TEMPERATURE PREDICTION FOR

CONTROL ROD DRIVE MECHANISM MOTORS

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Reviewed By: _____
J. K. Eggebroten
Technical Services
Engineering Superintendent

I. ABSTRACT

Public Service Company has recently completed testing that confirms analytical model predictions of control rod drive mechanism (CRDM) motor temperature performance. This analytical model will allow the prediction of CRDM motor temperatures as affected by changing reactor core parameters.

II. BACKGROUND

During the original qualification tests, the CRDM was immersed in a 180 degree Fahrenheit helium environment. Motor temperature varied between 200 and 230 degrees Fahrenheit, averaging 215 degrees Fahrenheit. Qualification at that temperature was expected to be adequate for an ambient CRDM cavity temperature of approximately 150 degrees Fahrenheit. It was predicted that cavity temperature would be maintained in the 150 degree range by the refueling penetration cooling system (FIGURE 1) and the thermal barrier between the CRDM and reactor (FIGURE 2).

Low power testing in 1975 generated higher than predicted temperatures in the prestressed concrete reactor vessel (PCRV) concrete near the refueling penetrations. Slight differential pressures in the primary helium coolant between the orifice valve and upper control rod drive assembly resulted in higher than anticipated helium circulation in the upper part of the assembly. As an orifice valve was closed in a given region, differential pressures, helium flow, and attendant heat load increased. Installation of improved seals reduced the problem but did not eliminate it. Circulation of the primary helium coolant over the orifice valve motor (OVM) plate was the major heat load. Some hot helium also flowed into the CRDM cavity through penetrations in the OVM plate (FIGURE 3).

Rise-to-power tests conducted in the 1977-1978 time frame at power levels up to 70% produced CRDM temperatures up to 213 degrees Fahrenheit. Between 1978 and 1981, during the series of reactor tests RT-485, 485A and 485B, temperatures were monitored in the CRDM cavities of five different core regions, R-4, R-5, R-34, R-35 and R-36. These temperatures were measured by several thermocouples installed in each of the five CRDM cavities. The maximum CRDM motor temperature measured during these tests was 231 degrees Fahrenheit in R-36 (REFERENCE 1).

General Atomic Company (GAC), the nuclear steam system supplier (NSSS) and CRDM manufacturer, correlated the measured CRDM motor temperatures to other measurable and predictable quantities with the following equation, derived from a heat balance on the control rod drive and orifice assembly (CRDOA) penetration (REFERENCE 2 and REFERENCE 3).

$$\frac{T_{crdm\ motor} - T_{c.w.}}{T_{core\ inlet} - T_{c.w.}} = f\left[\Delta P_{core}\ \frac{K_{orif}}{K_{orif} + 4\,FL/D}\right]^{\frac{1}{2}}$$

$$y = f(x), \quad \text{where } x = \left[\Delta P_{core}\ \frac{K_{orif}}{K_{orif} + 19}\right]^{\frac{1}{2}}$$

$$y = \frac{T_{crdm\ motor} - 100}{T_{core\ inlet} - 100}$$

where the parameters are defined as follows:

Tc.w. -- liner cooling water temperature (100°F).

Korif -- orifice flow control valve loss coefficient, determined by valve position.

4 FL/D -- core frictional loss (19).

Tcore inlet -- core inlet temperature (°F).

ΔPcore -- core differential pressure (PSID).

f -- region specific flow function.

The square root term on the right hand side of the equation is proportional to the flow within the control rod drive penetration. The functional relationship of the right and left hand terms in the equation can be determined by setting each equal to x and y.

Within a given region, the functional relationship was found to be consistently linear. Between regions, however, no definite relationship was evident. This implied that the model could predict temperatures in any one penetration, but that no projection of data from one penetration could be made to predict temperatures in another. Based on data available from the five instrumented regions, GAC projected a maximum CRDM motor temperature of 260 degrees Fahrenheit for any region configuration. Since no data was available from the other 32 core regions, the projection was limited (REFERENCE 4).

In 1985, Public Service Company added resistance temperature devices (RTD's) to the closure plate, orifice valve motor plate and CRDM motor of each of the 37 regions (FIGURE 4). Although this allowed temperatures in all regions to be monitored, extended plant outages and operation at reduced power levels prevented collecting the data necessary to make confident projections. RT-500 testing in March, 1988, helped complete large data sets, allowing x and y values to be measured from a wide variety of reactor conditions (i.e., varying orifice positions, core delta P and core inlet temperatures) and to be plotted for each core region (Enclosure 1 through 37). The resulting graphs of 36 of the 37 regions show a strong correlation of measurements to the model for predicting CRDM motor temperatures. Region 26, for reasons not yet fully understood, but does not demonstrate a linear correlation. This region is not a matter of concern, however, because its temperature begins to decline after reaching a maximum of 195° Fahrenheit.

III. CONCLUSION

These graphs, projected for any expected combination of orifice positions and core delta P, will allow prediction of maximum CRDM motor temperatures for each region. This, in turn, will allow determination of maximum temperatures expected for CRDM motors during projected operational conditions. Any alteration to the configuration of control rod drives and orifice assemblies within a refueling penetration, such as takes place during refueling, will also alter the characteristics that yield region-specific flow functions. For that reason, temperature predictions for a given region apply only to the current fuel cycle. Predictions of temperatures for Cycle Five and beyond will require a redetermination of the region-specific flow functions for the altered regions. The worst case flow functions for future cycles, however, are not expected to differ significantly from those observed in Cycle Four.

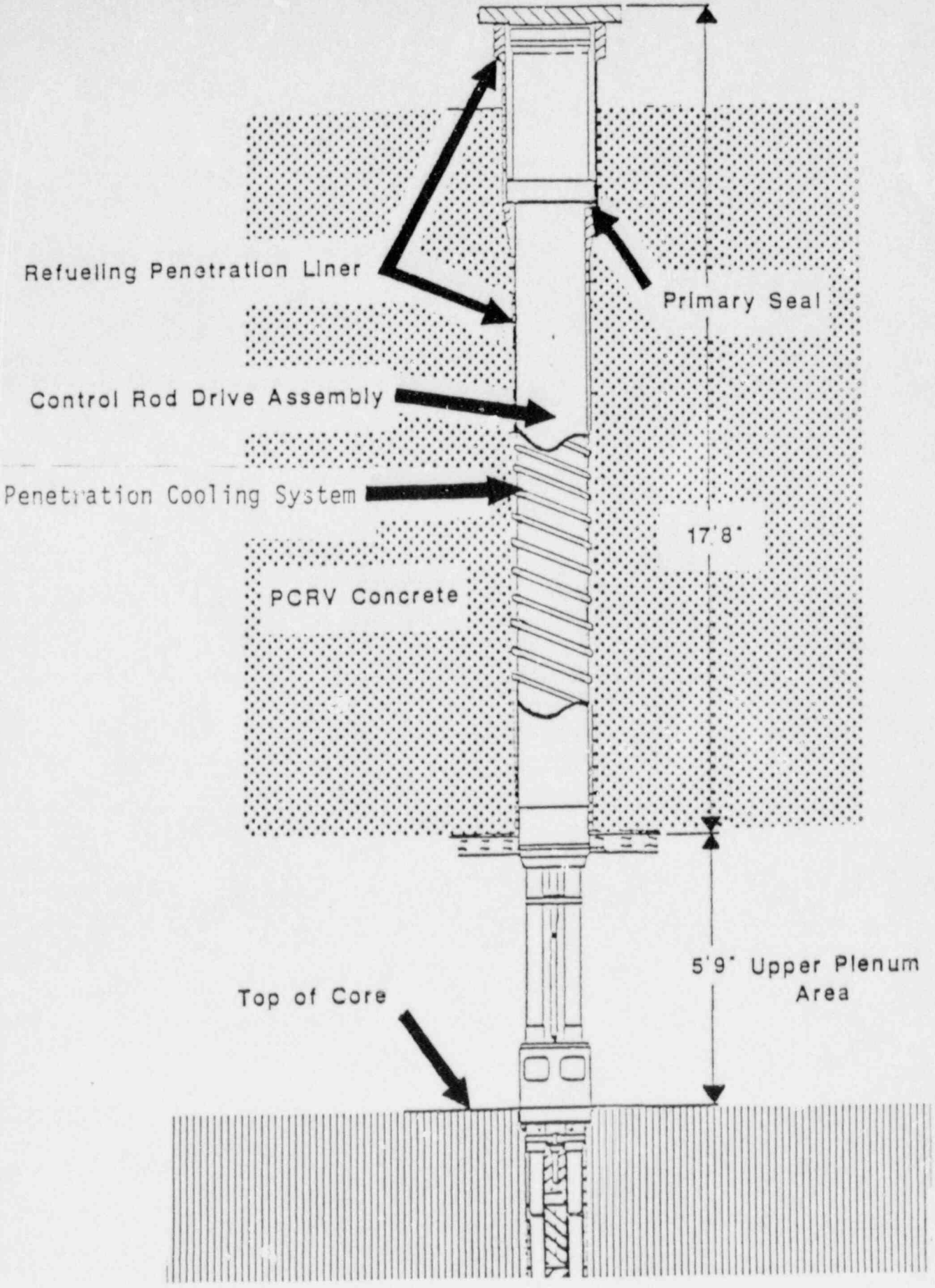
IV. REFERENCES

1. Fort St. Vrain Reactor Test Control Records RT-485, RT-485A, RT-485B, February 9, 1978, to November 7, 1981.

2. J. V. Del Bene and J. F. Follin, "Correlation of FSV Control Rod Drive Motor Temperatures," GA Memo SAB:066.JVDB:81, June 4, 1981.

3. J. V. Del Bene and J. F. Follin, "Correlation of FSV Control Rod Drive Motor Temperatures," GA Memo SAB:144:JVDB:81, December 10, 1981.

4. Letter from William A. Graul, GAC, to H. L. Brey, PSC. Subject: Transmittal of the Review of the Control Rod Drive Motor Temperature Data, December 22, 1981, GP-1283.



PRESTRESSED CONCRETE REACTOR VESSEL (PCRV)
REFUELING PENETRATION

FIGURE 1

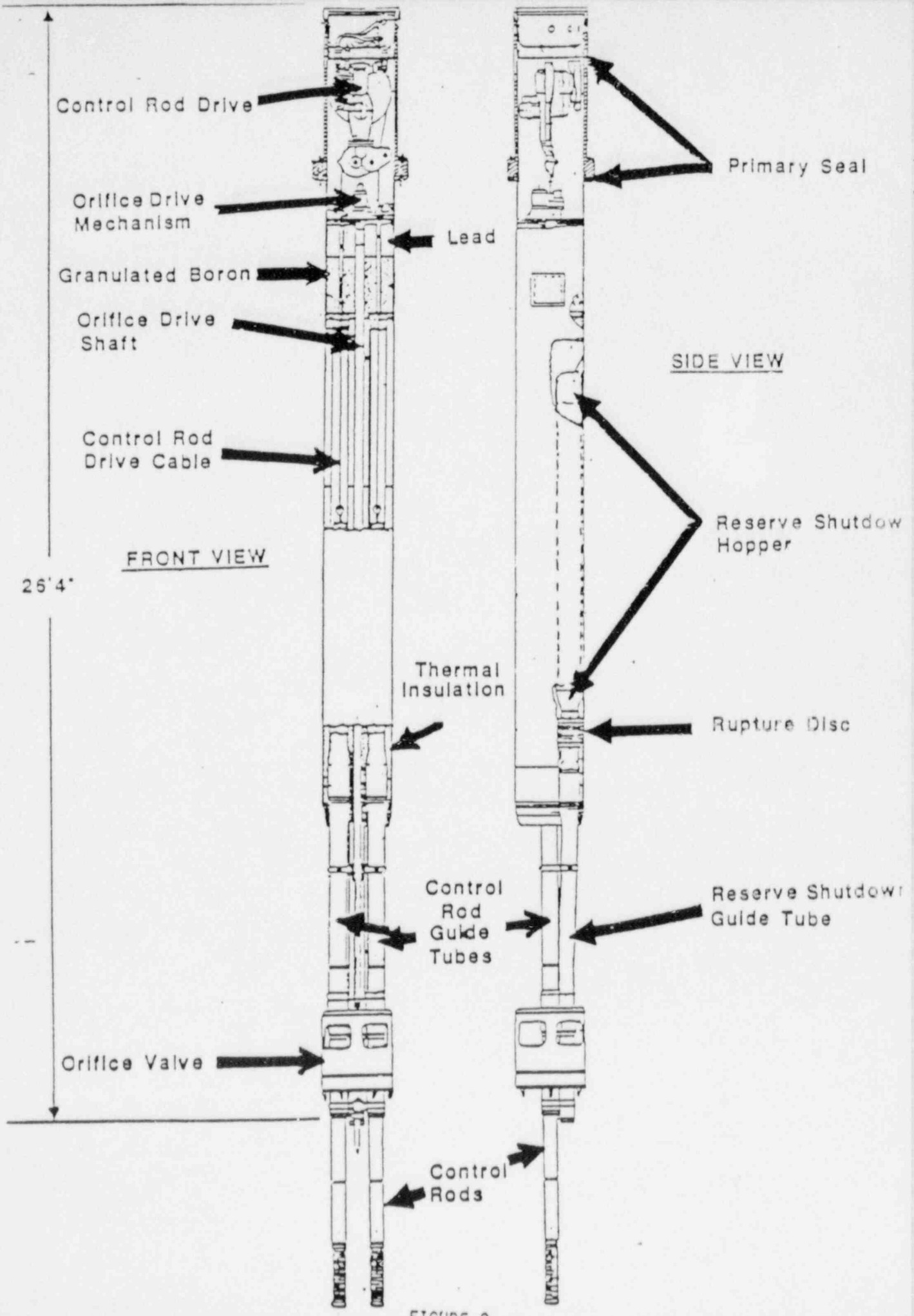

Control Rod Drive
Orifice Drive Mechanism
Granulated Boron
Orifice Drive Shaft
Control Rod Drive Cable
FRONT VIEW
26'4"
Orifice Valve
Lead
Thermal Insulation
Control Rod Guide Tubes
Control Rods
Primary Seal
SIDE VIEW
Reserve Shutdow Hopper
Rupture Disc
Reserve Shutdow Guide Tube

FIGURE 2

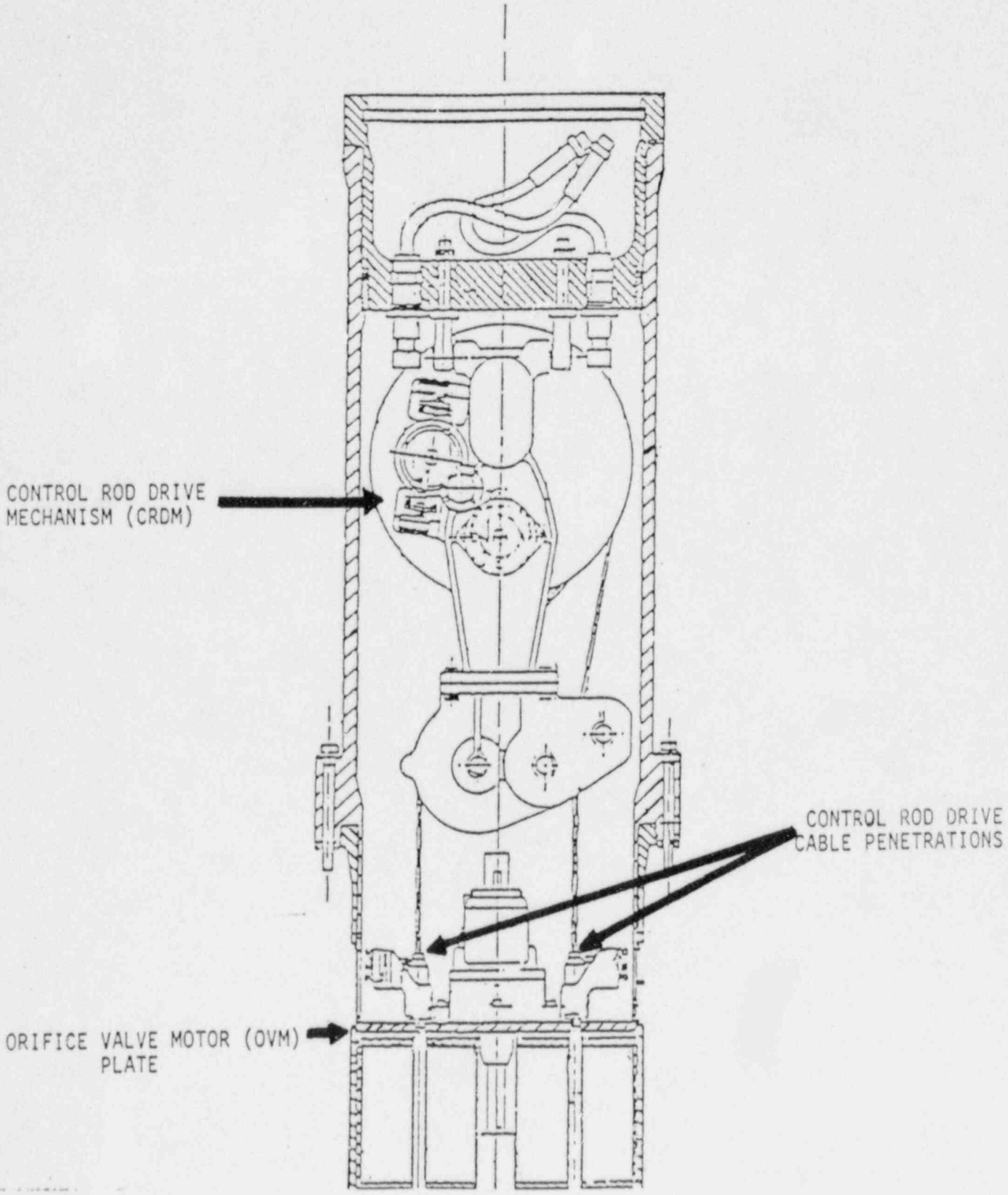
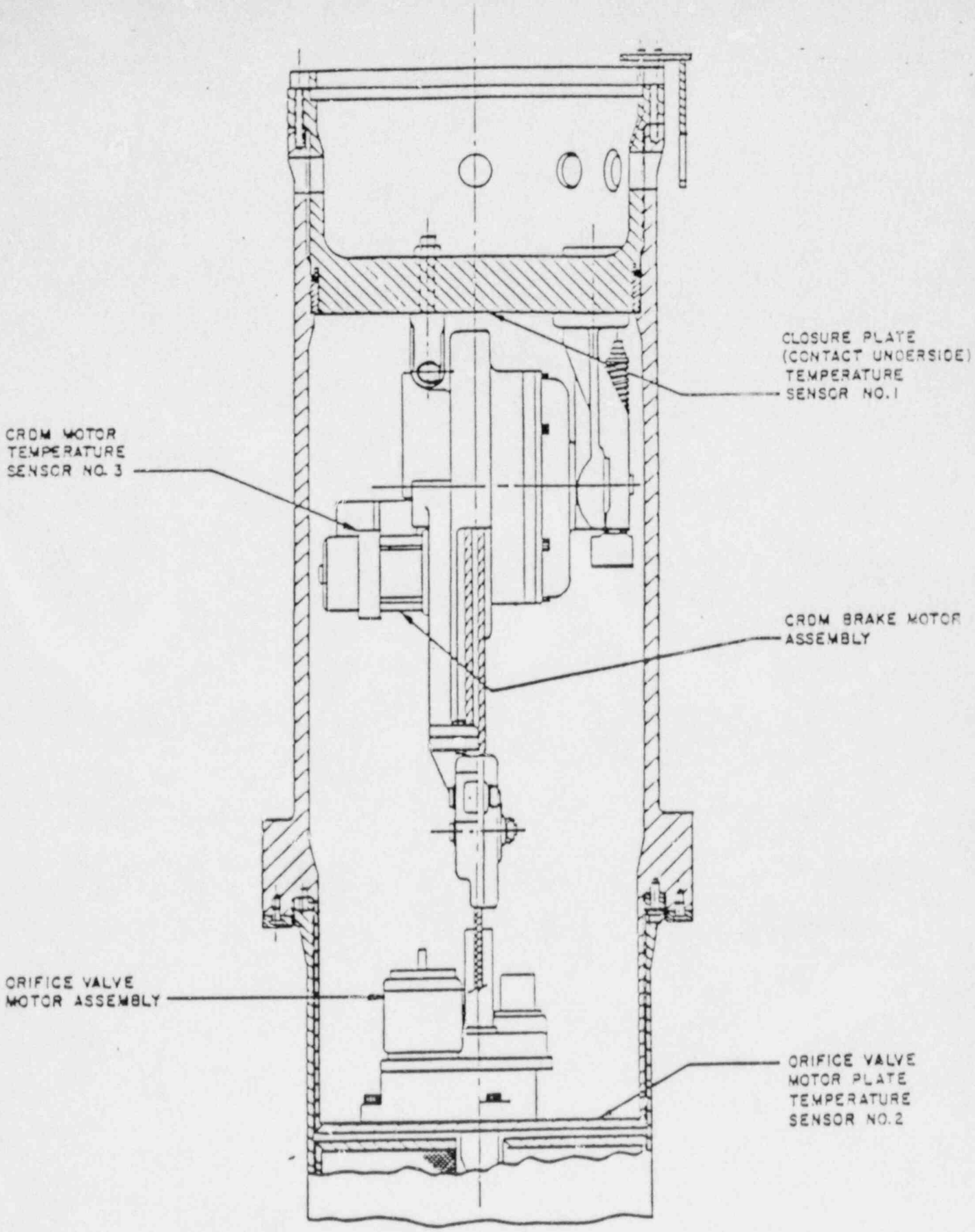

