Bucket Wheel Excavator Instructions

This model of an O&K (Orenstein and Koppel AG) bucket wheel excavator is based on pictures of the prototypes that were in service in the Great Canadian Oil Sands Ltd. project (later named Suncor) in northern Alberta, Canada. It is reported that each machine could load a 150-ton truck every 35 seconds with a bucket wheel diameter of 44 feet. Suncor parked the huge excavators for good in 1993 and switched to 240-ton trucks, large power shovels and ore crushers.

The model (Fig. 1) was scaled from photocopies of pictures of the prototype that were found in mining magazines in the 1970's. Since the scaling is based on the height of a man in one of the pictures the proportions of the various components of the model will at best be approximate. As well, the pictures were small and/or unclear so the details of features on the model are a guess. The model is about 6' 5" long, 20" wide and 3' high (not including the mast at the front top of the support boom). The scale is approximately 1:40. At the Toronto Hobby Show in November 2001, it was a hit with the children since bucket wheel excavators had been showcased on the Discovery Channel the week before the show.

The components of the model have the following weights:

- base including crawler track units: 51 lbs.
- superstructure: 47 lbs.
- bucket wheel boom: 17 lbs.
- discharge conveyor: 11 lbs.

Total weight: 126 lbs.

The model can be built in six sections which can be identified in Fig. 1:

1) the four crawler track units

2) the base (which is supported by the crawler tracks)
   - guides
   - slew drive
   - steering
   - wiring
   - spider

3) the superstructure
   - deck
   - upright supports
   - upper boom and counter balance

4) the bucket wheel and boom
   - bucket wheel
   - boom
   - roller assemblies
   - chute
   - pulley block

5) the discharge conveyor
   - slewing bearing
   - discharge conveyor upper pivot

6) the operator's cabin
   - motor house

Liberal use is made of Exacto (Argentina) and Ashok Banerjee parts, especially the large axle (5/16") system. An EX after the part number indicates Exacto as the supplier, AB indicates Ashok, and MW indicates MW Models. The model incorporates 13 electric motors several of which are of the gearhead type purchased at Princess Auto (sells new and recycled stuff - you never know what you will find).

Since all motors are non-standard and may not be readily available, the builder will have to adapt the motors that are available. Nine of the motors were of the Norm Lacroix (Canon) type which MW Models and Ashok Banerjee also sold at various times. Washers spelt with a capital means standard Meccano washers should be used. If thinner washers are specified, these are brass 8-32 or M4 washers available by the thousands at a good fastener supply shop. Sizes of components are often given in terms of the number of holes, i.e. part 6a would be 3-h Strip. Special tools needed in the construction include locking forceps, a long blade 1/8" screwdriver, a bolt holding screwdriver, and a strip/plate curving machine.

The model is large and quite heavy, and has probably been overbuilt. Weight could be reduced by using less bracing, fewer built-up girders, and by replacing Flat Plates with Flexible Plates and/or Narrow Strips. The bucket wheel boom when hoisted, slightly lifts the back side of the superstructure turntable bearing race off the rear flanged wheels of the spider; reduction of weight especially at the front end of the boom is recommended. Even with the weight, the crawler tracks readily move the model forward and back, and the steering works, but there is considerable complaining if tracks on one side move in a direction opposite to the tracks on the other side, the model is just too heavy. Corn was used as the material loaded and conveyed by the model, and it can transport a lot of corn in a short period of time. The smaller kernels tend to end up lodged in various locations in the model. Jelly beans or lima beans might be a better medium.

Left and right refer to the sides of the model when viewed from behind.

1) Crawler Track Units

There are four separate crawler track units, each consists of a frame, a pivot post, and two tracks driven by an electric motor. A side view of a unit with one track removed is shown in Fig. 2a. Each unit swivels about a vertical large axle (5/16" diameter) mounted in a 3x3x3-h square support box which can rock from front to back to accommodate uneven terrain. The crawler track frame on each side is a shorter version of the one shown on pages 94-96 of B.N. Love's 'Meccano Constructors' Guide. In the following the "front" has the track tensioning springs (to the left in Fig. 2a) and the "back" has the crawler track drive sprockets. The track frame on each side of the unit consists of a box girder built up of four 15-h Angle Girders (8b), slotted holes vertical and inside the box girder (Fig. 2b). The outside pair of Angle Girders are joined by two 3x5-h Flat Plates bolted as shown in Fig. 2a, by a 3-h Flat Girder at the front located behind the tensioning spring, and by two 2-h Triangular Flat Plates (77) bolted to the rear end holes of the 15-h Angle Girders. The bolts holding the 77's together also hold a 3-h Strip and a 3-h Narrow Strip the end holes of which serve as the bearing for the axle of the crawler track drive sprocket. The inside pair of 15-h Angle Girders are joined by a 3x5-h Flat Plate, a 3x3 Flat Plate (74) bolted as shown in Fig. 2c, and by a 3-h Flat Girder at the front located behind the tensioning spring. The inside 8b's are also joined by a 3-h Corner Bracket (133), one three-hole side against the rear side of the 3-h Flat Plate (74), the other three-hole side on the bottom 8b. A 2½" Slotted Strip (55b) is bolted by its slotted hole to the centre diagonal hole of the 133. A Triangular Flat Plate (77) is bolted to the 2nd and 3rd holes (from the back end) of the 55b, and the same two bolts hold a 3-h Narrow Perforated Strip. The 77 is also bolted to the end hole of the inside lower 8b. A 9-h Strip overlaps the 2nd to 10th slotted holes of the lower inside 8b to reinforce the bearings for the axles carrying the Flanged Wheels. The end (slotted) hole of the upper 8b serves as the bearing for the drive axle. This bearing is reinforced by three stacked 3-h Narrow Perforated Strips offset from the 8b by a washer on each bolt. It will be necessary to cut the edge from a washer to clear the 133. (It should be possible to use 4-h Narrow Strips to avoid mutilating a washer.)

The central support box pivots on a 2 3/8" Axle (common length for the recent French parts) which is carried in a Coupling (63) (Figs. 2b, 2c). The Coupling is bolted to the 7th and 8th round holes (counted from the rear) of the top flange of the 8b by 5/8" Pivot Bolts (147d), but spaced from the 8b by three stacked 6-h Narrow Strips. The Coupling is then properly positioned to be further bolted by its end threaded holes through the Flat Plates and the slotted holes of the 8b. These latter two bolts also secure a 4-h Flat Girder by its slotted holes. The Flat Girder, held as low as possible, serves as part of the bearing for the Axles carrying the idler 3/4" Flanged Wheels (20b) which can be seen top, centre of Fig. 2a. The mate of the 4-h Flat Girder can also be seen in Fig. 2a.

The tensioning mechanism is the same on both sides. It consists of a 4-h Narrow Slotted Strip (245a-EX) and a 4-h Slotted Strip (55a) bolted (with dome head Bolts) to the 3-h Flat Girder. Dome head Bolts were used to avoid fouling the spring. A 1x2-h Angle Bracket (12b) supports a 2" Axle which has a Rod-Strip Connector (212) on the front end, followed by a Mini Spacer (38b) and a 19.5 mm Spring (120c).

The sides of the box girder are linked by two 3x3-h Flanged Plates (51b), the lower edges of which can be seen in Fig. 2b between the 1 1/8" Flanged Pulleys. One washer should be placed on each bolt, between the outside pair of Angle Girders (8b) and the Flanged Plates. This is necessary to provide the clearance for the drive gears. The sides are also joined on the top by two 4-h Flat Girders (Fig. 2a), each extended by the elongated holes of a 2-h Flat Girder. (Five-hole Flat Girders are too short.) The bolts in the front and back holes of the 2-h/4-h Flat Girder combination also holds Angle Brackets (12), by their slotted holes, with the vertical portion of the pairs of Angle Brackets positioned as close to each other as permitted by the slotted holes. The round holes of the Angle Brackets support 2" Axles held in place by Washers Mini Spacers (59b). The Axles provide part of the upper support for the crawler track.

The front idler wheels (pairs of 2" Pulleys; or pairs of 2" Circular Plates (146b-AB) bolted to Bush Wheels) are held in the tensioning device by a 2 ½" Axle, and are as shown in Bert Love's book. The outside edges of the Pulleys or Circular Plates are held apart by ½" bolts. Collars and Washers are used to centre the idler wheel which is free to rotate on the Axle.

Each track-driving sprocket is built up using two 2" Circular Plates (146b-AB), between which is a three-way Rod and Strip Connector (without boss). See Fig. 3. One inch Axles are inserted into the Rod and Strip Connector and these protrude about 1/4" through three of the holes in a 13 hole Narrow Strip curved into a circle. (One of these Axles links the two end holes of the Narrow Strip.) An 8-hole Bush Wheel is attached on the outside of the Circular Plate assembly by three 1" Bolts and an 8-h Wheel Disk on the inside are held together by nuts on the inside against the Wheel Disk. These Bolts then pass through the second Circular Plate, then an 8-hole Bush Wheel (boss pointing inside) on the outside of the second Circular Plate, which are all bolted together to clamp

the 13-hole narrow strip so that the 1" axles provide a positive drive to the crawler track. The ends of the 1" bolts engage the holes in a 57-tooth Gear Wheel which has its boss pointing away from the Circular Plate. The Circular Plate assembly and Gear Wheel are free on a 2" Axle held in place by a Collar. As discussed above, stacked 3-hole Narrow Strips bolted to the inside of the upper 8b's of the frame form the bearings for a 3 1/2" Axle on which are bolted 15-tooth Pinions at each end and two 57-tooth gears (bolted together) (Fig. 2b). The 15-tooth Pinions mesh with the 57-tooth Gear Wheels held by the 1" Bolts on the track sprockets. The two 57-tooth gears (bolted together) are driven by a 19-tooth pinion in the gear box.

Before the two sets of box girders can be joined together as a unit the central support box with the large vertical axle must be assembled. Its base consists of a French Flanged Plate (51f) with the centre hole of the flanges reinforced by stacked pairs of 3-h Strips, see Fig. 2b. The top of the 51f is reinforced by a 3x5-h Flat Plate (74a) and two 3-h Angle Girders bolted by their round holes and overlapping the 2nd and 4th rows of three holes on the 51f. These bolts also hold 3x3-h Flanged Plates (51b) on each side. Two additional 3-h Angle Girders are bolted by their round holes to the tops of the 51b's. A 3x3-h Flat Plate (74) is bolted on one end of the support box to the two 3-h Angle Girders. The 74 is pushed down as far as permitted by the slotted holes in the Angle Girders. (The steering arms point inwards on the model. Therefore the Flat Plate (74) will be on the back of the front two track units, and on the front of the rear two track units.) To construct the steering arm, a 2x3-h Flanged Plate (51a-French) is bolted to, and overlaps, the top two horizontal rows of holes of the 74. Two 5-h Narrow Angle Girders (275b-AB) are bolted to the end holes and below the upper flange of the 51a. Two 2-h Narrow Angle Girders (275n-AB) are bolted to the end holes below the lower flange of the 51a. The 5-h and 2-h Narrow Angle Girders are joined by Corner Brackets (133a), see Fig. 2a. The 5-h Narrow Angle Girders are joined at their far end by a Set Screw (69) threaded into a Collar. The 2 ½" Axle must turn freely in the Collar. The Axle is supported at the its back end by a 3-h Strip bolted to Angle Brackets held in the centre holes of the upper and lower flanges of the 51a. Packing with washers will be necessary to ensure the Axle is parallel with the 5-h Narrow Angle Girders. The Axle is held in place by a Collar to the inside of the support, and by a Swivel Bearing (165).

The top of the support box holds a 1 1/4" diameter steel washer (with a 5/16" diameter centre hole). It is held in place by 4 bolts with low profile heads. Notches are filed to accommodate the Bolt heads holding the 3-h Angle Girders, see Fig. 2a. A second 1 1/4" washer rests on the bolt heads and forms the bearing race for nine 3/16" ball bearings. The 5/16" large axle is 4 5/8" long and is tapped at one end for Meccano thread. A Pivot Bolt (147d) passes through the centre hole of the Flanged Plate (51f), Washers and a Nut are added, and then the Pivot Bolt is screwed into the end hole of the large axle. Sufficient washers are used to give a snug fit on the 51f but not binding. The Nut is locked against the large axle. The back side of the central support box can now be completed with two 1½" x 1" Corner Brackets (133b), see Fig. 2d. The final few nuts will require the use of forceps.

The pair of track frame box girders are joined, top and bottom, by 5-h Angle Girders bolted to the third holes from the front of the 15-h Angle Girders. The 5-h Angle Girders are joined by a 3x3-h Flat Plate, see upper left in Fig. 2b. A 5-h Flat Girder joins the two sections on the top front and rear. The 5-h Flat Girders on the lower side of the gear box (to be described next) provide additional rigidity.

The sides of the gear box consist of 9x2-h Flat Plates (73h-AB) joined at the motor end by a Corner Flanged Plate (51d) and by three 2x3x2-h Double Angle Strips (46a) bolted as shown in Figs. 4a and 4b. (9-h Flat Girders could be used instead of the 73h's.) 5-h Strips overlap the back five holes on the inside of the Flat Plates to increase bearing surface. The Canon motor is attached to the 51d by M3 bolts. These bolts pass through the slotted holes of the Angle Brackets (12), through the bottom holes of the Flat Trunnions (126a), through the 51d and then screwed into the motor. The 19-t Pinion on the shaft of the motor engages a 57-t Gear Wheel mounted on a 3" Axle. The axle turns in the apex holes of the Flat Trunnions and in the top hole of three stacked 3-h Strips. An 11-tooth pinion (26n) is fixed to the back end of the 3" Axle. The three 3-h Strips are bolted together by their bottom hole to the back side of a 1x2-h Angle Bracket (12b). The 12b is bolted to the centre hole of the middle 46a but offset from it by a washer to ensure the middle hole of the 3-h Strips aligns with the round hole of a Threaded Handrail Coupling (136b). The 136b is bolted by its threaded boss to the 4th hole of the 9x2-h Flat Plate. The 136b is also supported from below by a 3/4" Bolt fixed to the centre hole of the 46a. Care must taken to ensure the end of the bolt which is screwed a few turns in the bottom threaded hole of the 136b does not foul the 1 1/4" Axle (18c) running through the 136b and the centre hole of the sandwiched 3-h Strips. A Stokys narrow 26-t pinion (21150) is mounted on the front end of the 1 1/4" Axle and a 16-t Bevel Gear (30a) is mounted at the back end. The Bevel Gear engages a 48-t Bevel Gear (30c) mounted on a 1½" Axle that also holds a 19-t Pinion. This Pinion meshes with a 57-t Gear Wheel

mounted on another 1½" Axle mounted in the end hole of the Flat Plates. The Axle also holds a 19-t Pinion that engages the pair of bolted 57-t Gear Wheels described above (Fig. 2d). A 5-h Flat Girder is bolted by its slotted holes to the Angle Brackets at the front end. Another 2½" Flat Girder is also bolted by its slotted holes to the rear Double Angle Strip. The gear box is mounted on the two track frames on ½" Bolts located in the 5th hole from the front on the 15-h Angle Girders, and on Threaded Bosses (64) (see Figs. 2b, 2e) located in the 3rd hole from the back end of the 15-h Angle Girders.

