FLAME STABILITY AND PROPAGATION UNIT

Installation and Commissioning

SERVICES REQUIRED:

Single Phase Electric Power

The equipment has been wired as follows:

Red wire - LIVE
Black wire - NEUTRAL
Green wire - EARTH

A label at the rear of the unit indicates the operating voltage, 220-240V or 110-120V. Conversion is possible, refer to factory for details.

Two suppliers will be required:

1. Flame Propagation and Stability Unit
2. Flane Speed Ignition Unit

Gas

The equipment is designed for operation on most conventional gas fuels, e.g. Propane, L.P.G., Methane (Natural Gas), Town Gas. Gas supply should be at a minimum pressure of 125mm (5") water gauge.

Flexible plastic tubing from the gas supply should be connected to the hose nozzle at the rear of the unit. Ensure tubing is suitable for gases, e.g Propane and L.P.G. can react on rubber.

Ventilation and Safety

Unit should be operated in a well ventilated area and sited well away from inflammable or heat sensitive material.

Do not allow the unit to run with the gas control valve open if no flame has been established.

ASSEMBLY

1. Identify all items against Packing List. Report any loss or damage immediately.
2. Place unit on a firm work surface and connect electrical and gas supplies.
3. Position Burner Block Assembly (C551/10/11) and connect air pipe (large ribbed) and gas pipe (clear plastic tubing) to it.
4. Check Piezoelectric Gas Lighter (C551/11/1) for operation and position on plastic hook at rear of unit.
5. Mixing Tubes (C551/10/5 - C551/10/8) can now be screwed into the Burner Block. No sealing material is required.
6. For flame speed measurement remove mixing tube and replace with Angled Adaptor (C551/10/3). Fit locking ring (C551/7/7) and attach 25mm plastic tube (C47/3) over ring.
7. Arrange plastic tube as required and connect Flame Speed Ignition Adaptor (C551/10/4) to other end. Attach spark plug cap to igniter plug and attach earth wire to adaptor base.
8. Connect Ignition Unit (C551/14) to supply and test, by pressing trigger button, that spark occurs.

OPERATION

1. Switch on air blower. Open air control valve and ensure air flow

is through to burner block. Open gas control valve and ignite mixture on mixing tube, using a Piezoelectric gas lighter. Actual quantities to give good light-up will be found by experience as they vary with different tubes and gases in use.

2. When using flame speed measurement tube, assemble as per instructions 6-8. Open air and gas controls as before and establish flame over gauze on Igniter Adaptor with Piezoelectric gas lighter. (Suitable air/fuel ratio for light-up will be found by experience.)

   When flame established, adjust controls for desired air/fuel ratio. When ratio is set, wait approximately 5 seconds until flame is steady then close air and gas controls completely. At the same time operate the ignition unit trigger. Two operators will be required, one to operate the air/fuel ratio controls and close them at the moment of ignition, the other to operate the ignition unit and operate the stop watch to determine the time of flame travel between measured reference points on the plastic tube.

   Typical results from tests of this type are given on Page 12.

3. Smithells separation demonstration is achieved by slipping the ring FPSU/6 over one of the mixing tubes (a close sliding fit), and then a glass tube over the ring. The gas/air mixture is ignited in the normal way with the mixing tube protruding clearly above the glass tube.

   Adjust to produce a clearly defined blue cone and then lift the glass tube by means of the brass ring until the brass ring is just below the top of the mixing tube. It is not advisable to hold this position for long as the glass becomes hot and is then difficult to handle.

To extinguish flame turn off the gas valve and purge the system with air for a few seconds. When finished with unit, isolate electrical and fuel supplies.

NOTE: During use the fittings, mixing tubes, etc., will become HOT. The use of a heat resistant glove is recommended when handling these items.

EXPERIMENTS AND DEMONSTRATIONS WITH FLAME PROPAGATION & STABILITY UNIT

1. Investigation of stability limits of gaseous fuels.
2. Methods of improving stability limits.
3. Smithells flame separation.
4. Measurement of flame speed of air/gas mixtures.

Additional experiments which can be carried out with attachments made by the operator

5. Flame trapping and effects of various sections.
6. Temperature measurements.

1. <u>Investigation of Stability Limits of Gaseous Fuels</u>

For any burner operating on gaseous fuel there will be several well defined areas of operation that depend both upon the air/fuel ratio of the mixture supplied and the loading, or heat input, per unit area of nozzle.

In order to compare the limits of stable operation of various burners operating on various gaseous fuels, it is common to plot test results on a 'Fuidge' diagram.