CONTROL ROD DRIVE
MECHANISM (CRDM)
CONTROL ROD DRIVE
CABLE PENETRATIONS
ORIFICE VALVE MOTOR (OVM)
PLATE

FIGURE 3

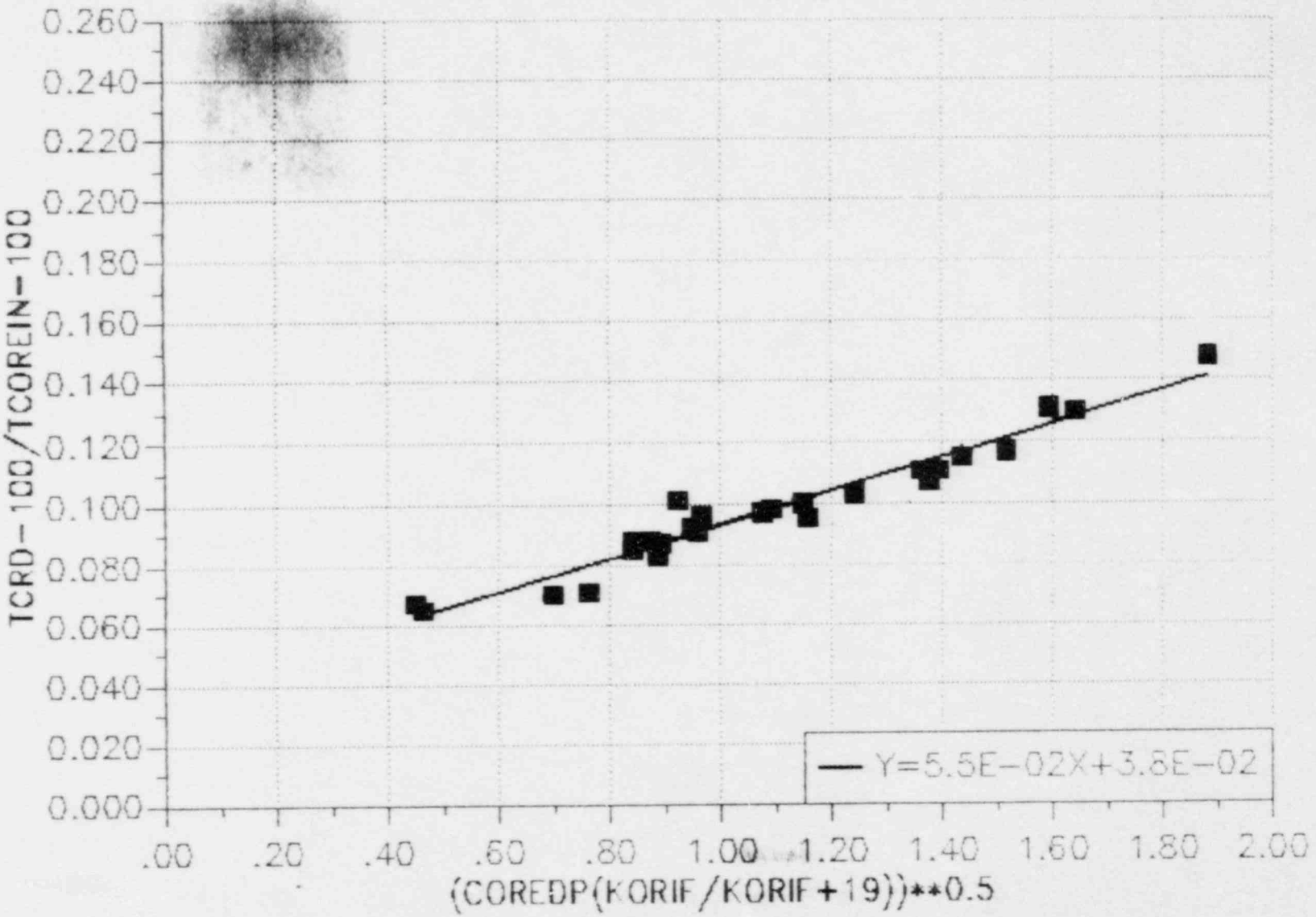


Control Rod Drive Mechanism
Temperature Sensor Locations

FIGURE 4

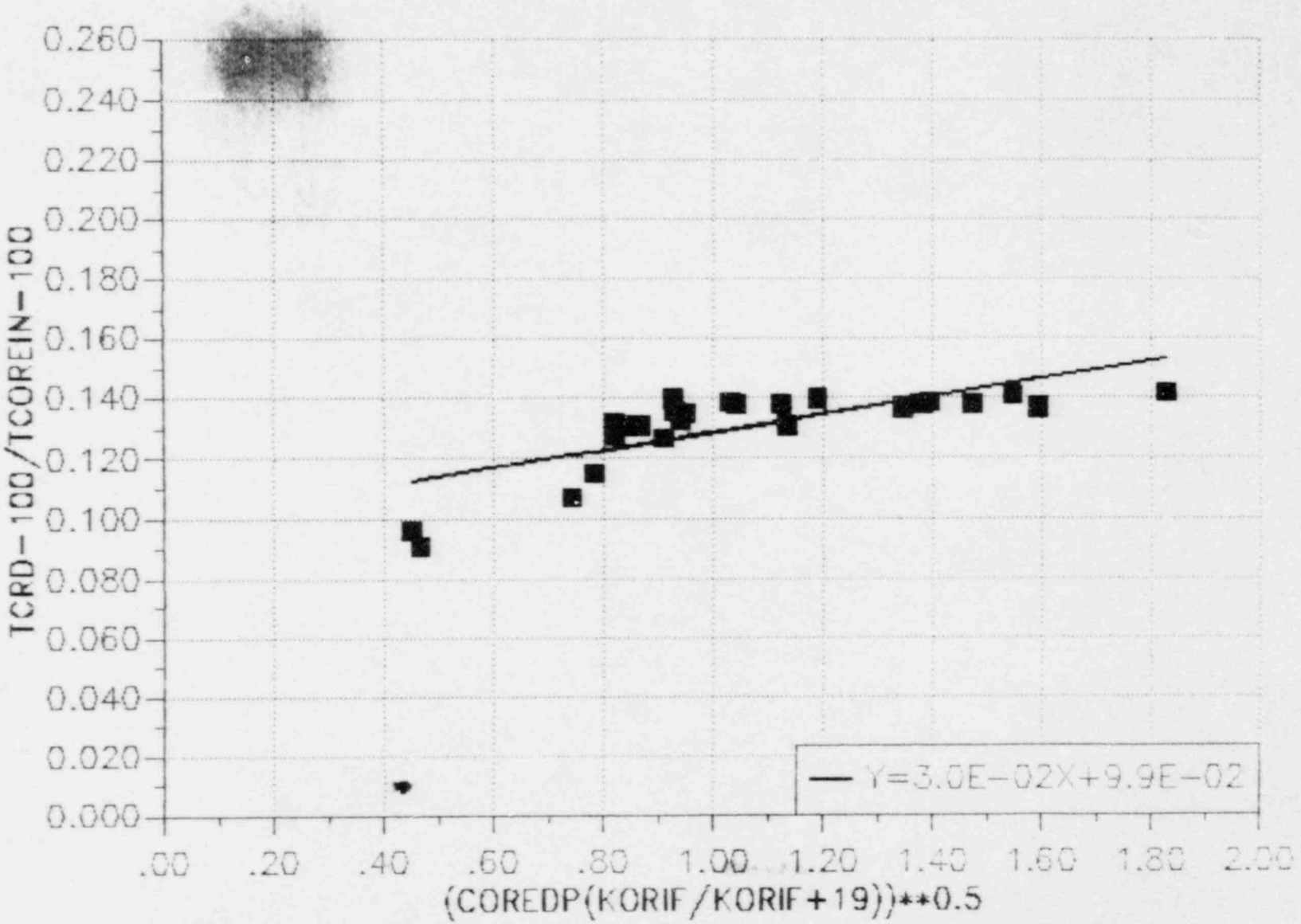
Enclosure 1

REGION 01



Enclosure 2

REGION 02



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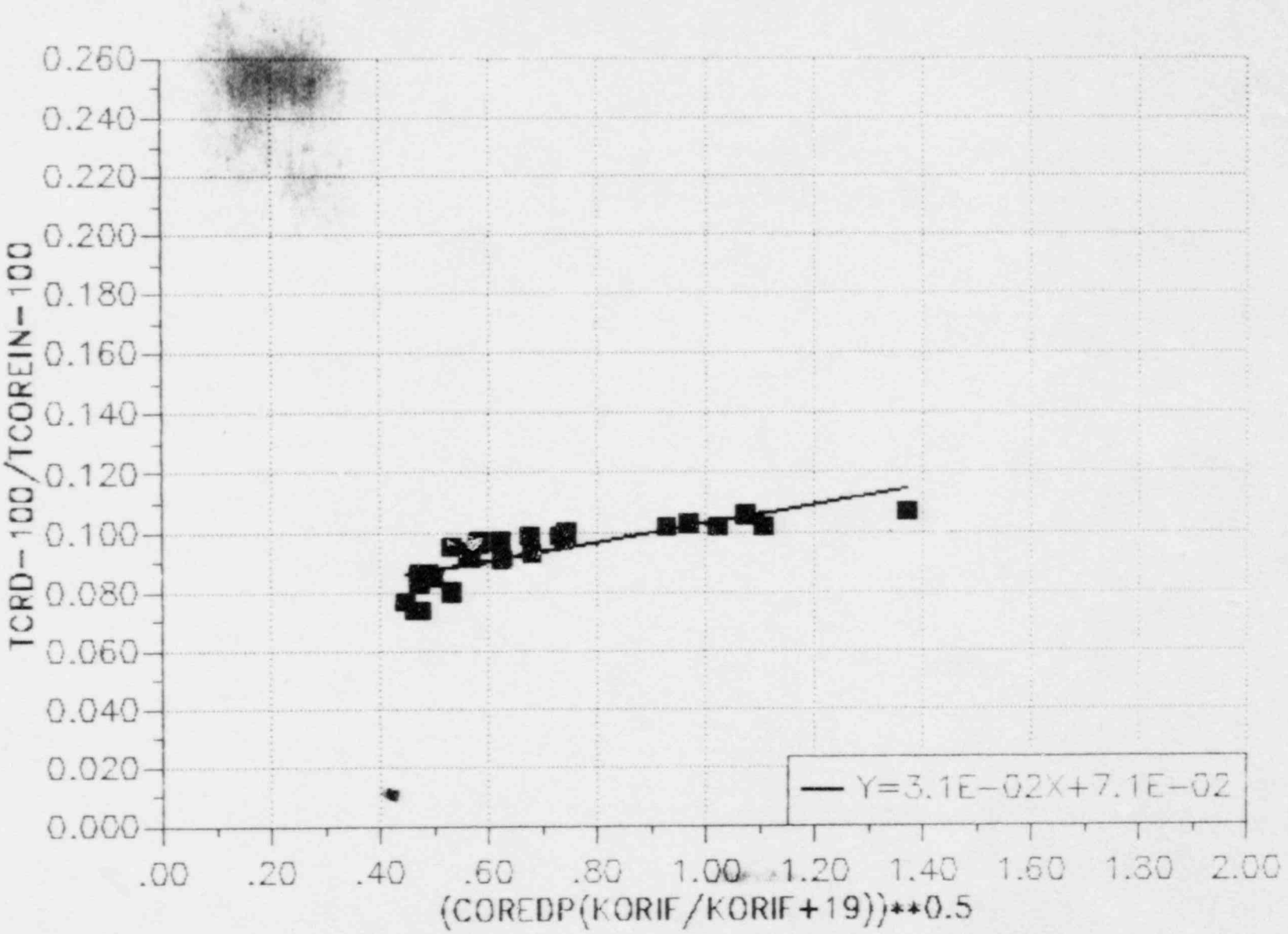
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(COREDP(KORIF/KORIF+19))**0.5
Y=3.1E-02X+7.1E-02

