

REFERENCES

1. Montier, R.M. and Orszulik, S.T. "Chemistry and Technology of Lubricants"
New York : VCH Publishers, Inc., (1992) : 83-122 .
2. Asseff, P.A.. "Lubricating Theory and Practice", ASLE Annual Meeting
(1982).
3. David, E. R. "Process for preparing molybdenum-containing compositions
useful for improved fuel economy of internal combustion
engines", US Patent 4,456,538 , (1984).
4. Daniel, T.C. "Additive composition and gear lubricant compounded
therewith" WO Patent 88/08874 , (1988).
5. Carl, K. E., Jr. "Ashless antiwear-antioxidant lubricating oil additive", US
Patent 5,405,554 , (1995).
6. Sheldon, H. "Anti-wear lubricity additive for low-sulfur content diesel fuels",
US Patent 5,490,864 , (1996).
7. Kirk-Othmer. "Encyclopedia of Chemical Technology Vol.2", 4 th Ed.,
New York: John Wiley & Sons, (1992) : 709-728.
8. Babara, E.; Stephen, H. and Gail, S. "Ullman's Encyclopedia of Industrial
Chemistry Vol. A19 ", 5 th Ed., New York : VCH Publisher Inc.,
(1991) : 49-60.

9. John, A. M. "Alcohol", Research Associate Colgate-Palmolive, , New Jersey : Research Center Piscataway, (1968) : 136-143.
10. John, A.M. "Alcohols : Their chemistry, properties and manufacture", Reinhold Book Corporation., (1968) : 463-464.
11. Georges, R. "Novel metallic dithiophosphates and their use as additives for lubricating", US Patent 4,288,335 , (1981).
12. Robert, F.B. "Molybdenum IV compounds, process for preparation thereof and lubricant compositions containing same", US Patent 4,428,861 , (1984).
13. Stephen, A.L. "Oxymolybdenum dialkyldithiophosphates and lubricants containing same", US Patent 4,290,902 , (1981).
14. Gunter, C. "Metal dithiophosphate process and/composition" US Patent 4,085,053 , (1978).
15. Maurice, B. "Metal dihydrocarbyl-dithiophosphyl-diithiophosphates their manufacture and use as additives for lubricants", US Patent 4,882,446 , (1989).
16. Terence, C. "Dithiophosphates" EP Patent 322 235 A2 , (1988).
17. Wolfram, S. "Process for the preparation of dialkyldithiocarbamates of multivalent metals", US Patent 4,859,787 , (1989).
18. Abbas, K. "Process for metal salts of hydrocarbyl dithiophosphoric acid", US Patent 5,380,448 , (1995).

19. Abbas, K. "Process for metal salts of hydrocarbyl dithiophosphoric acid", US Patent 5,384,054, (1995).
20. Yoshihiro, M. "Lubricating oil composition containing molybdenum and zinc compounds for internal combustion engine", US Patent 4,925,596, (1990).
21. Sarin, R. and Gupta, A.K. "Synthesis and performance evaluation of O,O-dialkylphosphorodithioic disulphides as potential anti-wear, extreme-pressure and antioxidant additives", Tribology International, Vol. 26 no. 6, (1993) : 389-394.
22. Liehpao, O.F. "Copper salts of thiodipropionic acid derivatives as antioxidant additives process of making the same and fuel composition thereof", US Patent 4,956,108, (1990).
23. Shriver, D.F., Atkins, P.W. and Langford, C.H. "Inorganic Chemistry", 2nd. Ed., Oxford University Press, (1994): 325-358.
24. Jacob, J.H. and Morton, B. "Ashless lube additives containing complexes of alkoxylated amines dihydrocarbyldithiophosphoric acid, and adenine", US Patent 5,308,517, (1994).
25. Armgard, K.E. , Edmund, F.P. "Lubricating oil composition", US Patent 4,960,528, (1990).
26. Pouchert, C.J. "The aldrich Library of Infrared Spectra", 2 nd. Ed., Aldrich Chemical Company, Inc., (1975): 66F.

27. "Sadler Standard Carbon-13 NMR Spectra", Sadler Research Laboratories, Inc., (1977) : 135C.

28. Liehao, O.F. "Lubricant additives", US Patent 5,282,988 , (1994).

APPENDICES

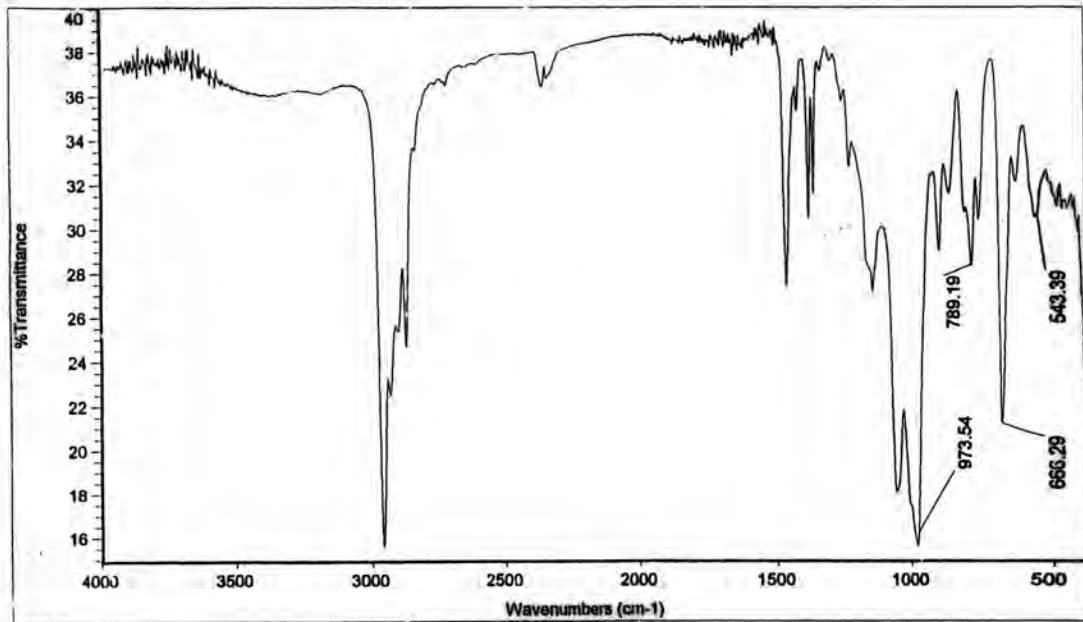
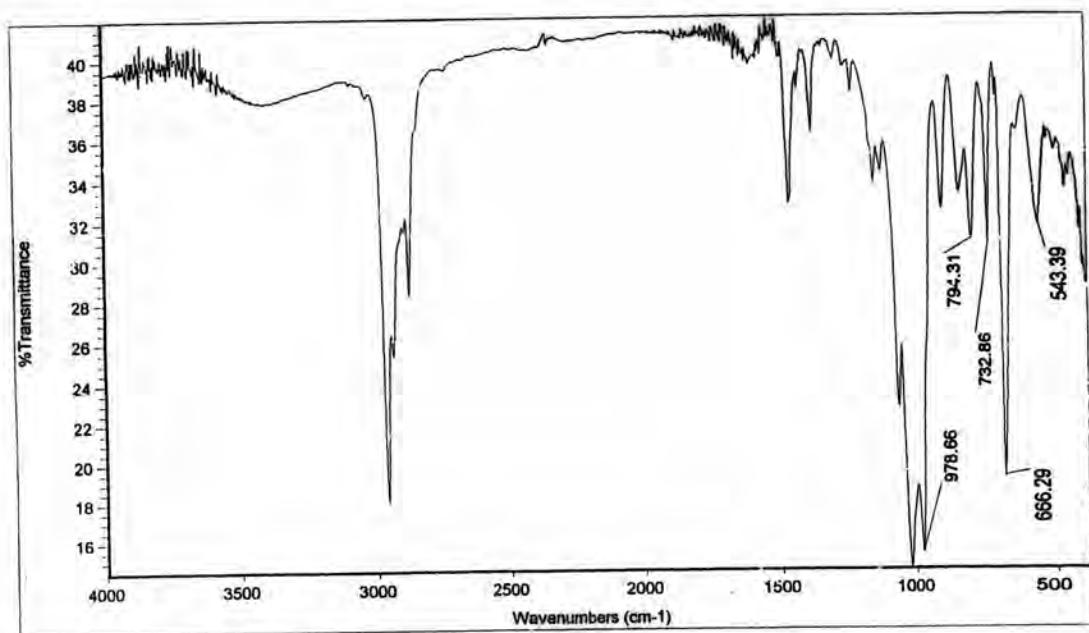
APPENDIX A1 FT-IR Spectrum of products**Figure A1-1 FT-IR Spectrum of ZDDP from isoamyl alcohol****Figure A1-2 FT-IR Spectrum of ZDDP from n-butanol**

