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Canada Centre for Mineral and Energy Technology / Centre canadien de la technologie des minéraux et de l'énergie

THERMAL PROPERTIES OF DOPED AMMONIUM NITRATE.
PART 1. EVALUATION USING ACCELERATING RATE CALORIMETRY

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ABSTRACT

The thermal stability of three ammonium nitrate (AN) samples, KNO_3 doped, NiO doped and CuO doped, were evaluated using an accelerating rate calorimeter and they were compared to A.C.S. grade AN. The onset decomposition temperature of NiO doped AN was detected at 235°C which indicates higher stability than KNO_3 doped AN and CuO doped AN. KNO_3 doped AN sample produces more residue after ignition, approximately 14%.

KEYWORDS: ammonium nitrate, potassium nitrate, nickel oxide, copper oxide, thermal stability, accelerating rate calorimetry.

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PROPRIÉTÉS THERMIQUES DU NITRATE D'AMMONIAQUE DOPÉ
PARTIE 1. ÉVALUATION D'ÉCHANTILLONS DE NITRATE D'AMMONIAQUE AU MOYEN DE LA CALORIMÉTRIE À VITESSE ACCÉLÉRÉE

P.P. Lee* et R.R. Vandebeek**

RÉSUMÉ

La stabilité thermique de trois échantillons de nitrate d'ammoniaque (NA) additionnés de KNO_3, de NiO et de CuO a été évaluée au moyen d'un calorimètre à vitess accélérée, et comparée à celle du nitrate d'ammoniaque de qualité A.C.S. Au départ, la température de décomposition du nitrate d'ammoniaque additionné de NiO était de 235°C, ce qui indique une stabilité plus élevée que la température de décomposition de l'échantillon de nitrate d'ammoniaque additionné de KNO_3 et que celle de l'échantillon additionné de CuO. L'échantillon de nitrate d'ammoniaque additionné de KNO_3 est celui qui a produit la plus grande quantité de résidus après l'inflammation, soit environ 14%.

MOTS CLÉS: nitrate d'ammoniaque, nitrate de potassium, oxyde de nickel, oxyde de cuivre, stabilité thermique, calorimétrie à vitesse accélérée.

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INTRODUCTION

Ammonium nitrate (AN) is attractive for use in propellants and explosives because it can be obtained technically in a very pure state, it is chemically stable and it has low sensitivity to friction and shock. The restrictions to use are its hygroscopic property and its five polymorphic forms. At atmospheric pressure it can exist in five modifications from below -18°C to its melting point at 169.6°C. These phase transitions and the effects of the additives on these phase changes have been investigated. The phase transitions can be influenced by purity, thermal history, moisture content and crystallographical inhomogeneities as reported previously [1-9].

During the heating and cooling thermal cycle, AN experiences volume changes at phase transitions. Particularly at 32°C, crystal form IV changes to form III, which involves a volume change of 3.6% [7]. This expansion or contraction occurs in the temperature range of use of rocket motors or explosives. There have been failures of rocket motors, as a result of excessive pressure caused by cracks and excess burn surface resulting from the undesirable expansion and contraction. Much work has been done to overcome these difficulties. Some compounds such as NiO, CuO, ZnO, MgO, KNO_3, KF have been used in modifying the phase transition temperature [1-9]. Mishra reported that the addition of 10-17% by weight of potassium nitrate results in a large amount of residue in the combustion products and it tends to corrode and plug the rocket nozzle. A development patented by Mishra [10] provides solution to the above problems. The addition of 0.5 to 2% by weight of KF eliminated the undesirable volume changes in the temperature range of use of ammonium nitrate in rocket motor and explosives (-55°C to 80°C).

The thermal stability of ammonium nitrate has been extensively studied. It is a relatively stable compound which first decomposes and then explodes if heated while confined [11,12]. When ammonium nitrate is heated, it decomposes exothermically into nitrous oxide and water. At the same time, it dissociates endothermically into ammonia and nitric acid. As a result of these two concurrent reactions, the molten mass of nitrate tends to reach a steady-state temperature, which is a function of ambient pressure and of the heating rate [13]. The thermal decomposition of fertilizer grade AN prills and AN in the presence of transition metals has also been examined by ARC [14-17].

A number of established thermal stability test techniques are widely used in evaluating hazards associated with runaway exothermic reactions. Micro-thermal techniques such as differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) use very small sample sizes which can introduce non-representative sampling problems with heterogeneous samples. Macro-thermal techniques, e.g. accelerating rate calorimetry (ARC) and the sensitive detector of exothermic process (SEDEX), tend to be used specifically for the detection of exothermic behaviour in considerably larger size samples. The ARC records lower initial temperatures for exothermic reactions due to heat accumulation effects [18]. Its limitation is that no quantitative data can be obtained for endotherm.

The Canadian Explosives Research Laboratory is equipped to evaluate thermal hazards of energetic materials. An accelerating rate calorimeter (ARC) has been used for evaluation of thermal hazards of materials associated with exothermic reactions. Differential scanning calorimetry (DSC) is an established analytical technique. Particularly it is useful to compensate for the weakness that the quantitative data of endotherms are not accessible by ARC. This report, part 1 of 2, describes the use of ARC to study the exothermic reaction of doped AN. Part 2 describes the influence of dopants on the phase transitions of AN and a discussion on the reactions occurring above the melting point under different degrees of confinement using DSC technique.

EXPERIMENTAL

Materials

Three doped ammonium nitrate samples were obtained from Defence Research Establishment Valcartier (DREV) and stored at room condition for evaluation. A.C.S. grade ammonium nitrate stored in a desiccator was used for comparison. The samples are listed as follows:

1. Ammonium nitrate, A.C.S. grade, white crystal, obtained from Anachemia Chemicals Ltd.

2. Ammonium nitrate and KNO_3, DREV lot # TP-8619, beige coloured powder.

3. Ammonium nitrate and NiO, DREV lot # TP-8629, green coloured powder.

4. Ammonium nitrate and CuO, DREV lot # TP-8630, blue coloured powder.

Accelerating Rate Calorimetry (ARC)

Thermal decomposition of ammonium nitrate samples has been studied by ARC. This instrument was made by Columbia Scientific Industries in Austin, Texas. It was designed to maintain the sample in a near perfect adiabatic environment. Heat from the decomposition reaction is held in the reaction mass and the decomposition proceeds as a self-accelerating reaction. The theories and operation have been published [19,20] and will not be discussed in this paper.

All measurements were conducted using wide-mouth cylindrical Hastelloy C bombs weighing approximately 49 grams each. Six stainless steel screws secured a thin metal disk and a Teflon gasket to a flange on the bomb. Approximately 1 gram samples were accurately weighed into the sample container which resulted in a Ø value of about 12. Ø value is defined as:

$$\text{Ø} = 1 + \frac{C_V\,(\text{bomb})\,M(\text{bomb})}{C_V\,(\text{sample})\,M\,(\text{sample})}$$

where C_V is the specific heat and M is the mass.