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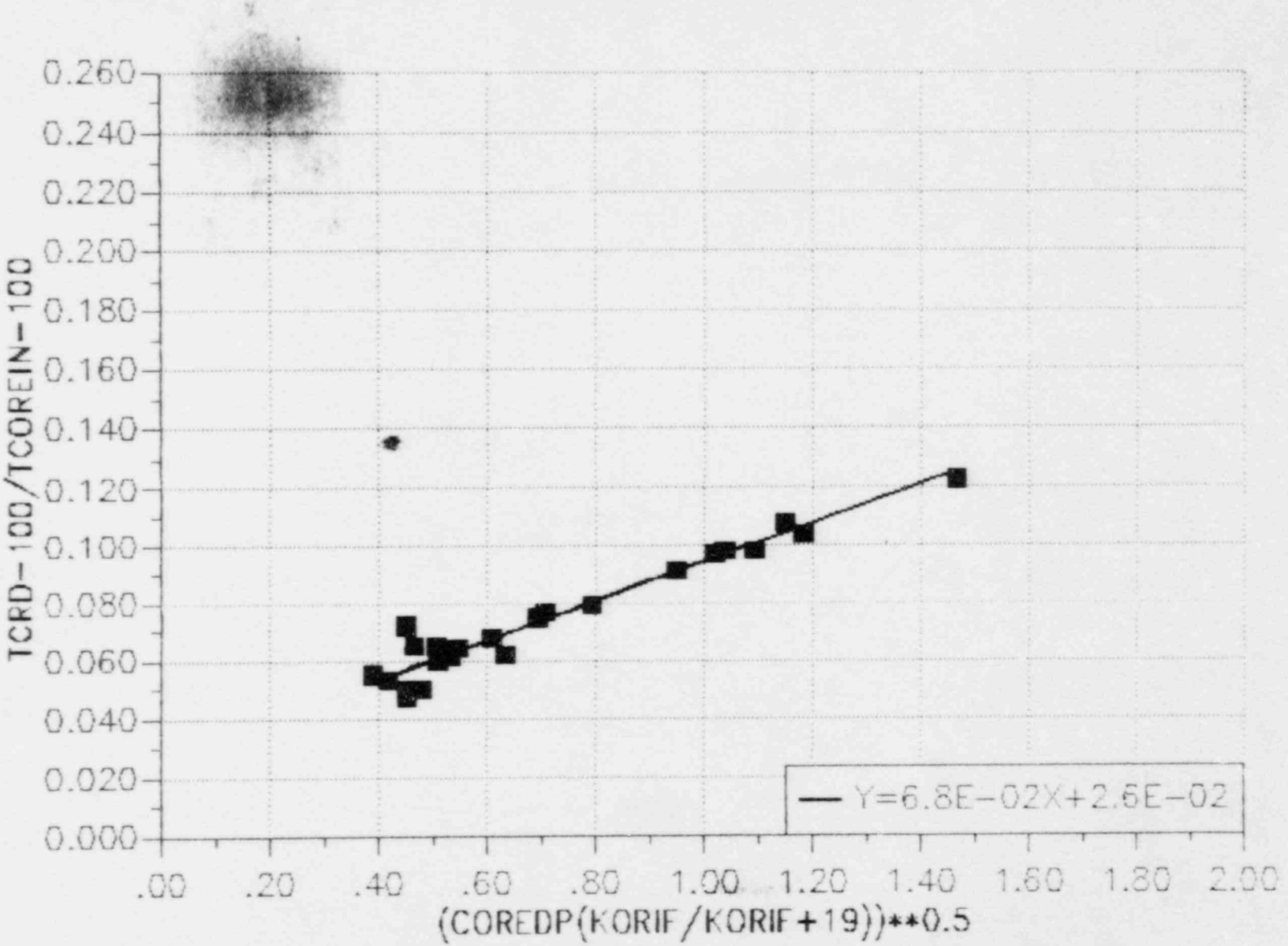
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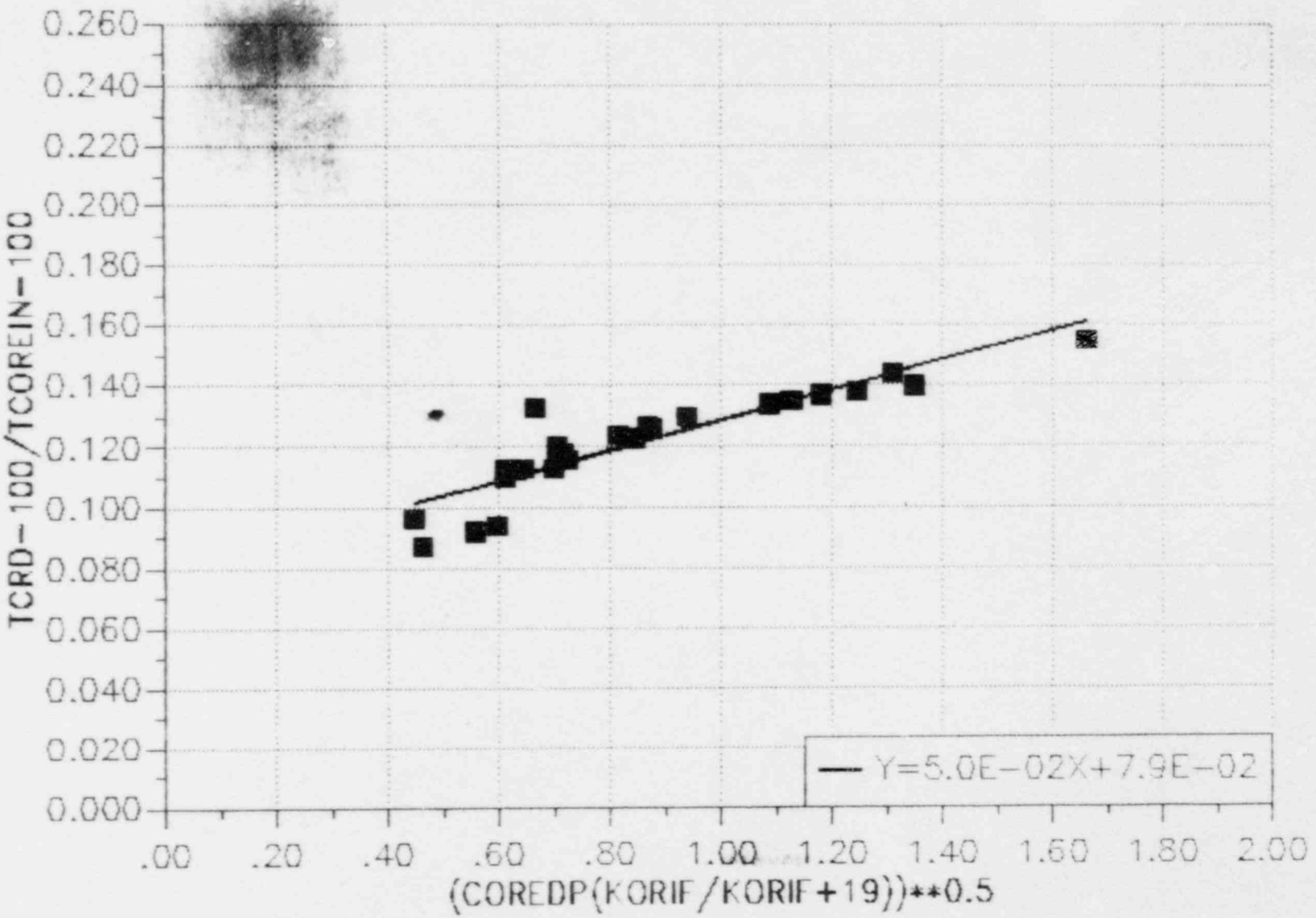
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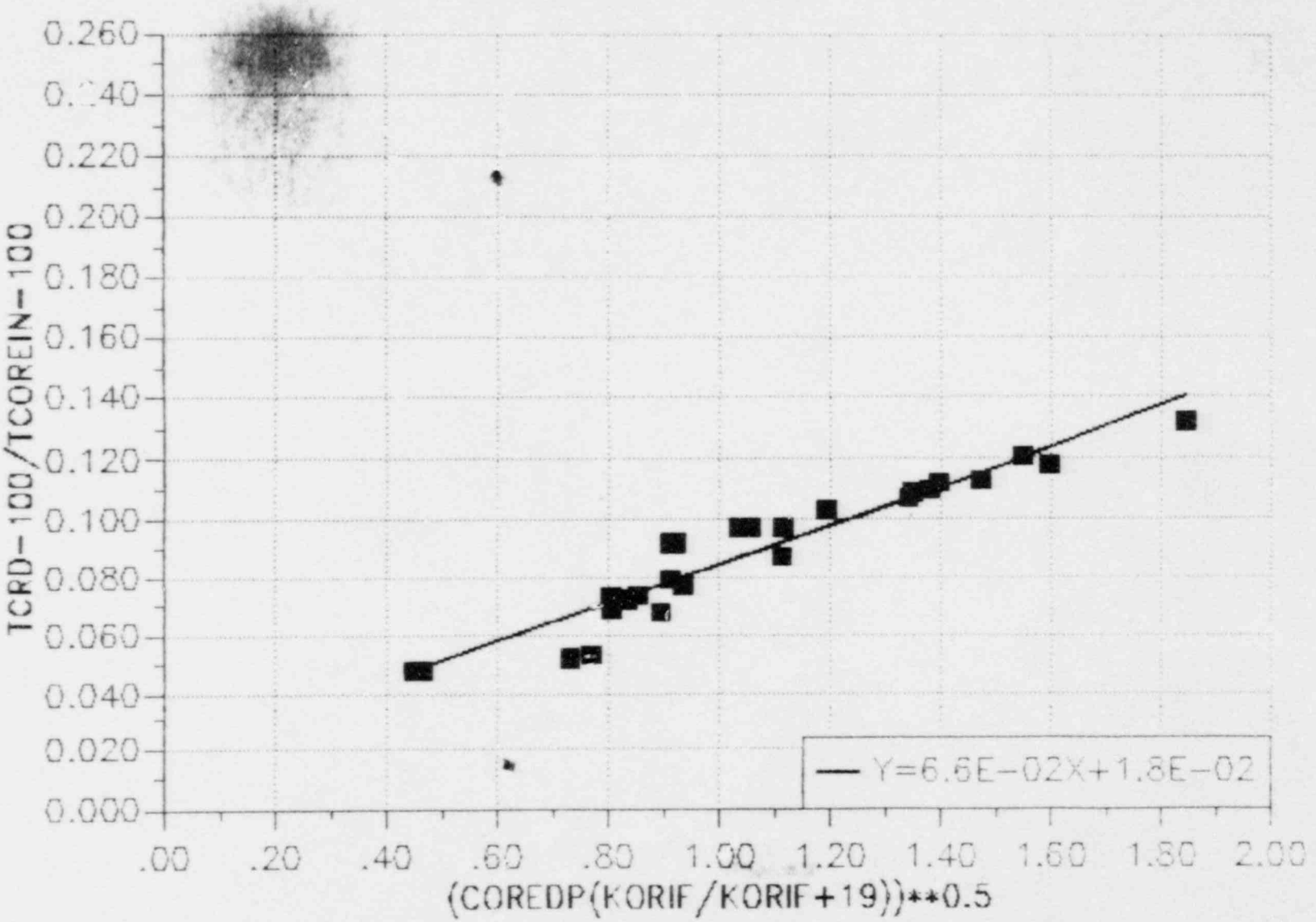
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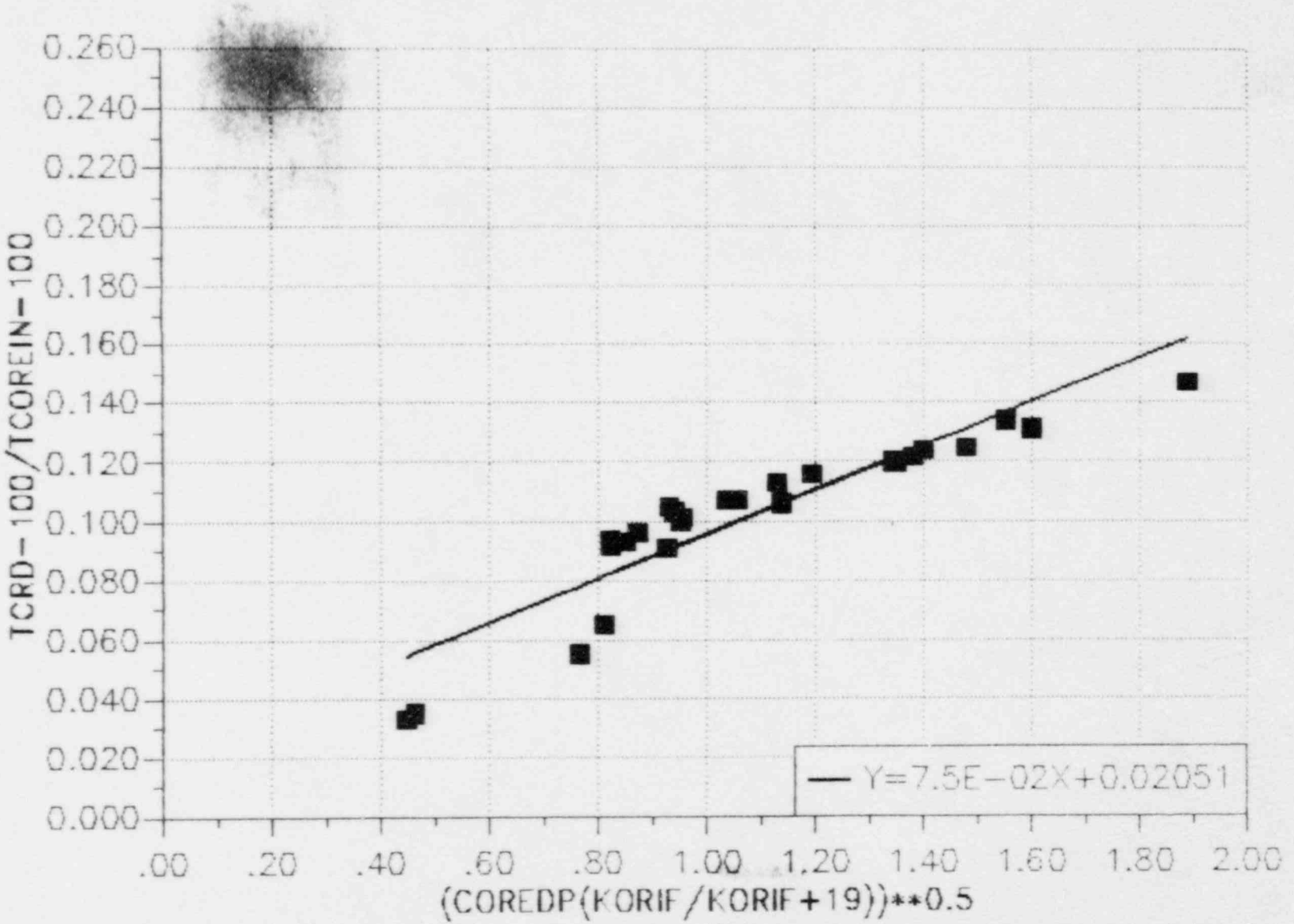
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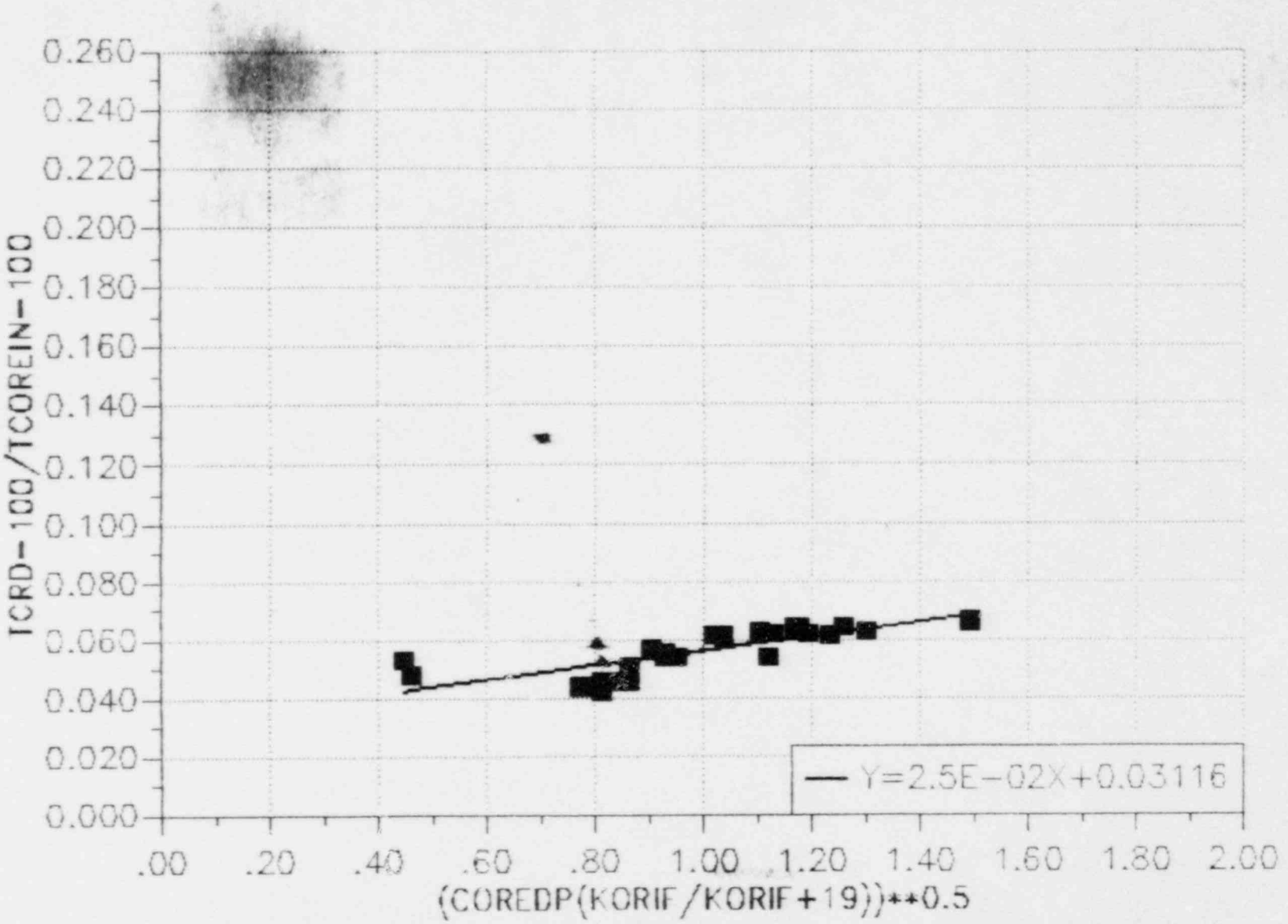
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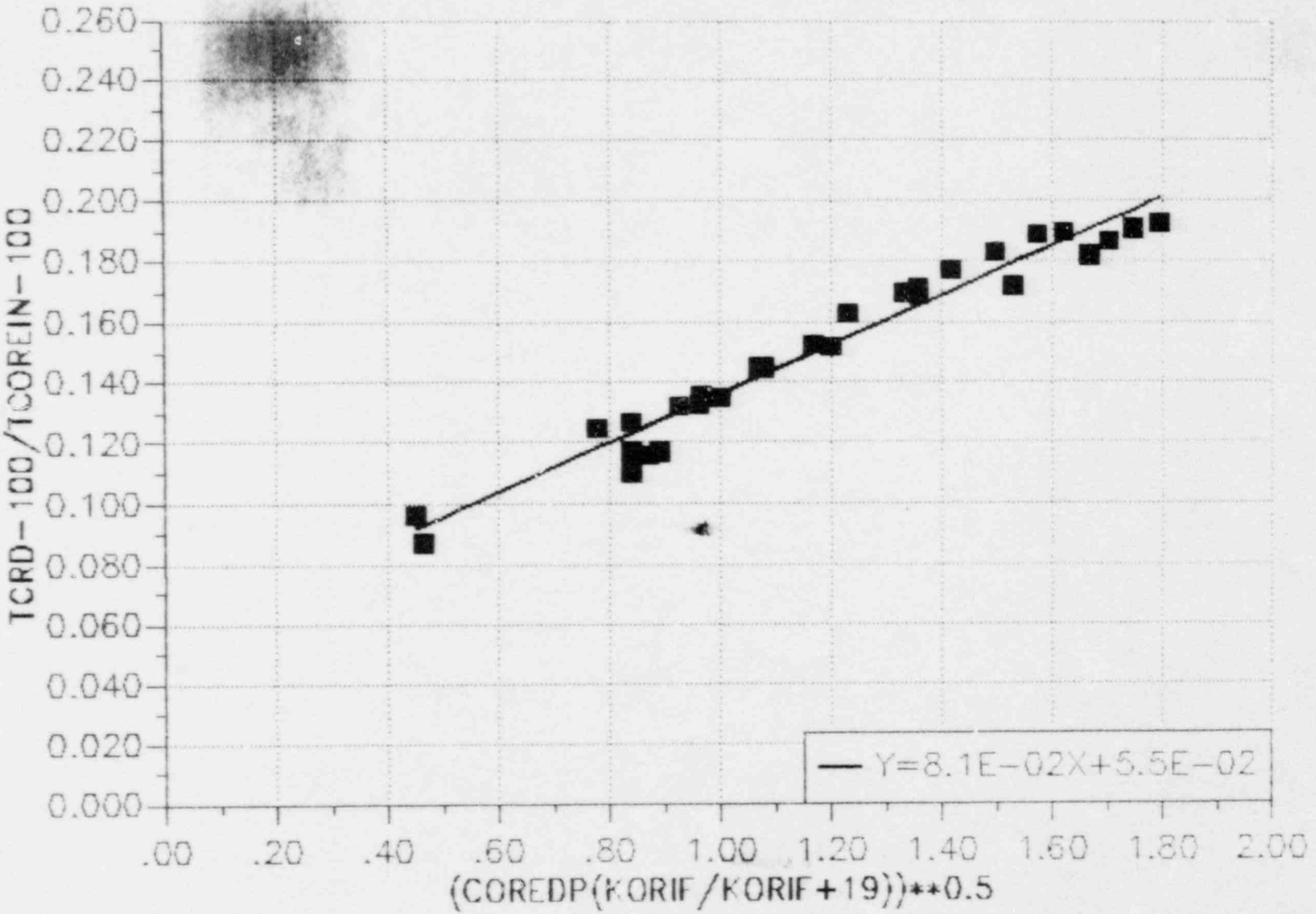
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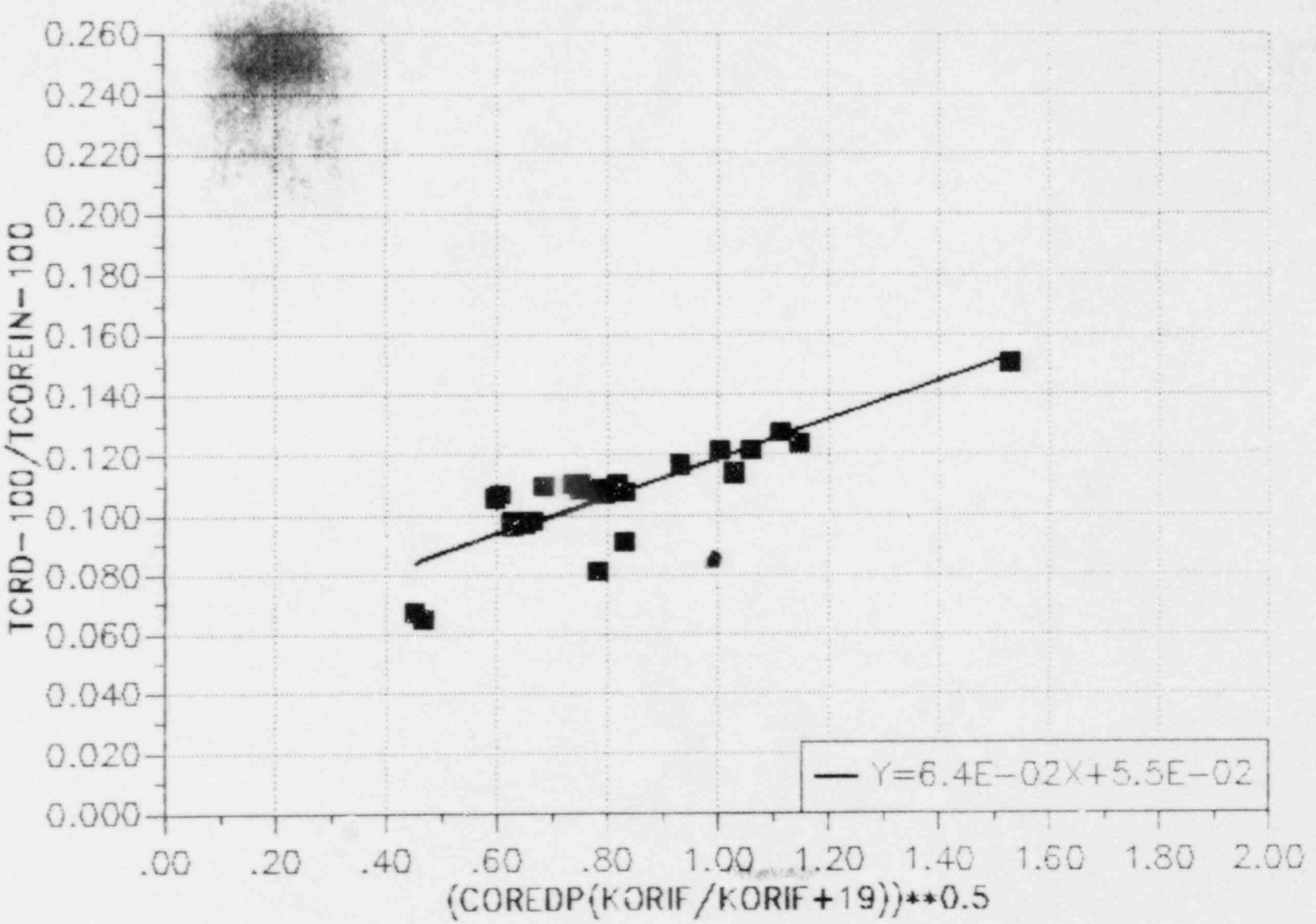
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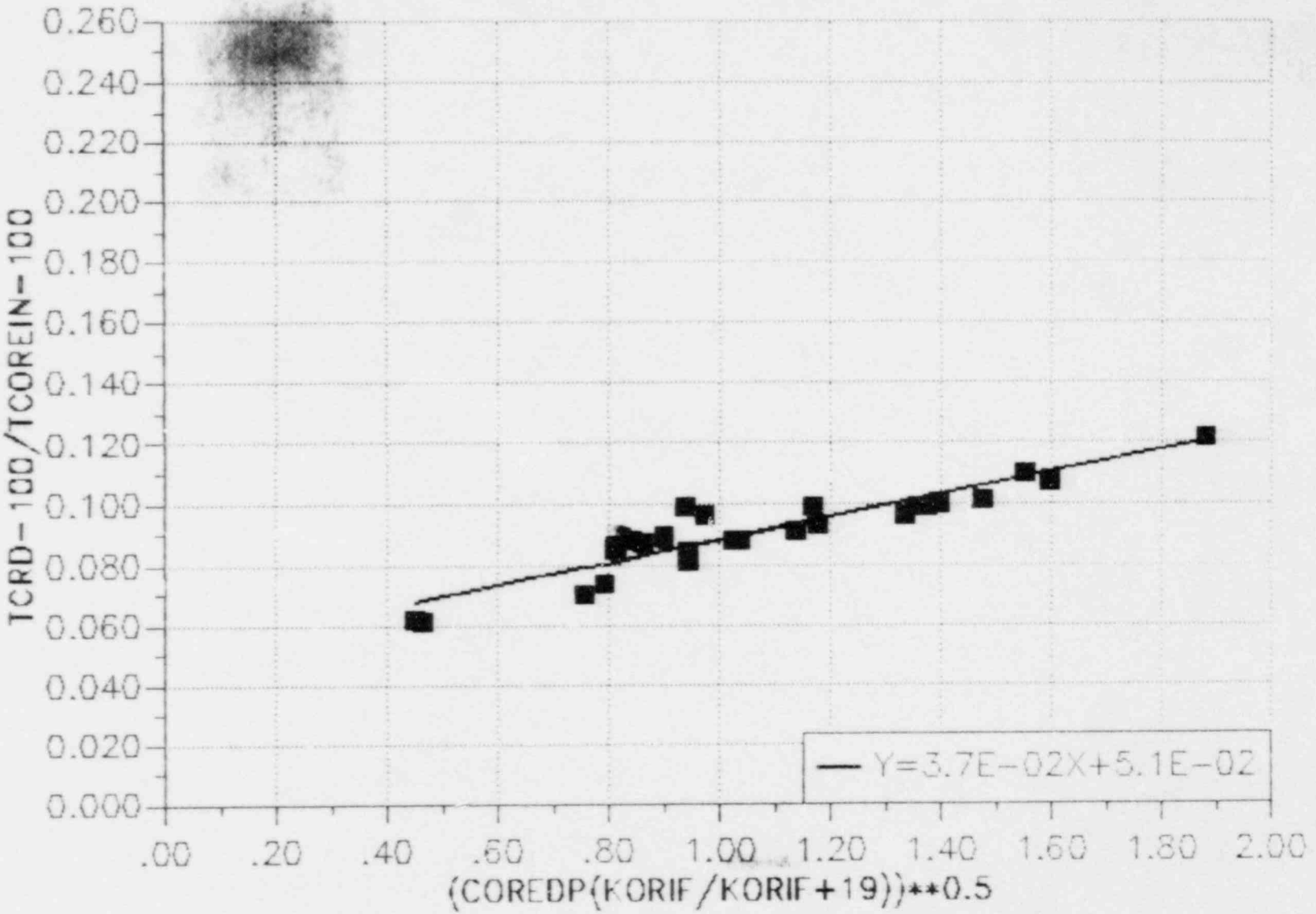
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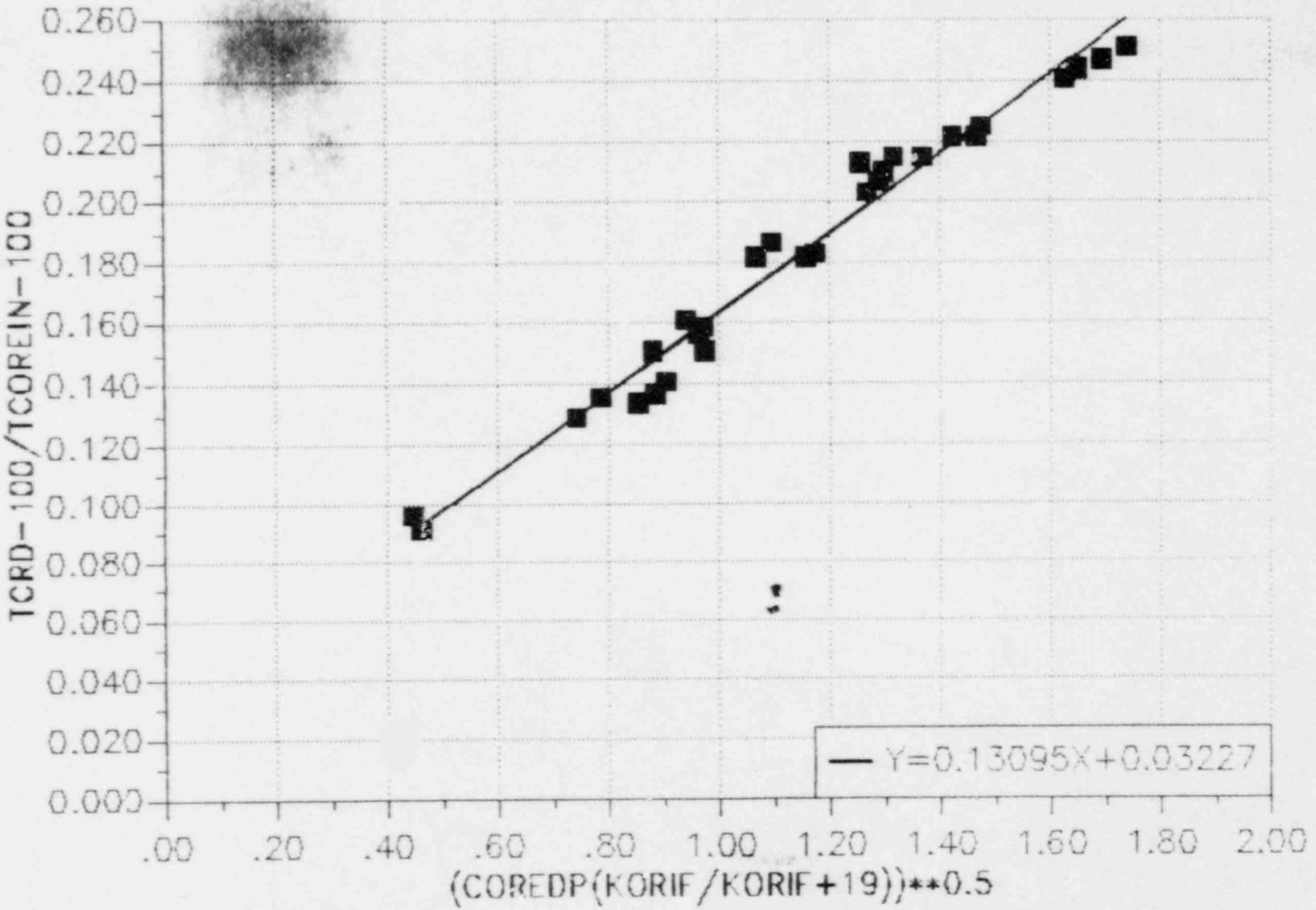
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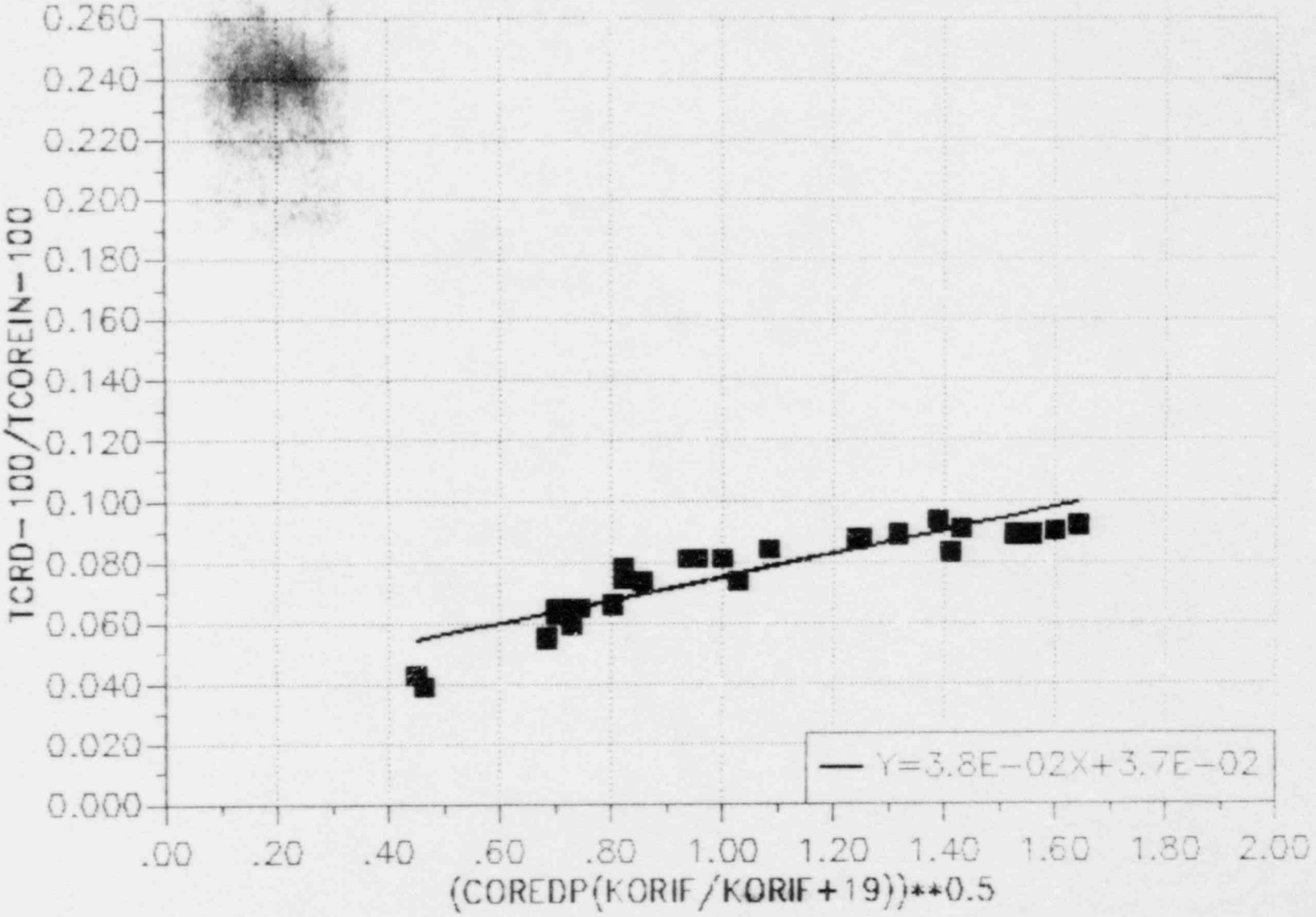
Enclosure13

