

MACROSCOPIC THERMO CONT'D

LEC. 2 SP4 15

①

I) TWO MORE USEFUL ^{MATH} PROPERTIES
OF POINT/THERMO FNS:

(see, ^{eq.} Moran & Shapiro, "Fundamentals
OF ENGINEERING THERMO"):

Let x, y, z represent any
3 of h, s, u, P, T, g, a . THEN

$$\left[\frac{\partial x}{\partial y} \right]_z = \frac{1}{\left[\frac{\partial y}{\partial x} \right]_z}$$

$$\left[\frac{\partial x}{\partial y} \right]_z \left[\frac{\partial y}{\partial z} \right]_x \left[\frac{\partial z}{\partial x} \right]_y = -1$$

II) USING SAME APPROACH AS IN
LECTURE 1, SP6. 2013, WE
CAN DERIVE A GENERALIZED
DIFFERENTIAL EQN. FOR h
(INVOLVING ONLY DIRECTLY MEASURABLE
PARAMETERS $P, T, \tilde{v}, c_p, c_v$):

$$dh = C_p dT + \left[\tilde{v} - T \left. \frac{d\tilde{v}}{dT} \right|_P \right] dP \quad (2.1)$$

III) Generalized differential for ds
(version 2);

1) $S = S(\tilde{v}, T)$

$$\Rightarrow ds = S_{\tilde{v}/T} d\tilde{v} + S_{T/\tilde{v}} dT$$

2) From derivn of du :

$$T S_{T/\tilde{v}} = C_v$$

3) From Maxwell relns:

$$S_{\tilde{v}/T} = P_{T/\tilde{v}}$$

4) $\therefore$
$$ds = \frac{C_v}{T} dT + P_{T/\tilde{v}} d\tilde{v} \quad (2.1)$$

IV) How are thermo tables
for ideal gas props u , h , and
 s generated?

A) 1) For ideal gas (and from
gen'd differentials for

How are h, u, s gotten for gases L2 SP6 15
(3)

$du, dh, & ds$:

$$\left. \begin{aligned} du &= C_v(T) dT \\ dh &= C_p(T) dT \end{aligned} \right\} \begin{array}{l} \text{(proved in} \\ \text{HW 1} \end{array}$$

$$\left. \begin{aligned} du &= C_v(T) dT \\ dh &= C_p(T) dT \end{aligned} \right\} \begin{array}{l} \text{" " " " } \\ \text{HW 1} \end{array}$$

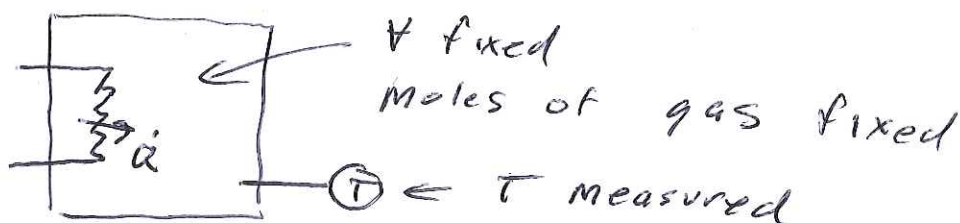
$$ds = \frac{C_v(T)}{T} dT + P_{12}/\tilde{v} d\tilde{v}$$

$$\oplus \text{ I GAS: } P = RT/\tilde{v} \Rightarrow P_{12}/\tilde{v} = \frac{R}{\tilde{v}}$$

$$\therefore \left[ds = \frac{C_v(T)}{T} dT + \frac{R}{\tilde{v}} d\tilde{v} \right] \quad (3.1)$$

STEP 1 : EXPERIMENTALLY MEASURE

U AS A FN. OF MEASURED T :



$$\oplus \quad U(T_2) - U(T_1) = \Delta Q_{IN}$$

$$\text{or } U(T) = U(T_{ref}) + \int_{T_{ref}}^T \overset{\substack{\uparrow \\ \text{measured}}}{dQ}$$

STEP 2:

$$du_r = \Delta u_r = C_v(T) \Delta T = \Delta Q$$

$$\Rightarrow \boxed{C_v(T) = \frac{dQ}{dT} \in \text{msd}}$$

STEP 3: Given $C_v(T)$, THEN:

$$\boxed{u(T)_{\text{gas}} = u_{\text{ref}} + \int_{T_{\text{ref}}}^T C_v(T) dT} \quad (4.1)$$

