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PERFORMANCE STUDIES OF TUBULAR FLAT PLATE COLLECTORS *

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1 Introduction

The plots of efficiency versus the ratio of the temperature difference above the ambient to the solar insolation are well made and well- known-and they are straight lines or curves intersecting the two axes having two intercepts with the two axes. In contrast to the vast literature available on tubular flat plate collectors, the studies on the variation of different parameters are quite limited and the plate efficiency factor F_p, heat removal factor F_R and the useful heat gain Q_u, are not evaluated upon the knowledge of its various parameters. In order to design a tubular flat plate collector, one has to know the dimension of the different parameters. These are tube spacing, tube diameter, fluid flow rate, heat loss coefficient, bond conductance, tube thickness, plate thickness and heat transfer coefficient. These parameters are varied and different graphs are plotted and different parameters may be chosen from the plotted graphs for design and construction of flat plate tubular collectors. Here computations have been made for flat plate efficiency factor F_p, heat removal factor F_R, heat gained by fluid,Q_u, using several materials like Aluminium, Copper, Silver, Tin, Galvanized Iron(G.I.), Steel and Polyvinyl Chloride(P.V.C.) which are used in combination for the tubes and fins.

Circular tubes are considered for the tubular collectors for easy fabrication and commercial production. The allowed duct shapes are circular, oval, hexagonal, triangular, rectangular and square. Graphs are drawn and computations have been made for different parameters and found that some parameters are very important for the performance calculation of collectors.

2 Numerical Computation

For this paper computations of different parameters have been made using the data in Husain(1990, to be published) and Husain and Quayum (1985) and (1985).

3 Results

Table-1 illustrates the effect of various design parameters such as U_L,k_p,m_p,h_c, W and F_p for Copper fin with P.V.C.tubes. Table-2 shows the effect of various parameters for Aluminium fin coupled with G.I. tubes. Tables-3 and 4 show different duct shapes. These show that rectangular duct is the best and the circular duct is the next.

Graphs from Fig. 1 to 5 are for comparison of G.I. with P.V.C., it can be seen that G.I. is better than P.V.C. Graphs from Fig. 6 to 12 show copper and silver are the best and aluminium is the second best. Graphs from Fig. 13 to 17 show the comparison of Silver, Copper, Aluminium, G.I., Tin, Steel and PVC. It can be seen from the graphs that Silver is the best, Copper is the second best and PVC is the worst.

4 Nomenclature

U_L=over all heat loss coefficient, $W/m^2 -^o C$; W=tube spacing,m; m_t=tube thickness,m; m_p=plate thickness,m; k_t=tube conduc tivity,$W/m -^o C$; k_p=plate conductivity, $W/m -^o C$; k_f= fluid thermal conductivity, $W/m -^o C$; h_c=heat transfer coefficient, $W/m^- oC$; G=flow rate of fluid, Kg/sec; d=inner tube diameter,m; c_b=bond conductance, $W/m -^o C$; b=outer tube diameter,m;

Acknowledgments

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5 References

Husain, M.S. (1990, to be published). Bondings for Tubular Solar Collectors, Proceedings of World Renewable Energy Congress, University of Reading, U.K.

Husain, M.S. and Quayum, M.A. (1985). Some studies on Flat Plate Collectors, Proceedings of International Conference on Physics and Energy for Developement, Dhaka, Bangladesh, 229-236.

Husain, M.S. and Quayum, M.A. 1985). Studies of Flat Plate Collectors for Coupling of fin and tube materials, Procceedings of National Solar Energy Convention, 1984, Feb. 10-12,1985, SWH-63-65, Bhopal, India.

Table 1. Effect of different heat transfer, tube spacing and K_pa_p(0.005, 0.02, 0.04) from collector(copper) and P.V.C.tubing.