Each track consists of 21 five-hole Flat Girders (103f), to which are bolted the new French Flanged Plate 51c (same size as two Double Angle Brackets). The 51c's are linked by Fishplates and French Pivot Bolts 147g. It was necessary to alternate the Bolts, that is, if all the heads are on the same side of the track, the track will not be straight since the threaded portion of the Pivot Bolt is slightly smaller in diameter. (Short Axles could have fixed this problem.) With the full weight of the model the tracks tended to slip out of the groove of the Flanged Wheels and/or off the 2" idler pulley when steering was attempted. This problem was corrected by:

1. Adding 5-h Strips (5), shaped as can be seen in Fig. 2d, to each 103f to prevent the bolt heads from digging into the table. The 5's were shaped using the jig shown on page 98 of B.N. Love's Meccano Constructors' Guide.

2. Following an idea of Jan Schroef to add a perforated strip to run between the flanges of the track Flanged Plates (51c). A 10-h strip was manufactured and shaped as can be seen in Fig. 2e and fixed to the front 3x3-h Flanged Plate by an Obtuse Angle Bracket, and at the back to a 3-h Narrow Strip fixed to Triangular Plates (77) bolted as shown to the 15-h Angle Girders.

There are four crawler track assemblies on the model which pivot about the vertical large axle (5/16" diameter from Exacto). Also a pair of track assemblies on one side can be reversed relative to the other side which allows the model to turn in its own diameter.

2) The Base

Pictures of the prototype base were not available so the construction is ad hoc. Fig. 5a shows the upper side of the base and Fig. 5b shows the underside. The support for the bearing race for the turn table is constructed of a double ring of 9-h Curved Strips (85-EX), see Fig. 5a. These two rings are separated by a Nut and two Washers on ½" Bolts joining the two layers together. (This construction is similar to that described on page 16 of Everything Roller Bearings, edited by Philip Webb; available from MWMO.) There are 14 Curved Strips in each ring, twelve joints are overlapped two holes, and two joints are overlapped one hole to make a ring of exactly 100 holes. (Suggestion: use six or more 33-h strips, joined by an Axle in their centre hole as a jig to ensure the rings are perfectly round. Place short Threaded Pins in the end holes of the 33-h strips to engage the holes in the Curved Strips.) The bearing ring on which the 3/4" Flanged Wheels of the spider rest is made of a double layer of butt joined Flat Girders curved in a strip bender. The outer layer consists of four 25-h, and one 4-h Flat Girders. The inner layer consists of three 25-h, one 11-h, and two 9-h Flat Girders. Although there is a slight difference in the circumference of the two concentric rings of Flat Girders, by carefully choosing Flat Girders it should be easy to have all holes accept a bolt. This ring of Flat Girders is fixed in place by 3/4" bolts, with washers on each end, passing through the slotted holes of the Flat Girders and between the two rings of Curved Strips. The nuts and bolts on this assembly should be tightened on a flat surface to ensure the bearing race of Flat Girders is perfectly true.

The bearing race is supported on two box girders which intersect as a cross, see Figs. 5a and 5b. The larger box girder (3x4-h cross section), shown supporting the two steering motors in Fig. 5b, is built up from four 31-h Angle Girders, with the upper two each extended by a 2-h Angle Girder to make 33-h Angle Girders. The upper 33-h and lower 31-h Angle Girders are joined by the end round holes of 4-h Angle Girders (located on the inside of the box girder with the round hole flange pointing to the nearest end of the box girder, Fig. 6). The 4-h Angle Girders are bolted to the 3rd from the end holes of the 33-h Angle Girders, and to the 2nd from the end holes of the 31-h Girders. These bolts also secure 4-h Flat Girders (by their round holes) on the inside of the 4-h Angle Girders, and, these bolts also hold more 4-h Angle Girders (by their slotted holes, flange pointing inwards) on the OUTSIDE, but spaced from the 31 and 33-h Angle Girders by one Washer. The 4-h Flat Girders, are bolted by their slotted holes to the 2nd from the end holes of the 33-h Angle Girders, and to the end holes of the 31-h Angle Girders. These bolts in the 33-h Angle Girder also hold 2x3-h Corner Brackets (133b) which can be sandwiched between the 33-h Angle Girder and the 4-h Flat Girders. (It may be necessary to place the 133b's on the outside of the 33-h Angle Girders, they are not identical.) A 3x3-h Flat Plate (74) is bolted to the inner 4-h Angle Girders to ensure rigidity. End holes of 11-h Braced Girders (100) align with the 4th and 14th holes of the 33-h Angle Girder and with the 3rd and 13th holes of the 31-h Angle Girder. Additional 4-h Angle Girders

are bolted by their round holes (flange pointing to the nearest end) to the 15th and 14th holes on the inside of the 33 and 31-h Angle Girders. These bolts also hold additional 4-h Angle Girders (by their round holes) on the outside, see Fig. 5b. The inner 4-h Angle Girders are joined by a 3x3-h Flat Plate (74).

The two sides of the large box girder are joined by Flat Plates (3x11-h Flat Plates (74d-EX) were used on the top and 3x6-h Flat Plates were used on the bottom, see Figs. 5a, 5b). While the inside of the back end (end with the cables in Fig. 5b) of the large box girder is still accessible, place 3/8" Bolts in the 5th holes of the 33-h Angle Girders, shaft pointing up, add a thin washer on each Bolt and tighten in place with a nut. The Bolts will secure a 3-h Flat Girder which in turn holds a plastic 1" Pulley (w/o boss) which serves as one of the five guides for the Flanged Ring (167b) bolted to the superstructure to be described later. (Bolt heads can be seen in the upper right of Fig. 8b; nuts on the inside of the box girder were very hard to secure after the box girder was closed in.) The ends of the 33-h Angle Girders are joined on top by 3-h Flat Girders (103h), slotted holes to the outside. The centre slotted hole of the 103h is bolted to holes in the 100-h circular strips of the turntable race. The head of one of these bolts can be clearly seen in Fig. 6. Motors and gearing for steering the crawler track assemblies will be added to the bottom of the large box girder. Perforated Strips that provide a larger bearing surface for the steering gearing Axles can be added now (see for example 7-h Strips in Fig. 7). The smaller box girder (3x3-h cross section) is constructed in two identical sections, each section extending orthogonally from each side of the middle of the larger box girder. Each smaller box girder section is framed by 15-h Angle Girders on the top and 13-h Angle Girders on the bottom. The upper and lower Angle Girders are joined by 3x9-h Flat Plates. These sides are bolted to the 4-h Angle Girders attached near the centre of the larger box girder described in the previous paragraph, see Figs. 5a, 5b and 6. The bolts also hold 3-h Angle Girders (by their round holes) on the INSIDE of the smaller box girder. These 3-h Angle Girders are joined by a 3-h Flat Girder. Similar 3-h Angle Girders (joined by a Flat Girder) are held by bolts located in the 4th hole from the end of the upper (15-h) and 2nd hole from the end of the lower (13-h) Angle Girders. These bolts also hold a 3-h Flat Girder on each side, inside the box girder. These bolts also hold additional 3-h Angle Girders (by their slotted holes, pointing inwards) separated by a Washer from the outside of the 13-h and 15-h Angle Girders. The offset ends of the 15-h and 13-h Angle Girders are linked by 3x3-h Corner Brackets (133). The sides of the small box girder are joined on the bottom by a 3x11-h Flat Plate. Note that the width of the box girder must be made narrow as possible using the slotted holes of the 13-h and 15-h Angle Girders, in order for the box girder to fit between the 4-h Angle Girders bolted near the centre of the large box girder. The sides are joined on the top by three 3-h Flat Girders on each section. The centre slotted holes of the end Flat Girders support the 100-h circular strips of the turntable race. As on the large box girder an 1" plastic Pulley (w/o boss) with a Rubber Ring (155) rotates on a Pivot Bolt (147f) fixed by locknuts to the centre slotted hole of a 3-h Flat Girder on the left side of the base. 5-h Flat Girders are centered on both upper sides of the larger box girder, to connect with the inner end holes of the 15-h Angle Girders of the smaller box girder; these cannot be seen as they are beneath the slip ring disk in Fig. 5a. This construction requires forceps and patience.

A framework of 1x2x1-h built-up channel girders link the ends of the box girders to the cylindrical supports of the crawler track units, see Figs. 5b, 6 and 7. Each channel girder orthogonal to the ends of the large box girder consists of two 9-h Angle Girders (9a). The two 9a's are joined by the 4-h Angle Girders bolted to the large box girder (previously described), and by a 6-h Flat Girder. The round holes of the upper 9-h Angle Girder point down, and the slotted holes of the lower 9-h Angle Girder point up. The attachment of the channel girder to the large box girder is strengthened by a 3x3-h Corner Bracket (133). The opposite end of the channel girder is extended by a 4-h Flat Girder (103g); the slotted holes in the channel girder and in the 103g allow vertical adjustment of the 103g. The end holes of the 103g are bolted to the 3rd and 4th holes (from the top) of the cylindrical support.

Each channel girder orthogonal to the ends of the small box girder consists of an upper 9-h Angle Girder (round holes down) and a lower 10-h Angle Girder (slotted holes up) built up of two 5-h Angle Girders. The upper and lower Angle Girders are joined by the 3-h Angle Girder (described previously) bolted near the end of the small box girder. This attachment is strengthened by a 2x2-h Corner Bracket (133a) (Fig. 7). They are also joined by a 2-h, a 5-h and a 3-h Flat Girders. These channel girders are attached to the cylindrical support by a 2-h Angle Girder. The 2-h Angle Girder is attached by its slotted holes by Bolts that pass through the middle holes of the 3-h Flat Girder, but spaced from the Flat Girder by a collar on each bolt plus a washer on the upper bolt. The angle in the 2-h Angle Girder may need to be reduced to approximately 80 degrees to mate properly with the cylindrical support (Fig. 8b).

Each cylindrical support is built up from three 5-h Cylindrical Girders (261b-EX), joined by their 2nd and 4th holes by Formed Fishplates (262-EX). (Assembly is aided by obtaining a washer with a 1 3/32" diameter

hole and placing in over the outside of the cylinder formed by the three 261b's.) The cylinder is capped on each end by an End Cap for Circular Girders (263-EX). The 263's have a 5/16" diameter hole and accept the Large Axle of the crawler track assembly.
As well as being bolted to the channel girders as previously described, the cylindrical support is bolted to the turntable race by a 3/4" Bolt in the slotted hole, 2nd from the top of the cylindrical support, through the slotted holes of the turntable Flat Girders, and through the double ring of 100-h circular strips. The cylindrical support is offset from the turntable Flat Girders by three Washers. (Note: four holes in the 100-h circular strips will align exactly with the centre, slotted holes of the 3-h Flat Girders fixed to the ends of the box girders. However the Flat Girders in the turntable race have 104 holes. There are 24 clear holes in the turntable Flat Girders between the pair of 3/4" Bolts holding the cylindrical supports at the front, and at the back of the base. (The large box girder runs from front to back.) It will be necessary rotate the turntable such that the holes on the cylindrical supports align with the appropriate holes in the Flat Girders and at the same time the holes in the circular strips align with the centre, slotted holes of the 3-h Flat Girders at the ends of the box girders.)

Each corner holding the cylindrical supports is strengthened by a 9-h Angle Girder bolted to the lower side of the channel girders as shown in Fig. 5b. A 1x2-h Angle Bracket (12b) joins the Angle Girder to the cylindrical support. Use washers as necessary. Three of the corners are also strengthened by 15-h Angle Girders (8b) connected to the upper side of the channel girders. These can be seen in Fig. 5a. The 8b's have been strengthened with a 13-h Angle Girders, but the latter are not necessary.

Guides

Two of the Flanged Ring (167b) centering guides (upper right in Fig. 5a) have already been described which are located on either side of the Large Tooth Pinion (167c) which slews the superstructure. These two guides are adjusted and fixed to ensure the Large Tooth Quadrants (167a) bolted to the Flanged Ring (to be described below) are centered. Three adjustable guides are provided to aid installation of the superstructure on the base. These guides are shown in Fig. 5a and each consists of two Curved Strips, Stepped (89a) pivoted on a Pivot Bolt (147g). The Pivot Bolt passes through the top Curved Strip, then a thin washer, a Collar, two Washers, the second Curved Strip, 3 Washers, a Nut, thin washer, the 5th slotted hole of the 15-h Angle Girder, another washer and then a Nut. The end holes of the Curved Strips hold a Collar secured by its threaded holes using Shouldered Bolts (140z). One end of a 2½" Screwed Rod (80d) is held by locknuts on both sides of the centre (unthreaded) bore of the Collar. The 80d passes through two of the threaded holes of a Four Hole Collar (140y) and then through a slotted hole of the turntable race Flat Girders. The 140y is sandwiched between the slotted holes of two 2-h Flat Girders and held in place by Shouldered Bolts. The 2-h Flat girders are bolted to the 100-h circular strips. The outside end of the 80d is lock nutted to a Screw Rod Coupling (63e-MW). The length of 80d in the Screw Rod Coupling is adjusted such that the plastic 1" Pulley (w/o boss) with Rubber Ring (155) is in light contact with the Flanged Ring. The plastic Pulley is held by a 5/8" Pivot Bolt (147d) lock nutted to the lower Curved Strip. The 80d's are backed out before installing the superstructure; once the superstructure is in place the 80d's are screwed in until the 63e/nut are tight against the outside of the turntable Flat Girders.

Slew Drive

The slew drive assembly can be seen in Figs. 5a, 5b, 8a, 8b. A 12V, 120 RPM gearhead motor is used to drive the slew Pinion (167c) through reduction gearing. If a gearhead motor with lower RPMs is available, much of the reduction gearing shown could be reduced. The gearhead motor is mounted on a 3-h Angle Girder which in turn is mounted on a 3x3-h Flat Plate (74) which in turn is bolted to a 9-h Girder Frame (161d-EX), see Fig. 5b. A 6-h Girder Frame (161b-EX) extends the 161d by four holes. The two Girder Frames are offset approximately ½" by a 3/4" Bolt and a 3-h Flat Girder (lower centre of Fig. 8a). The offset is to accommodate the crawler track steering Screwed Rod that can be seen in Fig. 7. The key aspect of this assembly is the positioning of the Large Tooth Pinion (167c). The 167c is fixed on a 2 ½" Axle which rotates in two 5-h Strips that sandwich the slotted holes of a 5-h Flat Girder (which allows adjustment of the location of the bearing). The 5-h Strips and Flat Girder are offset by five Washers on ½" Bolts from a 7-h Flat Girder (to the right of the Pinion in Fig. 8b) and from a 6-h Flat Girder (to the left of the Pinion). Note that the boss of the 167c fits down between the two Flat Girders. The 5-h Flat Girder is also fixed by the two bolts with dome heads which do not have washers under them and can be seen in Fig. 8b. These Bolts also hold an 11-h Strip below the 7-h and 6-h Flat Girders and links them for additional strength. The 7-h Flat Girder is extended one hole by a 6-h Angle Girder (Fig. 8a) bolted by its slotted holes to the round holes of the Flat Girder. The 6-h Flat Girder has a 4-h Angle Girder bolted by its slotted holes to the right most four round holes of the 6-h Flat Girder (Fig. 8a). A 5-h Angle Girder is bolted by its round holes and extends one hole to the right of the 4-h Angle Girder in Fig 8a. The 5-h Angle Girder

round hole flange is on the inside of the 4-h Angle Girder. The end slotted hole of the 5-h Angle Girder is bolted to the top end hole of the channel girder, closest to the small box girder. The 4-h Angle Girder is linked to the 6-h Girder Frame by a 3-h Flat Girder. The 6-h Angle Girder on the left side in Fig. 8a is extended by one hole by another 6-h Angle Girder. The end slotted hole of this second 6-h Angle Girder is bolted to the top end hole of the channel girder closest to the large box girder, see Fig. 8b. The 6-h Angle Girder is linked to the 9-h Girder Frame by a 4-h Girder Frame. An 11-h Strip overlaps the round holes of an 4-h Flat Girder (left in Fig. 8b) and a 6-h Flat Girder (right in Fig. 8b), and these are fixed with the 11-h Strip against the lower flanges of the 5-h Angle Girder and the 6-h Angle Girder. The 4-h Flat Girder is also fixed by an 81 on the left in Fig. 8b, and the 6-h Flat Girder by an 80d on the right. Two stacked 5-h Strips below the 6-h Flat Girder provide a bearing for the Axle. Stacked 7-h Strips above the slotted holes in the long flange of the 9-h Girder Frame provide bearings for both Axles (Figs. 5b, 7, 8b). The various slotted holes allow adjustment of the slew drive assembly. A 16-tooth Bevel Gear (30a) on the gearhead motor drives a 48-tooth Bevel Gear (30c) mounted on a 2 3/8" Axle (French). A 19-tooth Pinion also mounted on this Axle drives a 95-tooth Gear Wheel mounted on the 2 ½" Axle that holds the 167c. Tighten the Grub Screws well in the 167c as the Pinion tends to loosen after several days operation.

