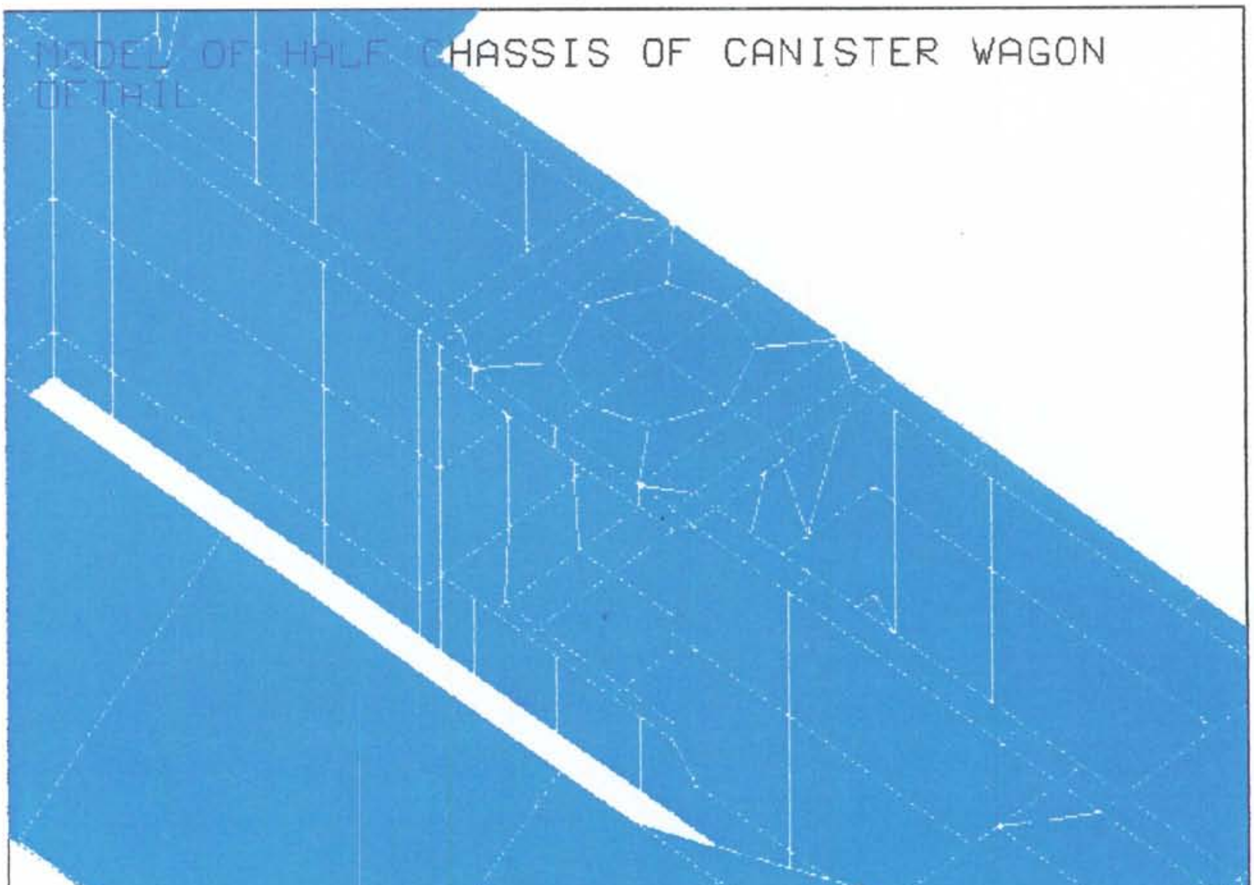
