Machinery and equipment for utilization of crop residues as feed

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TECHNOLOGY FLOW AND EQUIPMENT

The handling of straw for feed on individual farms in China has mostly been done manually, with the aid of little machinery. However, with increased scales of production and reduced labour force as town enterprises develop and attract away workers, it is inevitable that there will be a gradual move towards mechanization of animal husbandry. Of course, the process will take a long time considering the situation in the country. The purpose of this chapter is to introduce machinery and equipment suitable for different levels of mechanization of straw feeding. It will present types, uses and selection principles of machinery and equipment for upgrading and utilizing straw as feed.

The technical flow from straw collection and processing to feeding could take many routes, from simple to complex, depending on the level of upgrading, the nutritive value of the straw, and commercialization of straw products (Figure 6-1).
Figure 6-1. Technical flow chart of residue processing
Flows and are manual handling systems, some elements of which can be replaced by machines nowadays. Flow is the best processing method to increase intake and utilization of an entire crop without further treatment than the kneading into thread-like pieces. This is appropriate for maize stover of high nutrient value. The final process of flows and is ammonia treatment. The difference between flows and is that is used for whole straw, such as rice and wheat straw, while is suitable for maize stover. The final step of flow is heat extrusion. Its key part is the heat extrusion equipment. Flow shows that, after ammonia and chemical treatment, straw needs to be ground and mixed with nutrients, and finally pelleted or wafered. Straw treated by this method has the advantages of being of high density, easy to store and transport (marketing), reduces waste at feeding and avoids diet selection by the animal.

Both flows and are suitable for ensiling maize or sorghum stover. In flow , harvesting, bundling, transporting, chopping and loading into a trench silo are performed separately, and most of them can be done manually, but the chopper or so-called silage cutter is absolutely necessary. In flow , the residues are harvested, chopped and loaded into the wagon using a combine, then transferred to a silo.

The processes used for upgrading of straw for feeding and the

| Table 6-1. Machinery selection for various technical processes in upgrading straw |
|----------------------------------|----------------------------------|
| Process                          | Machine type                     |
| Straw collection                 | Rectangular baler; round baler; stacker; stationary baler. |
| Loading and transport            | Bale loader mounted on wagon or trailer; round bale wagon; stacker; wagon; trailer. |
| Kneading and cutting             | Kneading and cutting machine. |
| Chopping                         | Cylinder chopper; flywheel chopper. |
| Heat extrusion                   | Heat-extrusion equipment. |
| Ammonia treatment                | Ammonia treatment equipment at normal temperature; heated ammonia equipment; ammoniation tank; ammoniation oven. |
| Grinding                         | Hammer mill; fixed head mill; claw-type mill; double roller mill. |
| Pelleting or wafering            | Pelleting equipment; wafering equipment. |
| Silage cutting, chopping and loading | Silage combine and trailer. |
machinery options are listed in Table 6-1.

COLLECTION, LOADING AND TRANSPORT EQUIPMENT

Collection, loading and transport equipment for long and loose straw

Straw collector
It is used to collect straw into small stacks, or to bring them to a large one. It consists of a collecting platform, left and right handspikes, a frame and a pulley support (Figure 6-2). The collecting platform includes a

![Figure 6-2. Straw collector](image)


collecting fork, a side bar and a fence.
The machine slides forward, with an angle of 5-7° from the ground, to collect straw with the fork. When the fork is full, hydraulic arms are engaged to lift it about 30 cm high from the ground. Then the tractor moves straw to the stack. After lowering the platform, the tractor is backed to unload the straw. There is no stereotype for this machine. Because of its simple structure, users can construct them themselves.

Stacker
There are many types of stacker, including derrick stackers, fan stackers, conveyor belt stackers, slide stackers and hydraulic stackers. For a hydraulic stacker (Figure 6-3), the operation is the following:

(i) the collecting platform is lowered;
(ii) the straw-pushing board (3) is moved back by the hydraulic
(iii) the collecting fork is used to gather the straw until it is full;
(iv) the large arm (6) lifts it;
(v) a hydraulic cylinder opens cover (1);

(vi) the hydraulic cylinder (2) moves the straw pushing board (3) forward and pushes the straw out.

**Figure 6-3. Straw stacker**


**Pick-up-and-press stacker**

This consists of a flail-type pick-up chopper, a blower tube with rectangular cross section, a directing cover, a movable top cover, a chamber, a chamber rear door, and a chain conveyor for discharging (Figure 6-4).

The flail type pick-up chopper is used to pick up and chop straw. The airflow, generated by the high-speed rotation of the chopper, blows straw into the chamber through the tube and directing cover. When the
chamber is full, the tractor stops moving forward. The top cover is moved down by the compression mechanism to press the straw into the chamber, then the top cover is lifted again. The machine continues to go forward picking up straw again. Generally, a stack can be formed by repeating the above process two or three times. In order to discharge (unload) the stack, the tractor is stopped, the rope is pulled to unlock the chamber’s rear door, the hydraulic piston is activated to lift the top cover to its highest position. The chamber’s rear door and the top cover open automatically at the same time and the chain conveyor is engaged automatically to move the stack out. When the stack touches the ground, the tractor is driven forward slowly so as to unload the stack on the ground.

The technical parameters of the 9JD-3.6 pickup stacker made in Qiqihaer agricultural and livestock machinery plant are:

Overall dimensions (cm): length, 724; width, 398; height, 458.5
Net weight: 4 200 kg
Chamber volume: 33 m³
Power source: 44.4-73.5 kW tractor
Working width: 198 cm
Stack dimensions (cm): length, 430; width, 260; height, 300
Stack weight: ca 3 000 kg
Stack density: 70-110 kg/m³

Stack wagon (stack conveyer)
When the straw stack made by the pick-up-and-press stacker is to be used, it needs to be transported to the feeding site by the stack wagon. The stack wagon (Figure 6-5) is a large platform supported by wheels. On the platform, there are three conveying chains with claws driven by a hydraulic motor fitted at the rear of a pick-up roller and a supporting roller. In operation, the wagon is backed up to the stack. The platform is tilted by the hydraulic cylinder so that the rear roller touches the ground. Then the pickup roller is inserted under the stack. The stack is moved up onto wagon by the combined action of the pickup rollers and reversing of the tractor. When the stack is on the wagon, the platform is returned to the horizontal position and can move off with the stack. After arriving at the feeding site, the platform is tilted again; the chain conveyors are driven in reverse to unload the stack.

The technical parameters of the 7DY-3.6 stack wagon made in Qiqihaer Agricultural and Livestock Machinery Plant are:

Figure 6-5. Stack wagon

Balers
An baler is a machine used to compress hay or straw into bales for easy transport and storage. A baler is the simplest minimum package for marketing.

Balers are divided into stationary balers and field balers. They are further classified into rectangular balers and round balers according to the bale shape produced. According to density of bale, they could be high (200-350 kg/m³), medium (100-200 kg/m³) or low density (<100 kg/m³) balers.

Rectangular pick-up baler
The 9KJ-1.4A rectangular pick-up baler (Figure 6-6), made by the Inner Mongolia Baochang Livestock Machinery Plant, is used as an example for the general structure and function of rectangular pick-up balers. It makes bales from the straw windrow left by the combine. The machine consists principally of a pick-up reel, a conveying and feeding system, a compressing chamber, a bale density adjuster, a bale length controller, a needle-and-tying mechanism, a crank-linkage mechanism, a power transmission, and hauling system.

It is powered from the power take-off (PTO) of the hauling tractor. The straw windrow is lifted from the ground by a pick-up reel having spring teeth (14) and transferred continuously to a conveying and feeding mechanism (3) as the baler moves forward along the windrow. The conveying and feeding mechanism (3) pushes individual charges of hay into the bale chamber (6) from the side at intervals when the piston (2) is withdrawn. The piston reciprocates under the function of the crank-linkage mechanism to press the material into the bale. When the bale reaches the required length, the needle-and-tying mechanism is engaged automatically to bind the bale, which is then pushed out from the chamber by successive bales and is discharged to the ground.
Rectangular bales can be lifted and loaded either by hand or by a loading machine mounted on the side of a truck or trailer and driven by a ground wheel. The Jilin Baicheng Agricultural and Livestock Machinery Factory also make this kind of baler, model 9JKC-2.7.
Basic specifications of the 9KJ-1.4A rectangular baler:

- **Overall dimension (cm):** length, 480; width, 270; height, 145
- **Power source:** 22 kW from tractor PTO
- **Working speed and output:** 5 km/hour; 5000 - 7000 kg/hour
- **Piston frequency:** 70-80 strokes per minute
- **Feed rate:** 1.5-2.5 kg per cycle
- **Nominal pick-up width:** 141.4 cm
- **Working width:** 160 cm
- **Bale size (cm):** Length, 60-120; width, 46; height, 36
- **Bale weight and density:** 15-25 kg; 100-180 kg/m³
- **Baler net weight:** 1480 kg

**High density baler**

The 92FY-300 high density baler (Figure 6-7) manufactured by the Inner Mongolia Yakeshi Forestry Machinery Plant is taken as an example to describe basic structure and working process. It is a stationary baler equipped with front and rear wheels. It can be hauled to the working site by a tractor. The density of the bale reaches 300 kg/m³. An electric or diesel motor or the tractor's PTO can supply the power (17 kW). A belt, a chain and a gear by a linkage mechanism drive an eccentric axis that moves the piston back-and-forth. At the same time, the conveying mechanism moves up-and-down to feed the straw into the compression chamber. The bales are fastened with three steel wires (diameter, 2 mm;
Basic specifications are:

- Overall baler dimensions (cm): length, 77; width, 150; height, 254 cm
- Net weight of the baler: 4 tonne
- Bale size (cm): length, 50-65; width, 36; height, 46 cm
- Bale weight: 30-35 kg
- Piston displacement: 62 cm
- Piston frequency: 30 times per minute
- Output: 50-80 bales per hour
- Reference price: ¥ 35 000

Round baler

The round baler is a new kind of pickup baler. The bales are round, 90-200 cm in diameter. It has the advantages of simple structure and convenience for adjusting and use. The round bales resist the rain, are convenient for feeding and adapted to outside storage. They also save on wire. As a result, they are being increasingly used.

