SILICA PRECIPITATION AND SCALING IN DYNAMIC GEOTHERMAL SYSTEMS*

E. G. Bohlmann, A. J. Shor and P. Berlinski
Oak Ridge National Laboratory
Oak Ridge, TN 37830

We are modifying an existing 100 gpm titanium loop to provide a facility for studying the formation of silica precipitates, their properties and fates, principally as a function of brine composition, temperature, and flow conditions. This loop demonstrated excellent serviceability over a period of years in saline water corrosion studies (to 275°C and 2 M NaCl), with and without pollutant additives such as H_2S, NH_3, and SO_2, and should be equally useful in this application. Simulated silica saturated geothermal waters are prepared by circulating part of the loop flow (∿1 gpm) through a bypass column filled with amorphous silica powder. Exploratory studies in a Once-Through Development System (described below) indicated that porous Vycor (Cornin- Glass Code #7930, 97% SiO_2, 3% B_2O_3) was a suitable material for loading the column. A recent run at ∿ 220°C confirmed this: the system approached equilibrium in agreement with calculation and with the anticipated 15 psi pressure drop through an 18 in. deep bed of 140-200 mesh Vycor powder.

A second ∿1 gpm stream is circulated through a heat exchanger in which dynamic scaling studies will be conducted. Design variables include: overall ΔT to 125°C, linear flow rate of 4-7 fps, Reynolds' number of 10^4 to 10^5. The heat exchanger is divided into five consecutive segments so successive temperature intervals can be instrumented to monitor changes in heat transfer characteristics; selective destructive examination, when desired, is also facilitated. Blind end flanges on each segment permit borescope examination of scales <u>in situ</u> and sampling access. The stream leaving the heat exchanger is reheated by an electrical reheat system to replace the 40 kw heat equivalent removed at maximum ΔT and recycled.

In order to prevent overheating of the windings, transformer oil is circulated through the pump stator to maintain a temperature of 50 to 100°C. Thus the motor end of the canned motor pump, which normally operates in the same composition fluid as is circulating in the loop, would be a potential site for scale formation. In order to eliminate this possibility, silica free feed solution is pumped through the pump motor compartment into the loop proper. This results in the necessary letdown of 1 gph of solution saturated with silica at the temperature of column operation; this stream is available for monitoring the scaling characteristics of the solution or preparing scaled specimens for other studies. An injection pump can be used to modify the composition of the stream as desired.

---

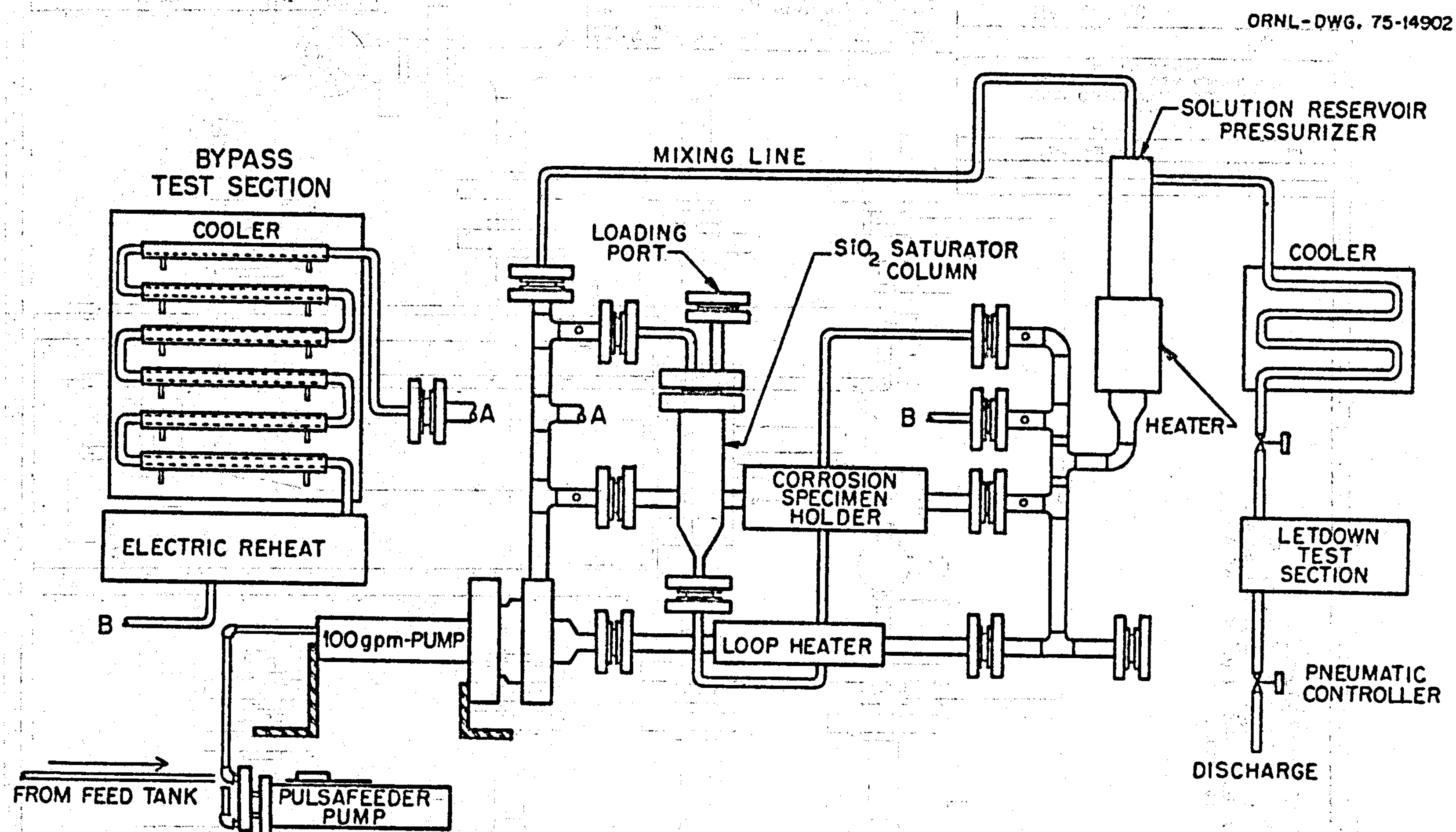
*Research sponsored by U. S. Energy Research and Development Administration under contract with Union Carbide Corporation.

