their earlier stages either of the broad divisions stated and diverges only at the later stages. The apparent divergence between red and white wine processes consists only in that for the former, fermentation precedes drawing off and pressing, while for white wines the order is reversed. Actually, other differences are entailed which will be discussed under the topic of white wine manufacture. Red wine manufacture is somewhat simpler and will be considered here.

The sequence of operations in the manufacture of red wines is indicated in the flow sheet, Fig. 36.

```
Grape Bunches
  ↓
Stemming (Partial or complete)
  ↓
Crushing
  ↓
Fermentation
  ↓
  (optional)
Sterilization by Sulphur Dioxide and
  Starting with Cultured Yeast
  ↓
Drawing Down and Pressing
  ↓
First Ripening and Secondary Fermentation
  ↓
  (optional)
Second Ripening → Fining, filtration, etc.
  ↓
 Bottling or Cask Ripening → Pasturization
  ↓
```

**Fig. 36.**—Flow Sheet of red wine manufacture.

When the grapes are at the proper stage of ripeness the bunches are plucked and brought to the winery. This may vary in size from the home of the French peasant to the large commercial wineries with capacities for thousands of gallons of wine. There can be, at this stage, no delay, since the grapes may become infected if left piled in bunches. The next stages to the starting of the fermentation must follow in rapid order.

**Stemming.**—If stemming is practiced, it may be done by hand, by the use of a screen which will pass the grapes, but not the stems, and which may be operated manually with the aid of a rake to spread the grapes over it, or may be mechanically shaken or vibrated. Another means of stemming, is a machine comprising a stationary, horizontal, perforated metal cylinder fitted internally with a revolving shaft having arms which cause the
grapes to travel along the cylinder and drop through the holes or slots in its wall. Stemming may also be done after crushing. A strainer of suitable size with proper openings and fitted with revolving blades serves this purpose excellently.

The stems can furnish tannin to the juice if the skin and seeds are deficient in this respect. However, they also contain substances which “brown” the color and spoil the flavor of the finished wine. They may also introduce difficulties in handling the crushed mass.

**Crushing.**—In order to liberate the juice of the grapes and inoculate it with yeast, it is necessary that the grapes be crushed. Probably a sort of pestle or stamper operated in a container is even now used to crush grapes in small lots. By far the greatest amount, however, are crushed in a roll machine. This consists of a hopper into which the grapes are placed and from which they feed between two grooved rolls turning toward each other at different rates of rotation. The grooves catch the grapes from the hopper, and one roll passes over grapes held in the grooves of the other, crushing them. The crushed grapes may fall directly into the fermenting vat, or into a tank whence they may be pumped to the proper vat. In adjusting the machine it is only necessary that the rolls be so spaced that the seeds pass through uncrushed. Roll crushers are available in any size desired, from the domestic “one lug” to the large machines found in California. In any case their capacity is usually great compared with vat and other facilities required in the winery. There are possibly still existing, and there certainly were in the past, rural districts in which the grapes were placed directly in the fermenting vat, and the crushing done by the bare feet of men and women who walked around on the mass.

**Fermentation.**—The general considerations involved in the fermentation of grapes to produce wine have been discussed in Chapters V and VI. The fermentation of the crushed grapes is started as desired, either naturally or by means of a starter, and means to control the temperature must be available if very large batches are being fermented. These may include water cooling coils or as in parts of California, the construction of
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the vats with thin cement concrete walls so the evaporation serves to effect some cooling. Even chloroforming the yeasts, temporarily to arrest the fermentation and stop heat production has been attempted. This control of temperature, it is repeated for emphasis, is necessary because the desired yeasts function best between 70° and 80° F. while the disease bacteria are favored by temperatures over 90°. It should be noted, however, that yeasts can be "trained" to work at unusually low or high temperatures when the climate, as in Southern California, requires it. The first visible evidence of active fermentation is the formation of carbon dioxide. This is liberated in bubbles which become entrapped in the skins and cause them to rise and mat at the top.

Fig. 37.—Redwood tanks. 17,000-25,000 gallons capacity. (Courtesy of the American Wine and Liquor Journal, New York.)
of the vat forming a "cap." When this cap is exposed to the air, the upper surface of the cap quickly ferments to completion and offers an excellent start to vinegar bacilli. At the same time the grape pigment becomes oxidized and bleached. To avoid this there are two alternative practices. The cap may be broken up and pushed down manually, or even as in some districts in France trodden down by men who enter the vats stripped, for this purpose. Alternatively a grid is installed in the vat about six inches below the level of the must, to keep the cap submerged. In this case it is necessary, to obtain aeration and uniform fermentation, that the liquor be circulated by pumping it from the bottom of the vat and allowing it to pour back at the top. A combination of these systems is often favored. The fermentation is kept open until the yeasts have multiplied and developed strongly and then the cap is submerged to avoid the dangers of open fermentation.