Examples of these are given on Pages 11 and 13. The three regimes shown may be investigated in the following manner:

<u>A. Yellow Tipping</u>

Install the smallest diameter mixing tube and light the unit using the method described on Page 2 'Operation'. Shut the air control valve and note that the flame will have a yellow tip and may, depending upon the gas used, be producing smoke.

Gradually open the air valve and, preferably against a white background, note when the yellow tip disappears and is replaced by a blue non-luminous flame. Repeat this experiment for increasing gas flows and again using the two larger burners.

Sample results and the calculation method are shown for coal gas on Page 10.

The results for the three burners when plotted on a Fuidge diagram should form a continuous line as shown in the examples on Pages 11 and 13. However, due to boundary layer and velocity profile effects within tubes of this diameter, it is possible that deviations will occur.

<u>B. Lift Off</u>

Light the burner as outlined in the previous section and gradually increase the air flow with a constant gas flow.

If sufficient gas flow exists the yellow tipping will disappear and the characteristic blue flame will be established.

Further increases in the air flow will result in the flame becoming more fierce and some lifting of the flame will occur around the surface of the burner.

The condition is now being approached where the velocity of the gas/air mixture leaving the burner approaches the mixture flame speed.

Under certain conditions of low burner loading this condition may be unstable and the flame will light back down the tube. Should this occur, the gas should be shut off and the tube allowed to cool.

If sufficient gas is present and the air flow is further increased, the flow velocity will exceed the flame speed and the flame will 'lift off' and extinguish. The gas flow should be shut off immediately and the air flow and original gas flow recorded.

Repeat the above procedure for various gas flows using the three burner tubes.

Plot these results as before on the 'Fuidge' diagram.

* Note that with certain high flame speed gases it may not be possible to achieve complete lift off using the larger burners.

C. Light Back

The light back condition will to some extent depend upon the gas being burnt and the burner tube installed. For example, it may not be possible due to velocity profile effects to get the lower flame speed gases such as Propane and Methane to light back in the smaller diameter tubes.

Install the largest diameter burner and ignite the gas/air mixture.

With a low burner loading (depending upon the gas being burnt) increase the air flow until the yellow tipping disappears and a blue flame is established. Further increases in the air flow will result, if the burner loading is low enough, in the flame speed exceeding the flow velocity and the flame front moving down the tube to the inlet port. At this point record the gas and air flow and immediately extinguish the flame.

Repeat these readings for various gas flows and reducing burner size. Plotting of these results on a Fuidge diagram should produce the lower portion of the light back curve.

The upper portion is unstable and easily confused with lift off, but data may be obtained with extreme care if lighting of a gas/air mixture in this region is considered. However, for these tests extreme care should be exercised as a large quantity of inflammable gas/air mixture may leave the tube before ignition and light back is achieved. For this reason a well ventilated site is recommended.

2. Methods of Improving Stability Limits

When one of the cone stabilisers is fitted it is clearly evident that the stability limits of a particular mixing tube are considerably improved. It can also be shown that any object, for example, a piece of wire placed in the stream of mixture just above the mixing tube causes turbulence and recirulation and permits combustion above the lift-off condition.

3. Smithells Flame Separation

(See notes under 'Operation')

4. Measurement of Flame Speed

(See notes under 'Operation')

5. Flame Trapping

If the flame speed measurement tube or a similar piece of material is cut, flame traps made from various pieces of gauze or other material can be placed in the gas/air mixture and their effectiveness ascertained. In a similar manner bends and changes of section made up from pieces of perspex can be investigated.

6. Temperature Measurement

The Flame Propagation and Stability Unit is a useful means of providing a controllable source of heat for experiments on thermocouples and their limitations.

FLAME SPEED METHANE

Flame Front Timed Over 3.05m

Indicated Gas Flow	Gas Flow 10^{-3} m³ s^{-1}	Indicated Air Flow	Air Flow 10^{-3} s^{-1}	Time Seconds	Average Time Seconds	Flame Speed m s^{-1}	Air/Fuel Ratio
9	0.060	28	0.525	5.4 5.6 5.5 5.5 5.5	5.5	0.555	8.74
10	0.065	28	0.525	8.5 8.5 8.8 8.6	8.6	0.355	8.07
8	0.054	28	0.525	3.5 3.5 4.0 4.8 4.2	4.0	0.763	9.7
7	0.049	28	0.525	3.8 4.2 4.0 3.8	3.95	0.772	10.7
6	0.043	28	0.525	5.0 4.8 4.5 4.8 4.7	4.76	0.641	12.2
5	0.038	28	0.525	5.9 5.7 6.1 6.2 6.0	6.0	0.508	13.7
4	0.033	28	0.525	10.3 10.8 9.5 9.0 11.5 9.0 10.0	10.0	0.305	15.7