REGION 13



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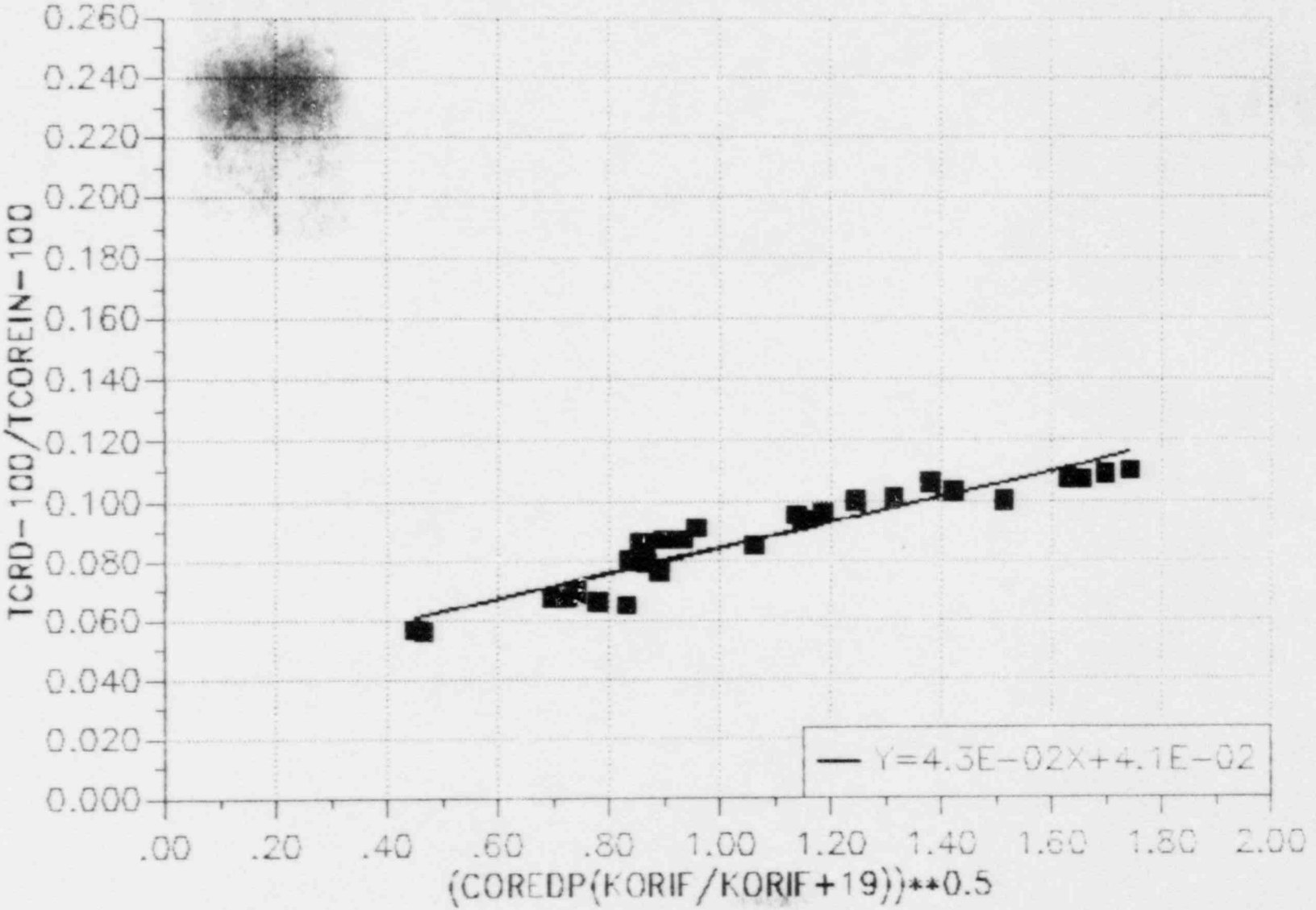
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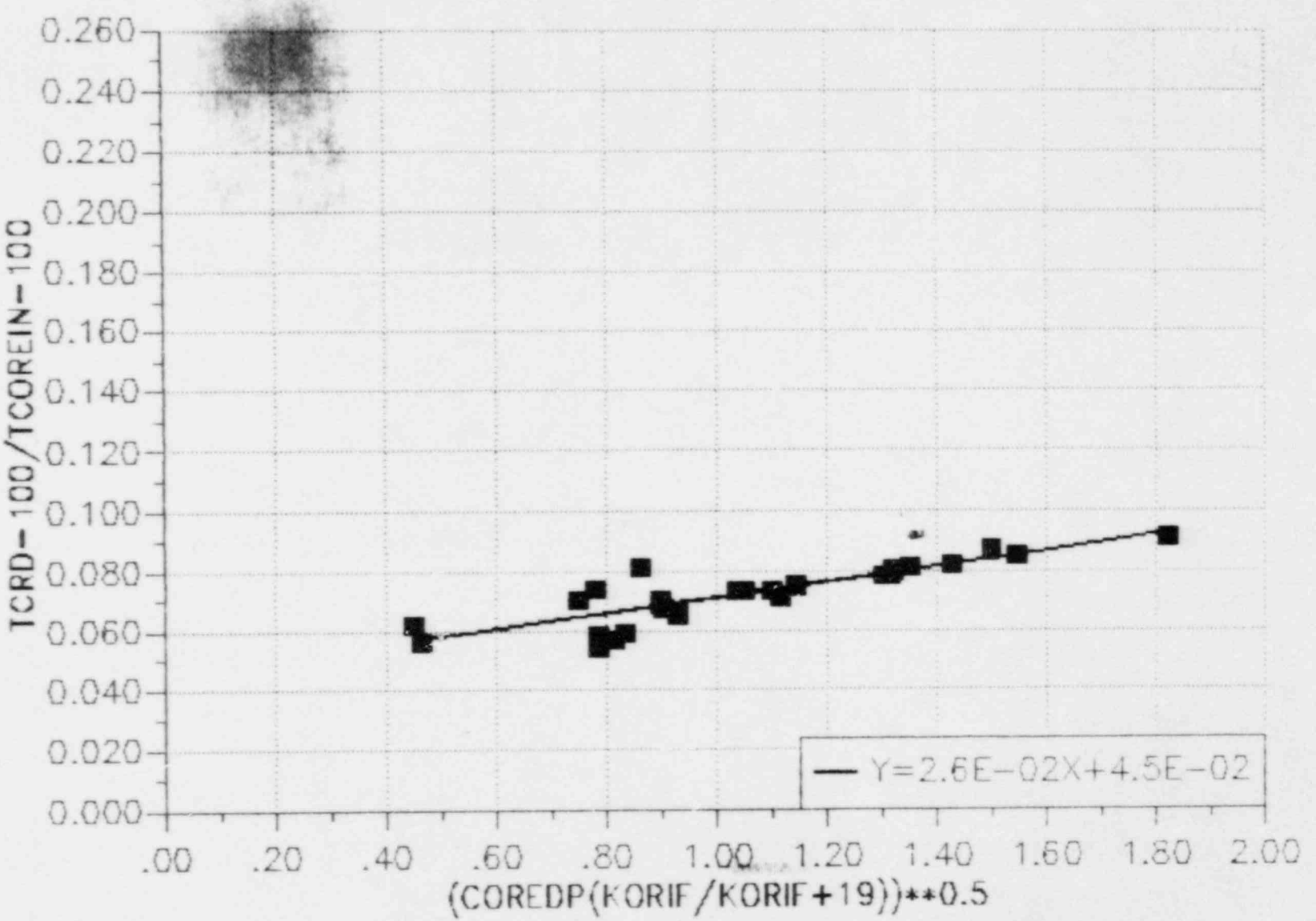
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Y=2.6E-02X+4.5E-02