Based on the form of working unit, round balers can be classified into long-belt type, short-belt type, chain type and roller type. They are also classified into inside winding type and outside winding type by their working principle. Long-belt and chain types are inside winding; short-belt and roller types are outside winding.

Figure 6-8 illustrates a belt, inside winding pick-up baler that consists of a pick-up reel, a conveying and feeding mechanism, a wrapping and pressing mechanism, a rear door for unloading, a transmission mechanism and a hydraulic operating mechanism. Its working process is shown in Figure 6-9. The windrow is lifted by a pickup reel (4) and rolled up to double smooth rollers (3) where it is pressed into a flat layer, then conveyed to the baler chamber. With the upper belt the straw moves upward by friction to a certain height, then rolls down to the lower belt by gravity to form the core of the bale, which continually rolls, increasing the diameter. When the bale reaches the desired size it is discharged from the lower belt. The springs fixed in the swing arms in the two sides of the bale chamber...
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Figure 6-8. Inside wrapping pick-up round baler


Figure 6-9. Operating principle of the wrapping and pressing mechanism

STAGES: A. Forming the core of the bale. B. Making the bale. C. Discharging the bale


maintain the pressure of the belt on the bale's surface. The pressure increases with bale size, resulting in low density on the inside of the bale but high density on the outside. Inside wrapping means that the volume of the wrapping and pressing chamber enlarges during pressing to keep a constant pressure on the bale. The bales formed by inside wrapping have much higher density than by outside wrapping and keep their shape for longer during storage. However,
the structure of an inside wrapping baler is more complicated. When the bale reaches the desired size, an indicator alerts the driver to engage the hydraulic distributor in order to activate the binding mechanism. The twine is passed by the tube and fed with straw to the chamber. The twine is wrapped around the circumference of the bale, then cut by a blade. The rear door is lifted hydraulically. The bale is then discharged to the ground.
The round baler manufactured by the Jilin Baicheng Agricultural and Livestock Machinery Plant belongs to this type. Its specifications are:

- **Overall dimensions (cm):** length, 485; width, 245; height, 243
- **Net weight:** 1,900 kg
- **Power source:** 40.4 kW from tractor hydraulic system
- **Working speed and output:** 5 km/hour; 8-12 bale/hour
- **Bale weight:** 450-500 kg
- **Bale diameter and width:** 180 cm; 150 cm
- **Width of pick-up:** 140 cm

Round bales must be loaded, transported and unloaded by machine due to their heavy weight. The 7KY-4 round bale transporting wagon made in China is hydraulically driven and equipped with an automatic pickup mechanism. It can pickup and load round bales with flexibility and accuracy. Four bales can be transported simultaneously.

Harvesting machine for maize silage

Several new cultivars of maize have been popularized in large areas of China, and some of these cultivars have a green stalk at harvest, so they are fit for ensiling. Stover can be harvested, chopped and loaded by a long-stalk cutting platform fitted to a silage harvester (also called a silage combine), and then put into the silo. The 9SQ-10 cylinder-type forage
harvester made by the Chifeng Livestock Machinery Plant belongs to this type. When the machine is equipped with a long-stalk cutting platform, its parameters are as follows:

Dimensions (cm): length, 620; width, 310; height, 288.6

**Figure 6-11.** 93ZT-1000 straw chopper


**Figure 6-12.** Chopping action of cylinder-type straw chopper

Weight: 1 180 kg;
Power supply: 40.4-58.8 kW from tractor
Cylindrical chopping device:
  cylinder rotation speed: 1 120 rpm;
  cutting blades: 6
  harvesting rows: 2

The Beijing Combine Factory has designed a self-propelled maize harvester (model 4YZ-4) that accomplishes picking, husking, ear collecting, stover and leaf chopping, and returning to the ground or throwing into a trailer as a single-pass operation. It is well suited to harvest maize before sowing wheat. It harvests four 70-cm rows with an efficiency of 1-2.5 ha/hour. The engine power is 110.25 kW, and its weight is 9 tonne. The reference price is ¥ 150 000.
CROP RESIDUE PROCESSING MACHINES

Choppers

The chopper is mainly used for stalk forage, such as rice straw, wheat straw, maize stover and maize for ensiling. Straw choppers can be classified by size into small, medium and large. The small-size chopper is mainly adapted for chopping dry straw or silage on small-scale farms. The large chopper also called a silage chopper is mainly used for silage on cattle farms. The medium chopper is normally suited to cutting dry straw and silage, so it is called a straw-silage chopper.

Choppers can be divided into cylinder or flywheel types, according to the mode of cutting. Large- and medium-size choppers are generally flywheel types, to facilitate throwing silage, but the majority of small choppers are cylinder type. Large and medium choppers are usually

![Structure of a 932P-1000 type chopper](image)

**Figure 6-14. Structure of a 932P-1000 type chopper**

### Table 6-2. Some chopper types, their technical parameters and manufacturers in China

<table>
<thead>
<tr>
<th>Model</th>
<th>Type &amp; Speed (rpm)</th>
<th>Cutting length (mm)</th>
<th>Power (kW) &amp; Capacity (kg/hour)</th>
<th>Weight (kg) &amp; Size (km/60; cm)</th>
<th>Price (¥)</th>
<th>Maker</th>
</tr>
</thead>
<tbody>
<tr>
<td>932P-400 Straw chopper (Feima)</td>
<td>800</td>
<td>15, 35</td>
<td>0.75</td>
<td>400</td>
<td>730</td>
<td>(1)</td>
</tr>
<tr>
<td>932F-1000 Straw chopper (Feima)</td>
<td>800</td>
<td>15, 35</td>
<td>3.0</td>
<td>1000</td>
<td>1190</td>
<td>(1)</td>
</tr>
<tr>
<td>932F-1600 Straw chopper (Feima)</td>
<td>800</td>
<td>15, 35</td>
<td>4.0</td>
<td>1600</td>
<td>1236</td>
<td>(1)</td>
</tr>
<tr>
<td>932F-400 Straw and veg. chopper (Feima)</td>
<td>500</td>
<td>5, 7, 15, 35</td>
<td>0.75</td>
<td>400</td>
<td>706</td>
<td>(1)</td>
</tr>
<tr>
<td>90F-25 Sludge chopper (Feima)</td>
<td>800</td>
<td>15</td>
<td>6.5</td>
<td>1000</td>
<td>2200</td>
<td>(1)</td>
</tr>
<tr>
<td>90F-40 Straw chopper</td>
<td>700</td>
<td>13, 22, 35</td>
<td>13.0</td>
<td>4000</td>
<td>6300</td>
<td>(2)</td>
</tr>
<tr>
<td>PCG-80 Sludge chopper</td>
<td>450</td>
<td>6-106</td>
<td>10.0</td>
<td>9000</td>
<td>6300</td>
<td>(2)</td>
</tr>
<tr>
<td>90P-16 Straw and veg. chopper (Feima)</td>
<td>800</td>
<td>15, 35</td>
<td>3.0</td>
<td>2000</td>
<td>600</td>
<td>(3)</td>
</tr>
<tr>
<td>90F-100 Sludge chopper (Feima)</td>
<td>800</td>
<td>9, 20, 25</td>
<td>4.0</td>
<td>2000</td>
<td>1400</td>
<td>(4)</td>
</tr>
<tr>
<td>932T-1000 Straw chopper (Yue)</td>
<td>800</td>
<td>13, 25</td>
<td>3.0</td>
<td>1600</td>
<td>1188</td>
<td>(5)</td>
</tr>
<tr>
<td>90F-4 Straw chopper</td>
<td>Cylinder</td>
<td>15-20</td>
<td>5.5</td>
<td>2000</td>
<td>4100</td>
<td>(6)</td>
</tr>
<tr>
<td>90F-8 Straw chopper (Xiamen)</td>
<td>Flywheel</td>
<td>15, 14</td>
<td>n.a.</td>
<td>12000</td>
<td>15000</td>
<td>(6)</td>
</tr>
<tr>
<td>90C-10 Straw chopper</td>
<td>Cylinder</td>
<td>13, 26</td>
<td>3.0</td>
<td>1600</td>
<td>800</td>
<td>(7)</td>
</tr>
<tr>
<td>90C-9 Straw chopper</td>
<td>Cylinder</td>
<td>6, 10, 25</td>
<td>10.0</td>
<td>Sludge 6000</td>
<td>5700</td>
<td>(8)</td>
</tr>
<tr>
<td>932F-2500 Straw chopper (Xiamen)</td>
<td>850</td>
<td>8-25</td>
<td>7.5</td>
<td>2000</td>
<td>2300</td>
<td>(9)</td>
</tr>
</tbody>
</table>

**NOTE:** n.a. = Information not supplied.

**KEY TO MANUFACTURERS:** (1) Liaoning Fengcheng Congfang Machinery Plant. (2) Beijing Linhai Agricultural and Livestock Machinery Plant. (3) Beijing Yanjing Livestock Machinery Co. (4) Shijiazhuang Agricultural and Livestock Machinery Plant. (5) Inner Mongolia Wulanhot Livestock Machinery Plant. (6) Shandong Feicheng Chopper Plant. (7) Henan Fugou Scientific Instrument Plant (Moa). (8) Shandong Xi'an Livestock and Milk Machinery Plant. (9) Xinjiang Livestock Machinery Plant.
equipped with road wheels for easy movement, while small-size choppers are normally stationary.

