FORINTEK CANADA CORP.
Western Region
6620 N.W. Marine Drive
Vancouver, B.C.
V6T 1X2

GAS FURNACE OPERATION AND PRODUCTS OF COMBUSTION

by
S. McIntyre

August 1988

S. McIntyre
Technician
Research and Development Dept.

M.R. Clarke
Manager
Research and Development Dept.

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GAS FIRED FURNACE OPERATION AND CONTROL

The following is a description of the operation and control of a gas fired furnace as it applies to lumber dry kiln operations (Figure 1).

Start-Up Sequence and Furnace Operation

1. The kiln is charged, the wet bulb wick is checked, water flow to the wick is checked, baffles are in place and doors are closed.

2. Recorder-controller charts are in place and wet- and dry-bulb settings are made.

3. Check that the gas pressure in the gas line is normal.

4. The burner valve is closed as its coil is de-energized due to the fact that the air pressure switch, the flame failure switch and the timer switch are open.

5. The manually operated main switch on the electrical panel is now placed in the "ON" position.

6. Start the kiln circulation fans.

7. Wait until the circulation fans have attained operating speed and then start the heat fan.

8. Wait until the heat fan is up to speed and then start the burner fan. (If all fans were started at once they would draw too much current and cause an overload on the line, causing the circuit breaker to trip.) There will either be a pressure switch or a motion detector on the furnace heat fan motor shaft. If not enough pressure is generated to close the pressure switch or no motion is detected, the system will fail to start (or will shut down if in operation). The operation of the burner fan is controlled by a pressure switch. If there is not enough pressure generated to close the switch, the system will fail to start (or will shut down during operation due to insufficient combustion air to maintain the burner flame).

9. If both the heat and burner fans continue to operate, a timing device will begin to operate. Timer switches T1 to T5 will all be open. Timer switch T1 will close and a short purge period begins. (This will assure that all combustibles are cleared from the combustion chamber before ignition occurs thus avoiding any chance of an explosion.)

10. When the purge period is over, timer switch T2 will close and energize the ignition transformer which causes the igniter to spark.

11. Timer switch T3 will now close which will open the pilot flame gas valve and the pilot flame will be lighted by the igniter sparks.

12. The flame scanner or a flame rod will detect the pilot flame. This will complete the scanner electronic circuit and the flame failure switch will close.

13. After a short period of time that allows the pilot flame to become stable, switch T4 will close. This will energize the burner valve and the furnace will begin to operate on low flame.