	W =	0.025	0.05	0.075	0.1	0.125	0.15	0.175	0.2
a =30.98 K_pa_p=0.005 U_L =4.8 h_c =100	F	0.9916	0.9100	0.7842	0.6563	0.5481	0.4629	0.3972	0.3462
	F_p	0.9438	0.8480	0.7255	00.6100	0.5144	0.4393	0.3808	0.3350
a =15.5 K_pa_p=0.02 U_L =4.8 h_c =100	F	0.9979	0.9758	0.9330	0.8760	0.8114	0.7451	0.6811	0.6218
	F_p	0.9461	0.8852	0.8161	0.7447	0.6755	0.6115	0.5538	0.5029
a =10.95 K_pa_p=0.04 U_L =4.8 h_c =100	F	0.9989	0.9877	0.9652	0.9331	0.8939	0.8499	0.8036	0.7566
	F_p	0.9464	0.8920	0.8353	0.7782	0.7226	0.6696	0.6202	0.5746
a =30.98 K_pa_p=0.005 U_L =4.8 h_c =400	F	0.9916	0.9110	0.7842	0.6563	0.5481	0.4629	0.3972	0.3462
	F_p	0.9642	0.8817	0.7630	0.6456	0.5369	0.4670	0.4052	0.3565
a =15.5 K_pa_p=0.02 U_L =4.8 h_c =400	F	0.9979	0.9758	0.9330	0.8760	0.8114	0.7451	0.6811	0.6218
	F_p	0.9667	0.9221	0.8638	0.7984	0.7313	0.6667	0.6069	0.5531
a =10.95 K_pa_p=0.04 U_L =4.8 h_c =400	F	0.9989	0.9877	0.9652	0.9331	0.8939	0.8499	0.8036	0.7566
	F_p	0.9671	0.9252	0.8854	0.8370	0.7867	0.7364	0.6876	0.6411
a =43.36 K_pa_p=0.005 U_L =9.4 h_c =100	F	0.9837	0.8417	0.6606	0.5146	0.4112	0.3390	0.2872	0.2488
	F_p	0.8955	0.7431	0.5865	0.4659	0.3801	0.3189	0.2739	0.2399
a =21.68 K_pa_p=0.02 U_L =9.4 h_c =100	F	0.9959	0.9539	0.8783	0.7874	0.6961	0.6129	0.5409	0.4802
	F_p	0.8996	0.7978	0.6953	0.6020	0.5219	0.4554	0.4008	0.3561
a =15.33 K_pa_p=0.04 U_L =9.4 h_c =100	F	0.9979	0.8763	0.9344	0.8783	0.8146	0.7490	0.6854	0.6264
	F_p	0.9003	0.8085	0.7218	0.6429	0.5730	0.5123	0.4599	0.4152
a =43.36 K_pa_p=0.005 U_L =9.4 h_c =400	F	0.9837	0.8417	0.6606	0.5146	0.4112	0.3390	0.2872	0.2488
	F_p	0.9324	0.7954	0.6359	0.5077	0.4149	0.3483	0.2993	0.2621
a =21.68 K_pa_p=0.02 U_L =9.4 h_c =400	F	0.9959	0.9539	0.8783	0.7874	0.6961	0.6189	0.5409	0.4802
	F_p	0.9368	0.8583	0.7659	0.6736	0.5899	0.5179	0.4575	0.4073
a =15.33 K_pa_p=0.04 U_L =9.4 h_c =400	F	0.9979	0.9763	0.9344	0.8783	0.8146	0.7490	0.6854	0.6264
	F_p	0.9376	0.8707	0.7981	0.7253	0.6560	0.5927	0.5362	0.4865

Table 2

Effect of different heat transfer, tube spacing and $k_p m_p$ from collector (aluminium) and G.I. tube.

U_L	$k_p m_p$	m	W	F	F_p	F_R	Q_u (W)
2.0	0.005	20	0.025	0.9965	0.9929	0.9720	884.52
"	"	"	0.1	0.8120	0.8239	0.8095	736.69
"	"	"	0.15	0.6465	0.6657	0.6563	597.21
"	"	"	0.2	0.5138	0.5361	0.5300	482.28
"	0.1	4.47	0.025	0.9998	0.9943	0.9734	885.76
"	"	"	0.1	0.9881	0.9681	0.9482	862.90
"	"	"	0.15	0.9706	0.9422	0.9234	840.28
"	"	"	0.2	0.9465	0.9111	0.8935	813.09
4.0	0.005	28.3	0.025	0.9930	0.9859	0.9433	869.68
"	"	"	0.1	0.6924	0.7137	0.6923	636.92
"	"	"	0.15	0.5001	0.5293	0.5174	476.01
"	"	"	0.2	0.3774	0.4075	0.4004	368.41
"	0.1	6.3	0.025	0.9996	0.9886	0.9478	871.96
"	"	"	0.1	0.9766	0.9382	0.9014	829.27
"	"	"	0.15	0.9436	0.8914	0.8581	789.47
"	"	"	0.2	0.9000	0.8382	0.8087	744.03
9.4	0.005	43.4	0.025	0.9837	0.9676	0.8789	832.36
"	"	"	0.1	0.5142	0.5512	0.5216	493.99
"	"	"	0.15	0.3387	0.3790	0.3649	345.92
"	"	"	0.2	0.2485	0.2852	0.2771	262.46
"	0.1	9.7	0.025	0.9992	0.9737	0.8840	837.11
"	"	"	0.1	0.9466	0.8661	0.7946	752.49
"	"	"	0.15	0.8775	0.7785	0.7204	682.22
"	"	"	0.2	0.7963	0.6914	0.6453	611.10