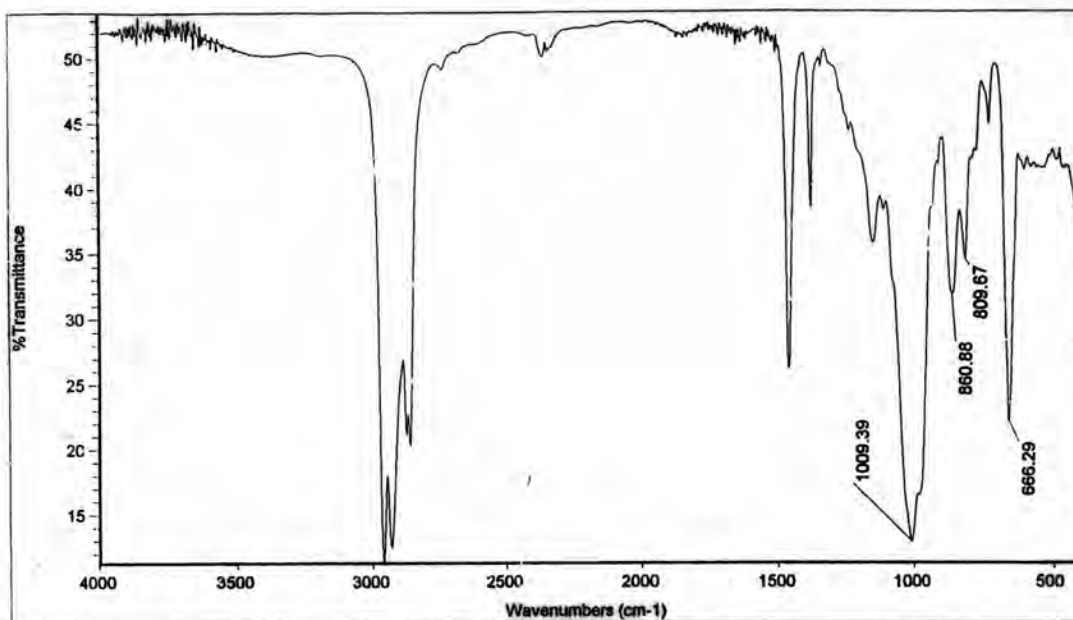
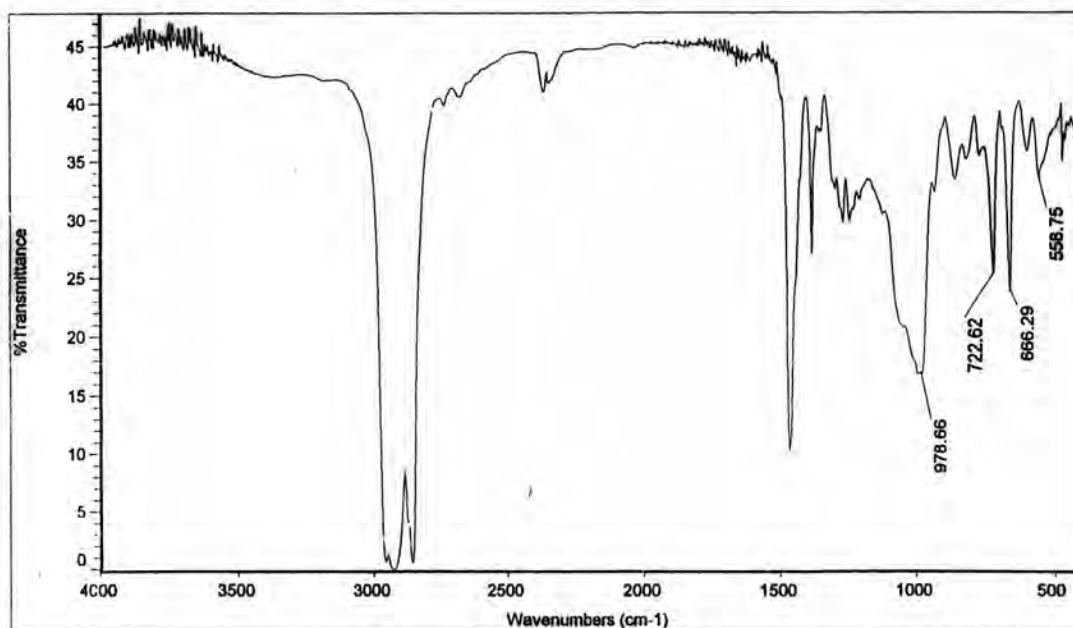
Figure A1-3 FT-IR Spectrum of ZDDP from 2-ethyl hexanol**Figure A1-4 FT-IR Spectrum of ZDDP from n-octanol**

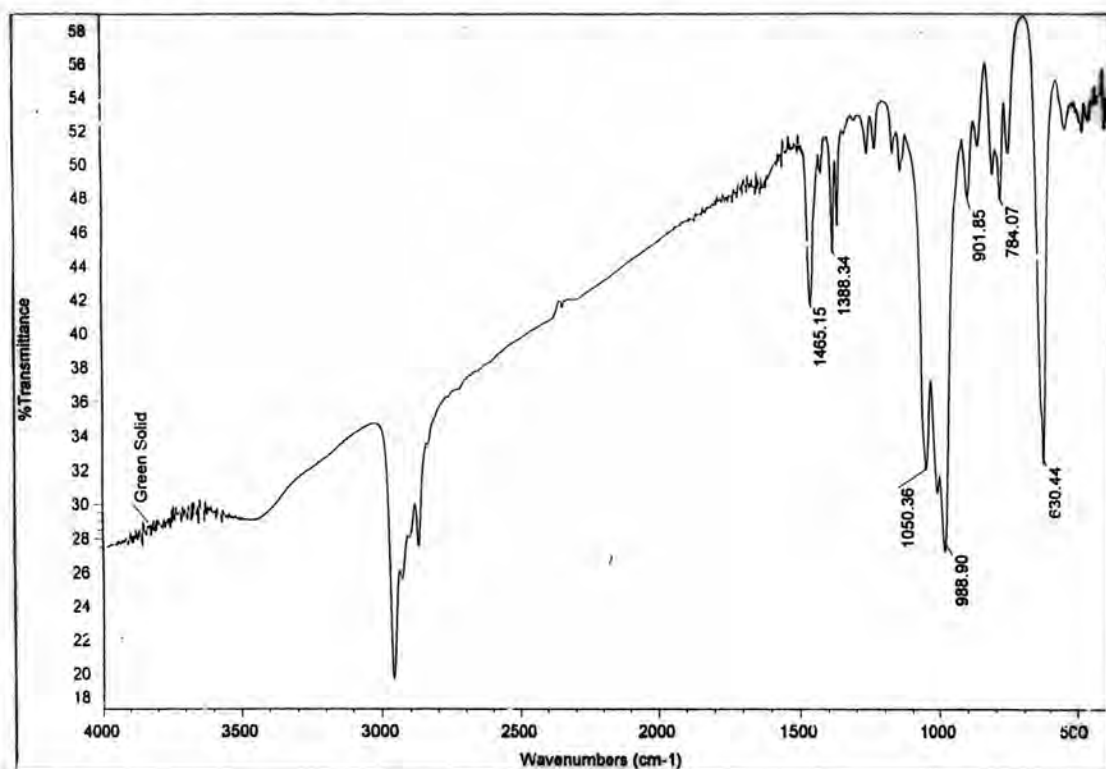
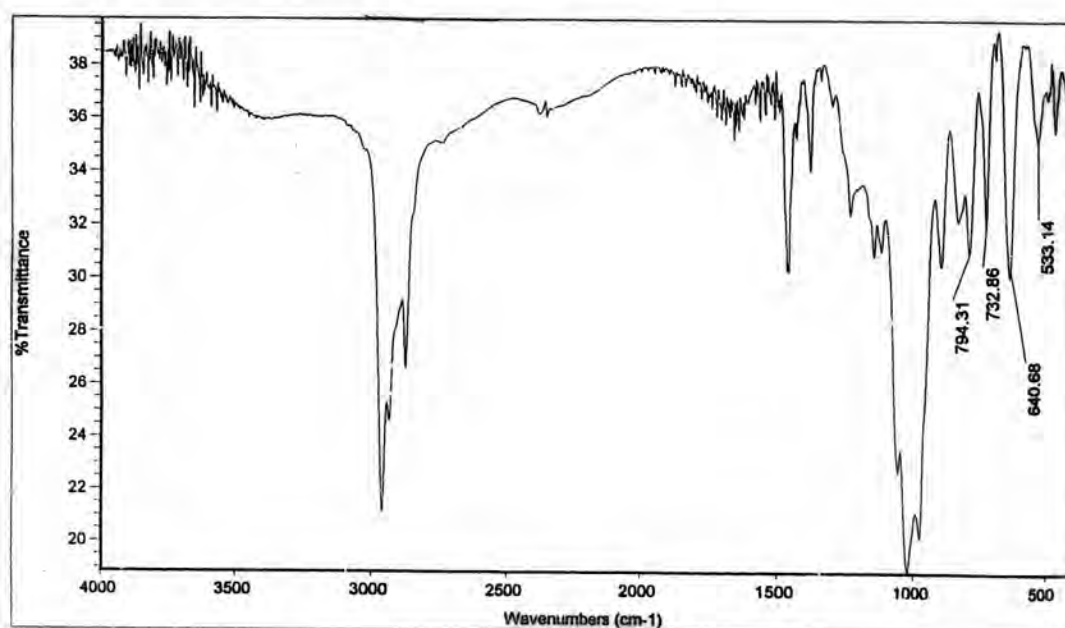
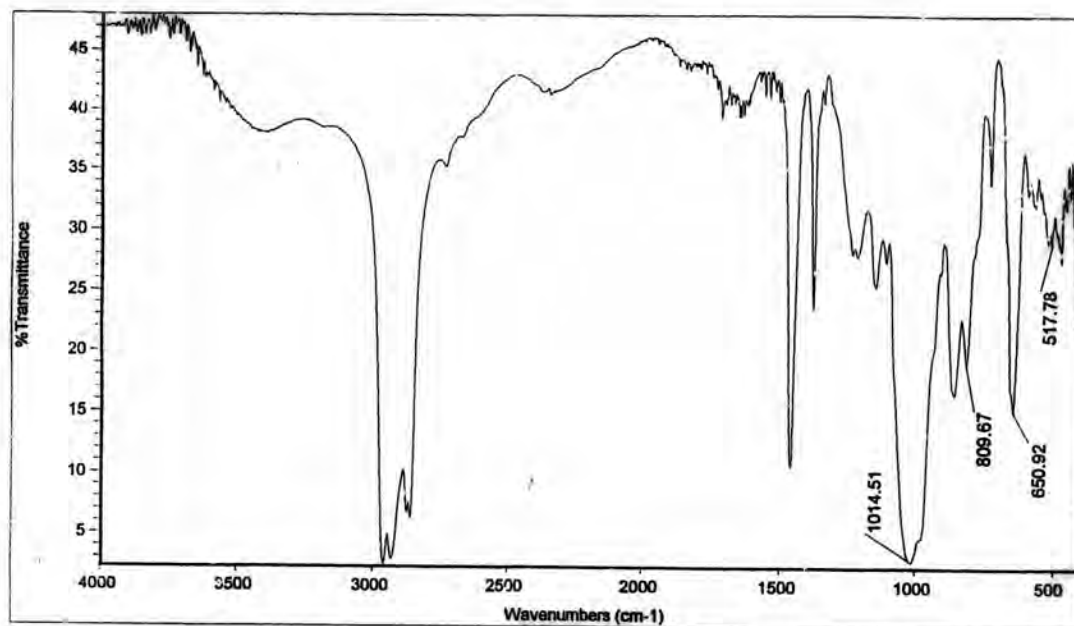
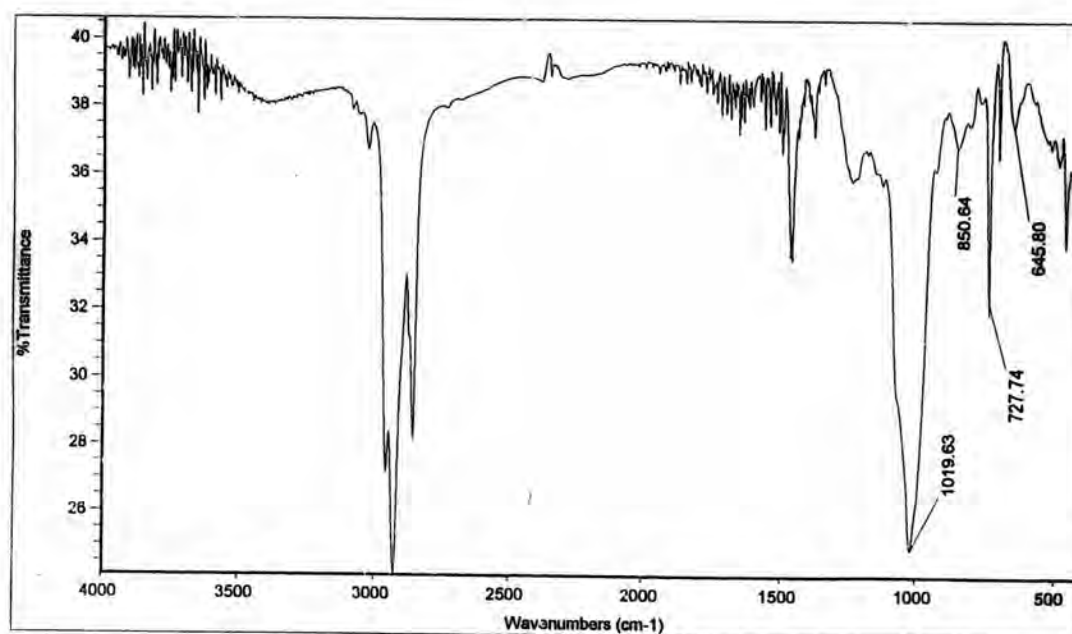
Figure A1-5 FT-IR Spectrum of CuDDP from isoamyl alcohol**Figure A1-6** FT-IR Spectrum of CuDDP from n-butanol