DISCLAIMER

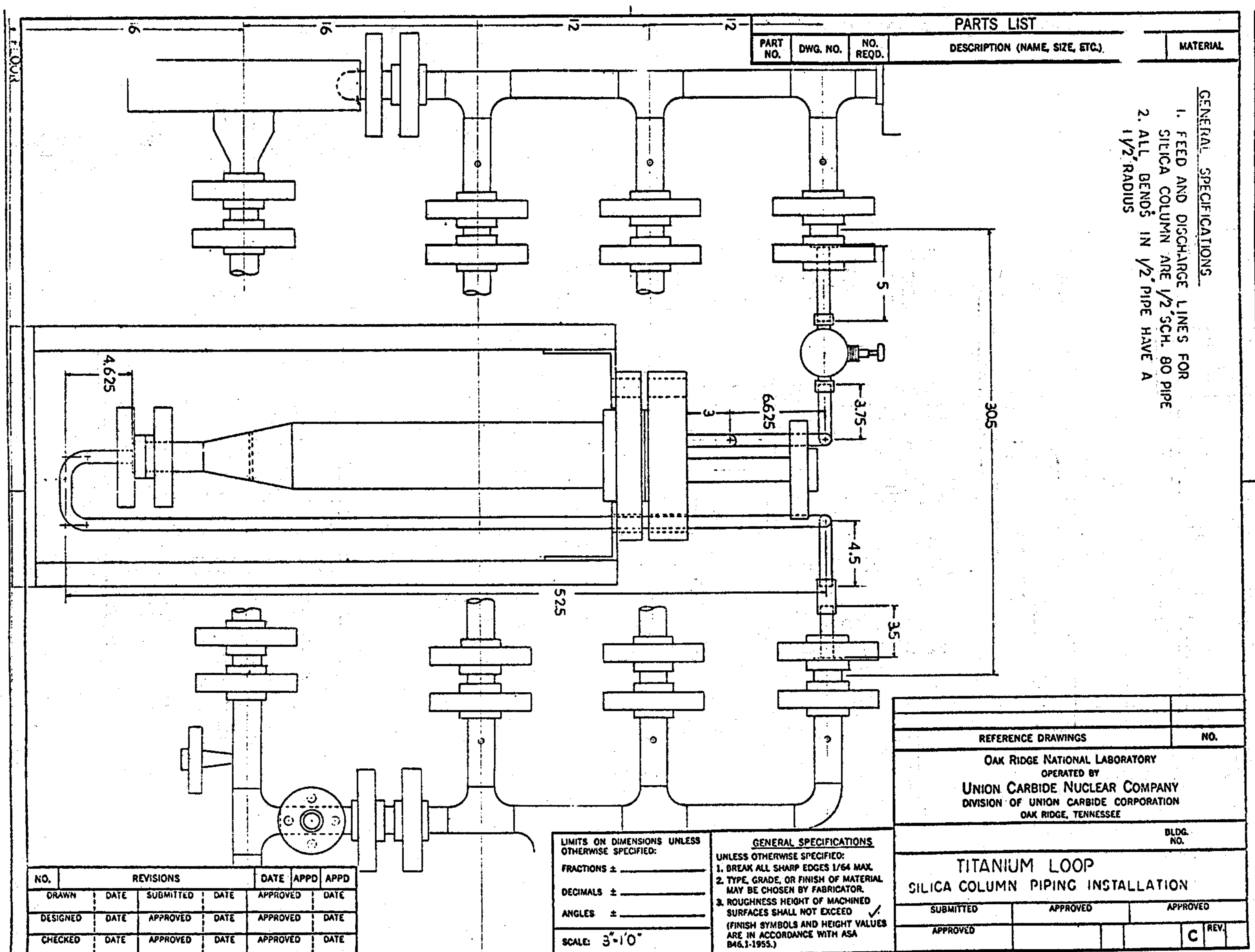
DISCLAIMER

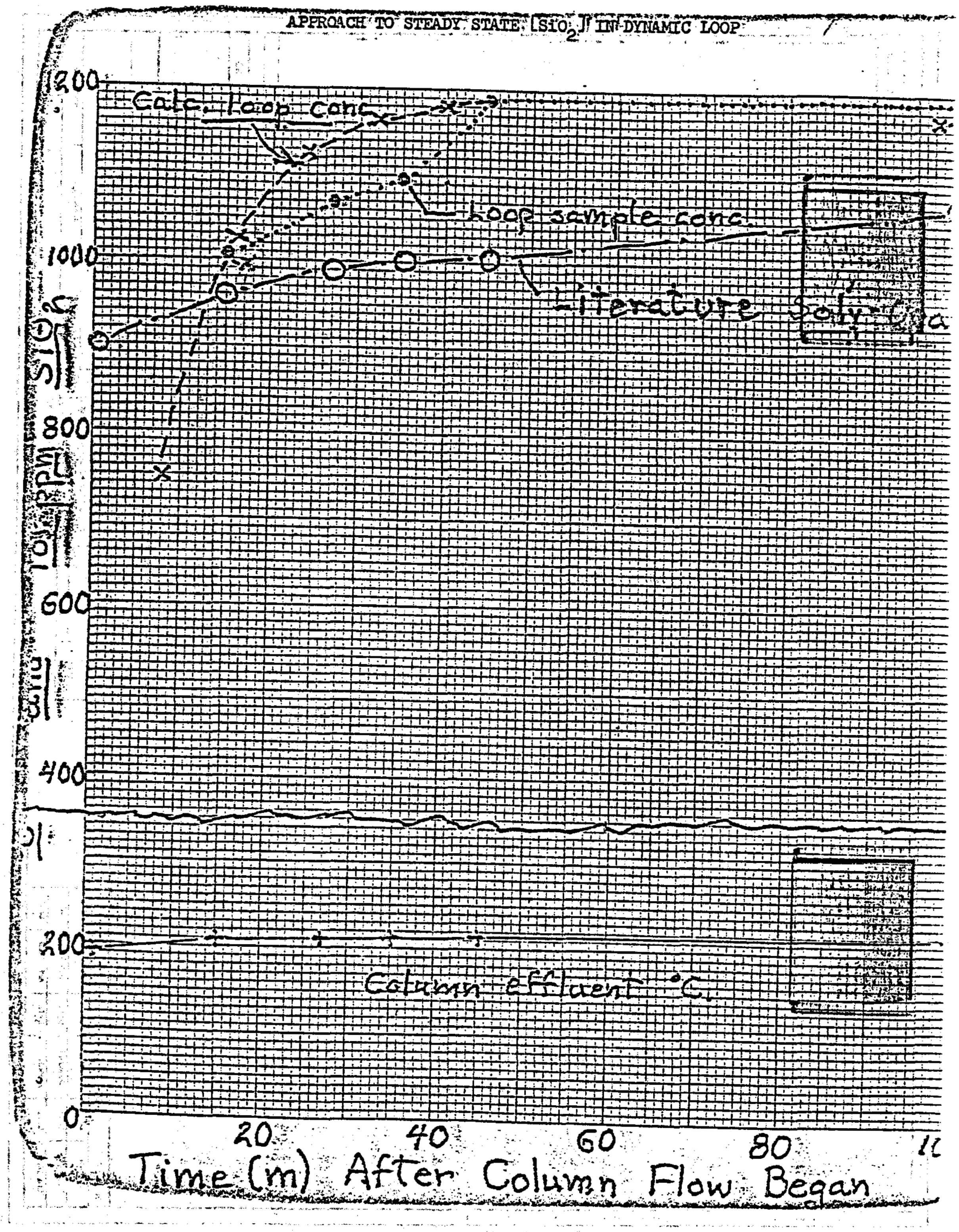
Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Initial consideration of the modification of the 100 gpm loop pointed up the need for a Once-Through Development System to produce design data and experience. The system involves a high pressure Pulsafeeder feed pump, preheater, saturator column, and letdown system - which have changed and evolved with needs and experience. The system was originally used to provide specifications for design of the dynamic loop saturating column. Other uses to be discussed: Preparing stock and special silica solutions for bench scale studies. Studying solutions to letdown valve plugging problems. Scaling studies in the letdown system(s) a. conditions promoting scaling; b. provide scale samples for development of characterization methods.