A Square Bearing Plate (252-EX) is bolted to the centre of the large box girder, bottom side, see Fig. 5b. A 1 1/4" diameter steel washer (with a 5/16" diameter centre hole) is bolted to the centre of the large box girder on its top side to the 5-h Flat Girders. Care must be taken to ensure the centre of the 252 and the steel washer is concentric with the circular Flat Girders of the turntable race. A Drift can be centered in the large boss of the 252 and the steel washer by using Aeroplane Collars (59a). Fig. 9 shows the location of one of the Large Tooth Quadrants (167a) and of the Flanged Ring (167b). It is recommended that four 167a's be assembled on the 167b along with two 19-h Strips to centre the167b on the Drift fixed in the 252's. Once the 252's are centered, this jig allows final adjustments of the guides positioning of the 167c. This is also the opportunity to ensure that no bolt heads foul the Large Tooth Quadrants. Once the slew assembly is positioned the Girder Frames may be fixed to the lower side of the channel girders by 3-h Strips, see Fig. 5b, use spacers as required.

Steering

The crawler track steering mechanisms can be seen in Fig. 5b. Each Canon motor is mounted on the large box girder and drives by two Driving Bands (186a) a 1 ½" Pulley and a second 1 ½" Pulley (w/o boss- 21a-EX). The two Pulleys are bolted together but separated by a Small Spacer (38b). The motor has two small rubber Pulleys (23c) on its shaft. The 1 ½" Pulleys are mounted on a 3" Axle, the other end of which carries a 19-tooth Pinion. The Pinion meshes with a 57-tooth Gear Wheel mounted on a 5" Axle. Each end of the Axle carries a Universal Coupling (140). The free ends of the Universal Couplings hold Screw Rod Adapters (173a) to which are lock nutted 4 ½" Screwed Rods. These Screwed Rods engage in two of the threaded holes of Swivel Bearings mounted on the crawler track steering arm.

Wiring

An 11-h Insulating Flat Girder can be seen on the left side of Fig. 5b which serves as a terminal strip for the five pairs of wires feeding the seven electric motors in the base. The five pairs of wires feed:

1) The slewing gearhead motor;
2) The front steering Canon motor;
3) The rear steering Canon motor;
4) The two Canon motors in the left side crawler track units;
5) The two Canon motors in the right side crawler track units.

The crawler track motor feed wires go to 3-h Insulating Flat Girders (508), one for each unit, fixed vertically on the outsides of the channel girders (Fig. 5b). Also apparent in some of the figures are horizontal 508's each holding two Narrow Angle Brackets (239-EX), an 1" Wiper Arm (531), and a diode. There are four of these to limit the rotation of the steering arms of the crawler track units (see Diagram 1). These are optional but can prevent the crawler track units from jamming the steering mechanism. The 531's are activated by the orange plastic Shock Absorbers (120e) that are seen fixed to the steering arm in Fig. 2a. The particular track unit in Fig. 2a is located below the 11-h Insulating Flat Girder and has two 120e's fixed to the steering arm; the front track units have one each of the 120e's.

12V power needs to be provided for the 4 circuits in the superstructure. Rather than trailing a power cord from the superstructure, an eight track slip ring disk was prepared (Fig. 5a). The disk is 6 3/4" in diameter and must easily pass through the inner diameter of the Large Tooth Quadrants. It was manufactured from a small sheet of printed circuit board material with a metal film on one side. After cutting a disk out of the sheet, it was mounted on a Square Bearing Plate (252-EX). Using a 5/16" Large Axle, the disk was turned in an electric drill, and the metal film was

scored with a sharp knife. It is recommended that each slip ring be 5 mm wide. The centre brass disk serves as the inner slip ring, but it would have been simpler to have had 8 rings instead of the 7. (The original eighth ring had to be removed since the diameter was too large.) Ring gaps of about 3 mm implies that the Flanged Ring extending down from the superstructure must be concentric with the centre Large Axle of the base. Small holes were drilled through each slip ring, 20 gauge wire was introduced from below, and then soldered in place on the top (Fig. 5a). Epoxy glue was used to hold the wire on the underside of the disk. The disk is held by four small machine bolts (the heads are under the brass disk, and insulated from it) on a 252 mounted on a 4½" Large Axle. The Large Axle is held firmly in the Square Bearing Plate bolted to the bottom centre of the large box girder of the base. A Large Axle Coupling (255-EX) is firmly fixed to the top end of the Large Axle protruding above the slip ring disk. This Coupling will serve as a fixed reference for the discharge conveyor (to be described in a later section). The feed cable for these four circuits enters the back of the base and is clamped to the Flanged Plate (51f) seen on the lower left in Fig. 5b. A 5-h Insulating Flat Girder (a portion of which can be seen below the 51f in Fig. 5b) serves as terminal plate for the eight wires.

Spider

The spider supports thirty-two 3/4" Flanged Wheels (20b) bolted to a circular strip of 96 holes. An inner circular strip of 78 holes enhances rigidity. The two circular strips are linked by pairs of 1x3-h Double Angle Strips (48) wherever holes on the inner and outer circular strips align, which is every 5th or 6th hole on the outer circular strip , see Fig. 9. Extra strength is provided by 4-h Narrow Strips. These are attached to the inner circular strip by Angle Brackets (12).

3) Superstructure

Deck

The deck of the superstructure consists of five U-girders each constructed of two Angle Girders joined by their round holes. Portions of all five can be seen in Fig. 10a which shows the underside of the deck. The middle three U-girders are built up from 37-h Angle Girders (7a). The front U-girder (lower right in Fig. 10a) is 35 holes but there is no reason it cannot be 37 holes as well. (Fig. 10a was taken at an early stage of construction and in the final model the Curved Strips are not bolted as shown in the figure.) The upper arm of the rear U-girder is built up to be 27-holes long while the lower arm is a 25-h Angle Girder. The U-girders are linked on the underside of the deck by Flat Plates as can be seen in Figs. 10a and 10b. There are seven clear holes between each U-girder. The sizes of the Flat Plates used are not critical, but they must present a smooth support for the upper race of the turntable. The upper race is bolted in the centre holes of the front and back U-girders, and to the 3rd from the end holes of the centre U-girder. The upper race is identical to the one described for the base.

The upper sides of the U-girders are linked by two large box girders: 2x4-h in cross section and 37 holes long including the tapered portion at the rear (see Fig. 11a). Flat Girders are placed between the bottom slotted holes of the 37-h Angle Girders of the box girders, and the upper flanges of the U-girders. The Flat Girders extend from the first front hole of the box girder to the 26th hole (i.e. a 19-h and a 7-h Flat Girder are used). Each side of the box girder is constructed as follows, beginning at the front:

1) 4-h Flat Girder (103g), slotted holes to the front, in the 2nd and 3rd holes of the 37-h Angle Girder on the inside of the box girder.

2) 4-h Angle Girder (9e) bolted by its round hole to the 3rd hole of the 37-h Angle Girder. (The 103g in the previous item is inside the 4-h Angle Girder.) The 9e is linked to a similar Angle Girder on the other side of the box girder by a 4-h Flat Girder. This adds cross-sectional rigidity to the box girder.

3) 11-h Braced Girder in the 4th to 14th holes of the 37-h Angle Girder.

4) 4-h Angle Girder with cross-sectional support as in 2) above in the 15th hole of the 37-h Angle Girder.

5) 11-h Braced Girder in the 16th to 26th holes of the 37-h Angle Girder.

6) 4-h Angle Girder with cross-sectional support as in 2) above in the 27th hole of the 37-h Angle Girder.

7) 4-h Flat Girder in the 27th and 28th holes of the 37-h Angle Girder. The Flat Girder is inside the 4-h Angle Girder in 6) above. Slotted holes of the 4-h Flat Girder to the back.

8) 2x2-h Corner Bracket (133a) in the 36th and 37th holes, free hole to the front.
The top of each box girder is constructed from two 25-h Angle Girders, linked by their slotted holes by a 25-h Flat Girder. The front round holes of the 25-h Angle Girders are bolted to the top holes of the 4-h Angle Girder described in 2) above.

Two 7-h Angle Girders are bolted by their round holes (slotted holes out and up) on the top of and to the first and 7th holes of the 25-h Angle Girders on the LEFT box girder. A similar 7-h Angle Girder is bolted to the inside top of the RIGHT box girder. These 7-h Angle Girders will serve to attach the back part of the upright supports (to be described below) to the box girders.

The sloping top of the rear section of the box girders is built up from two 9-h Angle Girders and a 9-h Flat Girder. The sloping top is bolted to the rear slotted hole of the 4-h Flat Girder (see 7) above) and to the free hole of the Corner Bracket described in 8) above.

It was found easier to construct the box girders before bolting to the five deck U-girders, however forceps will be required. There are 15 clear holes between the pair of box girders when mounted on the U-girders. The box girders are bolted by their 2nd front hole to the front U-girder.

The rear decking is filled by eleven Flat Sector Plates (54a-EX). These are linked on their outside circumference by five 11-h Curved Strips (89), see Fig. 11a. The inner portions of the Flat Sector Plates, between the box girders, are linked by three 7-h Curved Strips (84-EX) overlapped by three holes. These 7-h Curved Strips are extended at each end by another 7-h Curved Strip, but placed under the Flat Sector Plates. The Flat Sector Plates are bolted to the end holes of the rear U-girder, to the 4th holes from the ends, and to the 6th holes from the ends (through the box girder). The Flat Sector Plates are also bolted to the 5th holes from the ends of the second from the rear U-girder.

The outer ends of the 2nd and 3rd U-girders are attached to the slotted holes of Flat Girders, the outside edge of which is bolted to a 19-h Angle Girder (8a) on each side of the superstructure (Fig. 11b). The Flat Girder and Angle Girder end one hole in front of the 4th U-girder (the U-girder's ends are covered by the Flat Sector Plates). The round holes of the 8a are extended downwards by 3x11-h Flexible Plates. The Flexible Plates extend around the entire circumference of the superstructure; 3x5-h Flexible Plates with slotted holes are used as needed in the curved sections. The rear side is braced by 3x3-h Corner Brackets (133) fixed to 3-h Angle Girders and to Angle Brackets, see the top of Fig. 10b. The lower edge of the Flexible Plates on each side are fastened to 19-h Girder Frames (161h-EX) which serve as lifting points for the superstructure. The 161h's are connected by screwed Rods to the lower end holes of the middle three U-girders. The front curved sections on each side are built up of two 5-h Curved Strips (90) on top, and two Formed Slotted Strips (215) on the sides. These Curved and Formed Strips are linked by 5-h Strips to a 25-h Angle Girder on the front. The space between the Angle Girder and the front (1st) U-girder is filled by flat plates (Fig. 11c).

Upright Supports

The fronts of the main upright supports are 32-h channel girders (1x2x1-h in cross section) built up from 25-h and 7-h Angle Girders. The lower end of the right 32-h channel girder can be seen in the centre of Fig. 11c. The round holes of these Angle Girders are joined in the front by Flat Girders. The lower ends of the channel girders are bolted to the front, lower holes of the box girders on the deck (see Fig. 11c), and to the top hole of the 4-h Flat Girders (see 1) above). The channel girder is inside the lower Angle Girders of the box girder, and outside the 4-h Flat Girders. The channel girders are thus tilted back about 13 degrees from the vertical. A 7-h Flat Girder, slotted holes up, is bolted to the 7th and 8th holes on the INSIDE flange of the 32-h channel girder. The back round hole of the 7-h Flat Girders is bolted to the 6th hole of the 7-h Angle Girder that was bolted to the top of the box girder (see upper right of Fig. 11a). The lower slotted hole of a 25-h Angle Girder is bolted to the back slotted hole of the 7-h Flat Girder. The 25-h Angle Girder is connected to the front 32-h built up channel girder by, starting at the bottom:

1) a 7x5-h Flat Plate (which is also bolted to the slotted holes of the 7-h Flat Girder just described, see Figs. 11a, 37a).

2) a 5-h Strip bolted to the centre, front hole of a Square Bearing Plate (252-EX), see Figs. 37a, 12. The 252 is bolted to the top rear three holes of 1) above and to the bottom, rear three holes of 3) below.

3) a 7x5-h Flat Plate

4) a 9x7-h Flat Plate

5) a 3x7-h Flat Plate

6) a 3x7-h Flat Plate (74b): this Flat Plate extends one hole above the end of the 32-h channel girders and the end of the rear 25-h Angle Girder.

7) 15-h Angle Girders are bolted by their slotted holes to the top front and rear holes of 6) above (Figs. 12, 13, 14).

8) a 5x9-h Flat Plate extends 6) above, up six holes, The top front and rear holes of this Flat Plate are bolted to the 9th holes (counted from the top) of the 15-h Angle Girders.

9) a Flat Sector Plate (54a-EX) is bolted to the top holes of the Flat Plate in 8) and to the top holes of the 15-h Angle Girders.

The left upright support (the support that is front, centre in Fig. 12) is extended to the left by a built-up 29-h angle girder, round holes out and pointing to the front. The 29-h angle girder parallels and reaches the same height as the 25-h Angle Girder (discussed above) on the inside rear of the upright support. The lower end of the 29-h angle girder overlaps four slotted holes of a 7-h Angle Girder (9b). The round holes of the 9b face the front. The lower slotted hole of the 9b is bolted to the second slotted hole, from the rear, of a 5-h Angle Girder which is located between the first and second U-girders of the decking. The 5-h Angle Girder is bolted by its round holes to the underside of a 9-h Angle Girder (clearly visible in Fig. 12) which in turn is bolted to the 1st and 2nd U-girder. The space between the 29-h and 25-h Angle Girders is filled by two 7x11-h and one 7x3-h Flat Plates. The left upright support is further strengthened by, starting at the bottom:

a) a 5-h Angle Girder (Figs. 12, 15) bolted by its round holes to the bottom holes of the bottom 7x11 Flat Plate. A 1x1-h Angle Bracket bolted to the 5-h Angle Girder inner slotted hole secures it to the 7-h Angle Girder on the box girder (there is a 5-h Angle Girder bolted to the box girder in the figures, but it should have been a 7-h).

b) a small channel girder built up from a 7-h Flat Girder and two 7-h Angle Girders is bolted by the front holes of the Angle Girders to the 10th holes of the upright support 32-h channel girder (see Figs. 12, 15). An 8-h built-up strip braces the 7-h channel girder to a 2-h Angle Girder bolted to the 29-h built-up angle girder.

c) a similar 7-h channel girder as b) above is bolted to the 24th holes of the 32-h channel girder.

d) a 7x3-h Flat Plate occupies the equivalent position as 6) above, on the inside of the outer flange of the 32-h channel girder (see Fig. 15).

e) a 7-h Angle Girder is bolted by its round holes (slotted holes up and pointing out) to the middle holes of the 7x3-h Flat Plate. An 8-h built-up strip connects the front slotted hole of the 7-h Angle Girder to the left slotted hole of a 4-h Angle Girder fixed to top of the top 7x11-h Flat Plate. A 4x5-h Triangular Flexible Plate completes the bracing.

f) 2-h Angle Girders are bolted by their bottom round holes to the top end holes of the 7x3h Flat Plate. The 2-h Angle Girders are linked by 3-h Flat Girders to the 15-h Angle Girder (described in 7) above). An 11-h Angle Girder is bolted to the top free hole of each 3-h Flat Girder and tilted in and bolted to the 3rd hole from the top of the 15-h Angle Girder.