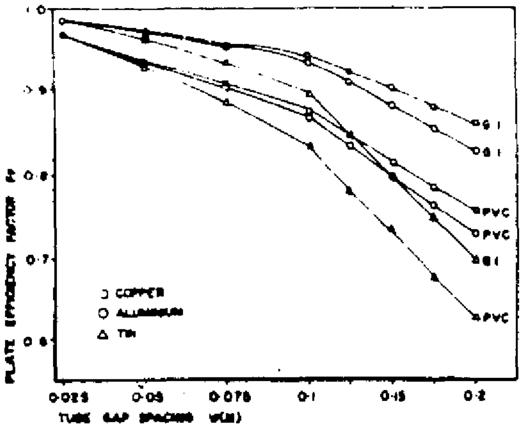
Table 3.

Effect of different duct shape and tube spacing on thermal efficiencies from collectors and G.I. tube

Sample	Duct shape	F	F_p	F_R	Q_u (W)
Aluminium	triangular	0.9777	0.9396	0.8955	827.46
	square	0.9759	0.9318	0.8884	820.92
	circular	0.9759	0.9297	0.8865	819.16
	hexagonal	0.9759	0.9315	0.8882	820.67
	oval	0.9729	0.9100	0.8686	802.60
	rectangular	0.9797	0.9453	0.9007	832.24
Copper	triangular	0.9875	0.9469	0.9021	833.58
	square	0.9865	0.9400	0.8959	827.80
	circular	0.9865	0.9379	0.8940	826.04
	hexagonal	0.9865	0.9396	0.8955	827.46
	oval	0.9848	0.9193	0.8771	810.42
	rectangular	0.9887	0.9518	0.9066	837.69
Tin	triangular	0.9298	0.9035	0.8627	797.13
	square	0.9245	0.8920	0.8522	787.44
	circular	0.9245	0.8902	0.8506	785.93
	hexagonal	0.9247	0.8919	0.8521	787.36
	oval	0.9159	0.8649	0.8275	764.57
	rectangular	0.9359	0.9138	0.8721	805.80

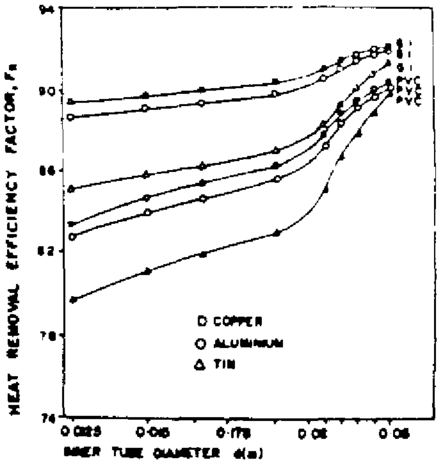
Table 4. Effect of conductivity and hydraulic diameter on thermal efficiencies (fin and tube are of same material)

Sample	n	K_{β}	Duct shape	F	F_p	F_R
Aluminium	6.43	211	Triangular	0.9773	0.9390	0.8950
			Square	0.9741	0.9234	0.8808
			Circular	0.9757	0.9297	0.8865
			Hexagonal	0.9746	0.9256	0.8828
			Oval	0.9721	0.8854	0.8462
			Rectangular	0.9764	0.9351	0.8914
Copper	4.76	385	Triangular	0.9874	0.9466	0.9019
			Square	0.9856	0.9325	0.8891
			Circular	0.9865	0.9380	0.8941
			Hexagonal	0.9859	0.9344	0.8908
			Oval	0.9845	0.9124	0.8708
			Rectangular	0.9869	0.9431	0.8987
Steel	13.51	47.8	Triangular	0.9083	0.8867	0.8474
			Square	0.8968	0.8622	0.8250
			Circular	0.9023	0.8730	0.8349
			Hexagonal	0.8984	0.8656	0.8281
			Oval	0.8893	0.8369	0.8018
			Rectangular	0.9051	0.8803	0.8415
Silver	4.564	419	Triangular	0.9884	0.9473	0.9025
			Square	0.9868	0.9334	0.8899
			Circular	0.9876	0.9389	0.8949
			Hexagonal	0.9870	0.9353	0.8916
			Oval	0.9857	0.9133	0.8716
			Rectangular	0.9880	0.9440	0.8995
G.I.	11.77	63	Triangular	0.9285	0.9020	0.8613
			Square	0.9193	0.8801	0.8414
			Circular	0.9237	0.8895	0.8499
			Hexagonal	0.9206	0.8831	0.8441
			Oval	0.9132	0.8559	0.8192
			Rectangular	0.9259	0.8964	0.8562
Tin	11.7	64	Triangular	0.9293	0.9026	0.8619
			Square	0.9201	0.8807	0.8419
			Circular	0.9245	0.8895	0.8499
			Hexagonal	0.9214	0.8838	0.8447
			Oval	0.9141	0.8566	0.8199
			Rectangular	0.9268	0.8958	0.8557
P.V.C.	241	0.15	Triangular	0.1008	0.2527	0.2494
			Square	0.0943	0.1965	0.1945
			Circular	0.0973	0.2231	0.2206
			Hexagonal	0.0952	0.2045	0.2024
			Oval	0.0906	0.1605	0.1592
			Rectangular	0.0969	0.2370	0.2341