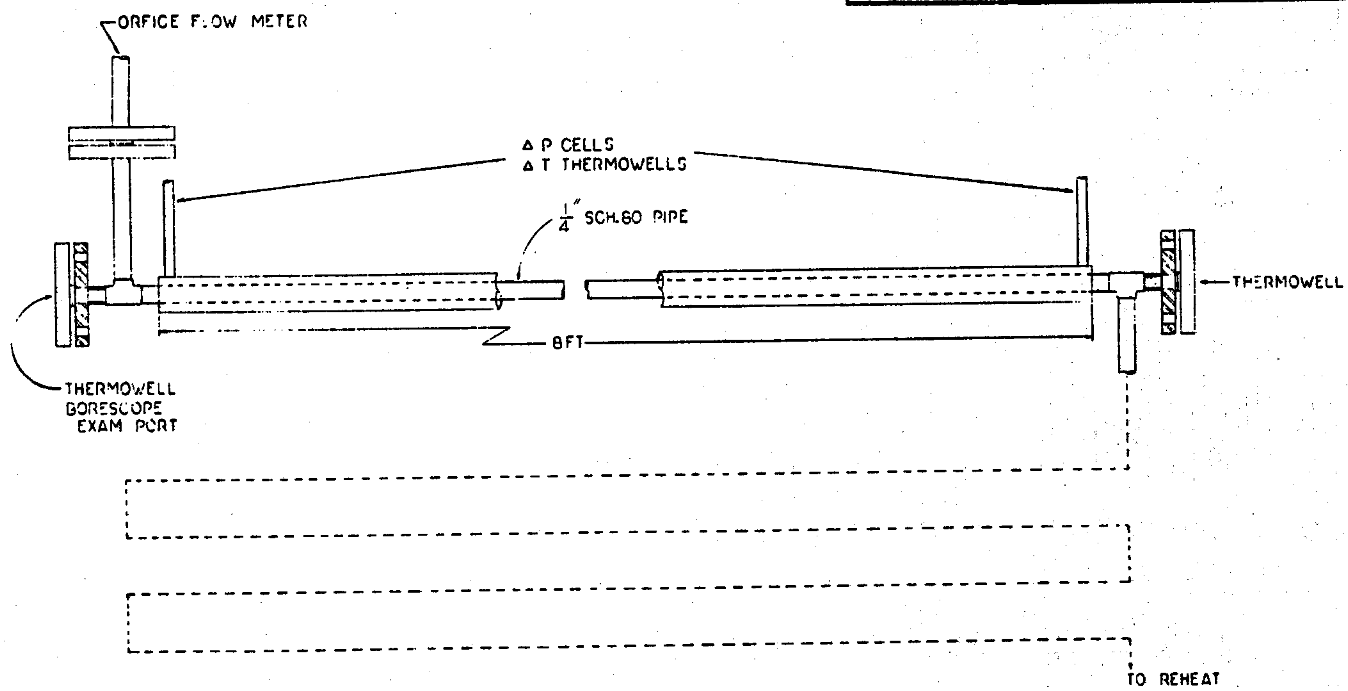
TITANIUM LOOP FOR SILICA PRECIPITATION AND SCALING STUDIES


PARTS LIST
PART NO.
DWG. NO.
NO. REQD.
DESCRIPTION (NAME, SIZE, ETC.)
MATERIAL
GENERAL SPECIFICATIONS
1. FEED AND DISCHARGE LINES FOR SILICA COLUMN ARE 1/2" SCH. 80 PIPE
2. ALL BENDS IN 1/2" PIPE HAVE A 1 1/2" RADIUS
FLOOR
9
16
12
12
5
305
4.625
3
6.625
3.75
4.5
525
3.5
REFERENCE DRAWINGS
NO.
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE
BLDG. NO.
TITANIUM LOOP
SILICA COLUMN PIPING INSTALLATION
SUBMITTED
APPROVED
APPROVED
APPROVED
C
REV.
LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED:
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE: 3"=1'0"
GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES 1/64 MAX.
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. ROUGHNESS HEIGHT OF MACHINED SURFACES SHALL NOT EXCEED
(FINISH SYMBOLS AND HEIGHT VALUES ARE IN ACCORDANCE WITH ASA B46.1-1955.)
NO.
REVISIONS
DATE
APPD
APPD
DRAWN
DATE
SUBMITTED
DATE
APPROVED
DATE
DESIGNED
DATE
APPROVED
DATE
APPROVED
DATE
CHECKED
DATE
APPROVED
DATE
APPROVED
DATE


APPROACH TO STEADY STATE [SiO2] IN DYNAMIC LOOP
Calc. loop conc.
Loop sample conc.
Literature Soly.
Column effluent °C.
Temp. ppm SiO2
1200
1000
800
600
400
200
0
20
40
60
80
Time (m) After Column Flow Began

PART NO.	DWG. NO.	NO. REQD.	DESCRIPTION (NAME, SIZE, ETC.)	MATERIAL

PARTS LIST



TITANIUM LOOP AT BYPASS

NO.	REVISIONS	DATE	APPD	APPD

DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED:
FRACTIONS ±
DECIMALS ±
ANGLES ±
SCALE:

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP EDGES 1/64 MAX.
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. ROUGHNESS HEIGHT OF MACHINED SURFACES SHALL NOT EXCEED ✓
(FINISH SYMBOLS AND HEIGHT VALUES ARE IN ACCORDANCE WITH ASA B46.1-1955.)

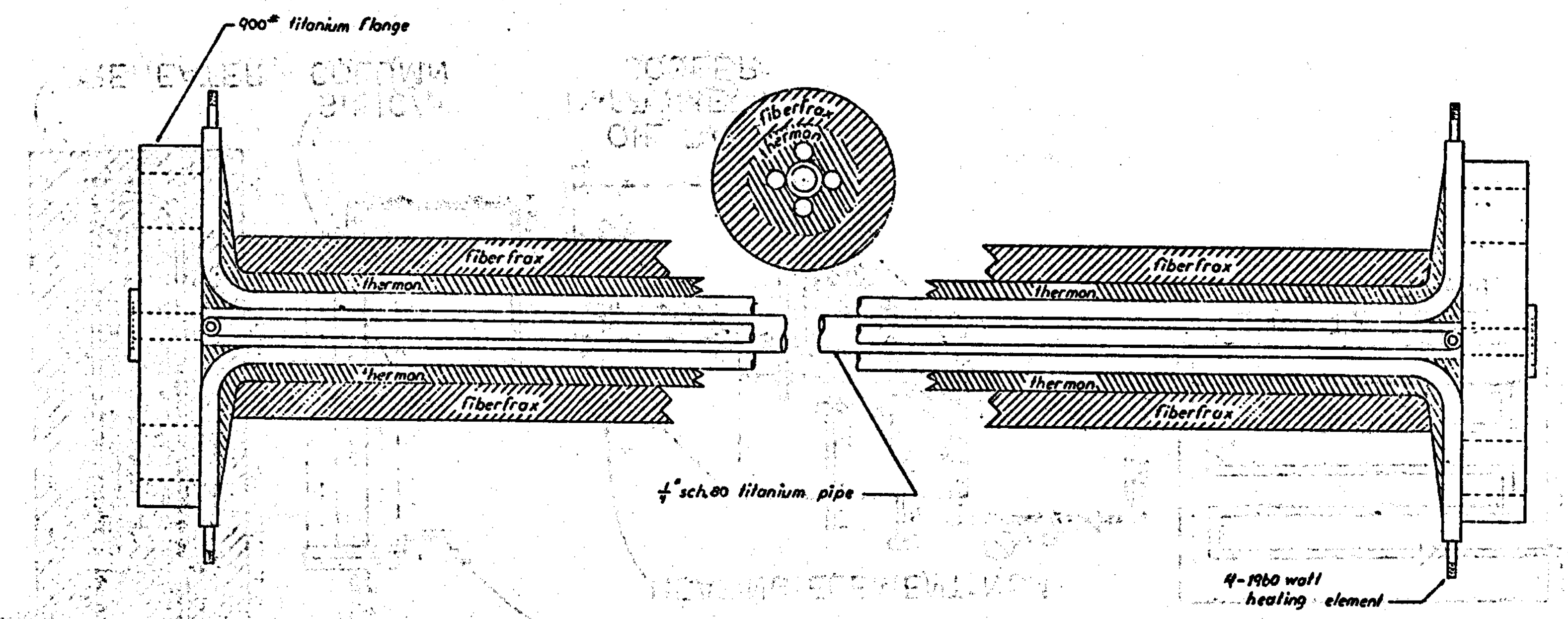
REFERENCE DRAWINGS	NO.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

BLDG. NO.