The step-heat method was employed in all the tests. First the sample and the bomb were heated to a start temperature of 100°C. Then the calorimeter was allowed to thermally stabilize for 30 minutes. Next came the search mode where the self-heat rate was monitored at a threshold detection limit of 0.02°C/min. The process of "heat-wait-search" was continued until a self-heat greater than 0.02°C/min was detected. After the detection of an exotherm, time and temperature data were collected until the end of the reaction.

RESULTS ANND DISCUSSION

The thermal stability of three samples, KNO_3 doped AN, NiO doped AN and CuO doped AN were examined by ARC. An A.C.S. grade ammonium nitrate crystal was used for comparison. Approximately 1.5 gram of A.C.S. grade ammonium nitrate was used for testing which resulted in a Ø value of 9. While 1 gram of the doped AN was used due to its reactivity.

For A.C.S. grade AN, an increase in the self-heat rate was detected at a temperature above 195°C. The first exotherm occurred and terminated after a short time. Taking the average of three repeated tests, the exotherm leading to ignition was detected at 218°C. Plots of self-heat rate as a function of 1/T are compared in Fig. 1 and the data are detailed in Table 1. Total weight loss after reaction was 98%.

When the KNO_3 doped AN was heated to 170°C (just above the melting point) and cooled, it separated into two layers with two different colours, white and beige. The first increase in self-heat rate occurred at 200°C and the onset temperature leading to ignition took place at 220-230°C with an average temperature of 225°C. In the early stages of decomposition, the reproducibility of the onset temperature was poor but the values became more consistent at a rate above 0.1°C/min as shown in Fig. 2. The amount of residue after reaction is approximately 14%.

TABLE 1

THERMAL DECOMPOSITION OF DOPED AMMONIUM NITRATE SAMPLES

RUN #	SAMPLE WT. (gm)	Ø	INITIAL DATA		AT 0.1 °C/min		AT 2 °C/min		AT MAX. RATE		ΔT_{AB} (°C)	WT. LOSS (%)	2 °C/min TO MAX RATE TIME (min)
			T_o (°C)	M_o (°C/min)	T (°C)	M (°C/min)	T (°C)	M (°C/min)	T_m (°C)	M_m (°C/min)			
AMMONIUM NITRATE (A.C.S. GRADE)													
200	1.5237	8.9	218.75	0.028	235.37	0.101	267.42	2.066	289.25	102.000	76.48	98.2	3.15
206	1.5058	9.0	215.46	0.022	233.08	0.107	262.54	2.050	286.73	112.666	75.45	98.1	3.24
379	1.5134	8.8	221.66	0.026	234.26	0.098	264.25	2.000	291.92	110.500	75.14	----	3.92
AN + KNO_3 (TP-8619)													
380	1.0406	12.7	231.57	0.029	241.60	0.103	261.27	2.033	290.98	107.714	60.43	87.3	3.16
384	1.0670	12.2	224.53	0.022	239.18	0.100	263.72	2.000	291.44	170.000	68.01	83.3	2.83
389	1.0130	12.8	219.33	0.030	236.95	0.100	261.37	2.105	279.18	105.000	67.82	87.6	3.01
AN + NiO (TP-8629)													
383	1.0370	13.1	232.72	0.024	246.75	0.104	272.28	1.935	294.14	59.500	65.10	91.5	3.13
386	1.0520	12.2	236.45	0.039	243.07	0.102	266.61	2.000	283.82	120.500	59.31	94.8	2.94
387	1.1135	11.9	236.07	0.024	238.68	0.108	267.15	1.909	294.74	47.500	61.44	95.1	3.73
AN + CuO (TP-8630)													
385	1.0160	12.2	221.97	0.047	233.99	0.102	259.52	2.105	290.04	126.666	68.07	93.5	3.32
388	1.0945	11.8	226.49	0.029	234.10	0.106	259.13	2.000	282.67	105.833	58.54	93.7	3.33
390	1.1068	11.8	226.40	0.031	235.42	0.107	265.56	1.937	287.79	117.500	68.06	93.7	3.53

For the NiO doped AN, an increase in the self-heat rate was detected at 220°C. The initial rate data of the major exotherm was found to average 235°C for the three tests (Fig. 3). Weight loss averaged 94%.

The third sample tested (CuO doped AN) indicated an increase in the self-heat rate at 215°C. Initial temperature for the major exothermic reaction was 225°C and the decomposition curves are shown in Fig. 4. Total weight loss was 94%.

After the melting point and before the exotherm leading to ignition, the doped AN samples showed instability with slow increase in self-heat rate as a general phenomenon. Usually the self-heat rate fluctuated at the region of detection limit and it varied slightly for each test. The reaction profile for the initial decomposition is complicated probably as a result of the properties of complex components in the doped AN.

All AN samples ignited with pressure built up and the cover disks were distorted after reaction. When the reaction rate is too fast, the thermocouple cannot accurately track the temperature. Therefore a temperature was determined at a self-heat rate of 2°C/min and it was defined as before ignition. The time from before ignition to maximum rate was about 3 minutes and it should raise some concern in hazard evaluation.

When the experimental results are interpreted, it is necessary to consider the type of test equipment and the experimental conditions employed. There are many factors that can affect the determined values. It includes sample size, method of heating, rate of heating and nature of sample. Hence, the application of these results should be considered carefully.

CONCLUSION

The onset decomposition temperature of NiO doped AN was detected at 235°C which is higher than the other two samples. However, when overall decomposition patterns are compared, more variations are found for the NiO doped products. One advantage of the NiO doped AN over the KNO_3 doped product is the reduced amount of solid residue in the combustion products.