Changes During Fermentation.—While the most marked change during fermentation is the conversion of grape sugar into alcohol and carbon dioxide, other changes of smaller magnitude but equal importance to the quality of the finished wine also occur.

As indicated previously, some of the acid present in the fresh must is consumed by the yeast. The drop in acidity is about 40%, or from an original acidity of 0.5-1.5% expressed as tartaric, to an acidity of 0.3-0.7% in the finished wine. This includes volatile acids formed which should not exceed 0.15%.

Protein matter present in the grapes is also partly consumed during fermentation. The manner of this consumption was discussed in Chapter V. The end products, organic acids, esterify with the alcohol of the wine and contribute largely to its bouquet.

The liquid extracts tannin and coloring matter from the skins and seeds of the grapes. The former, as previously stated, is of great importance to the soundness and clarity of the wine. The coloring matter of the grapes is, of course, the obvious distinguishing feature of red wine. This color includes a group of substances of obscure composition, which are called enolic acids. They probably do not go into complete solution in the liquid, but
rather into colloidal solution. Hence, the cell walls of the grapes must be broken down either by fermentation or heating (as in making bottled grape juice) before the color dissolves. It is possible that the alcohol may also have something to do with dissolving the color. Over-ripe grapes, in which it is possible that the pigment is over-oxidized, yield a paler wine than those in which the grapes were gathered at the peak of their ripeness.

Many other known and unknown changes of minor importance occur during the fermentation even when it is running its proper course. Coagulation of a portion of the albuminous and pectinous substance present may be mentioned as an example. However, the main changes have been indicated and the key to all is the conversion of sugar to alcohol.

Completion of First Fermentation.—The rate of this conversion varies, as might readily be foretold, with the temperature, the vigor and numbers, and the strain of yeast. At the best, about 4 per cent of sugar per day is converted, so that a must containing originally 20% of sugar, will be fermented dry in about five days. Actually the time required may be anything between three days and three weeks.

At some time during the active fermentation or very shortly after its completion the fermented juice or new wine must be separated from the marc, the pressed residue of grape skins and pulp. The exact stage at which this is done is very largely a matter of pure choice although to some slight extent climatic factors serve as a guide. In the French Bordeaux district pressing is not done until two or three weeks after the end of the violent fermentation on the theory that thereby strength is added to the wine. In the Burgundy district a reverse theory is held that the shorter the fermentation the better the wine. Hence no time is lost between the completion of the fermentation and the separation of new wine from marc. Here in the United States it is the general custom to draw down and press even before the completion of fermentation. It is stated that in the Sandusky wineries there was often as much as ten per cent of sugar in the must at the time of pressing. All three practices will produce good wines. Like the choice between open, submerged or combined
fermentation, the election probably depends on the judgment and skill of the wine maker.

**Pressing.**—Once the choice of time has been made, the mode of separation between new wine and marc remains essentially the same. By opening a tap at the bottom of the fermenting vat, a very considerable portion of the new wine will drain off without pressing. This portion of the yield is usually less harsh and matures more rapidly than the press juice. Hence it is usually kept separate from succeeding portions of juice.

When the drainage is essentially complete, the remaining saturated mass is transferred to a press. These range from small hand-screw affairs to large hydraulic presses. Their principle of operation is nevertheless identical with that of the old home jelly-bag. The mass is placed in a press and the solid matter confined within a strong porous cloth, the filter cloth. When pressure is applied the new wine is squeezed out and the solids remain in the cloth. In order to avoid clogging of the pores of the cloth by the finer portions of albuminous and other matter in the mass, it is essential that pressure be applied gradually although it may finally be exerted to the limit of the machine used. Even with this precaution, it is usual to open the press, loosen the mass and repeat the pressing once or twice. Some of the wineries which are more interested in quantity than quality of product, moisten the residue in the press with water, before the third pressing to wash out as much extractable matter as possible. This last pressing is called *pinette* in France and may not be sold.

**Aging and Racking.**—The new wine produced in the manner described is still far from the finished product which is marketed. It is low in alcohol and it still contains unfermented sugar, excess tartaric acid and tannin in solution. It is cloudy due to the presence of suspended yeast cells, albuminoids, pectinous materials, etc. Its flavor is harsh and the aroma quite grapey rather than winey. Time is required for the completion of fermentation, the settling of suspended solids, and the ripening of the flavor. Usually these processes are accomplished by storing the new wine in oak casks at a cool temperature (50° F.) during the winter. A great deal of settling takes place, aided by the formation
of cream of tartar (potassium acid tartrate) crystals. With the spring and approach of warm weather, the wine is “racked.” That is, it is carefully poured or siphoned off from the sediment into new clean casks. The importance of this process is much greater
than appears from its simplicity. During the racking, some aeration takes place resulting in the solution of oxygen in the wine. This oxygen acts on the remaining albuminoids in the wine to precipitate them. It also improves the color and flavor. If the wine is to be fortified, the alcohol is added in portions at each racking. Artificial aeration is often employed to accelerate the processes desired. The sequence of aging and racking is repeated at intervals of a month to six months until the wine is ready for bottling.

