TECHNICAL MANUAL

OPERATION AND MAINTENANCE
SMALL HEATING SYSTEMS

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OPERATION AND MAINTENANCE
SMALL HEATING SYSTEMS

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*This manual supercedes TM 5-642, Jun 46 and rescinds TM 5-644, Jul 46 and TM 5-646, Jun. 46

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CHAPTER 1
INTRODUCTION

1-1. Purpose and scope.

a. This technical manual provides basic information for facilities personnel regarding the operation and maintenance of small heating systems and related equipment. Generally, the manual covers low pressure steam boilers (less than 15 psig), low pressure hot water boilers (less than 30 psig), space heaters, unit heaters, and warm air furnaces. The term "small" is used in the context of this manual to differentiate from the high pressure systems and equipment that are covered in detail in TM 5-650, Central Boiler Plants.

b. This manual makes reference to specific types of equipment commonly in use at Army installations. System and equipment descriptions contained in the manual are general in nature. Equipment manufacturers' technical literature and manuals should also be used for reference, training, and troubleshooting specific equipment.

1-2. References.

Related publications are listed in Appendix A.

1-3. Abbreviations and terms.

Abbreviations and special terms used in this manual are explained in the Glossary.

1-4. Organization and responsibility.

The operating and maintenance personnel for heating systems are organized in accordance with the applicable Army regulations and staffing guides. Supply and administrative support are provided by other divisions, branches, and/or sections within the Directorate of Engineering and Housing. There are significant differences at the installations in the quantity, type, and use of equipment. Therefore, personnel responsibilities may vary locally to provide the necessary operating and maintenance functions. In some cases, an individual may well perform both operation and maintenance. In all instances, coordination is required with the work management functions (planning, estimating, scheduling, recording data, etc.).

a. Operating personnel. Operating personnel have the responsibility to fire the equipment in the most efficient and economical manner. This includes the performance of equipment adjustments and simple routine maintenance work consistent with good operating practice.

b. Maintenance personnel. Maintenance personnel have the responsibility to maintain heating systems in good operating condition. This includes keeping equipment information files and necessary records of the maintenance work performed.

1-5. Systems overview.

The main heat conveying media for space heating systems are steam, hot water, and warm air.

a. Steam. Water heated to the boiling point evaporates and produces steam as long as heat is added. If the heat is removed or reduced, evaporation will stop or decrease. The quantity of heat contained in each pound of steam depends on its pressure and temperature. Steam can be generated and used as either saturated or superheated steam. Chapter 4 gives detailed information on steam systems.

(1) *Saturated steam.* For each steam pressure, there is a specific temperature at which the steam will become saturated. When steam is saturated, a drop in temperature or an increase in pressure will cause part of the steam to revert to water. There are two types of saturated steam: dry, i.e., without moisture; and wet, which is intermingled with moisture, mist or spray. Saturated steam is commonly used for space heating and process heat.

(2) *Superheated steam.* When steam has a temperature higher than its corresponding saturation pressure, it is called superheated steam. The difference between the temperature of superheated steam and its saturation temperature is called the superheat. Usually, superheated steam is generated in central heating plants when necessary to avoid condensation in the steam lines of the plant and the distribution system, or to drive steam turbines. Normally in such instances, not more than 50F superheat is imparted to the steam.

(3) *Total heat content.* A certain amount of heat is needed to change water into steam. The specific amount depends on the initial condition of the water and the desired pressure and temperature of the steam. The amount of heat required to convert water at 32F into steam at a specific pressure and temperature is called the total heat content (or enthalpy) of the steam at that particular pressure and temperature. As pressure rises from atmospheric conditions up to about 450 psia, the total heat content of dry saturated steam increases. At higher pressures, the total heat decreases as pressure increases. However, superheating increases the total heat content of the steam at any

pressure. Any thermodynamic steam table will show the total heat content of steam at different pressures and temperatures.

b. Hot water. Hot water is a very useful carrier of heat. Circulating in a closed system, the water absorbs heat in a boiler or heat exchanger and releases it to the heat using equipment. Hot water systems can be classified as high temperature, medium temperature, and low temperature. Chapter 5 gives detailed information on hot water systems.

(1) *High temperature water*. High temperature water (HTW), above 350F is usually generated in central heating plants and then delivered to the consumers by a distribution system. A heat exchanger is normally used in each building to convert the HTW into low temperature water for use in space heating.