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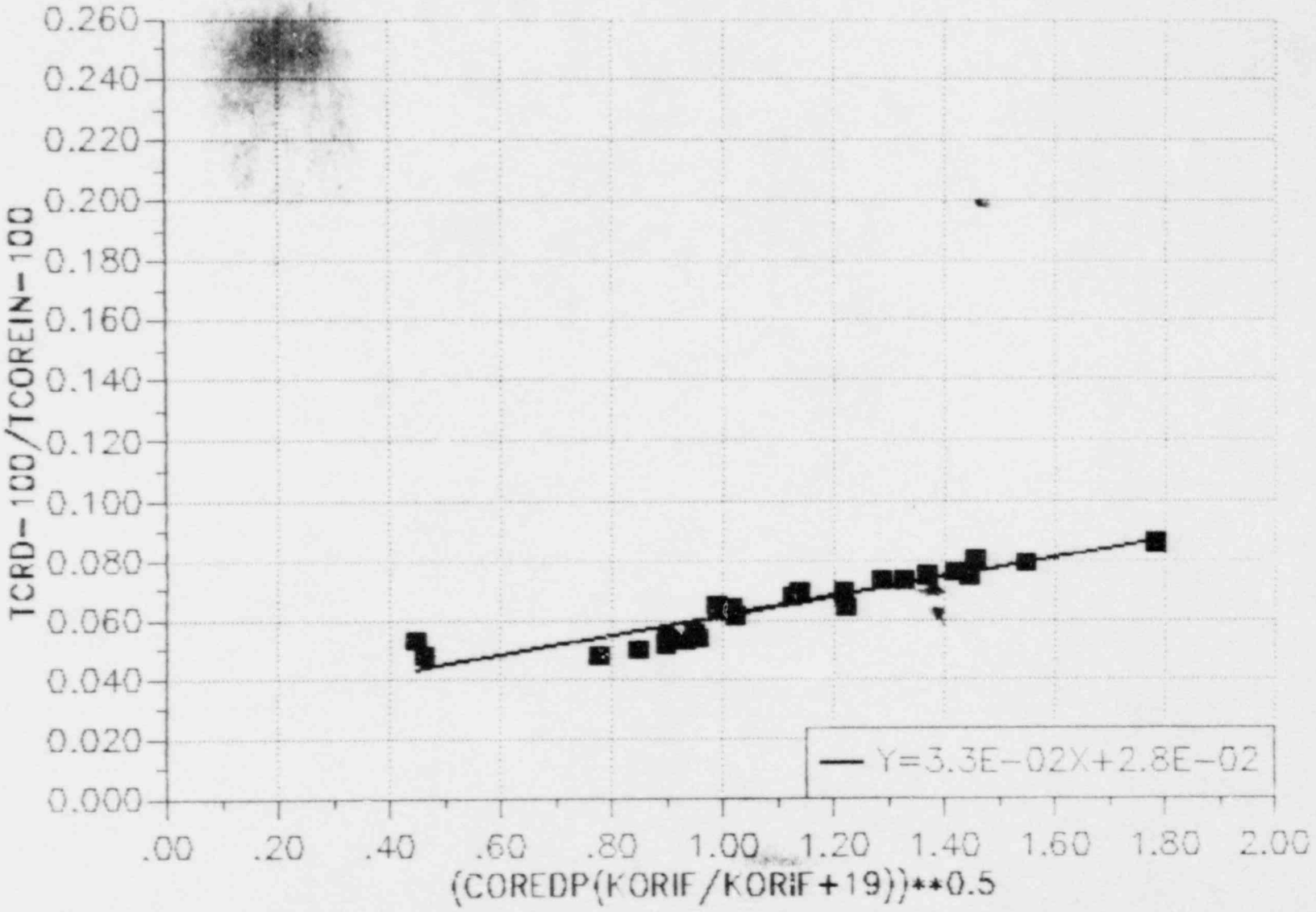
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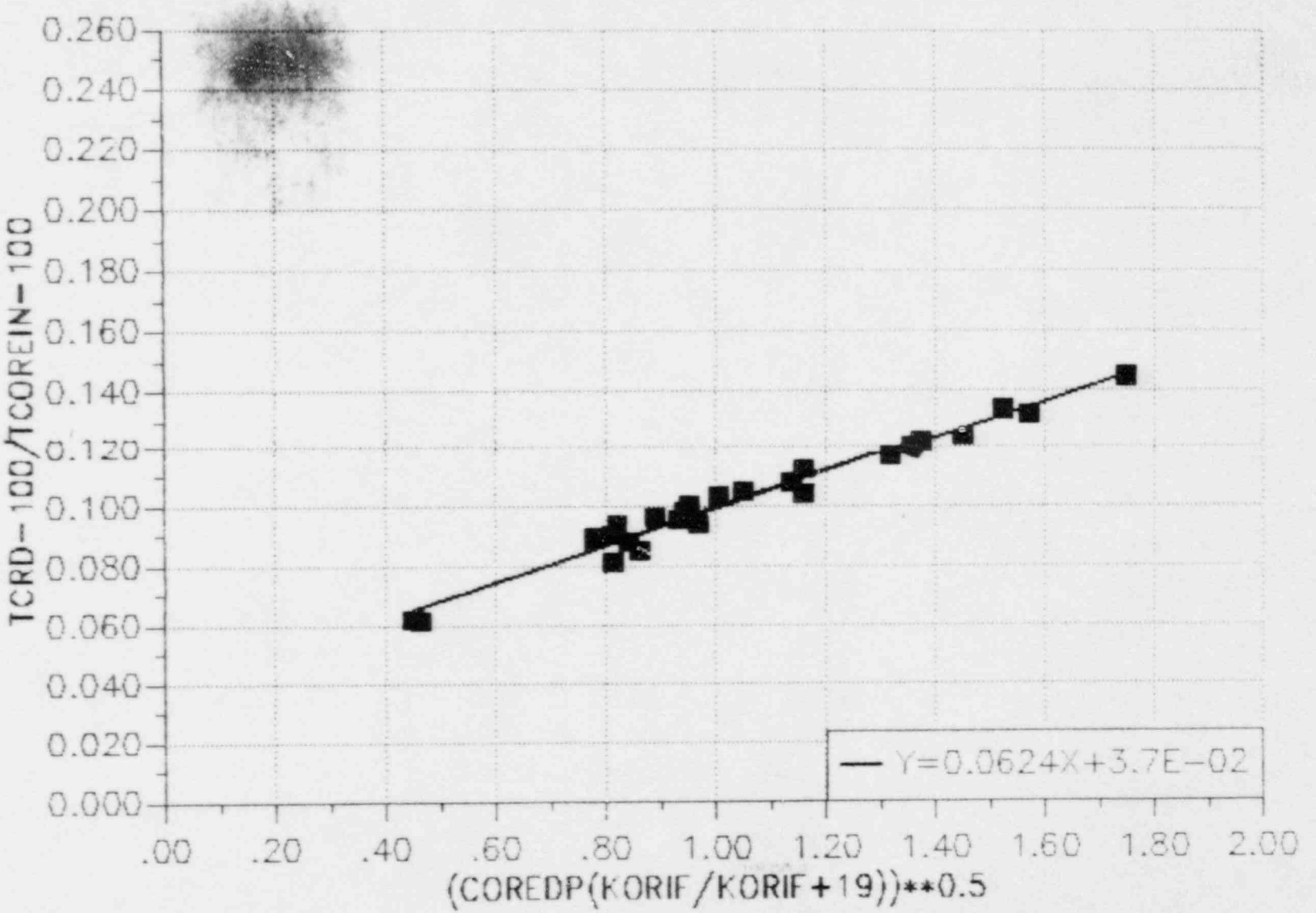
REGION 17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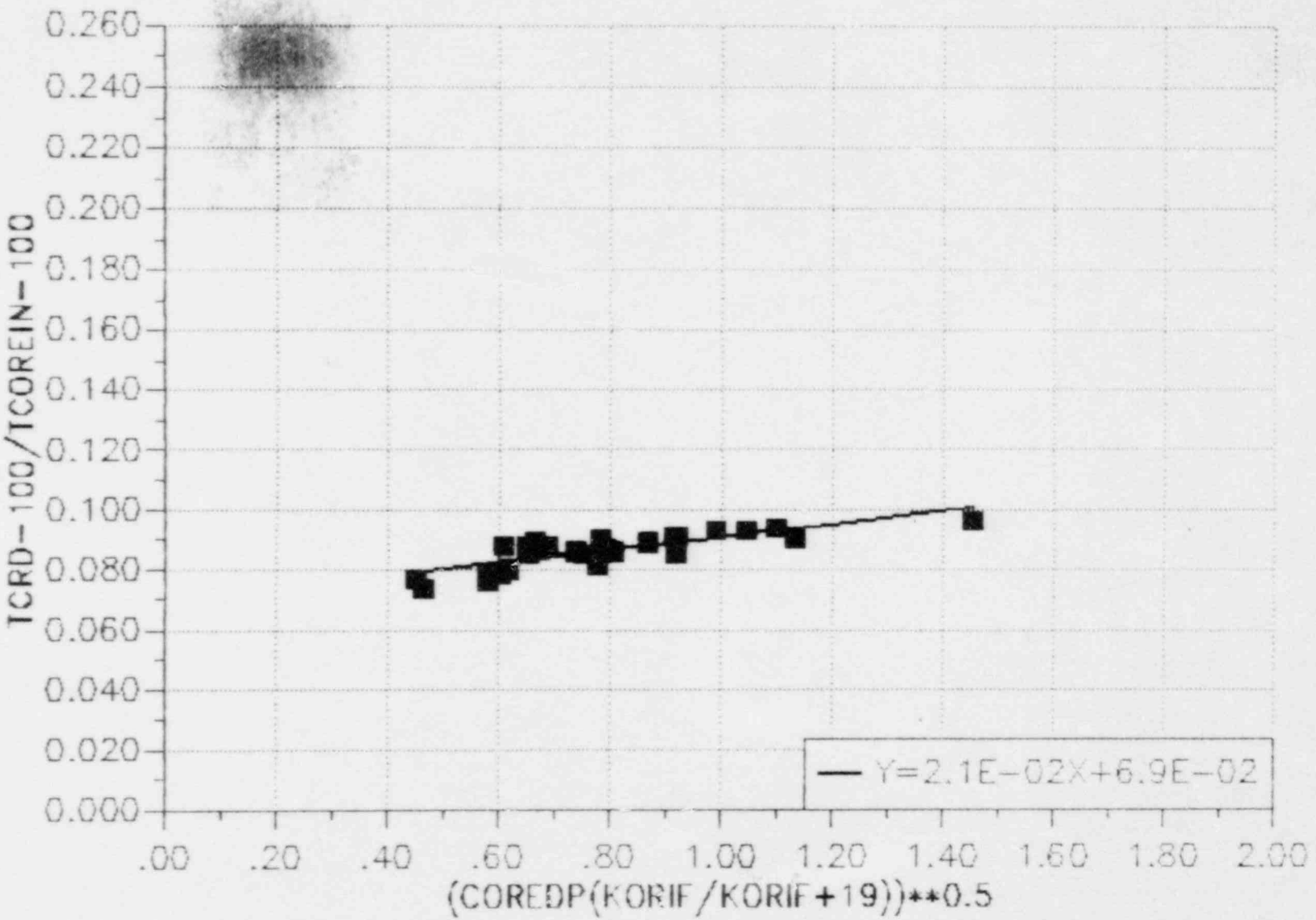
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TCRD-100/TCOREIN-100
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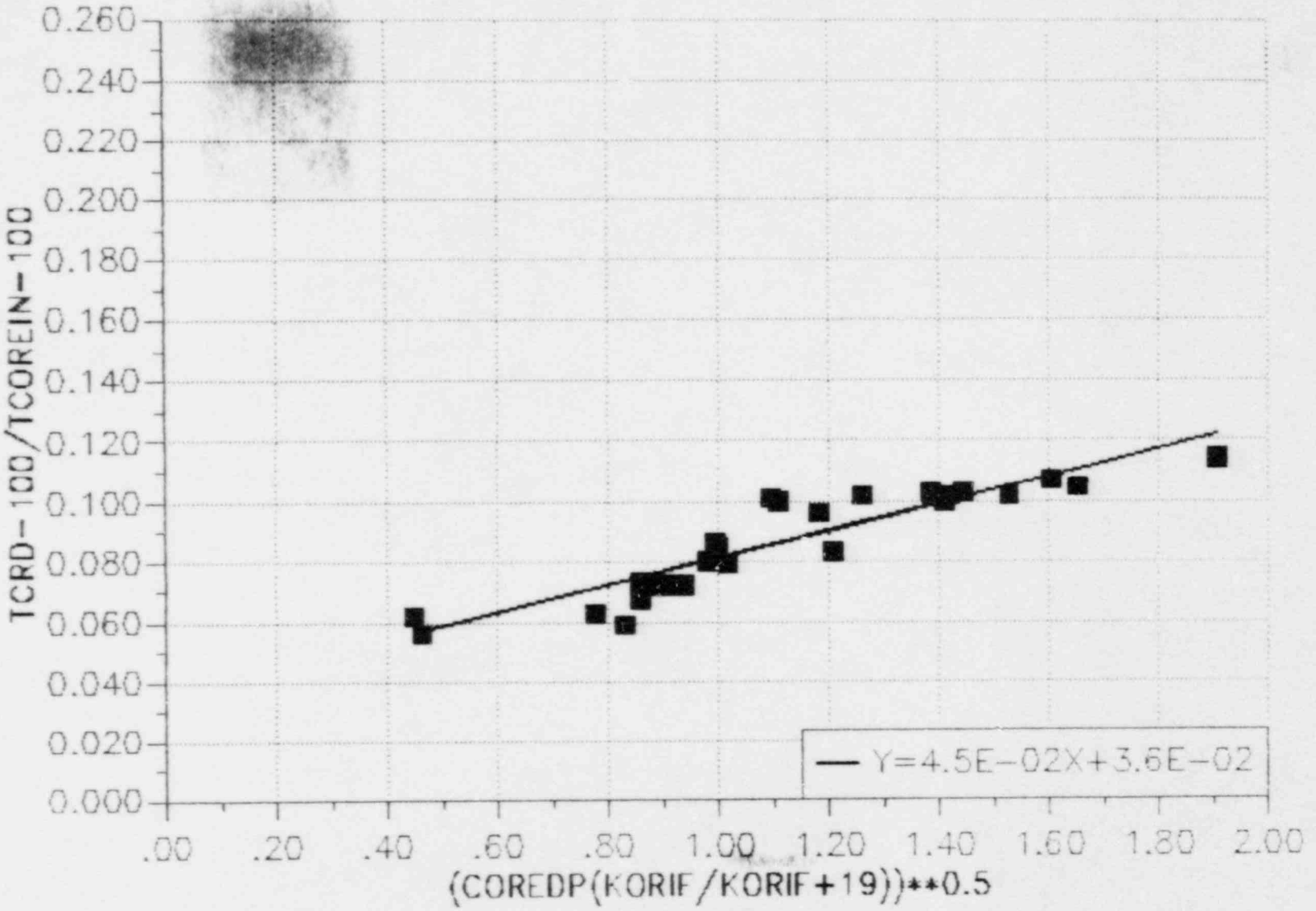
REGION 19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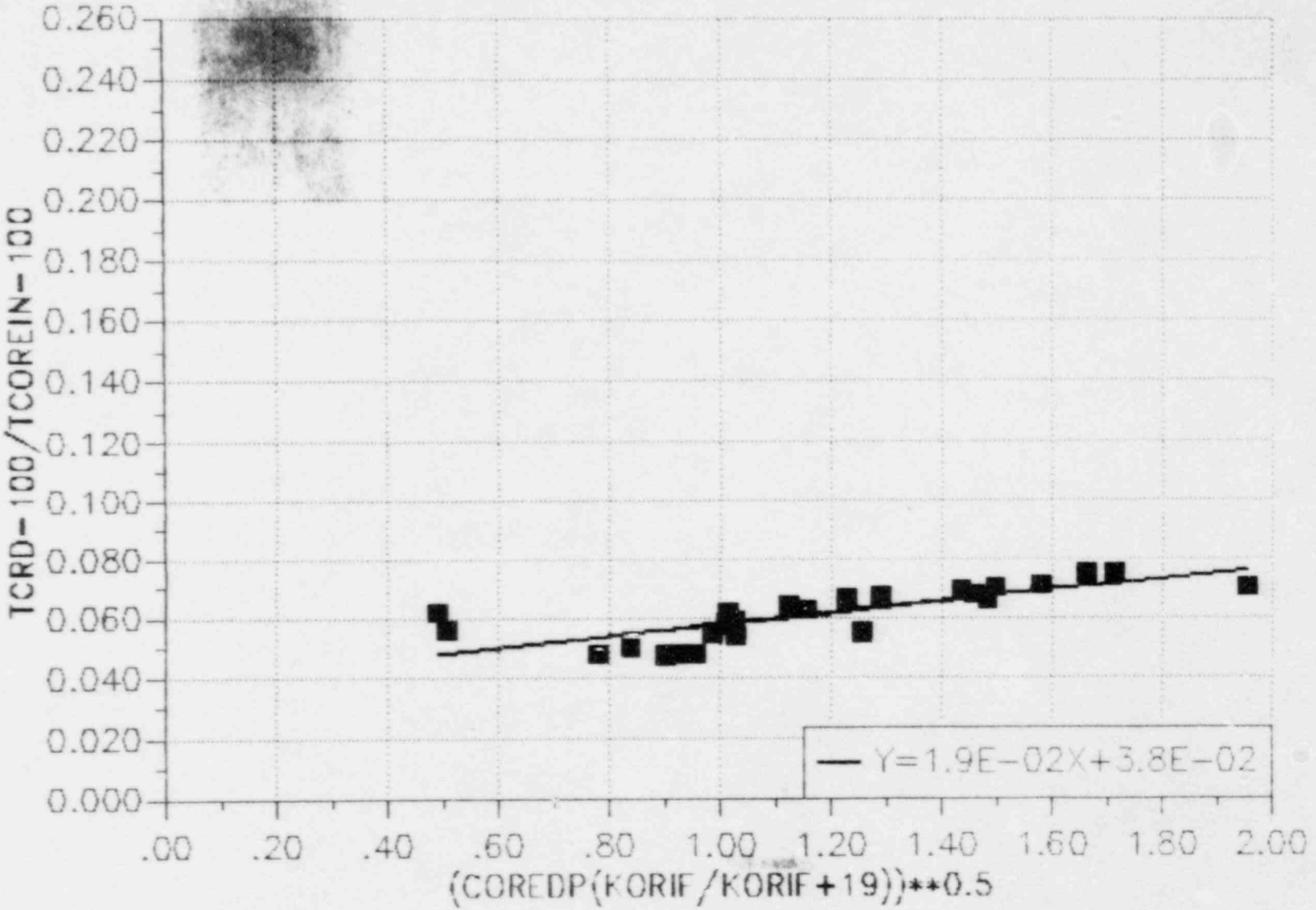
Y=4.5E-02X+3.6E-02

REGION 20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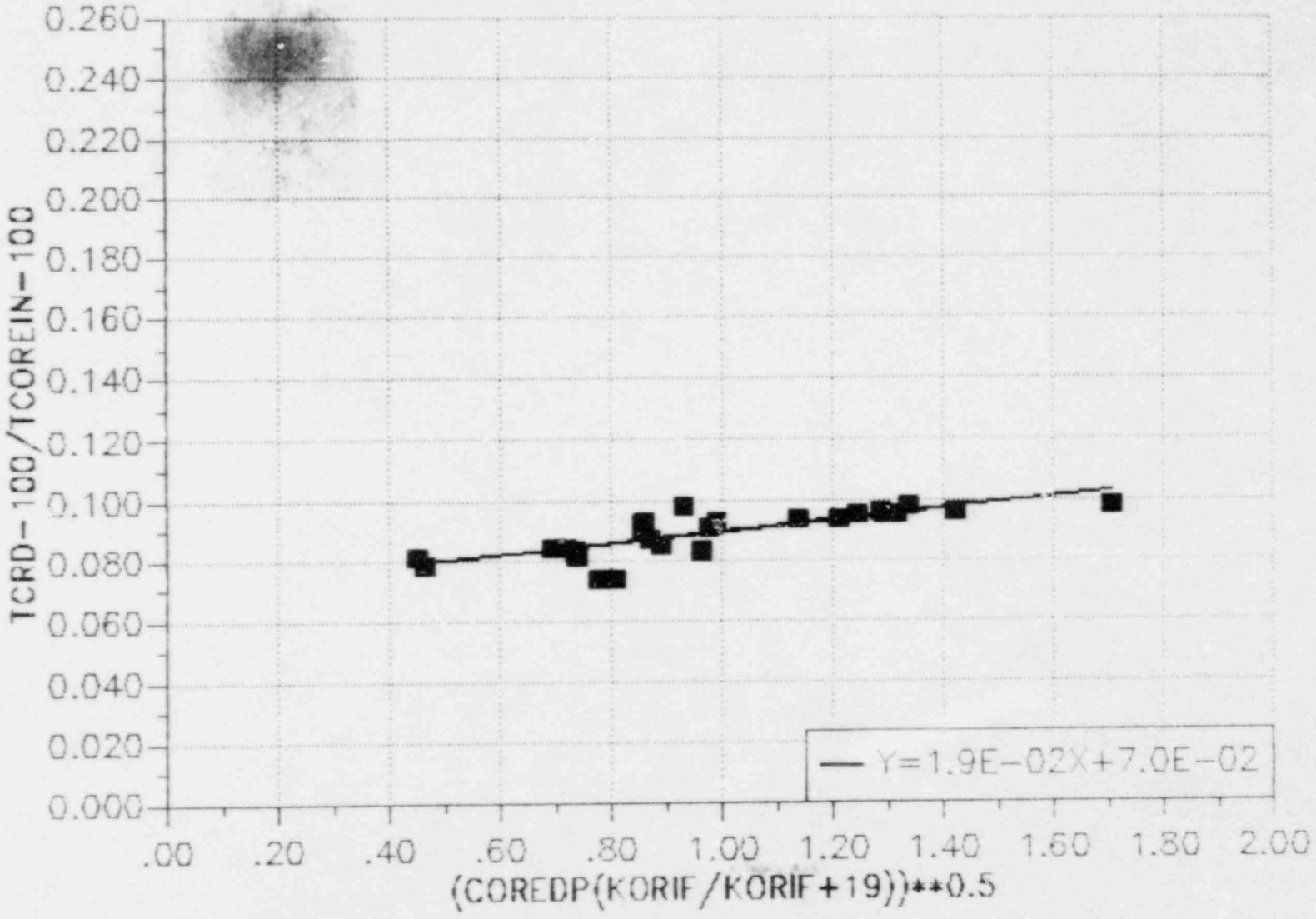
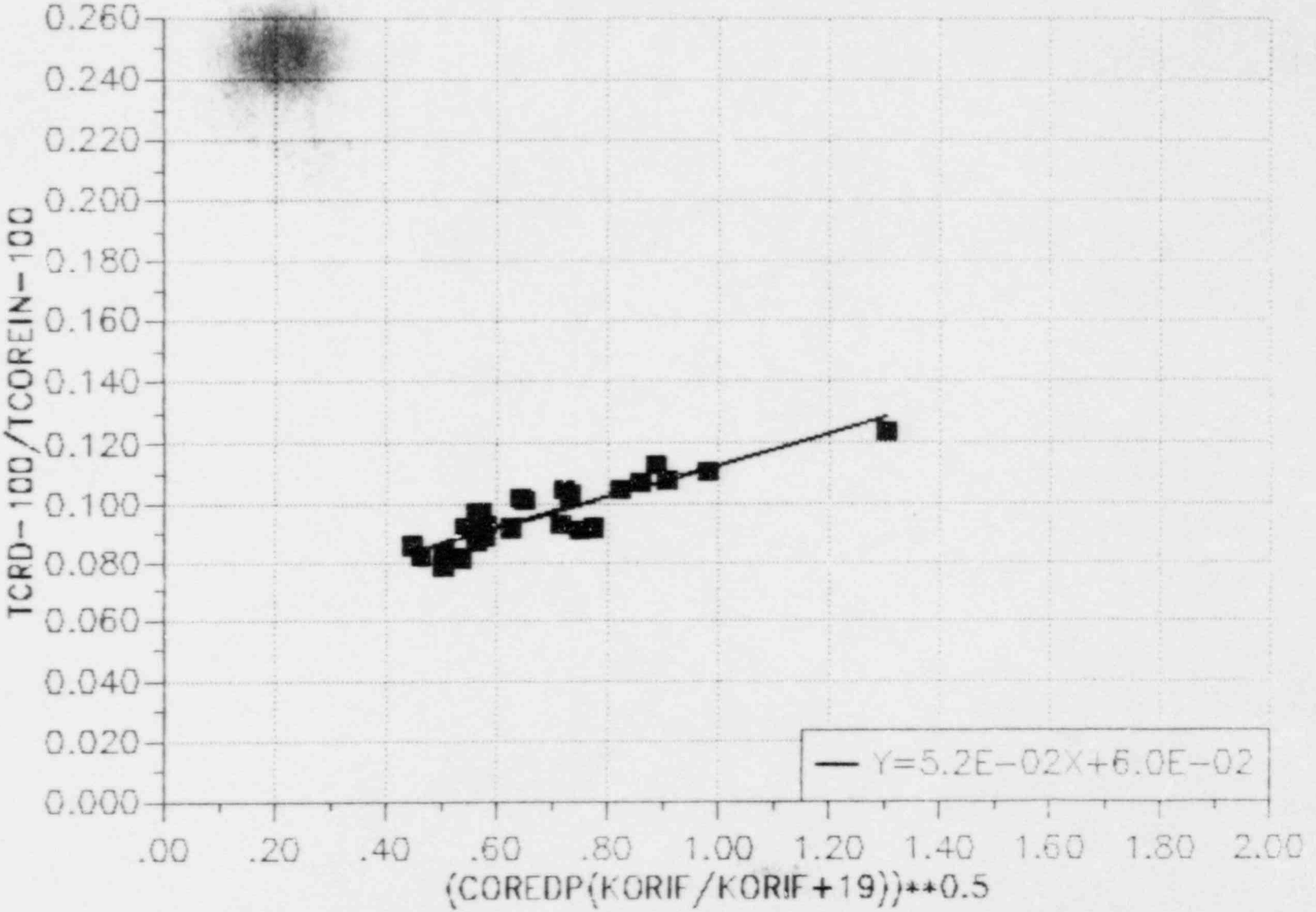
(COREDP(KORIF/KORIF+19))**0.5
Y=1.9E-02X+3.8E-02

