STUDIES OF MAXIMUM PRESSURE DROP IN SPOUTED BEDS

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ABSTRACT

Studies of pressure drop in spouted beds was investigated, using some typical Nigerian grains, rice, beans, corn and groundnut as the solids and compressed air as the spouting medium. The pressure drop across the bed and the minimum spouting velocities were measured. Dependence of the peak (maximum) pressure drop on bed height, grain density and mean particle diameters were evaluted.

Two important correlations for predicting peak pressure drops were developed.

(1) - Δ Pmax = $(82.7x10^{-4Sp}$ = + (1.6114) H + (25x10-3 -Sp -8.80)dp.

(2) - Δ Pmax = $(8.35x10^{-3}$ Sp + 1.626) H + $26x10^{-5}$ Sp - 0.21

The validity and universality of these equations were tested and confirmed by using literature data for various grains obtained under different experiment conditions. These expression were found to be more convenient and compare favourably with similar equations.

INTRODUCTION

The spouted bed is a solid- fluid contacting device which is used for the agitation of solid materials that are two coarse and uniform in size for good fluidization to occur . This is achieved by forcing the fluid upwards through a small orifice at the centre of a conical base rather than distributing it evenly across the bed as in case of fludization. A hydrodynamic pattern which is different from that in a fluidized bed is thus established (1). Solids are rapidily carried upwards by the incoming fluild, forming a central core surrounded by a dense anulus of downward moving Solids. The particles return in the form of a fountatin at the top of the bed. The downward moving anulus and the air flashing from the centre apout provide a dense phase counter current contact between the fluid and the solids, fig. 1. Such a beed has been found to be very useful in the drying of food grains (2,3).

Quite a few materials, namely peas,wheat, paddy, mustard seed, sand, gravels of various size ranges have been successfully spouted (4). The high peak in pressure drop is usually associated generally with entry of a high velocity gas into a bed solids. The occurance of a peak in the curve of pressure drop versus flow rate prior to the onset of both spouting and fluidization can be attributed to the energy required by the gas jet to rapture the packed bed structure. Some investigators as reported in (4) on the basis of data for several solid material arrived at the relationship that the maximum pressure drop approximately equates the height of the bed per unit cross sectional area.

This relationship is equivalent to the statement:

$-\Delta p_{max} = HS_{bg}$ .....(1)

A survey of literature reveals that meagre data on pressure drop in gas solid spouted beds are availble.

In the present study, peak pressure drop at different bed heights for different grains - rice, beans, corn and groundnut were determined with the view of obtaining the necessary hydrodynamic parameters necessary for designing a spouted bed grain dryer.

EXPERIMENTAL PROCEDURE

The spouting bed used in this study was fabricated from aluminium sheet at Nigerian Engineering Works Ltd (NEW), Trans Amadi Port Harcourt. The column is cylindrical with a conical base, terminating in a gas inlet pipe Fig. 1.

The bed dimensions are as follows:
Column diameter, Dc = 0.07 (M)
Inlet pipe diameter, D1 = 0.01 (M)
Cone angle, 0 = 60°
Total height of the column H = 0.651(M). The inlet pipe has a distributor made from wire quaze of about 1.5mm. The column was fitted with a sight - window 2 x 60 cm made from thin transparent perspex.

A U-tube mercury manometer attached to the bed was used to measure the pressure drops across the distributor and the bed. Air was supplied to the bed from high powered compressor. Air flow into the bed was controlled by a valve and the air flow rates were measured by means of a rotameter.

Four different grains, rice, beans, corn and groundnut were investigated.

In conducting the experiments, a definate amount of each grain sample was changed into the column and the bed level adjusted. Air was allowed to flow through the static bed at an increasing rate. Depending upon the system, conditions, spouting will set in.

RESULTS AND DISCUSSIONS

Data for the peak pressure drops for the grain samples tested were obtained from the plots of pressure drops flow rate curves. Fig. (2-5).

As the flow rate is increased from zero, the bed undergoes several changes before reaching the stable spouted state at point C in the figures. Steps which are observable visually as a step wise lowering of the upper surface of the bed. Corresponding to this decrease porosity, the pressure drop - flow rate curves shown in figure (2-5), show an increase along AB. This is because at a certain flow rate, the particles surrounding the cavity are compressed against the materials above them forming a greater resistance to flow. Therefore, depite the existence of a hollow cavity, the total pressure drop across the bed continued to rise until it gets to the maximum Δ Pmax) at point B. The corresponding superficial air velocity is noted with Um.

As the flow rate is increased beyond point B, the height of the internal spout has become large in comparison with the packed solids above the spout, this offers less resistance to flow and therefore pressure drop decreases along BC. The spout then breaks through the bed surface. The pressure drop remains constant after the spout has broken through the bed surface along C-D because the incoming gas simply passes through the spout region causing the fountain to shout up higher without any significant effect on the total pressure drop.

It is further observed from table (1) that pressure drop is maximum in the case of finest and denser particles. Rice with the highest density and smallest particle size has the highest peak, followed by corn with about the same particle size but different density. The pressure drop is lowest for groundnut. This is expected because for a given bed height, the finest and most dense particles having highest bulk density will have the maximum bed weight and since pressure drop across a spouted bed is approximately equivalent to the bed weight per unit are (1), the finest particles are expected to have the maximum pressure drop.