(2) *Medium temperature water*. Supply water temperature for this type system ranges from 250F to 350F and is used for distribution systems, large space heaters, absorption refrigeration, and industrial purposes.

(3) *Low temperature water*. Supply water temperature for this type system is below 250F and is used for space heating. Generally, this manual covers low temperature hot water systems and equipment.

c. Warm air. Unlike steam and hot water, which are fed through pipes to space heating equipment from which heat is dispensed by radiation and convection, warm air supplies direct heat. In warm air systems, the cold air is heated by blowing it through a furnace casing or heat exchanger. The warmed air is then distributed through air ducts to the areas where heating is required. Chapter 6 gives detailed information on warm air systems.

1-6. Energy conservation policy.

a. All Army installations should have a management improvement program that includes policies and guidelines relating to the efficient use and conservation of utilities. Conservation measures should be implemented by supervisory, operating and maintenance personnel and by the users. The importance of keeping equipment properly used, adjusted, and maintained cannot be overemphasized.

b. Periodic reviews should be made of all factors influencing fuel selection to determine whether the fuel used still remains the most cost efficient for a particular installation. Also, the feasibility of improving or modernizing firing methods for current fuels should be considered.

c. The greatest boiler operating efficiency is obtained when units are operated at or near their full load ratings. Therefore, two boilers should never be operated if one can carry the load without exceeding its rating. Supervisors should review daily operating logs to insure proper boiler operation. Give specific attention to the percentage of CO_2 in the flue gas and temperature of the gas. These are good indicators of operating efficiency and depend on the proper balance between the rate of fuel feed, combustion air supply, draft, and stack temperature.

d. Periodically inspect heated facilities. Observe thermostat settings and advise users when incorrect settings are found. Correct settings may be posted. Also, identify those facilities where excessive heat is lost due to improper insulation and open doors or windows and take corrective actions.

CHAPTER 2

FUELS

Section I. COAL

2-1. General.

Coal is a mineral originated from decayed trees, ferns, and other types of vegetation. It is composed of varying proportions of carbon, hydrogen, oxygen, nitrogen, sulfur, and several noncombustible materials which make up the ash. The ash is composed mainly of silica, alumina, iron, lime, and small quantities of magnesia. Coal used as commercial fuel consists primarily of volatile matter, fixed carbon, sulfur, ash, and water. The types of coal used at military installations are anthracite, bituminous, sub-bituminous and lignite. Table 2-1 gives the heating value for these coals.

Table 2-1. Heating Value of Typical Coals

Classification	*Group*	*Heating Value (BTU/ lb.)*
Anthracitic	Metal anthracite	12,745
	Anthracite	12,925
	Semianthracite	11,925
Bituminous	Low volatile	13,800
	Med. volatile	13,720
	High volatile A	12,850
	High volatile B	12,600
	High volatile C	11,340
Sub-bituminous	Type A	11,140
	Type B	9,345
	Type C	8,320

Section II. FUEL OILS

2-2. General.

Fuel oils are derived from crude petroleum. Crude petroleum is a mixture of hydrocarbons and small amounts of nitrogen, sulfur, and vanadium; the amount of each substance present varies with the petroleum source. There are two types of crude petroleum available in the United States, paraffin-base and asphalt- or naphthene-base. Paraffin-base crudes are found in the Appalachian mountain range and in the Midwest. Asphalt-base crudes are found in Texas and California. Paraffin-base crudes yield many valuable lubricating oils. The asphalt-base crudes furnish the major part of commercial fuel oil used in the United States. The various products derived from petroleum, including fuel oils, are separated by fractional distillation. This is a process by which liquids with different boiling points are separated from solution by repeatedly evaporating and condensing portions of the mixture.

2-3. Classification of fuel oils.

In general, fuel oils can be divided into two major classifications: distillate and residual.

a. Distillate fuel oils. When the fractional distillation process is applied to crude petroleum, the gaseous and light substances boil off first, followed by gasoline, kerosene, and then light and heavy distillate fuel oils (gas oils).

b. Residual fuel oils. When marketed as a fuel,. the “bottom” or residual material from the distillation process is called residual fuel oil. Since crude petroleum from various sources differ widely in composition, there is considerable difference in these oils. In general, they are heavy, dark and viscous compared to the lighter and more fluid distillate oils.

c. Commercial grade fuel oils. Commercial-grade fuel oils are generally classified according to physical characteristics and use. Current standards designate five basic grades of heating fuel oil: Nos. 1, 2, 4, 5, and 6.