14. The timer now opens T2 and T3 shutting off the igniter and the pilot.

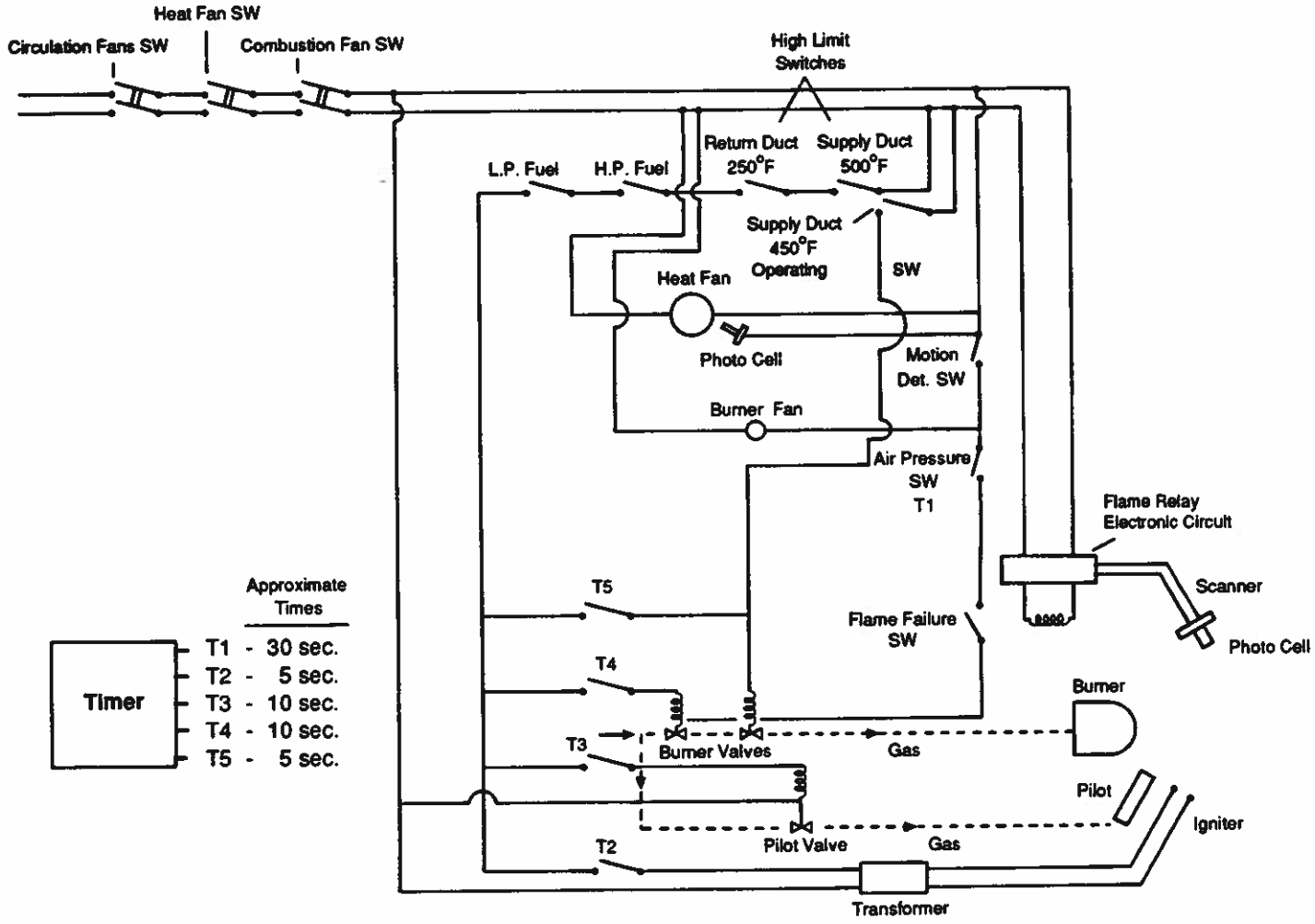


Fig. 1 Furnace Control

15. After a short period when low flame has become established, T5 will close and high fire will commence. The flame will now be controlled by the kiln controller.

16. If for any reason at all flame failure occurs, the flame failure switch will close. This will break the scanner circuit and when the scanner can no longer detect a flame, the burner circuit will be broken and the gas valve will close.

17. There are pressure switches on the gas line in front of the burner. A low pressure switch and a high pressure switch. Should the gas in the line fall below the level where a stable flame can be maintained, the low pressure switch will close the gas valve. Should the pressure in the line rise above the normal working pressure, the gas valve will be closed by the high pressure switch.

18. There are two high limit switches in the supply duct. One is the operating switch set for about 450°F which is the temperature that the furnace may attain when operating on high fire, should the temperature rise above 450°F, the burner will switch to low fire. The second high limit switch is set for about 500°F. Should the operating switch fail and the temperature rise above 500°F then the burner will shut down

19. There is a high limit switch in the return duct that should be set for about 25°F above the highest dry-bulb set point of the schedule being used (i.e., if the highest dry-bulb set temperature is 225°F, then the high limit switch should be set for about 250°F). Should the temperature rise above 250°F for any reason including a fire in the kiln, the furnace will shut down completely and the vents will close.

COMBUSTION

Since natural gas is the principle gas burned to heat lumber dry kilns, this section will describe the combustion of methane.

Analysis of Natural Gas in B.C.*

94.9%	Methane
3.6%	Ethane
1.1%	Propane
0.3%	Carbon
.9%	Nitrogen
0.1%	Oxygen

* Information obtained from Inland Natural Gas Co. Ltd.

Reactions which take place with the emission of heat and light are called combustion reactions. Most combustion reactions involve burning and atmospheric oxygen such as the burning of natural gas. In a reaction of this type, the carbon fuel is burned to carbon dioxide and the hydrogen to water.

$$C + O_2 = CO_2$$
$$2H_2 + O_2 = 2H_2O$$

Natural gas is principally methane CH_4.

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

Requirements for Complete Combustion

1. There must be enough air supplied so that the oxygen can combine with all the combustibles in a fuel.

2. There must be turbulence so that all the combustibles can be mixed with the oxygen.

3. The temperature of the furnace must be above the ignition temperature of the fuel to ensure complete combustion.

4. The fuel must have time to completely combust before leaving the furnace chamber.

Combustion Air

Air is made up of 21% oxygen and 79% nitrogen, by volume, and the products of combustion (Figure 2) are H_2O, CO_2, N_2 and O_2.

Theoretical air is the amount of air needed to supply the exact amount of air needed for the combustion process. If less air is supplied, then instead of the CO_2 (carbon dioxide), a poisonous gas will be produced, CO (carbon monoxide).

To make sure that all the combustibles are mixed with oxygen, more air than the theoretical amount of air is needed. This is called excess air.

The amount of air supplied for combustion is usually dictated by the measurement of the amount of CO_2 detected in the flue gas. Larger quantities of air are supplied until the maximum amount of CO_2 is obtained. The draft is then cut back until just a trace of CO is obtained. The draft is then increased until the CO cannot be detected. This is usually the point at which the most efficient combustion is taking place, the point at which the maximum amount of heat is being liberated using the minimum amount of air.

The percentage of excess air required for proper combustion of a fuel may vary from 10% to 60% or even higher. Gaseous fuels, such as natural gas will take much less excess air than a solid fuel such as wood as it will easily mix with the oxygen in the air.