Figure A1-7 FT-IR Spectrum of CuDDP from 2-ethyl hexanol**Figure A1-8 FT-IR Spectrum of CuDDP from n-octanol**

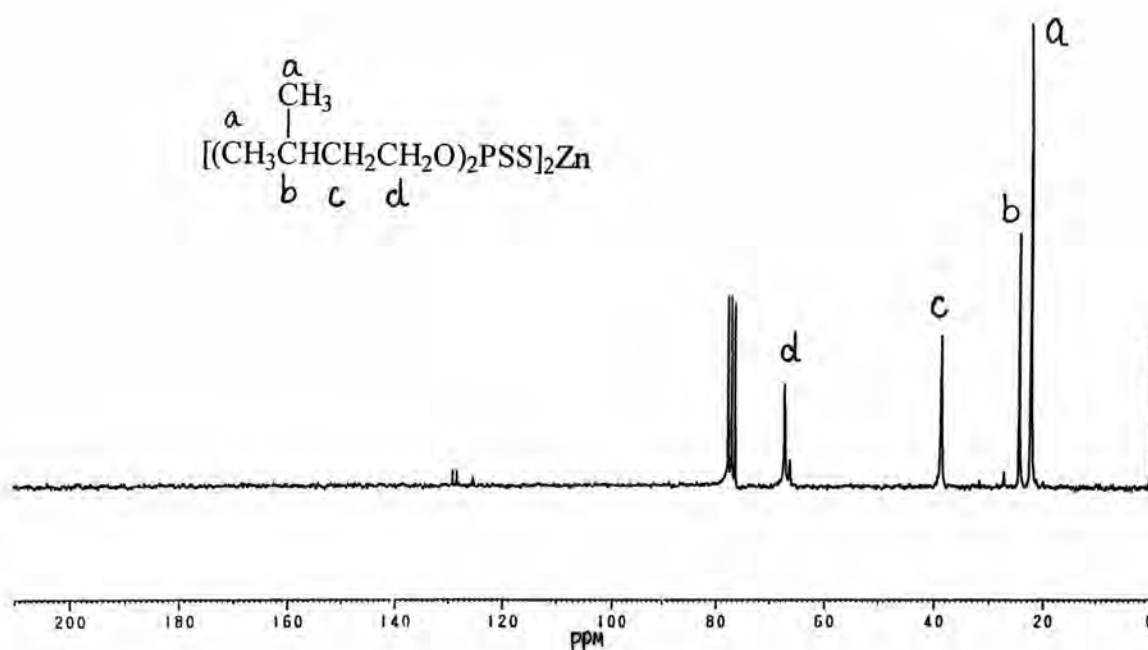
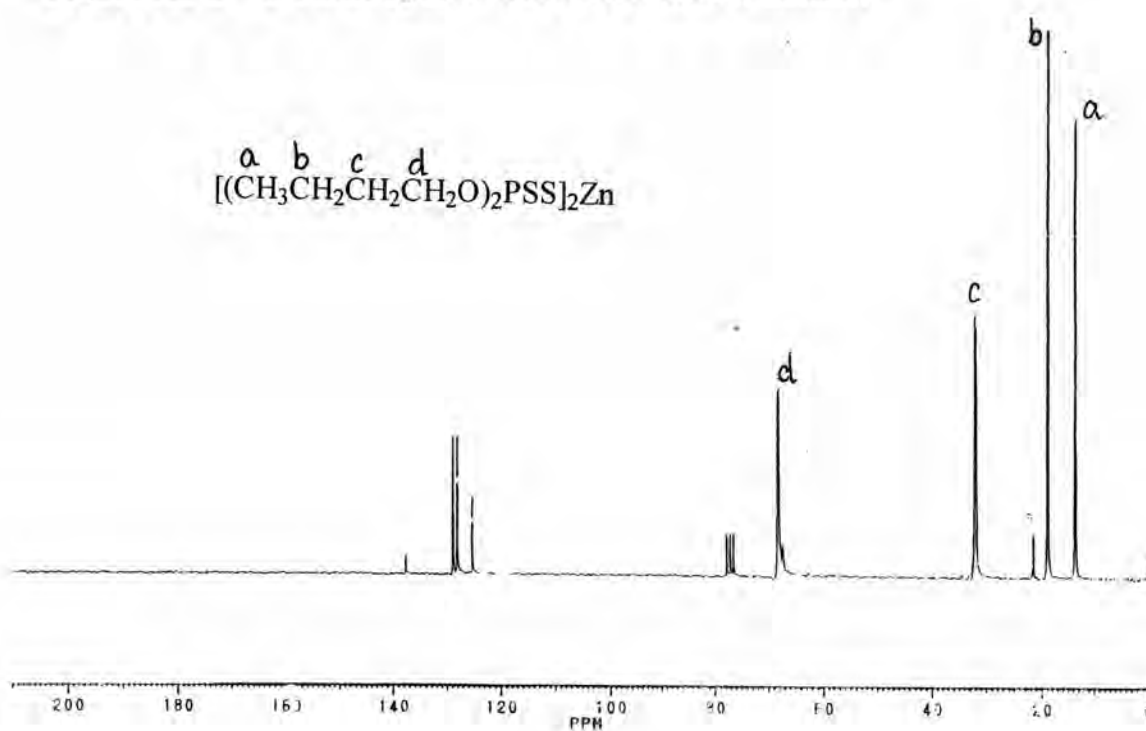
APPENDIX A2 ^{13}C -NMR Spectrum of productsFigure A2-1 ^{13}C -NMR Spectrum of ZDDP from isoamyl alcoholFigure A2-2 ^{13}C -NMR Spectrum of ZDDP from n-butanol