(1) *No. 1 oil.* This is a light volatile distillate with essentially the same burning characteristics as kerosene. It is generally used in vaporizing pot type burners under domestic heating boilers and furnaces. The average heating value is approximately 135,000 Btu per gallon.

(2) *No. 2 oil.* This is slightly heavier distillate than No. 1 oil. It is used as domestic fuel oil in some types of vaporizing burners and in high and low pressure atomizing burners. Its average heating value is approximately 139,000 Btu per gallon.

(3) *No. 4 oil.* This oil may be 100% residual material. However, for marketing purposes, it is generally blended with sufficient distillate stock to meet viscosity and flashpoint requirements for the grade. Grade No. 4 oil, like grades No. 1 and 2,

atomizes under normal conditions without heat. The approximate heating value is 145,000 Btu per gallon.

(4) No. 5 oil. This oil, like No. 4, can be a straight residual product; but it is also marketed in many areas as a blend of distillate and residual stocks. No. 5 oil has medium viscosity. Installations that use it generally have oil heating facilities. The heating value of No. 5 oil is approximately 150,000 Btu per gallon.

(5) *No. 6 oil.* No. 6 oil is a high viscosity, residual material. It is used in large commercial and industrial steam generating plants and in certain industrial processing operations. Its use requires preheating facilities for transportation unloading, pumping, and atomization. The heating value averages approximately 154,000 Btu per gallon.

d. Diesel fuel oils. Diesel fuel oils vary widely in characteristics. The cetane number, a measure of the ignition quality of the fuel which influences engine roughness, varies from a minimum of 40 for grades 1-0 and 2-0 to 30 for grade No. 4-0. Diesel fuels are normally used for firing stationary engines and not for heating.

2-4. Oil tanks.

Tank installation is largely governed by local conditions. Listed here are the principles of tank installation that give greatest freedom from service problems. Adhere as closely to these recommendations as local conditions permit.

a. Indoor or elevated outdoor tanks. Whenever possible, install single-pipe gravity oil feed inside or elevated outside tanks. (See figure 2-1.) Use a 1/4-inch globe valve at the tank rather than a larger valve, which may cause "tank hum".

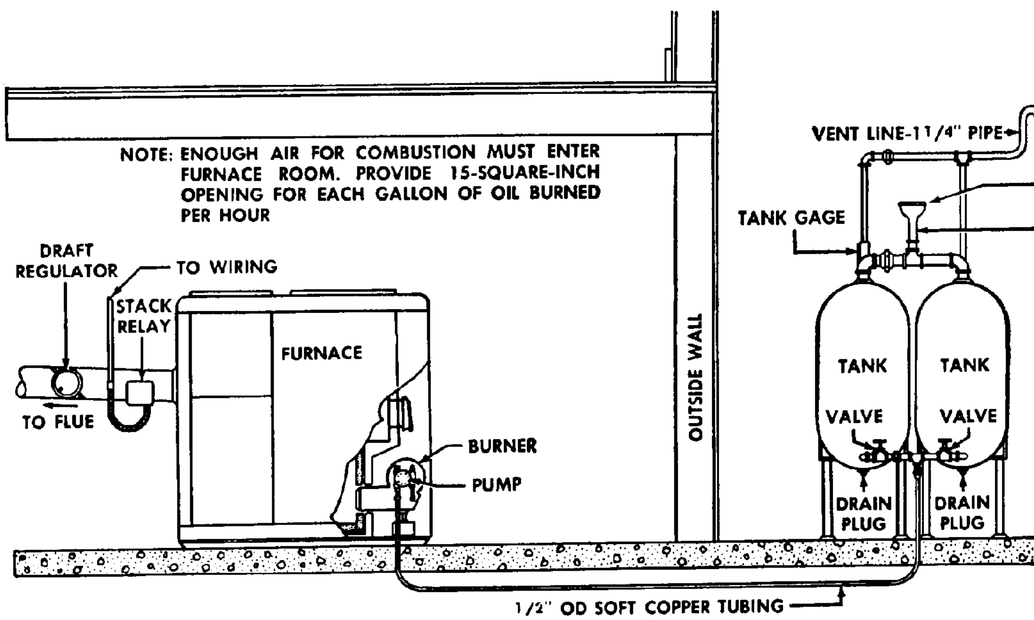

Figure 2-1. Inside or elevated outside oil tank installation.

