cc: WEE

Eric Shatwell
Exhibits
Aycliffe

REPORT ON THE POSSIBLE APPLICATION OF U.C.C. TECHNIQUES AT AYCLIFFE

1. INTRODUCTION AND SUMMARY

In the report on my visit to Union Carbide Corporation's P.V.C. Plant at Texas City, I described their philosophy for obtaining maximum output rate. I carried out some calculations in the Appendix, based on extrapolations from data available at that time, which indicated that with a high degree of automation, as in existence at Texas City, their philosophy was justified. I also indicated that it might well be that if we had the same degree of automation at Aycliffe, it would pay us to adopt their philosophy.

At the time when my report was being issued, further data came into my hands, when Research & Development Report No. 1824 by Mr. J. R. Wallace was circulated, giving details of experiments carried out in the 50 gallon autoclave to determine the reaction rate curves with I.P.P. at a great many different concentration levels. This led me to examine the original reaction rate curves and these have been plotted on graph No. 1 (see Appendix).

Using this graph and the reaction time-concentration curves on Fig. 5 of R. & D. Report No. 1824 (which is reproduced as graph No. 2), calculations were carried out to check whether, in fact, an application of Union Carbide's philosophy would be of profit to Aycliffe. These calculations, which are given in detail in Section 2 of this report, led to the following conclusions.

(i) With present outcycle times, the direction in which we have been currently progressing at Aycliffe will give the best output rate. (Section 2.5).

(ii) If the average outcycle time could be reduced by use of automation or other techniques to 3 hours per batch, the best output rate could be obtained either by (a) using present methods or (b) running to 81% conversion instead of 89-90% - the resin would then not be VY.18 however.

The calculation of (a) + (b) is given in 2.6 and 2.8, the slight difference between them being within the range of error of the data and assumptions made.

Since these calculations did not show any benefit at Aycliffe by using U.C.C.'s techniques and philosophy, the calculations in the Appendix of the report on my visit to the United States were checked and done again, using the new data which had become available. These are reproduced under Section 2 and show that the errors in extrapolations made in calculating the original results were such that they nullified one of the conclusions drawn from the calculations, i.e. that Union Carbide's philosophy was the best for their plant. In fact, both methods would lead to almost identical output rates, and the method to be chosen would depend upon the properties required in the final resin and also the diminution in vinyl chloride efficiency, which would be expected when handling larger quantities of recovered monomer. This can be seen by comparing the calculations under 3.2 with those under 3.1. It does not, however, invalidate the main conclusion of the calculations, which was that Union Carbide would obtain at least 20% increase in output rate by using our water addition techniques.

A check was then made on what output rates could be expected from 5,500 gallon autoclaves, as proposed in the design summary for the extension of the V.R. These are shown in Section 4. They confirm the scale-up factor used in the Outline of Project Report No. A.45 of May 1964 of 1.5 between 5,500 gal. and 3,000 gal. autoclaves, and indicate that output rates of 800,000 to 900,000 lb./week of VY.18 should be obtainable from the 5 proposed new autoclaves.

The reason for the error in extrapolation in the original report was because it was not realised that the initial reaction rate at different I.P.P. concentrations was almost the same. It had been assumed, from what evidence was then available, that the curves ran parallel to each other at increasing I.P.P. concentrations.

2. U.C.C. Techniques v. Aycliffe Techniques for Aycliffe 3,000 Imp. gal. Autoclave

2.1 Assumptions made (based on previous measurements):

The overall heat transfer coefficient U = 52 BTU/(hr)(ft^2)($^\circ$F).

The reaction temperature is 54°C.

The cooling water temperature is 14°C.

Effective jacketed area of autoclave = 250 ft.^{2}

Temperature rise of cooling water at maximum flow = 8°C.

Reaction rates at various I.P.P. concentrations follow curves in Fig. I.