This completes construction of the left upright support.

The right upright support is the mirror image of 1) to 9) above. It also includes the equivalent of c), d), and f). The extension to the right incorporates the operator's cabin and its lift mechanism. These will be described in a later section.

Upper Boom and Counter Balance

NOTE 1: There are 15 clear holes between the upright supports. However a 15-h Strip will not fit between them. 14-h strips and angle girders will bolt nicely between the long U-girders of the upper boom. This causes some difficulties with centering the rear conveyor support, but these can be (and were) overcome. However if I were building the model again I would be tempted to shim between the upright supports so that the upper boom could be constructed using 13-h Angle Girders and Strips for cross struts.

NOTE 2: In the prototype the front end of the upper boom is tapered i.e. it is narrower at the front (location of the hoisting cables) than where it is bolted to the upright supports. This is not replicated in the model.

The U-girders of the upper boom bolted to the top of the upright supports are 71 holes long. They are built up on each side from 49-h Angle Girders (7) (the top 7 has round holes up and pointing in, and is on the inside of the second 7, which has slotted holes of the lower flange pointing in), see Fig. 14. The 7's are extended to the rear by an 11-h Angle Girder (9) and a 15-h Angle Girder (8b) on the upper arm of the U-girder, and by an 8b on the lower arm. The U-girders are bolted by their 31st and 33rd holes (counted from the front) to the top of the upright supports. The U-girders are spaced from the 15-h Angle Girder at the top of the upright supports by a 3-h Strip on each side (to allow the bracing strips on the side of the upper boom to be bolted in the 30th and 34th holes of the U-girder).

The lower U-girders on the balance arm (to the rear of the upright supports) are 56 holes long:

- the upper flange has round holes which point in, and beginning from the front, is built up using a 19-h and a 37-h Angle Girder all butt joined;

- the bottom flange (with slotted holes pointing in) is built up from the front by a 6-h, two 19-h's, 5-h, and 7h Angle Girders.

The U-girders are located on the inside of the upright supports and bolted at their front hole to the second hole down and second hole from the front of the 3x7-h Flat Plate described in 6) on page 14. The U-girders are also bolted to the top rear hole of the Flat Plate. Construction of the back end of the balance arm and cross bracing should be clear from Figs. 16, 17, 18. A small cab covers the hoist mechanism and is held closed by a Screwed Rod that can be seen to the right in Fig. 17.

The bucket wheel is hoisted by cord wrapped on two Cylinders (216) each clamped by means of four 3" Screwed Rods (80c) between an 8-h Bush Wheel (24) and a 66-t Gear Wheel (27h-AB). The 216's are loose on a 6 ½" Axle which is journalled in three 7-h Strips (3), one on each end and one between the 216's. The rear holes of the 3's (and the front hole of the middle 3) are fixed in the slotted holes of 1x2-h Angle Brackets (12b) which are bolted by their short lugs to the base plate (9x11-h and a 3x9-h Flat Plates). The front end of the middle 3 can be seen in Fig. 18. The front hole of each outer 3 is fixed in a slotted hole of the long arm of a 2-h Girder Bracket (161t-AB). The slotted holes allow for vertical adjustment of the 27h's.

The gear train for the hoist begins with a 3/8" Pulley (23c-EX) on the motor which drives a 2" Pulley (20a) fixed on a 3 ½" Axle (16) journalled in the rear top holes of 3x3-h Flat Plates (74) each bolted to the slotted holes of 3-h Angle Girders (9f) which are bolted to the base plate but separated from it by three stacked 3-h Strips (6a). 2-h Flat Girders are stacked on the 74's to increase the bearing surface. A 19-t Pinion is fixed near the left end of the 16 which meshes with another 27h fixed on a 4" Axle (15b) which is journalled in the top round holes of 3-h Flat Girders (103h) which are bolted by their two remaining round holes to the top front two holes of the 74's (see Fig. 16). The 15b has a 19-t Pinion fixed on its left end which meshes with a 60-t Gear Wheel (27d) fixed on another 15b which is journalled in 2x2-h Triangular Plates (77) which are bolted to the top two slotted holes of the 103h's (Fig. 16). A wide 25-t Pinion (25b) is fixed on the 15b which meshes with both 27h's fixed to the 216's.

The lower U-girders on the front boom are 32 holes long:

- the upper flange has slotted holes which point in, and beginning from the front, is built up using 2-h and two 15-h Angle Girders all butt joined;

- the bottom flange (with round holes pointing in) is built up from the front by 11-h, 2-h, and 19-h Angle Girders.

The rear hole of each U-girder is fixed to the inside top hole of the 32-h upright support channel girder (see Fig. 21). The front hole of the lower U-girder on each side is linked to the upper 71-h long U-girder by a 3x5-h Flat Plate (74a) (see Fig. 20a) extended down by a 3x5-h Triangular Flat Plate (76a-EX). The front of the U-girders are linked by a 3x14-h flat plate built-up from three overlapping 3x6-h Flat Plates (73) fixed at each end to the slotted holes of 2-h Angle Girders (9g) which are held in the upper two vertical holes of the 74a's. The 3x14-h flat plate has bolted to it (Fig. 22):

- a 3-h Angle Girder (9f) with its slotted holes pointing in and overlapping the second column of holes from each end;

- a Channel Bearing (160) fixed in the fourth column of holes from each end;

- a 2x3-h Flanged Plate (51a) fixed to the centre two columns.

Eight 73's are fixed to the rear pointing flanges of the above, the back ends of which are bolted to similar components (i.e. 9g's, 160's and a 51a). Several of these can be seen in Fig. 22 and in the upper right of Fig. 14. These components are bolted to a 2x14-h flat plate built-up from a 2x11-h (75k-AB) and a 2x3-h (75e-AB) Flat Plates. Note that the 2x14-h flat plate is bolted to the lower two holes of the components to allow the hoisting cord to pass from the Pulleys back to the hoisting gear. A 14-h angle girder built-up from two 7-h Angle Girders (9b) is bolted to the lower edge of the 2x14-h flat plate with the angle girders slotted flange extending to the front beneath the eight 73's. Each end of the 2x14 flat plate is bolted to the slotted flange of a 9g which is bolted to a 5-h Strip which are fixed to the upper U-girder. An 11-h Angle Girder can be added along the top row of holes of the 2x14 flat plate, but is not necessary. Eight 1 ½" Pulleys (21) are free to turn on an 8" Axle which passes through the two 74a's and the eight 73's; the left end of the Axle can be seen in Fig. 20a. Bosses point towards the centre for the four inner 21's, the bosses of the other four point away from the centre. The lower U-girders are linked by three built-up 14-h angle girders, fixed by their slotted holes to the slotted holes of the upper flanges of the U-girders in holes 2, 11, and 20 from the back end.

Slewing Gear

Since the slewing gear, consisting of the Flanged Ring (167b) and Large Toothed Quadrants (167a), extends down approximately 2 3/4" below the Flat Plates on the underside of the deck, a means of support is required before the slewing gear is installed, see the last section 'Setup'. The slewing gear is centered under the middle U-girder of the deck with the top of the 167a's 2" below the under side of the Flat Plates, i.e. the slewing gear is offset below by two Couplings and a Threaded Boss at the four locations shown in Fig. 10c. Where an offset sits directly on the U-girder, a washer is added to compensate for the thickness of the Flat Plates. Under the 'Discharge Conveyor' section the alignment of Wheel Discs on the centre hole of the middle U-girder will be described. It is recommended that steps be taken to ensure the centre of the slewing gear coincides with the centre holes of the Wheel Discs. A 19-h insulating flat girder is bolted by its middle and end slotted holes, and separated by 1 ½" from the underside of the Flat Plates as shown in Fig. 10c. Eight Bent Wiper Arms (533) are offset below the insulating flat girder by Plastic Spacers (38a) and located as shown in Figs. 10b, 10c. These are arranged to contact the rings on the slip ring disk shown in Fig. 9.

4) The Bucket Wheel and Boom

Bucket Wheel

The bucket wheel consists of 14 individual buckets bolted on a rim that is 56 holes in circumference. Each side of the rim consists of eight Stepped Curved Strips (89b) overlapped by one hole (Figs. 23a, 23b). Each bucket consists of two 1/4 Circular Plates (214a-EX), a 3x5-h Plastic Plate (194), two 3-h Strips (6a), two 2x2-h Corner Brackets (133a) and four Angle Brackets (12). Two Narrow Angle Brackets (239-EX) and a 6a join each side of the rim in the space between each bucket. On the left side of the bucket wheel (Fig. 23a) the three-hole bases of eight Flat Trunnions (126a) are sandwiched between the 214a's and the 89b's, spaced by four clear holes on the rim, and apex hole towards the centre. A pair of Flat Rings, 8 3/8" outside diameter (145d-EX) sandwich the Flat Trunnions and are bolted to the apex holes of the 126a's. (To reduce weight, the left 145d could be omitted.) It is suggested that dome head bolts and thin washers be used on the inside of the bucket wheel to avoid fouling the chute assembly to be described later. These bolts also secure the assembly to a 7 ½" Circular Plate (146f-AB). An 110-t Circular Strip (145c-EX) is attached to the Circular plate by the eight dome head bolts and separated from it by a Washer and Mini Spacer (38b) on each bolt.

A built up bearing attached to the bucket wheel revolves on a 3 ½" Large Axle (256c-EX). On the left side of the 146f the bearing consists of a Wheel Flange (137), with the flange pointing right, mated with the flat side of a Square Bearing Plate (252-EX). These are offset from the 146f by a Collar and three Washers on each of four Bolts that pass through the 137, the 252, the Collar and Washers, the 146f and though a Face Plate (without boss 109a) that reinforces the 146f on the inside. An 8-h Large Axle Bush Wheel (253-EX), boss towards the 109a, is off-set from the 109a by a Coupling (63) on each of four bolts, see Fig. 24.

Boom

The bottom frame for the boom consists of three long girders. The built-up U-girder on the lower right is 74 holes long and can be made up of two 49-h Angle Girders (7) and two 25-h Angle Girders (8) bolted together by their slotted holes (Figs. 23b, 25). The built-up U-girder on the lower left is 68 holes long and can be made up using 19-hole (8a), and 49-h Angle Girders (Figs. 23a, 26). The built-up girder in the lower middle is also 68 holes long and consists of an 8a and a 7 end-joined with Strips. The right and left U-girders are joined underneath (Fig. 27) starting at the back by:

- a 13-h Strip (1e) second hole from the back end;

- the slotted holes of a 13-h Angle Girder (8c) fifth hole from the end (slots pointing back);

- the slotted holes of an 8c eighth hole from the end (slots pointing front);

- the slotted holes of an 8c in the 16th hole from the back end (slots pointing back);

- an 1e in the 26th, 34th, 46th, and 54th holes from the back end.

The centre 68-hole girder (slotted holes down) is joined to the 78-hole U-girder, beginning at the front by:

- a 6-h Angle Girder (9c) at the front (bolted on the top of the long girders by its slotted holes, see Fig. 25;

- a built-up 8-h angle girder at the 5th holes from the front, fixed to the 68-h girder by an Angle Bracket;

- a 3" Screwed Rod in the 10th holes;

- a 9-h Angle Girder in the 13th holes, fixed to the round holes of the 68-h girder by means of a Threaded Boss and three Washers (can be clearly seen in Fig. 25);

- a 6-h Strip on the top side at the 18th holes;

- the four 13-h Strips and two of the 13-h Angle Girders listed in the previous paragraph, fixed to the 68-h girder by Angle Brackets and 3-h Angle Girders;

- 5-h Angle Girders (9d) at the 36th , and 47th holes counted from the front (see lower left in Fig. 27). The 9d's are attached to the U-girder by 3-h Angle Girders. Cross bracing is added to taste. However cross bracing, consisting of two 9-hole Strips bolted to the 6-hole Angle Girder at the front, is recommended (see lower right in Fig. 24).

The pivot for the boom consists of two Large Axle Couplings (255-EX), one on each side bolted to the bottom of the U-girders, pivoted on an 8" Large Axle (256-EX). The Couplings are also bolted to the vertical side of the rear-most 13-h Angle Girder (8c). 2-hole Girder Brackets (161t-AB) (Figs. 26, 27) bolted to the 8c second from the back, have been used to further support the Couplings. A 1x2-h Angle Bracket (12b) could have been used instead. A 15-h Flat Girder (103k) is bolted above the rear 13-hole Strip and extends one clear hole back of the Strip (Fig. 27). The 103k is parallel to the U-girder on the left side with 2 clear holes between the two girders. The 103k is also bolted above the second from the back 8c. A 2-hole Flat Girder extends the 103k to the third from the back 8c. The 103k supports the conveyor belt alignment assembly. The 2x2h Corner Bracket and the 4-h and 7-h Angle Girders, which can be seen on the right in Fig. 27, are not necessary.

The sides of the boom are similar (see Figs. 23b, 26) with the following exceptions:

- a vertical 9-h Angle Girder is used in the left back corner (Fig. 29b);

- the right back side has a 7-h Strip extended upward (overlapped three holes) by a 5-h Angle Girder (Fig. 29a);

A 7-h Angle Girder (9b) is bolted by its end slotted hole above and in the 15th hole from the front of the left U-girder and extends inward to a 3-h Angle Girder bolted to the middle 68-hole girder. The left end of the 9b can be seen in Fig. 23a immediately behind the bucket wheel. The horizontal flange of the 9b points to the front. A vertical built-up 8-h Angle Girder is bolted to the 9b and completes the front of the rectangular portion of the left side of the boom. Cross bracing consisting of a 5 ½" Slotted Strip (55) (bolted by its lower end to the left round hole of the 9b) and a 9-h Strip (bolted by its lower end hole to the 5th from left round hole of the 9b) have their top end holes bolted to the 13-h built-up angle girder located just behind the bucket wheel. On the right side the equivalent vertical strut is an 8-h Strip (3a-AB), joined to the top of the U-girder by an Angle Bracket (Fig. 23b). The upper 53-hole angle girder on each side can be built up from two 25-h Angle Girders and a 3-h Angle Girder. Five vertical built-up 8-h strips on each side join the lower U-girders (by means of 3-h Angle Girders and Angle Brackets) to the upper 53-hole angle girders and are located 9, 18, 27, 36 and 45 holes from the back. 11-h Strips are used for diagonal bracing.