Modifications in the temperature of storage, etc., all have their effect on the wine. Madeiras and sherries, for example, owe their special flavors to aging at a higher temperature than is usual for other wines. Some special wines may have sugar or condensed must added to them at the racking. For the simple red wines two or three rackings at intervals of six months are generally sufficient to produce a satisfactory wine.

Once the wine has ripened satisfactorily, efforts are made to arrest any further changes. Usually this requires that the wines be bottled and thereafter stored in a cool place with a minimum of disturbance. Sometimes the wine is pasteurized before bottling. This consists in heating it briefly to kill off as many bacteria as possible. The difficulty is always that more heat or time of exposure are required for complete sterilization than the flavor of the wine will permit without harm. Hence a compromise is made. Pasteurization temperatures range from 120°-150° F. and times from a very few seconds at the higher temperatures to a quarter hour at the lower heats. The entire operation is one which can only be performed on a large scale with the best possible equipment and control. Fortunately the dairy industry has furnished various machine designs and the technique of their operation which can be transferred unchanged to the wine industry.

**White Wines**

In general the manufacture of white wines is very similar to that of red. The basic difference as will be noted by comparison of the flow sheet for red wines, Fig. 36, and a similar flow sheet
for white wines, Fig. 39, is that red wines are fermented on the whole crushed mass, while white wines are pressed before fermentation so that only the juice is fermented.

This basic difference necessitates other variations between the manufacture of red wine and that of white. The plucking and pressing operations are the same. Since there has been no fermentation to break down the walls of the grape cells, higher pressures are required to ensure a good extraction of juice.

**Sterilization.**—Most of the wine yeasts are found on the skins of the grapes and remain there during the pressing. Hence the fresh grape juice is deficient in yeast and would ferment slowly and poorly if only the natural yeast were relied on to cause fermentation. During this long slow process, disease bacteria would have ample opportunity to flourish and spoil the wine, especially since little or no alcohol is present, the acid is low and the tannin which comes from the skins and seeds is also very low. Hence it is preferable and indeed almost essential that the must or press juice be sterilized and then re-started with fresh vigorous yeast culture. The usual manner of sterilization is by means of sulphur dioxide which is introduced generally by burning sulphur in the cask into which the must will be placed.

The usual way of burning sulphur in a cask is to use sulphur matches or tapes, which are strips of thin cotton cloth which have
been dipped several times in melted sulphur. These tapes are hung on an iron wire about eighteen inches long, bent up at one end to hold the tape and fastened to a bung at the other. This method has the defect that some of the sulphur melts and drips on to the bottom of the vat, where it is incompletely burned. This incompletely burned sulphur may communicate a bad taste to the wine. The same is true of the burning of the cloth to which the sulphur is attached. A better method is to use thin paper instead of cloth for the tapes and to burn them in a sulphur cage. A sulphur cage is simply a hollow cylinder of iron, or better, of porcelain, open on top and closed below, sufficiently narrow to enter the bunghole and sufficiently long to hold the required amount of sulphur tape. The cylinder is pierced with numerous holes in all parts except the bottom inch, which acts as a cup to catch all the melted sulphur. The cylinder is suspended at eighteen inches below the head of the vat by means of a piece of iron wire attached to a bung. An alternative method is to add to the must a suitable amount (about one one-hundredth of 1%, 0.01%) of potassium metabisulphite (K₂S₂O₅). This compound contains 56% of sulphur dioxide in an available form and therefore furnishes a more controllable means of dosing the wine than does burning sulphur. The effect of this addition is to kill off harmful bacteria and temporarily to inactivate the yeast. Hence the must is inactive for a time and may be clarified by filtration, centrifuging in a cream separator, or even by settling and decantation. The latter process, which is generally used only in the smaller wineries, must be performed within 24 hours of the addition of sulphur dioxide so that the commencement of fermentation by the yeasts still present in the residue does not stir up the sediment again.

The sterilized and clarified must is now ready for its fermentation. An active culture of yeast is added in about a proportion of 2-10% by volume of the must. The temperature must be raised if necessary to 80° F. so that the yeast multiplies rapidly and continues its activity until enough alcohol is formed to protect the wine against disease. In small wineries heating is done by suspending a milk can or bucket of hot water in the must. The