NBSIR 81-2373

An Evaluation of the MSHA Temperature-Pressure Spray Ignition Test for Hydraulic Fluids

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Center for Fire Research
Washington, DC 20234

September 1981

Final Report

Prepared for:

U.S. Bureau of Mines
Pittsburgh, Pennsylvania 15213

and

ne Safety and Health Administration
adelphia, West Virginia 26059

NBSIR 81-2373

AN EVALUATION OF THE MSHA TEMPERATURE-PRESSURE SPRAY IGNITION TEST FOR HYDRAULIC FLUIDS

Joseph J. Loftus
Adalberto Maldonado-Rosado
Paula J. Allen

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Center for Fire Research
Washington, DC 20234

September 1981

Final Report

Prepared for:
U.S. Bureau of Mines
Pittsburgh, Pennsylvania 15213

and

Mine Safety and Health Administration
Triadelphia, West Virginia 26059

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

The alternate temperature pressure spray ignition test proposed in this report, for measuring the flammability of hydraulic fluids intended for use in underground coal mines, is intended to provide for a simple quantitative measurement which can be used for quickly rating or ranking fluids for flammability resistance. The method is not proposed nor intended to provide for a standard measurement of the properties of materials.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

An Evaluation of the MSHA Temperature-Pressure Spray Ignition Test for Hydraulic Fluids

Joseph J. Loftus, Adalberto Maldonado-Rosado and Paula J. Allen

Abstract

The Mine Safety and Health Administration (MSHA) Temperature-Pressure Spray Ignition Test for determining the fire resistance of hydraulic fluids was evaluated in spray ignition tests on 14 different hydraulic fluids including water glycols, synthetics, and invert emulsions. Results of these and of other tests designed to evaluate the test method and its procedures are discussed in this report.

Key words: Hydraulic fluids; spray ignition; fire resistance.

1. INTRODUCTION

At the request of the Mine Safety and Health Administration (MSHA) and the Bureau of Mines (BOM), the Center for Fire Research at the National Bureau of Standards (NBS) evaluated the operational characteristics of the fire test methods used by MSHA to qualify hydraulic fluids as fire resistant and suitable for use in underground coal mines. There are three test methods described in the Code of Federal Regulations [1][1] that an hydraulic fluid must meet to be rated fire resistant. They are: (1) Autogenous ignition; (2) Effect of evaporation on the flammability of hydraulic fluids; (3) Temperature-pressure spray ignition.

This report is an evaluation of the Temperature-Pressure Spray Ignition Test. The test equipment was assembled and standard tests were performed on 14 different hydraulic fluids. A calibration procedure was developed for the system. Also, an alternative measure of a fluid's flammability was developed to eliminate the subjective nature of the present measurement.

2. TEST MATERIALS

The 14 different hydraulic fluids used for the evaluation tests included two water glycols, seven synthetics, and five invert emulsions.

Invert emulsions are fluids which consist of oil in a water emulsion in which water is the continuous phase, and may vary from 40 to 90 percent.

---

[1] Numbers in brackets refer to the references at the end of this report.

Synthetics are fluids which contain organic esters (e.g., phosphates) or synthetic hydrocarbons.

Water glycol fluids consist of a water glycol solution with at least 35 percent water.

The fluids were obtained from manufacturers who normally supply these materials to the underground coal mining industry and who report that the fluids meet the flammability requirements cited for hydraulic fluids in the above Code of Federal Regulations.

Table 1 lists specific gravity and viscosity measurements (made by NBS) for the fluids. At 20°C (8°F) the specific gravities ranged from 0.91 to 1.15 g/cm^3 and viscosities ranged from 38 to 417 centistokes. At 37.7°C (100°F) viscosities ranged from 21 to 168 centistokes and at 65°C (150°F) from 10 to 53 centistokes.

3. TEST METHOD

Virtually all the equipment used to mine or remove coal from the working face is hydraulically operated. A rupture of the hydraulic lines could release a high pressure fluid spray. If this spray were to encounter an ignition source, such as a hot surface or a small open flame, it could produce flaming conditions that would make fire a significant threat to the lives of the miners

Table 1. Viscosity of hydraulic fluids at various temperatures

Fluid No.	Type	Specific Gravity	Viscosity (Centistokes)			
		g/cm^3	°C	20	38	65
1	Water Glycol	1.08		82	46	22
2	Water Glycol	1.06		83	52	23
3	Synthetic	0.99		191	94	32
4	Synthetic	1.14		263	88	24
5	Invert Emulsion	0.92		153	86	34
6	Synthetic	1.14		417	168	37
7	Invert Emulsion	0.94		120	76	25
8	Synthetic	1.20		38	21	10
9	Synthetic	1.13		144	54	18
10	Synthetic	1.15		95	45	15
11	Invert Emulsion	0.91		231	134	53
12	Synthetic	1.14		118	60	18
13	Invert Emulsion	0.93		290	130	52
14	Invert Emulsion	0.92		162	90	38

and cause damage to mining machinery. The Temperature-Pressure Spray Ignition Test attempts to determine fluid fire performance under simulated spray conditions.

In this test, hydraulic fluids at a temperature of 65°C (150°F) and under a pressure of 1034 KPa (150 PSIG) are sprayed (in separate tests) across each of three different ignition sources. These are: (1) electric sparks; (2) a propane torch flame; (3) a flaming trough (made by igniting cotton gauze soaked in kerosene).

3.1 Apparatus

Figure 1 shows a schematic diagram of the Temperature-Pressure Spray Ignition Test apparatus used in this evaluation. The system consists of the following parts:

1. A 1000 cm^3 (1 liter) capacity sample cylinder (fitted with heating elements) to contain and heat fluids to testing conditions.

2. An atomizing round spray nozzle having a discharge orifice of 0.64 mm (0.025 in) in diameter, reported by the manufacturer to be capable of discharging 12.4 liters (3.28 gallons) of water per hour with a spray angle of 90 degrees at a pressure of 689 KPa (100 PSIG).