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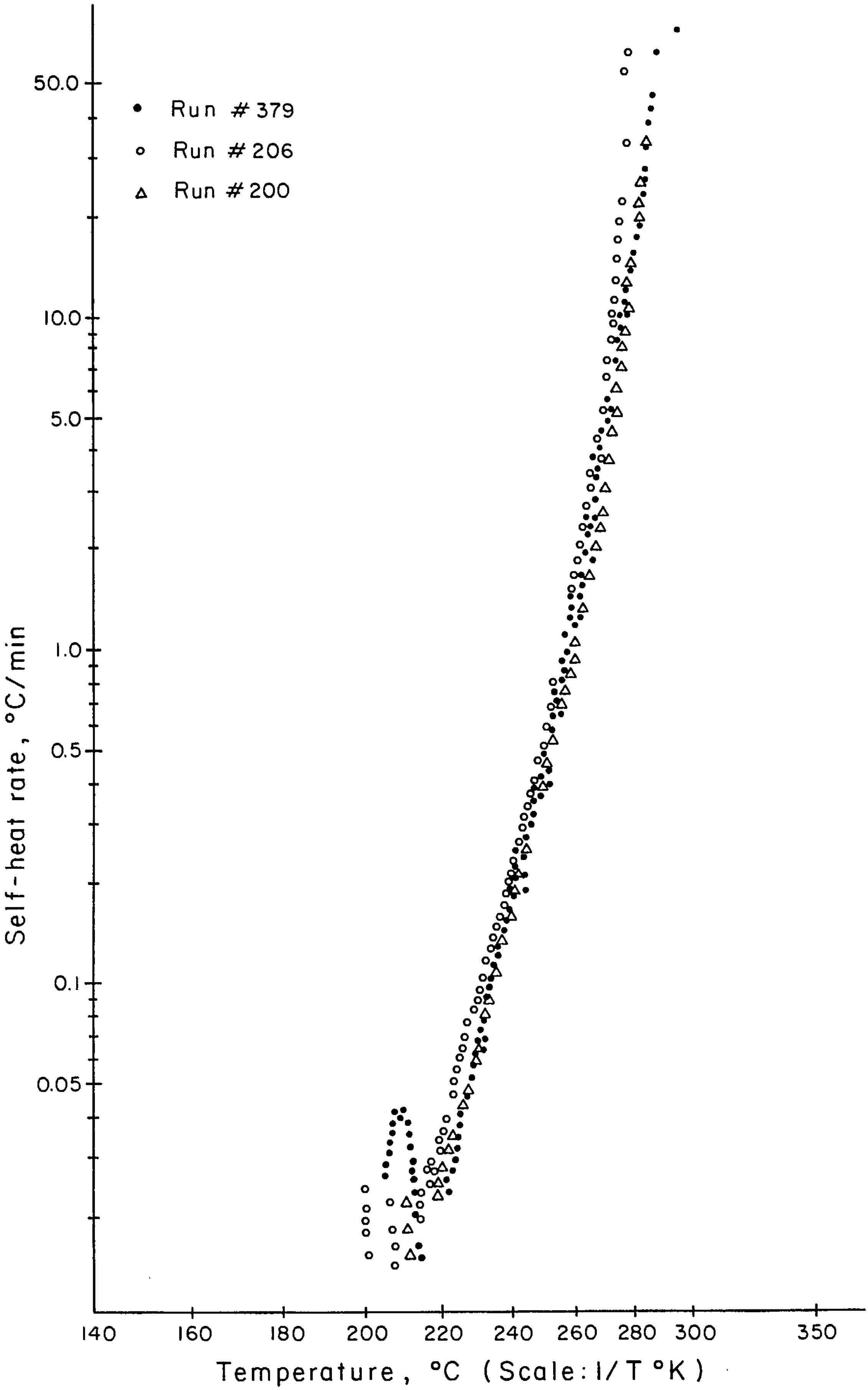

Fig. 1 - Thermal decomposition of ammonium nitrate.

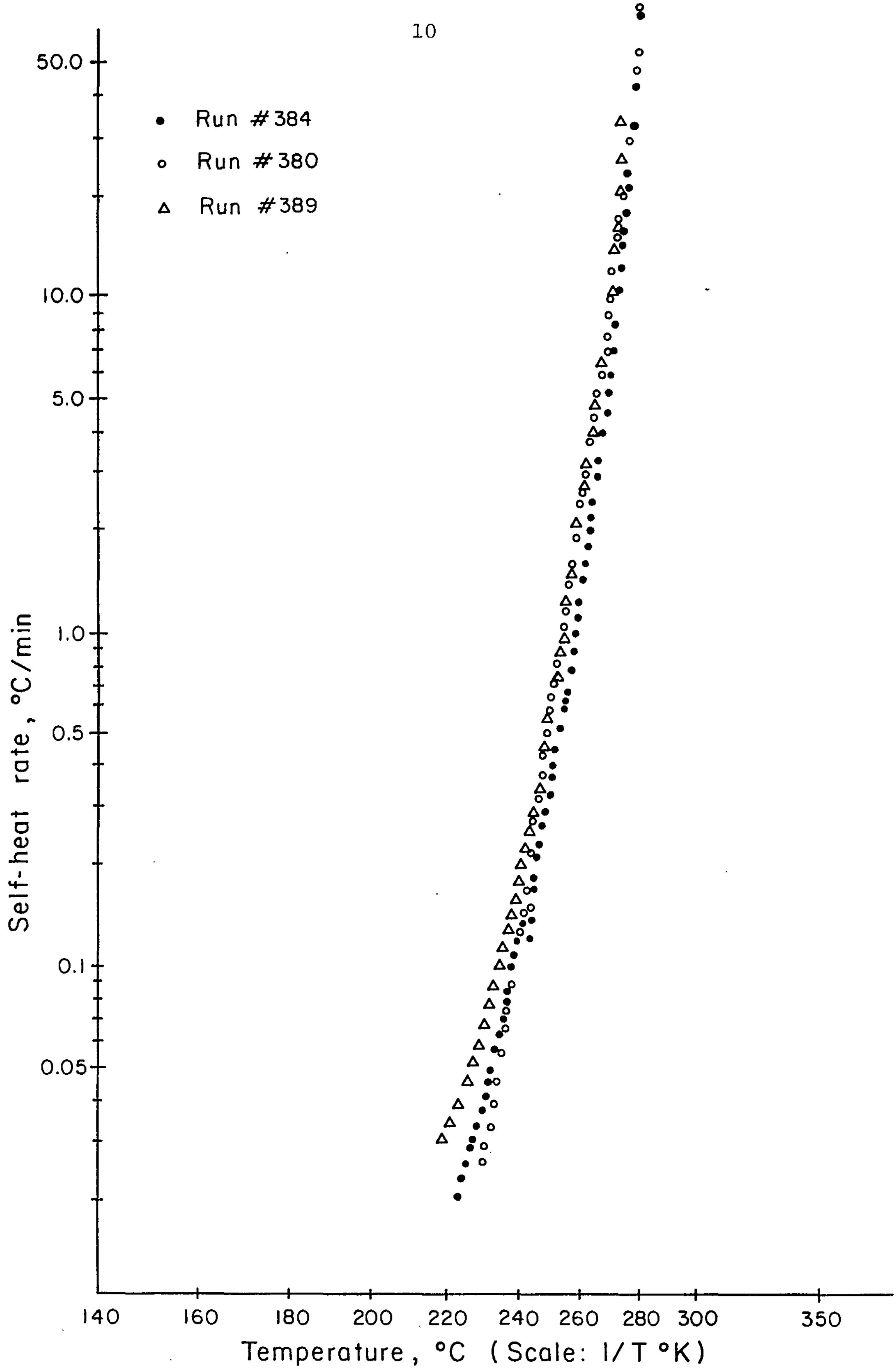

Fig. 2 - Thermal decomposition of KNO_3 doped ammonium nitrate.