PEAK PRESSURE DROPS AT DIFFERENT BED HEIGHT (- Δ Pmax)

Grain	sp(kg/m3)	dp(m)	at 0.10m	0.12m	0.15m
Rice	1700	0.0034	0.46	0.49	0.53
Corn	1150	0.0083	0.74	0.85	0.92
Beans	1000	0.0053	0.46	0.53	0.71
Ground-nut	750	0.0068	0.53	0.56	0.81

For the same grains under investigation, two important correlation were developed for predicting peak pressure drops.

(1) $-\Delta P_{max} = (82.7\times10^{-4}Sp + 1.614)H + 25\times10^{-3}Sp - 8.80)dp$ ...(2)

(2) $-\Delta P_{max} = (8.35\times10^{-3}Sp + 1.626)H + 26\times10^{-5}Sp - 0.21$ .....(3)

The two correlations predict very well for the experimental grains, fig. (6). They are also found to be valid for other grains such as kale seed, wheat, coal under different experimental conditions Table 2 and give a better prediction than proposed by other investigators (i.e. equation 1).

TABLE 2

CONFIRMATION OF VALIDITY OF EQUATIONS 2 AND 3 FOR DIFFERENT EXPERIMENTAL CONDITIONS

SOURCE	Dc	Di	0	MATERIALS	dp	Sp (deg)	Sp (km/m^3)	H (M)	Δ Pm observed (KM/M^2)	Δpm by EQ3 (KN/M^2)	Δ Pm EQ (2) (kn/m^2)	Pm by EQ. (1) (kn/m^2)
(1) Mach , W. (3)	0.305	0.0254	180	KALE SEED	0.0017	52	580	0.15	0.93	0.96	0.91	0.85
								0.30	1.42	1.90	1.88	1.70
								0.60	3.73	3.85	3.82	3.41
								1.20	7.55	7.68	7.70	6.82
								1.80	11.77	11.53	11.585	10.24
(2) GELPE-RRIM ET ELL (4)	0.152	0.0095	60	WHEAT	0.0048	55	830	0.28	2.15	2.42	2.40	2.25
								0.71	6.06	6.07	6.08	5.76
								0.35	2.72	3.00	3.00	2.86
								0.52	4.23	4.46	4.45	4.22
								0.28	2.20	2.40	2.40	2.26
								0.42	3.87	3.61	3.59	3.40
(3) BLYAK-HER' ET ELL (5)		0 305	0.0254	60 COAL		0.0018	67.5	740 0.43	2.92	3.30	3.31	3.10
								0.59	4 .45	4.50	4.58	4.43
								0.93	6.99	7.00	7.20	6.56

CONCLUSION:

Studies of pressure drop in spouted beds show that the dependence of the peak pressure drop on bed height is linear (fig. 8) and depends much on the density and diameter of the particles

(1) $-\Delta P_{max} = (82.7\times10^{-4}Sp + 1.614)H+(25\times10^{-3}Sp-8.80)dp$

(2) $-\Delta P_{max} = (8.35\times10^{-3}Sp + 1.626)H+ 26\times10^{-5}Sp-0.21$

The validity and universality of these equations were tested and confirmed by using literature data for various other grains obtained under different experimental conditions.

NOMENCULATURE

dp	=	particles size, m
ΔP_{max}	=	maximum or peak pressure drop Kpa
UMS	=	Minimum spouting velocity M/Sec.
Sp	=	particles density
ΔP	=	Pressure drop
H	=	Bed height M
θ	=	Cone angle O
DC	=	Column diameter M
Di	=	Internal column diameter M
Ht	=	Total height of the bed M.