TITANIUM LOOP
COOL DOWN BYPASS

SUBMITTED | APPROVED | APPROVED
APPROVED | C | REV.



REFERENCE DRAWINGS	NO.

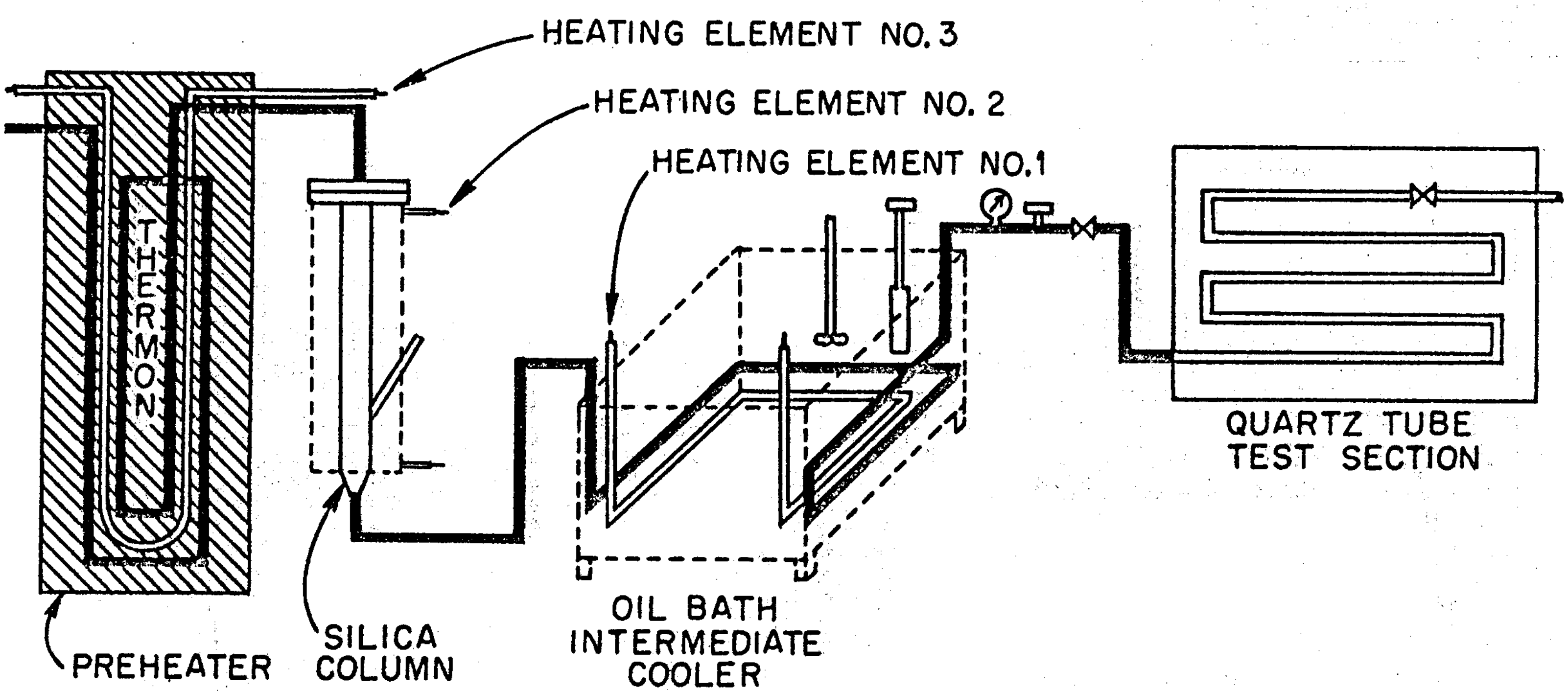
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

TITANIUM LOOP — BLDG. NO.

REHEAT SECTION - COOLDOWN BYPASS

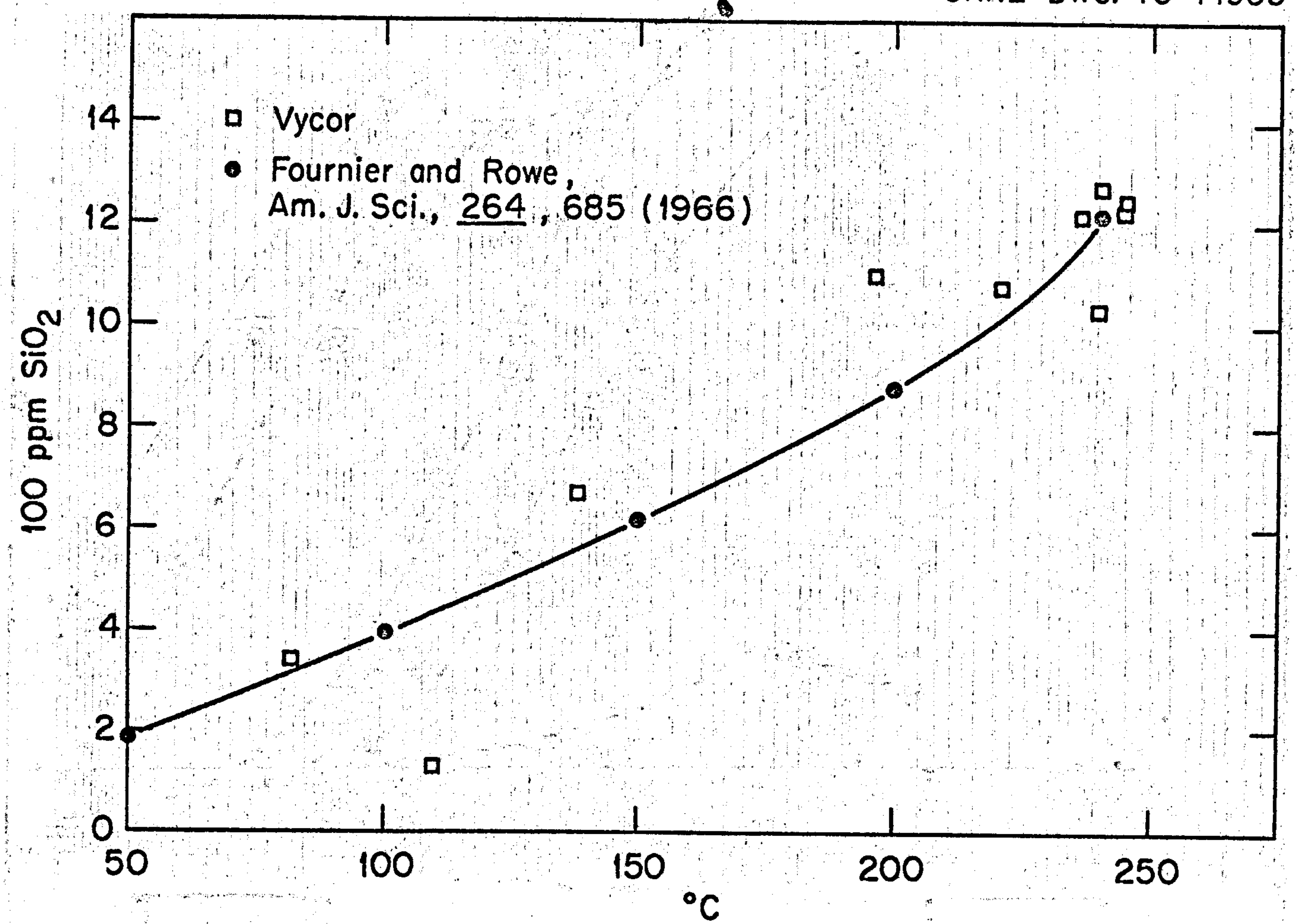
SUBMITTED	APPROVED	APPROVED
APPROVED		C RLV.