b. Tubing. For all installations, use a continuous piece of ½-inch copper tubing from the oil tank to the burner and a similar piece for the return when required. The principle is to minimize the number of joints and to thus minimize the possibility of air or oil leaks.

c. Overhead piping. For inside installations where it is necessary to run the piping between the tank and burner overhead (when the burner is either above or below tank level), the two-pipe system is recommended. This system requires the use of a two-stage pump.

d. Underground outside tank. Install underground outside tanks according to the following instructions and figure 2-2:

(1) Install a continuous piece of copper tubing from a point 3 inches above the bottom of the tank up through a compression fitting in the top plug, over into the basement, and into an approved check valve. Where possible, drop this feed-line inside the building to a point level with the bottom of the tank before the check valve.

(2) Use a ½-inch IPS straight compression connector (for ½-inch tubing) for running the ½-inch copper tubing through the tank cap. Drill out the

inside of the connector, allowing the tubing to slip completely through; drill and tap the tank cap for ½-inch IPS to receive the connector. Slip the tubing through the connector and down to the proper point 3 inches above the tank bottom. Tighten the connector, locking the tubing in the proper position.

(3) Install the return line in the opposite end of the tank, using the technique described for the suction line, above. Carry it to within 5 inches of the bottom. This creates an oil seal between the two lines and any agitation caused by return oil is safely away from the suction line.

(4) A 2-inch fill line and 1¼-inch vent line are recommended. Carry the vent well above ground and terminate it with a weather-proof cap. Pitch the vent line down toward the tank.

(5) Use special pipe dope on all iron pipe fittings that carry oil.

(6) Treat all underground outside tank and piping surfaces with a standard commercial corrosion resistant paint or preparation.

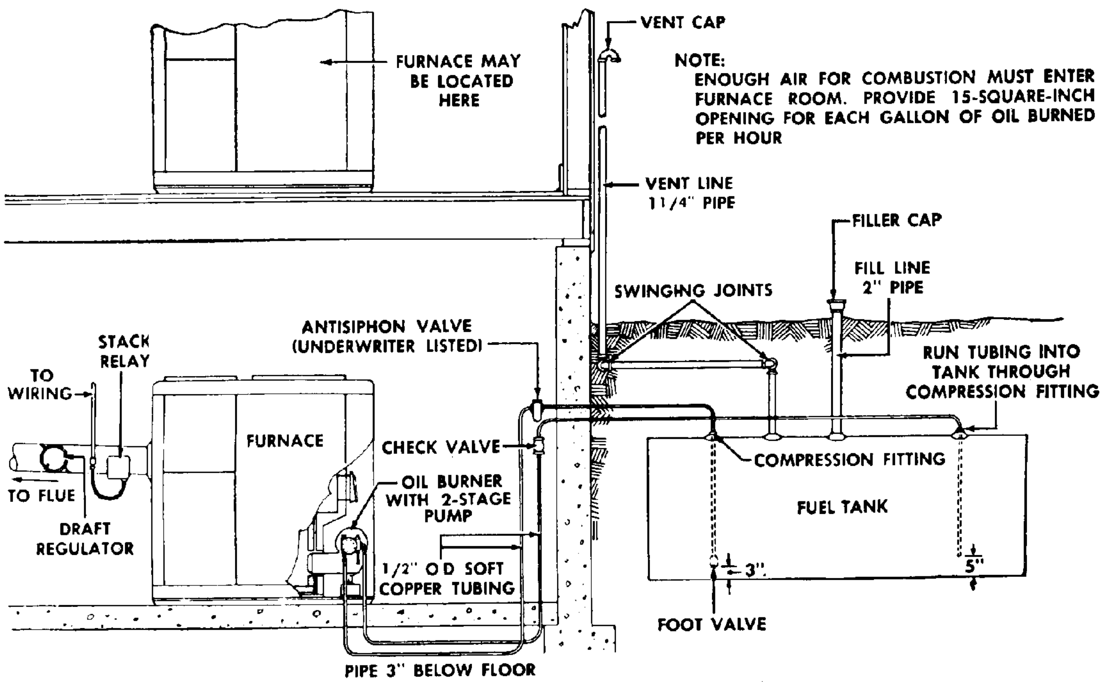

Figure 2-2. Buried oil tank installation.