2.2 Calculation of Maximum Tolerable Reaction Rate

$$q = U.A.\Delta tm.$$

$\Delta ti = 54-14 = 40^\circ C$)
$\Delta to = 54-22 = 32^\circ C$) $\frac{\Delta ti}{\Delta to} \not> 2$

$$\therefore \Delta tm = \frac{40 + 32}{2} = 36^\circ C.$$

$$q = 52 \times 250 \times 36 \times 1.8$$

$$= \underline{840,000 \text{ BTU/hr}}.$$

Since ΔHr = 700 BTU/lb.

Max. reaction rate tolerable = $\frac{840,000}{700}$

$$= \underline{1,200 \text{ lb./hr}}.$$

2.3 Calculation of output rate per autoclave hour using U.C.C. level of 75% full, making VY.18 at 90% conversion, and with H.P. water addition to make up volume contraction and also to fill autoclave up to 90% full.

Charge wt. = 7,600 lb.

Volume contraction = $350 \times \frac{7,600}{9,140}$ = 290 Imp. gal.

(350 gal. is contraction at 9,140 lb. charge wt.)

$\therefore$ Total quantity of water to add = $290 + (\frac{90 - 75}{100}) 3,000$

$$= 290 + 450$$

$$= 740 \text{ Imp. gal.}$$

If this is added over the last hour of reaction and the H.P. process water temperature = 10°C.

Heat absorbed = 7,400 x (54-10) x 1.8 BTU/hr.

∴ Reaction rate it will control = $\frac{7,400 \times 44 \times 1.8 \text{ lb./hr.}}{700}$

= $\frac{7,400 \times 44 \times 1.8 \times 100}{700 \times 7,600}$ = 11%/hr.

∴ Maximum tolerable reaction rate = $\frac{1,200 \times 100}{7,600}$ + 11

= 15.8 + 11

= 26.8%/hr

From Fig. 1

Reaction time = 7 hrs.
With full automation outcycle time = 3 hrs.

∴ Total cycle time = 10 hrs.

∴ Output rate = $\frac{7,600 \times .9}{10}$

= 684 lb./auto.hr.

And on 5 autoclaves = 575,000 lb./week.

2.4 Present output rate of VY.13 using current Aycliffe methods

i.e. 90% full 90% conversion charge at 9,140 lb.

Reaction time = 8 hrs.
Outcycle time = 4.5 hrs.
Cycle time = 12.5 hrs.

Output rate = $\frac{9,140 \times .9}{12.5}$

= 657 lb./auto. hr.

and on 5 autoclaves = 550,000 lb./week

2.5 Output rate at present conditions, with full automation giving 3 hrs. outcycle time.

Reaction time		8 hrs.
Outcycle time		3 hrs.
Cycle time		11 hrs.
Output Rate	=	$\frac{9,140 \times .9}{11}$
	=	748 lb./auto.hr.
and on 5 autoclaves	=	627,000 lb./wk.

2.6 Output rate using present methods, but increasing charge weight to condition where termination is on temperature rise with a slight pressure drop. This was done during W/E. 11.9.64.

Charge wt. 9,800 lb. Conversion = 89%

Reaction time	=	7.5 hrs.
Outcycle time	=	4.5 hrs.
Cycle time	=	12.0 hrs.
Output Rate	=	$\frac{9,800 \times 0.89}{12}$
	=	728 lb./auto. hr.
and on 5 autoclaves	=	610,000 lb./week

2.7 As 2.6 but with automation to reduce outcycle times to 3 hours.

Output rate	=	$\frac{9,800 \times 0.89}{10.5}$
	=	830 lb./auto.hr.
and on 5 autoclaves	=	696,000 lb./week

2.8 U.C.C. run their QYTQ7, equivalent to VY.18, to 81% conversion. If we ran VY.18 to 81% conversion, it would be no longer VY.18, but probably much more like VY.11. However, output rates have been calculated as follows, assuming it was an acceptable proposition.

In fact, it is doubtful whether the drying plant could cope with it.

2.9.1 U.C.C. level of of 75% full, making up contraction in volume and falling to 90% by H.P. water addition. This is in fact 2.3 to 81% conversion.