ORNL-DWG. 75-14904



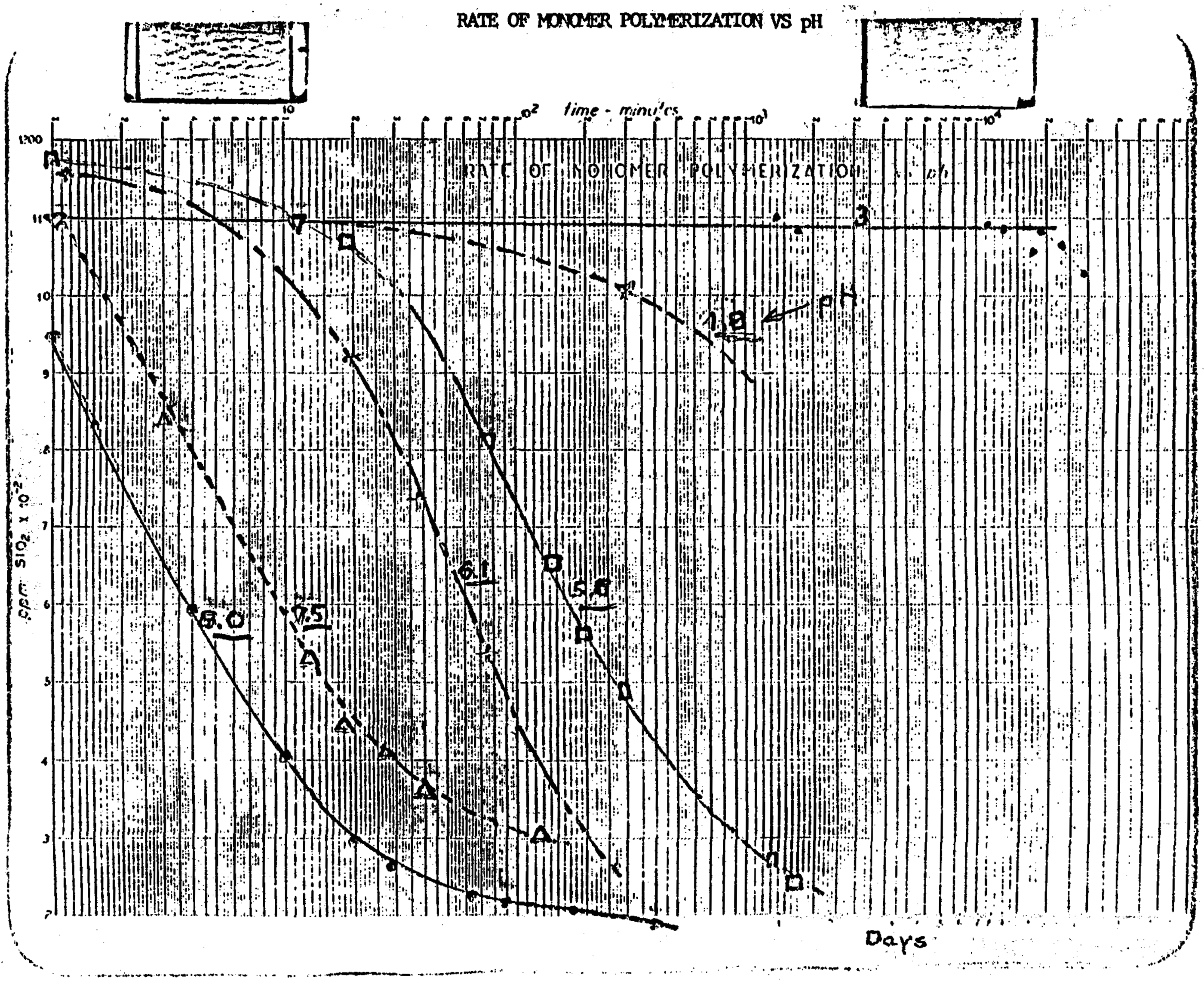
SILICA DEPOSITION DEVELOPMENT SYSTEM

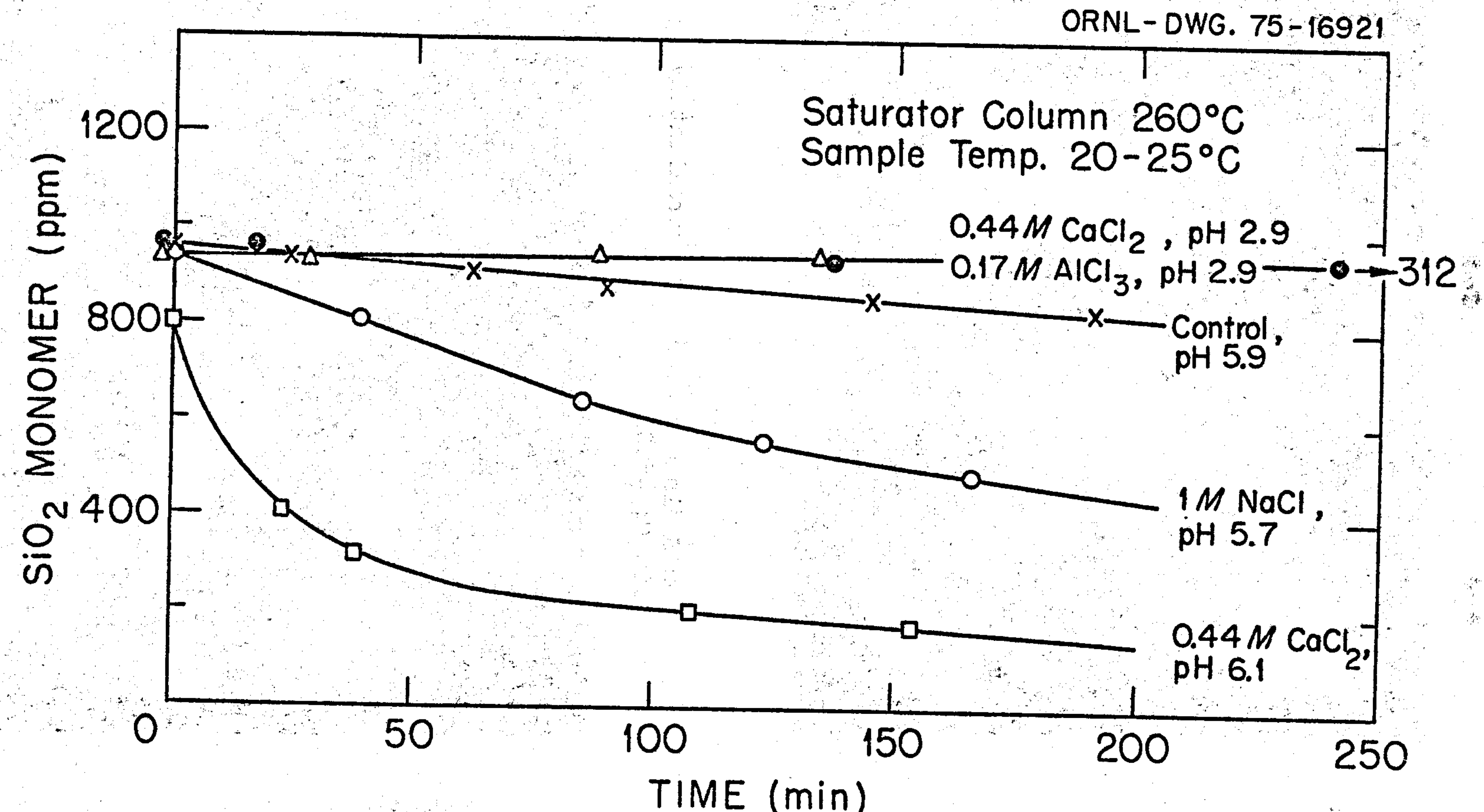
ORNL-DWG. 75-14903



SiO_2 SOLUBILITY IN WATER *vs* TEMPERATURE, VYCOR COLUMN

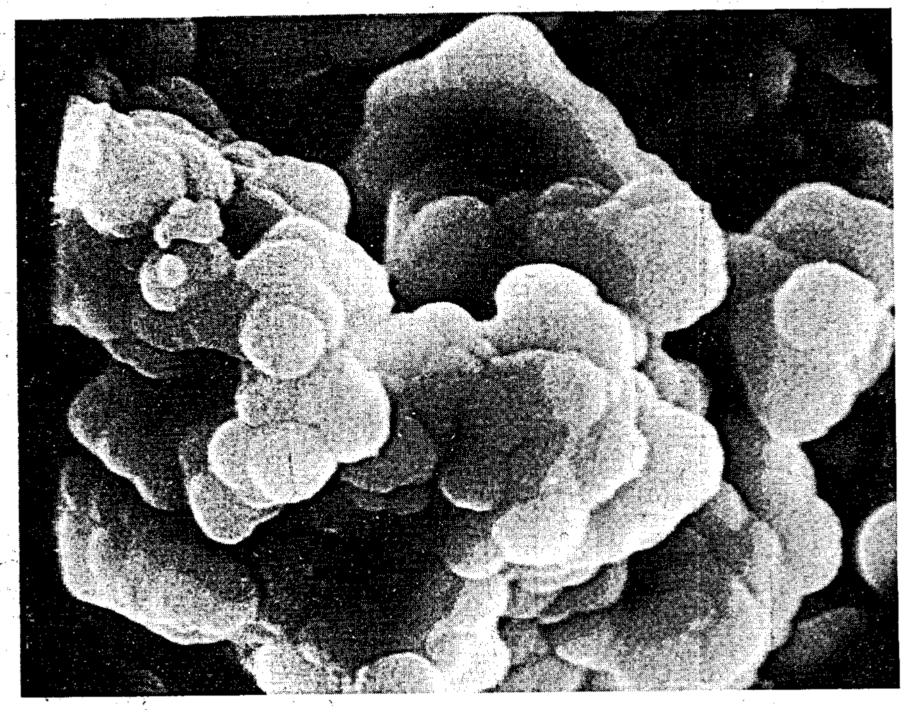
RATE OF MONOMER POLYMERIZATION VS pH



