C-1. Secondary Recovery.

In simple terms, secondary recovery is the addition of basic water flood or gas flood (i.e., pressure maintenance) as a continuous force. Secondary recovery methods should be introduced very early in the life of a field while the income and profits from the wells are high enough to pay for the additional equipment and installation costs.

As noted in the following sections, there are many problems with water and gas as drive mechanisms. Nevertheless, they both contribute greatly to enhanced recovery. They can double the amount of oil produced from the reservoir during the life of the wells.

Water flood is the term used to describe the increase in oil recovery by injecting water into an oil-producing reservoir. When gas is injected, it is not referred to as gas flood, but instead is referred to as pressure maintenance.

The term injection well is a general term that means that either water or gas is injected into a well.

Water disposal is a term used when water does not enter an oil-producing zone.

C-2. Water Injection and Water Flood.

In the early years of experimenting with enhanced recovery, water flood was introduced. This secondary recovery practice solved a major problem of well operation. It provided a way to dispose of undesirable water without the water being used to stabilize firewalls around tank batteries, control vegetation growth, and water lease roads. At the same time, the water raised production of the available oil in the reservoir.

Water flood remains a keystone to many methods of enhanced recovery. It is an excellent second-stage recovery technique and is also a major factor in slugging and blending and extends deeply into many tertiary recovery procedures throughout the producing life of the reservoir.

One problem with water flood is that it is difficult to push water through the formation as a vertical wall—that is, the water will spread out in the formation rather than move through it evenly. Gravity pulls the leading edge of the water down and causes it to move downward as it progresses through the reservoir. It can travel under the oil and leave a large amount of oil behind.
Nevertheless, water continues to be one of the best enhanced recovery tools available. Water flood should be carefully designed and properly installed because it will probably be in place for the life of the well or until equipment needs major changes.

C-3. Preparing a Well for Water Injection.

**Downhole preparation.** When preparing an injection well, the casing must be tested for leaks, a packer added near the casing perforations to seal the annulus space, and the space filled with a packer fluid to protect it from corrosion. This process must receive formal approval before it can be placed in operation and must be witnessed by regulating agencies when installed. Pressure in the annulus is checked regularly to determine that the casing or tubing has no leaks and that the injection pressure in the tubing is not excessive.

**Wellhead preparation.** When preparing the wellhead for water injection, the pumper will typically have a full opening master gate on the tubing. The wing assembly, as pictured in Figure 2, includes a valve, a solids screen, volume meter, throttling valve to regulate volume, a pressure gauge, and a check valve to prevent fluid loss from the injection well in the event of a line breaking.

C-4. Operating the Water Flood System and Typical Problems.

Some water injection systems require a collection system to gather all water from several tank batteries. This may involve large water holding tanks, filters, a high-volume injection pump with water distribution lines to each well, and choke valves. Other low-pressure, small-volume, one-injection well systems can be very simple in design and operation (Figure 3).

A problem that may occur is oil accumulation in the water disposal system. This can be solved by installing a skimmer tank immediately ahead of the pump. The skimmer tank is a simplified wash tank or gun barrel. Oil enters the tank, is recovered, and is pumped back into the oil production system. Water below this level is injected.

![Figure 2. A wing valve used for water injection.](courtesy of Baker SPD, a Baker Oil Tools company)

![Figure 3. Low-volume, low pressure water disposal and injection system.](image)
**Intermittent Operation.** Automating the water flood system for a basic automated injection system is a very simple procedure when simply injecting water that is produced on the lease. A simple hydrostatically controlled on/off switch arrangement to control the injection pump is all that is needed (Figure 4). If the system is small and the tank will not run over if the system should fail to function properly during the 16-hour period that the pumper is off the site, no backup system is required.

If a larger volume is produced, a second higher level control is satisfactory to give a fluid level backup system. Normally, the lower control will start the system as the water level accumulates to a set height and turn it off when it is pumped down to a lower level. If the system should fail, the water level in the tank will build up, and the upper control will engage as a system safety on/off pump control switch. This switch will periodically need to be operated to verify that it will function if needed.

**C-5. Gas Injection and Pressure Maintenance.**

The re-injection of produced gas into the formation for reservoir pressure maintenance also plays a large role in secondary recovery. Gas injection wells are in operation where it is essential that all or part of the produced gas be re-injected for pressure maintenance. As gas is collected from the tank batteries, it needs to be dried sufficiently either through a gas plant or through a gas scrubber to remove enough distillate or condensate to allow it to be re-compressed for injection.

The gas injection well is prepared in a manner similar to a water injection well. In addition, it will usually have a safety valve installed in the tubing string near the surface to protect the well from blowout if the surface injection line should break.

An example of a gas injection well for pressure maintenance is shown in Figure 5. Note that in this variety, injection gas comes from either side if the unit. This well has a downhole safety valve.
The first problem encountered with the gas injection recovery method is that although the gas was injected as a wall, it is very light. Consequently, as it travels through the formation, it migrates to the upper areas of the reservoir, travels over the heavier liquids (including the crude oil), and leaves very large pockets of oil behind.

The second problem encountered is that being lighter than oil, the gas will have a tendency to *finger*—that is, break into smaller streams—and channel to the recovery well, bypassing much of the oil and reducing the sweep efficiency.

The third problem is that it is difficult for the injected gas to recombine with the oil remaining in the formation. It can even make the remaining oil heavier and harder to move.