FUIDGE DIAGRAM

TYPICAL EXTRACT OF RESULTS FROM HILTON FLAME PROPAGATION AND STABILITY UNIT

COAL GAS

Port Area 10^{-6} m²	Ind. Gas Flow cm	Gas Flow 10^{-3} m³ s^{-1}	Air Flow Indicated cm				Air Flow 10^{-3} m³ s^{-1}				Primary Air/Fuel Ratio				Burner Loading MW m^{-2}
			YT	LB	LBO	LO	YT	LB	LBO	LO	YT	LB	LBO	LO	
67.7	2	0.026	-	2.5	8.4	12.0	-	0.075	0.175	0.233	-	2.9	6.8	9.03	7.147
	3	0.029	-	3.8	9.2	13.8	-	0.103	0.193	0.258	-	3.5	6.6	8.8	7.972
	4	0.037	-	4.8	10.2	15.1	-	0.113	0.205	0.283	-	3.1	5.6	7.7	10.171
	12	0.081	2.3	-	-	22.7	0.075	-	-	0.425	0.93	-	-	5.3	22.266
	14	0.093	2.6	-	-	24.5	0.082	-	-	0.458	0.88	-	-	4.9	25.565

Calorific value of coal gas = 18.61 MJ m^{-3}

$$\text{Burner Loading} = \frac{\text{Gas Flow} \times \text{Calorific Value}}{\text{Port Area}}$$