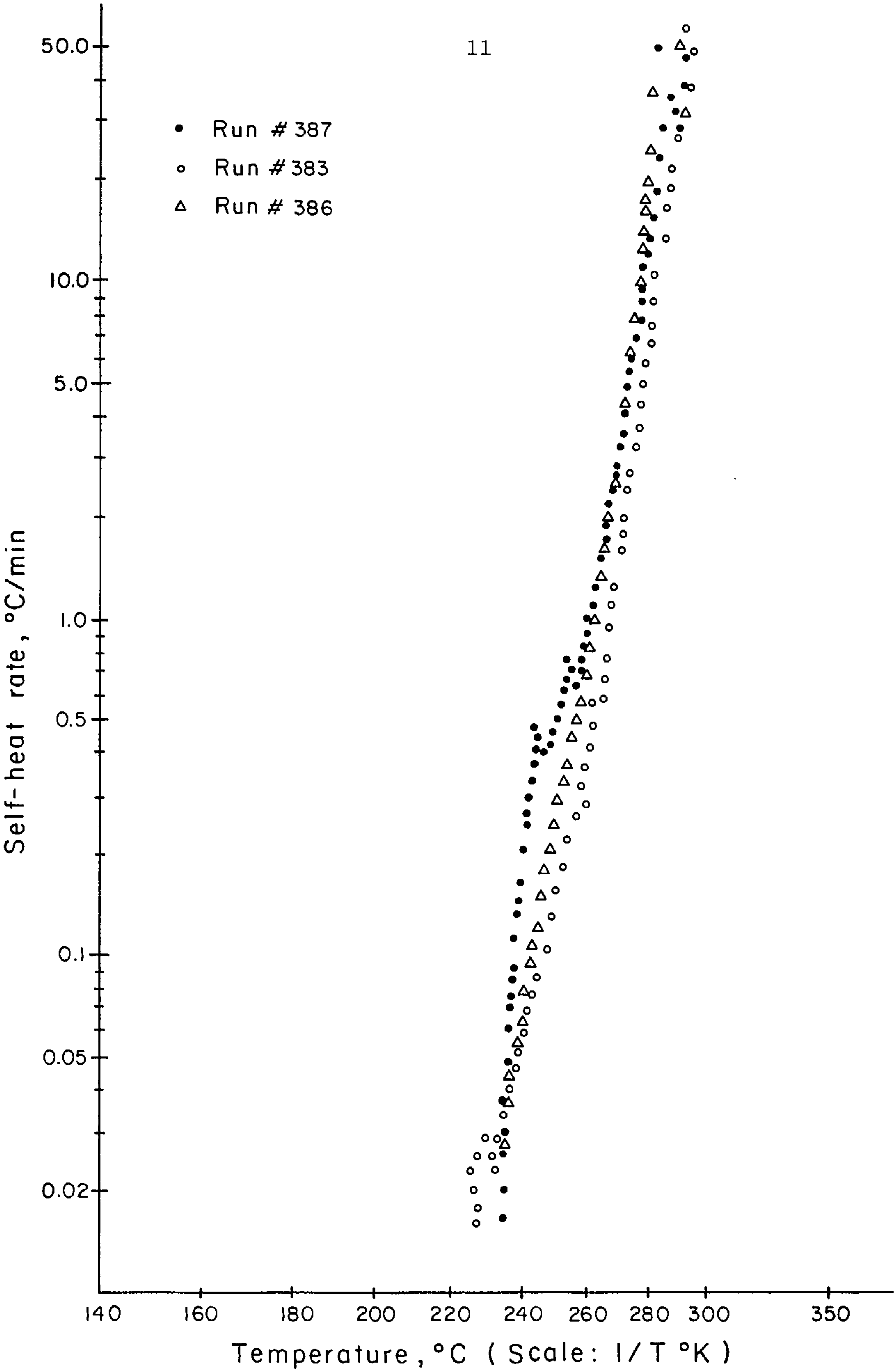

Fig. 3 - Thermal decomposition of NiO doped ammonium nitrate.

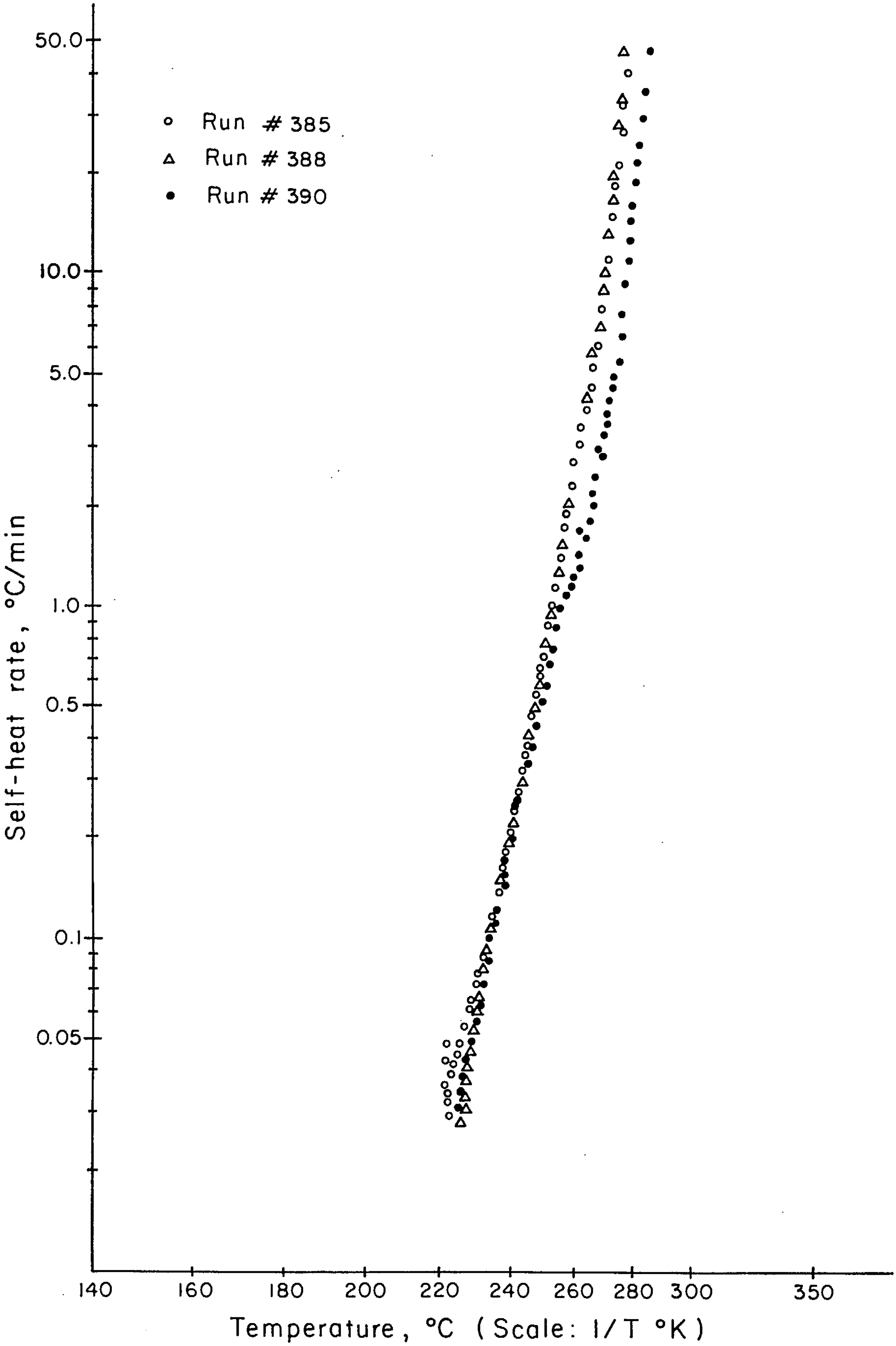

Fig. 4 - Thermal decomposition of CuO doped ammonium nitrate.