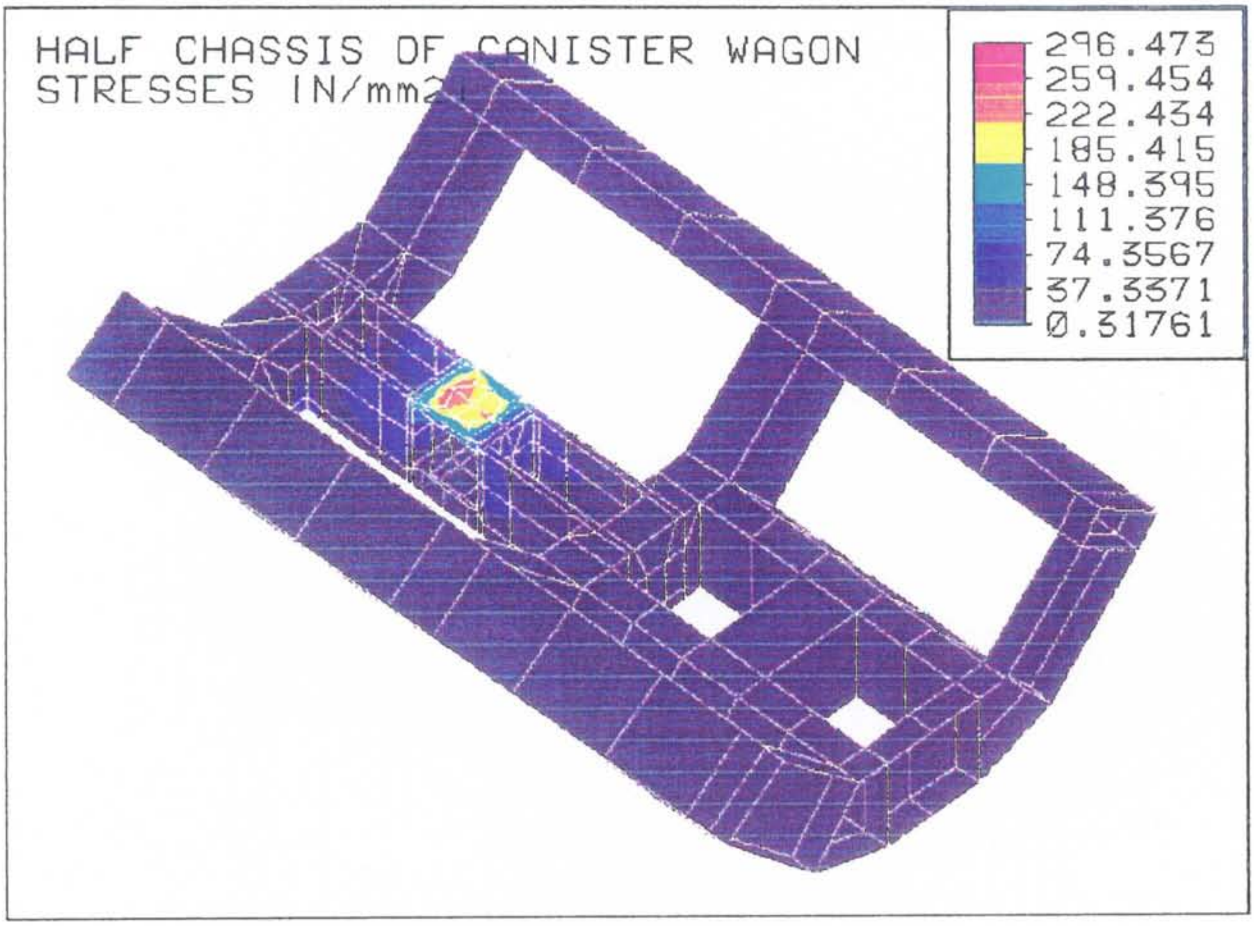
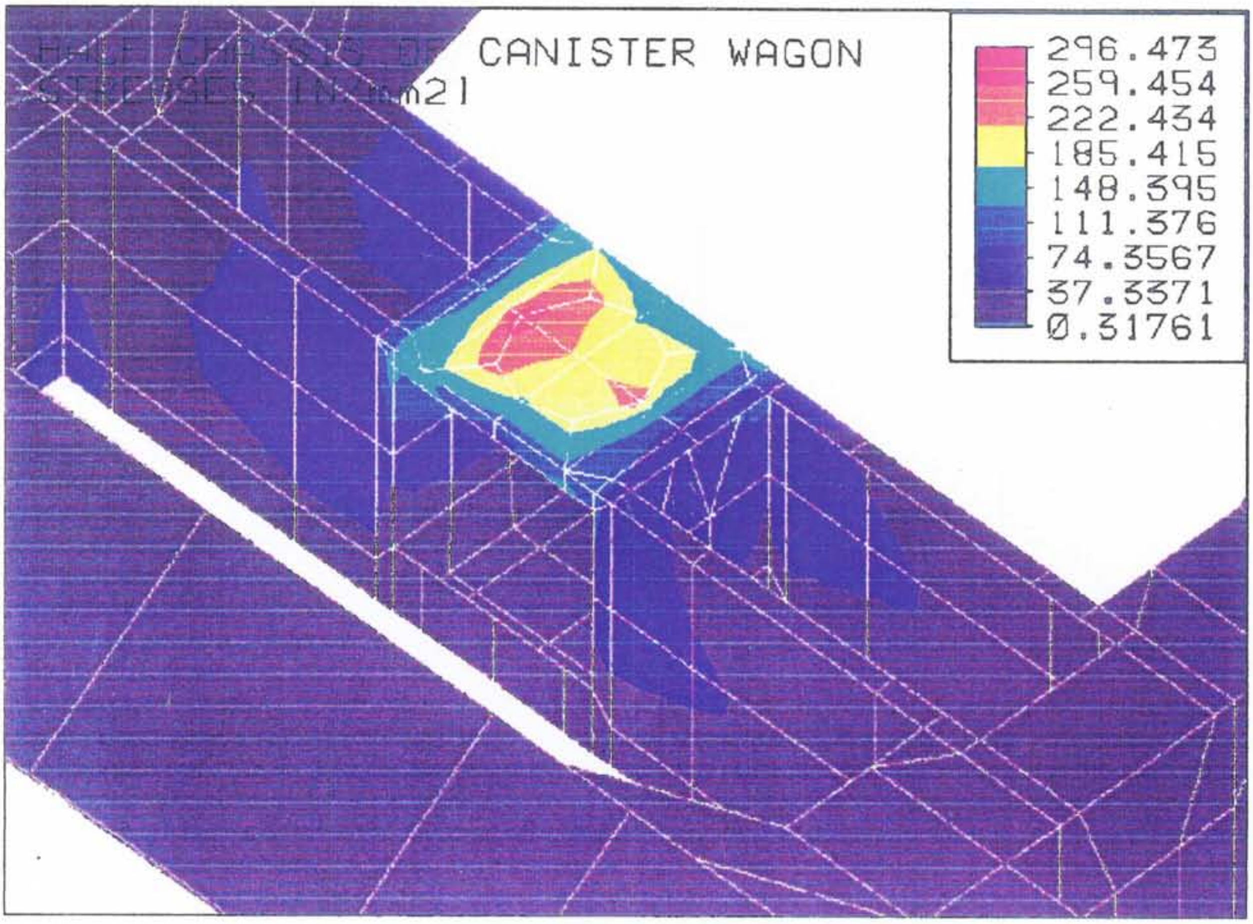
0.91216
0.76014
0.60811
0.45609
0.30406
0.15204
1.7e-05