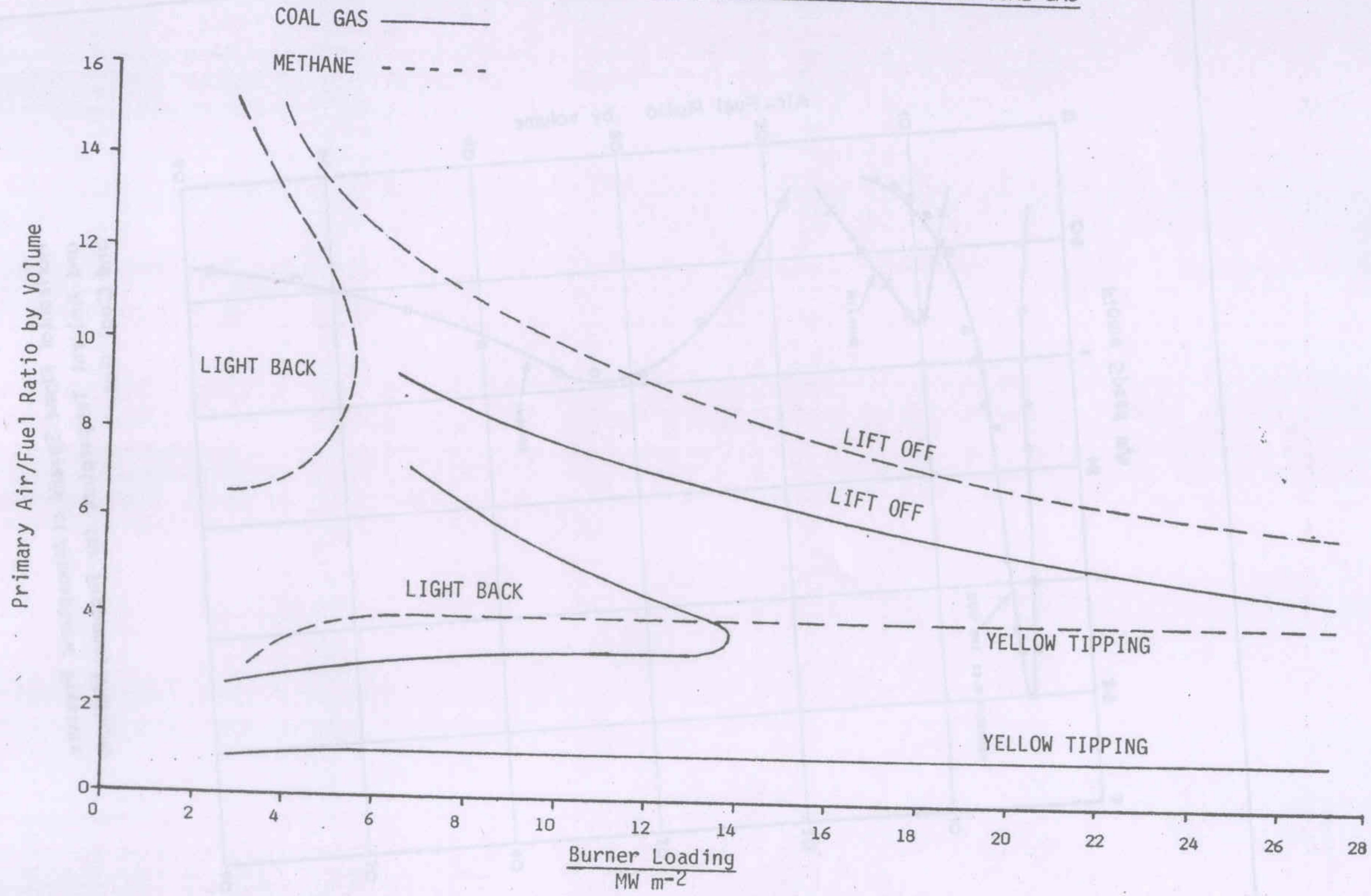
YT = End of Yellow Tipping

LB = Light Back into Port Tube

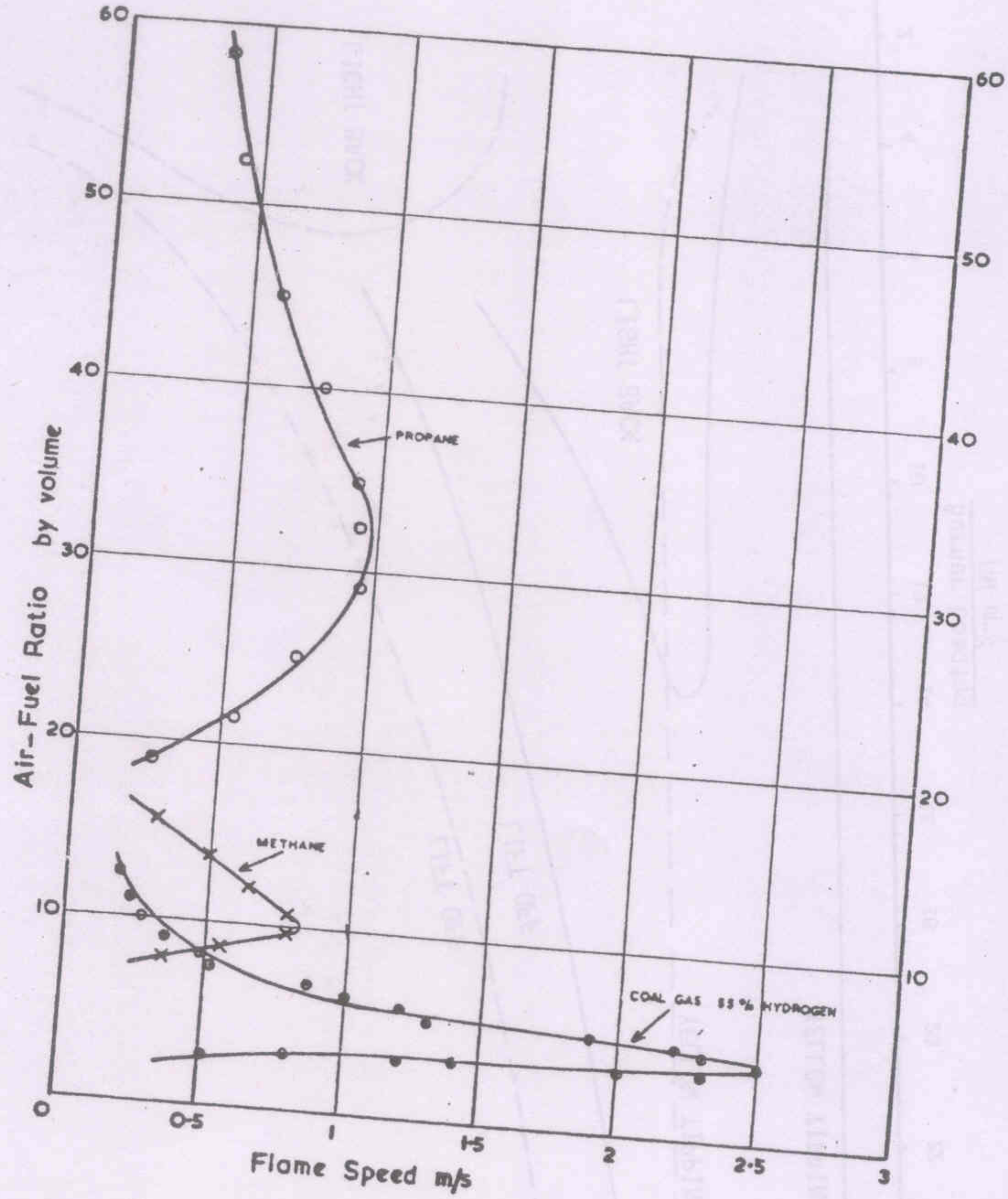
LBO = Light Back onto Top of Port Tube

LO = Lift Off (Loss of Flame)