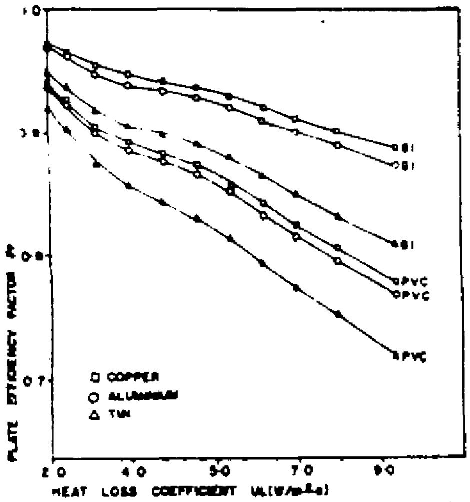
Fp Vs W FOR VARIOUS TUBE SPACING

Fig.1



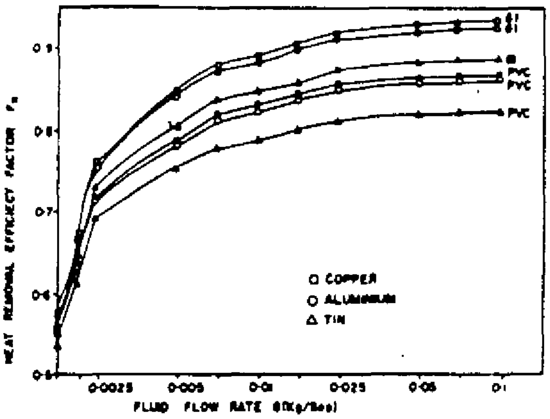
FR Vs d FOR VARIOUS INNER TUBE DIAMETER

Fig.2



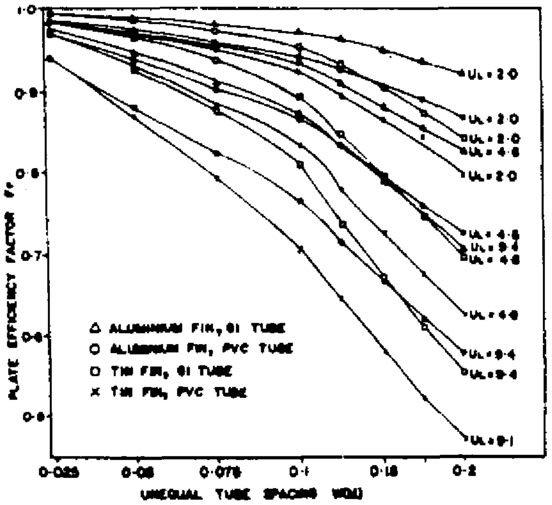
Fp Vs UL FOR VARIOUS HEAT LOSS COEFFICIENT