Figure A2-3 ^{13}C -NMR Spectrum of ZDDP from 2-ethyl hexanol

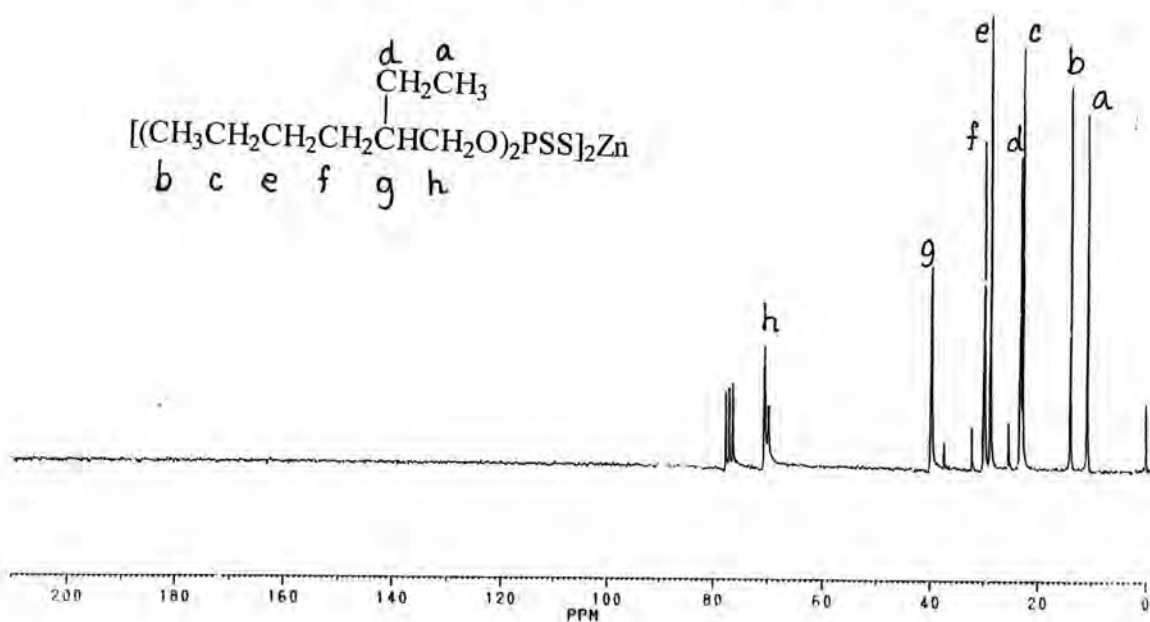


Figure A2-4 ^{13}C -NMR Spectrum of ZDDP from n-octanol

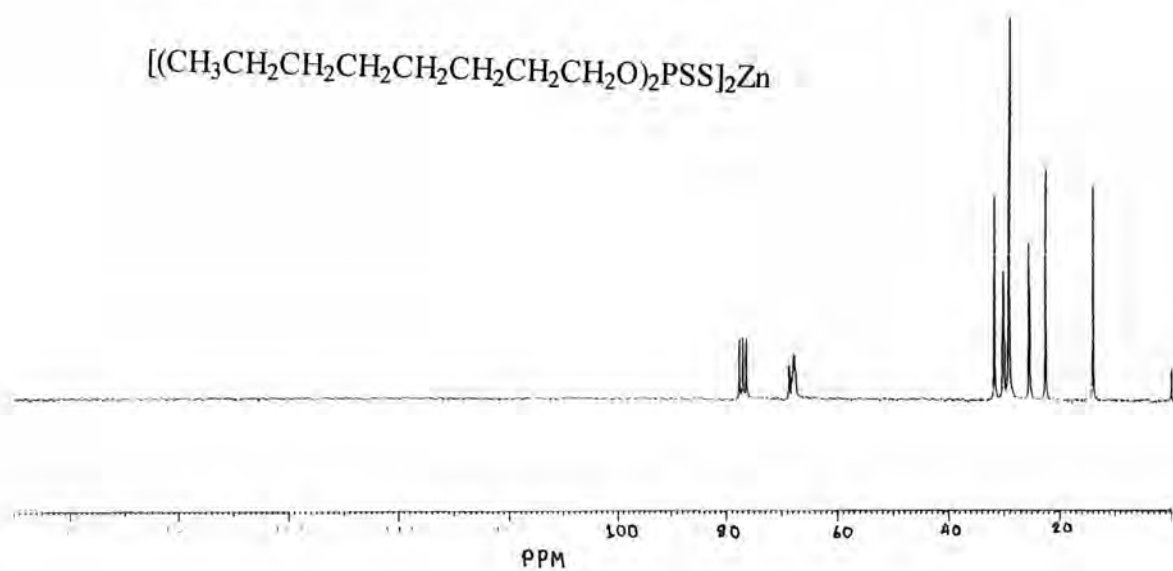


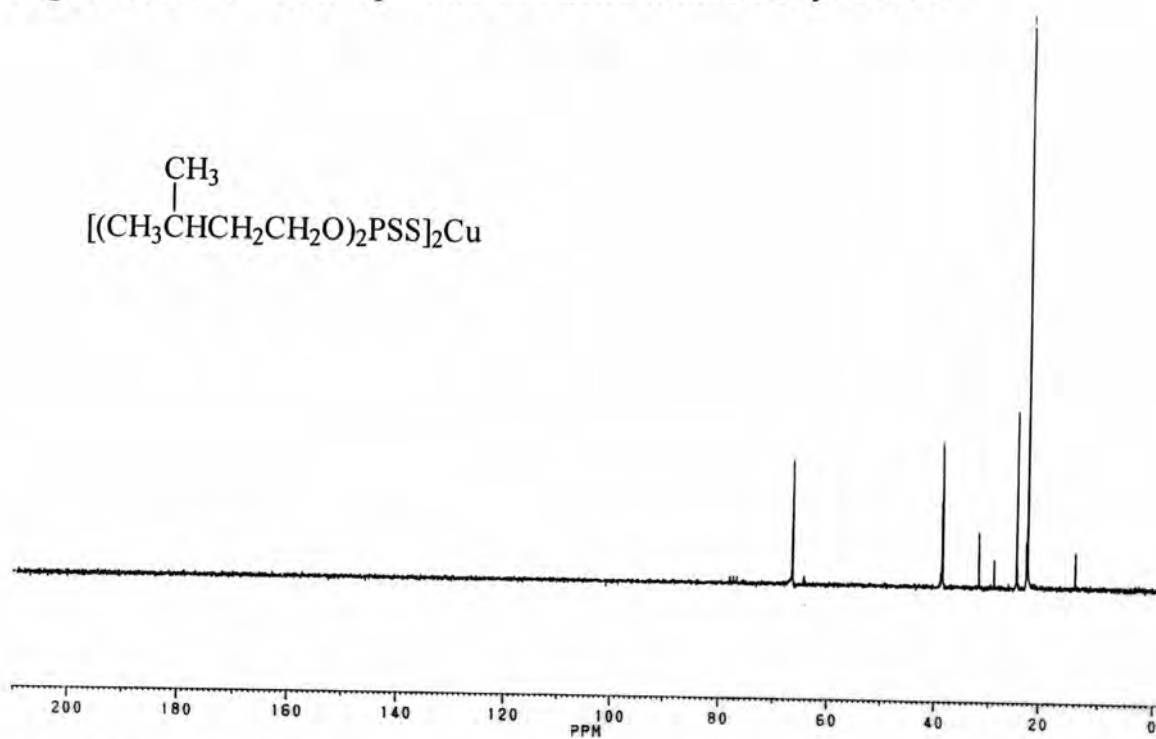
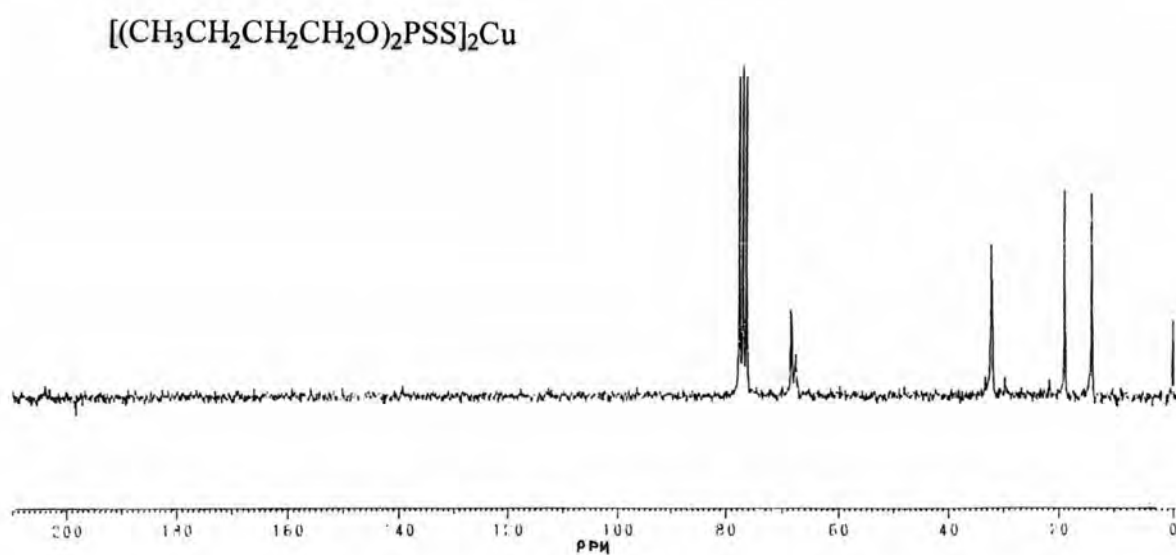
Figure A2-5 ^{13}C -NMR Spectrum of CuDDP from isoamyl alcohol**Figure A2-6** ^{13}C -NMR Spectrum of CuDDP from n-butanol

Figure A2-7 ^{13}C -NMR Spectrum of CuDDP from 2-ethyl hexanol

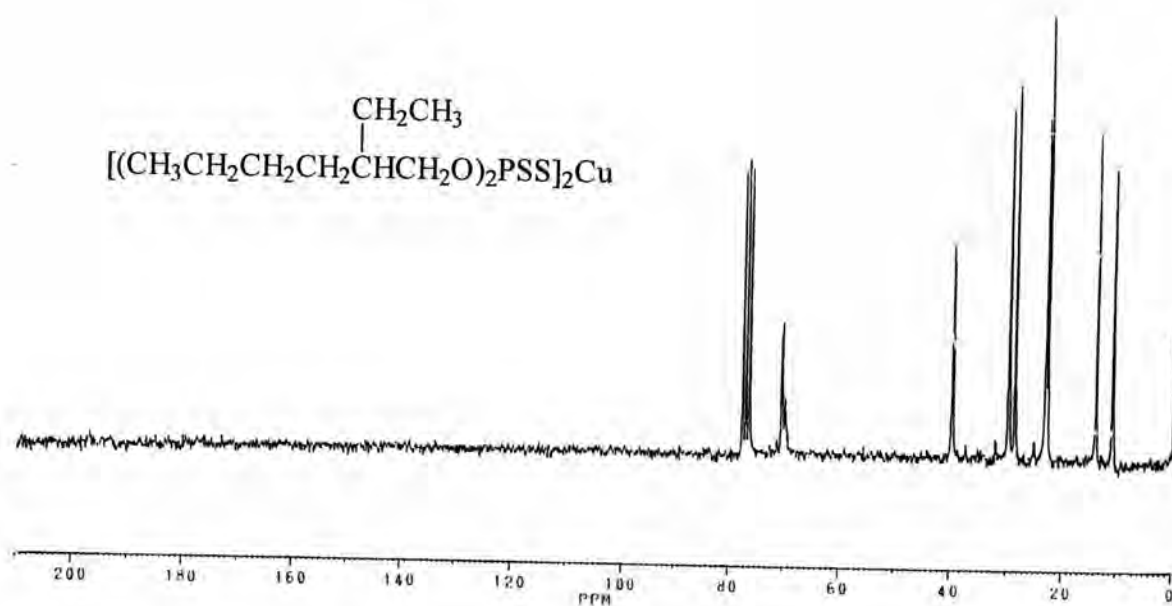
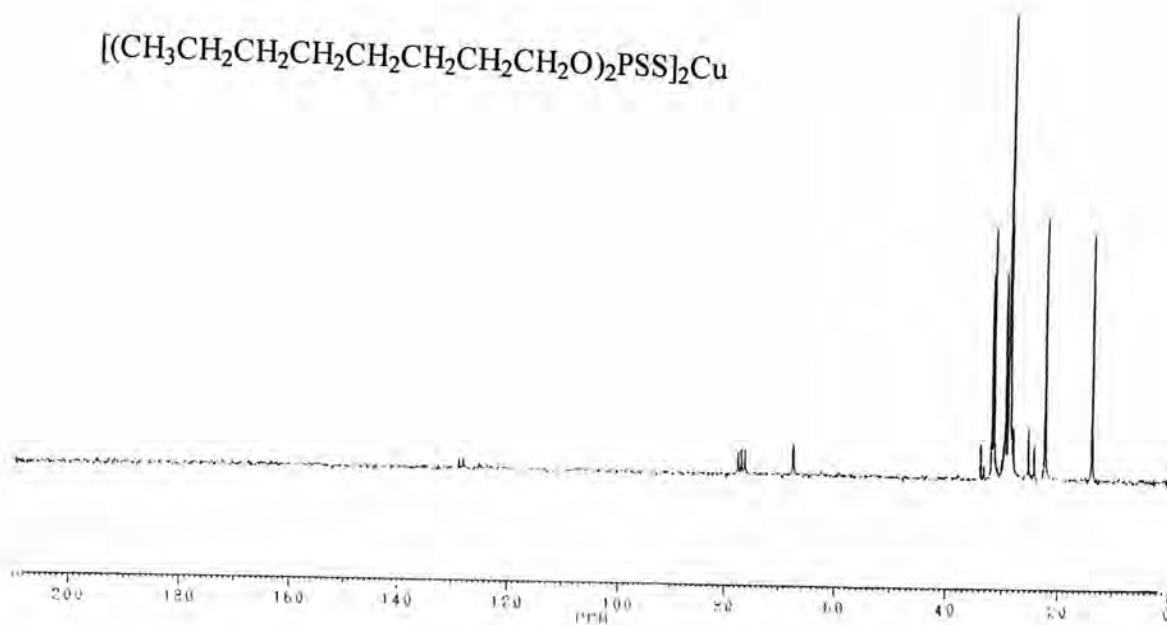