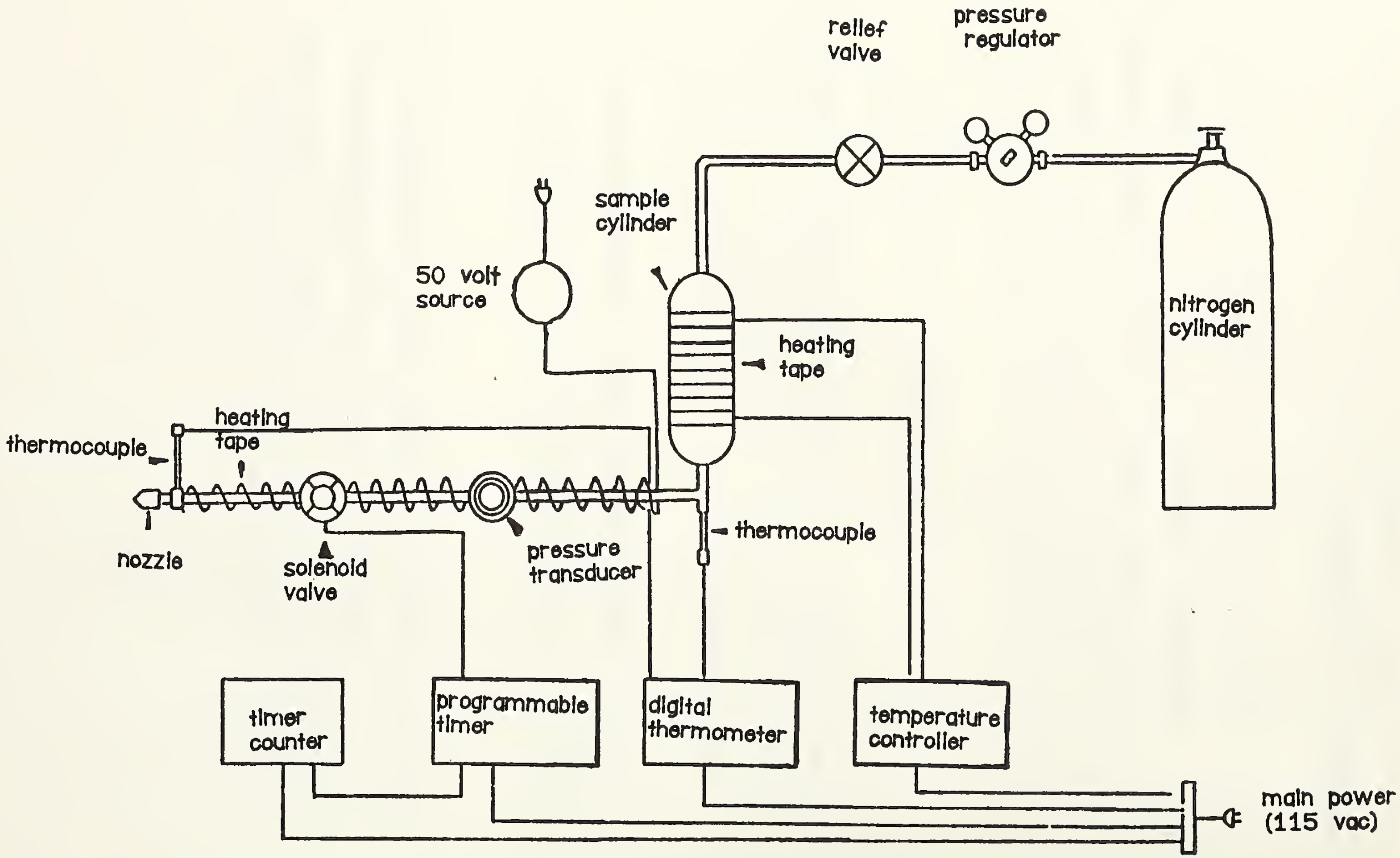

FIGURE 1
SPRAY IGNITION TEST APPARATUS

3. A commercial pressurized cylinder containing nitrogen with customary regulators, valves, tubing, and connectors to supply nitrogen to the sample cylinder.

4. Additional apparatus includes a timer counter, programmable timer, digital thermometer, temperature controller, pressure transducer, solenoid valve and two shielded chromel alumel thermocouples to monitor fluid temperatures in the sample cylinder and at the spray nozzle.

3.2 Test Procedure

1. Test hydraulic fluid is added to the sample cylinder and is heated to the test temperature of 65 $\pm$ 5°C (150°F).

2. The filled cylinder is pressurized to the testing pressure of 1034 KPa (150 PSIG).

3. Fluid is sprayed (for up to 1 minute) into each of the three different ignition devices held in the spray at a distance of 45 cm (18 in) from the spray nozzle. [Note: Although not specified in the Code of Federal Regulations, MSHA also conducts tests at 60 and 90 cm (24 and 36 in) distances from the spray nozzle.]

4. A fluid is rated for flammability in accordance with provisions of test outlined in 3.3 Test Criteria.

3.3 Test Criteria

A hydraulic fluid material meets the requirements of the spray ignition test when visual observations show that it's spray does not ignite or produce flaming for 6 continuous seconds or more (when the ignition source is 45 cm (18 in) or more from the spray nozzle).

4. "MSHA TEST" - SPRAY IGNITION RESULTS

Table 2 lists the results of (CFR's) tests on 14 different hydraulic fluids. Each spraying fluid was exposed to three different ignition sources. Only one fluid (no. 10), ignited when exposed to electric sparks. (Note: Sparks were generated across a 1.25 cm (1/2 in) air space separating two copper electrodes.) The flaming cotton and propane torch ignition sources produced identical results. Of all the fluids tested, only three did not ignite from any exposure--two water glycols (nos. 1 and 2) and one synthetic (no. 3). Certification based on tests at MSHA's Approval and Certification Center on similar type fluids indicated that all these fluids were acceptable by the above test procedure.

5. FLOW RATE CHARACTERIZATION

Because of the above noted disagreement (between MSHA and CFR) in rating fluids for fire performance, the spray system's flow rate was characterized. Initially, water was used to calibrate several

Table 2. Results of MSHA spray ignition tests on hydraulic fluids

Fluid		Ignition Source		
No.	Type	Torch (Benzomatic)	Electric Sparks	Flaming Cotton
1	Water Glycol	N	N	N
2	Water Glycol	N	N	N
3	Synthetic	N	N	N
4	Synthetic	I	N	I
5	Invert Emulsion	I	N	I
6	Synthetic	I	N	I
7	Invert Emulsion	I	N	I
8	Synthetic	I	N	I
9	Synthetic	I	N	I
10	Synthetic	I	I	I
11	Invert Emulsion	I	N	I
12	Synthetic	I	N	I
13	Invert Emulsion	I	N	I
14	Invert Emulsion	I	N	I

N - Nonignition
I = Ignition

nozzles. This was followed by a characterization of hydraulic fluid flow rates through a stainless steel nozzle at the same operating temperature of the test method but at different pressures.

5.1 Calibration

A simple, rapid procedure for calibrating the nozzle flow rate was developed. The procedure requires that a preweighed plastic bag be secured around the tip of the spray nozzle. The plastic bag is sufficiently large to contain approximately 1 liter of fluid. The spray system is activated and the fluid discharged into the plastic bag for 1 minute. The volume of fluid discharged and the rate of discharge can be calculated from fluid's specific gravity and the weight of fluid collected in the plastic bag.

Using this procedure, six nozzles were calibrated. Three were brass nozzles purchased by MSHA and three were stainless steel nozzles obtained directly from the manufacturer. Table 3 lists the flow rates obtained by discharging water through each nozzle. The manufacturer rated these nozzles at (3.28 GPH) at a pressure of 689 KPa (100 PSIG). The last column in table 3 shows the percent difference between the measured flow rates and that claimed by the manufacturer. The stainless steel nozzles showed a much smaller difference in flow rate than the brass nozzles.

Table 3. Flowrate measurements for spray nozzles using water at room temperature and 100 psig

	cc/min	GPH	% Difference From Expected*
Brass Nozzles			
No. 1	234	3.71	+13
2	339	5.37	+64
5	240	3.80	+16
Stainless Steel Nozzles			
No. 1	222	3.52	+ 7
2	203	3.22	- 2
3	224	3.55	+ 8

* Expected flow 3.28 GPH.

5.2 Pressure Variations

The effects of variations in pressure on the flow rate of discharging fluid were studied to determine the precision with which the pressure must be monitored. If small fluctuations in pressure produced large fluctuations in the discharge rate, fire performance in this test may vary and account for the observed discrepancies.