Fig.3



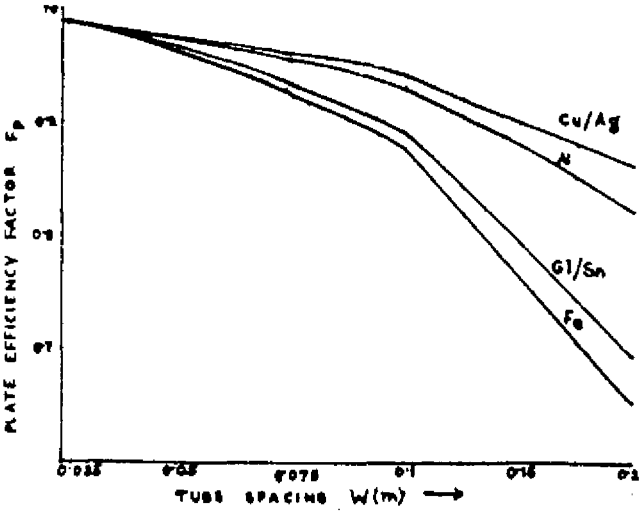
FR Vs ṁ FOR VARIOUS FLUID FLOW RATE

Fig.4



Fp, Vs W FOR VARIOUS TUBE SPACING & HEAT-LOSS COEFFICIENT FOR ALUMINIUM & TIN FIN COUPLED WITH GI & PVC TUBE

Fig.5



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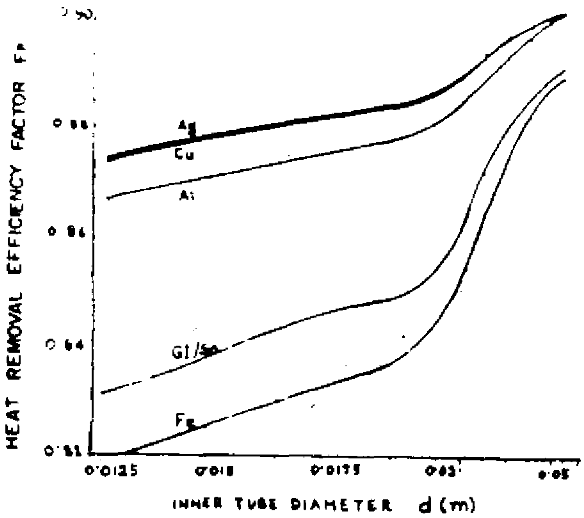