Cylinder choppers

There are many types of cylinder chopper. The 93ZT-100 chopper (Figure 6-11), made by Wulanhaote Livestock Machinery Factory in Inner Mongolia, is taken as an example to describe the structure of a chopper.

The machine consists primarily of mechanisms for feeding, chopping, and throwing, with a transmission, a clutch and a frame. The principles of operation are illustrated in Figure 6-12.

The main parts of the feed mechanism are a chain conveyor, pressing rollers, and upper and lower feed rollers. For the upper feed roller, springs are used for pressure, with a cross-groove shaft coupled with a compact structure for driving. The chopping and throwing mechanism is in one unit, which consists of a main shaft, a blade rotor, rotating blades, a throwing vane and stationary blades. Gear teeth are 13, 22, 65 or 56. By changing the gear used, the speed can be adjusted to obtain various cutting lengths.
Flywheel choppers

Flywheel chopper operation is illustrated in Figure 6-13, showing a feed chain, upper and lower feed rollers, a stationary lower blade, a cutter and a throwing fan. The straw is fed via the feed chain into the feed rollers, pressed and moved forward by them, then cut into pieces by the combination of upper and lower blades, and it is finally blown by the fan to the storage site or silo.

![Figure 6-16. Tangential-feed grinder](image)


Figure 6-14 shows the outline of a 93ZP-1000 straw chopper produced by the Liaoning Fengcheng Donsfeng Machinery Factory. Its output is 1 000 kg/hour, the length of chopped pieces are 15 mm or 35 mm and the rotary speed of the main shaft is 8 000 rpm. It has 2 movable blades, a power supply of 3 kW from an integral motor, weighs 110 kg, and its overall dimensions are 95 cm long, 98 cm wide and 140 cm high.
Some types of straw choppers, their technical parameters and their manufacturers in China are shown in Table 6-2.

Grinders
Grinding methods and grinder types
There are four main grinding methods: impacting, grinding, crushing and sawing (see Figure 6-15). Impacting is suitable for hard and brittle raw materials, such as maize feed; sawing is better for large and fragile feed; and crushing and grinding are used for tough feed.
Many mills combine different methods. Those commonly found are hammer, fixed head, claw and roller mills. The hammer mill is well suited for straw feed. The roller mill uses a pair of opposed toothed rollers that rotate simultaneously in opposite directions and at different speeds to grind the feed. Roller mills are mainly used for grinding oil cakes. The principles of operation are illustrated in Figure 6-15 (5).

Hammer mills

Hammer mills grind material by the impact of a high-speed rotary hammer. Hammer mills are either tangential-feed or axial-feed types, according to their structure.

Figure 6-16 shows the structure of the 9FQ-50 tangential-feed mill made by the Hongxing Machinery Factory in Jiangxi Province. The mill comprises a feeding part, a grinding chamber and a collector. The feeding part comprises a feed hopper and a feed control flap. The grinding chamber consists of a rotary disk, a hammer, a serrated plate and a screen. The major parts of the collector include a fan, a feed conveying tube and a collection hopper.
Fed from the feed hopper in a tangential direction, the material is impacted and driven to the grinding chamber by the rotating hammers with high speed. The material in the grinding chamber is firstly hit and ground to some extent by hammers, and then thrown at high speed at the serrated plate and the peripheral screen fixed inside the chamber to be further ground through impact with the serrated plate and friction with the screen.

The process then repeats until the particles pass through the screen and are discharged from the grinding chamber. The process inside the grinding chamber includes the functions of impacting, shearing and kneading, which improves the efficiency of grinding. The feed product is sucked from the discharging door to the conveying tube by a fan, then enters the collection hopper, and is finally discharged from the collection hopper after the meal settles out from the air stream.

The axial-feed mill (Figure 6-17) differs from the tangential-feed mill in both the direction of feeding and in primary cutting action. Straw fed from the axial-feed hopper is firstly chopped into small pieces by the primary cutting mechanism fixed in front of the grinding chamber, and these pieces then fall into the grinding chamber. Thus the load on the grinding chamber is reduced; and the feeding capability and efficiency of processing improved. The axial-feed mill is especially suited to grinding straw with high moisture content.

The advantages of the hammer mill are high productivity, wide application and fine particle output. It can be used to mill maize, concentrate feed, green grass and various straws with high moisture and fibre content, so it is also called a grass powder miller. However, energy consumption is high.

The fixed-head mill differs from the hammer mill in that its blade is fixed to the rotary disk rather than connected to it by a pin, so it has much higher grinding capacity.

Claw mills
Claw mills hit and grind material with claws fixed in a rotating disc, and are suitable for concentrate grinding because of compact structure, small volume and light weight.
### Table 6-3. Characteristics of some grinders produced in China

<table>
<thead>
<tr>
<th>Model and Type*</th>
<th>Speed (mm)</th>
<th>Output (kg/h)</th>
<th>Capacity (kg/h)</th>
<th>Power (kW)</th>
<th>Weight (kg)</th>
<th>Price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Rotor A</td>
<td>Screen</td>
<td>Maize</td>
<td>Straw</td>
<td>Maize</td>
<td>Straw</td>
</tr>
<tr>
<td>9FQ-40B Feed</td>
<td>3800 rpm</td>
<td>95</td>
<td>800</td>
<td>160</td>
<td>880</td>
<td>3200 rpm</td>
</tr>
<tr>
<td>mill (Fengzhou)</td>
<td>400; 3</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>9GF-50B Feed</td>
<td>3200 rpm</td>
<td>95</td>
<td>800</td>
<td>160</td>
<td>880</td>
<td>3200 rpm</td>
</tr>
<tr>
<td>mill (Fengzhou)</td>
<td>500; 1.2</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>6FC-308A Feed</td>
<td>3800 rpm</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>mill [Fixed head]</td>
<td>300; 3</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>9FQ-40-20 Feed</td>
<td>n.a.</td>
<td>n.a.</td>
<td>1000</td>
<td>170</td>
<td>850</td>
<td>3600 rpm</td>
</tr>
<tr>
<td>mill [H]</td>
<td>n.a.</td>
<td>n.a.</td>
<td>1000</td>
<td>170</td>
<td>850</td>
<td>3600 rpm</td>
</tr>
<tr>
<td>9F-45A High efficiency feed</td>
<td>3600 rpm</td>
<td>90</td>
<td>900</td>
<td>190</td>
<td>120</td>
<td>880 rpm</td>
</tr>
<tr>
<td>mill (Fengzhou)</td>
<td>400; 1.2</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>9F-40 Feed</td>
<td>3600 rpm</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>mill [H]</td>
<td>n.a.</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>9F-50A Feed</td>
<td>3600 rpm</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>mill [H]</td>
<td>n.a.</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>9FS-50A Feed</td>
<td>3600 rpm</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>mill [C]</td>
<td>n.a.</td>
<td>n.a.</td>
<td>600</td>
<td>150</td>
<td>120</td>
<td>900 rpm</td>
</tr>
<tr>
<td>9SF-50 Straw</td>
<td>3437 rpm</td>
<td>134</td>
<td>1518</td>
<td>15</td>
<td>845</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>Mill (Hongxing)</td>
<td>500; 1.2</td>
<td>76</td>
<td>706</td>
<td>15</td>
<td>845</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>9FQ-40-20 Feed</td>
<td>3730 rpm</td>
<td>130</td>
<td>1000</td>
<td>7.5</td>
<td>180</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>mill (Hongxing)</td>
<td>400; 2</td>
<td>22</td>
<td>165</td>
<td>7.5</td>
<td>180</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>9F-50 Feed</td>
<td>3440 rpm</td>
<td>69</td>
<td>884</td>
<td>13</td>
<td>488</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>mill (Hongxing)</td>
<td>500; 1.2</td>
<td>13.7</td>
<td>175</td>
<td>10</td>
<td>488</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>9F-37-1 Feed</td>
<td>4000 rpm</td>
<td>40</td>
<td>250</td>
<td>7.5</td>
<td>128</td>
<td>690 rpm</td>
</tr>
<tr>
<td>mill (Jinling)</td>
<td>370; 1</td>
<td>n.a.</td>
<td>50</td>
<td>7.5</td>
<td>128</td>
<td>690 rpm</td>
</tr>
<tr>
<td>9F-500 Feed</td>
<td>3280 rpm</td>
<td>&gt;125</td>
<td>850</td>
<td>11</td>
<td>200</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>mill (Dangyu)</td>
<td>800; 2</td>
<td>&gt;20</td>
<td>400</td>
<td>11</td>
<td>200</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>9F-400 Feed</td>
<td>3000 rpm</td>
<td>&gt;142</td>
<td>600</td>
<td>7.5</td>
<td>150</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>mill (Dangyu)</td>
<td>400; 2</td>
<td>&gt;25</td>
<td>250</td>
<td>7.5</td>
<td>150</td>
<td>1050 rpm</td>
</tr>
<tr>
<td>9SF-850 Straw</td>
<td>2500 rpm</td>
<td>107</td>
<td>800</td>
<td>11</td>
<td>2157.2741005</td>
<td>3200</td>
</tr>
</tbody>
</table>