Enclosure 21

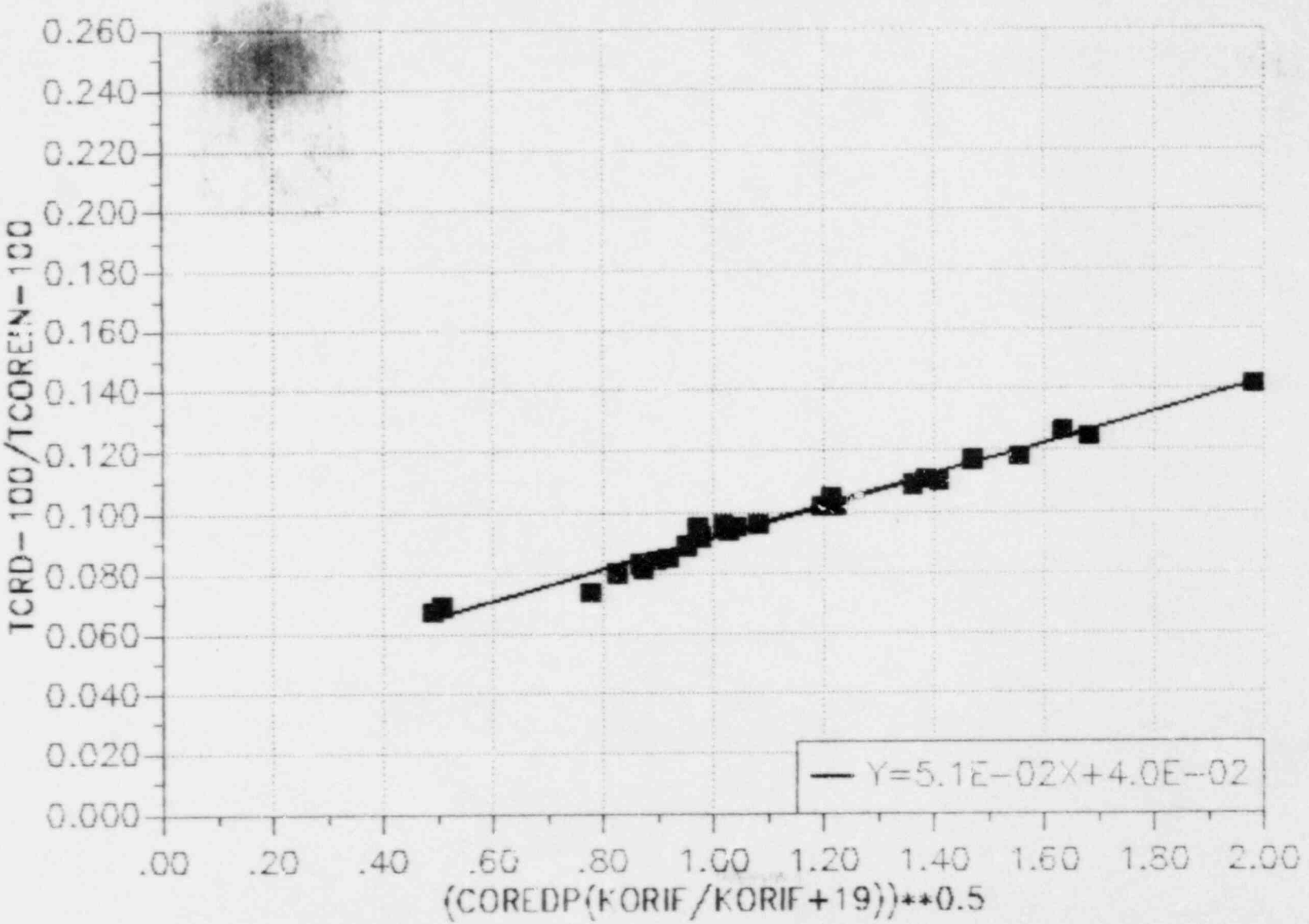
REGION 21



REGION 22


0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=5.2E-02X+6.0E-02

REGION 23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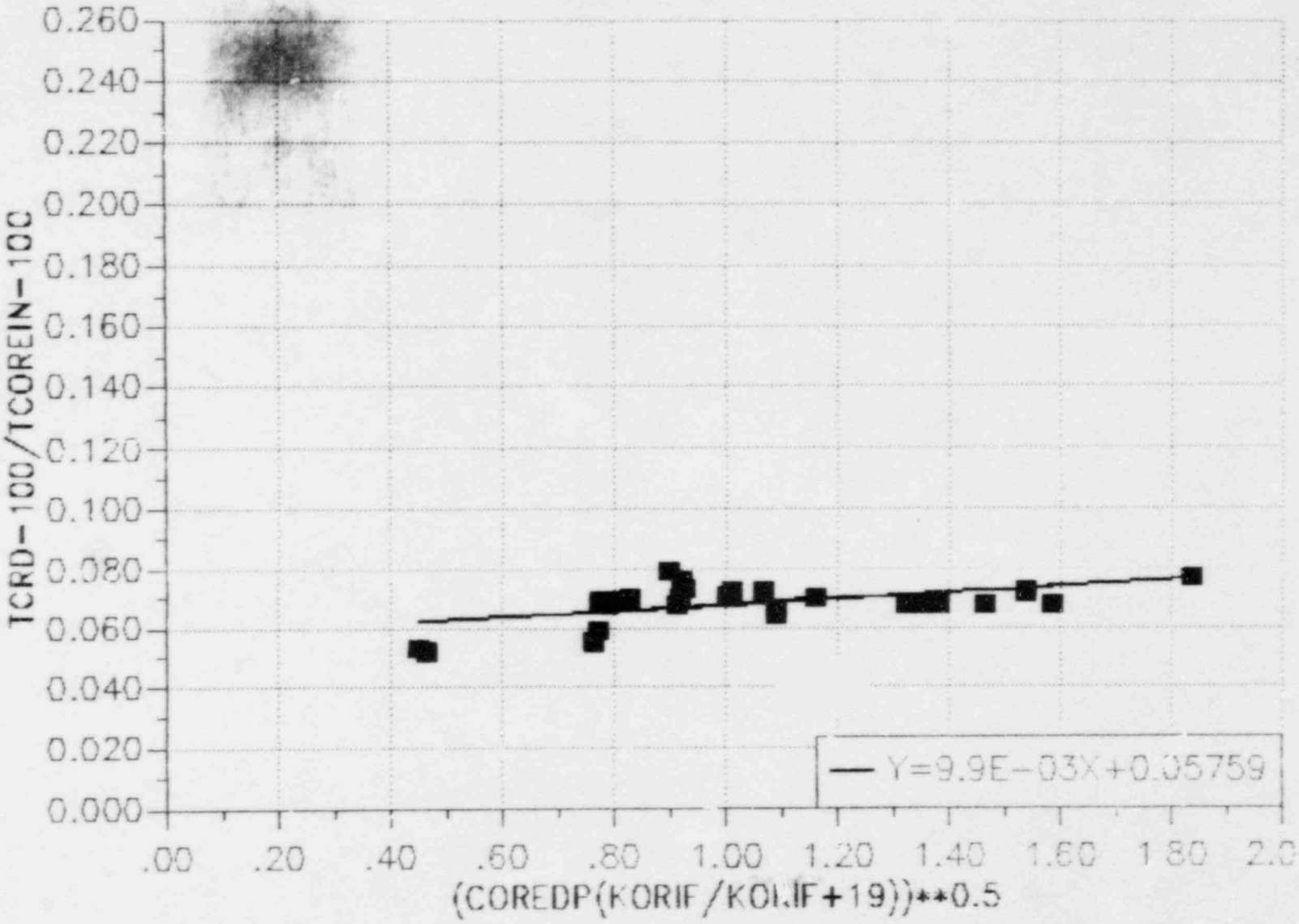
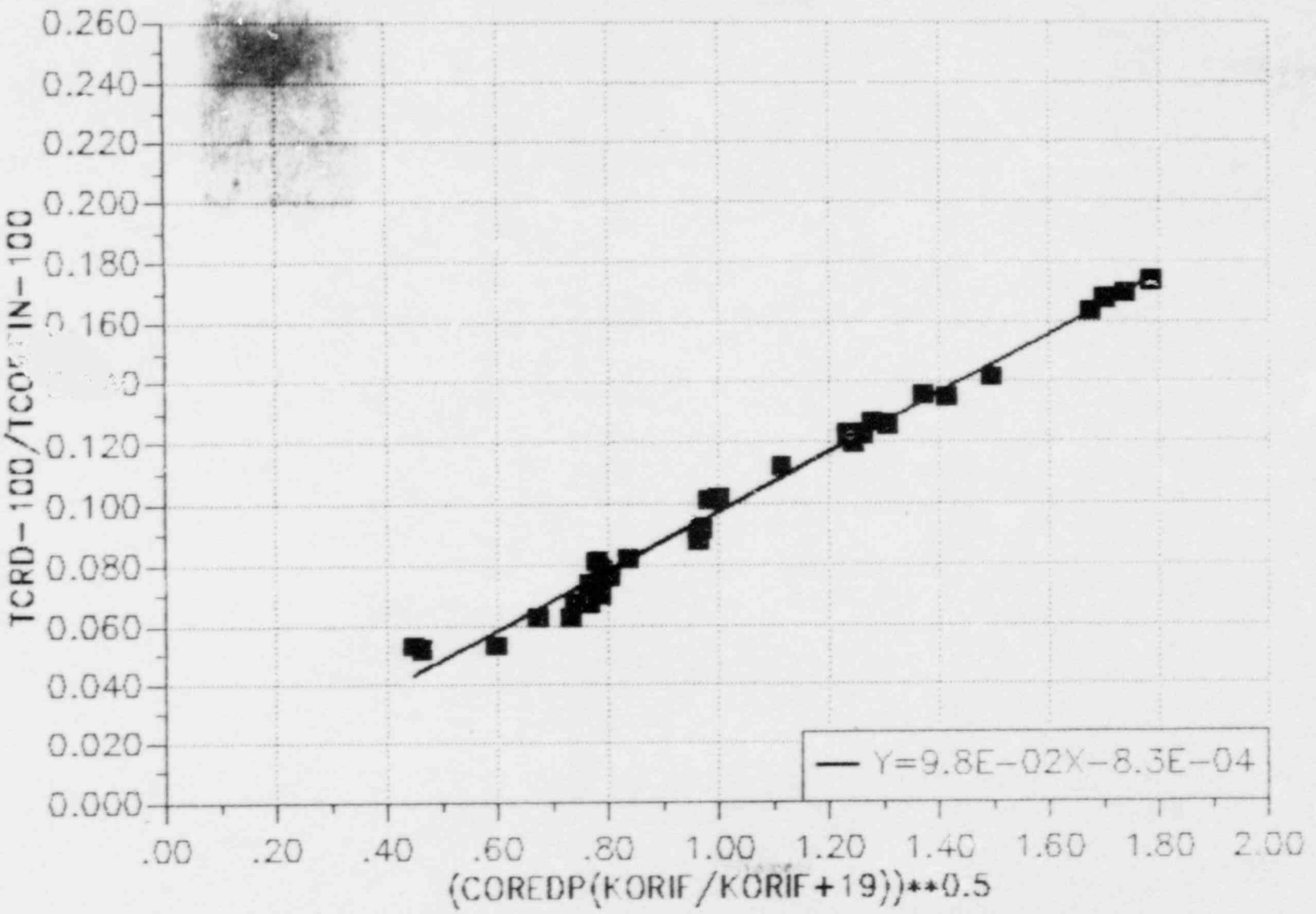
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=5.1E-02X+4.0E-02

REGION 24


0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.0
(COREDP(KORIF/KOUF+19))**0.5
Y=9.9E-03X+0.05759

REGION 25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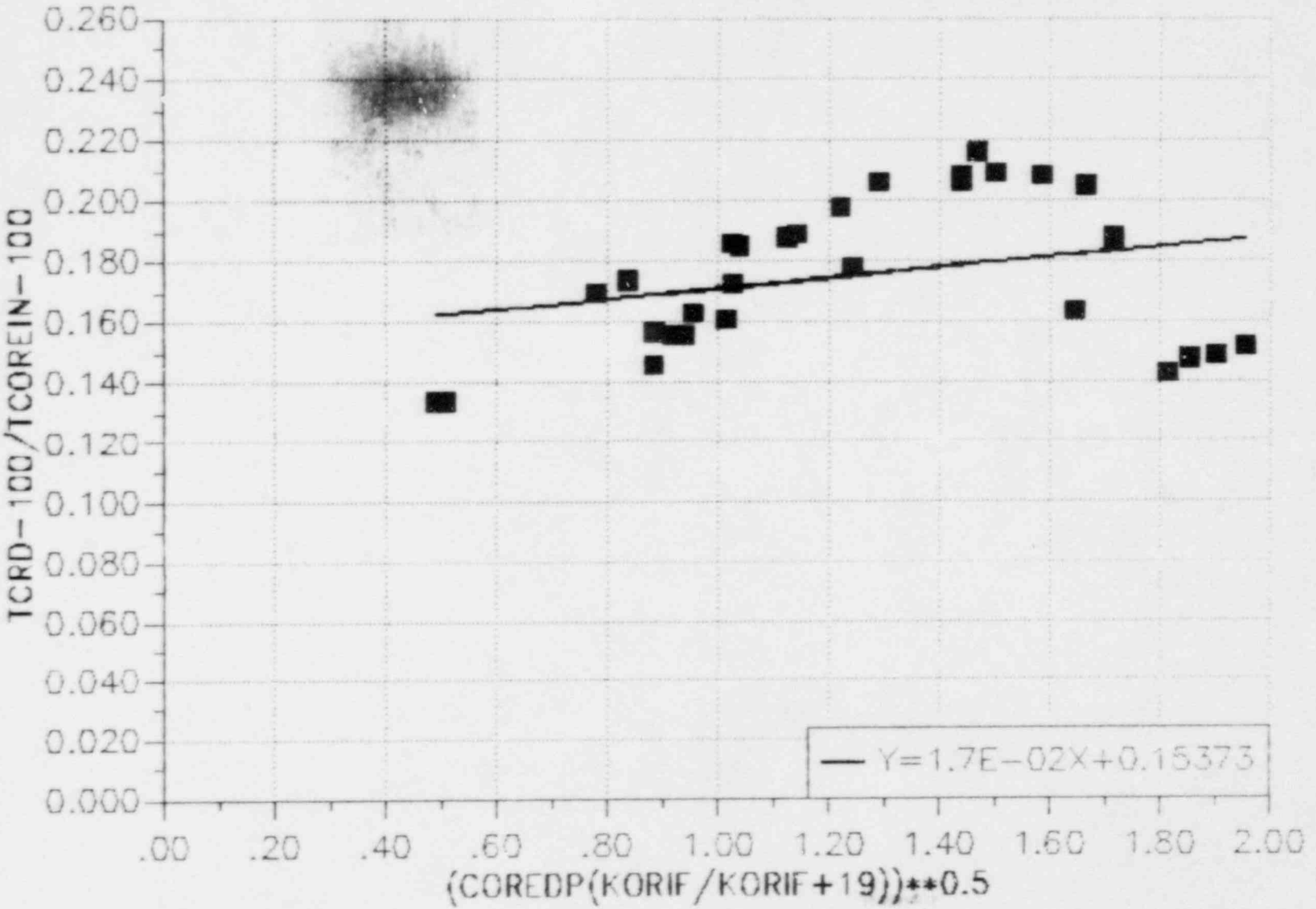
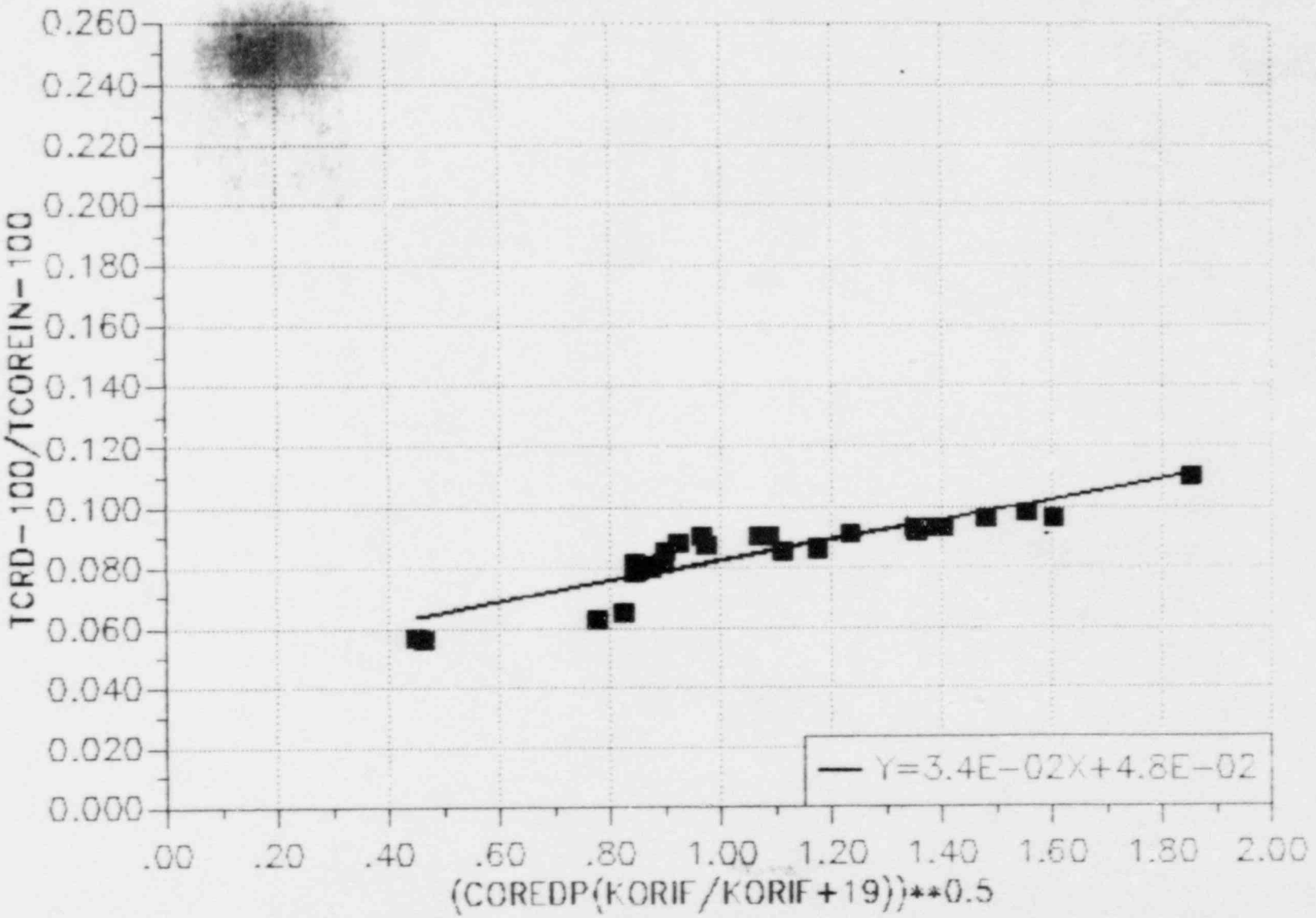
0.240
0.220
0.200
0.180
0.160
0.120
0.100
0.080
0.060
0.040
0.020
0.000
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=9.8E-02X-8.3E-04