Section III. NATURAL GAS

2-5. General.

Natural gas is the most commonly used gaseous fuel in small heating systems. Natural gas is usually odorless and requires the addition of odorants to permit detection. According to its content of hydrogen sulfide it is known as "sweet" or "sour". Sour natural gas is normally thought of as gas containing more than 1.5 grains of hydrogen sulfide per 100 cubic feet of gas. Its heat value varies from approximately 950 to 1,150 Btu per cubic foot.

2-6. Gas handling and storage.

The supply company normally delivers natural gas to consumers by pipeline. Storage tanks therefore are not normally included in a consumer's gas system installation. A gas handling system consists of all or some of the following items:

a. Pressure reduction station. This is used to reduce the supply pressure and maintain a relatively constant pressure despite variations in supply.

b. Low pressure safety shut-off valve. The function of this valve is to interrupt gas flow to burners if the supply pressure drops below a predetermined value.

c. Flow meter. This meter indicates and records the volume of gas consumption.

d. Pressure and temperature gauges. These aid the operator to control and supervise operation of the equipment.

e. Vents, drains, moisture separators, and relief valves. Vents are used to purge the system and remove all air and inert gases during filling procedures. Moisture separators and drains remove condensate from the system; relief valves prevent abnormally high gas pressure if the system reducing valve malfunctions.

2-7. Gas handling precautions.

Natural gas is toxic, and its presence in appreciable quantities is a serious health hazard. Gas diffuses readily in air resulting in possibly explosive mixtures. Because of these characteristics, be sure there are no leaks present and exercise caution when lighting gas fired equipment.

Section IV. LIQUEFIED PETROLEUM GAS

2-8. General.

Because of the special characteristics of liquefied petroleum gas (LPG), it must be handled and stored with great care in properly designed tanks and equipment. If handled carelessly, whether through failure to understand its characteristics or for other reasons, this fuel presents a definite hazard to life and property.

2-9. Characteristics.

The principal commercial products are butane, isobutane, and propane. They are closely related, are all derived from natural gas or petroleum refining gas, and are on the border line between a liquid and a gaseous state at atmospheric pressure.

a. Vaporizing point. At ordinary atmospheric pressure with necessary heat of vaporization added, butane will boil at 31F. The boiling point of isobutane is 10F and the boiling point of propane is -44F.

(1) Under pressures higher than atmospheric the boiling points are higher than at atmospheric pressure. The fuel, if placed under pressure, can be held in a liquid state and transported by tank car, truck or cylinders. However, LPG must be in the vaporized or gasous state to be used as a fuel.

(2) To change these petroleum products from a liquid to a gasous state the liquid must be maintained at the boiling point and the latent heat to produce vapor must be added. For small installations, heat from the atmosphere in warm climates or from the ground in colder climates, is usually sufficient to vaporize the liquid. In cold climates, where temperatures of the liquid will drop below its boiling point, a vaporizer must be used; that is, the liquid is passed through a heating device which will apply sufficient heat to vaporize it. The gas flows from the tank through a valve and pressure regulator. The regulator reduces tank pressure to the low pressure required to operate appliances. Although pressure on the tank may be 100 psi, the pressure regulator reduces this pressure to about 6 to 8 ounces, or less, per square inch.

b. Specific gravity. Natural gas is lighter than air and in case of a leak, will float away and be dissipated in the air. However, vapors from liquefied petroleum gases are heavier than air and therefore tend to settle in low points. In making installations, this must be carefully considered and bottom ventilation provided in basements in which a furnace or appliance is used. Basement installations are definitely not recommended and must not be made unless absolutely necessary and all safety aspects are considered.

2-10. Specifications.

a. Propane. As a gas (60F at 14.7 psi), the heating value of propane is approximately 2,500 Btu per cubic foot. As a liquid (-45F at 14.7 psi), the heating value of propane is 91,800 Btu per gallon or 21,560 Btu per pound.

b. Butane and isobutane. As a gas (60F at 14.7 psi), the heating value of butane and isobutane is 3,100 Btu per cubic foot. As a liquid (12F at 14.7 psi), the heating value is 102,400 Btu per gallon, or 21,500 Btu per pound.