FEE SCHEDULE FOR STANDARDIZED TESTING CONDUCTED AT CANMET'S MINING RESEARCH LABORATORIES

R. Jackson

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FEE SCHEDULE FOR STANDARDIZED TESTING CONDUCTED AT CANMET'S MINING RESEARCH LABORATORIES

Rand Jackson*

ABSTRACT

As part of a decision to enhance CANMET's cost recovery efforts, the Mining Research Laboratories have compiled a fee schedule proposed for standardized testing. These fees reflect actual costs associated with testing and discount charges which, in the present fee structure, include overheads incurred solely due to government-driven policies.

In order to simplify costing, positions have been reduced from some 70 different classifications to 6. These include junior, intermediate and senior professionals, junior and senior technologists and general technicians. Also, some equipment charges will be levied directly against the client to account for their larger capital and operating costs. For MRL, this equipment includes; the rock mechanics test system, the dust tunnel facility and the radiation calibration facility. Attempts to include charges for the computer system proved too difficult to quantify.

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Keywords

Cost Recovery, Fee Schedule, CANMET, Standard Testing

TARIFICATION DES ESSAIS NORMALISES AUX LABORATOIRES DE RECHERCHE MINIERE DE CANMET

par

Rand Jackson*

RESUME

Dans un effort de recouvrement accru des coûts de CANMET, les Laboratoires de recherch minière ont préparé un tableau des tarifs proposés pour les essais normalisés. Ces tarifs comprennent les frais réel des essais et les frais d'escompte qui, dans la tarification actuelle, correspondent aux frais généraux dus uniquement aux politiques gouvernementales.

Pour simplifier l'éstablissement des coûts, le nombre des postes a été réduit de 70 à 6. Il s'agit de postes de professionnels stagiaires, intermédiaires et principaux, de postes de techniciens stagiaires et principaux et de postes de techniciens généraux. En outre, certains frais pour l'équipement seront directement exigibles du client pour tenir compte des frais d'immobilisation et d'exploitation élevés. Aux LRM, cet équipement comprend: le système d'essais de mécanique des roches, la soufflerie à poussière et l'installation d'étalonnage des rayonnements. On tente d'inclure des frais d'informatique qui sont avérés trop difficile à quantifier.

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Mots clés

Recouvrement des coûts, tarification, CANMET, essais normalisés

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INTRODUCTION

The Canada Centre for Mineral and Energy Technology (CANMET) has been directed to enhance its revenues through increased cost recovery. As part of this mandate, it has been deemed necessary to revise the current fee structure to reflect those costs which are directly attributable to work carried out for outside agencies as opposed to including overhead charges incurred as a result of government driven priorities.

Mining Research Laboratories (MRL), in accordance with the revised hourly charge-out rates for employees recommended by CANMET's Research Program Office, has compiled a new fee schedule for standardized testing conducted by four of its laboratories. These include tests done by the Canadian Mine Technology Laboratory (CMTL), the Canadian Explosive Atmospheres Laboratory (CEAL), the Canadian Explosives Research Laboratory (CERL) and the Elliot Lake Laboratory (ELL). MRL's Backfill Laboratory located in Sudbury is currently being set up and will submit its proposed test charges when it is in full operation.

PROPOSED FEE SCHEDULE FOR STANDARDIZED TESTS

A major revision in the current cost recovery schedule of hourly costs involves the reduction of some 70 position classifications to only 6. These are; junior, intermediate and senior professionals, junior and senior technologists and general technicians. The current classifications included in the above groups along with each group's revised recoverable hourly rate is included in Table 1. These rates have been applied to averaged test times and personnel requirements supplied by the managers of the various laboratories.

Equipment charges previously covered by overall capital depreciation have been modified to recognize the greater operating costs involved in some types of equipment. Accordingly, costs associated with the operation of the rock mechanics test system, dust tunnel and radiation instrumentation calibration facilities at MRL will be charged directly to the client. Suggested rates were determined on the basis of 1740 possible operating hours per year and are presented in Table 2.

It has been suggested that use of the computer system at MRL also be charged for on an hourly basis. It is, however, difficult to determine a per test cost for use of the system. For the majority of applications, the actual CPU time involved in analyzing the results of one test procedure was in the tens of seconds resulting in negligible charges relative to the manpower costs. It is also difficult to standardize charges when

Table 1: Position Reclassification and Revised Hourly Rates

GROUP	CATEGORIES		RECOVERABLE HOURLY RATE
Senior Professional (Sen.Prof)	EN-ENG-05 SE-RES-03 SE-RES-04	PC-04 PC-05 SM-00	110.00
Intermediate Professional (Int.Prof)	PC-02 PC-03 EN-ENG-03 EN-ENG-04	CH-03 CH-04 SE-RES-02	86.00
Junior Professional (Jun.Prof)	SE-RES-01 EN-ENG-01 EN-ENG-02	CH-01 CH-02 PC-01	58.00
Senior Technologist (Sen.Tech)	EG-ESS-06 EG-ESS-07 EG-ESS-08 EG-ESS-09	EL-04 EL-05 EL-06	66.00
Junior Technologist (Jun.Tech)	EG-ESS-02 EG-ESS-03 EG-ESS-04 EG-ESS-05	DD-03 DD-04 EL-03	48.00
General Technician (Gen.Tech)	GL-BOB-08 GL-BOB-10 GL-EIM-10 GL-EIM-11 GL-ELE-02 GL-ELE-03 GL-ELE-05 GL-ELE-06 GL-MAM-07 GL-MAM-08 GL-MAM-09 GL-MAM-10 GL-MAM-11 GL-MDO-05 GL-MDO-06 GL-MST-11 GL-MST-12	GL-MOC-06 GL-MOC-07 GL-MOC-08 GL-MOC-09 GL-PRW-06 GL-PRW-08 GL-PRW-09 GL-SMW-08 GL-SMW-09 GL-VHE-08 GL-VHE-09 GL-WOW-09 GL-WOW-10 GS-STS-03 GS-STS-04 GS-STS-05 GS-STS-07	44.00

investigators in one facility utilize a main frame system for applications which are being performed on PC's elsewhere. Charges relating to computer use, therefore, have not been included here. Also, it is felt that costs associated with supplies for each program would best be recovered by charging the client directly, rather than attempting to incorporate them in a per test charge.