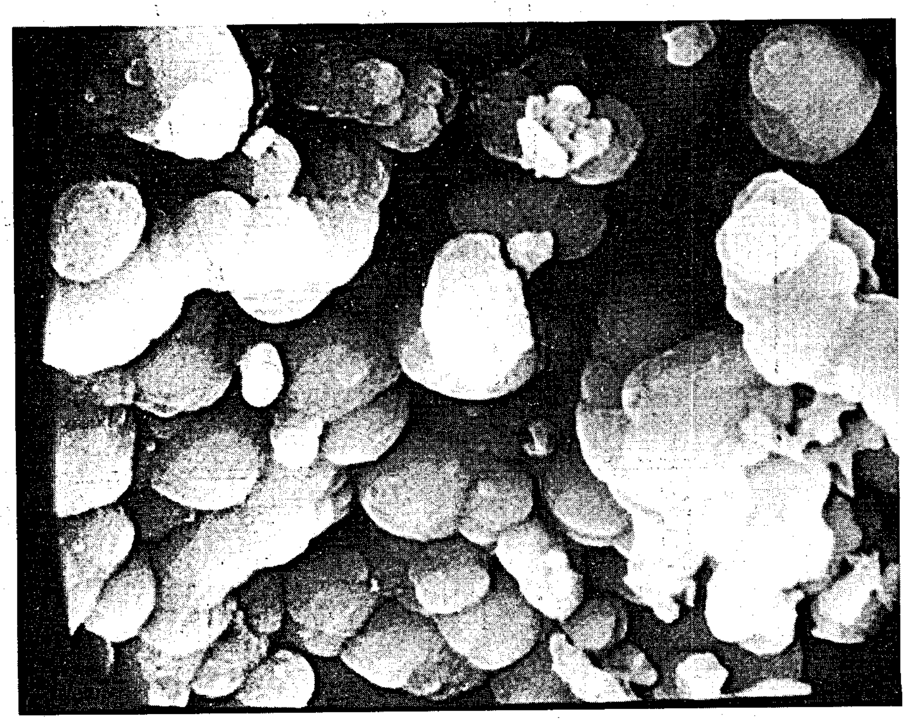


EFFECT OF SALTS ON SILICA MONOMER DISAPPEARANCE

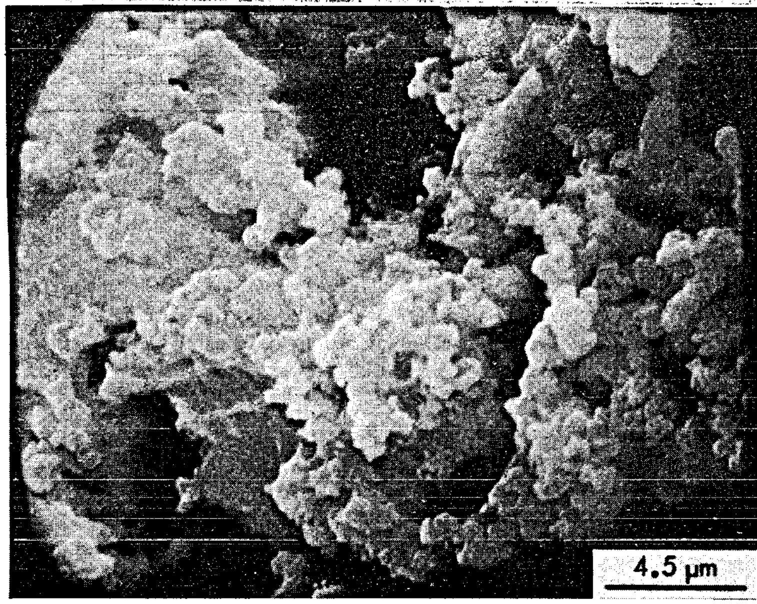
On Carbon Steel at approximately 100°C;
4500x



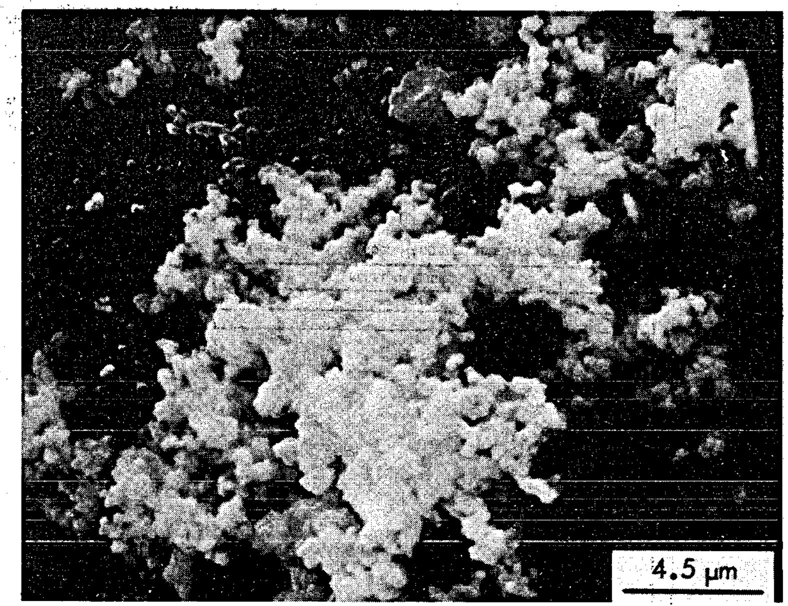
On Stainless Steel at approximately
100°C; 4500x