5.2.1 Water

The flow characteristics of a standard nozzle [Binks 0.64 mm (0.025 in) diameter orifice] was determined by measuring the total flow of water at 65°C (150°F) with delivery pressures ranging from 689 KPa (100 PSIG) to 6890 KPa (1000 PSIG). Flow measurements were made using the described procedure for nozzle flow rate calibration. Figure 2 shows flow data for seven different pressures. Here the total flow is plotted against the time of discharge. As expected, the total flow increased linearly with increasing pressure. Water discharge through the nozzle is about three times greater at 1000 PSIG than 100 PSIG.

5.2.2 Hydraulic Fluids

Total flow measurements for an invert emulsion fluid (no. 14) at 65°C (150°F) and at six different pressures are shown in figure 3. Compared to water flows (see figure 2) this fluid (and all other

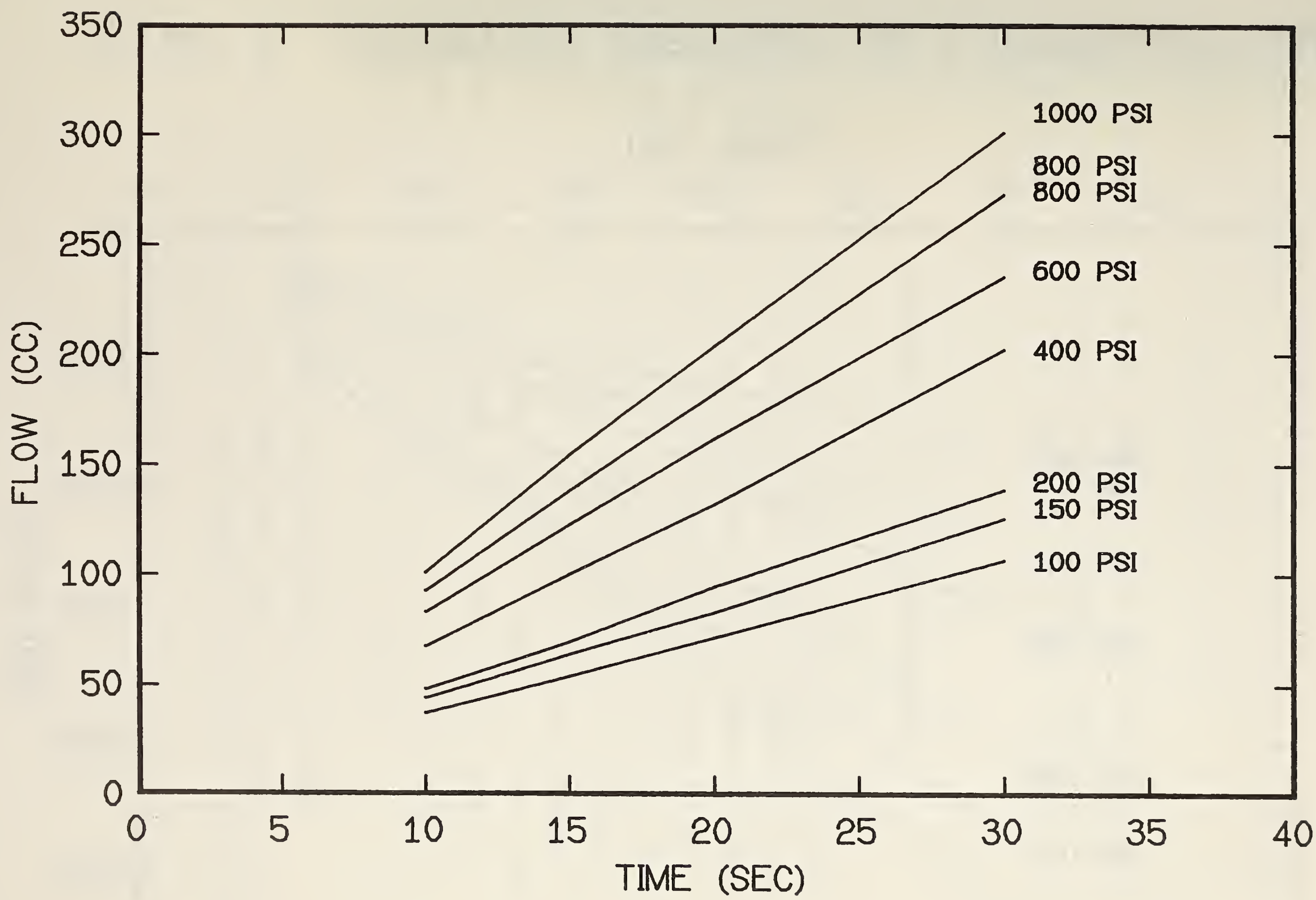

FIGURE 2. EFFECT OF PRESSURE ON WATER SPRAY

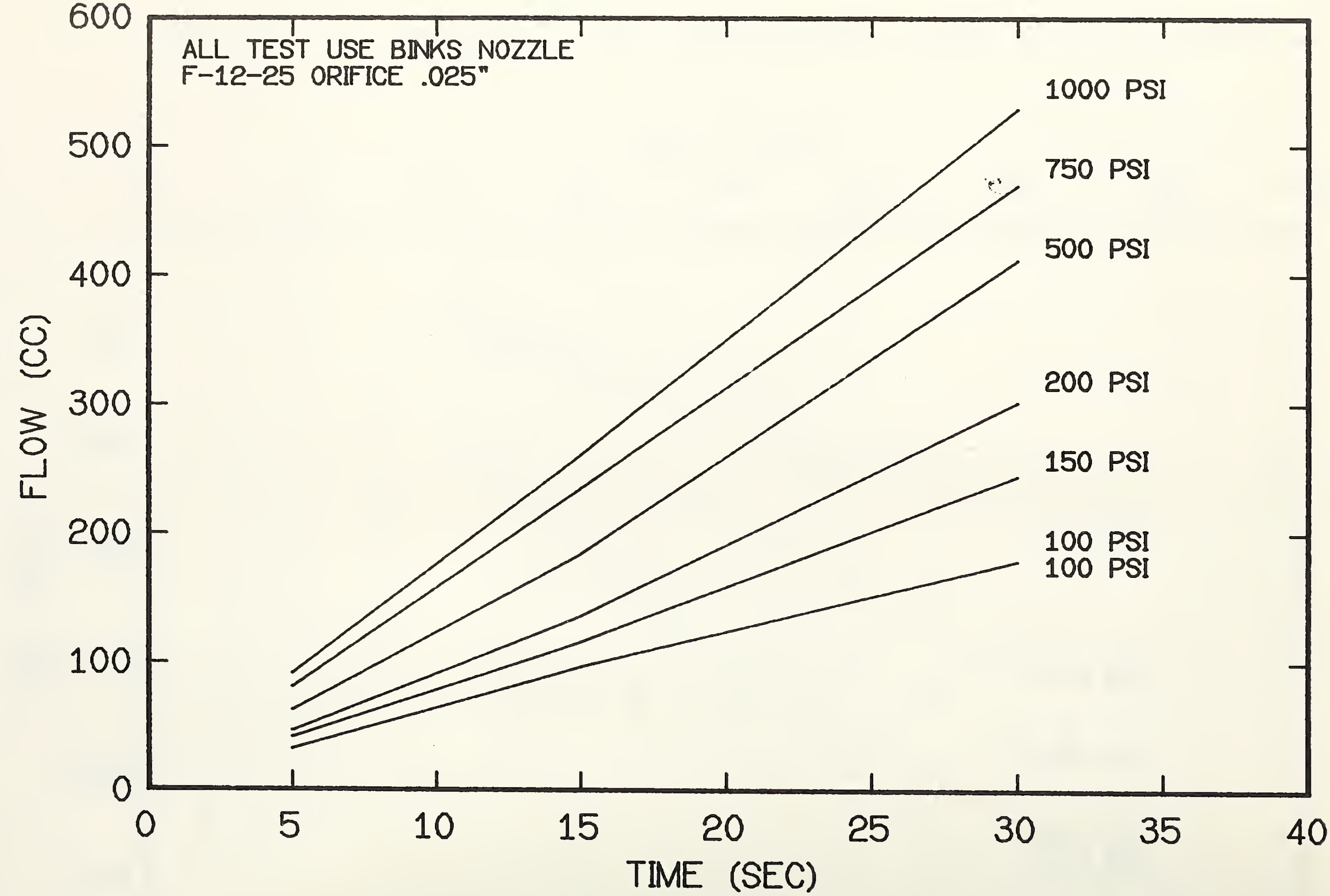

FIGURE 3. EFFECT OF PRESSURE ON A HYDRAULIC FLUID

hydraulic fluids tested exceeded the water flow by values ranging from 31 to 131 percent. Table 4 lists flow values for all 14 test fluids and water when sprayed under test conditions.

An examination of this table shows that the general rank order for decreasing fluid flows was invert emulsions, synthetic and water glycol. All of the invert emulsions double the flow value observed for water.

CONCLUSIONS - FLOW RATE CHARACTERIZATION

Flow rate characterization measurements were made to determine if differences in flows might be responsible for differences found between MSHA spray ignition test results (all 14 fluids were certified) and CFR's results (obtained using MSHA spray ignition test procedures) where only three of the 14 fluids were rated as passing fluid materials. Although the MSHA spray nozzle flow rates were found to be higher (13-64%) than the nozzle manufacturer's reported value of 3.28 GPH at 100 psig pressure (see table 3) and CFR's nozzle flows were more closely aligned with the specified flow rates, it would appear that these differences would not be large enough to account for the differences in test results seen here.

CFR would thus attribute these differences to "operator observations" (i.e., Did the fluid spray ignite and flame for 6 seconds continuously or not?). Quite possibly CFR was more critical of test events than MSHA.

In order to avoid this qualitative method of obtaining test results, CFR thus sought to develop a more objective (quantitative) means of test whereby numbers (i.e., temperature and heat flux values) would be used to rate or rank fluids for flammability resistance. This alternate spray ignition test method would thus essentially eliminate subjective interpretations of test results.

