certain type of operation. Of course, the effect on service life of any particular load spectrum must be anticipated.

One exception to the arbitrary time standard for operation at high temperatures or sustained high powers is the case of the afterburner operation. When the cooling flow is only that necessary to prevent excessive temperatures for adjacent structure and equipment, sustained operation past a time limit may cause damage to these items.

THRUST AUGMENTATION. Many operating performance conditions may require that additional thrust be provided for short periods of time. Any means of augmenting the thrust of the turbojet engine must be accomplished without an increase in engine speed or maximum turbine section temperature. The various forms of afterburning or water injection allow the use of additional fuel to provide thrust augmentation without increase in engine speed or turbine temperature.

The *afterburner* is a relatively simple means of thrust augmentation and the principal features are light weight and large thrust increase. A typical afterburner installation may add only 10 to 20 percent of the basic engine weight but can provide a 40- to 60-percent increase in the static sea level thrust. The afterburner consists of an additional combustion area aft of the turbine section with an arrangement of fuel nozzles and flameholders. Because the local flow velocities in the afterburner are quite high, the flameholders are necessary to provide the turbulence to maintain combustion within the afterburner section. The turbojet engine operates with airflows greatly in excess of that chemically required to support combustion of engine fuel. This is necessary because of cooling requirements and turbine temperature limitations. Since only 15 to 30 percent of the engine airflow is used in the combustion chamber, the large excess air in the turbine discharge can support combustion of large amounts of additional fuel. Also, there are no highly stressed, rotating members in the afterburner and very high temperatures can be tolerated. The combustion of fuel in the afterburner brings additional increase in temperature and volume and adds considerable energy to the exhaust gases producing increased jet velocity. The major components of the afterburner are illustrated in figure 2.14.

One necessary feature of the turbojet engine equipped with afterburner is a variable nozzle area. As the afterburner begins functioning, the exit nozzle area must increase to accommodate the increased combustion products. If the afterburner were to begin functioning without an increase in exit area, the mass flow through the engine would drop and the temperatures would increase rapidly. The nozzle area must be controlled to increase as afterburner combustion begins. As a result, the engine mass flow is given a large increase in jet velocity with the corresponding increase in thrust.

The combustion of fuel in the afterburner takes place at low pressures and is relatively inefficient. This basic inefficiency of the low pressure combustion is given evidence by the large increase in specific fuel combustion. Generally, the use of afterburner at least will double the specific fuel consumption. As an example, consider a turbojet engine capable of producing 10,000 lbs. of thrust which can develop 15,000 lbs. of thrust with the use of afterburner. Typical values for specific fuel consumption would be $c_t=1.05$ for the basic engine or $c_t=2.1$ when the afterburner is in use. The fuel flow during operation would be as follows:

fuel flow = (thrust) (specific fuel consumption)

without afterburner,

$$\text{fuel flow} = (10{,}000)\,(1.05) = 10{,}500 \text{ lbs./hr.}$$

with afterburner,

$$\text{fuel flow} = (15{,}000)\,(2.1) = 31{,}500 \text{ lbs./hr.}$$

The low efficiency of the afterburner is illustrated by the additional 21,000 lbs./hr. of fuel flow to create the additional 5,000 lbs. of