2-11. LPG storage and handling.

At Army installations, gas handling and storage equipment upstream of the tank pressure reducing valve are usually the property of the gas supplier. The pressure reducing valve and all equipment downstream is government property. This may include a pressure reducing station, low pressure safety shutoff, flow meter, pressure and temperature gauges, vents, drains, moisture separators and relief valves. Do not tamper with nongovernment property. Most fuel supplied as LPG is commonly designed to conform with the properties of propane. Equipment designed for handling and storing butane (a lower pressure gas under similar operating conditions) must not be used for propane. The vapor pressure of propane at 60F temperature is 92 psig; if the temperature rises to l00F the vapor pressure increases rapidly with temperature rises.

Equipment for storing and handling propane is rated at 250 psi to provide a reasonable margin of safety.

a. LPG storage. LPG is stored in pressure tanks with the gas vapor filling the upper portion. Tanks are fitted with a liquid line and a vapor line connected to the vaporizing equipment (if used) and a liquid line and a vapor line connected to the unloading pit. In addition, the tank is usually provided with a safety valve, a thermometer well, a pressure gauge, a 90 percent full indicator, and a sliptube type of gauge for determining the liquid level in the tank. Any valve pit or other below grade location where leakage of gas or liquid might occur, is vented by a pipe stack tall enough to carry off the vapors. Because LPG is heavier than air, the vent stack must have a mechanical exhauster operated by either power or wind.

b. LPG handling precautions. When handling LPG, take the following precautions:

(1) Any work required in a fume-filled or contaminated area must conform to all safety regulations to eliminate personnel hazards. LPG is odorless, colorless, tasteless; it is odorized with the same odorants as natural gas. Although LPG is not poisonous, exposure to a room or pit full of gas causes a synthetic intoxication; and if exposure is prolonged, asphyxiation (smothering) results. LPG is heavier than air and will hang to the floor or ground.

(2) Avoid contacting the liquid with the hands or any part of the body. When LPG is released from a container and evaporated, it absorbs heat from anything it touches. Therefore, any part of the body which comes in contact with the liquid may be frozen. If this happens, as a first aid measure, thaw the affected part immediately by applying cold water or cold pads. Then treat exactly as a burn and get medical assistance.

(3) Avoid leaks. LPG will ignite only when it vaporizes and mixes with sufficient air to form a combustible mixture. Vapor leaks permit such mixtures to form. A leak will burn close to or at a distance from the opening, depending on the gas pressure and the size of the opening.

(4) Comply with rules and regulations governing transportation, storage, and dispensing of LPG. Most petroleum derivatives such as kerosene, gasoline, natural gas, or LPG are combustible and, when not handled carefully, can be explosive and dangerous. When properly handled, suitably housed, and controlled, they can be used safely.

c. LPG piping. Liquefied petroleum gas acts as a solvent of all petroleum products; for that reason, use a special pipe dope containing no mineral oils or rubber. Because gases revert to their liquid state when cooled below respective boiling points, bury gas lines below the frost line. Never run LPG lines under concrete floors, and run under buildings only when absolutely necessary. Bury supply lines parallel to and at least two feet away from building walls. Install separate takeoffs and risers for each appliance and enter the building at the nearest practicable point to the appliance or furnace. Whenever possible, run lines inside buildings using a single length of pipe without joints.

d. Installation and control of LPO systems. For furnace installations, pressure regulators are not required at the furnace. Take the pressure reading at the furnace manifold and set the pressure at the regulator on the liquefied petroleum tank or atomizer. Furnaces using LPG require a manifold pressure of 11 to 13 inches water gauge, whereas with natural gas, a pressure of 2.5 to 5 inches water gauge is required. Follow manufacturer's recommendations covering manifold pressures for liquefied petroleum gas at the furnace. If gas lines serving other appliances, such as water heaters, space heaters, or cooking appliances are taken from the line serving the furnace, an approved double-diaphragm, low-pressure regulator is installed in the take-off line or lines to reduce pressure in these lines to the required pressure. These regulators are vented to the outside of the building, not under the pilot as with natural gas. (See figure 2-3.) Furnaces are equipped with 100-percent-cut-off valves. That is, all gas, including pilot gas, is cut off if the pilot is extinguished. Furnaces with two or more pilots have a separate pilotstat for each pilot, all wired in series. Each of the small solenoid valves installed in the pilot line is wired in parallel with the usual main burner electric solenoid valve. If any pilot should go out, its pilotstat breaks the circuit and shuts off the gas supply for all main burners and pilots.