Figure A2-8 ^{13}C -NMR Spectrum of CuDDP from n-octanol



APPENDIX A3 % Composition of products from XRF and EA

Table 1 Composition of ZDDP from isoamyl alcohol

ZDDP	%Zn	%P	%S	%C	%H
Calculated	10.84	10.28	21.20	39.37	7.29
Found	12.91	9.32	18.13	40.81	7.63

Table 2 Composition of ZDDP from n-butanol

ZDDP	%Zn	%P	%S	%C	%H
Calculated	11.95	11.33	23.38	35.07	6.58
Found	11.71	11.65	24.22	34.91	6.34

Table 3 Composition of ZDDP from 2-ethyl hexanol

ZDDP	%Zn	%P	%S	%C	%H
Calculated	8.48	8.04	16.59	49.78	8.82
Found	8.27	7.98	16.21	47.56	7.69

Table 4 Composition of ZDDP from n-octanol

ZDDP	%Zn	%P	%S	%C	%H
Calculated	8.48	8.04	16.59	49.78	8.82
Found	8.19	7.85	16.18	48.81	8.33

Table 5 Composition of CuDDP from isoamyl alcohol

CuDDP	%Cu	%P	%S	%C	%H
Calculated	10.56	10.3	21.3	39.9	7.3
Found	10.15	10.07	20.42	40.21	7.49

Table 6 Composition of CuDDP from n-butanol

CuDDP	%Cu	%P	%S	%C	%H
Calculated	11.64	11.37	23.46	35.20	6.60
Found	10.54	11.21	22.59	34.84	6.47

Table 7 Composition of CuDDP from 2-ethyl hexanol

CuDDP	%Cu	%P	%S	%C	%H
Calculated	8.25	8.06	16.63	49.90	8.84
Found	8.12	8.10	16.67	47.98	8.20

Table 8 Composition of CuDDP from n-octanol

CuDDP	%Cu	%P	%S	%C	%H
Calculated	8.25	8.06	16.63	49.90	8.84
Found	7.96	7.63	15.94	48.72	8.74

Table 9 Composition of MoDDP from isoamyl alcohol

MoDDP	%Mo	%P	%S	%C	%H
Calculated	24.18	7.81	16.12	5.54	8.06
Found	0	11.92	17.79	8.72	12.71

Table 10 Composition of SnDDP from isoamyl alcohol

MoDDP	%Sn	%P	%S	%C	%H
Calculated	9.96	10.38	21.42	7.36	10.71
Found	0	12.36	17.93	8.83	11.81