Reaction time 6.5 hrs.
Outcycle time 3.0 hrs.
Cycle Time 9.5 hrs.

$$\text{Output Rate} = \frac{7,600 \times 0.81}{9.5}$$

$$= \underline{648 \text{ lb./auto.hr.}}$$

and on 5 autoclaves = 544,000 lb./week

2.9.2 Present best Aycliffe method with full automation (like 2.7) to 81% conversion.

Reaction time 6.5 hrs.
Outcycle time 3.0 hrs.
Cycle time 9.5 hrs.

$$\text{Output Rate} = \frac{9,800 \times 0.81}{9.5}$$

$$= \underline{835 \text{ lb./auto.hr.}}$$

and on 5 autoclaves = 710,000 lb./week

2.9.3 Present best Aycliffe method (2.6) to 81% conversion.

Reaction time 6.5 hrs.
Outcycle time 4.5 hrs.
Cycle time 11.0 hrs.

$$\text{Output rate} = \frac{9,800 \times .81}{11.0}$$

$$= \underline{724 \text{ lb./auto. hr.}}$$

and on 5 autoclaves = 606,000 lb./week

3. Recalculation of Results in Appendix I of Report on visit to America. The same assumptions are made but new reaction data on I.P.P. used (from graph No.1).

3.1 Maximum Reaction Rate - no change

= 1,670 lb./hr.

3.2 Using U.C.C. charge wt. 11,500

Max. rate of reaction - same = 14.5%/hr.

Reaction time = 11.5 hrs.
U.C.C. Outcycle time
= 3.5 hrs.
Cycle time = 15.0 hrs.

$$\text{Output rate} = \frac{11,500 \times .9}{15}$$

= 694 lb./auto.hr.

3.3 Check on U.C.C.'s rate if they used I.P.P. - figures are correct, except that I.P.P. concentration to give this would be 0.0175 phm.

3.4 If U.C.C. ran at 90% full with same M/W ratio

(a) Full pressure drop.

Reaction time = 13.0 hrs.
Outcycle time = 3.5 hrs.
Cycle time = 16.5 hrs.

$$\text{Output Rate} = \frac{13,800 \times 0.9}{16.5}$$

= 756 lb./auto.hr.

(b) Going to 81% conversion.

Reaction time = 10.0 hrs.
Outcycle time = 3.5 hrs.
Cycle time = 13.5 hrs.

$$\text{Output rate} = \frac{13,800 \times .81}{13.5}$$

= 828 lb./auto.hr.

3.5 Run at 90% full with increased M/W ratio (Aycliffe)

(a) Full pressure drop.

Reaction time 13.0 hrs.
Outcycle time 3.5 hrs.
Cycle time 16.5 hrs.

$$\text{Output rate} = \frac{14,300 \times .9}{16.5}$$

$$= \underline{782 \text{ lb./auto. hr.}}$$

(b) 81% Conversion

Reaction time 11.0
Outcycle time 3.5
Cycle time 14.5

$$\text{Output rate} = \frac{14,300 \times .81}{14.5}$$

$$= \underline{794 \text{ lb./auto. hr.}}$$

3.6 Run at 75% full with Aycliffe M/W ratio.

- Original was correct = 772 lb./auto.hr.

3.7 With Water Addition

3.7.1 At 75% full

3.7.1.1 U.C.C.'s present method using I.P.P.

Only difference in cycle times.

Reaction time 6.75 hrs.
Outcycle time 3.5 hrs.
Cycle time 10.25 hrs.

$$\text{Output rate} = \frac{11,500 \times .81}{10.25}$$

$$= \underline{910 \text{ lb./auto.hr.}}$$

3.7.1.2. If made up to 90% full.

Reaction time = 6.25 hrs.
Outcycle time = 3.5 hrs.
Cycle time = 9.75 hrs.

Output rate = $\frac{11,500 \times .81}{9.75}$

= 965 lb./auto.hr.

3.7.1.3 Running to 90% conversion - make up of volume contraction.

Reaction time = 8.0 hrs.
Outcycle time = 3.5 hrs.
Cycle time = 11.5 hrs.

Output rate = $\frac{11,500 \times 0.9}{11.5}$

= 964 lb./auto.hr.