EXAMPLE OF 'FUIDGE' FLAME STABILITY DIAGRAM FOR METHANE AND COAL GAS

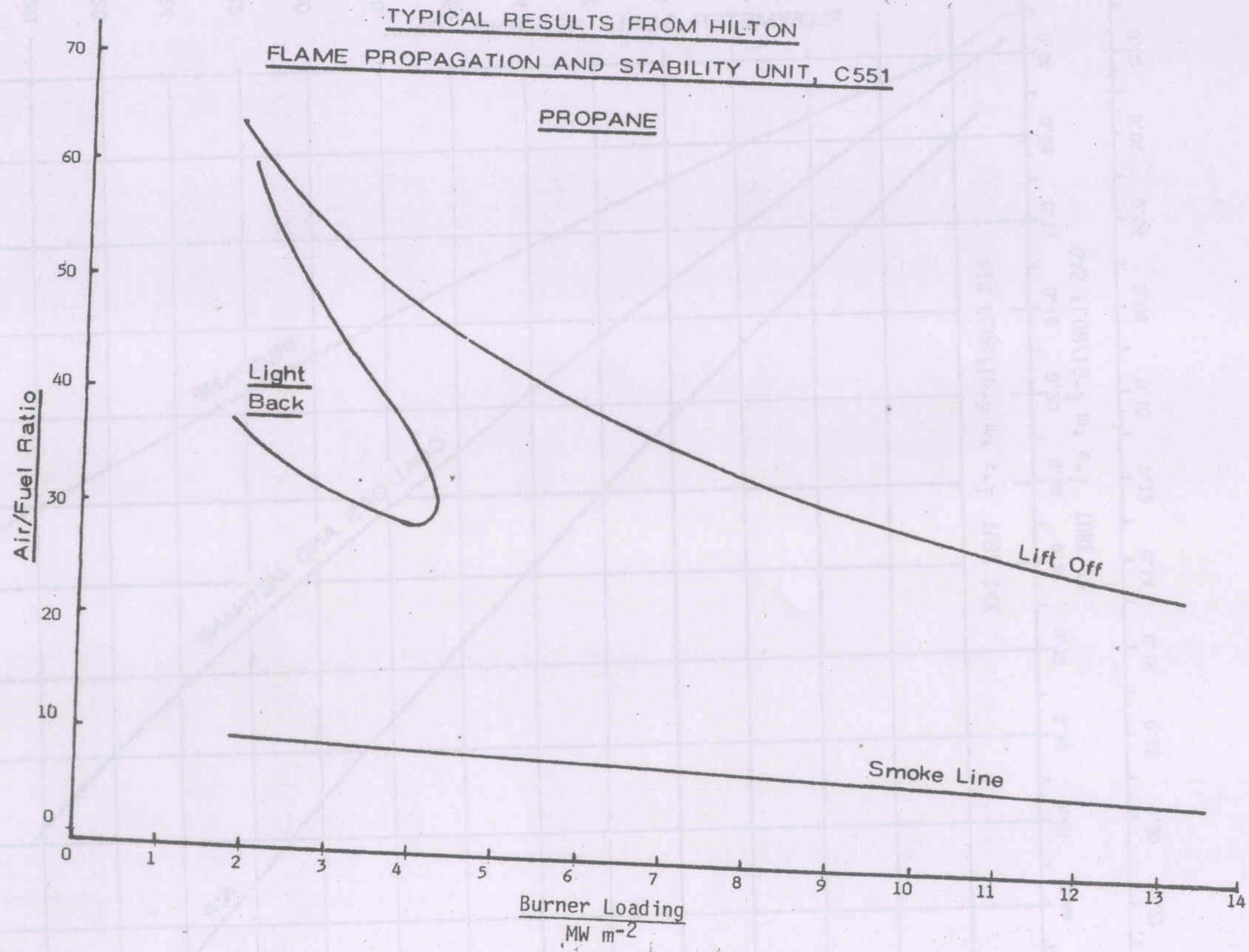


Horizontal Flame Speeds at Atmospheric Pressure and Ambient Temperature for Propane, Methane and Coal Gas.



TYPICAL RESULTS FROM HILTON FLAME PROPAGATION AND STABILITY UNIT, C551

PROPANE



FLOWMETER CALIBRATION CURVES

HILTON FLAME PROPAGATION AND STABILITY UNIT, C551