APPENDIX A4 Thermogram from TGA

Figure A4-1 Thermogram of pure lubricating based oil

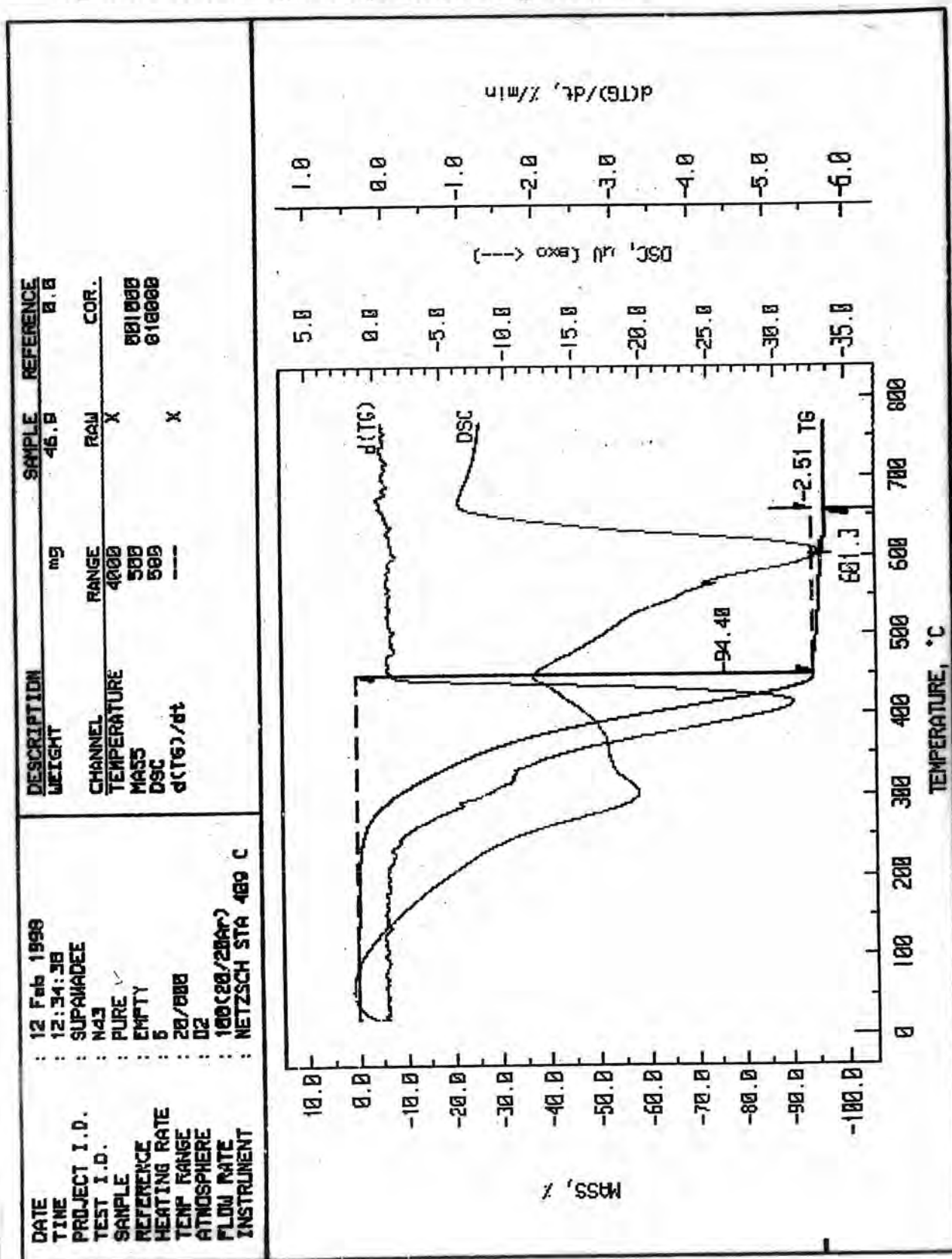


Figure A4-2 Thermogram of lubricating based oil with 0.5% concentration ZDDP

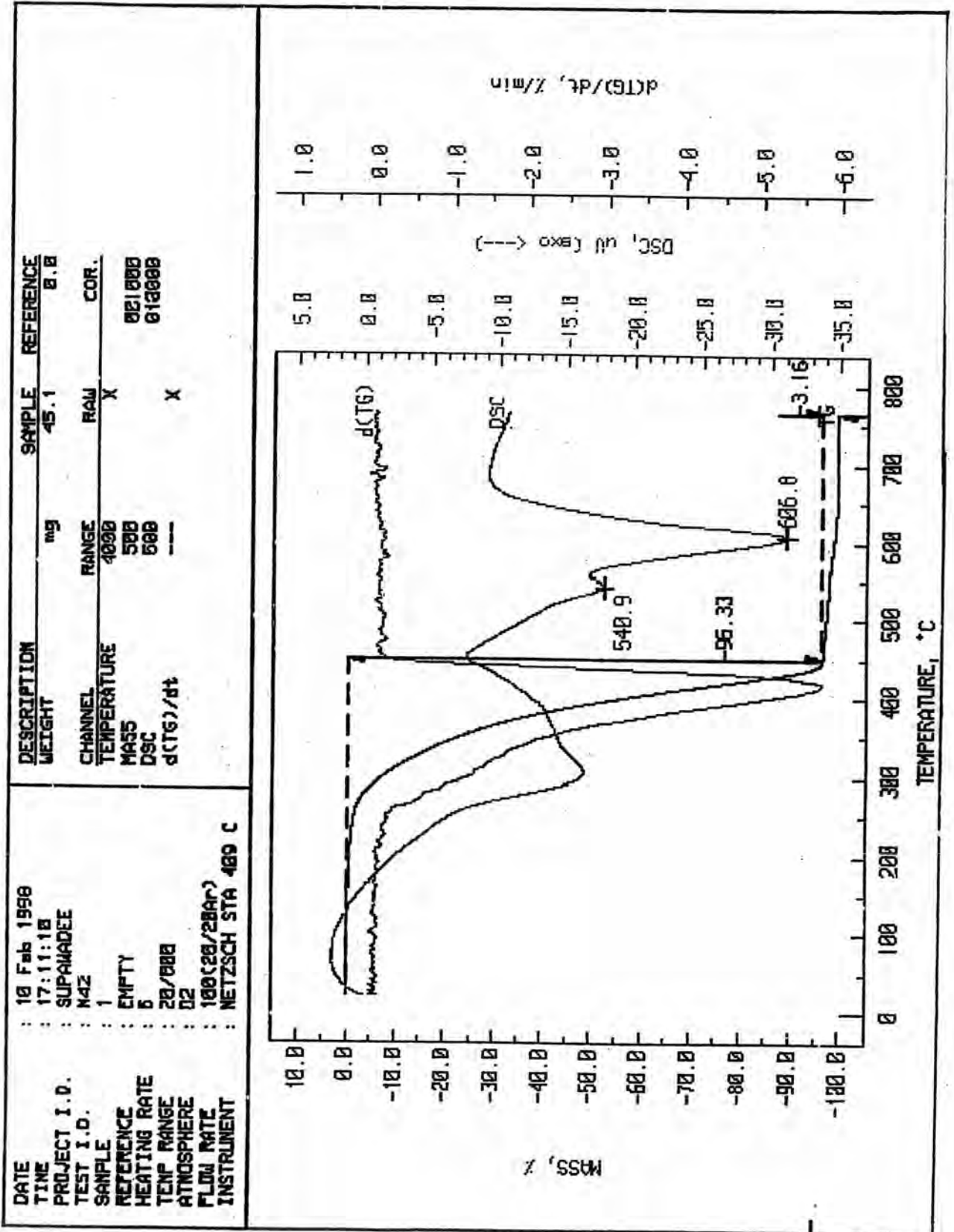


Figure A4-3 Thermogram of lubricating based oil with 1% concentration ZDDP

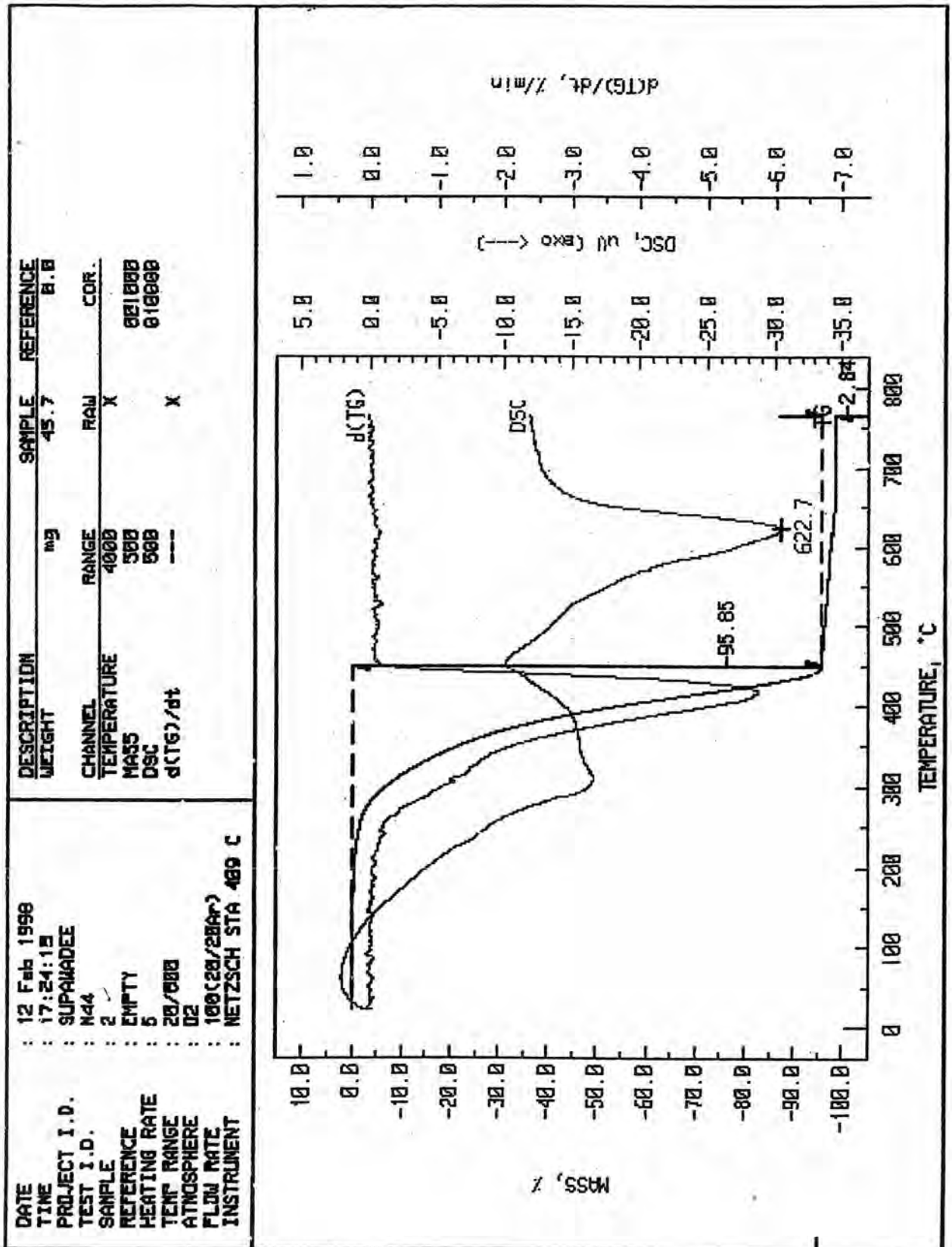


Figure A4-4 Thermogram of lubricating based oil with 1.5% concentration ZDDP

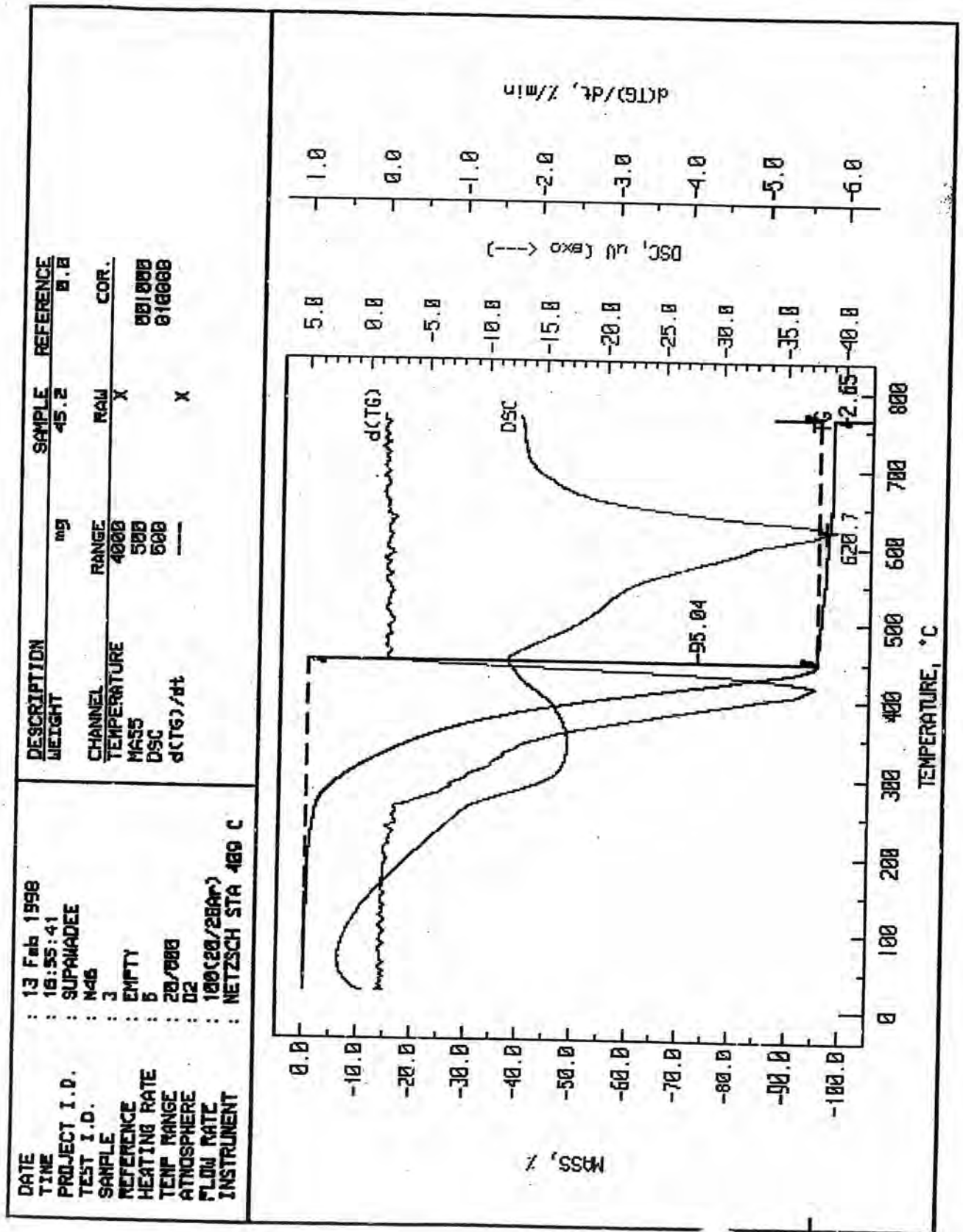


Figure A4-5 Thermogram of lubricating based oil with 2% concentration
ZDDP

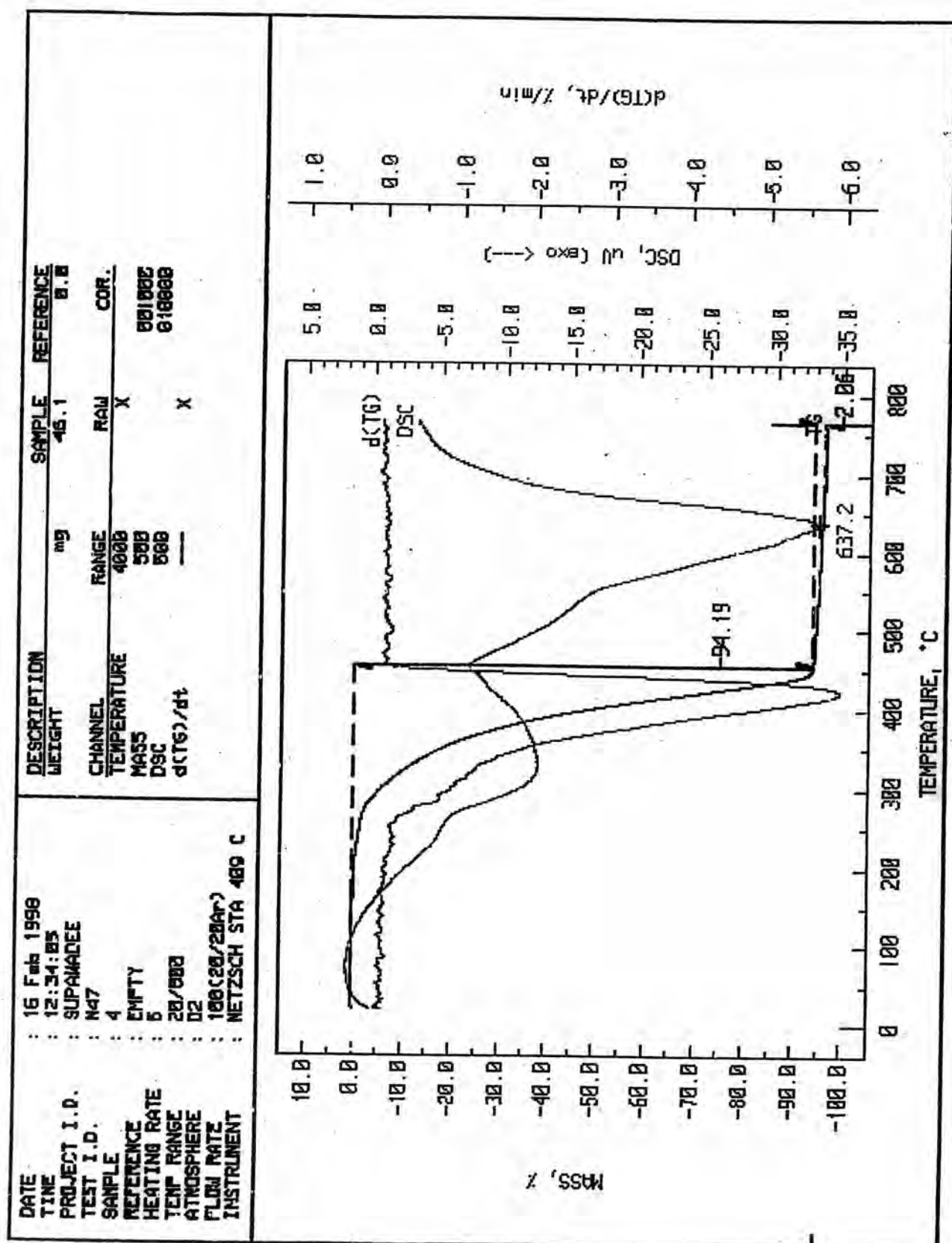


Figure A4-6 Thermogram of lubricating based oil with 0.5% concentration