**NOTES:** *Types are [H] = hammer; [C] = claw. n.a. = information not provided.

**KEY TO MANUFACTURERS:**
- [1] Beijinntexnaxan Grinder Plant
- [2] Shandong Hugan Farm Machinery Plant
- [3] Inner Mongolia Ningcheng General Machinery Plant
- [4] Liaoning Fengcheng Machinery Plant
- [5] Heilongjiang Angmg Farm and Livestock Plant
- [8] Shandong Taishan Farm and Livestock Machinery Plant
- [9] Xinjiang Livestock Machinery Plant
Figure 6-19. Illustration of kneading machine structure


Table 6-4. Characteristics of some kneading machines in China

<table>
<thead>
<tr>
<th>Model and type*</th>
<th>Rotor Ø (mm)</th>
<th>Rotor speed (rpm)</th>
<th>Power Capacity (kW)</th>
<th>kg/h</th>
<th>Weight (kg)</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>93RD-40 Straw Kneading</td>
<td>400</td>
<td>2680</td>
<td>7.5 x 10</td>
<td>100</td>
<td>120</td>
<td>190</td>
</tr>
<tr>
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<td>1050</td>
<td>n.a.</td>
<td>13712589</td>
<td>1.550</td>
</tr>
<tr>
<td>93RD-40 Straw Kneading</td>
<td>400</td>
<td>2680</td>
<td>7.5 x 18</td>
<td>120</td>
<td>190</td>
<td>1368127</td>
</tr>
<tr>
<td>Machine [H]</td>
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<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>1368127</td>
<td>2.000</td>
</tr>
<tr>
<td>K-67-50 Straw Kneading</td>
<td>500</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Machine [H&amp;B]</td>
<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>9FB-1.5 Straw Kneading</td>
<td>500</td>
<td>1500</td>
<td>17 x 22</td>
<td>n.a.</td>
<td>16050122</td>
<td>2.500</td>
</tr>
<tr>
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<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>16050122</td>
<td>2.000</td>
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<tr>
<td>9FB-0.7 Straw Kneading</td>
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<td>5.5 x 10</td>
<td>n.a.</td>
<td>1323789</td>
<td>1.600</td>
</tr>
<tr>
<td>Machine [H&amp;B]</td>
<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>1323789</td>
<td>1.000</td>
</tr>
<tr>
<td>9FBRL-50 Multi-function feed</td>
<td>500</td>
<td>1500</td>
<td>7.5</td>
<td>n.a.</td>
<td>95</td>
<td>1.500</td>
</tr>
<tr>
<td>Kneading Machine [H&amp;B]</td>
<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>21554150</td>
<td>1.000</td>
</tr>
<tr>
<td>9FC-40 Straw Kneading</td>
<td>400</td>
<td>1500</td>
<td>7.5</td>
<td>n.a.</td>
<td>180</td>
<td>1.600</td>
</tr>
<tr>
<td>Machine [H]</td>
<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>180</td>
<td>n.a.</td>
</tr>
<tr>
<td>9FC-40B Straw Kneading</td>
<td>400</td>
<td>1500</td>
<td>4</td>
<td>n.a.</td>
<td>750</td>
<td>0.500</td>
</tr>
<tr>
<td>Machine [H]</td>
<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>750</td>
<td>0.200</td>
</tr>
<tr>
<td>9SF-45 Straw Kneading</td>
<td>450</td>
<td>1500</td>
<td>4</td>
<td>n.a.</td>
<td>50</td>
<td>1.000</td>
</tr>
<tr>
<td>Machine [H]</td>
<td>2500</td>
<td>1360</td>
<td>1050</td>
<td>n.a.</td>
<td>50</td>
<td>0.200</td>
</tr>
</tbody>
</table>

NOTES: *machinetypeare [D] = disc; [H] = hammer; [H&B] = hammer and blade.

n.a. = information not supplied

KEY TO MANUFACTURERS: (1) Liaoning Fangcheng Machinery Plant. (2) Beijing Linhai Farm and Livestock Machinery Plant.
(3) Henan Changzhou Machinery Plant. (4) Inner Mongolia Chifeng General Livestock Plant.
(5) Henan Changzhou Machinery Plant. (6) Henan Changzhou Mechanical and Electrical Equipment Plant.
(7) Jilin Jilin Farm Tool Plant. (8) Shanxi Xi'an Livestock and Milk Equipment Plant.
Figure 6-18 illustrates the structure of a claw mill with its feeding, grinding and discharging parts. The feeding includes a feed hopper, a feed control door and a feed tube. The grinding part consists of a rotary serrated disk, a stationary serrated disk and a ring screen. Claws are fixed on the rotary and the stationary disks alternately. The discharging part is a tube situated in the bottom of the machine.
After flowing into the grinding chamber from the feed hopper via the feeding door, the material is impacted, sheared, kneaded and gradually rubbed by claws into powder. At the same time, the airflow formed by high-speed rotation of the rotary serrated disk blows the powder out through the ring screen.

Factors influencing the effects of grinding

1. Type of material to be ground. The grinding output with the same energy consumption differs according to raw material. Output with cereal feed is higher than with roughage. With a screen hole diameter of 1.2 mm and a moisture content below 15 percent, the output in kg/kW is 45-60 for maize and sorghum; 17-22 for chaff; 12-16 for sweet potato vines; 8-12 for maize stover; 7-12 for sorghum stover; 6-10 for legume straw; and 3-4 for maize cobs (2 mm screen hole diameter).

2. Moisture content. The higher the moisture content, the lower the output and the poorer the energy efficiency. Generally, moisture content should not be higher than 15 percent.

3. Rotary speed of main shaft. Each type of mill has a range of
rotary speeds for the main shaft to obtain high output and low energy consumption for each feed. If the rotary speed is too low, the grinding capacity is decreased and feed discharge is hampered, so productivity is also reduced. In contrast, if the rotary speed is too high, idle energy consumption is increased, as well as wear, tear and vibration, and the total energy consumed is higher. The line speed for hammer mills made in China in recent years is about 70–90 m/sec.

(iv) Feed rate. If the feed rate is too high, ground feed cannot be discharged from the grinding chamber at the same rate, which results in clogging, which affects capacity. In contrast, if the feeding rate is too low, the milling capacity is not fully used and efficiency decreases.

The main mill types made in China are listed in Table 6-3.

Kneading machines
The kneading machine is a new kind of straw processing technique developed in China, combining chopping with grinding. The machine processes residues, especially maize stover, into thin thread segments of 8-19 cm, completely destroying its node structure. Palatability is greatly improved, and the intake of the entire crop is also increased to 95 percent from the original 50 percent. The structure of the kneading machine is shown in Figure 6-19. In operation, the rotor, diameter 40 cm, rotates at a high-speed (2 856 rpm) driving 16 hammers arranged in 4
groups, which impact the straw fed continually. A tilted serrated plate, whose teeth are arranged helically and with changeable height, and 6 stationary blades are fixed to the concave plate of the machine, in order to keep the impacted straw moving in axially with the help of a fan. Taking the 9RC-40 kneading machine, made by the Beijing Linhai Agricultural and Livestock Machinery Plant, as an example: the power supply is 7.5 -13 kW (the machine can also be driven by 8.82 -11.0 kW from a four-wheel drive tractor) and the output of model I is up to 1 000 kg/hour, with 2 000 kg/hour from model II.

The kneading machine can increase straw utilization considerably simply by physical processing and it is well suited for maize stover, which already has high nutrient value. Energy consumption is high, 1 to 2 times that of a normal chopping machine of the same output, because the final particles are finer. Because straw can also be softened during ensilage or ammoniation, this chopper can meet animals’ requirements when they do not directly eat straw.

The main types and technical parameters of the kneading machines
made in China are shown in Table 6-4.

Kneading and cutting machines

Kneading and cutting machine models 9LRZ-80 (Figure 6-20) and 9RZ-60 (Figure 6-21) were designed by the Non-conventional Feed Institute, China Agricultural University. They passed appraisal by MOA in 1998. The appraisal said that the machines were an innovation in China, with world-leading performance.

Kneading and cutting machines combine cutting, kneading and mixing in one operation. Maize stover, wheat and rice straw, bean vine and tuber vine can be processed to thread-like soft material.