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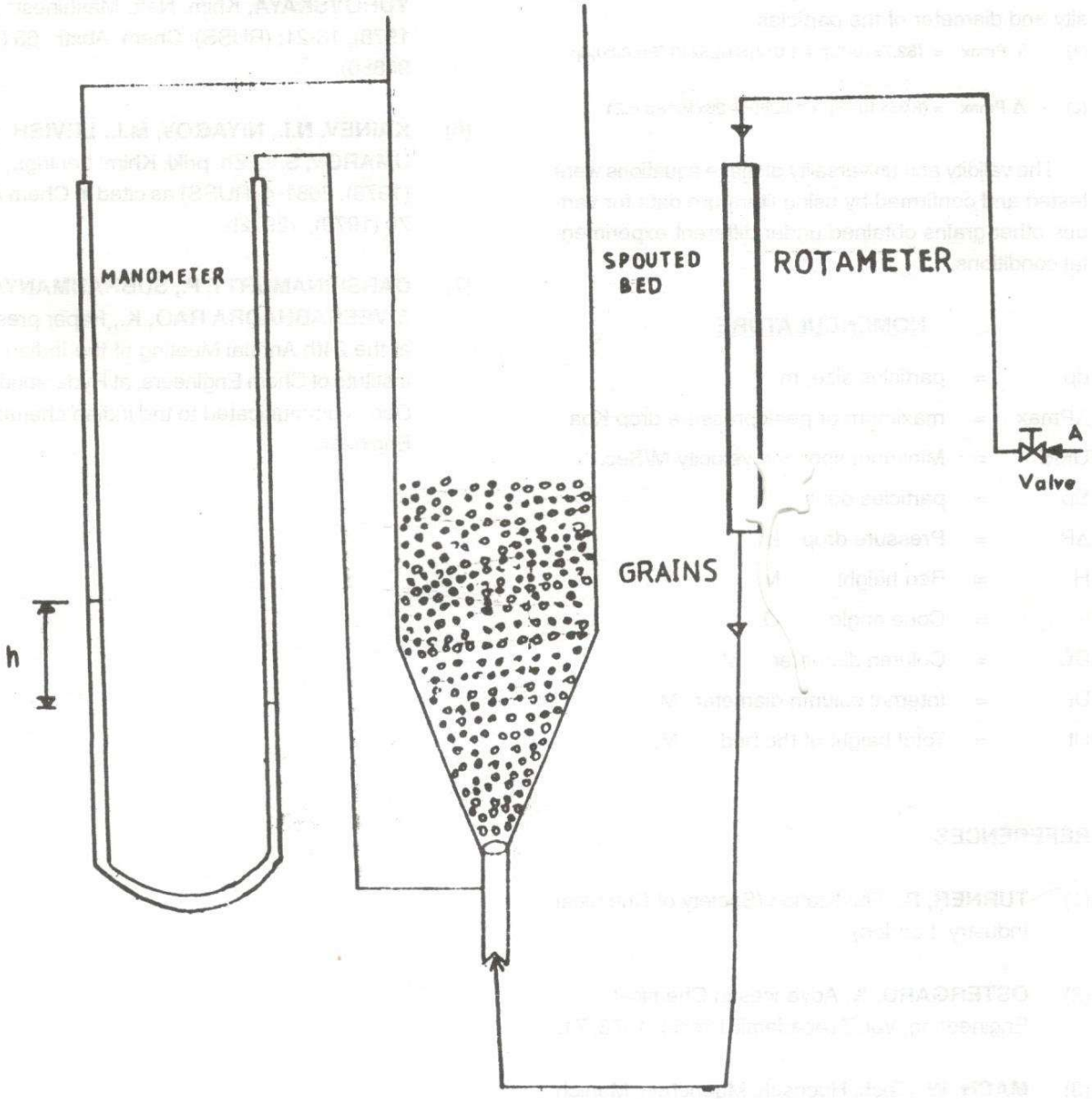