6. ALTERNATIVE SPRAY IGNITION TESTS

The new approach to spray ignition testing used the same test apparatus and temperature-pressure testing conditions as specified in the MSHA spray ignition test. The new test provided for measurement of heat (temperature rise) and energy (heat flux) developed by flaming fluid materials which values would yield a more quantitative measurement of flammability resistance. Numerical values are thus obtained for exhaust gas temperature rise and heat flux normal to the spray axis.

Temperature rise measurements are obtained with a thermopile made of nine chromel-alumel thermocouples (0.64 mm diameter) connected in parallel (see figure 4). The thermopile is shown mounted in the exhaust port of the test chamber (see figure 5).

Table 4. Comparison of fluid flows - hydraulic fluids and water sprayed at 65°C (150°F) and 150 psig

Fluid No.	Type	Flow cc/min*	% > Water
Water		214	0
8	Synthetic	280	31
9	"	318	49
1	Water Glycol	330	54
2	"	338	58
10	Synthetic	380	78
12	"	402	88
4	"	410	92
6	"	410	92
3	"	422	97
13	Invert Emulsion	434	103
11	"	442	106
7	"	482	125
14	"	486	127
5	Invert Emulsion	494	131

* Binks nozzle F-12-25 orifice 0.025 in used for test.

Heat flux measurements are made with a water cooled heat flux transducer (Medtherm Corporation, Model No. 64-1-20) mounted in one of the doors of the test chamber (see figure 5) and positioned to look into and across developing flame fronts generated by flaming fluid spray patterns.

The ignition source used for this spray test is the same as one of those used in the MSHA test; i.e., the flaming cotton or trough test.

6.1 Distance of Ignition Source

Three different spray nozzle to ignition source distances used by MSHA in their certification tests [45 cm (18 in), 60 cm (24 in), and 90 cm (36 in)] were evaluated by the CFR spray ignition test. An invert emulsion fluid (no. 14) was used as the single test fluid. Figure 6 shows a plot of temperature rise versus distance for the test fluid. The data show that the stack temperature rise was minimal for the 90 cm test. This was generally due to the fact that the spray did not travel far enough to reach or become involved with the ignition source. At 45 and 60 cm, the fluid sprays were easily ignited and flamed considerably. The greatest degree of flammability (highest temperature rise) was noted at the 45 cm distance. An examination of these curves shows that after 10 seconds of testing, the 45 cm distance (spray) had generated a temperature rise of 270°C (518°F) while for the same time period the 60 cm