The future developments of the series include the replacement of the cutting blades in the chopper by running blades; and the incorporation of a hammer in the kneading machine and of a mixing rotor in the mixer. There are now 16 running blades and 6 sets of fixed blades. Changing
the number of running blades and fixed blades will alter the cutting length and softness. The material will be thrown to the inner region of the cylinder, and will be chopped, cut and kneaded to thread-like form. When tubers and concentrate are fed into the machine together, material will be cut and mixed.

The new series has the following advantages:

The new axle structure increases the feeding capacity.
In the working cylinder, the running and the fixed blades will cut and knead at same time, so that energy can obviously be reduced.
By simply changing blade numbers, different lengths and softness can be obtained. It is suitable for green and dry materials, and especially for wet and tough material (such as palm nut shell, reeds, and chaste tree twigs).
It is suitable for maize stover silage. The processed material can be compacted easily. Without nodes remaining, the whole stalk can be eaten by the animal.

The 9LRZ-80 is appropriate for large farms. It requires a power source of 22-30 kW, and has a capacity of 6-8 t/hour, and an output of 0.39 tonne/kWh. Its node breaking efficiency is 99 percent.

The 9RZ-60 kneading and cutting machine can be equipped with a 15 kW electrical motor. The 9RZC-60 has an 18 hp diesel engine. Both have an output of 3-4 t/hour, and are suitable for medium-sized farms.

Compared to a chopper, the 9LRZ-80 can save 2 160 kWh and 1 080 work-days for processing 6 000 tonne of green stalks. Total savings are about ¥ 3 000.

Pelleting equipment
After being ground into meal, having had concentrates and other nutrient elements added, straw makes a complete feed, and can be pressed by a pelleting machine. The pelleted feed, containing all nutrients, increases palatability and intake, and at the same time decreases feed waste and reduces feeding time. However, the cost of equipment for pellet processing is high. The machine consists of a pelleting device, a steam
generator, an oil and molasses doser, a cooling device, a separator and a sieve.

There are two types of pelleting: disk die and ring die pelleting.

Figure 6-25. Flow chart of 93KCT-1000 complete roughage wafering set operation

Disk die pelletier
Several disk die pelleters have been made in China. Figure 6-22 shows a
disk die pelletier, comprising a screw conveyor, a gear-box, a stirrer and a
pelletiering device. The screw conveyer, whose rotary speed is adjustable, is
mainly used to control the charging rate. The stirrer situated under the
conveyor stirs the material, admitting steam through a side hole to heat
and cook the material while it is transferred to the pelletiering device. Inside
the die there are 2 to 4 press rollers and a disk with many holes (shown in
Figure 6-23). In operation, the disk rotates at a speed of 210 rpm. After
falling onto the disk die, the cooked meal is distributed evenly by a spade
and forced through the round holes of the die by the press. The cylindrical
pellets from the die are then cut into pieces 10-20 mm long by a blade
under the disk. Disk presses can be classified into three types: movable
die, movable roller and movable die and roller types. Hole diameter in the
die can be 4, 6 or 8 mm. The diameter of the roller ranges from 160 to 180
mm.

Ring die pelletier
The ring die press has been widely used in engineering. Figure 6-24 is
an illustration of its operation. The main parts are a screw conveyer, a
stirrer, a pelleting device and a drive mechanism. The screw conveyor, whose rotary speed can normally be changed gradually in the range of 0-150 rpm, is used to control the loading rate. A side opening to the stirring chamber allows steam to be injected. In the stirring compartment, the meal is mixed with over-saturated high-pressure steam. Sometimes oil, molasses and other additives are added during mixing. When ideal conditions cannot be met, water can be used instead of steam, but in this case mixing is poor, output is decreased, and energy consumption and friction are increased.

The mixed meal goes into the pelleting device, which consists of a ring die and pressing rollers. In operation, the ring die rotates, making the rollers turn and press the material through the cylindrical holes of the ring die. The cylindrical pellets rotate with the ring die, and are cut by a blade. The larger the hole diameter, the higher the output of the machine and the lower the energy consumption. Hole diameter is determined by animal requirements.

Wafering machinery for roughage

Wafers are about ten times the size of pellets. The wafering machine made by the Guangdong Huada Machinery Factory can make rectangular wafers 25 ¥ 25 mm or 30 ¥ 30 mm, and also cylindrical wafers of 8-30 mm in diameter. The density varies from 0.6 to 1.0 g/cm³.
and the bulk weight from 0.4 to 0.6 tonne/m³. The output is 600-1 000 kg/hour. Five operators are needed.

The 93KWH-40 waferer and the 93KWH complete wafering set have been developed by the Jiangxi Hongxing Machinery Plant. The rotary speed of the main press shaft is 167 rpm, the output is 300-600 kg/h, and the power needed 37 kW. The whole system’s energy needs are 62.5 kW.

After milling and addition of concentrates, chemical additives and other minerals, the straw is wafered to increase nutrient value, intake and digestibility. The wafered feed is not only easy to transport, to store and to feed, but also very convenient for marketing due to its high density.

Figure 6.28. Ammoniation oven heated by coal and steam

The wafering process is shown in a flow chart (Figure 6-25). After size reduction (chopping, grinding) to a specified size, controlled by the screen holes, roughage such as rice straw, wheat straw, maize stover, bulrush and sunflower stem is transported by forced air to the cyclone (2) and then to the buffering bin (3). The material from the bin (3) is conveyed via a double-screw conveyor (4) and a rationing conveyor (5) to the mixer (8), where chemical additives and concentrates are added separately at prescribed rates from hoppers (6 and 7). At the same time, water and steam are also added to the mixer. The uniformly mixed material falls to the wafering machine (11) to be made into cubes. The cubes are transferred to a horizontal cooler (13), and then drop to the packing machine.

STRAW TREATMENT EQUIPMENT

Ammoniation equipment for ambient conditions
The ammoniation reaction occurs at temperatures above 0°C. Reaction speed increases with temperature. There are many methods for ammoniation under normal temperature, such as stack ammoniation and use of an ammonia silo. Straw ammoniation can be carried out using various sealable containers.

The sources of ammonia for straw treatment are anhydrous ammonia, aqueous ammonia, ammonium bicarbonate and urea. When using aqueous ammonia, ammonium bicarbonate or urea, water should be added at a prescribed rate. Straw uniformly mixed with the ammonia source is sealed in the container for the ammoniation. Anhydrous ammonia is kept as a liquid under high pressure and therefore pressure containers are required to transport and store it. A minimum set of equipment, including perforated metal pipe (ammonia injection spear), volume meter, ammonia pressure meter and some safety equipment, are required for ammonia injection. Because anhydrous ammonia is a potentially dangerous and toxic material, stringent safety measures need to be taken.

Heating equipment for ammoniation
To the north of the Yellow River, the temperature is usually below 0°C in winter, and thus the ammoniation reaction can not happen. In order to
deal with this problem, some new ways for ammoniation were developed in these areas.
Heated ammoniation-bunker method
The traditional method for heating material using the smoke channels of a stove — a procedure widely used in rural areas to cultivate sweet potato seedlings in early spring — is used for straw ammoniation. It is called the heated ammoniation-bunker method. The structure of the bunker is shown in Figure 6-26. The operating steps are as follows: a bunker is constructed with brick and concrete, half underground. A stove is built at one end of the bunker, under which there are two smoke channels connected to a chimney at the other end of the stove. Firstly, the straw, mixed with the urea or
Ammoniation in tobacco curing houses

Tobacco curing houses are usually empty in winter. The straw is placed into the tobacco house, a urea or ammonium bicarbonate solution added, the straw well sealed, and then heated by burning coal. The house is kept at 40-50°C for 3-4 days for the ammoniation to be completed. This is a practical method in tobacco-growing areas.

Ammoniation in ovens

The ammoniation oven has proved to be an efficient item of equipment for livestock farms where straw ammoniation needs to be industrialized and delivered regularly according to a plan. Figure 6-27 outlines an oven with a straw trailer that can be pulled in and out. The source of ammonia can be anhydrous ammonia or ammonium bicarbonate. In Figure 6-27,
anhydrous ammonia is used. Of course, anhydrous ammonia needs to be transported and stored in pressure containers. Urea is not suitable for oven ammoniation, with its temperature as high as 90°C, because the ureases required to break down urea are destroyed at these temperatures. There are three heating options: electricity, steam or coal. The oven may be a metal box or of brick construction. The parameters for a 30 m³ metal box-oven heated by electricity are listed in Table 6-5. When an electric element is used to heat the oven, the temperature and heating time can be automatically controlled using a thermostat and timer. This oven has the advantages of simple operation, time and labour saving and high level of automation. A 30 m³ oven can treat 1.5 tonne of straw within 24 hours. The energy consumed per tonne of straw is less than 100 kWh, with a cost of ¥ 29 (in 1990), equivalent to the daily wage of two persons.

Steam is a convenient source of heat on cattle farms equipped with steam sterilizers. Oven temperature depends on steam pressure and supply time. Generally, oven temperature is maintained with steam at 70°C for 10-12 hours, then the straw is kept in the oven for a further 22-24 hours. Considering only the coal used, the cost of steam is only 40 percent of electricity.