FIG I Schematic diagram of one spouted bed unit

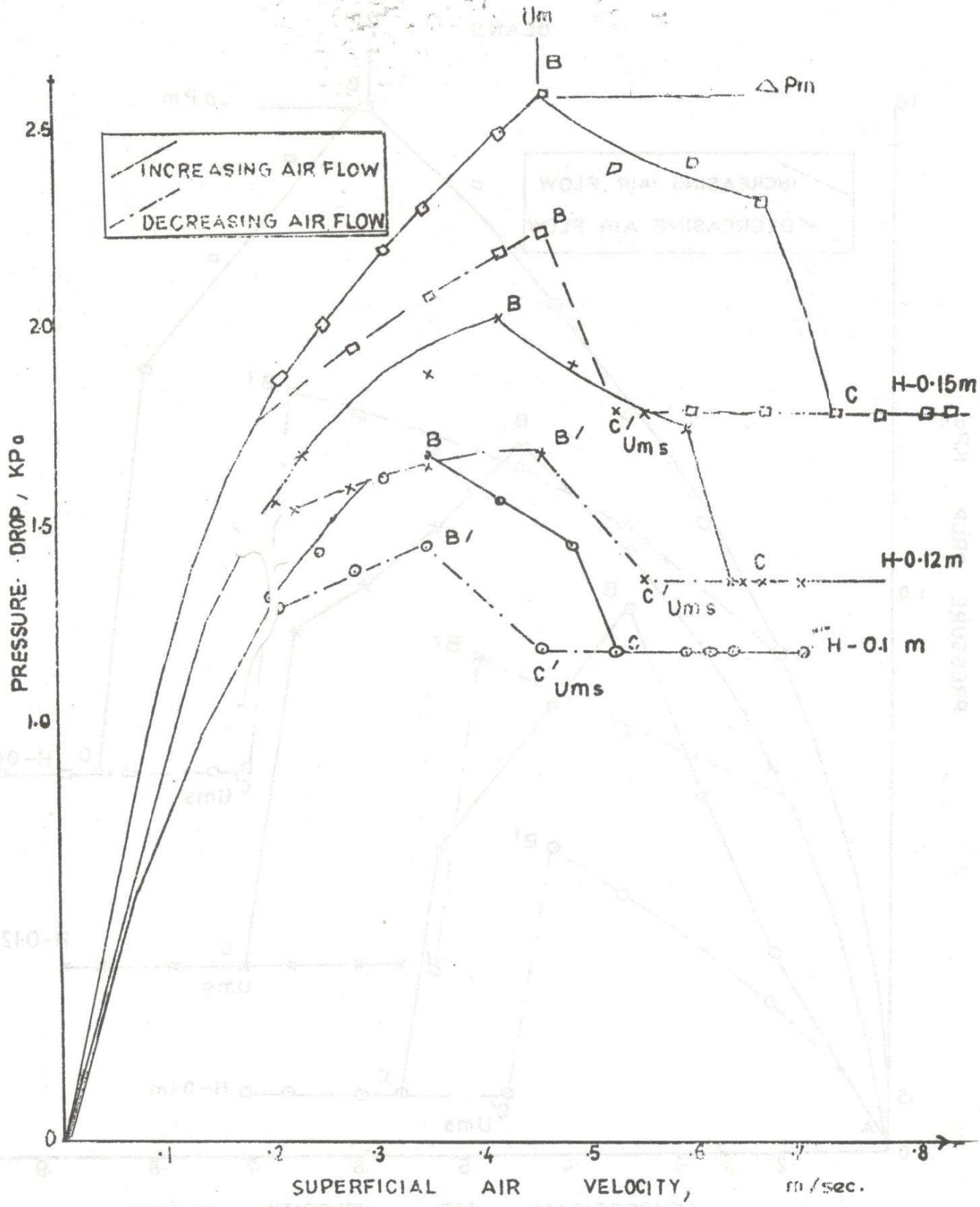


Fig 2. PRESSURE DROP – FLOW RATE CURVES FOR RICE

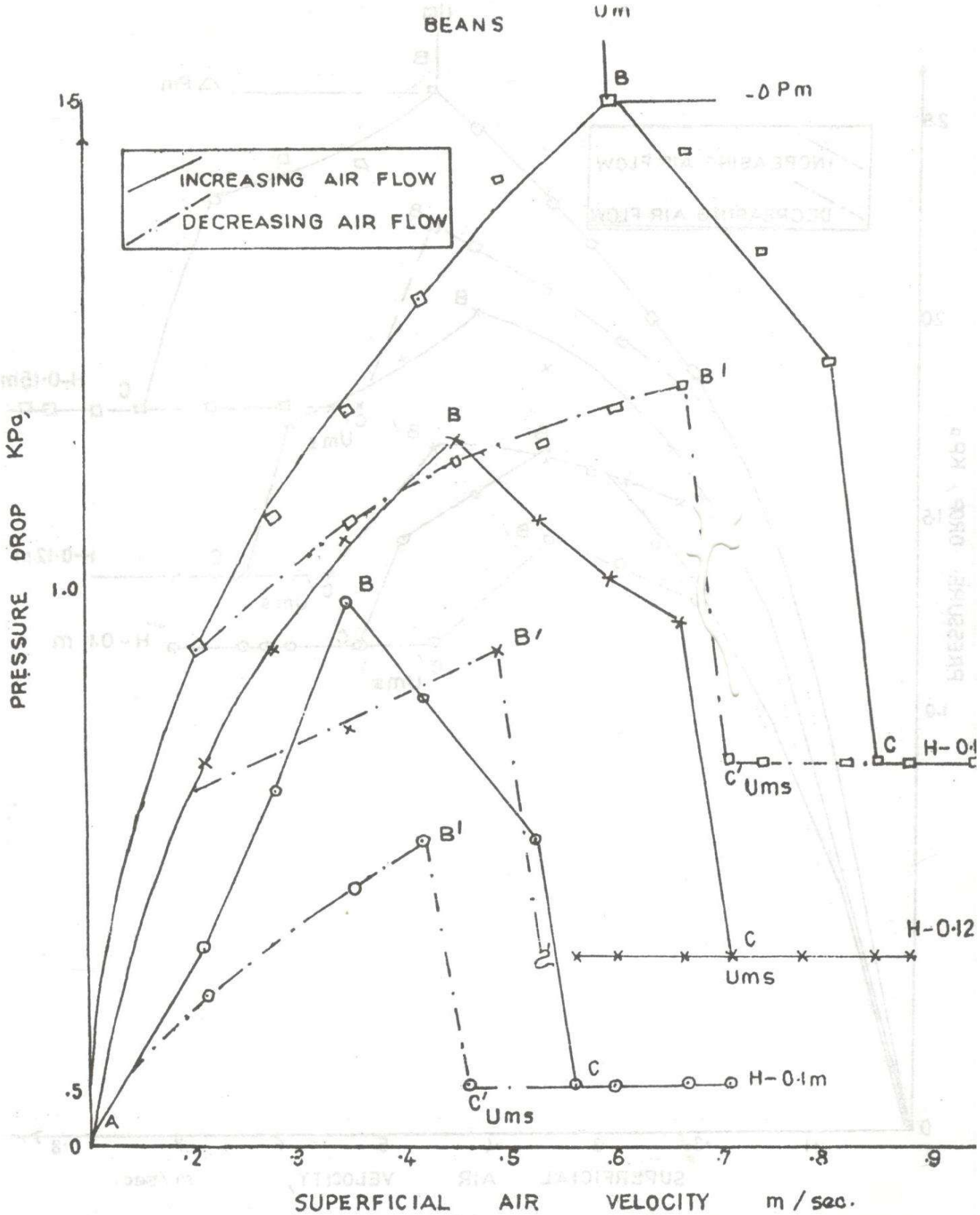