Table 2: Capital Equipment Costs and Suggested Hourly Rates

Equipment	Total Capital Cost	Suggested Hourly Rate
Rock Mechanics Test Facility	$1,000,000	$57.47
Dust Tunnel Facility	$300,000	$17.24
Radiation Calibration Facility	$400,000	$22.99

Table 3 summarizes the test types deemed suitable for standardized charges and the recommended fees for each of CMTL, CEAL, CERL and ELL, respectively. Tables 4 through 7 represent the detailed cost breakdowns for each laboratory including test type, current personnel classifications, revised personnel classifications, recommended hourly rates, incremental costs and total test fees.

The costs related to Elliot Lake's radiation test facility are, of necessity, only approximations as the equipment is still being installed. Accordingly, some readjustment may be necessary when the number of tests that can be performed per annum and the corresponding personnel requirements are determined.

Table 3: Proposed Fee Schedule for Standard Testing at Mining Research Laboratories

Laboratory	Name of Service	Total Test Fee
CMTL	A) Uniaxial Compression Testing	
	Standard Uniaxial	$ 270.50
	Post-failure Uniaxial	378.00
	B) Triaxial Compression Testing	
	Standard Triaxial	335.00
	Post-failure Triaxial	442.50
	Multi-stage Triaxial	442.50
	Triaxial Extension	442.50
	Multi-stage Extension	442.50
	Continuous Failure State	442.50
	C) Ultra-sonic Velocity Measurements	
	Atmospheric Pressure	
	Velocity Testing	143.00
	Dilatational Velocity Test	347.50
	Confined Dilatational	
	Velocity Tests	412.00
	D) Permeability Testing	1141.00
	E) Brazilian Tensile Test	121.00
CEAL	A) Explosion Proof and	
	Intrinsically Safe Equipment	
	Inspection of Dwgs. & Specs.	172.00
	Inspection of Prototype	172.00
	Standard Explosion Tests	581.00
	Overpressure Test:	
	Simple Device	132.00
	Complex Device	330.00
	Intrinsic Safety Tests	258.00

Table 3: cont'd

Laboratory	Name of Service	Total Test Fee
CEAL	B) Conveyor Belting	
	Flame Tests	225.00
	Drum Friction Test/Trial	206.00
	Static Conductivity	48.00
	Propane Burner Test/Trial	1431.00
	Oxygen Index Test	139.00
	Hot Plate Ignition	254.00
	C) Electric Cables	
	Horizontal Flame Test/Trial	230.00
	Vertical Flame Test	158.00
	D) Combustble Gas Detection Devices	
	Each New Device	964.00
	Retest After Failure	482.00
	E) Diesel Emissions Determination	
	Pre-test Administration	220.00
	Engine Installation and	
	Instrumentation	1050.00
	Preliminary Tests	1075.00
	Steady-state Engine and	
	Treatment Tests	4332.00
	Engine Removal	240.00
	Data Treatment and	
	Ventilation Prescription	3300.00
	F) Additional Flameproof Requirements	
	Engine Surface Temp. Tests	198.00
	Machine Surface Temp. Tests	198.00
	CH_4 Effect on Emission	456.00
	Drawing Examination of	
	Flameproof Components	430.00

Table 3: cont'd

CEAL	G) Mine Duct Material	
	Flame Test	249.00
	Gallery Flame Tests	359.00
	Static Conductivity	158.00
	H) Fire Resistant Hydraulic Fluids	
	Wick Flame Test	273.00
	Spray Ignition Test	273.00
	Fluid Stability Test	206.00
	Fluid Conditioning	412.00
	I) Quality Assurance Inspections	
	Factory Visit and Report	301.00
	J) Certification Costs	
	Preparation of New/Revised	
	Certification Documents	220.00
	K) Explosive Dust Properties	
	Maximum Explosion Pressure and	
	Maximum Rate of Pressure Rise	416.00
	Minimum Explosible Concentration	350.00
	Minimum Ignition Temperature	350.00
CERL*	A) Explosives of Classes 1 and 3	1551.00
	B) Explosives of Class 2	1551.00
	(cap sensitive)	
	C) Toxic Fumes for Above - Add	144.00
	D) Explosives of Class 2	1778.00
	(cap insensitive)	

Table 3: cont'd

CERL*	E) Explosives and Pyrotechnic	
	Substances of Classes 4.5 and	
	7.1 and Safety Certificates	1410.00
	F) Safety Cartridges of Class 6	495.50
	G) Detonators and Squibs of Class 6	969.00
	H) Detonating Cord of Class 3 and	
	Safety Fuse of Class 6	570.00
	I) Fireworks Class of 7.2.1 & 7.2.2	160.00
	J) Toy Pistol Caps of Class 7.2.1	244.00
	K) Toy Rocket Motors of Class 7.2.3	347.00
	L) Fireworks of Class 7.2.4 & 7.2.5	296.00
	M) Chemical and Thermal Analysis	
	for Classes 7.2.1 through 7.2.5	635.00
	N) Lighters	142.00
ELL	A) Radiation Instrumentation	
	Calibration	779.00
	B) X-Ray Silica Analyses	31.00

*Standard fees proposed for testing done by CERL include the cost of the associated supplies. Fees for the remaining labs, however, do not include costs of supplies and these must therefore be included when estimating future contract work.

Table 4: Fees for Standard Tests and Services Provided by MRL's Canadian Mine Technology Laboratory

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
A) Uniaxial Compression Testing						
Standard Uniaxial	1.0	GL-ELE-02	Gen.Tech	44.00	44.00	
	1.0	EG-ESS-07	Sen.Tech	66.00	66.00	
	1.5	PC-02	Int.Prof	86.00	129.00	
	0.5		Press	63.00	31.50	270.50
Post-failure Uniaxial	1.0	GL-ELE-02	Gen.Tech	44.00	44.00	
	1.5	EG-ESS-07	Sen.Tech	66.00	99.00	
	2.0	PC-02	Int.Prof	86.00	172.00	
	1.0		Press	63.00	63.00	378.00
B) Triaxial Compression Testing						
Standard Triaxial	1.0	GL-ELE-02	Gen.Tech	44.00	44.00	
	1.5	EG-ESS-07	Sen.Tech	66.00	99.00	
	1.5	PC-02	Int.Prof	86.00	129.00	
	1.0		Press	63.00	63.00	335.00
Post-failure Triaxial	1.0	GL-ELE-02	Gen.Tech	44.00	44.00	
	2.0	EG-ESS-07	Sen.Tech	66.00	132.00	
	2.0	PC-02	Int.Prof	86.00	172.00	
	1.5		Press	63.00	94.50	442.50
Multi-stage Triaxial,	1.0	GL-ELE-02	Gen.Tech	44.00	44.00	
Triaxial Extension,	2.0	EG-ESS-07	Sen.Tech	66.00	132.00	
Multi-stage Extension,	2.0	PC-02	Int.Prof	86.00	172.00	
Continuous Failure State	1.5		Press	63.00	94.50	442.50