Kiln Safety

Figure 2 shows that when natural gas is combusted with less than the theoretical amount of air, carbon monoxide is produced and a mixture containing one percent carbon monoxide, which is a poisonous gas can be fatal.

When natural gas is combusted with 20% excess air only four percent of the kiln atmosphere will be oxygen. The usual amount of oxygen by weight in air is 23%. One may still work in air containing only 18% oxygen. In air containing less than 16% oxygen, one's thought process begins to become confused and at 12% one looses consciousness and this is followed by death.

The following precautions should be taken to avoid these dangers:

1. Do not attempt to enter the kiln compartment while furnace is in operation.

2. If you must enter the kiln to change a wet-bulb wick or take a moisture check, shut off the furnace and sprays, open the vents and doors and allow the fans to operate for at least 5 minutes before entering.

3. Do not enter the kiln unless a second person who is knowledgeable about the operation of the kiln is present. This person should remain outside of the compartment unless the kiln has been shut down, doors are open and cooling has taken place.

4. Recognize the potential dangers from the products of combustion are:

   (a) poisonous gas

   (b) lack of oxygen

   (c) excess heat

Products of combustion in kiln atmosphere, employing other fuels for heating lumber dry kilns and using theoretical air are shown in Table 1.

Table 1

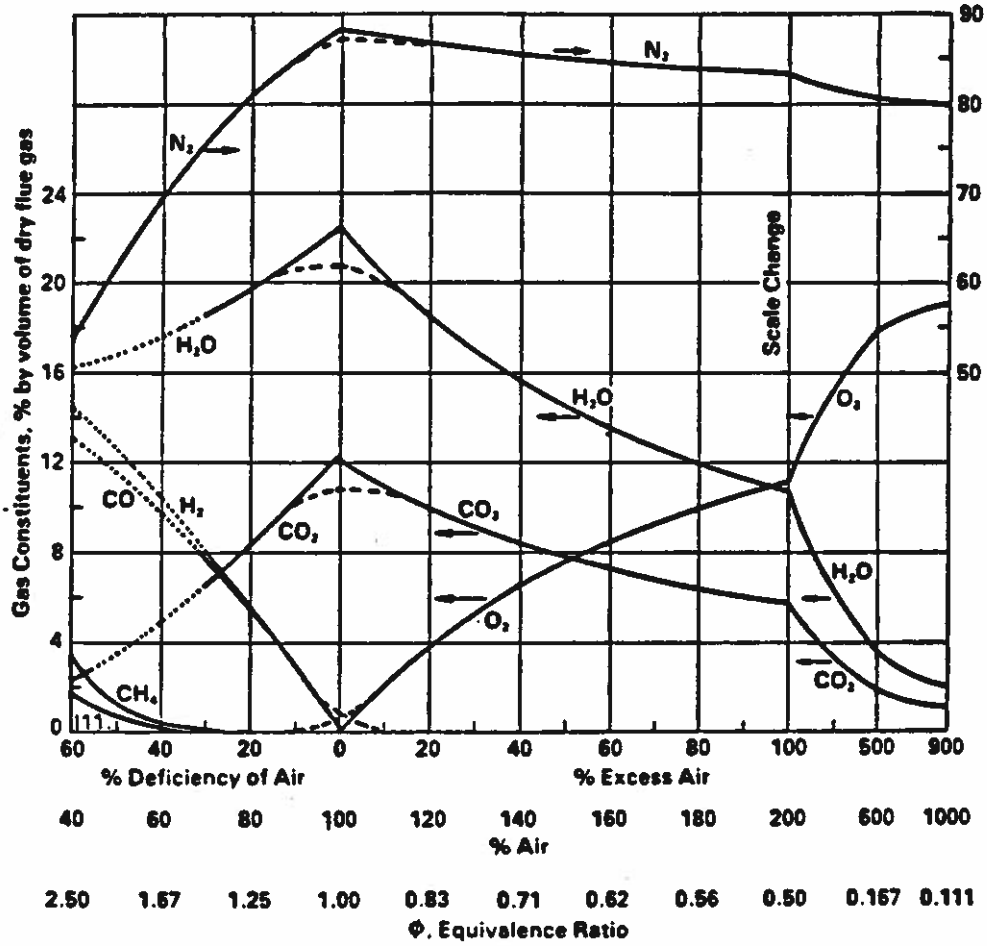
Products of Combustion by Volume

Fuel	Volume CO_2 %	Volume N_2 %	H_2O in Atmosphere %
Propane*	11.70	88.30	23.39
Butane*	13.72	86.28	18.29
Wood**	14.02	85.98	17.52

* Calculated from data found in Marks Standard Handbook for Mechanical Engineers, Ninth Edition, 1988.

** Calculated from Bramhall, G. (1978). Humidity of combustion products from wood and gaseous fuels. WFPL Report VP-X-182.

FIGURE 2. COMBUSTION ANALYSIS FOR 1108 BTU/FT3 NATURAL GAS



Extracted from North American Combustion Handbook. 2nd Ed. 1978. Edited by R.J. Reed