Fig. 7

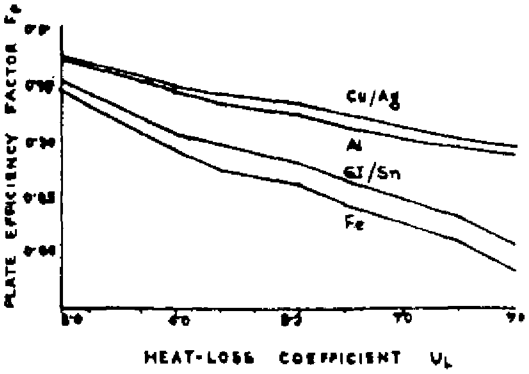

Fig. 8

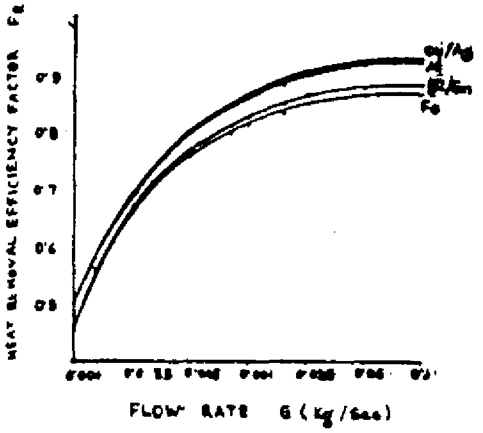

Fig. 9

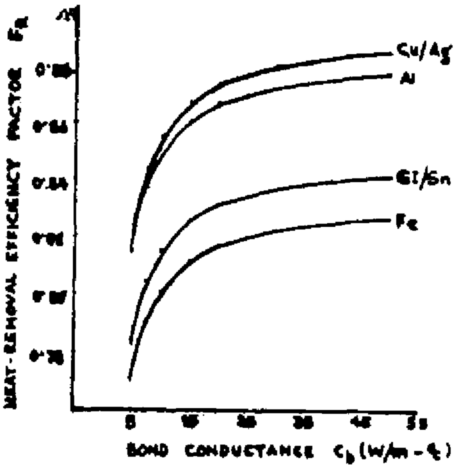

Fig. 10

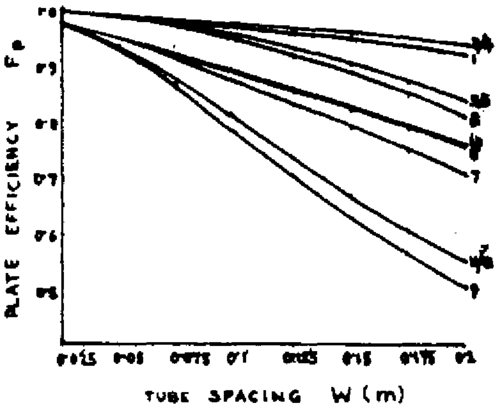

Fig. 11

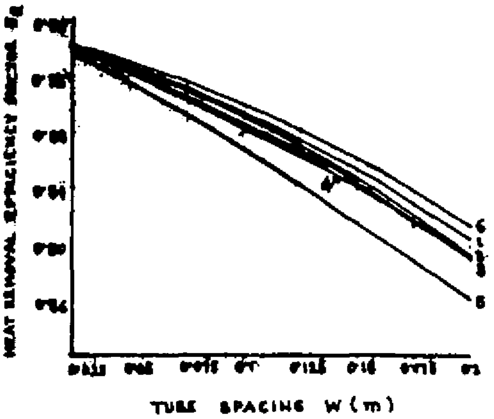

Fig. 12