Enclosure 26

REGION 26

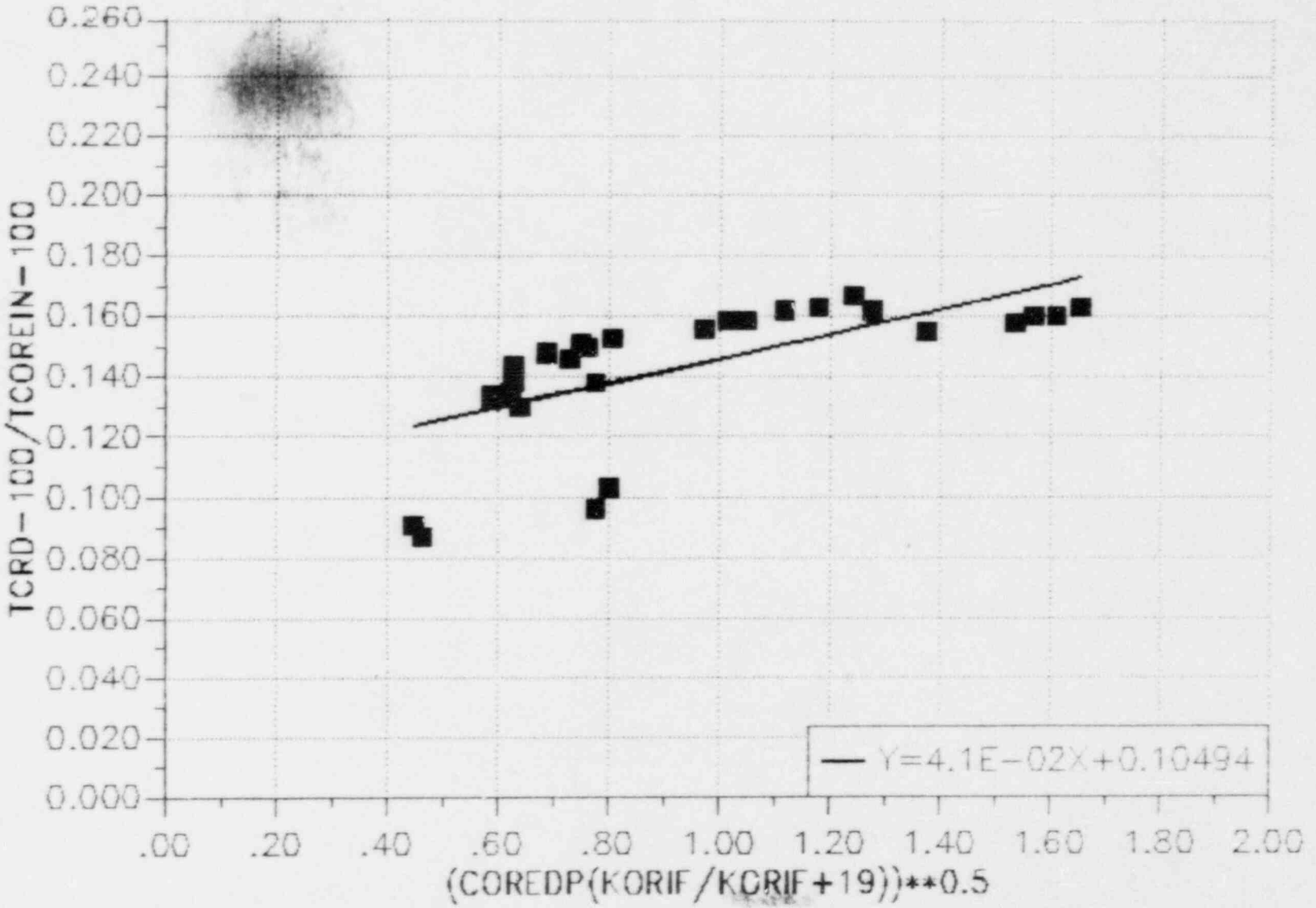


REGION 27

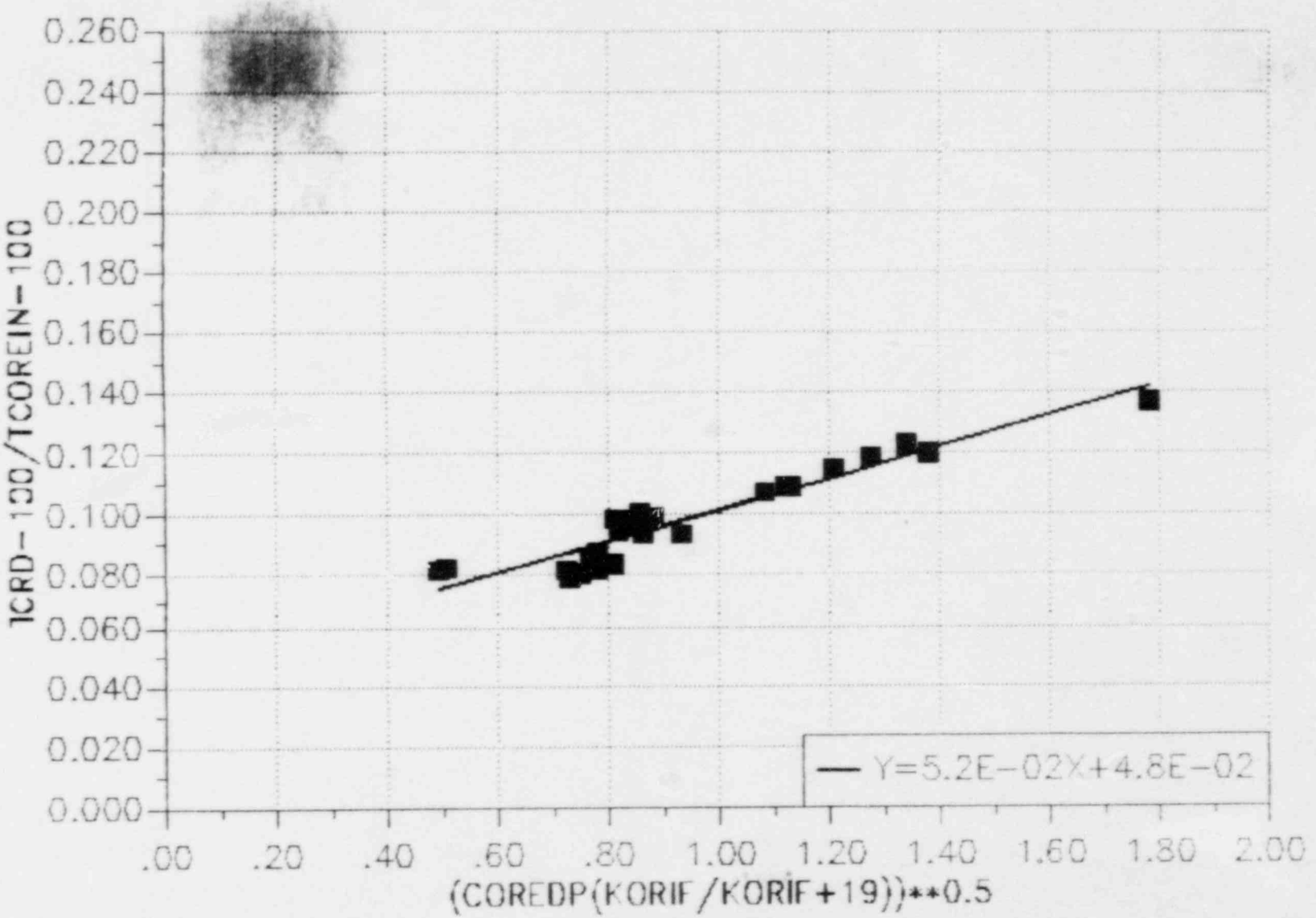

TCRD-100/TCOREIN-100
0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=3.4E-02X+4.8E-02

Enclosure 28

REGION 28



REGION 29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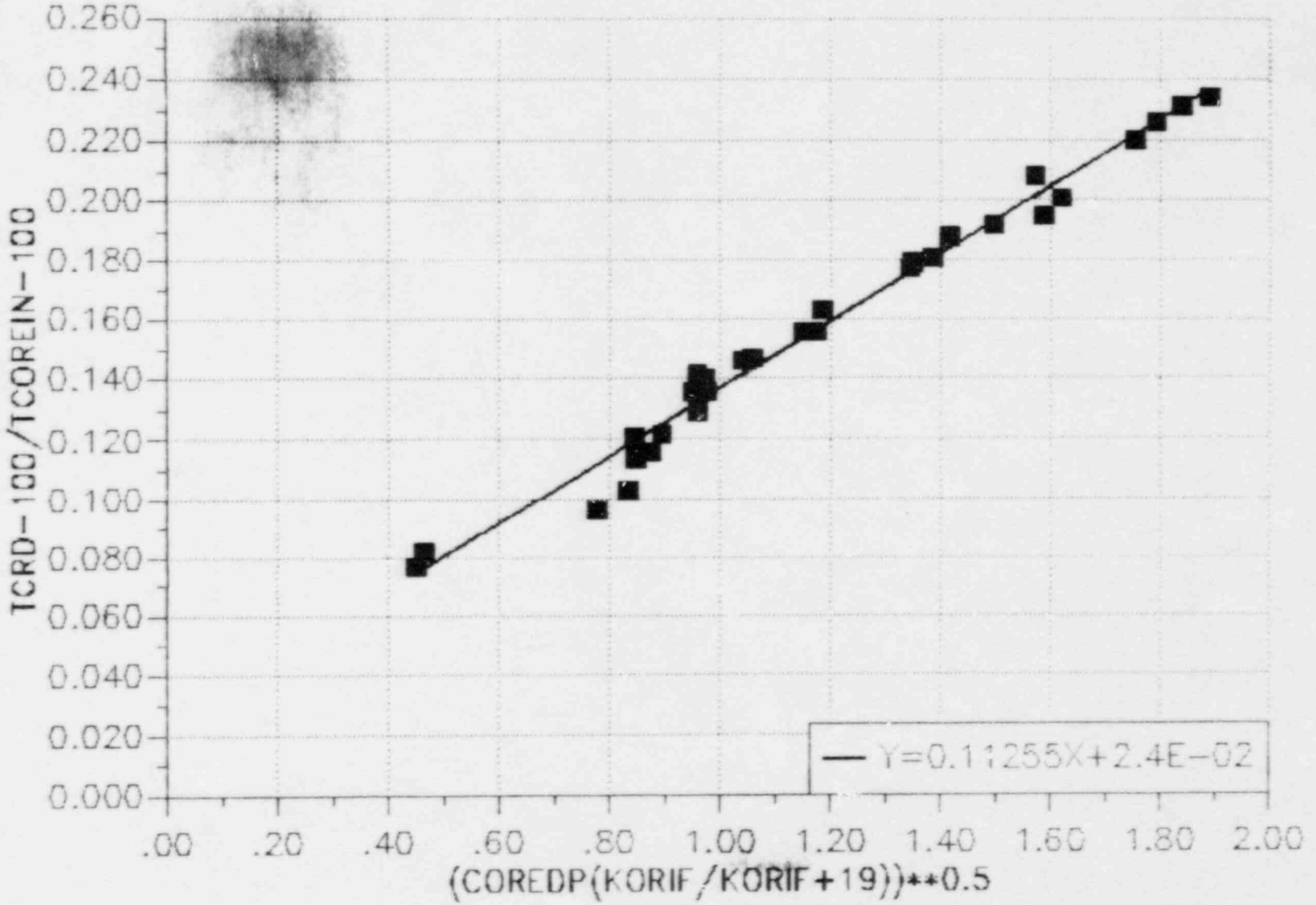
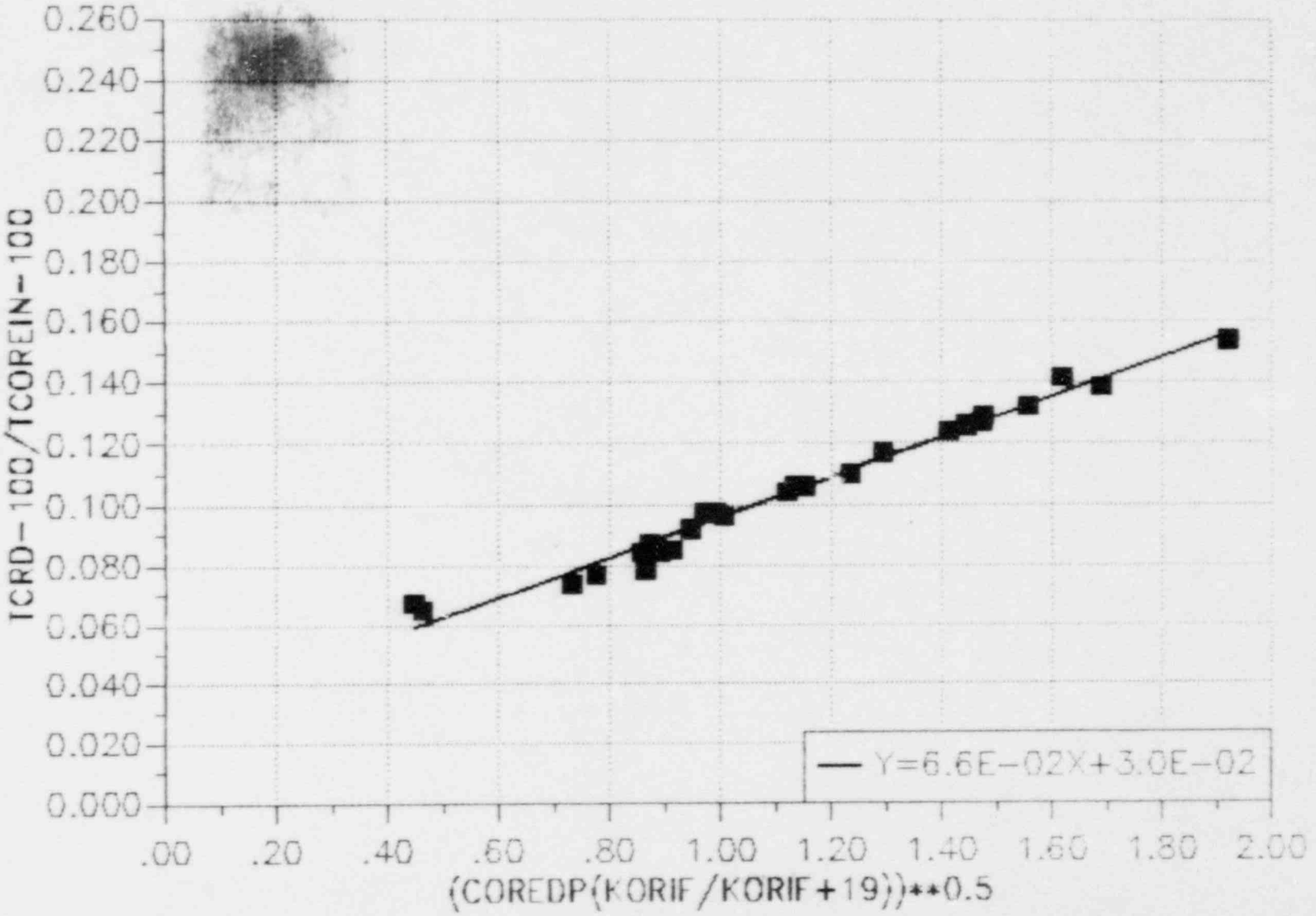
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
ICRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=5.2E-02X+4.8E-02