Fig 3 PRESSURE DROP FLOW RATE CURVES FOR BEANS

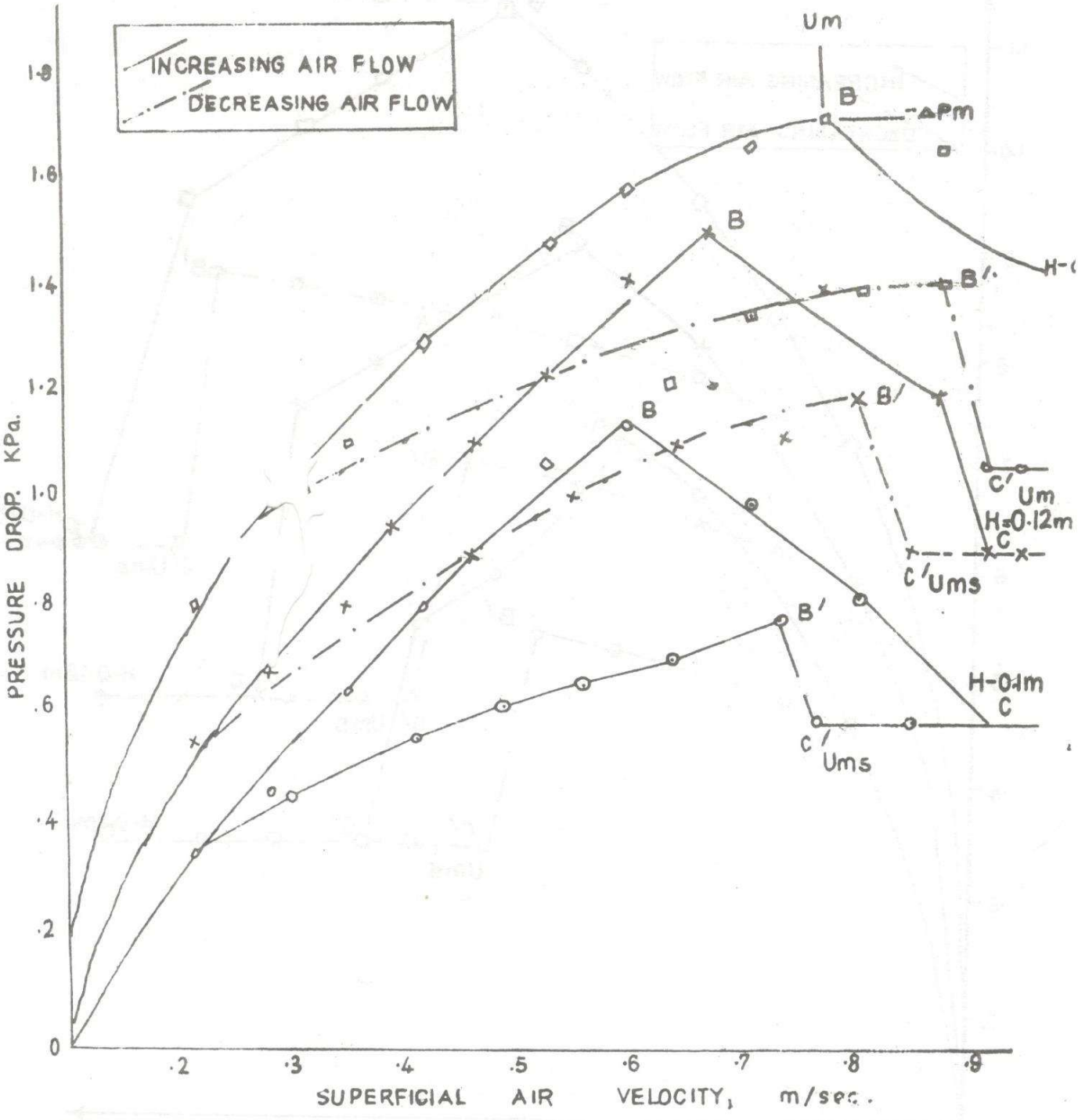


Fig 4 PRESSURE DROP FLOW RATE CURVES FOR CORN