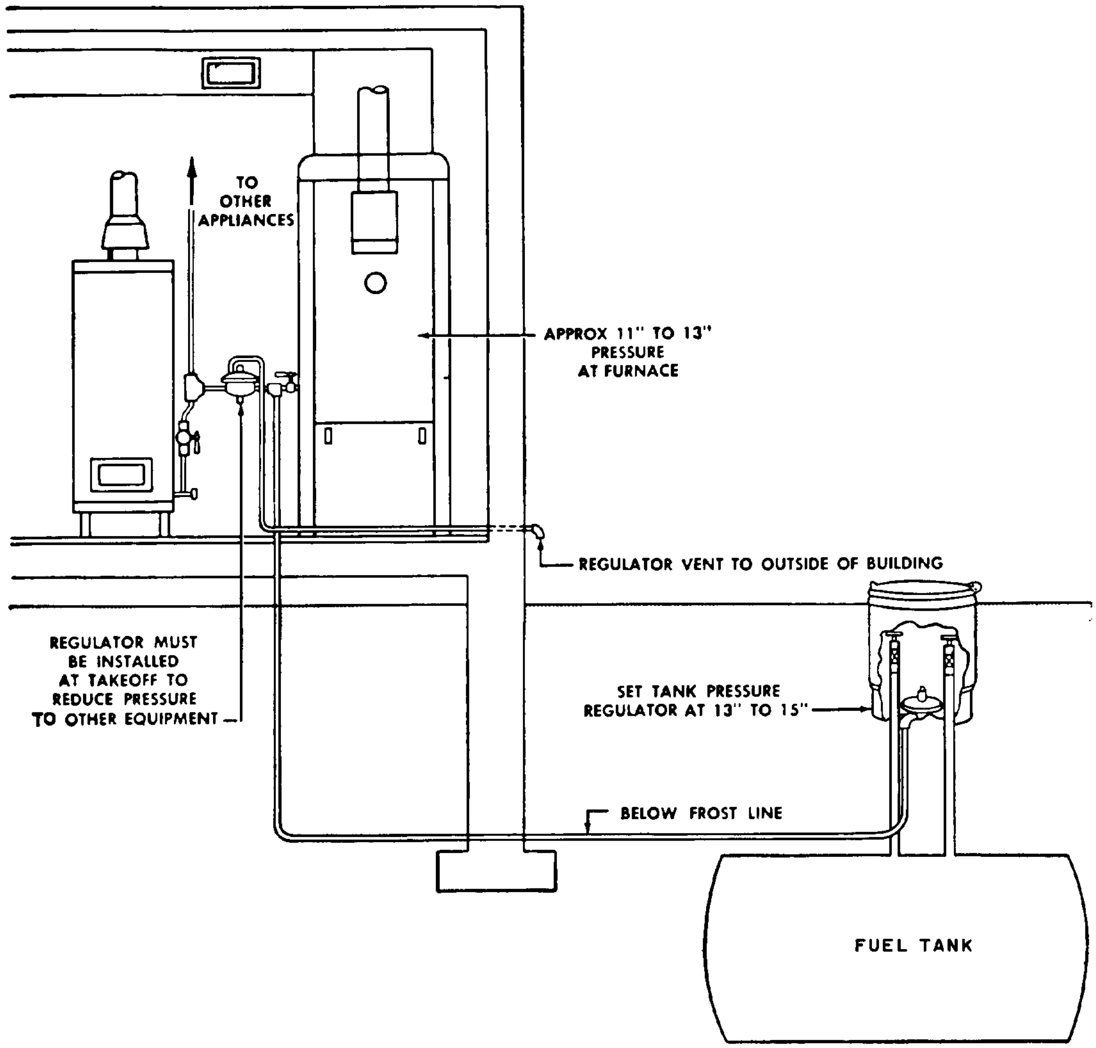

Figure 2-3. Typical LPG installation.