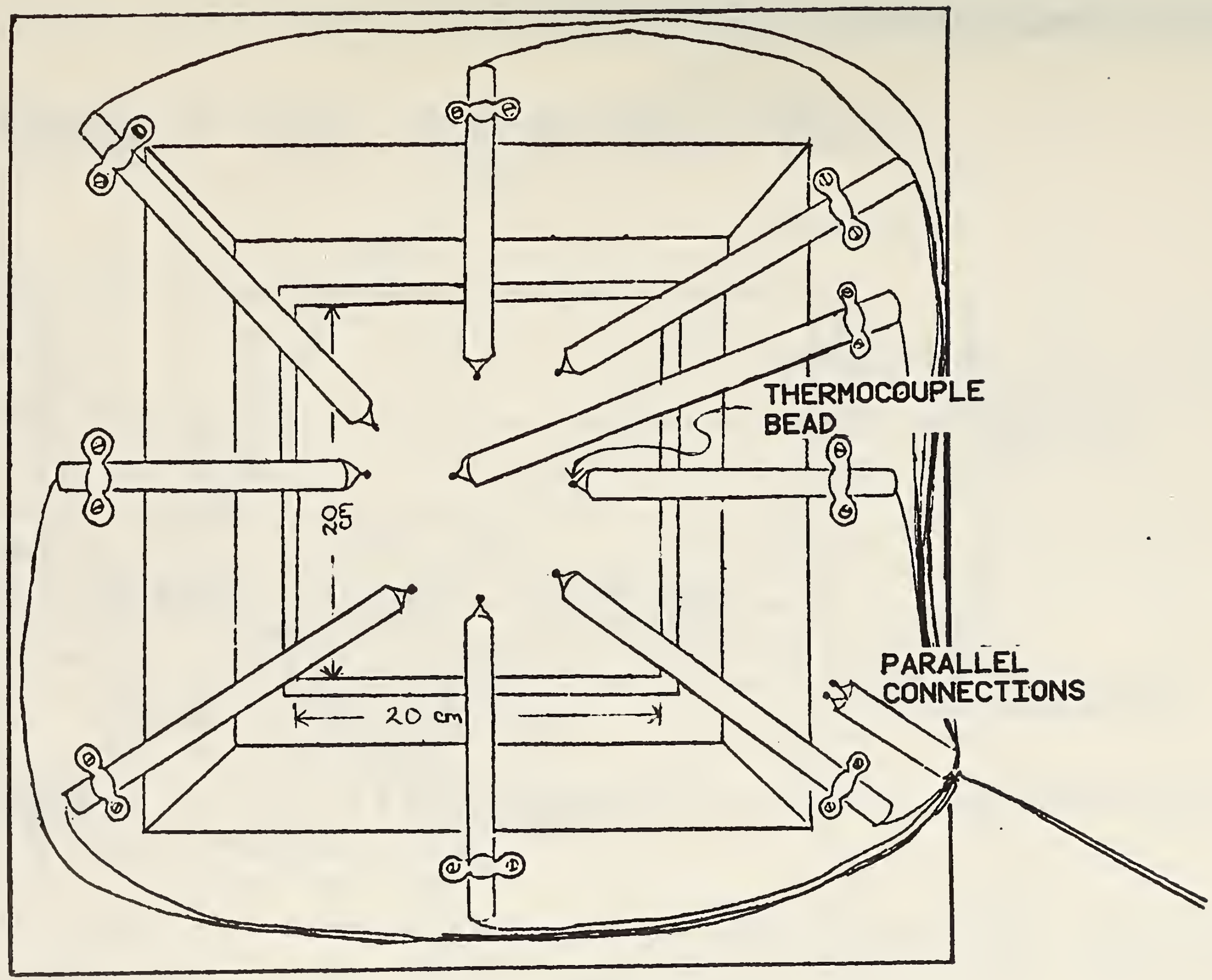

FIGURE 4. THERMOPILE FOR SPRAY IGNITION TEST

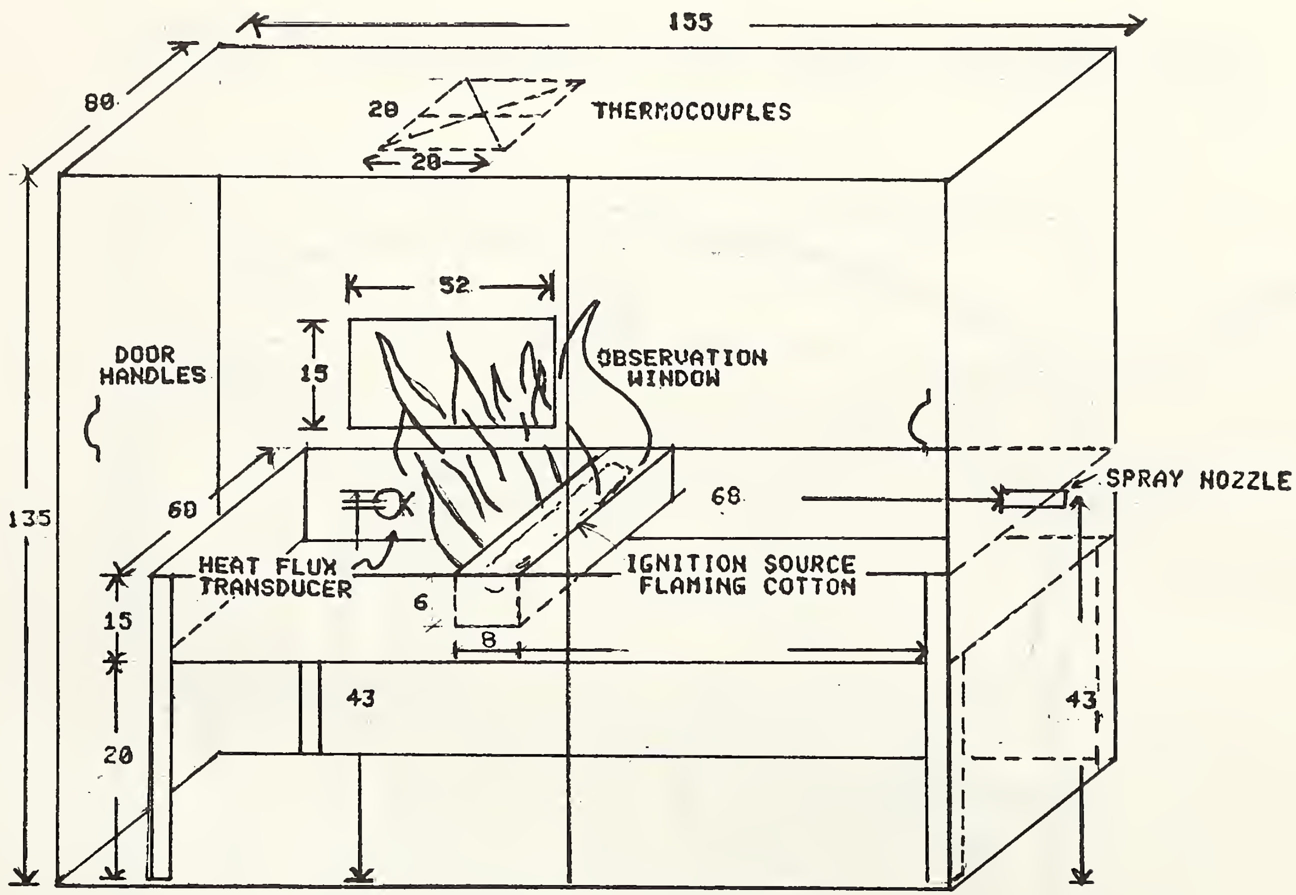

FIGURE 5. SPRAY IGNITION TEST CABINET

* ALL DEMINSIONS IN CENTIMETERS

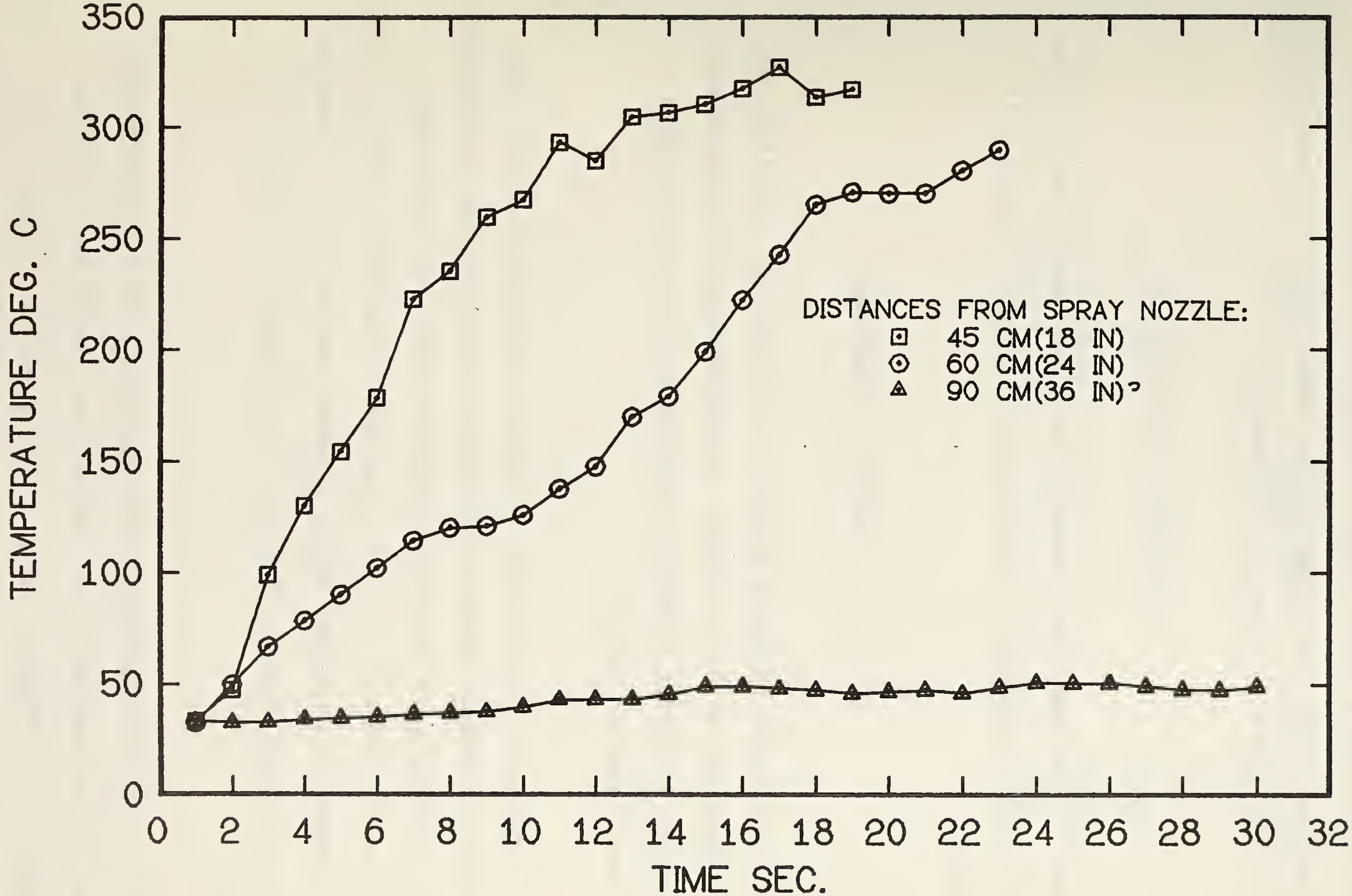

FIGURE 6. EFFECT OF DISTANCE- SPRAY NOZZLE TO IGNITION SOURCE ON THE FLAMMABILITY OF HYDRAULIC FLUID SPRAY

test spray produced a 120°C (248°F) of temperature rise. With the ignition at the 90 cm test location the temperature rise was less than 50°C even after 30 seconds of exposure.

6.2 Nozzle Orifice Size

Table 5 lists the spray nozzle type, spray angle, and orifice diameter for five different nozzles used for tests described in section 6.2.1.

6.2.1 Pressure Variations

Using an invert emulsion fluid (no. 14) as the test fluid and a test temperature of 65°C (150°F), stack temperature measurements were for four different pressures ranging from 100 to 500 PSIG. Results are listed in table 6.

An examination of this data shows that temperature rise and temperature differences were slight for all size nozzles at 100 PSIG. Negligible differences were also found for the .018 and .020 in nozzles even at 150 and 300 PSIG pressures. The MSHA (.025 in) spray nozzle produced the highest spray temperatures for all the nozzles tested at pressures ranging from 150 (the MSHA test pressure) to 500 PSIG.

The 10 second temperature rise cut off point was arbitrarily selected for two reasons (i.e.: safety and comparison of nozzle performance). To continue testing much beyond 10 seconds was

Table 5. Test nozzle orifices

Nozzle No.	Type	Spray Angle	Orifice (in)*
1	Hollow Cone	70	.014
2	Hollow Cone	90	.018
3	Hollow Cone	70	.020
4	Round Spray	90	.025
5	Hollow Cone	70	.028

* Note: Nozzle diameter values are reported in terms of inches by the nozzle manufacturers.

Table 6. Relation of nozzle size and fluid pressure to stack temperature rise

Nozzle No.	10 Sec Temperature Rise °C			
in	100 psig	150 psig	300 psig	500 psig*
1 (.014)	52	56	176	206
2 (.018)	47	43	48	106
3 (.020)	55	54	60	164
4 (.025)	50	105	257	*
5 (.028)	71	102	142	326

* Flaming too severe to obtain a 10 sec reading.

NOTE: Nozzle diameter values in inches and pressure values in psig are terms in common use by nozzle manufacturers.

judged unsafe and would have caused severe damage to test equipment. In the case of the MSHA (.025 in) nozzle data for 10 seconds was not obtained because of test severity.