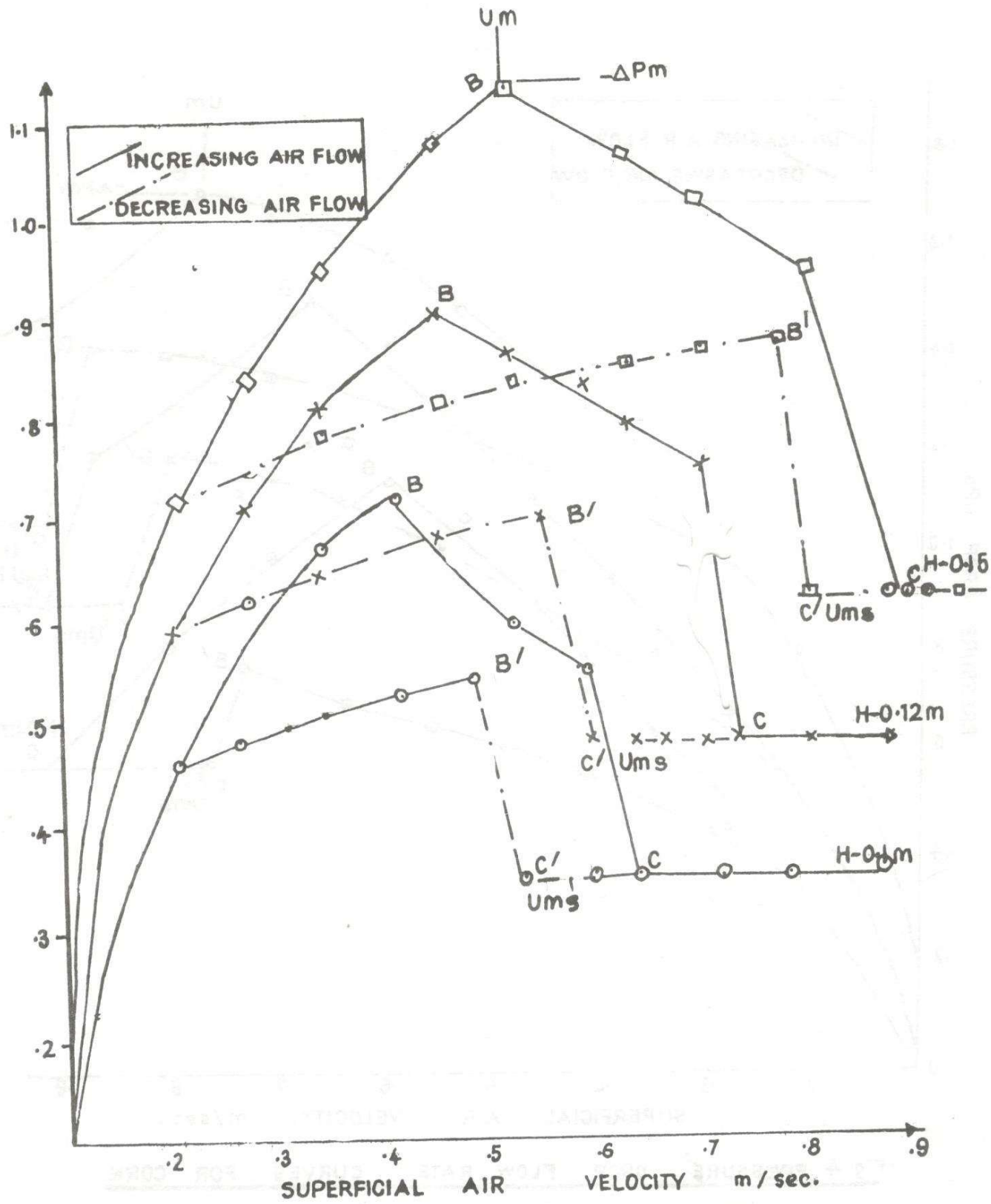


Fig 5 PRESSURE DROP — FLOW RATE CURVES FOR GROUNDNUT

ΔPMAX

fig (6) COMPARISON OF EXPERIMENTAL DATA WITH PREDICTIONS USING EQ (2, & 3)