A built up oven, heated with coal and steam, is shown in Figure 6-28. Its walls, top and bottom are constructed with bricks, cement and insulating material. The straw trolley can be pulled in and out. At one end of the oven,
a stove is built in a pit. The tank, situated above the stove, provides the water for steam generation. The hot air flows through the main channel (3) from one end to another, turns to the second channel, returns to the main channel again and is finally released via the chimney (4). The oven is equipped with a straw trolley, wheel tracks and hard rubber wheels. When hard rubber wheels are used, the straw trolley is easily moved for loading/unloading. Rails are used for guiding when loading and unloading.

In coal producing areas such as Shanxi province, heat from coal is ten times cheaper than from electricity. It is a convenient fuel for regions with sufficient supplies and cheaper labour.

Heat-explosion equipment
The principles of heat-explosion combine heat reaction and mechanical processing. Under the action of steam at 170°C, straw lignin is broken down and partly hydrolyzed. During the explosion, the particles impact each other inside the tube and at the same time the water trapped within cells rapidly expands to a gaseous state and physically tears apart the brittle cell wall. Straw is shredded into fine particles, greatly increasing its surface area. The quality of the treated straw is considerably improved. Equipment and a flow chart of the technology is shown in Figure 6-29.

After cutting by the chopper (1), the material is transported via the storing bin (2), the hopper (3) and charging valve (4) to pressure container (5). After being sealed, the container (5) is injected with low or medium pressure steam to a pressure of 0.5-1.0 MPa, supplied by the burner (6) and controlled by the discharge valve (7), and maintained at this high pressure for some time (from 1 to 30 minutes). The pressure is then abruptly released through the rotating ball valve (9), and the material discharged into container (10) through tube (8), for subsequent direct feeding or pelleting.

The cost of this equipment was ¥ 65 000 in 1990. The volume of the pressure container is 0.9 m³. Straw output is 300-400 kg/hour, coal consumed is ca 50 kg/hour, and the cost for treating 1 kg of straw is about ¥ 0.02.

After heat-explosion, the physical properties of the straw have been changed, and the intake of the entire crop is increased by 50 to
90 percent. The digestibility is increased more than 50 percent. The heat explosion treatment can eliminate the toxins of colza (rapeseed) and cottonseed cakes, and sterilize the faeces of chicken, duck and cattle to odourless materials.

**Figure 6-31.** The transfer system from the truck tank to the ammonia bottle

AMMONIATION WITH ANHYDROUS AMMONIA

Injection equipment
The full set of the ammonia injection equipment (Figure 6-30), developed by the Non-conventional Feed Institute of China Agricultural University, consists of an ammonia bottle, a high pressure hose, a flow meter, a low pressure hose (rubber hose) and an ammonia spear. Protective equipment (gas mask, rubber gloves and boots) must be used.

Table 6-8. Relationship between cattle number, straw amount, anhydrous ammonia and facilities required

<table>
<thead>
<tr>
<th>Cattle (ton/yr)</th>
<th>NH₃ need (ton/yr)</th>
<th>Trips of 3-ton tank truck</th>
<th>Trips of 7.2-ton tank truck</th>
<th>No. of 200-kg bottles needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 000</td>
<td>15 000</td>
<td>450</td>
<td>150 0.5</td>
<td>62.5 0.200</td>
</tr>
<tr>
<td>20 000</td>
<td>30 000</td>
<td>900</td>
<td>300 1.0</td>
<td>125.0 0.420</td>
</tr>
<tr>
<td>30 000</td>
<td>45 000</td>
<td>1350</td>
<td>450 1.5</td>
<td>187.5 0.625</td>
</tr>
<tr>
<td>40 000</td>
<td>60 000</td>
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<td>600 2.0</td>
<td>250.0 0.830</td>
</tr>
<tr>
<td>50 000</td>
<td>75 000</td>
<td>2 250</td>
<td>750 2.5</td>
<td>312.5 1.040</td>
</tr>
<tr>
<td>60 000</td>
<td>90 000</td>
<td>2 700</td>
<td>900 3.0</td>
<td>375.0 1.250</td>
</tr>
<tr>
<td>70 000</td>
<td>105 000</td>
<td>3 150</td>
<td>1 050 3.5</td>
<td>437.5 1.460</td>
</tr>
<tr>
<td>80 000</td>
<td>120 000</td>
<td>3 600</td>
<td>1 200 4.0</td>
<td>500.0 1.670</td>
</tr>
<tr>
<td>90 000</td>
<td>135 000</td>
<td>4 050</td>
<td>1 350 4.5</td>
<td>562.5 1.875</td>
</tr>
<tr>
<td>100 000</td>
<td>150 000</td>
<td>4 500</td>
<td>1 500 5.0</td>
<td>625.0 2.080</td>
</tr>
</tbody>
</table>

NOTES: (1) As anhydrous ammonia.
During treatment, the ammonia bottle should be laid horizontally, keeping vertically the line connecting the two valves: the upper for gas and the lower for liquid. One end of the high-pressure hose is connected to the lower valve and the other end to the high pressure end of the flow meter. One end of the low pressure hose is connected to the low pressure end of the flow meter and the other end to the ammonia spear.

After connecting the full set, operators should first put on their protective equipment: gas mask, rubber gloves, boots and suit. Second, the ammonia spear is inserted into the straw stack, about 0.5 m from the ground. Third, the lower valve is slowly unscrewed to inject the appropriate dose of ammonia according to the amount of straw. When finished, the valve is closed, but the spear kept in place for 4-5 minutes to allow ammonia left in the hose and spear to flow to the straw. Finally, the spear is pulled from the stack and the injection hole sealed with glue or tied with a string.

Using the flow meter, ammonia can be injected into the stack directly from an ammonia truck, avoiding ammonia transfer from tank to bottle. As a result, working efficiency is increased.

Construction of an ammoniation station
Anhydrous ammonia is the cheapest ammonia source, and, for this reason, treating straw with anhydrous ammonia has been advocated. However, aqueous ammonia is toxic, volatilizes easy and causes burns,
thus pressure containers are required for transport and storage. It is necessary to build an anhydrous ammonia supply system. Considering the practical radius of service and amount to be used, a county-level ammoniation station might be needed. Functions of the station are to obtain ammonia in large quantities from chemical (usually fertilizer) factories in tank trucks, store it in large containers, distribute it in bottles and also to perform the injection into the straw at farmer level. At the same time, the station also can market other ammonia sources (e.g. urea) and ammoniation equipment.

Figure 6-32. County-level ammoniation station
Selection of equipment for transport and storage

Many types of transport and storage facilities for anhydrous ammonia have been manufactured in China, including ammonia tank trucks, containers and bottles, some of which are listed in Table 6-7. The 3-ton Dongfeng truck tank and the 7.2-ton Hongyan 19 truck tank have been selected as the main models to meet requirements in a flexible manner. Anhydrous ammonia containers are mainly used in ammoniation stations connected with an ammonia supply system. When selecting ammonia containers, cost and uniformity of ammonia delivery should be taken into account. Because anhydrous ammonia can be transferred directly from a tank placed on a truck body into bottles, tanks may not be required for a county-level ammoniation station if funding is adequate.

When selecting ammonia bottles, the first factor to be considered is convenience for loading and unloading. Because hand tractors or small carts can easily transport a 400-litre (200 kg) ammonia bottle, they have been selected as the main type. The 40-litre (20 kg) bottles

<table>
<thead>
<tr>
<th>Building</th>
<th>Size (m)</th>
<th>Unit price (¥)</th>
<th>No.</th>
<th>Total cost (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office and dormitory</td>
<td>3.0 x 6.0</td>
<td>3000</td>
<td>7</td>
<td>21000</td>
</tr>
<tr>
<td>Truck garage</td>
<td>3.5 x 11.0</td>
<td>5000</td>
<td>1</td>
<td>5000</td>
</tr>
<tr>
<td>Car garage</td>
<td>4.5 x 6.5</td>
<td>3500</td>
<td>1</td>
<td>3500</td>
</tr>
<tr>
<td>Shed for urea storage</td>
<td>9.0 x 6.5</td>
<td>6000</td>
<td>1</td>
<td>6000</td>
</tr>
<tr>
<td>Platform for loading and unloading</td>
<td>15.0 x 4.0 x 1.0</td>
<td>3000</td>
<td>1</td>
<td>3000</td>
</tr>
<tr>
<td>Shed for ammonia bottles</td>
<td>3.0 x 11.0</td>
<td>5000</td>
<td>1</td>
<td>5000</td>
</tr>
<tr>
<td>Toilet</td>
<td>4.5 x 8.0</td>
<td>1000</td>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>Road, water and electricity facilities</td>
<td></td>
<td></td>
<td></td>
<td>10000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>54000</strong></td>
</tr>
</tbody>
</table>

**Table 6-11. Economics of a county-level ammoniation station for 20000 cattle**

<table>
<thead>
<tr>
<th>Cost</th>
<th>Yearly depreciation</th>
<th>Wages</th>
<th>Transport cost</th>
<th>Profit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td>45250</td>
<td>21000</td>
<td>67500</td>
<td>157000</td>
<td></td>
</tr>
<tr>
<td><strong>Buildings</strong></td>
<td>4850</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>50000</td>
<td>21000</td>
<td>67500</td>
<td>157000</td>
<td></td>
</tr>
<tr>
<td>Per kg of aqueous ammonia</td>
<td>0.1213</td>
<td>0.0054</td>
<td>0.0167</td>
<td>0.0300</td>
<td>0.0700</td>
</tr>
</tbody>
</table>

**NOTE:** (1) Aqueous ammonia sold annually is 900 tonne. (2) All values are in ¥
are well adapted for farmers ammoniating straw in stacks, because of their easy transport, loading and unloading. One 40-litre bottle can treat 700 kg of straw in a stack, avoiding weighing and other complex procedures, and it can be transported by bicycle. The Non-conventional Feed Institute of China Agricultural University and relevant factories have promoted the one bottle, one stack concept based on this small bottle, as recommended by FAO experts.