As expected the quantity of fluid discharged (from the large size nozzles) into the ignition source and its effect of flame intensity was more pronounced at the higher fluid pressures especially at 300 and 500 PSIG.

6.2.2. Temperature Variations

In the tests described here, the fluid temperature was varied while the fluid pressure was held fixed at 150 PSIG.

Table 7 lists the spray nozzle type, spray angle, orifice diameter, and the 10-second temperature rise values generated by sprays for fluids at three different test temperatures.

Data show that a 30°C spread in fluid temperature (65 to 95°C) did not appreciably affect the flammability of sprays from the smaller size (0.014, 0.018, and 0.020 in diameter) spray nozzles. Temperature rise values for these nozzles ranged from 41 to 61°C.

Temperatures generated by fluids sprayed from the larger size nozzles (0.025 and 0.028 in diameter) showed that the 65°C fluid produced values doubling those measured for the smaller size nozzles. At fluid temperatures of 80 and 95°C these temperature rise values were higher by almost a factor of 3.

Table 7. Temperature rise values generated by the flaming fluid sprays at various test temperatures

Spray Nozzle			10 Sec Temperature Rise °C		
			Fluid Test Temperature °C		
Type	Spray Angle	Orifice (in)	65°	80°	95°
Hollow Cone	70	.014	56	61	47
Hollow Cone	90	.018	43	53	41
Hollow Cone	70	.020	54	51	45
Round Spray*	90	.025	105	129	51
Hollow Cone	70	.028	102	184	162

* MSHA specified nozzle.

The highest temperature rise was recorded for fluid sprayed from the 0.028 in diameter nozzle when the fluid temperature was 80°C.

Using the standard MSHA nozzle, figures 7 and 8 show the effect of fluid temperature variation on stack temperature rise for invert emulsion and synthetic fluids. In general, increasing the fluid's starting temperature increases a fluid's flammability as measured by stack temperature.

6.3 Test Results at 65°C and 150 PSIG

Table 8 lists the peak temperature rise and heat flux values obtained for tests on hydraulic fluids using the CFR (alternate) spray ignition test method. Tests were made under MSHA test conditions of fluid temperature at 65°C (150°F) and fluid pressure of 150 PSIG. Results show that the two water glycol fluids and one synthetic resisted ignition and flaming in the tests, while all five invert emulsions and six of the seven synthetic fluids did ignite and flame vigorously. For safety reasons all tests were terminated between 10 and 30 seconds.