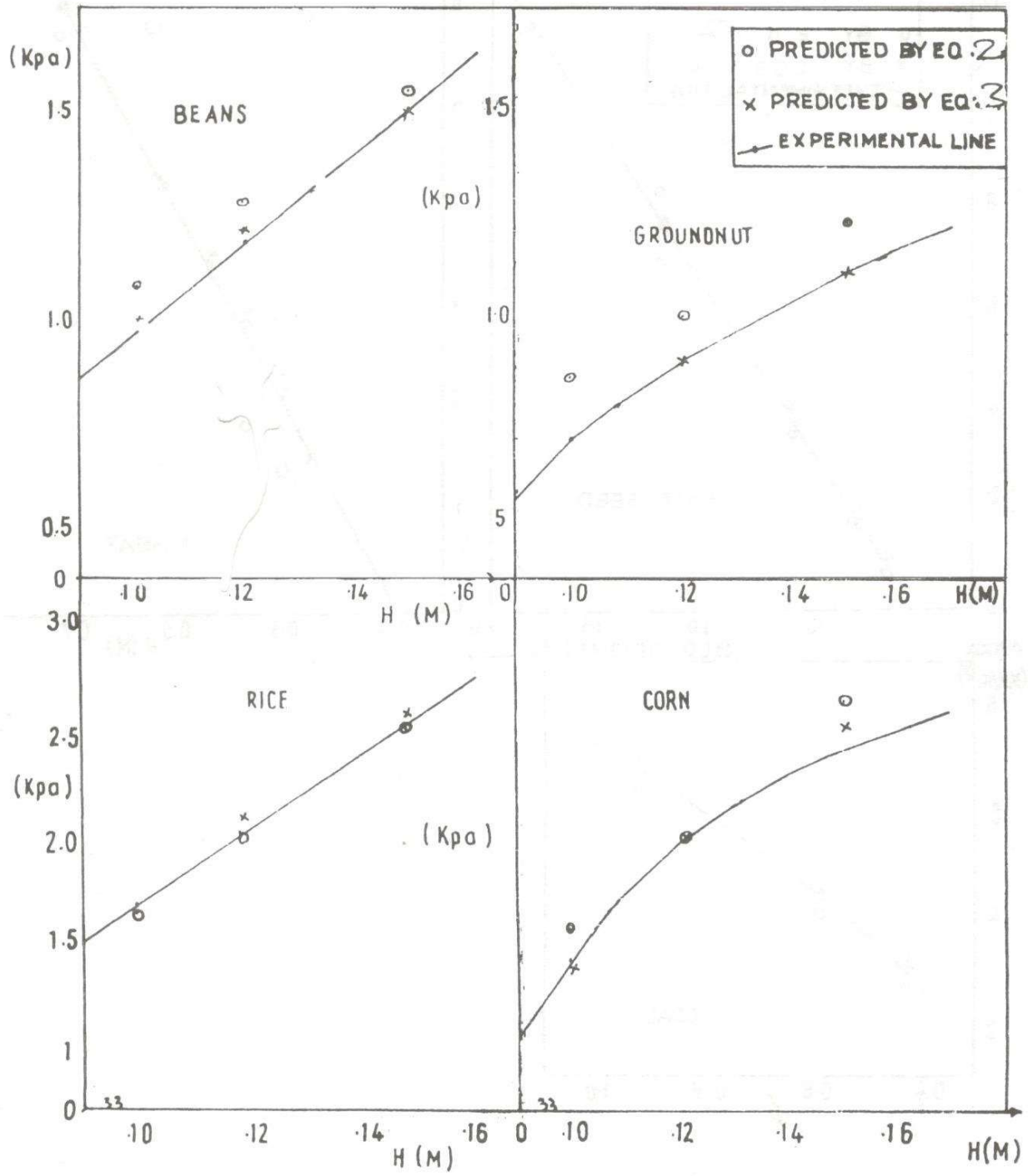
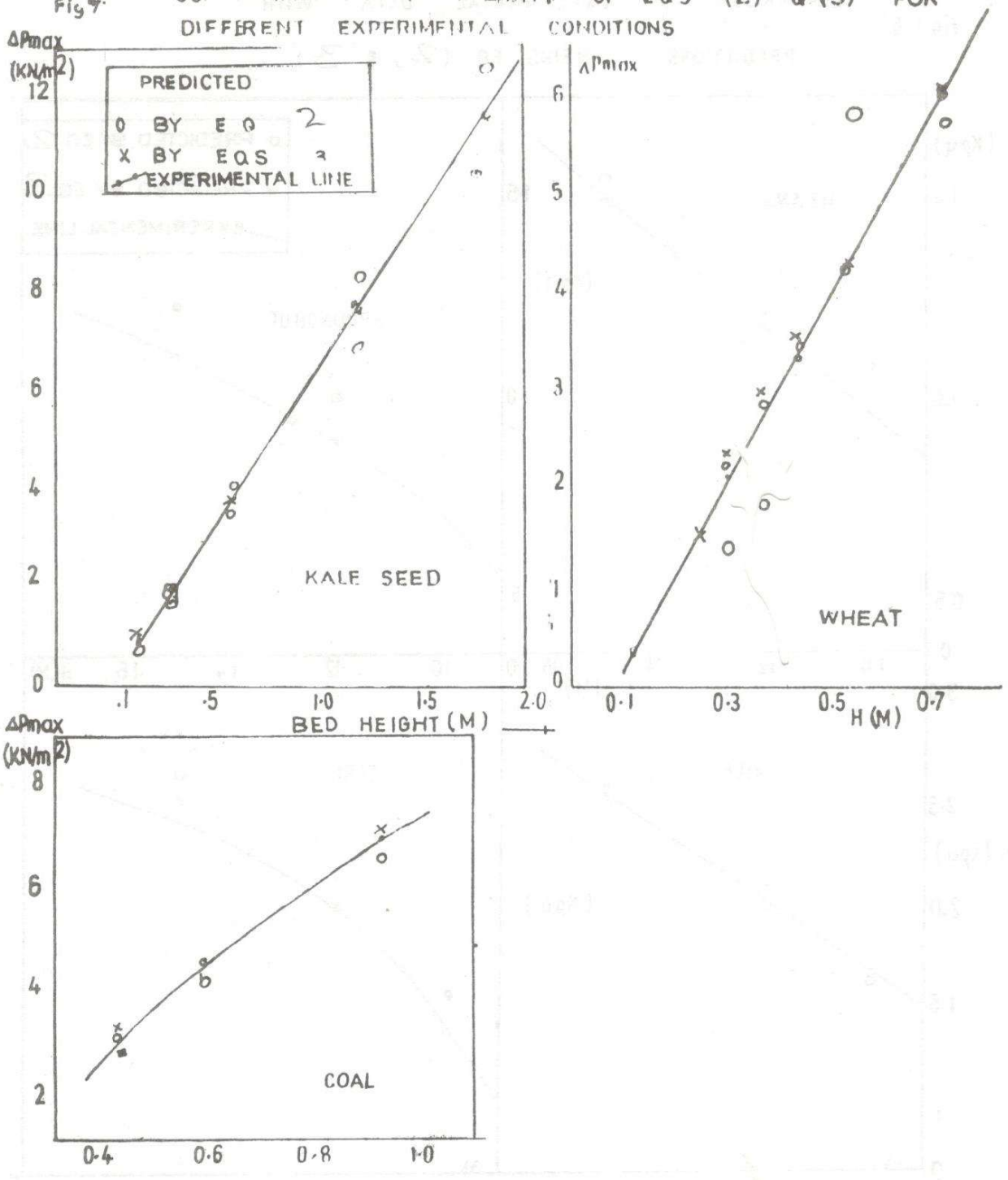