Ammonia transfer
One of the important roles of the ammoniation station is to transfer anhydrous ammonia from the truck tank to bottles. If the liquid level in the tank is nearly equal to that in the bottle, ammonia can not flow by gravity and a compressor is needed. Ammonia compressors are available in Denmark. In China, an ammonia compressor has been obtained by redesigning the corrosion-prone parts of an air compressor.

<table>
<thead>
<tr>
<th>Equipment Item</th>
<th>No. needed</th>
<th>Unit cost (¥)</th>
<th>Total cost (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small four-wheel tractor</td>
<td>1</td>
<td>7000</td>
<td>7000</td>
</tr>
<tr>
<td>Trailer for tractor</td>
<td>1</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>200 kg ammonia bottle</td>
<td>2</td>
<td>2000</td>
<td>4000</td>
</tr>
<tr>
<td>Ammonia filling and protective</td>
<td>1</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weighing scale (500 kg capacity)</td>
<td>1</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-</strong></td>
<td><strong>14750</strong></td>
<td><strong>14750</strong></td>
</tr>
</tbody>
</table>

The Non-conventional Feed Institute of China Agricultural University has successfully developed an anhydrous ammonia flow meter. The system of transferring ammonia from truck tank to bottle is shown in Figure 6-31. The ammonia transferring procedure is:

A high-pressure hose is attached between the liquid valve on the truck tank and the bottles. A gas hose is attached between the gas valve on the truck tank and bottle through the compressor.

The gas valve on the truck tank is opened and checked for any leakages (splits or cracks along the hose).

The bottle's gas valve is opened, then the truck tank's valve, and a check is made for leakage along the hoses.
The liquid valve on the bottle is then opened.
The compressor to transfer ammonia from the truck tank to the bottle is started before the liquid is released into the hose.
It is better to place an ammonia pressure meter on the bottle's gas valve, and to compare its value with that on the tank. If the pressure of the tank is consistently more than that of bottle, this means the system is working fine.

Layout of ammoniation station

Determining service scale and equipment. The technology of treating straw with anhydrous ammonia is already mature. The ammonia dosage should be 3 percent of the straw dry weight. It is estimated that 1.5 tonne of ammoniated straw are enough for one head of cattle a year. Table 6-8 is based on an assumption of 1.5 tonne per head per year, and 300 working days for the ammoniation station a year. Table 6-7 indicates that a farm with 10 000 beef cattle needs 15 000 tonne of ammoniated straw, requiring 450 tonne of anhydrous ammonia annually. The quantity of ammoniated straw and ammonia for other animal species can be estimated by converting other livestock units into cattle units. The type and number of ammoniation facilities are determined by the quantity of anhydrous ammonia needed per year. The number of trips is estimated based on truck tank size and distance between the station and the

Figure 6-33. Ammonia pressure change with temperature
fertilizer factory.

The total volume of bottles should be double that of the tank to ensure thorough discharge. That means that half of the bottles will be with farmers and the other half on station. The bottles should be recycled to accelerate turnover and improve working efficiency. In addition, small ammonia bottles holding 40 litre (20 kg) should also be available to facilitate farm work. At the station, ammonia is transferred from the truck to bottles through a hose controlled by a platform scale. Because the amount of ammonia remaining in each bottle varies, it is impossible to estimate the total amount transferred by a flow meter. At the same time, the amount in each bottle is an important consideration for safe transport, so flow meters are unsuitable for stations.

Equipment and its cost. Equipment and its cost in a typical ammoniation station serving 20 000 beef cattle are listed in Tables 6-8 and 6-9. The ammoniation of 30 000 tonne of straw requires 900 tonne of anhydrous ammonia, which can be transported by a 3-ton truck tank once daily (Table 6-7). At the same time, 30 small bottles with 200 kg and other facilities, such as a farm vehicle, a small four-wheel tractor and trailer, are also needed. Appropriate schemes can be planned for various sizes of ammoniation stations, based on the data in Table 6-9.

Personnel. For a typical ammoniation station serving 20-50 000 cattle, 5-7 persons are needed (1 manager, 2 drivers, 2-4 operators).

Construction requirements and plan layout. Each ammoniation station should be designed specifically for the service scale and land and equipment available. An ammoniation station for a 20-50 000-cattle catchment (typical county level) shows typical construction requirements and layout (see Figure 6-32). The area is 40 ¥ 40 m (1 600 m²). In order to quickly transfer ammonia from the tank truck to bottles, the difference in height between tank and bottle should be adequate. Thus, a 1-m platform (10) is suitable for loading and unloading. It has an inspection pit for checking or repairing vehicles. The platform can also be used for general loading and unloading operations. A shed beside the platform (8) holds 125 ammonia bottles
(200 kg each), standing vertically. At the end of shed (8) there is a storeroom (9) with a separate wall. A tractor can be driven close to shed (8). One person can load and unload with the aid of a movable gallows frame. The office (1) is used as a check point and for sales (urea, ammonia filling equipment and plastic sheets). The other rooms are an office (2), a meeting room and manager’s office, living rooms (3), toilet (4), large (5) and small (6) garages and stores for urea, ammonia filling equipment and plastic sheets (7). (11) are flower beds, and (12) are trees.
The living and administrative areas are located at the corner opposite to the ammonia source to minimize effects on people. Doors on opposite sides of the compound facilitate access of trucks and tractors. The whole yard is large enough for vehicles to turn around without the need to reverse.

A typical budget for the construction of a county-level ammoniation station is given in Table 6-10.
Economic assessment. The cost estimation is done taking into account the following factors:

- Depreciation of equipment and buildings over 10 years
- Wages at ¥ 250 per person per month
- Transport costs of ¥ 0.03/ton/km
- 5% profit on turnover
- Aqueous ammonia cost of ¥ 1.4/kg

The economics of a county-level ammoniation station serving 20,000 cattle are presented in Table 6-1. The price of aqueous ammonia reached ¥ 0.1434/kg after transport, storage and distribution by the ammoniation station. Except for personnel wages and transport fees, other costs were ¥ 87,050 per year. Investment in equipment and building construction was ¥ 24,500. It is estimated that 3 years are needed to recover the investment. The cost of buying the land and electricity also should be taken into account. In addition, possible additional income from sales of urea, ammonium bicarbonate and ammonia equipment is not considered.

County-level ammoniation station in parallel to the ammonia supply system in a fertilizer factory. Such a station can be built on an empty area inside or close to the fertilizer factory. A tank, with a volume 5 times that of expected daily use, can be connected to the ammonia source in the factory. The capacity for ammonia delivery can be increased with a larger tank, but the cost also increases. For a station serving 20,000 cattle, a 12.5 tonne tank is preferred. It costs about ¥ 52,000. Having a station associated with the fertilizer factory saves not only on transport but also on wages and building cost. The economic assessment can be done on a similar basis to that above.

Township-level ammoniation station. Such an ammoniation station would be responsible for supplying ammonia for straw ammoniation. It can be part of the agricultural machinery service system or can be contracted to a professional farmer. Most of the equipment required, listed in Table 6-12, can be shared with the agricultural machinery station.

The village-level ammoniation station requires 3 persons (¥ 200/month each). The running cost for a small four-wheel tractor is ¥ 30/day.
Anhydrous ammonia sales are 400 kg a day, or 120 tonne a year. The depreciation of equipment is calculated over 10 years. Cost of anhydrous ammonia handling is ¥ 0.147/kg.

Assuming that the cost for transport and storage of anhydrous ammonia is ¥ 0.227/kg for county and township-level ammoniation stations, and that 1 kg of anhydrous ammonia can treat 33.3 kg of straw, then the cost of treated straw is ¥ 8.3/ton. This estimation is based on general 1998 prices. When planning an ammoniation station, the economic assessment should be based on local costs.

**SAFETY OPERATION OF ANHYDROUS AMMONIA EQUIPMENT**

Treating straw with anhydrous ammonia has many advantages, such as high efficiency, low cost, simplicity of operation and elimination of parasite eggs and weed seeds. However, anhydrous ammonia is toxic and explosive, so pressure containers are required for transport and storage. It is very important to follow relevant national regulations for safe operation. The basis of these regulations should be well understood. Explosions of ammonia containers happen occasionally and have resulted in persons injured or even killed. All persons working with ammonia must learn from these accidents.