The upper left 53-hole angle girder is extended by a 3-h Angle Girder end-joined to an 11-h Angle Girder (9) that extends diagonally down towards the bucket wheel support bearing (Fig. 23a). The slotted flanges of both Girders are on the outside and point down. This built-up girder is strengthened by a second 9 with its round holes overlapping the rear eleven round holes of the built-up girder. This compound girder is attached to the outside of the 53-hole angle girder by a 5-h Strip, and to a built-up 13-h angle girder (that links the front ends of the 53-hole angle girders) by an Angle Bracket. A 2-h Angle Girder (9g) is joined by its slotted hole to the front slotted hole of the compound girder (Fig. 23a). The second slotted hole of the 9g holds a bolt in a Threaded Boss (64) the other end of which is bolted to an 8-h Large Axle Bush Wheel (253-EX), boss out. The Bush Wheel is connected to the front three holes of the U-Girder by two 3-h Strips and a Fishplate by Domed Bolts with heads on the inside and no washers under the heads. Domed Bolts are used to allow the bucket wheel to be located as far to the left as possible.

The drive gear for rotating the bucket wheel is housed between two 6-h Flat Girders (103e) one on each side of the U-girder and bolted to its 8th hole from the front. The inside Flat Girder is against the U-girder and the outside Flat Girder is spaced from the U-girder by a Collar, Threaded Boss and a Washer (Fig. 28). The round holes of 3-h Flat Girders (103h) overlap the upper three round holes of the 103e's, and the 103h's are bolted by their top slotted holes to either side of the upper compound girder (see Figs. 23a, 28). Washers should be used as needed to ensure all components are square and parallel. 3-h Narrow Strips (235g) are bolted to the slotted holes on both sides of both 103e's to serve as bearings for the 1½" Axle. To the right of the inside 103e the Axle holds an 10-t Large Tooth Pinion (145b-EX), a thin washer, the inner 103e, a 48-t Bevel Gear (30c) (boss to the left), four Washers, and the outer 103e. The (30c) meshes with a 16-t Bevel Gear (30a) fixed to the front end of a 3" Axle. The bearings for the Axle consist of two Couplings (63), each supported by two 2" Threaded Rods which in turn are fixed to the four corner holes of a 4-h Flat Girder (103g) and the U-girder (Fig. 23a). The 103g is supported on the inside

by a 3-h Angle Girder also bolted to the U-girder. A 1½" Pulley (21) is fixed to the back end of the 3" Axle and is driven by a 6" Driving Band (186a) by a ½" Pulley (23a). This Driving Band is recommended as it will slip should the bucket wheel catch. The 23a is fixed to an 11½" Axle which allows the electric motor to be located half way back in the boom and reduce the suspended weight on the boom. The drive to the Bucket Wheel will depend on the motor available. In this model a Canon motor, bolted to a 9-h Girder Frame (161d-EX), was used which had a rubber Pulley (23c) on the output shaft, linked by a 186a to a 1½" Pulley (21) fixed to the back end of the 11½" Axle (journalled in a Double Arm Coupling (62b) bolted to the 161d). The front end of the 11½" Axle is journalled in stacked 2x2-h Triangular Plates (77) bolted to a 3-h Flat Girder which is fixed to the 13-h built-up angle girder.

The inside bearing support for the bucket wheel large axle consists an 8-h Large Axle Bush Wheel (253-EX), boss in (i.e. pointing left) supported by the centre hole of a 3-hole Flat Girder and two 3-hole Strips (Fig. 24). The Flat Girder and Strips are bolted, but offset to the left approximately 5 mm by washers, to the 7th, 8th, and 9th holes of the middle lower 68-hole angle girder. (Fig. 24 shows 5-h Strips used as an offset, but these were replaced by washers to reduce weight.)

The front, right side of the boom consists of a compound girder similar to the one described above for the left side, except a 9-h Angle Girder replaces the 11-h Girder on the inside. As shown in Figs. 23b, 25, the lower end of the compound girder is attached to the apex of a Triangular Plate (77), which in turn is bolted to the 2-h Flat Girder, which in turn is bolted to a 2-h Girder Frame (261a-AB). A second 77 is bolted to the lower, front hole of the first 77, and to the top, front hole of the Girder Frame. The height of the centre of the front hole of the second 77 needs to be adjusted to be about one inch above the top flange of the U-girder. The end hole of a 7-h Strip (3) is bolted to this centre hole and is supported at the Strip's front end in the centre round hole of a vertical 3-h Angle Girder (9f). Again the centre of the 9f's centre hole should be one inch above the U-girder (which can be achieved by spacing another 9f from the 6-h Angle Girder that joins the front end of the right U-girder and the middle 68-hole angle girder. A second vertical 9f is similarly positioned above the middle 68-hole girder (bolted to the front slotted hole of yet another 9f which overlaps the first three holes of the 68-hole girder, Fig. 24), and the outside flange should be separated from the outside flange of the first vertical 9f by at least 3 5/16" to accommodate the front roller of the conveyor belt. A 6-h Strip (4) is bolted to the middle round hole of the second vertical 9f and extends back to the front hole of a Triangular Plate (77) which in turn is bolted by its lower back hole to the Large Axle Bush Wheel supporting the bucket wheel. This bolt also fixes the top hole of the 3-hole Strip discussed earlier. The Bolt holding the back end of the 4 passes into the threaded hole of an Aeroplane Collar (59a), which is separated from the 4 by a Washer.

The front roller for the conveyor belt is the recent version of the Cylinder (216a) (without a seam) which has Marklin Wheel Flanges (11040) on either end. These are similar to the Meccano Flanged Wheel (20) but the boss is inside the Cylinder and saves space. An axle (cut to 2 5/8") passes through the Marklin Wheel Flanges and is supported on both sides by a miniature pulley (3/8" Exacto, Marklin, or Stokys pulleys; bosses from old 1" Pulleys or thin Pinions (25c) could also be used). The miniature pulleys are threaded on 3½" Screwed Rods (80a) (see Fig. 24) which pass through the un-threaded holes of 59a's at their back ends, and through the centre slotted holes of the vertical 3-hole Angle Girders, and then through the lower hole of 2-hole Narrow Strips (806b) bolted to the top holes of the vertical Girders at the front (described in the previous paragraph) (Fig. 25). The front end of the right 80a is held by a locknut to a Threaded Boss (64); the end of the left 80a has a pair of locknuts. The Threaded Boss and the locknuts can be used to turn the 80a's to adjust the alignment of the front roller and adjust the tension of the conveyor belt.

The back roller for the conveyor belt, which is driven by a gearhead motor, is another 216a which is sandwiched between two Flanged Wheels (20) and held together by two 3" Screwed Rods (80c) which extend as far as possible past the left Flanged Wheel (Fig. 29b). A 4½" Axle passes through the bosses of the 20's and a 57-t Gear Wheel (27a) which has bolts in two of the outer holes to engage the ends of the 80c's. The Gear Wheel is driven by a 19-t Pinion on the output shaft of the gearhead motor. The upper, back, round hole of a 4-h Flat Girder (103g) serves as the bearing for the right end of the Axle (Fig. 29a). The 103g is bolted to the slotted holes of a 3-h Angle Girder which is bolted to the 3rd and 5th holes, from the back, of the upper flange of the U-girder. The centre of the bearing hole should be about one inch above the U-girder. The slotted holes in the Flat and Angle Girders allow considerable vertical adjustment. The bearing can be reinforced by 4-h Strips. A Slotted Strip (55a) is mounted by its end round hole on the Axle between the bearing and boss of the Flanged Wheel, and another Slotted Strip between the boss of the Gear Wheel and the Flat Plate discussed next. The 55a's hold a chute that transfers material from this conveyor to the discharge conveyor.

The left bearing of the Axle is a flat plate (a 3x5-h replica that came with the motor) onto which is mounted the gearhead motor. This plate has 5-h Angle Girders (9d) bolted vertically by their round holes along the short sides to the left of the flat plate (Figs. 29a, b). Axles pass horizontally through the upper and lower slotted holes of the 9d's. The slotted hole flange of the Angle Girders have 5-h Narrow Strips bolted to them and allow for left-right adjustment of the Flat Plate. The Angle Girders can slide front and back on the Axles and are held in place by a Collar toward the front end of the Axles. Short Couplings are mounted on the four ends of the Axles. The Couplings are threaded on vertical 4 ½" Screwed Rods (80b) mounted in the 15-h Flat Girder on the bottom (mentioned earlier, Fig. 27) and on a suitably positioned 11-h Angle Girder (9) near the top of the boom. The 80b's allow vertical adjustment of the 3x5-h flat plate. The 9 is held at its back hole by an Angle Bracket bolted to a Flat Trunnion (Fig. 29b) and by its front round hole bolted to a vertical 7-h Angle Girder which is held at its lower end by an Angle Bracket fixed to the 15-h Flat Plate. A 1x2-h Angle Bracket is fixed to the second slotted hole from the front of the 9, and to the second from the back built-up 13-h angle girder across the top of the boom (along the top of Fig. 29b).

The conveyor belt is a 2½" wide strip cut from the outer circumference of a 24" by 2.125" bicycle inner tube. These tubes come in a number of diameters. If this width is not available, buy the widest you can. The tubes I purchased from Canadian Tire have manufacturing lines running the circumference which makes cutting with scissors fairly easy. Although provision has been made for a variety of adjustments, both Cylinders need a crown if the belt is to stay in place. This can be achieved with tape, but excellent results were obtained by cutting three short bands or tubes from an old bicycle tube about 3/4, 1 1/4, and 2" long. Centre the shortest band on the Cylinder first and progressively add the longer bands (an example of a crown can be seen in Fig. 32b).

Roller Assemblies

The roller assemblies supporting the conveyor belt are constructed in three separate removable sections. As shown in Figs. 30a, b, the bottom portion of each section consists of sets of 5 plastic Washer Spacers (38a) mounted on 1½" Axles which are held between pairs of Narrow Angle Girders held apart by 1½" Bolts (111f-MW) (2" Screwed Rods could be used instead.) The horizontal flanges of the Narrow Angle Girders point away from each other. The front and middle sections are each 25 holes long. The rear section is 15 holes long. The rollers on either side are at a 45 degree angle, and each consist of two 38a's mounted on a 7/8" Pivot Bolt (147g), which is held by lock-nuts in Narrow Angle Girders for the front section, and in Obtuse Angle Girders for the other two sections. The heads of the Pivot Bolts secure the 1½" Axles in place.

Front Section

- 25-h Narrow Angle Girders (275m-AB) journal the 1 ½" Axles;

- a 13-h Narrow Angle Girder (275g-AB) and an11-h Narrow Angle Girder (275f) hold the 147g's on the right side of the section and are linked near the middle by a 3-h Narrow Strip (235g);

- two 5-h Narrow Angle Girders (275b-AB) and a 275f hold the 147g's on the left side of the section and are linked near the back end by a 5-h Narrow Strip (235). Note the gap near the front to accommodate the bucket wheel bearing.

- These Narrow Angle Girders are fixed at a 45 degree angle to the 275m's by Narrow Obtuse Angle Brackets (240-EX) as can be seen in Fig. 30b.

- Two Axles with Aeroplane Collars (59a-AB) and Springs (120b) can slide in the 275m's; the front Axle slips into the 2x3-h Corner Bracket (133b) which can be seen in Fig. 23b fixed to the U-girder, and the rear Axle also slips into a 133b which is bolted to the two slotted holes of a 2-h Flat Girder which is fixed to the slotted holes of the middle long angle girder. The centre of the top hole should be about 1 3/8" above the U-girder. Two 2-h Angle Girders (9g) are fixed by their slotted holes to the 5th and 6th from the front bottom holes of the 275m's as shown in Fig. 30b. The 9g on the right has a Narrow Reversed Angle Bracket (to hold the Axle in place) held by a spring loaded bolt in its front round hole. An Axle passes through the rear round holes of the 9g and into the end hole of the short arm of the red 133b that can be seen to the lower left in Fig. 24. The 133b is bolted to a 3-h Flat Girder which is bolted to the slotted holes of the middle 68-hole angle girder.

Middle Section

- 25-h Narrow Angle Girders (275m-AB) journal the 1 ½" Axles;

- 15-h and 9-h Obtuse Angle Girders (242k and 242f-EX) which hold the 147g's are connected to 275m's by 1x2-h Angle Brackets (12b). The 275m's project one hole past the back end of the 275f's.

- Four Axles with 59b's and 120b's slide in the 275m's and slip into the apex holes of two (yellow) Flat Trunnions (126a) fixed to the U-girder by 3-h Angle Girders as shown in Figs.23b, 21; and into a 133b and

a 126a fixed to the middle 68-hole angle girder as shown in Figs. 26, 27.

Rear Section

- 15-h Narrow Angle Girders (275h-AB) journal the 1 ½" Axles;

- a 15-h and a 13-h Obtuse Angle Girders (242k and 243h-EX) which hold the 147g's are connected to 275h's by Girder Frames (161b-EX). Note the gap on the rear left side to accommodate the gears of the conveyor belt drive.

- three Axles with 59b's and 120b's slide in the 275h's and slip into the top hole of a 3x3 Corner Bracket (133) on the right U-girder (Fig. 29a) and into the top hole of 2x2-h Corner Brackets (133a) mounted on 3-h Flat Girders (103h) which are in turn mounted on a 3-h Girder Bracket (161u-AB) which is fixed to the middle 68-h angle girder (Fig. 26).

Because of limited space beside the bucket wheel, and the need to reduce weight, Narrow Angle Girders held at a 45 degree angle by Narrow Obtuse Angle Brackets replaced the Obtuse Girders in the front section. Some considerations for the builder:

- A total 33 roller sets were used, a set in every second hole. The bicycle tube conveyor belt would function just as well with less support. However there should be a set at the ends of each section.

- Spring loaded Axles (using Aeroplane Collars and Springs (120b) between the Narrow Girders) were used to mount the conveyor sections in the boom. Two spring loaded Axles were used on the front section, four on the middle and three on the rear section. Easily removable sections save much time, especially when building the bucket wheel chute and assembling the adjustable motor drive at the rear of the boom.

- Narrow Angle Girders at 45 degrees could replace the Obtuse Girders and the Girder Frames, but the lower flange of the Narrow Girders foul the spring loaded Axles. This is the reason for the gaps in the Narrow Girders in the front section.

- The Girder Frame is moved forward 2 holes at the left rear of the back section. The Pivot Bolt is mounted in a 5-h Strip. This is to avoid fouling the Pinion on the electric motor driving the rear Cylinder.

- The front left side of the front conveyor section appears more complex in Fig. 30a then it now needs to be. A rebuild of the bucket wheel mounts and the chute have made this complexity redundant.

Chute

The individual buckets on the bucket wheel pick up the material (dirt, rocks, sand, etc.) which is kept in the bucket by means of a 3x25-h Strip Plate (195d-AB) curved along its length to match the inside circumference of the bucket wheel and extending from the bottom to near the top (Figs. 31a, b, c). One half inch flanges are bent at either end of the Strip Plate; at the top this flange is bolted to the front side of the chute. The left side of the chute (Fig. 31c) consists of an 11-h Flat Girder (103) bolted by its round holes to a 7-h Girder Bracket (161c-EX). The 103 is extended upwards by 5-h Strips bolted to the 3rd hole from each end of the 103. The Strips are bolted together at the top and the bolt also holds an Obtuse Angle Bracket. Fishplates are bolted in the 2nd hole from each end of the Girder and they are extended upwards by Obtuse Angle Brackets. The front side of the chute consists of two 7-h Flat Girders overlapped as shown in Fig. 31d, and held together by a 4-h Angle Girder and a 4-h Strip. The lower 7-h Flat Girder is bolted to the round holes of a 2-h Obtuse Angle Girder (242-EX) but spaced from the 242 by a Washer and a Mini Washer Spacer (38b) on each bolt. The slotted holes of the 242 are bolted to the end holes of the 161c using a 3/4" Bolt and a regular bolt held in a Threaded Boss (64). The end of the 3/4" Bolt has a Screw Rod Coupling (63e-MW) threaded part way on it, and locked in place by a regular nut. The 63e will take a Screwed Rod as part of the mounts to hold the chute in place. The back side of the chute (Figs. 31b, c) is similar except the lower Flat Girder is four holes in length, leaving a gap through which the material on the conveyor belt can pass.