3.7.1.4 With make up to 90% full

Reaction time = 7.0 hrs.
Outcycle time = 3.5 hrs.
Cycle time = 10.5 hrs.

Output rate = $\frac{11,500 \times .9}{10.5}$

= 998 lb./auto.hr.

3.7.2 At 90% full.

3.7.2.1 At 81% Conversion

Reaction time = 7.25
Outcycle time = 3.5
Cycle time = 10.75

Output rate = $\frac{13,800 \times .81}{10.75}$

= 1,040 lb./auto.hr.

3.7.2.2 At 90% conversion

Reaction time = 8.5
Outcycle time = 3.5
Cycle time = 12.0

$$\text{Output rate} = \frac{13,800 \times .9}{12.0}$$

$$= \underline{1,035 \text{ lb./auto.hr.}}$$

4 Expected output rate from proposed 5,500 Imp. gal. Autos. under Aycliffe conditions.

4.1 Tolerable Reaction Rate from jacket cooling.

Assumptions:

U = 52 BTU/hr. ft.^{2} $^\circ$F.

Reaction temperature = 54°C.

Others as per 2.1

Effective jacketed area = 340 ft.^{2}

$q = U A \Delta tm.$

$= 52 \times 340 \times 36 \times 1.8$

$= \underline{1,135,000 \text{ BTU/hr.}}$

$R = \underline{1,620 \text{ lb./hr.}}$

4.2 Using normal methods for VY.18

$$\text{Charge wt.} = \frac{5,500}{3,000} \times 9,140 = 16,800 \text{ lb.}$$

$$\text{Volume contraction} = \frac{350 \times 16,800}{9,140} = 644 \text{ Imp. gal.}$$

$$\text{Jacket controllable reaction rate} = \frac{1,620}{16,800} \times 100$$

$$= 9.65\%/\text{hr.}$$

$$\text{by water addition in last hour} = \frac{6,440 \times 44 \times 1.8}{700 \times 16,800}$$

$$= 4.35\%/\text{hr.}$$

Total acceptable reaction rate = 14.0 hrs.

Reaction time = 11.0 hrs.
Outcycle time = 4.5 hrs.
Cycle time = 15.5 hrs.

Output rate = $\frac{16,800 \times .9}{15.5}$

= 970 lb./auto.hr.

and on 5 autoclaves = 815,000 lb./wk.

4.3 Running with increased charge wt. to 89% conversion

Charge wt. = $\frac{9,800}{9,140} \times 16,800$

= 18,000 lb.

Volume contraction rate control = $\frac{18,000}{16,800} \times 4.35$

= 4.65%/hr.

Jacket controllable rate = $\frac{1,620}{18,000} \times 100$

= 9.0%/hr.

Max. acceptable reaction rate = 13.65%/hr

Reaction time = 10.5 hrs.
Outcycle time = 4.5 hrs.
Cycle time = 15.0 hrs.

Output rate = $\frac{18,000 \times .89}{15.0}$

= 1,110 lb./auto.hr.

for 5 autoclaves = 934,000 lb./week

Ratio of Output rate of 5,500 gal. to 3,000 gal.

(cf. 2.6) $\frac{1,110}{728} = 1.53$

Confirming the assumptions made in the design report.