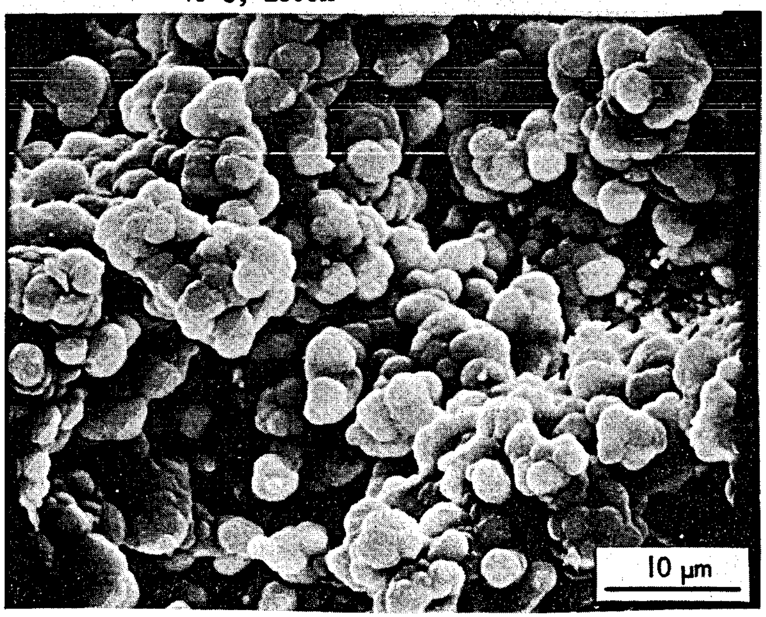
S-5540 On Carbon Steel at approximately 40°C; 4500x



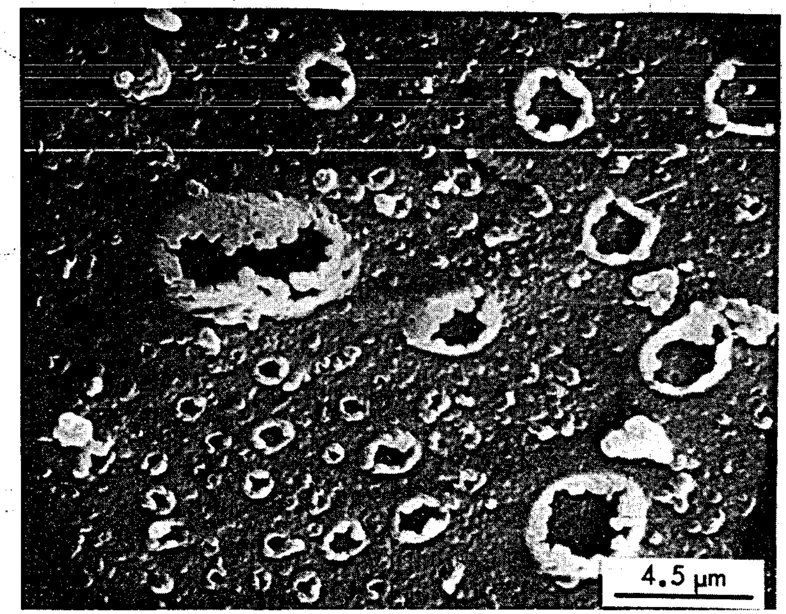
S-5551 On Stainless Steel at approximately 40°C; 4750x



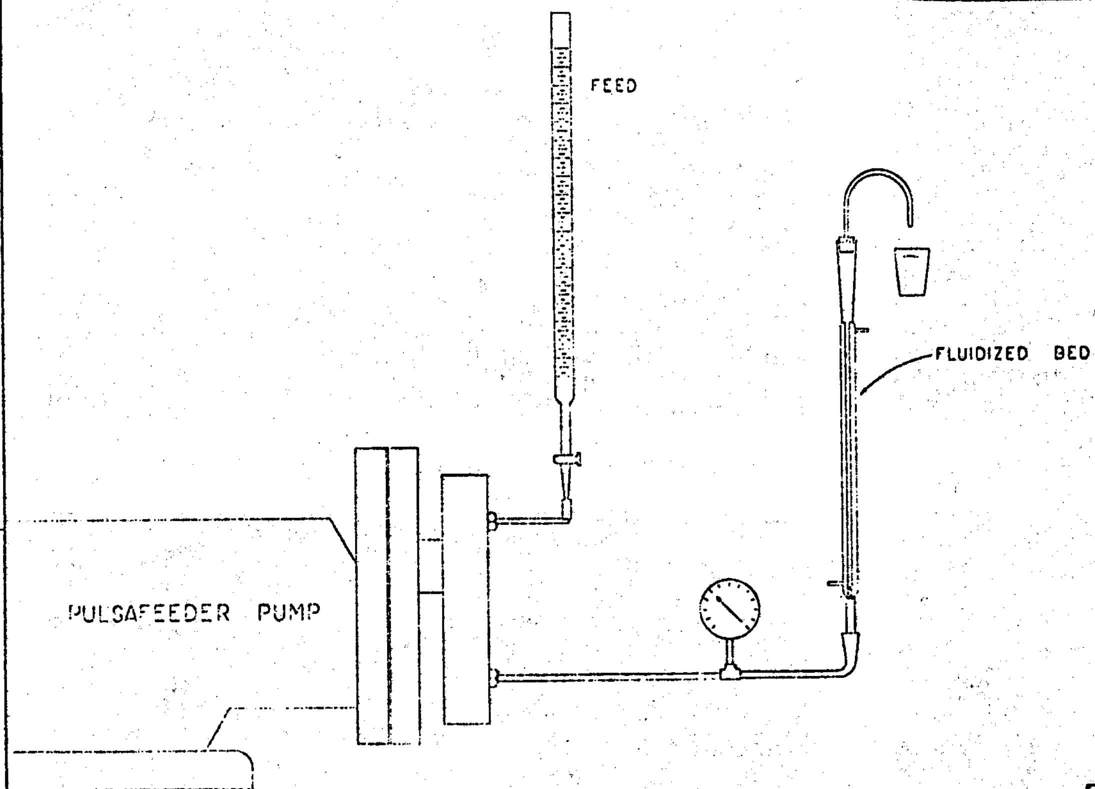
S-5548 On Stainless Steel at approximately 40°C; 1800x



S-5328 On Stainless Steel at approximately 40°C; 4500x



PART NO.	DWG. NO.	NO. REQD.	DESCRIPTION (NAME, SIZE, ETC.)	MATERIAL



NO.	REVISIONS			DATE	APPD	APPD
DRAWN	DATE	SUBMITTED	DATE	APPROVED	DATE	
DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE	
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE	

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED:

FRACTIONS ± ______

DECIMALS ± ______

ANGLES ± ______

SCALE:

GENERAL SPECIFICATIONS

UNLESS OTHERWISE SPECIFIED:

1. BREAK ALL SHARP EDGES 1/64 MAX.
2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR.
3. ROUGHNESS HEIGHT OF MACHINED SURFACES SHALL NOT EXCEED ✓ (FINISH SYMBOLS AND HEIGHT VALUES ARE IN ACCORDANCE WITH ASA B46.1-1955.)

REFERENCE DRAWINGS	NO.