The slide portion of the chute consists of two 7-h Curved Strips (84-EX) which are further curved in a strip bending machine. These, which are overlapped one hole, form a section of a cone, the upper edge of which, when properly curved, will match the outer perimeter of the Flat Ring (145d-Ex) and meet it at an angle of about 45 degrees. There are probably a number of ways of assembling the flexible plates in the slide portion of the chute, in this assembly 3x5-h Triangular Flexible Plates (221) are bolted at either end of the 84's as shown in Figs. 31e, f . Note the flat head machine screw in the second from front hole of the 84's in Fig. 31e; as unlikely as it seems, kernels of corn would line up and jam against the original dome head bolt as the corn exited off the top end of the 195d. Additional 221's are aligned with the 3rd to 5th holes from either end of the 84's, the 90 degree corner in the 5th hole. A 3x5 Flexible plate (188) is bolted to the centre three holes of the two 84's. Two 5x5-h Flexible Plates (190) are overlapped by their slotted holes and bolted to the middle hole of the 188, and to holes on the diagonal of the inner 221's.

The slide assembly is attached to the left side of the chute by the three Obtuse Angle Brackets discussed in the previous paragraph. A fourth Obtuse Angle Bracket is bolted underneath, and to the middle second hole from the lower end of the overlapped 190's (Fig. 31f). The other end of the Obtuse Bracket is bolted to a Threaded Boss (64) which in turn is bolted to the 7-h Flat Girder held at either end by the two 64's mentioned earlier. (A small portion of the 64 and Obtuse Angle Bracket can be seen in Fig. 31d.) The lower end of the slide is completed by a 7-h Strip, curved slightly to match the lower ends of the 190's, and fixed to them by three Obtuse Angle Brackets. The 7-h Strip is extended at each end as much as possible by Fishplates.

The right side of the chute assembly consists of a 9-h Strip and a 12-h built-up strip joining the front and back Flat Girders (Figs. 31e, f). The space between the strips is filled with two Triangular Flexible Plates (221) and a Flexible Plate (188). As can be seen in Fig. 31a, the side is extended down by approximately 1/4" by a strip of thin brass shim stock, which is required to prevent corn bouncing out from between the 9-h Strip and the conveyor belt. A similar shorter brass strip was added on the lower front of the chute.

The chute assembly has 4 mounts holding it in place. Two 2 ½" Screwed Rods are locknutted to the first and seventh round hole from the front of a 9-h Flat Girder (103c) (Figs. 31a, b, c). The 103c is attached by its end slotted holes to the end slotted hole of a built-up 8-h angle girder and the second-from-the-end slotted hole of a 9-h Angle Girder. The 8-h angle girder is fastened to the underside of the right U-girder, 5th hole from the front, and the 9-h Angle Girder is fastened to the 13th hole from the front of the boom, see Fig. 25. The 8 and 9-h Angle Girders are also fastened to the centre long angle girder by Angle Brackets. The chute assembly complete with the 3x25-h Strip Plate (195d is inserted in place and the 2 ½" Screwed Rods are screwed into the Screw Rod Coupling (63e-MW) mentioned above. A variety of adjustments are possible by all the slotted holes and the Screwed Rods to allow the 84's to just clear the inside of the rotating bucket wheel. The front of the chute assembly is bolted to a 1 ½" Screwed Rod which is held in a Threaded Boss, which in turn is held in a 3 ½" Screwed Rod mounted in the top holes of the 3-h Angle Girders located at the front of the conveyor belt (Figs. 23b, 24). A Corner Angle Bracket (154b) (see lower left in Fig. 24) is bolted to the lower slotted hole of the 7-h Flat Girder at the back of the chute assembly. The 154b is bolted to the appropriate hole in the sloping compound angle girder.

The lower end of the 195d is fixed by a 3/4" Bolt in the centre hole of its flange (Fig. 31c). The bolt is screwed into a short Threaded Coupling (64a) which in turn is supported by a 1 1/4" Bolt, in turn held in the lower round hole of a 3-h Flat Girder (103h). The upper two slotted holes of the 103h are bolted to the two lower holes of a 3-h Angle Girder (9f) which in turn is bolted to the 9-h Angle Girder mentioned above and braced with a Corner Bracket (133a). The arrangements allows for a variety of adjustments such that the Strip Plate just clears the inside of the bucket wheel. It is useful to curve the 195d to a radius that matches the inside of the bucket wheel prior to assembly.

Pulley Block

The pulley block for hoisting the boom can be seen hanging loose in Fig. 20a, and attached to the bucket wheel boom in Fig. 20b. The pulley block consists of six 4x5-h Triangular Flat Plates (76b-EX), each bolted to the round hole flange of 3-h Angle Girders (9f) which are bolted to a built-up 3x13-h flat plate. The eight 1 ½" Pulleys (21) are free to rotate on two 3 ½" Axles joined by a Short Coupling. The 21's are spaced by Washers and Washer Spacers (38a) in a similar manner to the 21's higher up in the hoist boom. The end holes of two 9-h Strips (2a) are bolted to the lugs of two Double Brackets (11), the front one bolted by its centre hole to the centre hole of the built-up 13-h angle girder (can be seen immediately behind the bucket wheel in Fig. 23a) that links the front ends of the 53-h angle girders. The rear Double Bracket is bolted to the centre hole of an 11-h Angle Girder (Fig. 20b) which is offset upward from the 5-h Strips bolted to each end by a Washer on each bolt. The offset is needed to align the round holes in the 2a's with the tops of the slotted holes in the 53-h angle girders. The pulley block is held in place by two built-up 7 ½" axles passing through the 53-h angle girders, the 76b's and the 2a's, and held in place by collars. The cord is heavy fishing line.

One pair of slip rings provide DC power for the bucket wheel drive motor, for the bucket wheel conveyor motor and for the discharge conveyor motor described in the next section. The power comes to the 3-h Insulating Flat Girder that can be seen in the right, upper portion of Fig. 11c. Two Socket Adaptor Bolts (613a-MW) receive the Miniature Plugs (612) that can be seen in the lower, right of Fig. 26.

5) Discharge Conveyor

The bucket wheel loads material onto the bucket-wheel conveyor belt described above. In the middle of the machine the material is transferred to the discharge conveyor belt, which carries the material to the back end and dumps it into a truck or a collecting box. The discharge conveyor pivots about a vertical

axis which is coincident with the slewing axis of the superstructure. The bucket wheel can be slewed from side to side while the end of the discharge conveyor remains fixed over the truck. At the Hobby Show, visitors who were familiar with the prototype advised that the back end of the discharge conveyor could be elevated but this feature has not been included in this model.

Both sides of the frame of the discharge conveyor are similar and are 74 holes long. The upper left side is made up of a 49-h (7) and a 25-h (8) Angle Girders, see Fig. 32b. On the upper right side the 7 is replaced by two 19-h Angle Girders (8a) to leave space for the gearhead motor located near the front of the discharge conveyor, Figs. 32a, 32c. A 15-h Strip overlaps the front 8a by four holes and overlaps all three holes of a 3-h Angle Girder at the front of the conveyor frame. The lower sides of the front half of the frame each consist of two 37-h Angle Girders (7a) bolted back-to-back by slotted holes (outside 7a) to round holes (inside 7a) with Braced Girders sandwiched between them (clearly seen in Fig. 33a). The Braced Girders and three 4-h Angle Girders link the upper and lower Angle Girders, see Figs. 32a and 32b. The lower frame on the back half of the discharge conveyor consists of a single 7a on each side, stepped up one hole from the front lower 7a's. The upper and lower Angle Girders are linked by suitable 3-h wide Flat Plates, 3-h Flat Plates, and 3-h Angle Girders at the back end.

The sides are linked along the bottom by an 11-h Angle Girder at the back (Fig. 32d), reinforced by Corner Brackets (133a); by two crossed 15-h Strips, two 11-h Angle Girders at the "step"; and at the front by 11-h Angle Girders linked by an 11-h Braced Girder (Fig. 32c).

The discharge conveyor can slew 180 degrees and this is achieved by a motor and reduction pulleys/gearing, some of which can be seen in Fig. 33a. This mechanism is tucked inside to keep the height of the discharge conveyor as low as possible on the superstructure. However the spacing between the inner 7a's is about 7 1/4" which causes complexities in the centering of a 5x11-h Flat Plate (70) (Fig. 33b) which serves as the upper bearing for the axles of the pulleys/gearing. The Flat Plate is extended in width as little as possible by 9-h Flat Girders (103c) bolted on top by their slotted holes on each side of the Flat Plate, leaving two clear holes at the front of the Flat Plate. The width is extended further by 2-h Flat Girders (103m) bolted by their slotted holes to the 2nd and 3rd holes from the front of, and on top of, the 103c's; and by 3-h Flat Girders (103h) that overlap the 2nd to 4th holes from the back of, and on top of, the 103c's, but are bolted in the 3rd and 4th holes only to avoid fouling the 3" Pulley. A portion of one of the 103h's can be seen in Fig. 33b. The front holes of the 70 are 13 holes back from the front of the discharge conveyor and is secured to the slotted holes of the inside bottom Angle Girder, but offset by one inch by 1" Screw Rod Couplings (one can be seen in Fig. 33b). The mounting bolts are in the front round hole of the 2-h Flat Girders and in the back round holes of the 3-h Flat Girders.

The output shaft of a Canon DC motor is in the centre round hole of a 5-h Flat Girder which has Threaded Couplings extending outwards from its end slotted holes. The Threaded Couplings which can be seen in Fig. 33a are centered between the inside bottom Angle Girders in the 30th hole from the front of the discharge conveyor. A 12" Driving Band Light (non Meccano) links a ½" Pulley (23a) on the motor shaft to a 3" Pulley while making a 90 degree bend around wide pulleys (dual ½" flanged wheels). The Driving Band is encouraged to stay on the wide pulleys by ½" plastic Pulleys without boss (23b) mounted in end hole of Obtuse Corner Brackets (133c). In the following construction Washers are used as required to align the pulleys and gears and to prevent fouling with bolt heads in the Flat Plate (70). The 3" Pulley is mounted, boss down, on a 1 1/4" Axle (18c) located in the back, centre hole of the 70 and in a Triangular Plate (77) bolted to 6-h Flat Girder (103e) (Fig. 33a). A 6" Driving Band on a miniature pulley (23c-EX) mounted on the same Axle below the 3" Pulley drives a 2" Pulley mounted, boss down, on another 1 1/4" Axle journalled in the 70 and in the centre hole of an 11-h Strip as shown in Fig. 33a. A 19-t Pinion (26), boss down, is mounted on the same Axle above the 2" Pulley. The Pinion meshes with a 95-tooth Gear Wheel (27c), boss down, mounted on another 1 1/4" Axle which has its lower bearing in the peripheral hole of a 7 ½" Circular Plate (146e-AB). The bearing is reinforced by a 15-h Strip. The Axle carries another 26, boss down, below the Gear Wheel. This latter Pinion meshes with another 27c mounted, boss down, on yet another 1 1/4" Axle and also carries a further 26, boss up, above the Gear Wheel. (The top ends of all four 1 1/4" Axles can be seen in Fig. 33b.) The last 26 meshes with a 133-tooth Gear Wheel (27b) which is mounted on a 2 ½" triangular Axle (316a) coming up through the centre hole of the 7 ½" Circular Plate. An Exacto version of the 27b was used since it has a more robust boss; there is considerable torque on the boss. The Circular Plate is bolted to the outside Angle Girders on each side (see Figs. 32d, 33a) and to a 5-h Flat Girder bolted to the front lower 11-h Angle Girder.

A word of caution. The 133-tooth Gear Wheel must be bolted as tightly as possible to the 2 ½" triangular Axle. Since the Gear Wheel has its boss down, access to the boss bolts is restricted by the Angle Girders and

the Gear Wheel. An 1/8" screw driver that passes through the holes in the Angle Girders can be used. A better solution would be to substitute the lower, front 11-h Angle Girder by two 5-h Angle Girders and leave a gap to have access to the bolts.

The conveyor belt is made from the same size inner tube as the bucket wheel boom conveyor. The front and back rollers for the conveyor belt, are constructed in the same fashion as the back roller on boom conveyor. It is important to add the crown to each roller. The front roller is free to rotate on a 4 ½" Axle, each end of which journalled in doubled 4-h Flat Girders, the right pair can be seen in Figs. 32a, 38b in front of the bevel gear on the gearhead motor. The top end of the left pair can be seen on the upper right of Fig. 32c. The 4-h Flat Girders are fixed by their slotted holes (to allow alignment of the roller) to the Angle Girders on either side using long bolts. The gearhead motor used here was low speed so a 21-t Bevel Gear (30e-MW) was used on the output shaft of the gearhead motor, and a 42-t Bevel Gear (30f-MW) on the roller. Other gear ratios can be used as appropriate. 3/8" Bolts lock-nutted in the boss of the 30f engage ½" Screw Rod Couplings (63e-MW) tightened on the 3" Screwed Rods holding the Flanged Wheels (20) in the ends of the Cylinder (216a).

The back Cylinder is mounted on a 3 ½" Axle (3 5/8" is ideal, check out your supply of recent French chopped end axles) journalled at each end in miniature pulleys, similar to the front roller on the bucket wheel boom (Fig. 34). 2 ½" Screwed Rods are in the threaded holes of the miniature pulleys and these are journalled on each side in the plain holes of Short Threaded Couplings (64a). The 64a's are bolted by their threaded longitudinal bore to 3-h Flat Girders which in turn are bolted to the upper and lower Angle Girders on each side. It may be necessary to insert two or more washers between the Flat Girders and the Angle Girders to ensure that the threaded bore of the miniature pulleys line up with the plain holes in the 64a's. The back end of the Screwed Rods are journalled in the centre slotted holes of 3-h Flat Girders. 2-h Narrow Strips are bolted to the top slotted hole of the 3-h Flat Girders and permit alignment of the Screwed Rods. A Threaded Boss is fastened by a lock nut to the end of each Screwed Rod, which are used to align the roller and to tighten the conveyor belt.

Three small rollers, consisting of plastic Washer Spacers (38a) mounted on Axles, are used to keep the lower half of the conveyor belt from rubbing on the 5x11-h Flat Plate and other structural members. The front most roller uses a 4 ½" Axle supported at each end by 3-h Narrow Strips bolted to Triangular Plates (77). The 77's are bolted to the 12th and 13th holes (counted from the front end) of the lower Angle Girders, and offset inward by a couple of Washers. The Narrow Strips slope upwards towards the front (Fig. 33b). Each end of the mid roller 4 ½" Axle is supported in the end hole of the long arm of Obtuse Corner Brackets (133c). The 133c's are bolted by their short arm to the 27th and 28th holes (counted from the front end) of the lower Angle Girders. The long arm slopes upward towards the front. A portion of this roller can be seen behind the 3" Pulley in Fig. 33a. The 5" Axle of the rear roller is supported in the 2nd hole (from the front) of the lower, rear 37-h Angle Girder (see 32d and left side of Fig. 33a).