Also listed in the table are 10-second temperature rise and heat flux values for all of the test fluids. An examination of these values shows that three invert emulsion fluids produced

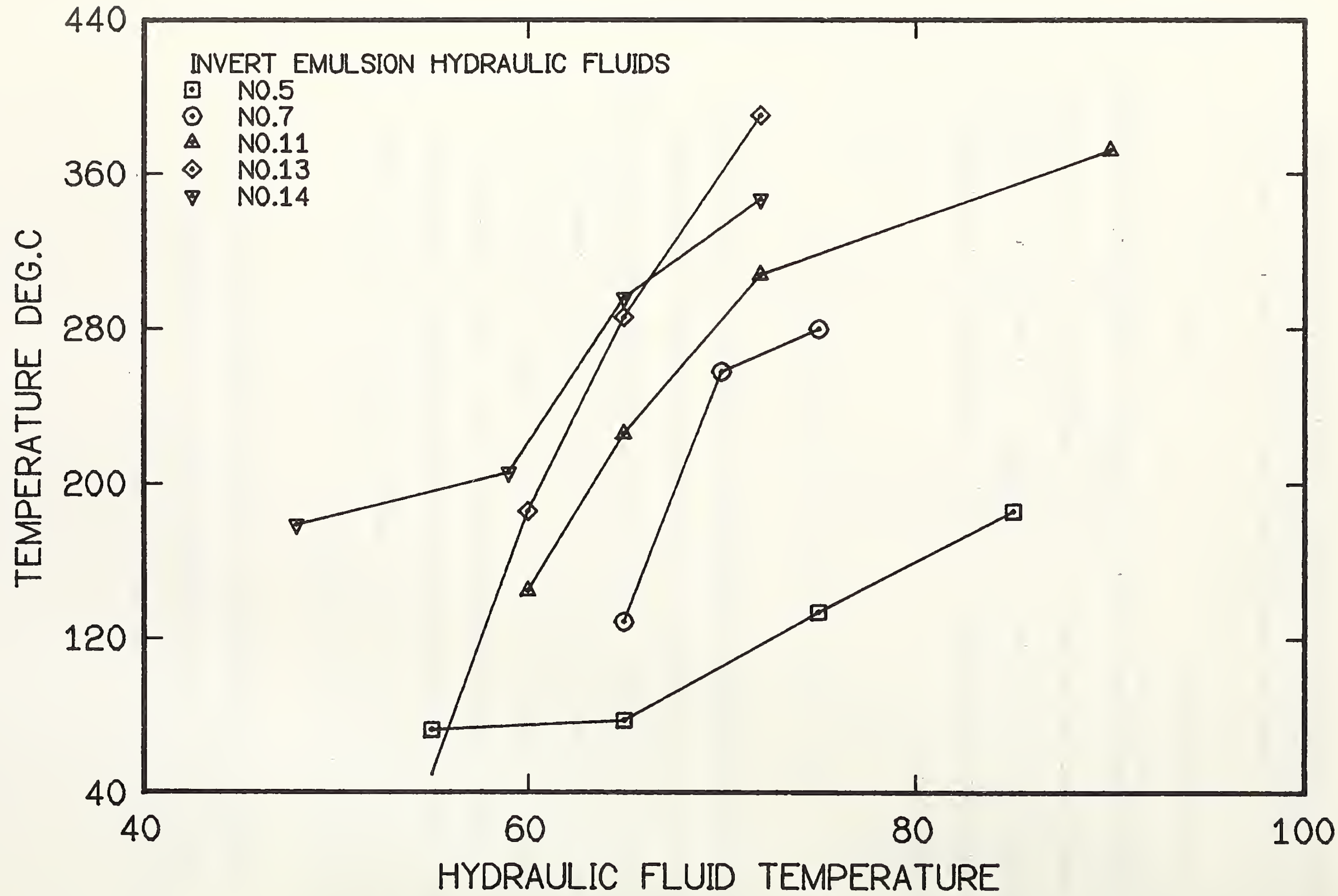

FIGURE 7.

RELATION OF FLUID TEMPERATURE TO FLAMMABILITY OF INVERT EMULSION HYDRAULIC FLUIDS

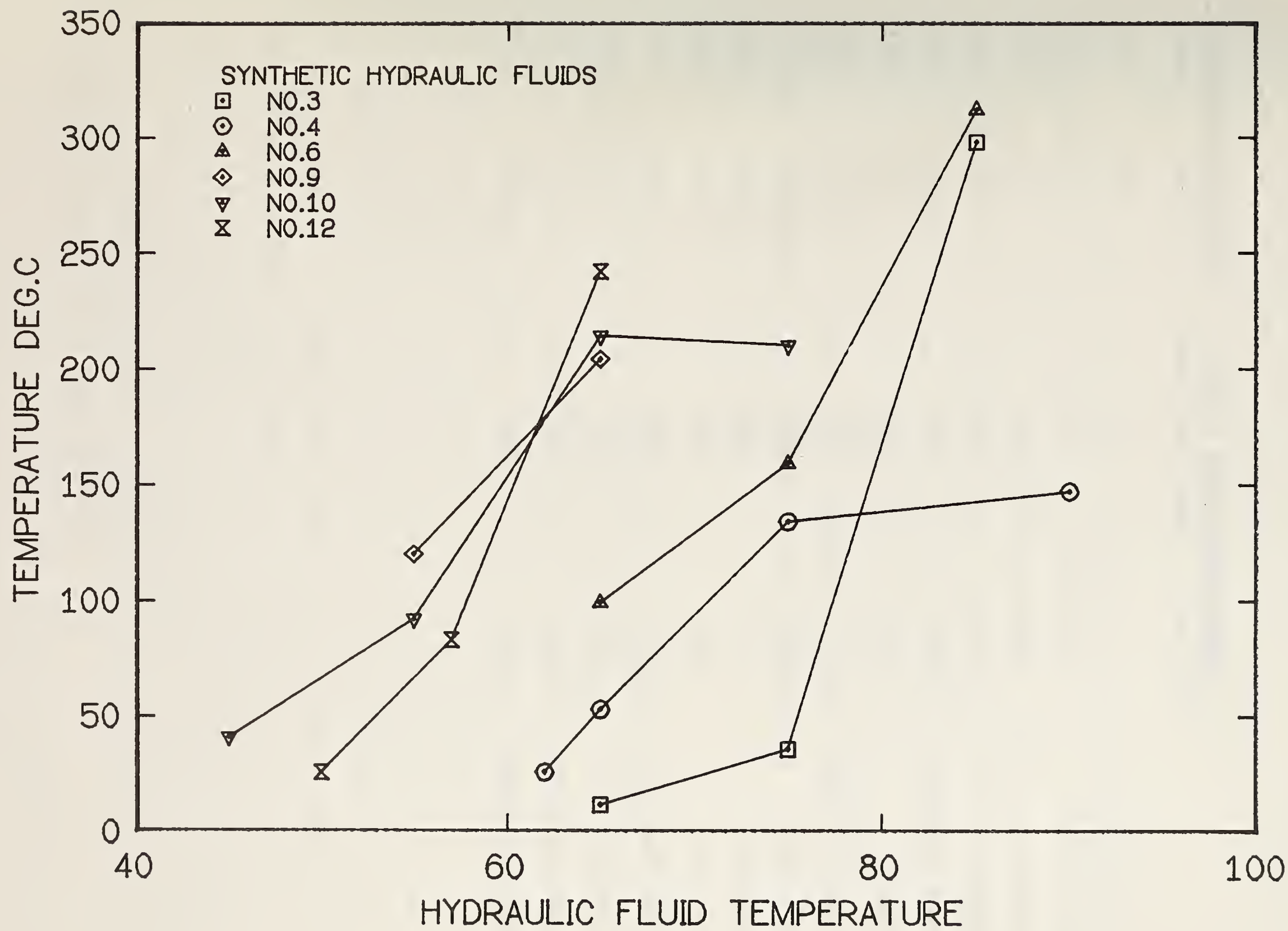

FIGURE 8.