Physical and chemical characteristics of ammonia, and safe operation

Ammonia is a colourless gas with suffocating and penetrating odour. Under pressure or at low temperature (-33 C) it condenses to a clear liquid. The physical and chemical characteristics of ammonia are:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>NH₃</td>
</tr>
<tr>
<td>Boiling point (at atmospheric pressure)</td>
<td>-33.4 C</td>
</tr>
<tr>
<td>Density of ammonia</td>
<td>0.596</td>
</tr>
<tr>
<td>Density of anhydrous ammonia</td>
<td>0.617 (at 20 C)</td>
</tr>
<tr>
<td>Solubility in water (at 15 C)</td>
<td>60 g/100 g H₂O</td>
</tr>
<tr>
<td>Vapour from 1 litre of anhydrous ammonia</td>
<td>1 000 litre</td>
</tr>
<tr>
<td>Solubility of gas in 1 litre of water</td>
<td>700 litre (20 C)</td>
</tr>
<tr>
<td>Explosion limits</td>
<td>15-28% (volume)</td>
</tr>
<tr>
<td>Safe concentration</td>
<td>0.0001 mg/litre</td>
</tr>
<tr>
<td>Toxic concentration</td>
<td>0.2 mg/litre</td>
</tr>
</tbody>
</table>
In the presence of water or steam, copper, zinc and aluminium, and alloys containing these metals, will be corroded by ammonia. These metals are therefore not to be used in ammonia equipment.

The pressure change in an ammonia container according to temperature is illustrated in Figure 6-33.
The chemical and physical characteristics of ammonia are the basis of the selection of ammoniation equipment and for safe operation:

From Figure 6-33 it can be seen that the ammonia pressure is 2x10^5, 5.3x10^5 and 14.8x10^5 Pa for temperatures of -10, 10 and 40 C, which correspond to normal winter, spring and autumn temperature in Beijing, respectively. According to regulations, the ammonia should not be used at temperature over 50 C, equivalent to a pressure of 2.07x10^6 Pa. Other factors are taken into account, and the design pressure for a truck tank is 2.2x10^6 Pa and 3x10^6 Pa for a bottle. Pressurized containers should not be exposed to the sun for a long period, nor be brought near fire.

Ammonia easily dissolves in water, a very important consideration in safety protection and accidents. On handling sites, enough water should be available, preferably tap water. A sign indicating safety water must be clearly displayed. If ammonia gets into the eyes or on the skin, it should be rinsed immediately with abundant water. If ammonia leaks into the air, water spray should be used to knock down the vapour. Spraying polluted areas with water reduces gas emission. Covering the nose with a wet towel is an efficient method of protection.

Ammonia’s density is lower than air density. If a large amount of ammonia is released to the air, people should rapidly leave the polluted area, moving into the wind. When driving out air from an ammonia container, the gas outlet valve should be in a low position. The boiling point of anhydrous ammonia is -33.34 C. When anhydrous ammonia vaporizes, a great amount of heat is absorbed. If the heat source is not sufficient, the process of volatilization is slowed down; and ammonia will remain liquid for longer. If anhydrous ammonia comes into contact with the skin, temperature will decrease and water will be absorbed, causing injury. If a great amount of ammonia liquid escapes from a damaged valve, if possible a soil or sand dam or a dig pit should be made around the discharge (because the ammonia boiling off will cool surfaces to -33.34 C) to reduce gas emission. Heat absorption from the air can be further reduced by spraying foam on the liquid.
ammonia, or simply covering it with a plastic sheet.
If it is impossible to dig a hole or to make a dam, the container should be rapidly turned so that the damaged valve is uppermost (from liquid to gas position), thereby reducing the speed of ammonia release, since 1 litre of anhydrous ammonia will vaporize into 1,000 litre of ammonia gas.
When the ammonia content in the air gets to 15-28 percent, it has reached the explosion limit. Below 15 percent, there is not enough ammonia for the explosion, and above 28 percent there is not enough oxygen. In practice, ammonia in the air or in containers should be kept below the explosion limit. For new ammonia containers or for those that have not been used for a long time, it is necessary to drive air out before using them. Adding a little ammonia into the container and opening the lower valve, the gas is pushed out into water through the hose. Repeating the process several times until there are no more bubbles in the water means that all discharged gas is ammonia. Since ammonia dissolves rapidly and thoroughly in water, in order to prevent air from going into ammonia containers, a little ammonia should be left in the bottle: that is to say, the pressure meter should remain at 0.05 MPa (0.5 atmospheres pressure). In addition, avoid fire on the handling sites to prevent explosions and self-ignition at 630°C. Attention should be paid during welding or repairing ammonia containers: ammonia should be purged beforehand.
Containers should not be filled to excess. Figure 6-33 clearly shows that the vaporizing pressure increases with temperature. If the container is completely full of ammonia, with no empty space for liquid expansion with increasing temperature, the pressure will increases at the rate of $1.5 \times 10^6 \text{Pa}/\text{C}$. If the temperature increases by 5°C, an explosion will occur. The amount of ammonia to be put in a container ($G$) should be calculated using the formula: $G = 0.53V$, where $V$ represents the real volume of the container (in litres) and 0.53 is the maximum filling factor (kg/litre).

Safety supervision of ammonia containers
In order to emphasize the management of pressure containers with explosion risk, Safety supervision regulations for gas bottles, Supervision regulations for pressure containers, and Management regulations for liquefied gas tank trucks have been promulgated by the National Council, the Ministry of Work and Personnel, and the Ministry of Chemical Industry. Clear regulations have been established for the design, manufacture, installation, usage and inspection or repair of pressure containers, as well as for reporting accidents.

Ammonia tank trucks and bottles are classed as medium-pressure container transport. As ammonia is very toxic, a container of more than 440 litre volume is a class II container, which can implies serious consequences in an explosion.

According to national regulations, the following points should be observed when using pressure containers:

Inspection and acceptance. The design and manufacturing company must have a Certificate of Approval from the appropriate authorities, and the products must have a quality certificate.

Keeping technical records. Detailed records should be kept, including dates, inspections, repairs, measures taken to resolve problems, and so on.

Personnel training. Operators must be trained, and receive the required qualification after passing an examination.

Care in handling. Valves should be opened slowly to prevent pressure from rising or falling too quickly.

Avoid overfilling. Do not overfill, to avoid high pressure and temperature.

Regular inspection. According to the specifications of the pressure containers, they should be inspected externally once a year and internally once every two years by the relevant authorities. After inspection, a visible and permanent label of the authority, with the year of inspection, must be affixed to the container.

Safe transport. Ammonia containers should be protected from impacts or overturning. Valves should be closed and caps well screwed on during transport. Loading and unloading must be done slowly. Ammonia containers should never be placed together with
other containers, especially oxygen bottles. Fire extinguishers must be available.

Regular maintenance. Pressure containers must be repaired and maintained regularly to prevent leaking. They should be kept in dry areas when not used.

Qualified drivers and operators. The drivers and operators of tank trucks must be trained and qualify by passing an examination. Moving and stopping ammonia tank trucks should respect not only normal traffic regulations but also special conditions. The relevant regulations should be written and displayed in the appropriate position in or on the vehicle.

Accident reporting. Any accident should be reported immediately to the relevant administration, police and labour department.

Regulations for safety in straw ammoniation

Ammonia is toxic and may explode under certain conditions. The ammonia containers are classed as pressure containers with risk of explosion. Treating straw with anhydrous ammonia can endanger life and health if not done correctly. It is therefore necessary to follow the precautions and regulations made by the Bureau of Animal Production and Health (MOA, 1990):

Safety operation regulations for straw ammoniation

Operators must have the necessary training, pass the examination and obtain their qualification.

Safety equipment available at the working site should include:
- an abundant supply of fresh water;
- filter masks with ammonia filters;
- gloves and boots made of rubber or another suitable material; and
- fire extinguishers.

Each new ammonia container must have an accompanying quality certificate that is properly filed.

Never overfill whenever adding ammonia to a container.

In summer, do not put ammonia containers in the sun. In winter, if ammonia flow is low, move containers to a warm place. Never heat them with fire.
During ammonia transport, storage and straw ammoniation, check containers and hoses for leakage or swollen parts. Stop operation to make appropriate repairs to damage if found.

Ammonia bottles must be firmly secured to the vehicle during transport to prevent them from falling due to movement. Be sure not to hit or to roll ammonia bottles during loading and unloading, which should be done slowly.

Screw and tighten valves during bottle transportation and storage.

Transport of anhydrous ammonia and oxygen in same wagon and storage in the same shed is strictly prohibited to avoid danger of explosion.

If there is still pressure in a container, do not repair or fasten any part under pressure.

When ammoniating straw, first place the spear into straw, then open the valve. Open and close ammonia-injecting valves slowly. During ammonia injection the gas pressure must be below 0.8 Pa. Do not hit the ammonia bottle with any tool.

Ammonia flow should stop when pressure drops to 0.05 Pa. The ammonia containers can not be used to store any other material without the written consent of the working department.

Ammonia containers must be checked regularly. The operators must wear protective equipment, including rubber gloves and protective suit, and stand upwind from the ammonia source.

If ammonia leaks to the air, people should lay down on the ground, cover their noses with a wet towel and move upwind. Fire is forbidden in the vicinity of the ammonia station and the site of straw ammoniation.

If an accident occurs, it should be immediately reported to administration and labour departments.