The roller assemblies supporting the conveyor belt are constructed similarly to those on the bucket wheel boom. The rear and middle sections are 25-holes long and are fixed to the upper Angle Girders by 5" Screwed Rods located in the 4th hole from each end of the rear roller assembly, and in the 3rd hole from each end of the middle roller assembly (Figs. 32b, 32d). The Screwed Rods prevent twisting of the discharge conveyor and there has never been a need to remove them. The front roller assembly is 15 holes long (Figs. 35a, 35b). It may be necessary to use a 13-h Obtuse Angle Girder on the right side of the roller assembly if the motor and gears interfere. The front roller assembly is held in place by three spring loaded 3 ½" Axles. The roller assembly is centered by bolting Narrow Obtuse Reversed Angle Brackets (825) to the upper inside Angle Girders of the conveyor frame (two can be seen in Fig. 33b).

As the conveyor can slew through 180 degrees it requires support of the back end. This is achieved by constructing a small tower, Fig. 36. Narrow Obtuse Angle Brackets (812d) are bolted by the end hole of their long arm to the 21st and 29th holes (counted from the front) of the upper Angle Girders on each side. The 812d's can be strengthened by a 2x2-h Corner Bracket (133a). The short arms of the 812d's are extended upwards by 7-h Narrow Angle Girders (275d). 9-h Narrow Strips also join the 812d's on each side. The upper ends of the (275d's) are extended upwards by bolting the short arms of additional 812d's to them, and these are also linked by Narrow 3-h Strips on each side. The long arms of the 812d's are bolted to a Channel Bearing (160). The upper bolts in the 160 also hold additional horizontal 812d's on each side, short arms to the rear, to which are bolted 28-h built-up Narrow Strips, which are in turn bolted to 2-h Narrow Angle Girders (275n-AB), which in turn are bolted to the upper Angle Girders of the conveyor frame. The upper front hole of the 160 holds a ½" Screw Rod Coupling with a centre transverse threaded bore (Mike Dennis). The centre bore will accept a long bolt from a support attached to the superstructure to be described later. A

Narrow Angle Bracket is bolted to the front, bottom hole of the 160. A 3-h Insulating Flat Girder (508) is bolted to the Narrow Angle Bracket but spaced forward from it by a plastic Spacer Washer (38a). Four Socket Adaptor Bolts (613a-MW) are fixed to the four end holes of the 508. Wires from the two electric motors on the discharge conveyor are attached to the 613a's. Mini Plugs (612) attached to wires coming down from the super structure will supply power to the motors (see Fig. 38b).

Slewing Bearing

The support for the discharge conveyor slewing bearing is centered over the Large Axle Coupling that can be seen in Fig. 9. 4-h Angle Girders (9e) are fastened vertically by their round holes to the large box girders on the deck of the superstructure , and spaced from them by a Collar and washer on each bolt (Figs. 37a, 11a, b). The bolts are in the 4th and 16th holes counting from the back end of the horizontal portion of the box girders and the slotted flanges of the 9e's face each other. A 3-h Girder Bracket (161u-AB) is also bolted to the 9th and 11th top inside holes of each box girder, offset by a Collar and washer, long flange down and pointing in. A Bolt in the 2nd slotted hole from the top of the 9e's holds the end round hole of a 3-h Angle Girder (9f) and then the end round hole of a 3-h Flat Girder (103h). 11-h Angle Girders (9) are fixed to the end slotted holes of the 9f's and to the 161u. Two round holes of additional 9e's overlap the two remaining round holes of the 103h's. 11-h Flat Girders (103) are bolted to the 9f's and 9e's, offset up by one washer. Four 3/4" Bolts project up from the 103's and the 161u's onto which the slewing bearing will be fixed.

The slewing bearing is constructed from two Flat Rings (143a-EX) loosely bolted together, but separated by Collars (Fig. 37b). Carefully centre and bolt an 8-h Wheel Disc (24a) to a 4" Circular Plate (146a) (Exacto plates are sturdier), then with the 24a to the inside, bolt a second 146a to the first separated by Nuts and washers. The separation distance is approximately one Collar plus a washer. Slip 35 Ball Bearings (168d) between the 143a's and the 146a's, tighten the bolts holding the 143a's together, and check for minimum play but free rotation. It may be necessary to adjust the spacing between the two 146a's. (It may make more sense to use nuts and washers between the Flat Rings, and Collars between the Circular Plates, as the nuts would then be accessible for adjustment. However it was done the other way around in this construction.) Four of the Bolts holding the 146a's together are 1" long and pass through corresponding holes in the 7 ½" Circular Plate (146e-AB) of the discharge conveyor. The longer bolts protruding through the Flat Rings as seen in Fig. 37b are temporary to hold the Collars in place for the photograph, to be replaced by the 3/4" Bolts that can be seen on the slew bearing support in Fig. 37a.

Before installing the discharge conveyor slewing bearing, centre and fix a Wheel Disc (24a) above and below the centre slotted holes of the middle U-girder of the deck of the superstructure. Attach two 19-h Strips (1a) to the Flanged Ring (168b) (that is fixed to the underside of the deck of the superstructure) so they intersect at the its centre, and pass an Axle through the 24a's and through the centre of the 1a's. Ensure the Axle is perpendicular to the U-girder and turns freely, then tighten the bolts holding the 24a's. Remove the Axle and the 1a's. Place a Collar in the upper cup of the Large Axle Coupling (255-EX) at the centre of the base, and with the spider in place, set the superstructure on the base and tighten the centering guide adjustments against the 168b. Insert the Axle again through the 24a's and into the Collar in the 255 and ensure the Axle is free to rotate. Make adjustments if necessary. Remove the Axle and the Collar. Fix Set Screws (69) in the threaded transverse holes at one end of a Coupling (63) and ensure the heads of the 69's will slip easily into the U-slots cut into the sides of the 255. Thread Bolts (37b) into one of the middle and into one of the other end threaded transverse holes of the 63 and use the 37b's to fix a 2" Triangular Axle (317) in the 63, with the 63 below the 24a's and the 317 protruding up through the 24a's. Fix a 133-t Gear Wheel (27b), boss down, on the upper end of the 317, but leave a small amount of the bore in the boss free to accept the lower end of a 2 ½" Triangular Axle (316a) that can be seen protruding from the boss of the 3" Pulley (19b) in Fig. 37c. Fig. 37d shows the upper end of the 316a protruding through, and fixed to, the boss of the 19b which has been strengthened with Collars that are bolted by their transverse threaded holes to the 19b. The Tyre (142b) against the 27b serves as a slip clutch should the discharge conveyor be manually moved by an over-enthusiastic spectator. The Washer (38d) (which is against the underside of the slewing bearing) and spring hold the Tyre against the 27b. Note that when placing the superstructure over the base, the clutch assembly can move up should the 69's not initially slip into the U-slots of the 255.

Discharge Conveyor Upper Pivot

The discharge conveyor is cantilevered to the back from the slewing bearing and requires an upper support which is shown in Fig. 38a. The second from the rear slotted hole of a 7-h Angle Girder (9b) (clearly seen in the lower centre of Fig. 38a) is bolted on each side of the inner back side of the main upright supports (six holes down from the top of the 25-h Angle Girder). The front slotted hole is bolted to the second from the top, second from the front, hole

of the 7x9-h Flat Plate. The round hole flange of the 9b is up, points in, and should be horizontal. The front round holes of the 9b's are bolted to the end slotted holes of a built-up angle girder (the left end can be seen in the lower right of Fig. 38a, and in Fig. 12) which consists of two 9b's linked by Flat Slotted Strips (215a). The distance between the main upright supports is not a multiple of one half inch, and use is made of the slotted holes in the 215a's to build up the angle girder. A similar built-up angle girder is bolted by its end slotted holes to the second from the back round holes of the 9b's (Fig. 38a). A 7-h Strip extends from these bolts to the 4th slotted hole of the front built-up angle girder. Two 6-h Angle Girders (9c), round holes overlapping, form a U-girder, the front round hole of which is bolted to the top centre hole of the front built-up girder (to the right of the control cabin in Figs. 21, 39a). A Bolt passes through the rear round hole of the U-girder, then through the centre round hole of a 3-h Flat Girder (103h) (slotted holes pointing back, can be seen in Fig. 38a), and through the centre hole of the rear built-up angle girder. The 6-h U-girder is extended to the back on each side by a 2-h Flat Girder (103m) bolted by its front lower round hole to the rear slotted hole of the U-girder. A 3-h U-girder is bolted by its front slotted holes to the rear, lower slotted holes of the 103m's. The front round hole of the 3-h U-girder is bolted to the centre slotted hole of the 103h. 7-h Strips, bolted to the upper, front round holes of the 103m's, extend diagonally up to the front and their front end holes are bolted to the lugs of a 1x2x1-h Double Bracket (11b) which is bolted to the centre of the rear, round hole flange of the 14-h built-up angle girder (can be clearly seen in the upper, right of centre of Fig. 21) which is bolted to the lower U-girders of the front support boom. The rear slotted holes of the 3-h U-girder are linked by 19-h Strips to the lugs of an 11b which is bolted to the centre two holes of the underside of a 14-h built-up angle girder (Figs. 14, 22) bolted the upper support boom. 15-h Angle Girders connect to the centre two slotted holes of this 14-h built-up angle girder and extend down to Threaded Bosses (64) which have a built-up screwed rod (~6 ½") through their transverse threaded bores. The built-up screwed rod is held by lock nuts at each end in the slotted holes of 2-h Angle Girders which are fixed by their round holes to the top of the lower rear balance boom in holes three and four counted from the front (Fig. 22). The 3-h U-girder is extended back one hole by two stacked Flat Trunnions (126a) (Fig. 38a). The apex hole of the 126a is bolted below a peripheral hole of a 6-h Large Axle Bush Wheel (253a-EX), boss up. The 253a is further supported by built-up 8-h angle girders, the front ends of which are bolted to the end, round hole of the 9b's fixed to the inside of the main upright supports. A second 253a (boss up) is fixed by four Bolts to the centre two slotted holes of two 14-h built-up angle girders (upper centre of Fig. 38a) with their round flanges vertical and facing each other and fixed by their slotted end holes to the 9th and 11th holes of the lower balance arm. It is recommended that a straight 18" Axle be run through the bosses of the 253a's down through the Wheel Disc bolted to the slewing bearing and then through the Wheel Discs bolted to the middle U-girder of the superstructure deck. Aeroplane Collars can be fixed in the bosses of the 253a's to centre the Axle. The various slotted holes in the support structure can be used to ensure alignment and that the Axle turns freely.

A 3 ½" Large Axle (256c-EX) is fixed in the bosses of the 253a's. On the 256c above the boss of the lower 253a are mounted a Large Axle Washer (257-EX), a Large Axle Collar (254-EX), and a Large Axle Coupling (255-EX), the 5/16" bore down, free to turn on the 256c. 18-h built-up strips pivot on Bolts held by locknuts in the lower threaded transverse bores of the 255. The lower end two holes of each 18-h built-up strip is bolted to the transverse threaded bores of another 255 (Fig. 38b). A 2" Bolt (111g-MW) in the longitudinal bore of the 255 (place a Collar in the 3/8" portion of the bore) screws into the transverse thread of the Screw Rod Coupling (63e) fixed in the small tower on the discharge conveyor (Figs. 38b, 36). With the discharge conveyor fixed to the slewing bearing and the back end of the conveyor supported, the 2" Bolt can be adjusted in the 63e to ensure the discharge conveyor is horizontal. (A small level placed on the discharge conveyor is recommended while making the adjustment.)

A Threaded Pin (115) is fixed in the rear hole of the lower 253a (Figs. 38a, b). A Collar is fixed to the 115 by Set Screws which also hold a 4-h Narrow Strip (235c) free to pivot on each side of the Collar. A Short Coupling (63d) is held by Set Screws in the lower end holes of the 235c's. A 2" Axle passes through the longitudinal bore of the (63d) and is held in place above by an Aeroplane Collar. The lower end of the Axle is fixed in a Short Threaded Coupling (64a) which has a 2" Screwed Rod fixed by a locknut to its lower end. The Screwed Rod carries a Screw Rod Coupling (63e) by its transverse bore which has a 3-h Narrow Strip (235g) and a Narrow Obtuse Reversed Angle Bracket (825) fixed to the ends. The lower holes of the 235g and 825 carry a 2 ½" Axle which slips into the upper end slotted holes of 3x5 Flexible Plates (188) of the discharge chute. The centre line of the bucket wheel conveyor belt is approximately 1 1/4" to the right of the centre line of the discharge conveyor belt and the discharge chute redirects the excavated material directly onto the discharge conveyor. The 9-h Flat Plates and 2x3-h Corner Brackets (133b) that can be seen in Fig. 35a help direct the material onto

the discharge conveyor belt. The base of the discharge chute (Fig. 38c) consists of a 5x5-h Triangular Flexible Plate (223) edged on the left by Curved Strip (90), and on the right by 2x3-h Obtuse Corner Bracket (133c), a 2" Slotted Strip (55a) and a second 133c. The left side consists of two 188's overlapped 4 holes; use is made of slotted holes for adjustments. The right side consists of two 188's overlapped 3 holes. The sides are connected to the base by Angle Brackets. A 5/8" Bolt on the right and an 1" Bolt on the left are fixed to the lower front holes of the chute and are used to locknut the chute to the slotted holes of the 55a's which are free to pivot on the Axle holding the rear conveyor belt cylinder of the bucket wheel boom.

The same pair of slip rings which provide power to the bucket wheel and conveyor belt motors also provide power to the discharge conveyor belt motor, these wires can be seen in Figs 38a and 38b. Another pair of slip rings provide power for the discharge conveyor slew motor. The Miniature Plugs (612) plug into the four Socket Adaptor Bolts (613a-MW) mounted on the 3-h Insulating Flat Girder which can be seen in Figs. 36, 38b.

6) Operator's Cabin

Four ½" Pulleys, two on each side of the back of the operator's cabin, travel between the outside front pointing slotted flange of a 38-h U-girder located behind the Pulleys, and the back pointing slotted flange of a 37 Angle girder (7a) located in front of the Pulleys. A portion of the top Pulley on each side can be seen in Fig. 39a. Each U-girder is built-up from two 7a's which overlap 36 round holes, the outer U-girder has the right slotted flange one hole higher (see Fig. 39c), the inner U-girder has the left slotted flange one hole higher. The round hole flange of the higher 7a is in front of the round hole flange of the lower 7a. The U-girders are linked to the back side of the right upright support by three 9-h Flat Girders (103c) and a 9-h Strip (2a) braced as can be seen in Figs. 11b, 14, 22, 38b. Two 5-h Angle Girders (9d), round hole flanges vertical and facing each other, are bolted by their slotted holes to the lower Flat Plate of the deck, see Fig. 11c. There is one clear hole between the back end of the 9d and the second from the front horizontal U-girder of the deck. The bottom slotted hole of the operator's cabin U-girders are bolted to the second from back hole of the 9d's. The short arm of two stacked 2x3-h Corner Brackets (133b) is bolted to the bottom two slotted holes on the outside flange the inner and outer U-girders, and the front end hole of the long arm is bolted to the third from the bottom slotted hole of the 7a's (Fig. 11c). The front pair of 7a's are linked at their top end round holes by the end slotted holes of a 5-h Angle Girder (Fig. 39b). Slip two ½" Pulleys without boss (23b) between the slotted flanges, then join the 4th slotted hole from the top of the U-girders to the 3rd slotted hole from the top of the 7a's by an 11-h Strip (2). Fix an 11-h Angle Girder (9) and a 3x7-h Triangular Flexible Plate (224) in the top slotted hole of the U-girder and then bolt the front slotted hole of the 9 to the front hole of the 2 (Fig. 39c). Omit the 224 on the inner U-girder. Link the top round holes of the U-girders using the slotted end holes of a 5-h Angle Girder (9d) (Fig. 39c) (use of a 5-h Strip would have avoided bending the 9d). Stack two 3-h Flat Girders (103h) and fix by their outer slotted holes to the 9d. Run a 3" Axle through the centre round hole of the 103h, and through the centre slotted hole of the front 9d. Add two stacked 3-h Narrow Strips to serve as an adjustable bearing for the Axle. Place a Worm Gear on the Axle Between the Girders and an 1 ½" Pulley (21) on its back end. Place a 3" Axle in the second from back hole of the 2's and fix an 1" Sprocket (96), a 57-t Gear Wheel (27a) (to mesh with the Worm Gear), and another 96 between the 2's. Place two more 96's on a 3" Axle journalled in the middle hole of the long arm of the 133b's at the lower end of the U-girders (Fig 11c).