MODEL OF HALF CHASSIS OF CANISTER WAGON

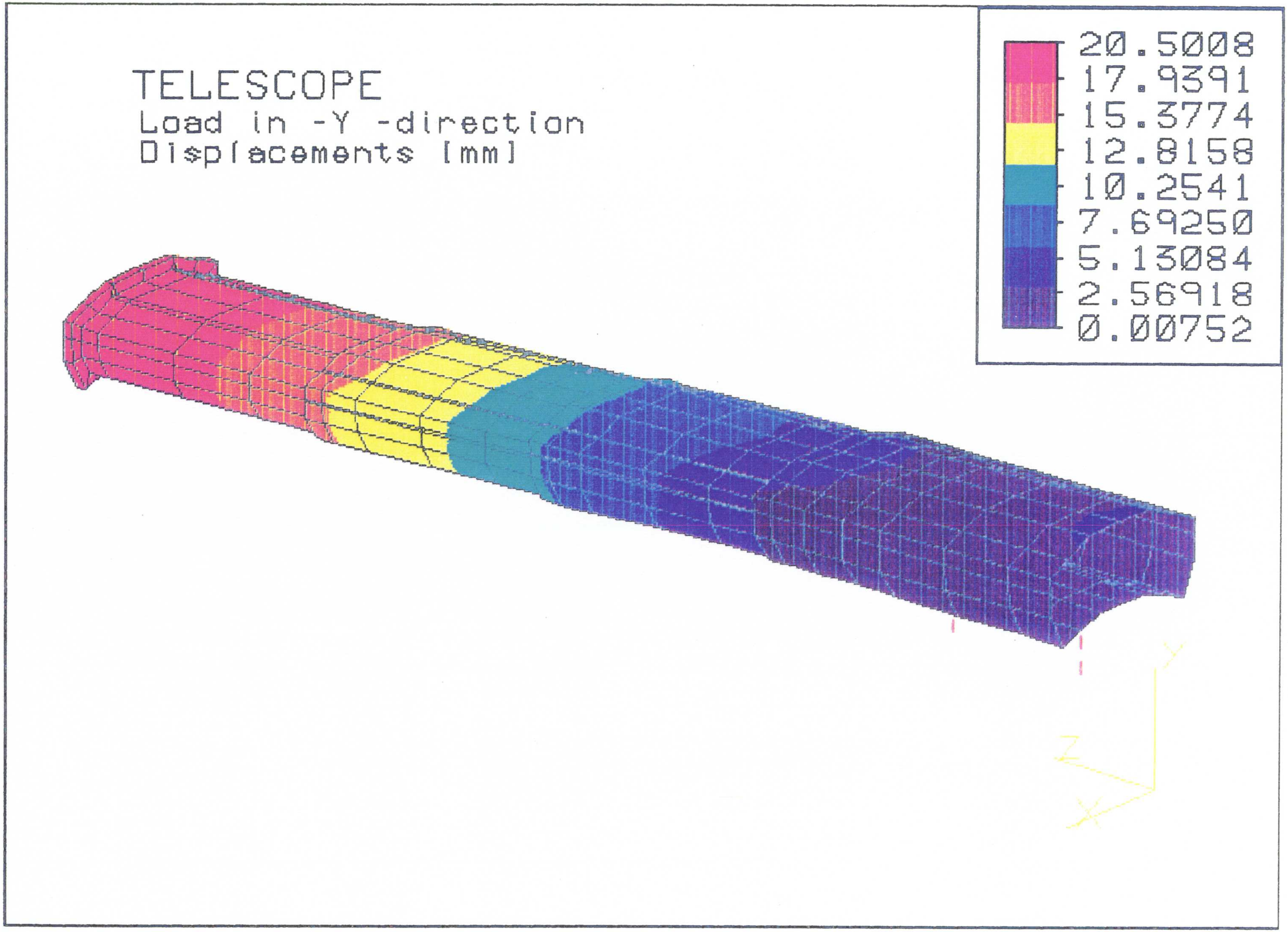

MODEL OF HALF CHASSIS OF CANISTER WAGON
DETAIL

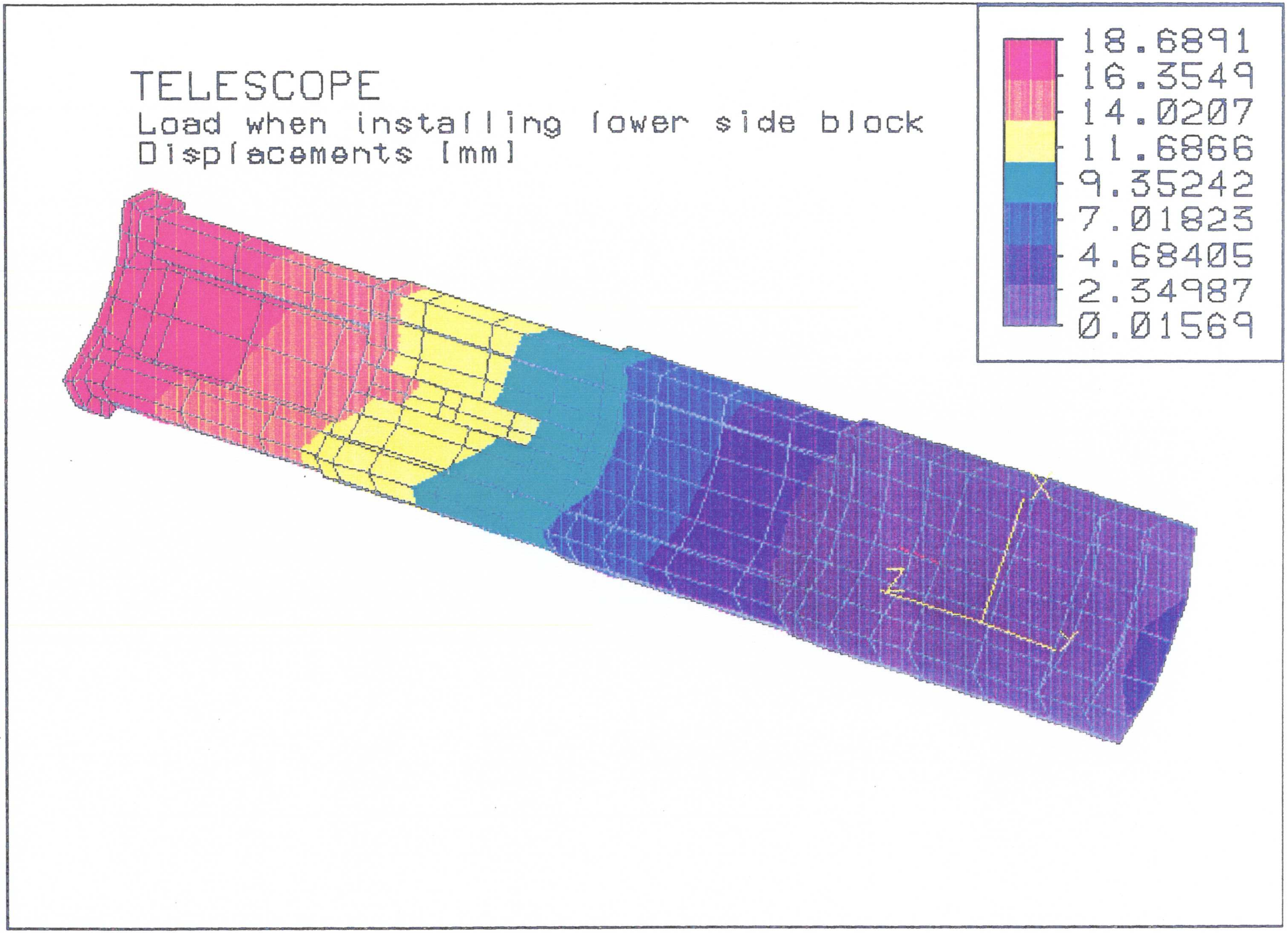


HALF CHASSIS OF CANISTER WAGON
STRESSES (N/mm2)
296.473
259.454
222.434
185.415
148.395
111.376
74.3567
37.3371
0.31761

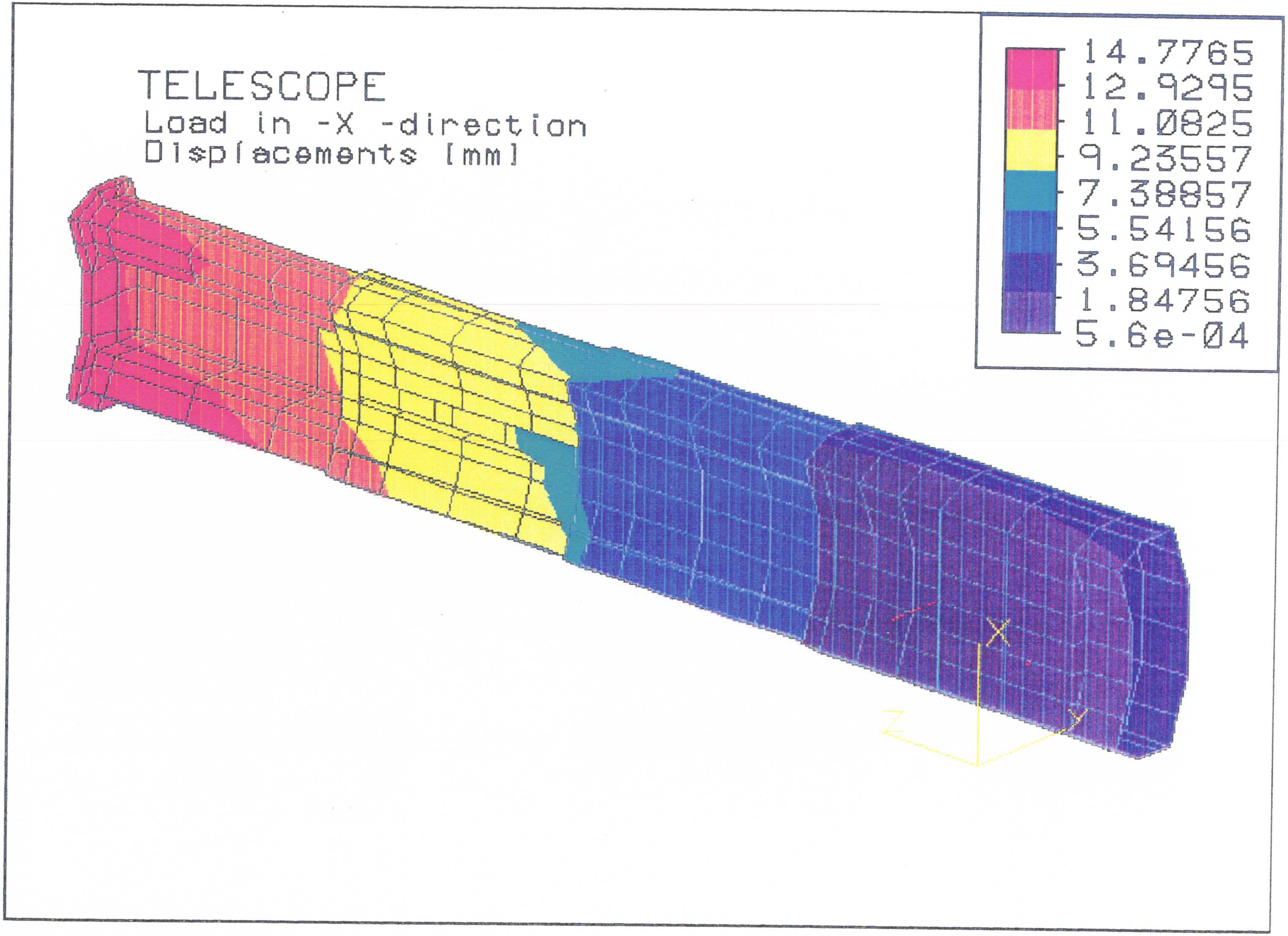


CANISTER WAGON
296.473
259.454
222.434
185.415
148.395
111.376
74.3567
37.3371
0.31761


TELESCOPE
Load in -Y -direction
Displacements [mm]
20.5008
17.9391
15.3774
12.8158
10.2541
7.69250
5.13084
2.56918
0.00752
Y
Z
X


TELESCOPE
Load when installing lower side block
Displacements [mm]
18.6891
16.3549
14.0207
11.6866
9.35242
7.01823
4.68405
2.34987
0.01569
X
Y
Z

APPENDIX 9


TELESCOPE
Load in -X -direction
Displacements [mm]
14.7765
12.9295
11.0825
9.23557
7.38857
5.54156
3.69456
1.84756
5.6e-04
X
Y
Z

TVO/SKB APS

Copercon
Mikko Suikki

15.5.1992

CYCLE TIME

Four wagon system

Minimum working time in a disposal area

BW1 + BW3	90 min
Canister Wagon	10 min
BW2 + BW3	60 min
	160 min

Wagons change in service area

Three changes required, each 15 min

45 min

Situation 1.

Distance 400 m
Speed 0.5 m/s
Driving time 13.33 min