REGION 30


0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=0.11255X+2.4E-02

REGION 31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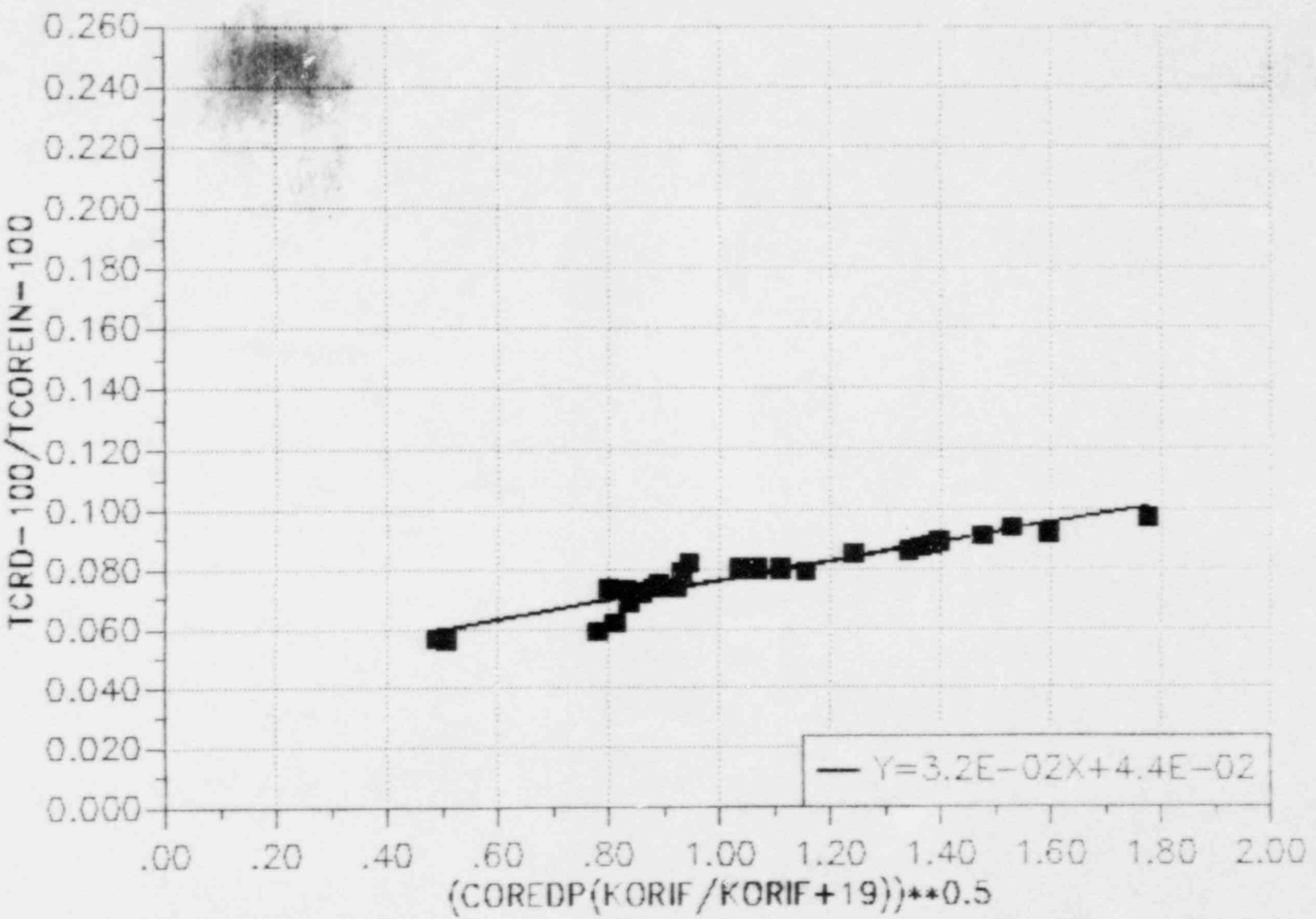
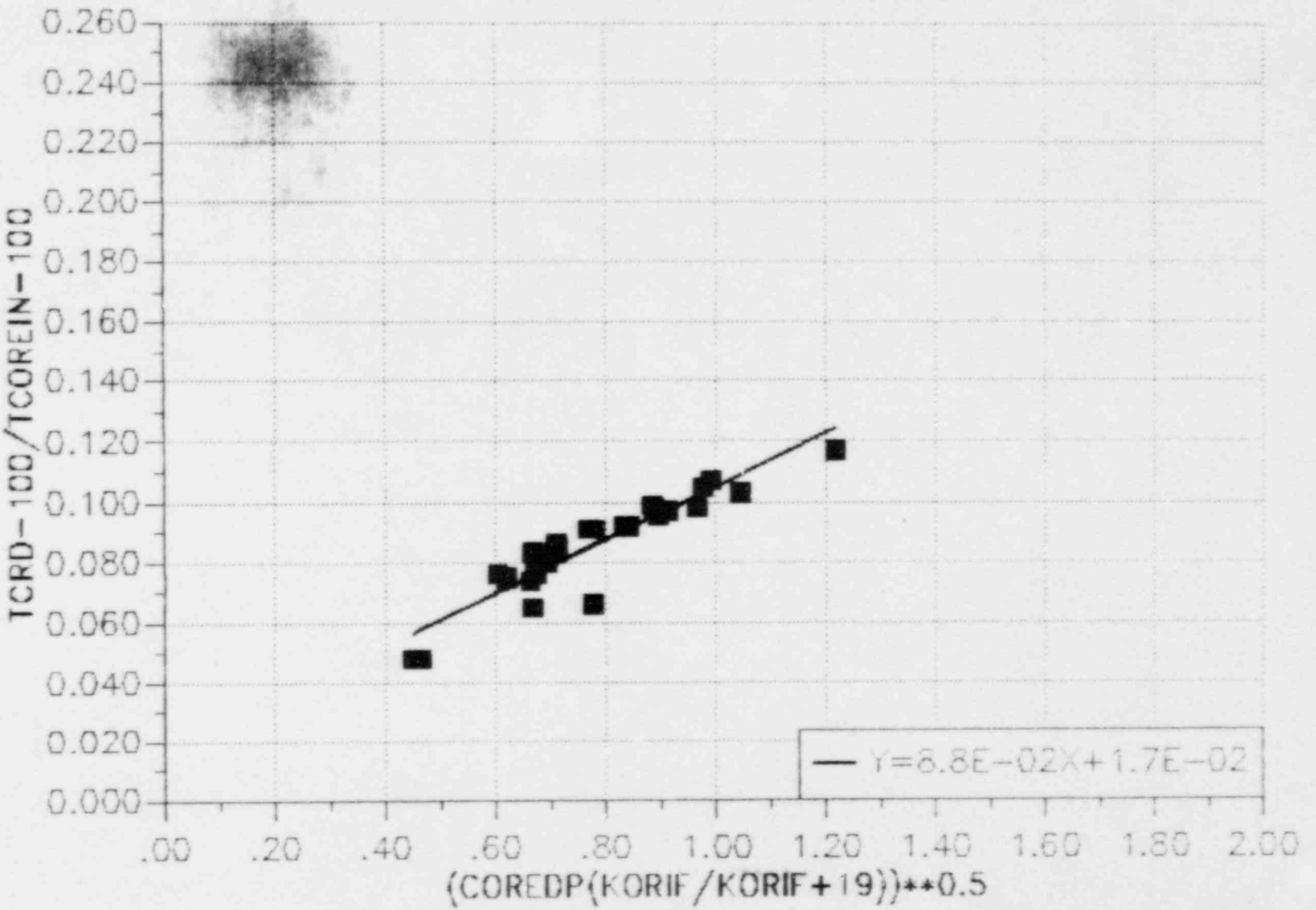
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
ICRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=6.6E-02X+3.0E-02

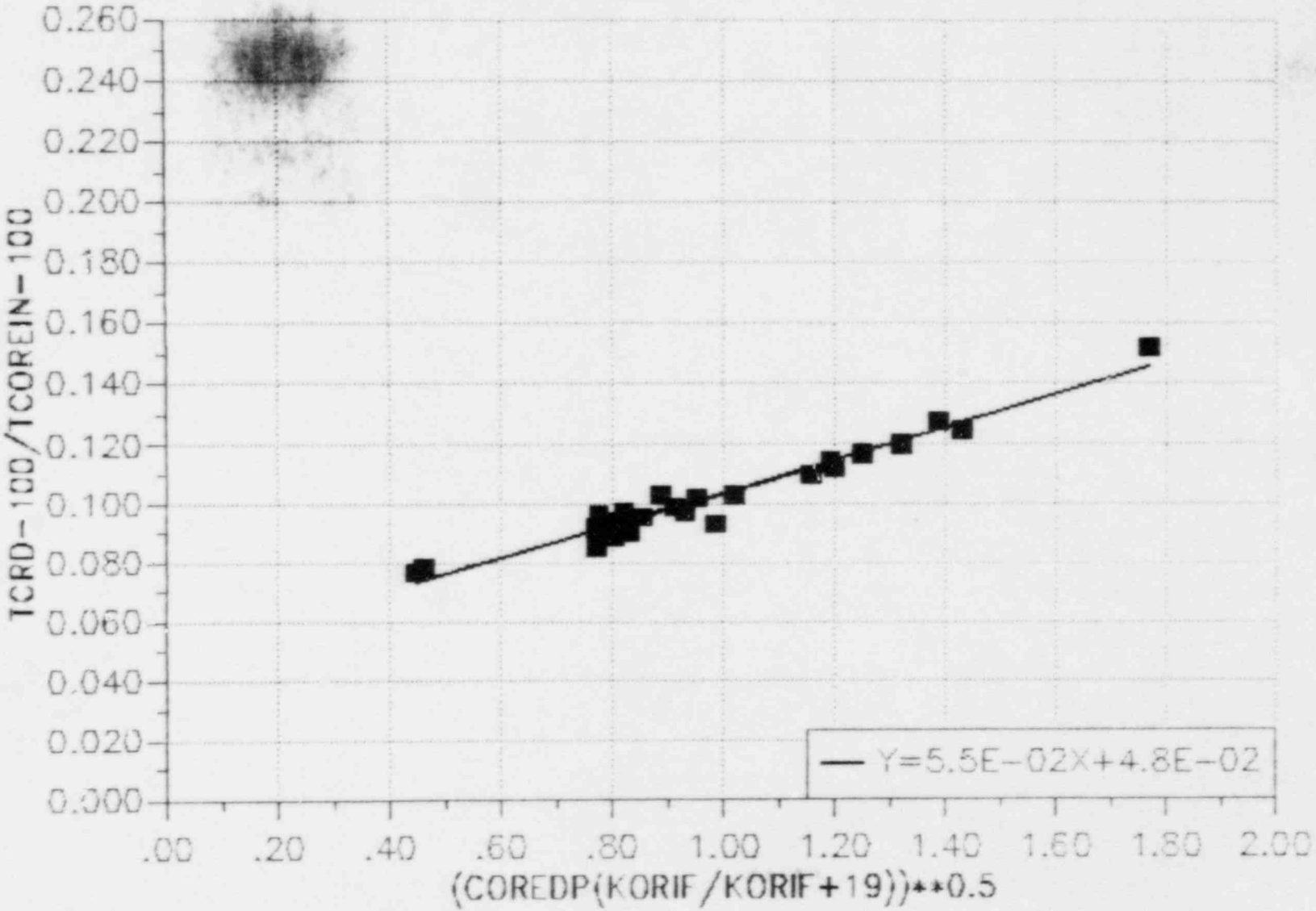
REGION 32


TCRD-100/TCOREIN-100
0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=3.2E-02X+4.4E-02

REGION 33

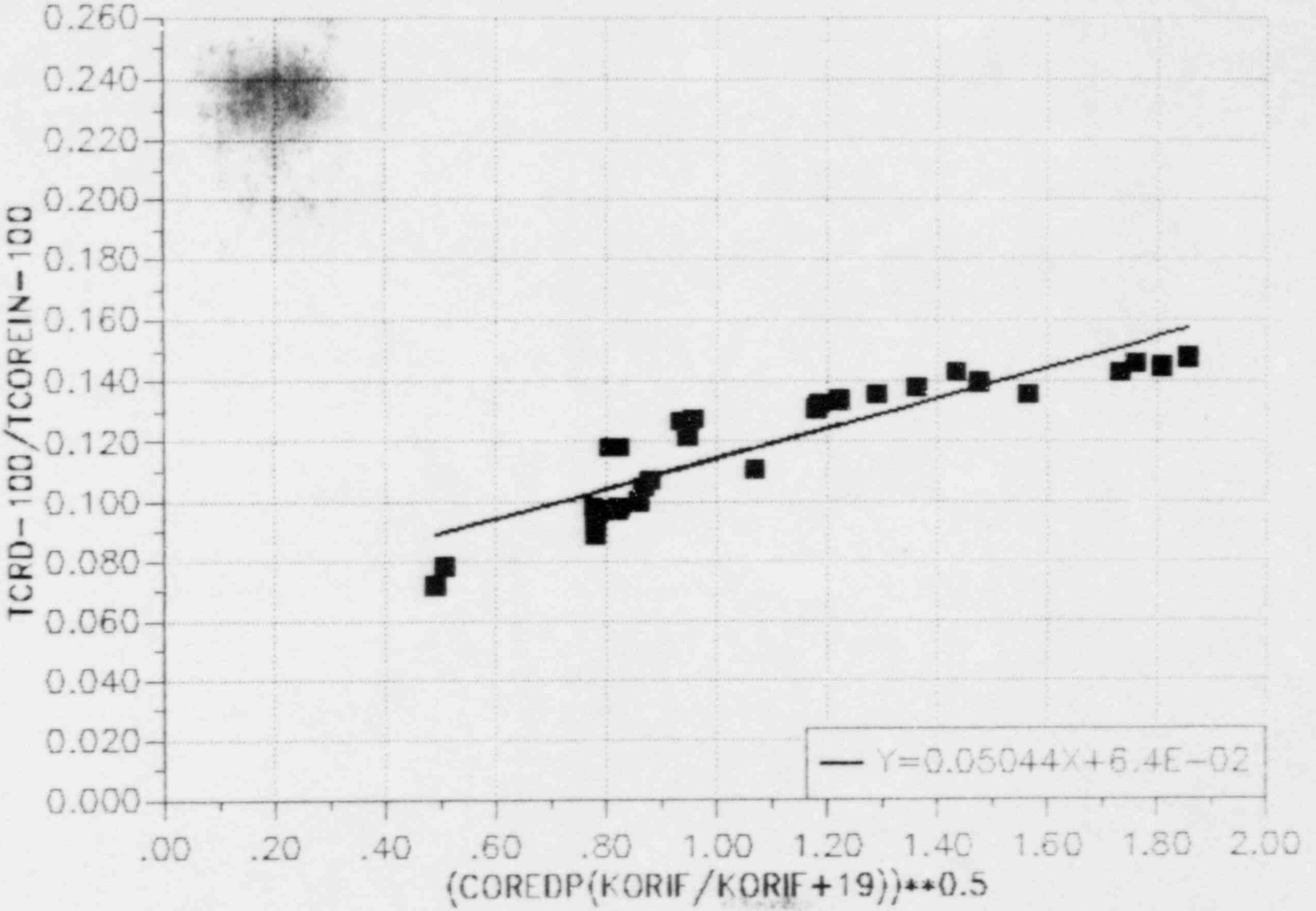

0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=6.8E-02X+1.7E-02

REGION 34

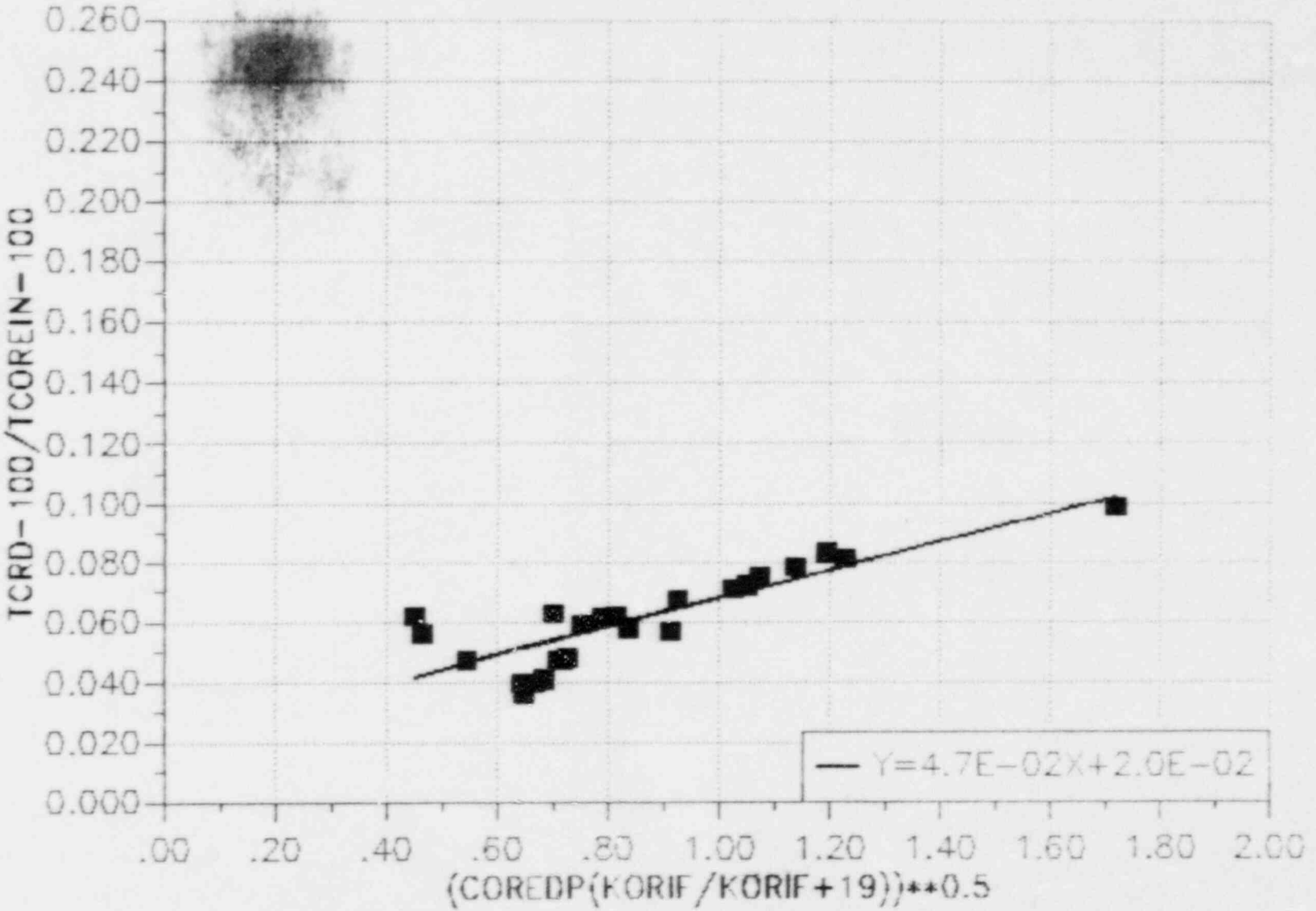

0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=5.5E-02X+4.8E-02

Enclosure 35

REGION 35

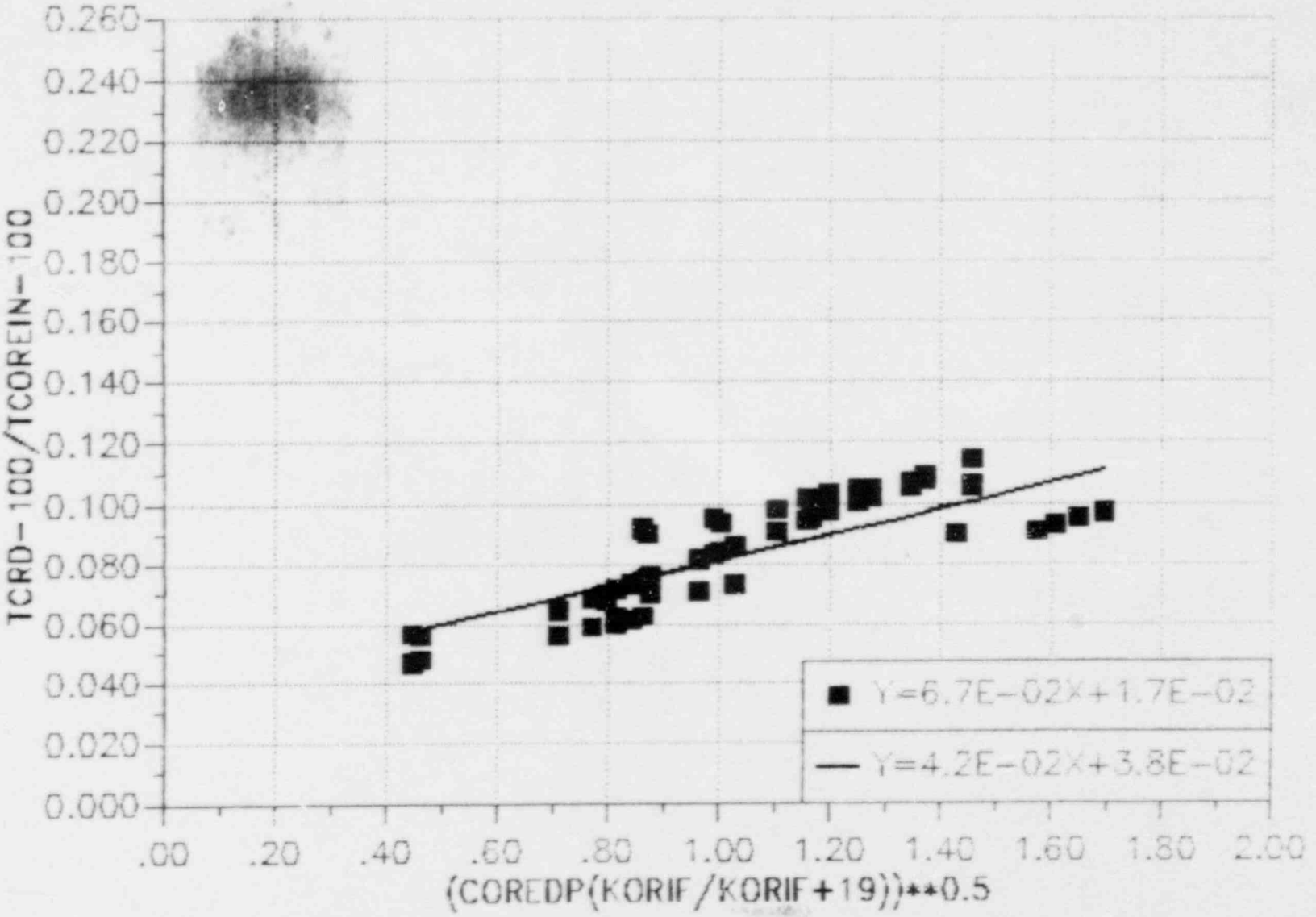


REGION 36


0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
TCRD-100/TCOREIN-100
.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
(COREDP(KORIF/KORIF+19))**0.5
Y=4.7E-02X+2.0E-02

Enclosure 37

REGION 37



Attachment 2 to

P-88152