The floor of the operator's cabin uses a 5x9-h Flat Plate (53a) extended to the front by two 2x3-h Flat Plates (75e-AB) (Fig. 39b). The left side of the cabin (Fig. 12) is connected to the floor by a 7-h Angle Girder (9b) (Fig. 39b) and consists of a 3x7-h (74b) Flat Plate, fixed to the 9b, and extended up by 2x5 Flat Plate (75g-AB). A 6-h Strip (4) fixes the front of the 75g to the 74b, and the round holes of a 6-h Flat Girder (103e) (slotted holes to the back) fix the back of the 75g. The equivalent 4 and 103e can be seen on the right side in Fig. 39a. The top row of holes of the 74b is extended one hole forward by a 4-h Strip (6). The front hole of the 6 is extended upwards by another 6 on each side, which then connect to the front round holes of 9-h Angle Girders (9a). The front 3x6-h Flat Plate (73) is connected to the floor by a 4-h Angle Girder (9e) . The 3x3-h Flat Plate (74) on the right side is connected to the floor by a 3-h Angle Girder. The door consists of a 3x5-h Flat Plate. The rear holes of the 9a's of the roof are connected by a 6-h Angle Girder (9c) which is connected to a 4-h Girder Frame (161) on the floor by a 103e (slotted holes pointing in) on each side of the back of the cabin. 1 1/8" Bolts (head to the front) are fixed in the second from the top slotted holes of the 103e's. The top lug of a Tension Spring (43) and the round hole of a Fishplate are slipped over the shank of each Bolt. The lower lugs of the 43's are held in the end link of a length of Sprocket Chain, and the other end links are hooked on the slotted holes of the Fishplates. Each chain engages the Sprocket Wheels (96) on each side. With reference to Fig. 39a, the top three holes of the 103e on each side overlap the round holes of a 3-h Flat Girder. A further 103e is bolted to the lower hole

of the first 103e fixed to the cabin and to the top hole of the 3-h Flat Girder. This construction allows the cabin to be horizontal while moving the it up and down between the girders. The tilted 103e journals Axles in its round holes which carry the ½" Pulleys without boss. Washers space the 103e's from the Pulleys to ensure bolts do not foul the 37-h Angle Girders. A ½" Bolt fixes a Plastic Spacer (38a) to the third slotted hole down of the 103e forming the back left side of the cabin. The 38a engages limit switches composed of Wiper Arms (533) held by Narrow Angle Brackets to Insulating Flat Girders (507). The 533's are located to prevent the cabin from descending into the deck (Fig. 11c) or ascending into the motor house (Fig. 39a). Wiring for the two limit switches is shown in Diagram 1. Power is provided by a pair of slip rings which feeds into the limit switches and then to the motor. A Corner Flanged Plate (51d) is added to the superstructure deck (Fig. 11c) to represent a step when the operator's cabin is at its lowest point.

Motor House

The front of the deck of the motor house consists of a 5x5 Flat Plate bolted to the front holes of the 11-h Angle Girders (9), extended back by a 2x7-h Flat Plate (75i-AB) transverse across the 9's (Fig. 39b). The 75i is extended further back by a 3-h Flat Girder (103h) fixed by its slotted holes below the 75i. Handrail Supports (136) (Figs. 13, 39c) in the end round holes of the 103h journal a 2" Axle on which pivots the front lower holes of 7-h Braced Girders (97). The front ends of the 97's are fixed to a 3x3-h Flat Plate (74) by 3-h Angle Girders. The roof consists of a 3x7-h Flat Plate connected to the front by an Angle Bracket. The rear ends of the 97's are connected by 4-h Angle Girders (9e) to a 3x5-h Flat Plate which is connected at its lower end to a 3x5-h Flanged Plate, the flanges of which hold a 3x3-h Corner Bracket (133) and a 2-h Girder Bracket (161t-AB) (Figs. 14, 39c). The lower front hole of the 133's has a 3-h Strip bolted to it, the Strip is tilted back to match the tilt of the U-girder. 75i's extend the decking on each side and are held by a 1x2-h Narrow Angle Bracket (812b) (second hole from the front) and by the short flange of the 161t.

7) Setup

An awkward aspect of the model is the weight which means it needs to be split into four components to be transported. Shipping boxes were constructed for the bucket wheel boom, and for the discharge conveyor. The base can be transported simply on the crawler tracks, but the superstructure requires special consideration since the slewing mechanism, consisting of the Flanged Ring and Large Toothed Quadrants, extends down approximately 2 3/4" below the Flat Plates on the underside of the deck. The transportation stand shown in Fig. 40 allows the superstructure to rest on the upper turntable race which was designed to carry the weight. The following steps are recommended when assembling the model:

- Place the base on a solid level surface, ensure all the crawler tracks are correctly positioned over the driving and idler wheels, and between the Flanged Wheels.

- Back off the three adjustable guides in the base turntable.

- Ensure the spider is correctly placed on the lower turn table race.

- Lower the superstructure turntable race onto the spider and ensure the Coupling below the discharge conveyor slewing bearing drops in to the Large Axle Coupling standing up from the centre of the base.

- Tighten the adjustable guides.

- Attach the power cables to the control box, an example of which is shown in Fig. 42. The control box takes 12 to 15 VDC and distributes the power to nine DPDT (double pole double throw) switches (centre off). Only the right switch in Fig. 42 does not require reversing, the bucket wheel and the conveyor belts normally run in one direction.

- Position a stand (an example is shown in Fig. 41) behind the superstructure, remove the upper Nuts from the four slewing bearing bolts and place the discharge conveyor in position. Hold the conveyor in place with at least two Nuts (it will be found that two of the bolts are partially hidden by the Gear Wheel, see Fig. 33b). It will be necessary to move the belt to the side to gain access to the bolts. Firmly fix the 3 ½" Gear Wheel on the end of the Triangular Axle. Put the belt back in place.

- Install the front roller assembly in the discharge conveyor.

- Attach the discharge conveyor upper pivot arm (see Fig. 38b). Ensure that the discharge conveyor is level.

- Plug the four Miniature Plugs in the Adaptor Bolts on the discharge conveyor. Using the control box verify the conveyor belt and the discharge conveyor slew work as expected.

- Position the stand in front of the superstructure, rest the bucket wheel boom on the stand, and position the 8" Large Axle in the Large Axle Couplings on the boom and in the Square Bearing Plates located

in the main upright supports. Tighten the Grub Screws in the Square Bearing Plates. Plug the two Miniature Plugs in the Adaptor Bolts in the 3-h Insulating Flat Girder located near the front of the superstructure (see Fig. 11c).

- Using the control box lower the pulley block to the bucket wheel boom. The cord tends to jump off the 1 ½" Pulleys unless tension is maintained on the cord. When in position insert the two built up axles (see Fig. 20b).

- Hoist the bucket wheel boom clear of the stand; check that the superstructure turntable race makes contact with all Flanged Pulleys on the spider. If the bucket wheel boom is too heavy, a counter balance will be required. A number of 5x11-h Flat Plates can be supported by long bolts below the base plate of the bucket wheel boom hoist (see Fig. 18).

Figure Captions

Figure 1

Completed model of an O&K (Orenstein and Koppel AG) bucket wheel excavator as used in the Alberta Tar Sands near Fort McMurray.

Figure 2a

One of the four crawler track assemblies with one track removed; front is to the left in the figure. The 1 1/4" steel washer has been raised to show the arrangement of bolts and the second washer on the top of the support box.

Figure 2b

View of the underneath of a crawler track frame. Electric motor and gearbox, which are removed, are normally fixed to the Threaded Bosses and the 3/4" Bolts.

Figure 2c

View of the inside on one of the track frames.

Figure 2d

View from the back of one of the crawler track assemblies. One track has been stretched out to show its construction.

Figure 2e

View of the underneath of a crawler track assembly, one track removed to show the placement of a 5" strip to keep the track on the 2" wheels at the front and back. Motor and gearbox in place.

Figure 3

Drive sprocket assembly for the crawler tracks.

Figure 4a

Electric motor and gearbox from above for the crawler track assemblies.

Figure 4b

Another view of the electric motor and gearbox for the crawler track assemblies.

Figure 5a

View from above front of the base.

Figure 5b

Underneath view of the base; the cables are at the back. Note the nine ball bearings resting in the End Cap. The bearings turn on the steel washer that can be seen in Fig. 2a.

Figure 6

Front end of the upside down base.

Figure 7

Side view of the upside down base.

Figure 8a

Superstructure slewing gear viewed from above.

Figure 8b

Another view of the superstructure slewing gear.

Figure 9

View of the base with the spider in place. A Flanged Ring (167b) and a Large Toothed Quadrant (167a) have been temporarily placed on the base to show the location of these components which are fixed to the underside of the superstructure.

Figure 10a

View of the underside of the superstructure to show the location of the 5 U-girders in the deck. The construction of the perimeter of the deck changed from this early photo.

Figure 10b

View of the underside of the superstructure with the Flanged Ring (167b) and a Large Toothed Quadrant (167a) fixed in place.

Figure 10c

View from below of the slewing gear beneath the superstructure. Front of the superstructure is to the upper left in the figure.

Figure 11a

Rear view of the superstructure deck and box girders.

Figure 11b

Another view of the superstructure deck and box girders.

Figure 11c

View of the front, right corner of the superstructure deck, and the lower end of the operator's cabin hoist.

Figure 12

View of the front, left side of the superstructure.

Figure 13

View of the right side of the counter balance boom. The motor house for the operator's cabin is in the forefront.

Figure 14

View from upper right of the counter balance boom; the upper support boom is to the right in the figure.

Figure 15

View of the left upright support.

Figure 16

Hoist assembly for the bucket wheel boom which is located at the rear of the balance boom. The cabin has been hinged back to show the construction.

Figure 17

Hoist assembly for the bucket wheel boom, cabin hinged back.

Figure 18

View of the hoist assembly cabin from below.

Figure 19

View from below of the upper support boom.

Figure 20a

View from below left of the upper support boom, and the pulley blocks for hoisting the bucket wheel boom.

Figure 20b

Lower pulley block fixed by two built-up Axles to the front of the bucket wheel boom.

Figure 21

View of the front right side of the completed model. Operator's cabin is in the centre of the figure. The operator is from one of the junior plastic sets.

Figure 22

View from above right of the upper boom, showing some of the cross bracing.

Figure 23a

View of the left side of the bucket wheel.

Figure 23b

View of the right side and top of the bucket wheel boom.

Figure 24

View from above of the right side of the bucket wheel and front of the boom. Conveyor belt, cylinder and chute removed.

Figure 25

View from the right side underneath of the bucket wheel and front of the boom.

Figure 26

View of the left, upper side of the bucket wheel boom.

Figure 27

View of the underneath rear portion of the bucket wheel boom.

Figure 28

View from underneath of the front left portion of the bucket wheel boom.

Figure 29a

Rear right portion of the bucket wheel boom. The boom pivots on a pair of Large Axle Couplings, one of which can be seen in the lower right of the figure.

Figure 29b

Rear left portion of the bucket wheel boom.

Figure 30a

Upper view of the three removable roller assemblies from the bucket wheel boom, front of each is to the left in the figure. Lower assembly is from the front of the boom; the assembly at the top of the figure is from the back of the boom.

Figure 30b

View from underneath of the three removable roller assemblies from the bucket wheel boom.

Figure 31a

The 3x25-h Strip Plate (195d-AB) curved along its length to match the inside circumference of the bucket wheel and extending from the bottom of the bucket wheel to the front of the chute. The Angle Girders in this figure can also be seen in Fig. 25. The components in this figure are orientated as in Fig. 23b.

Figure 31b

The right side of the 3x25-h Strip Plate and chute assembly viewed from below.

Figure 31c

The left side of the 3x25-h Strip Plate and chute assembly viewed from below.

Figure 31d

View of the underside of a portion of the chute assembly; front of the chute is in the lower part of the figure.

Figure 31e

Close up view of the right side of the chute, and behind it, the sloping left side of the chute showing the 7-h Curved Strips (84-EX).

Figure 31f

View from above of the sloping left side of the chute.

Figure 32a

View of the right side, front, and top of the discharge conveyor.

Figure 32b

View from the back end of the discharge conveyor. The conveyor belt has been moved back to show the roller assemblies. The front roller assembly has been removed.

Figure 32c

View of the front end of the discharge conveyor.

Figure 32d

View of the underneath of the discharge conveyor showing the roller assemblies from below.

Figure 33a

View from below of part of the slewing mechanism for the discharge conveyor.

Figure 33b

View from above of the 5x11-h Flat Plate that journals the 1 1/4" Axles of the discharge conveyor slewing mechanism. The conveyor belt has been moved back and the front roller assembly has been removed.

Figure 34

Back end of the discharge conveyor showing the alignment and tensioning mechanism for the Cylinder.

Figure 35a

Front roller assembly removed from the discharge conveyor, front is to the right in the figure.

Figure 35b

View of the underside of the front roller assembly, front is to the left in the figure.

Figure 36

View of the support tower for the discharge conveyor.

Figure 37a

View of the support structure for the discharge conveyor slewing bearing.

Figure 37b

Top side of the discharge conveyor slewing bearing. The four Bolt ends on the Flat Ring do not protrude further than the other eight once installed in the model. None of the Bolt ends should protrude past the nuts, else they may foul bolts on the bottom of the discharge conveyor.

Figure 37c

The 133-t Gear Wheel is stationary with respect to the base. The tyre on the 3" Pulley serves as a slip clutch should the discharge conveyor be turned manually.

Figure 37d

A method of reinforcing the boss of the 3" Pulley.

Figure 38a

Underside view of the upper support pivot for the discharge conveyor.

Figure 38b

View of the discharge conveyor in place in the superstructure, supported by the arm from the upper pivot. The discharge chute is supported at its back end by its support arm.

Figure 38c

View from below of the discharge chute.

Figure 39a

View of the operator's cabin. The upper limit switch can be seen near the top of the figure.

Figure 39b

View of the underside of the operator's cabin and the motor house.

Figure 39c

View from the back right side of the motor house; the cover is flipped forward.

Figure 40

Top view of the transportation stand for the superstructure. The top is a 21"x24" piece of 3/8" plywood and sits on a frame of 1 ½" x 1 ½" supports. The hole is 13" in diameter.

Figure 41

A support stand is almost essential when installing the bucket wheel boom and the discharge conveyor on the superstructure.

Figure 42

A control box for the 13 motors used in the model. Nine DPDT (double pole double throw) centre-off switches control the following movements:

- Steering of the front pair of crawler track assemblies.

- Steering of the rear pair of crawler track assemblies.

- Power the left pair of crawler track assemblies.

- Power the right pair of crawler track assemblies.

- Slew the entire superstructure.

- Hoist the bucket wheel boom.

- Slew the discharge conveyor.

- Raise/lower the operator's cabin.

- Rotate the bucket wheel and run the conveyor belts. The three functions are controlled by one switch. An off-on switch is all that is required.