Fig 9. CONFIRMATION OF VALIDITY OF EQS (2) & (3) FOR DIFFERENT EXPERIMENTAL CONDITIONS



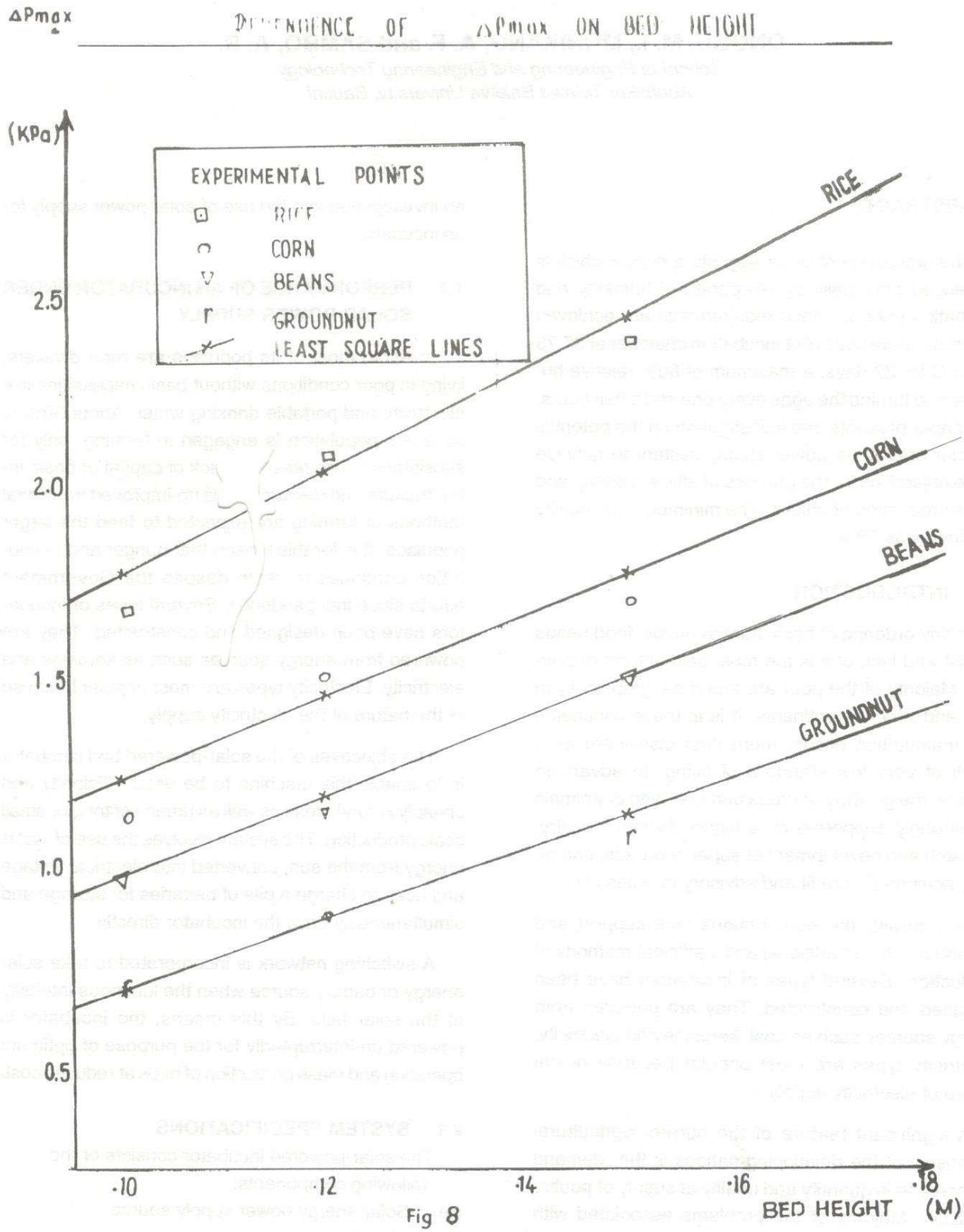

ΔPmax
DEPENDENCE OF ΔPmax ON BED HEIGHT
(KPa)
EXPERIMENTAL POINTS
RICE
CORN
BEANS
GROUNDNUT
LEAST SQUARE LINES
RICE
CORN
BEANS
GROUNDNUT
2.5
2.0
1.5
1.0
0.5
·10
·12
·14
·16
·18
BED HEIGHT (M)

Fig 8