CuDDP

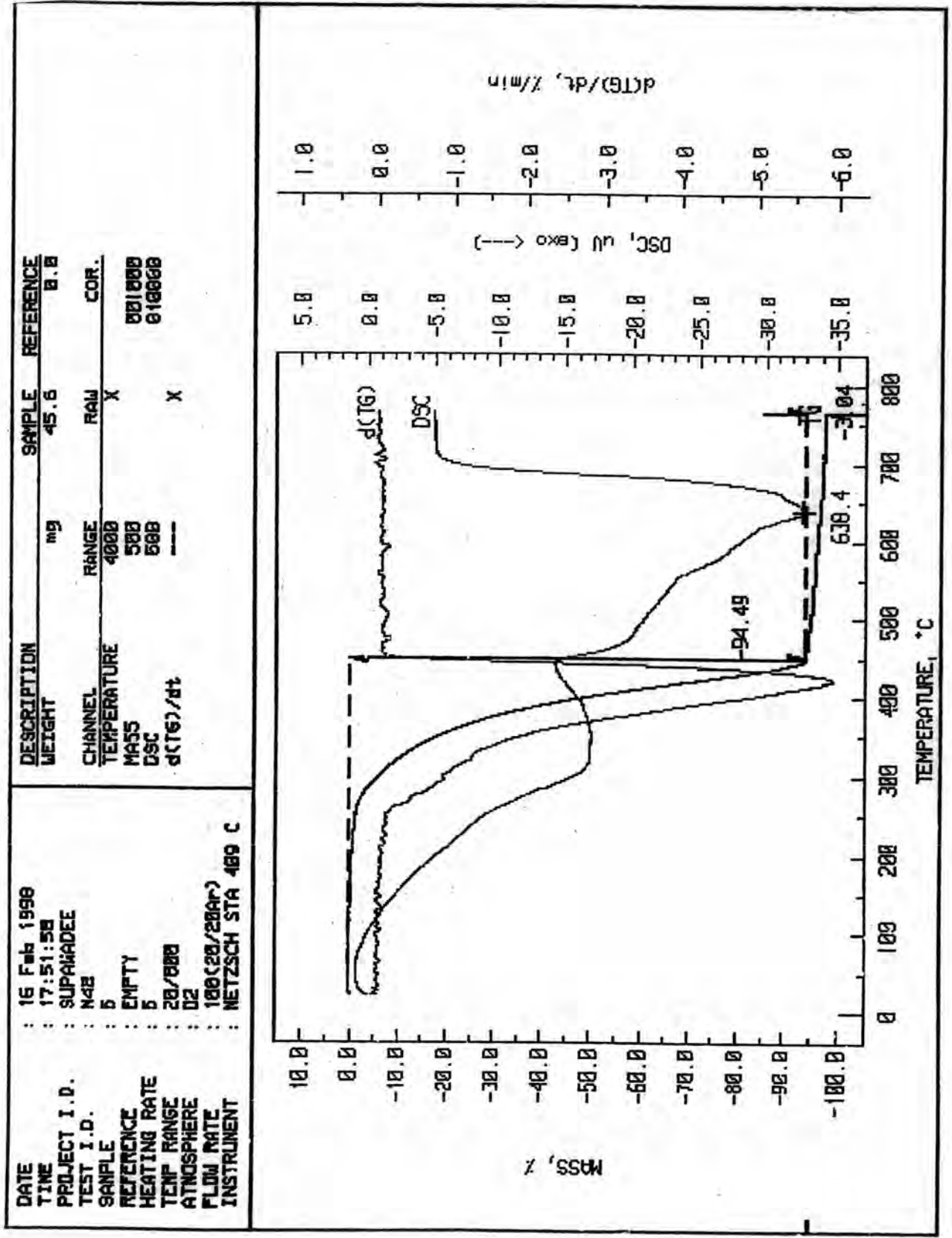


Figure A4-7 Thermogram of lubricating based oil with 1% concentration
CuDDP

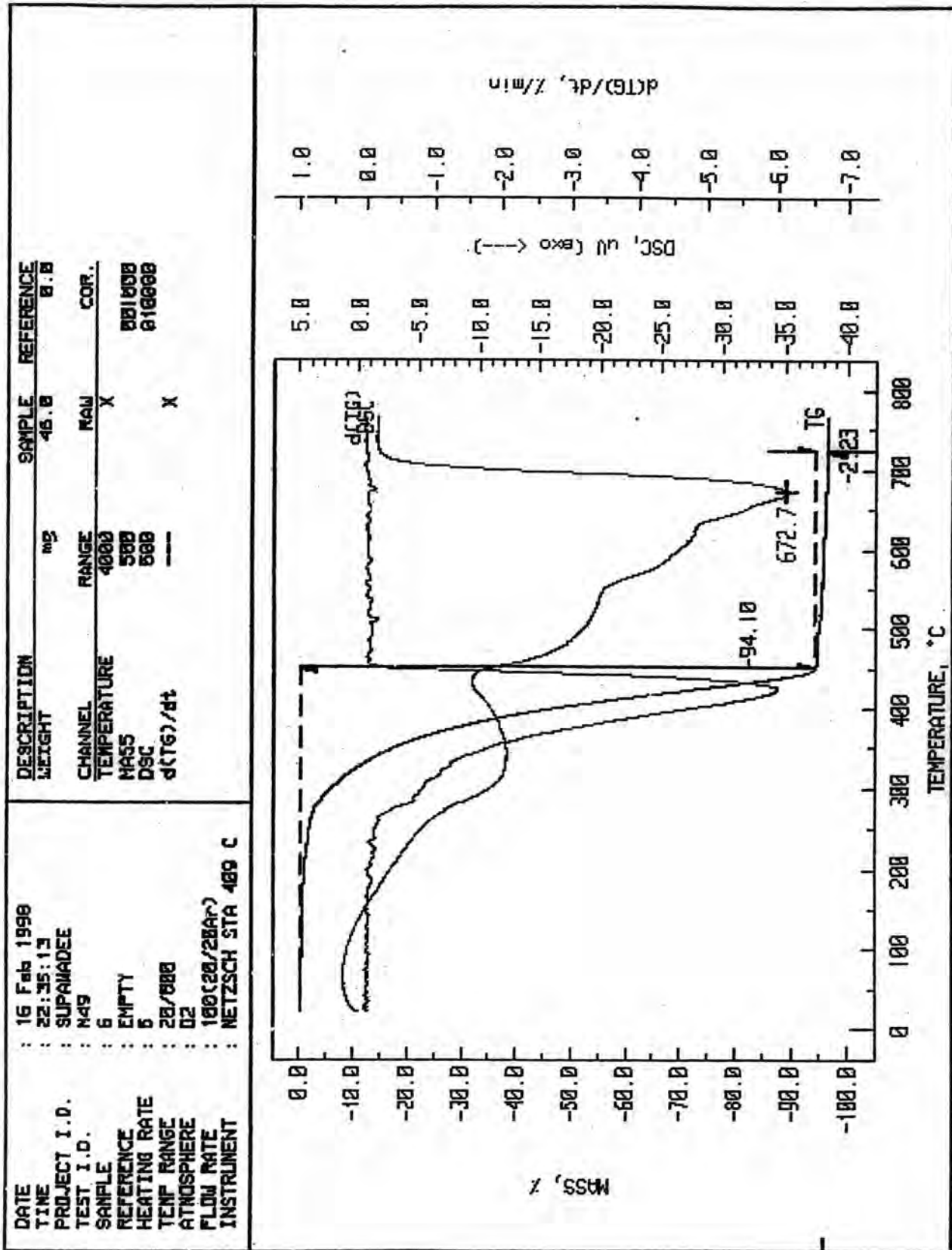


Figure A4-8 Thermogram of lubricating based oil with 1.5% concentration

CuDDP

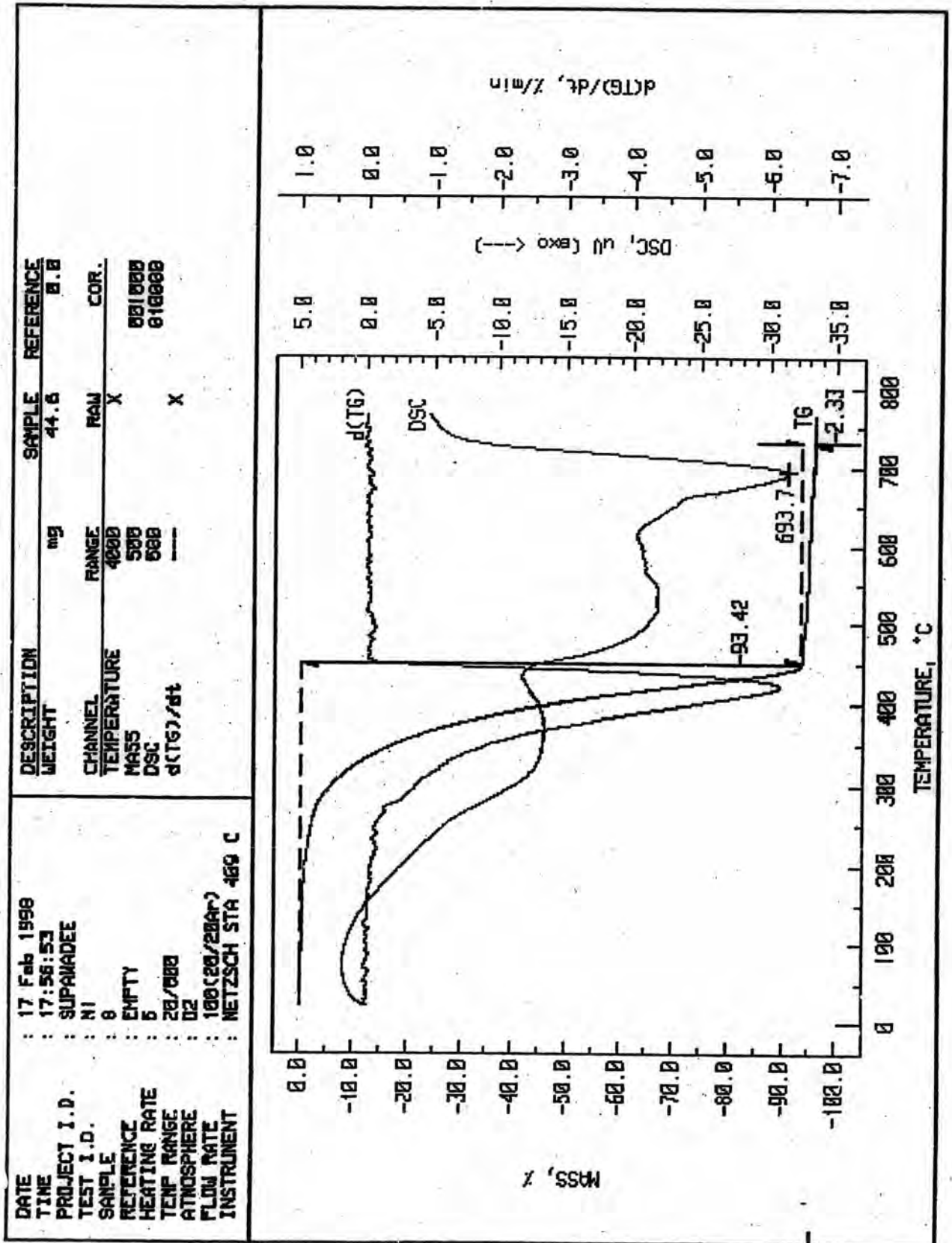


Figure A4-9 Thermogram of lubricating based oil with 2% concentration
CuDDP

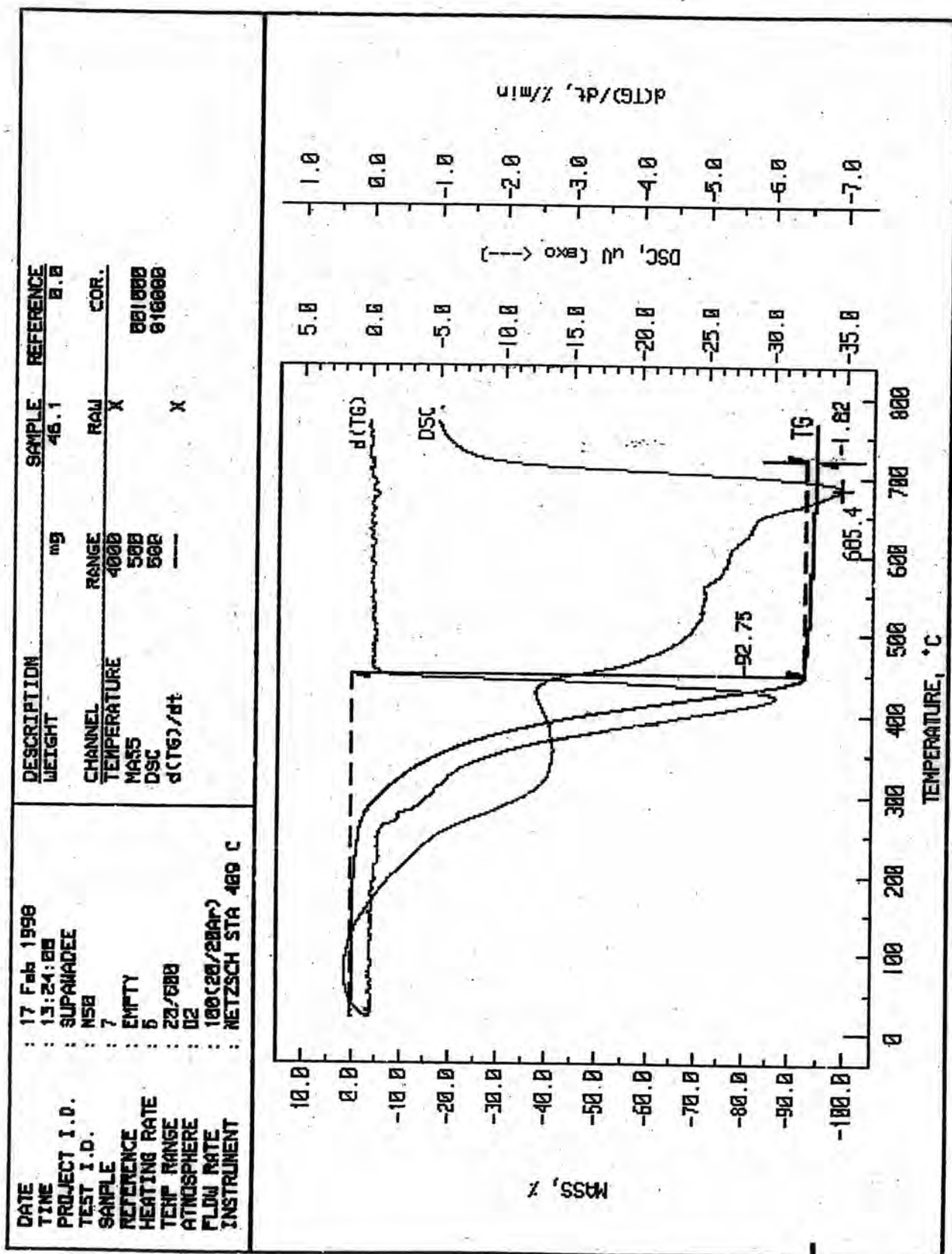
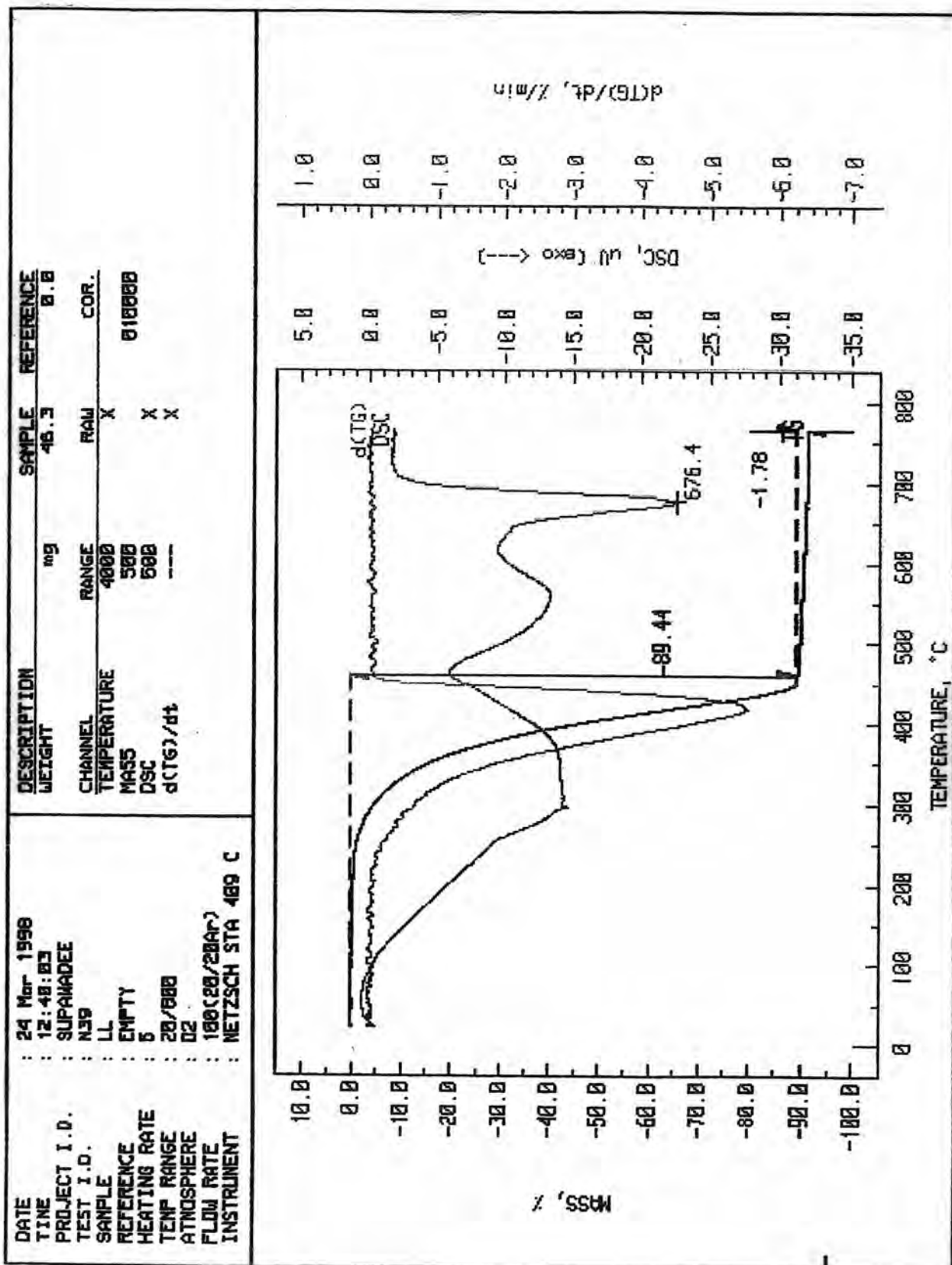


Figure A4-10 Thermogram of lubricating based oil with 7.7% concentration
ZDDP commercial



APPENDIX B Calculation of TAN from ASTM D974 Standard test method for acid and base number by color-indicator titration

Calculate the acid number as follows :

$$\text{Acid number, mg of KOH/g} = [(A-B)M \times 56.1] / W$$

where:

A = KOH solution required for titration of the sample, ml,

B = KOH solution required for titration of the blank, ml,

M = molarity of the KOH solution, and

W = sample used, g.

VITA

Miss. Supawadee Rakchitt was born on May 9, 1972 in Chonburi. She received her Bachelor of Science degree in Industrial Chemistry from the Department of Chemistry, Faculty of Science, King Mongkut's Institute of Technology, Ladkrabang in 1994. She began her graduate studies in the program of Petrochemistry and Polymer, Graduate School, Chulalongkorn University in 1995 and completed the program in 1998.