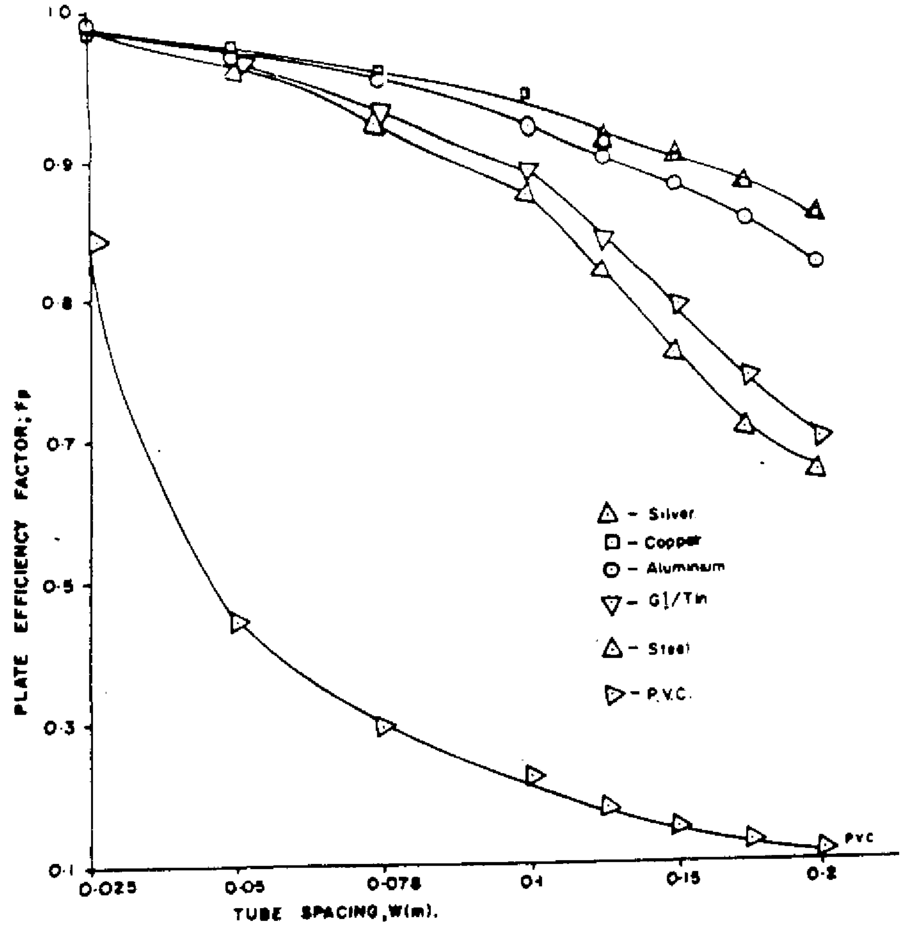

Fig. 13 Fp Vs W FOR UNEQUAL TUBE SPACING

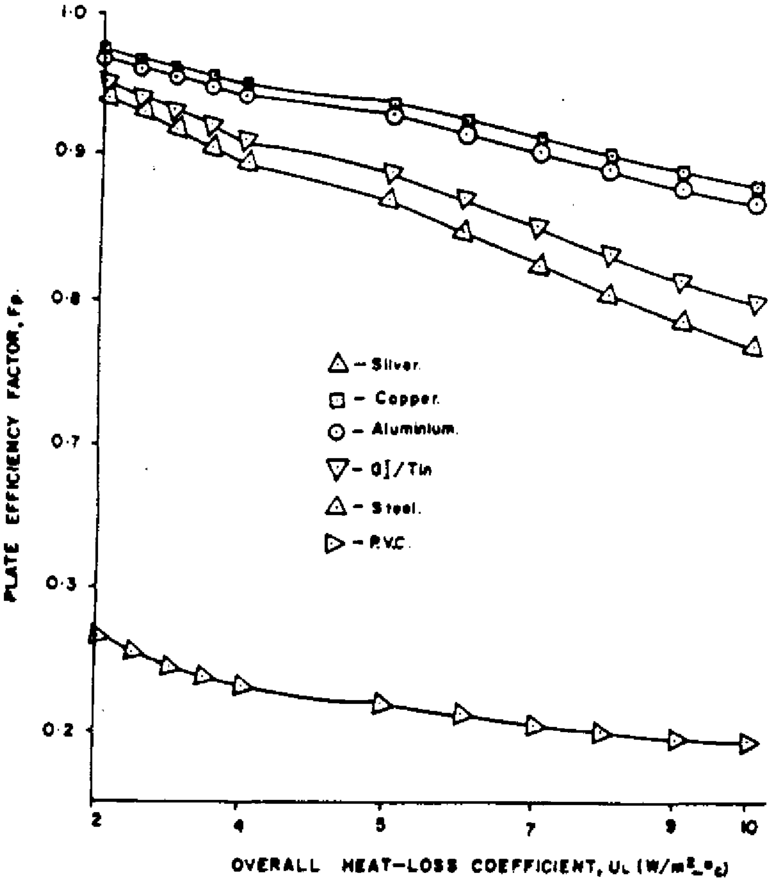

Fig. 14 Fp Vs UL FOR UNEQUAL OVEALL HEAT-LOSS COEFFICIENT.

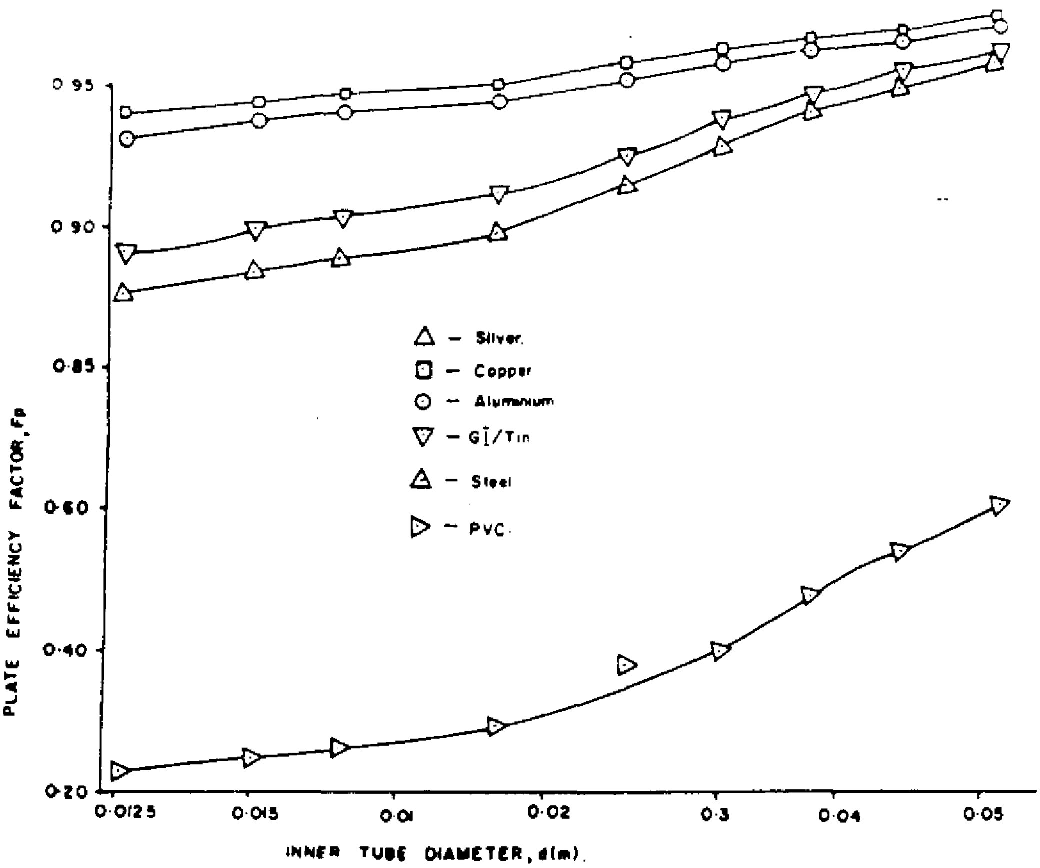

Fig. 15 Fp Vs d FOR UNEQUAL INNER TUBE DIAMETER.