Cycle time:

160 + 45 + 6x13.33 = 285 min = 4 h 45 m

Situation 2.

Distance 1000 m
Speed 0.5 m/s
Driving time 33.33 min

Cycle time:

160 + 45 + 6x33.33 = 405 min = 6 h 45 m

Situation 3.

Distance 4000 m
Speed 0.5 m/s
Driving time 133.33 min

Cycle time:

160 + 45 + 6x133.33 = 1005 min = 16 h 45 m

List of SKB reports

Annual Reports

1977-78
TR 121
KBS Technical Reports 1 – 120
Summaries
Stockholm, May 1979

1979
TR 79-28
The KBS Annual Report 1979
KBS Technical Reports 79-01 – 79-27
Summaries
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1980
TR 80-26
The KBS Annual Report 1980
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1981
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The KBS Annual Report 1981
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Stockholm, April 1982

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[4]KTH
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Sternö study site. Scope of activities and main results
Kaj Ahlbom[1], Jan-Erik Andersson[2], Rune Nordqvist[2], Christer Ljunggren[3], Sven Tirén[2], Clifford Voss[4]
[1]Conterra AB, [2]Geosigma AB, [3]Renco AB,
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P J Henderson, J-O Österberg, B Ivarsson
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Johan Claesson
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Sven Norman
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Description of the transport mechanisms and pathways in the far field of a KBS-3 type repository
Mark Elert[1], Ivars Neretnieks[2], Nils Kjellbert[3],
Anders Ström[3]
[1]Kemakta Konsult AB
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Description of groundwater chemical data in the SKB database GEOTAB prior to 1990
'Sif Laurent[1], Stefan Magnusson[2],
Ann-Chatrin Nilsson[3]
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Björn Lindbom, Anders Boghammar
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Jordi Bruno[1], Patrik Sellin[2]
[1]MBT, Barcelona Spain
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Sven Follin
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Kamlunge study site - Scope of activities and main results

Kaj Ahlbom[1], Jan-Erik Andersson[2], Peter Andersson[2], Thomas Ittner[2], Christer Ljunggren[3], Sven Tirén[2]

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