Table 4: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
C) Ultra-sonic Velocity						
Measurements						
Atmospheric Pressure	1.0	GL-ELE-02	Gen.Tech	44.00	44.00	
Velocity Testing	1.5	EG-ESS-07	Sen.Tech	66.00	99.00	143.00
Dilatational Velocity Test	0.5	GL-ELE-02	Gen.Tech	44.00	22.00	
(incl. 6 load increments)	3.5	EG-ESS-07	Sen.Tech	66.00	231.00	
	1.5		Press	63.00	94.50	347.50
Confined Dilatational	0.5	GL-ELE-02	Gen.Tech	44.00	22.00	
Velocity Tests	4.0	EG-ESS-07	Sen.Tech	66.00	264.00	
	2.0		Press	63.00	126.00	412.00
D) Permeability Testing	3.5	GL-ELE-07	Gen.Tech	44.00	154.00	
	15.0	EG-ESS-07	Sen.Tech	66.00	990.00	1144.00
E) Brazilian Tensile Test	0.5	GL-ELE-07	Gen.Tech	44.00	22.00	
	1.5	EG-ESS-07	Sen.Tech	66.00	99.00	121.00

*Most tests outlined above can be conducted at high temperature.
Charges for press time, however, will be increased to 7.5 hours as opposed to those noted.

Table 5: Fees for Standard Tests and Services Provided by MRL's Canadian Explosive Atmospheres Laboratory

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
A) Explosion-proof and						
Intrinsically Safe Equipment						
Inspection Drawings & Specs.	2.0	EN-ENG-04	Int.Prof	86.00	172.00	172.00
Inspection of Prototype	2.0	EN-ENG-04	Int.Prof	86.00	172.00	172.00
Standard Explosion Tests	7.5	EG-ESS-06	Sen.Tech	66.00	495.00	
	1.0	EN-ENG-04	Int.Prof	86.00	86.00	581.00
Overpressure Test:						
Simple Device	2.0	EG-ESS-06	Sen.Tech	66.00	132.00	132.00
Complex Device	5.0	EG-ESS-06	Sen.Tech	66.00	330.00	330.00
Intrinsic Safety Tests	3.0	EN-ENG-04	Int.Prof	86.00	258.00	258.00
B) Conveyor Belting						
Flame Tests	1.5	EN-ENG-03	Int.Prof	85.00	129.00	
	2.0	EG-ESS-05	Jun.Tech	48.00	96.00	225.00
Drum Friction Test/Trial	2.5	EG-ESS-05	Jun.Tech	48.00	120.00	
	1.0	EN-ENG-03	Int.Prof	86.00	86.00	206.00
Static Conductivity	1.0	EG-ESS-05	Jun.Tech	48.00	48.00	48.00
Propane Burner Test/Trial	4.5	EG-ESS-05	Jun.Tech	48.00	216.00	
	2.5	EN-ENG-03	Int.Prof	86.00	215.00	
			Burn Facility	1000.00*	1000.00	1431.00

*Please note that the equipment charge for the propane burner test was determined on a per test as opposed to hourly basis.

Table 5: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
B) Conveyor Belting: cont'd						
Oxygen Index Test	2.0	EG-ESS-05	Jun.Tech	48.00	96.00	
	0.5	EN-ENG-03	Int.Prof	86.00	43.00	139.00
Hot Plate Ignition	3.5	EG-ESS-05	Jun.Tech	48.00	168.00	
	1.0	EN-ENG-03	Int.Prof	86.00	86.00	254.00
C) Electrical Cables						
Horizontal Flame Test/Trial	3.0	EG-ESS-05	Jun.Tech	48.00	144.00	
	1.0	EN-ENG-03	Int.Prof	86.00	86.00	230.00
Vertical Flame Test	1.5	EG-ESS-03	Jun.Tech	48.00	72.00	
	1.0	EN-ENG-03	Int.Prof	86.00	86.00	158.00
D) Combustible Gas Detection						
Devices,						
Each New Device	12.0	EG-ESS-06	Sen.Tech	66.00	792.00	
	2.0	EN-ENG-04	Int.Prof	86.00	172.00	964.00
Retest After Failure	6.0	EG-ESS-06	Sen.Tech	66.00	396.00	
	1.0	EN-ENG-04	Int.Prof	86.00	86.00	482.00
E) Diesel Emissions Determination						
Pre-test Administration	2.0	SE-RES-03	Sen.Prof	110.00	220.00	220.00
Engine Installation and						
Instrumentation	15.0	EG-ESS-05	Jun.Tech	48.00	720.00	
	5.0	EL-06	Sen.Tech	66.00	330.00	1050.00

Table 5: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
E) Diesel Emissions Determination						
cont'd						
Preliminary Tests	7.5	EG-ESS-05	Jun.Tech	48.00	360.00	
	7.5	EL-06	Sen.Tech	66.00	495.00	
	2.0	SE-RES-03	Sen.Prof	110.00	220.00	1075.00
Steady-state Engine and						
Treatment Tests	38.0	EG-ESS-05	Jun.Tech	48.00	1824.00	
	38.0	EL-06	Sen.Tech	66.00	2508.00	4332.00
Engine Removal	5.0	EG-ESS-05	Jun.Tech	48.00	240.00	240.00
Data Treatment and						
Ventilation Prescription	30.0	SE-RES-03	Sen.Prof	110.00	3300.00	3300.00
F) Additional Flameproof						
Requirements						
Engine Surface Temp. Tests	3.0	EL-06	Sen.Tech	66.00	198.00	198.00
Machine Surface Temp. Tests	3.0	EL-06	Sen.Tech	66.00	198.00	198.00
CH_4 Effect on Emission	4.0	EG-ESS-05	Jun.Tech	48.00	192.00	
	4.0	EL-06	Sen.Tech	66.00	264.00	456.00
Drawing Examination of						
Flameproof Components	5.0	EN-ENG-04	Int.Prof	86.00	430.00	430.00