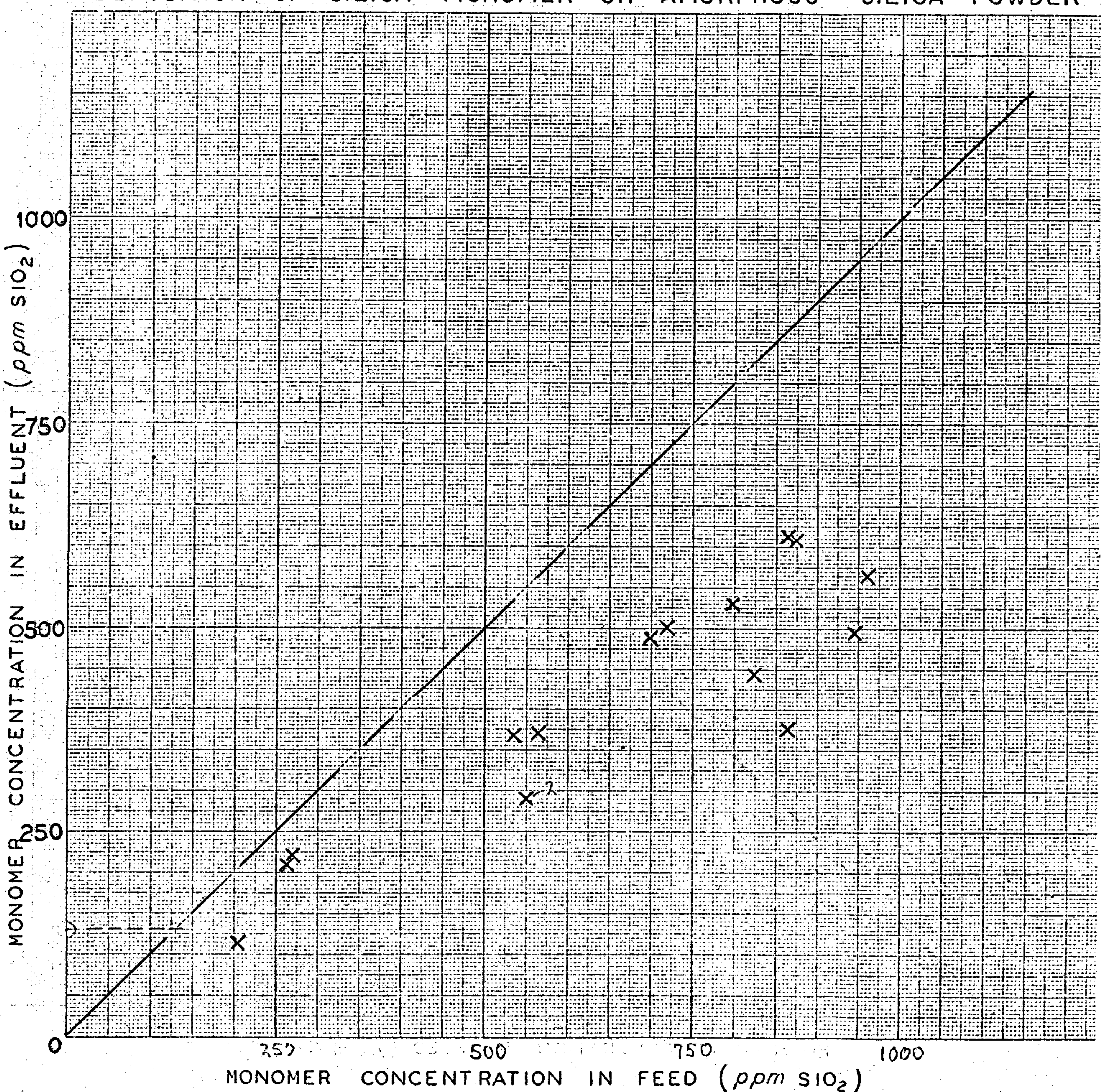
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
OAK RIDGE, TENNESSEE

BLDG. NO.

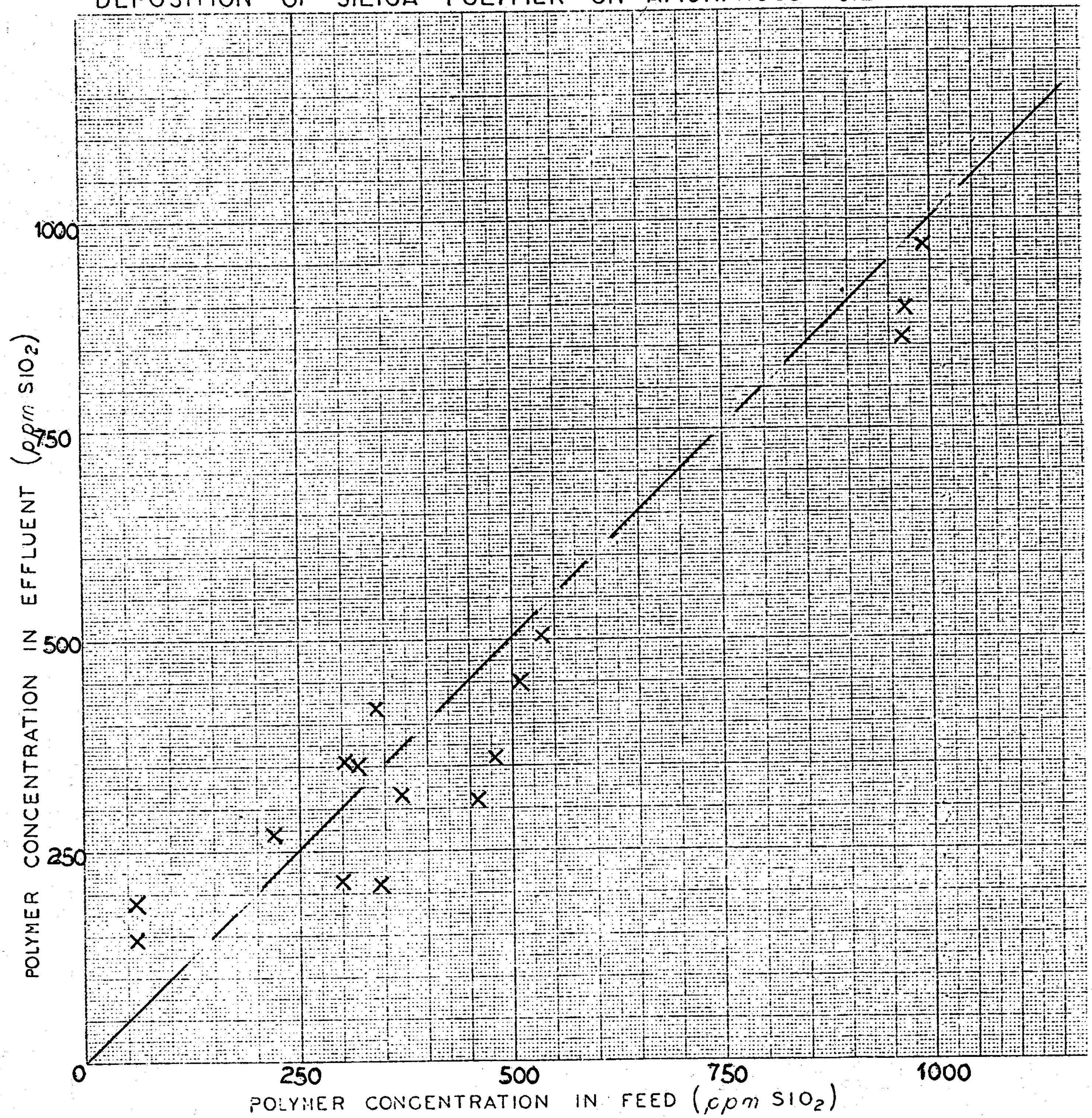
FLUIDIZED BED SYSTEM

SUBMITTED	APPROVED	APPROVED		
APPROVED			C	REV.

DEPOSITION OF SILICA MONOMER ON AMORPHOUS SILICA POWDER



DEPOSITION OF SILICA POLYMER ON AMORPHOUS SILICA POWDER



3