4.4 With reduced outcycle time to U.C.C. value

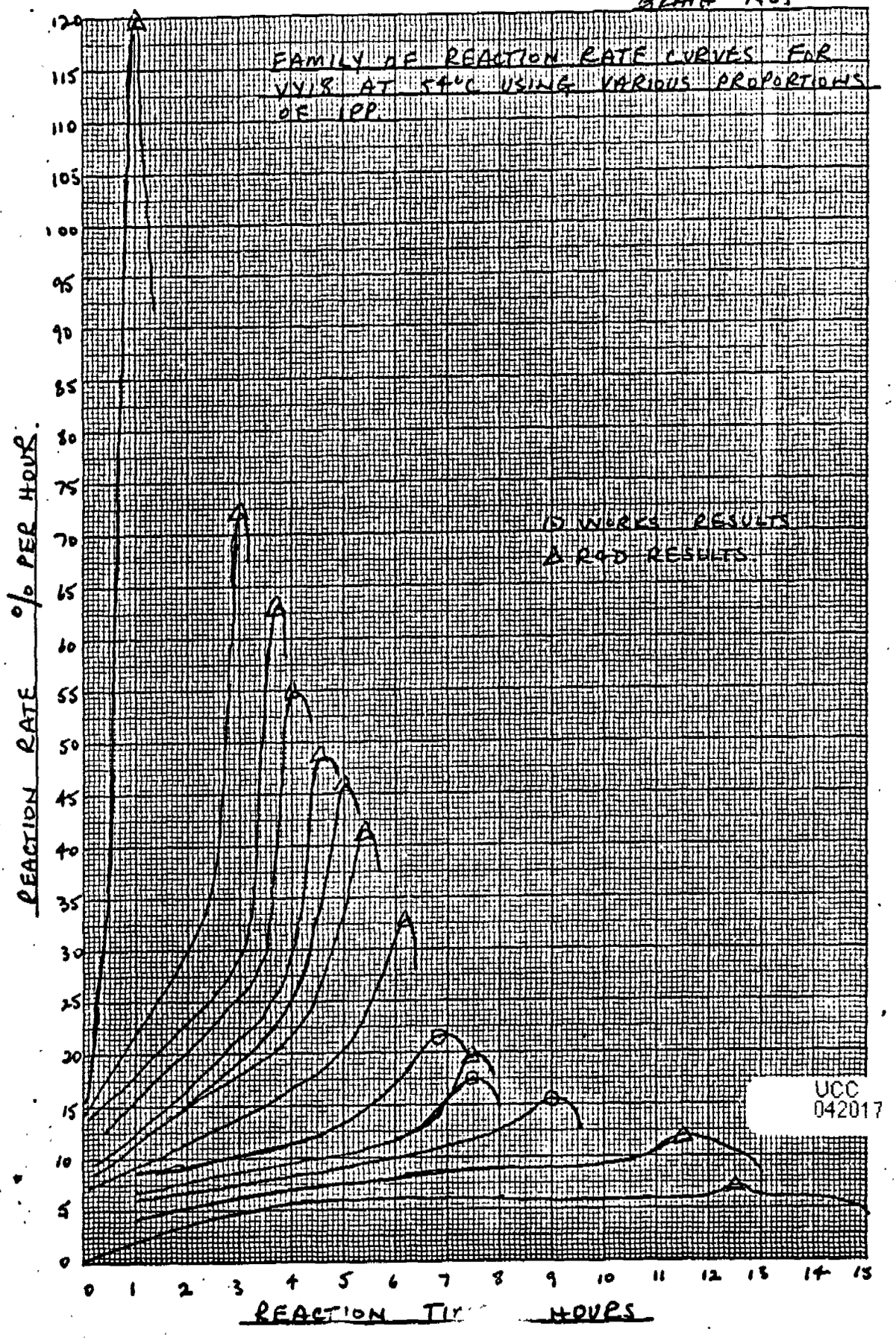
$$\text{Cycle time} = 14.0$$

$$\text{Output rate} = \frac{18{,}000 \times .89}{14.0}$$

$$= \underline{1{,}190 \text{ lb./auto.hr.}}$$

$$\text{for 5 autoclaves} = \underline{1{,}000{,}000 \text{ lb./week}}$$

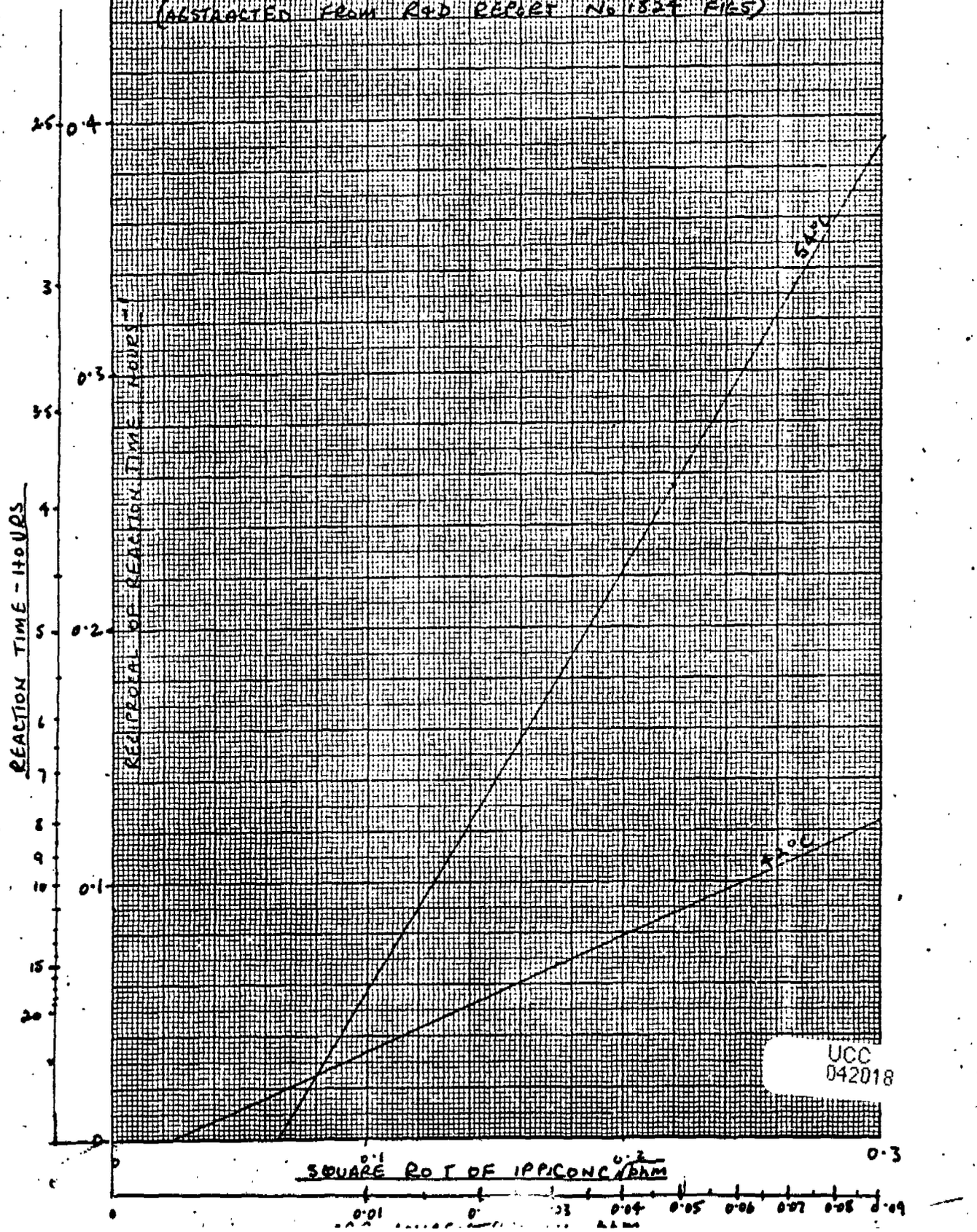
GRAPH NO. 1



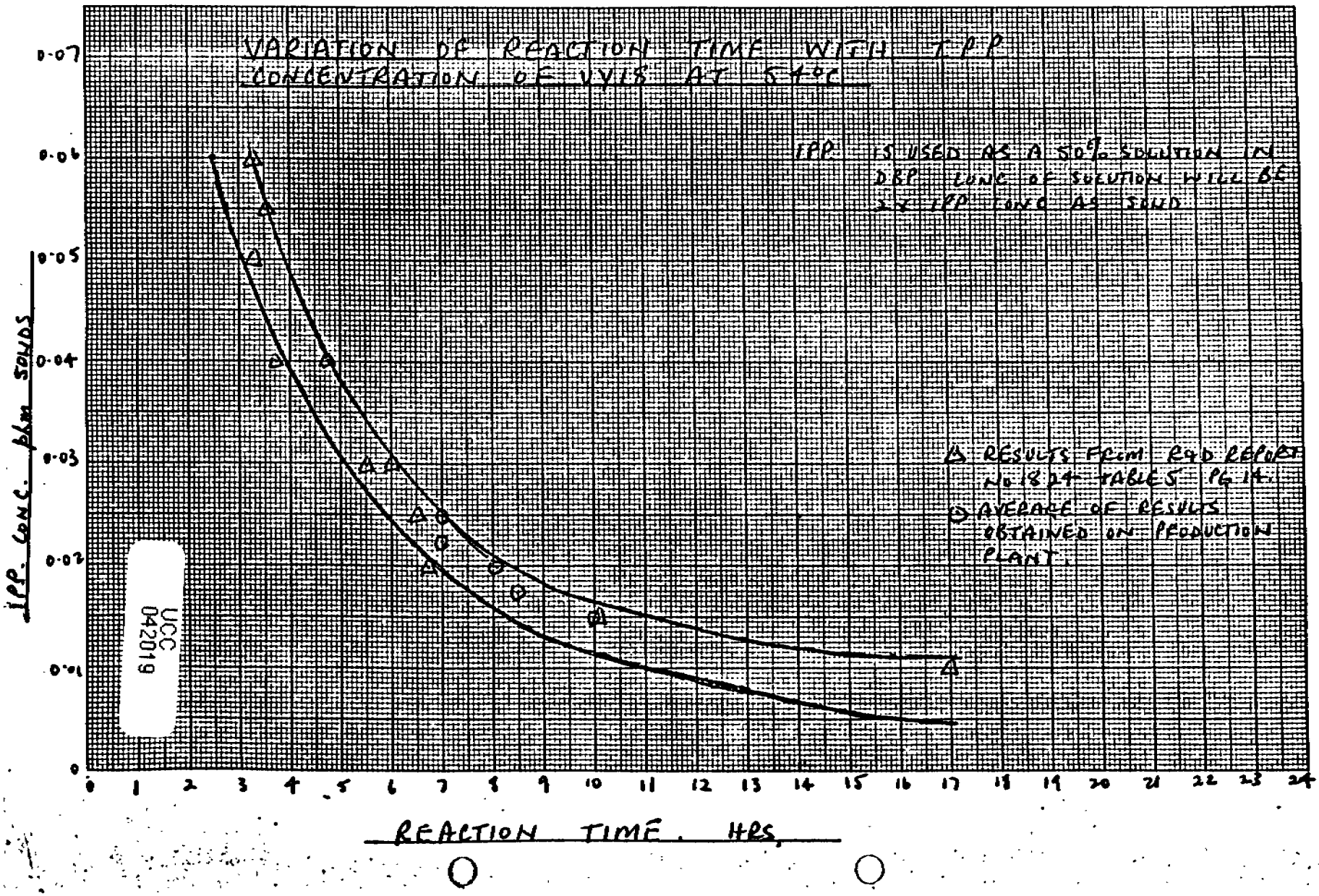
GRAPH No2

REACTION TIME - CONCENTRATION CURVES FOR I.P.P.

(ABSTRACTED FROM R&D REPORT No 1824 FILES)



CHALKWELL GRAPH SHEET No. 550 M/M. 1 & 1 C/M (34 x 13 C/M)



UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
ENGINEERING
SOUTH CHARLESTON, WEST VIRGINIA

MEMORANDUM

June 5, 1968

TO: Mr. G. K. Graeber
32nd Floor
New York Office

COPY TO: Mr. A. J. Costantin
Mr. J. H. Field

FROM: W. R. Manning and R. N. Wheeler

SUBJECT: Aycliffe Expansion - Special Project: 68-SP-215

We have reviewed the Pre-Project Feasibility Study for the proposed Aycliffe expansion and offer the following comments:

1. This study deals only with the profitability of the proposed expansion on a make-versus-buy basis, and does not examine the profitability of the overall compounding and captive use operation. Perhaps this has already been done in other studies, but if not, we believe it should be.