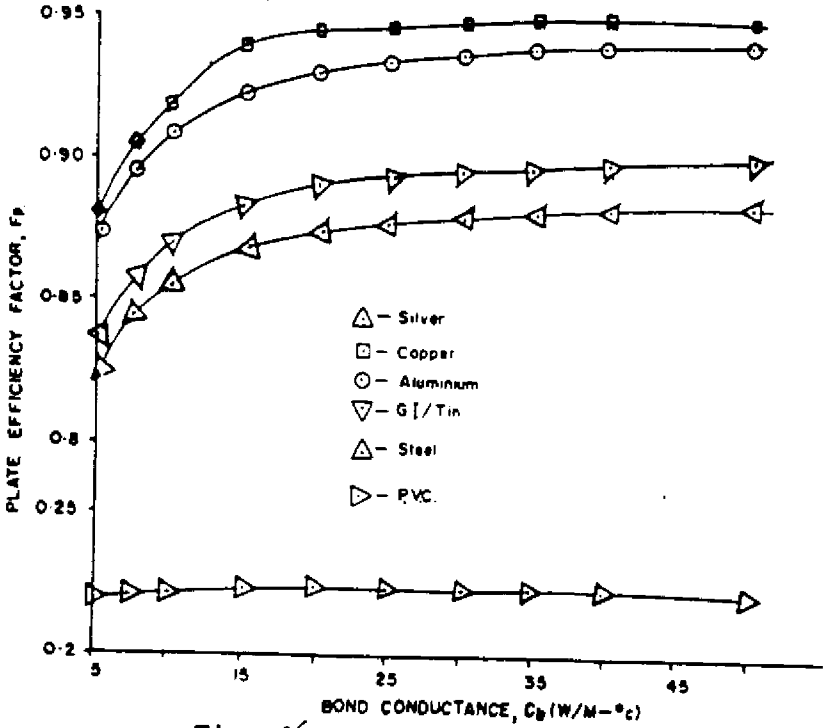

Fig. 16 Fp Vs Cb FOR UNOUAL BOND CONDUCTANCE.

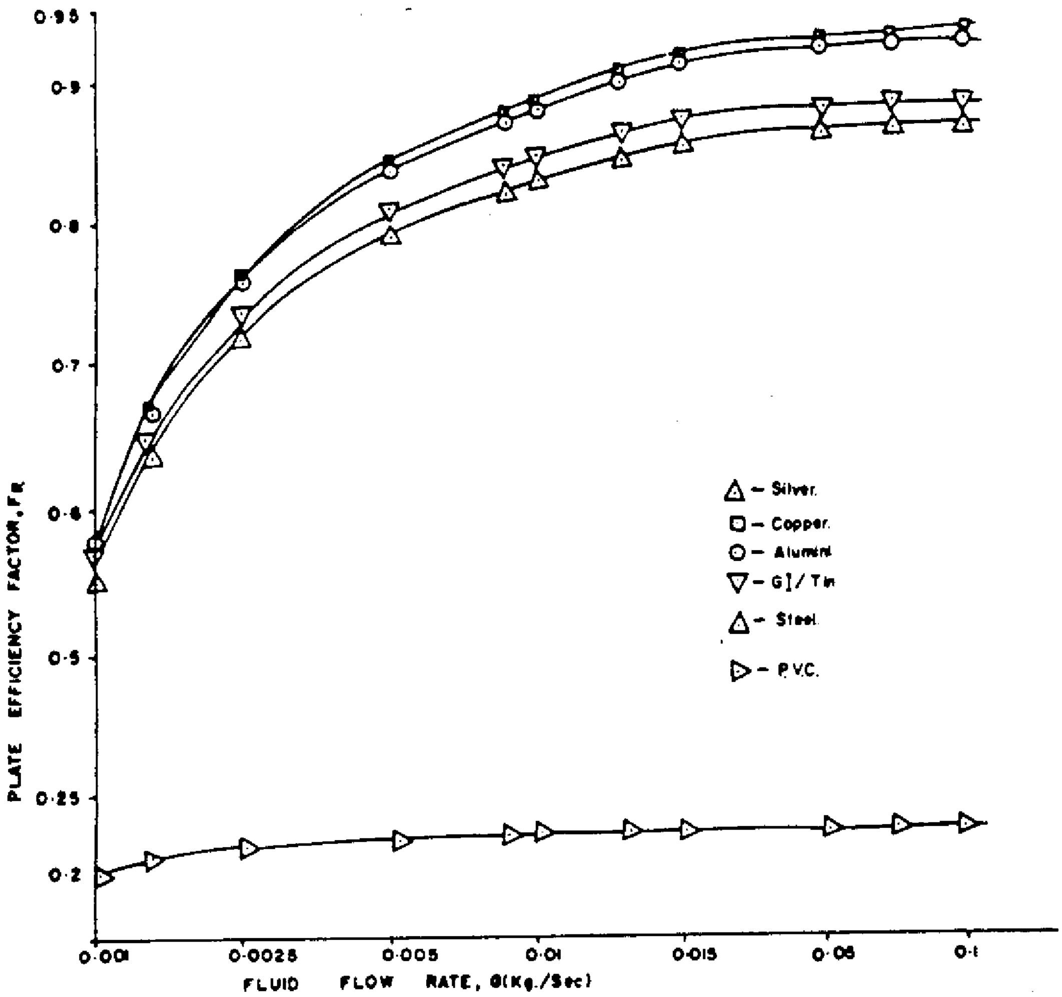

Fig. 17 Fp Vs G FOR UNEQUAL FLUID FLOW RATE