Use this
to
compute

I GAS
tbl
values
for
 $u(T)$

⊕

SINCE, FOR ENGINE APPLICATIONS
WORK USUALLY INCORPORATED IN
 Δ 's IN u , u_{ref} can be taken
as 0. ALTERNATIVELY,

STAT THERMO CAN BE USED
TO CALCULATE $u_{\text{ref}} = u(T_{\text{ref}})$.

where

$$u_{\text{ref}} = \langle E \rangle = \frac{\int E g(E) e^{-\beta E} dE}{\int g(E) e^{-\beta E} dE}$$

where

E = energy of a
microstate w/in our
(I GAS) system

How h_u is gotten for GASES

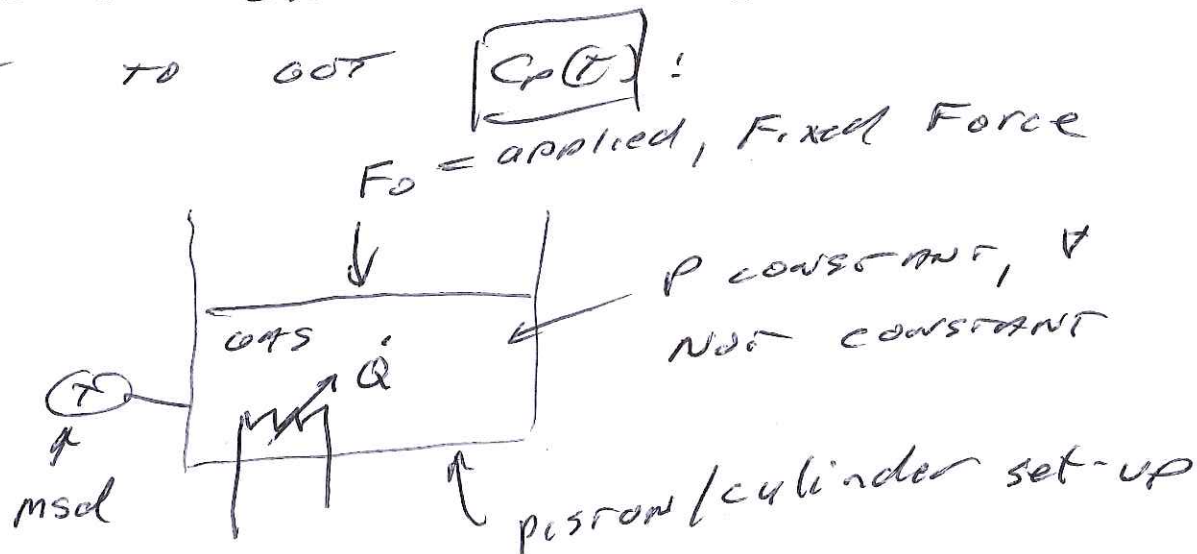
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$g(\epsilon) = \text{degeneracy of state } \epsilon$

$$\beta = 1/kT$$

& MORE ON THIS AS GO ALONG.

(B) SIMILAR EXPERIMENT CAN BE DONE TO GET $C_p(T)$:



$$\begin{aligned} \oplus \quad dh &= \cancel{m} du + \tilde{v} dP + P d\tilde{v} \\ &= dq - P d\tilde{v} + " + " \\ &= dq + \tilde{v} dP \end{aligned}$$

$$\Rightarrow \boxed{dh = dq} \quad \text{for this experiment}$$

(+) ALSO, as proven in HW 1
for an IDEAL GAS

$$\boxed{dh = C_p(T) dT}$$

$$\oplus \therefore \boxed{C_p(T) = dq/dT} \quad \text{measured}$$

How h.u.s gotten for gases

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$$\therefore h(T) = h_{ref} + \int_{T_{ref}}^T C_p(T) dT$$

use this
to compute
tbl values
for h_{IGAS} .

⊕ Get h_{ref} using:

$$i) h \equiv u + P \bar{v} \xrightarrow{RT}$$

$$ii) h_{ref} = u_{ref} + RT_{ref}$$

$$\left(R = \frac{\bar{R}}{MW} \right)$$

C) TO COMPUTE TABLE VALUES
OF $\boxed{S}$ (F GAS), USE

MSD $C_p(T)$ IN INFORMATION VERSION
OF (3.17).