2. We note that written-down (depreciated) values are used for fixed investment in ROI calculations. (Incidentally, are these based on the old or new value of the pound?) We use undepreciated, or gross, values for fixed investment in our own ROI calculations, and therefore we are not able to interpret properly the results reported. The use of depreciated values would of course lead to higher ROI values than we are used to seeing. Government grants and subsidies also increase the ROI values reported on a net basis.

3. In the estimates of working capital, it appears that account has been taken of resin inventory only and this is estimated at about six percent of annual production; this seems low. We agree that omission of accounts receivable and accounts payable may be justified, but we do not see the justification for omitting the cash element of working capital. We would normally estimate this to be 12 percent of total operating cost (plant cost plus distribution plus overhead).

4. We are not in a position to check the estimates of new fixed investment in detail, but the cost per pound seems to be of about the right magnitude, or perhaps even somewhat conservative. (8.1 cents per pound for P-S-G; 7.4 cents per pound for expansion by the suspension process.)

We also offer the following comments on the points raised in Mr. J. H. Field's letter of May 6, 1968.

1. The 80-percent limitation is apparently the result of a policy designed to protect their monomer purchasing position with ICI.

2. They are talking Imperial gallons: 1 Imp. gallon = 1.2 U. S. gallons. Their 5,500-gallon autoclave holds 5,500 x 1.2 = 6,600 U. S. gallons. They now have capacity of 28 million pounds per year. With the newly-authorized autoclave they will get only 2.25 million more, because drying capacity will limit. When drying capacity is increased by the expansion, the same autoclave will produce an additional 6.2 million.

3. We estimated (1967 L. R. Plan, p. C-13) that we would get 10% ROI on P-S-G at 10.2 ¢/lb sales price, rather than 11.4 ¢/lb. The 11.4 ¢/lb was the approximate average sales price for 60/40 homopolymer-copolymer suspension resin. The use of depreciated fixed investment apparently increases this to 15.0%, and government grants and subsidies increase the ROI (net basis) to 22.2% for P-S-G.

W. R. Manning
Engineering Manager, Vinyl Resins

R. N. Whaley
Production Manager, Suspension/
Non-Solvent/Dispersion Resins

WRM:RNW:rc

UNION CARBIDE CORPORATION
Coatings Intermediates Division — Texas City, Texas

To: Mr. G. K. Graeber
32nd Floor
NEW YORK OFFICE

May 6, 1968

cc: Mr. A. J. Costantin
Dr. W. R. Manning
Mr. R. N. Wheeler

RECEIVED
MAY 9 1968
R. N. Wheeler

Subject: Aycliffe Expansion - Special Project: 68-SP-215

George -

I've reviewed the report on Aycliffe expansion and have the following comments and questions:

1. I agree with your question - Why limit amount to 80% of needs? - I presume this is the point at which additional new investment in supporting facilities would be required.

2. I don't understand the capacity figures. What is 2.25 MM added to 6.2 MM in authorized 5,500-gallon autoclave? Also, I agree with you that 8.4 MM per year sounds high.

3. I can see how an incremental expansion of suspension might be justified on a captive usage basis (make vs. buy), but I don't see at all how the PSG unit is justified. We have estimated that in this country, we would get only 10% ROI on an all new PSG unit selling resin at 11.4¢ per pound and manufacturing monomer by oxychlorination unit. How do they get to 20%, even on a make vs. buy analysis, valuing resin at 10.1¢ per pound with monomer at 6.03¢ per pound? By copy of this letter, I'm asking Ray Manning for his comments on this point. Perhaps "investment grants" and "subsidies" are enough to make the difference. Who pays for these?

4. Further on PSG, we feel that if we were going to add total capacity, this is the process we would want to use. If Aycliffe can develop justification for a PSG plant somehow, it would be a good opportunity for us to get a reading on the process.

You've commented already on other points I noted. Ray Manning has a copy of this memo and is reviewing it from the standpoint of investments and economics primarily. He will forward comments to you directly.

J. H. Field

JHF/vl