Table 5: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
G) Mine Duct Material						
Flame Test	2.5	EG-ESS-05	Jun.Tech	48.00	120.00	
	1.5	ENG-03	Int.Prof	86.00	129.00	249.00
Gallery Flame Tests	3.0	EG-ESS-05	Jun.Tech	48.00	144.00	
	2.5	ENG-03	Int.Prof	86.00	215.00	359.00
Static Conductivity	1.5	EG-ESS-05	Jun.Tech	48.00	72.00	
	1.0	ENG-03	Int.Prof	86.00	86.00	158.00
H) Fire Resistant Hydraulic Fluids						
Wick Flame Test	3.0	EG-ESS-05	Jun.Tech	48.00	144.00	
	1.5	ENG-03	Int.Prof	86.00	129.00	273.00
Spray Ignition Test	3.0	EG-05	Jun.Tech	48.00	144.00	
	1.5	ENG-03	Int.Prof	86.00	129.00	273.00
Fluid Stability Test	2.5	EG-05	Jun.Tech	48.00	120.00	
	1.0	ENG-03	Int.Prof	86.00	86.00	206.00
Fluid Conditioning	5.0	EG-05	Jun.Tech	48.00	240.00	
	2.0	ENG-03	Int.Prof	86.00	172.00	412.00
I) Quality Assurance Inspections						
Factory Visit and Report	3.5	ENG-03	Int.Prof	86.00	301.00	301.00
J) Certification Costs						
Preparation of New/Revised						
Certification Documents	2.0	ENG-04	Sen.Prof	110.00	220.00	220.00

Table 5: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
K) Explosive Dust Properties						
Maximum Explosion Pressure						
and Maximum Rate of	5.0	EG-06	Sen.Tech	66.00	330.00	
Pressure Rise	1.0	RS-02	Int.Prof	86.00	86.00	416.00
Minimum Explosible	4.0	EG-06	Sen.Tech	66.00	264.00	
Concentrationn	1.0	RS-02	Int.Prof	86.00	86.00	350.00
Minimum Ignition Temperature	4.0	EG-06	Sen.Tech	66.00	264.00	
	1.0	RS-02	Int.Prof	86.00	86.00	350.00

Table 6: Fees for Standard Tests and Services Provided by MRL's Canadian Explosives Research Laboratory

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
A) Explosives of Classes 1 and 3	2.0	PC-03	Int.Prof	86.00	172.00	
	5.0	EG-ESS 6	Sen.Tech	66.00	330.00	
	18.0	EG-ESS 5	Jun.Tech	48.00	864.00	
			Supplies	185.00	185.00	1551.00
B) Explosives of Class 2	2.0	PC-03	Int.Prof	86.00	172.00	
(cap sensitive)	5.0	EG-ESS 6	Sen.Tech	66.00	330.00	
	18.0	EG-ESS 5	Jun.Tech	48.00	864.00	
			Supplies	185.00	185.00	1551.00
C) Toxic Fumes for Above - Add	3.0	EG-ESS 5	Jun.Tech	48.00	144.00	144.00
D) Explosives of Class 2	2.0	PC-03	Int.Prof	86.00	172.00	
(cap insensitive)	5.0	EG-ESS 6	Sen.Tech	66.00	330.00	
	16.75	EG-ESS 5	Jun.Tech	48.00	804.00	
			Supplies	472.00	472.00	1778.00
E) Explosives and Pyrotechnic	2.0	PC-03	Int.Prof	86.00	172.00	
substances of Classes 4, 5 and	5.0	EG-ESS 6	Sen.Tech	66.00	330.00	
7.1 and Safety Certificates	16.5	EG-ESS 5	Jun.Tech	48.00	792.00	
			Supplies	116.00	116.00	1410.00
F) Safety Cartridges of Class 6	1.0	PC-03	Int.Prof	86.00	86.00	
	0.75	EG-ESS 6	Sen.Tech	66.00	49.00	
	7.5	EG-ESS 5	Jun.Tech	48.00	360.00	495.00

Table 6: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
G) Detonators and Squibs of Class 6	2.0	PC-03	Int.Prof	86.00	172.00	
	0.5	EG-ESS 6	Sen.Tech	66.00	33.00	
	15.5	EG-ESS 5	Jun.Tech	48.00	744.00	
			Supplies	20.00	20.00	969.00
H) Detonating Cord of Class 3 and	1.0	PC-03	Int.Prof	86.00	86.00	
Safety Fuse of Class 6	1.5	EG-ESS 6	Sen.Tech	66.00	99.00	
	7.5	EG-ESS 5	Jun.Tech	48.00	360.00	
			Supplies	25.00	25.00	570.00
I) Fireworks of Class 7.2.1 & 7.2.2	0.5	PC-03	Int.Prof	86.00	43.00	
	0.5	EG-ESS 6	Sen.Tech	66.00	33.00	
	1.75	EG-ESS 5	Jun.Tech.	48.00	84.00	160.00
J) Toy Pistol Caps of Class 7.2.1	0.5	PC-03	Int.Prof	86.00	43.00	
	0.5	EG-ESS 6	Sen.Tech	66.00	33.00	
	3.5	EG-ESS 5	Jun.Tech	48.00	168.00	244.00
K) Toy Rocket Motors of Class 7.2.3	1.0	PC-03	Int.Prof	86.00	86.00	
	0.5	EG-ESS 6	Sen.Tech	66.00	33.00	
	4.75	EG-ESS 5	Jun.Tech	48.00	228.00	347.00
L) Fireworks of Class 7.2.4 & 7.2.5	1.0	PC-03	Int.Prof	86.00	86.00	
	1.0	EG-ESS 6	Sen.Tech	66.00	66.00	
	3.0	EG-ESS 5	Jun.Tech	48.00	144.00	296.00

Table 6: cont'd

Name of Service	Person-hours Required	Previous Classification	Proposed Classification	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
M) Chemical and Thermal Analysis	1.0	PC-03	Int.Prof	86.00	86.00	
for Classes 7.2.1 through 7.2.5	4.0	EG-ESS 6	Sen.Tech	66.00	264.00	
	5.0	EG ESS 5	Jun.Tech	48.00	240.00	
			Supplies	45.00	45.00	635.00
N) Lighters	0.5	PC-03	Int.Prof	86.00	43.00	
	1.5	EG ESS 6	Sen.Tech	66.00	99.00	142.00

The above fees are not applicable to certificates requested by the Explosives Branch, EMR. For companies seeking to have new explosives authorized under the Canada Explosives Act, and for which laboratory examination and certificate issuance are requested by the Explosives Branch, a standard examination fee of $125 per explosive applies.

Table 7: Fees for Standard Tests and Services Provided by Mining Research Laboratories
Elliot Lake Laboratories

Name of Service	Person-hours Required	Previous Classification	Proposed Classification*	Recoverable Hourly Rate	Incremental Cost	Total Test Fee
A) Radiation Instrumentation						
Calibration						
Instrument Review and Prep.	2.0	EG-ESS-08	Sen.Tech	66.00	132.00	
	2.0	SE-RES-03	Sen.Prof	110.00	220.00	
Analyses and Report Prep.	2.0	EG-ESS-08	Sen.Tech	66.00	132.00	
	2.0	SE-RES-03	Sen.Prof	110.00	220.00	
			Radiation Calibration Facility		75.00	779.00
B) X-ray Silica Analyses	0.5	GL-ELE-02	Gen.Tech	44.00	22.00	
	0.1	RS-RES-02	Int.Prof	86.00	9.00	31.00

REFERENCES

1. Adams, C.J. 'Cost Recovery Procedures for CANMET', Draft Document, March, 1988.