RELATION OF FLUID TEMPERATURE TO FLAMMABILITY OF SYNTHETIC HYDRAULIC FLUIDS

Table 8. Temperature rise and heat flux for hydraulic fluids at 65°C (150°F) and 150 psig pressure

Fluid No.		Temperature Rise (°C)*		Heat Flux Watts/Cm^2	
		10 Sec	Peak 13-30 Sec	10 Sec	Peak
1	Water Glycol	0	2	.02	.03
2	Water Glycol	5	8	.05	.05
3	Synthetic	3	12	.09	.15
4	Synthetic	6	53	.10	.38
5	Invert Emulsion	222	306	1.35	1.37
6	Synthetic	10	99	.16	.53
7	Invert Emulsion	34	129	.11	.43
8	Synthetic	140	158	.63	.70
9	Synthetic	70	204	.62	1.09
10	Synthetic	107	214	.82	1.19
11	Invert Emulsion	128	226	.51	.85
12	Synthetic	82	242	.71	1.09
13	Invert Emulsion	218	286	1.37	1.39
14	Invert Emulsion	216	296	1.37	1.48

* Temperature rise = peak temperature °C minus 30°C.

temperature rise values greater than 200°C (392°F), while one emulsion fluid and two synthetics showed temperatures greater than 100°C (212°F) in the initial 10-second time period.

The peak heat flux values, as expected, followed the same rise patterns as were measured for temperature, e.g.: the lowest values were recorded for the nonigniting water glycols and the highest values were observed for the fluids which produced high temperature rise values (296°C). Maximum recorded values for temperature rise and heat flux shown plotted in Figure 9 shows good correlation between these parameters. This suggests that either measurement could be used to characterize the flammability of the hydraulic fluids tested.

A comparison of the MSHA method's spray ignition test results with the Center's shown in Table 9 indicates that only three fluids (nos. 1, 2 and 3), two water glycols and one synthetic, did not ignite by MSHA standards. These fluids also performed well in the Center's tests showing temperature rises ranging from 2°C to 12°C. The main difference between the two test procedures is that the Center's test generally gives quantitative information, by providing for measurement of temperature rise and heat flux values generated by flaming fluids. These numbers can be used to rate or rank hydraulic fluids according to their fire resistance performance. The MSHA test on the other hand only provides for a Pass/Fail concept which in effect provides no information on the overall severity of flaming exhibited by a burning fluid.

FIGURE 9.

RELATION OF HEAT FLUX TO EXHAUST TEMPERATURE

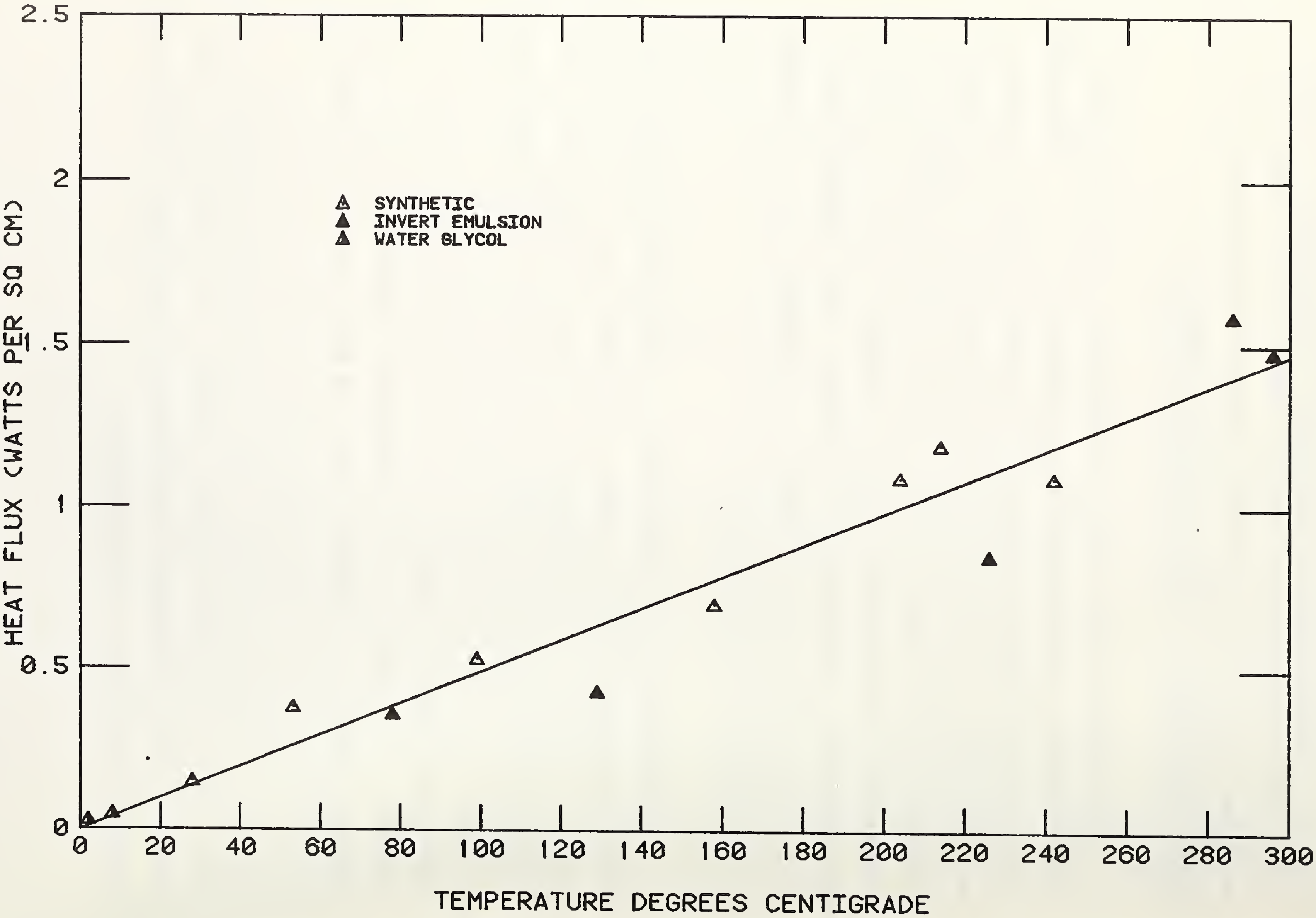

Table 9. Comparison of spray ignition test results on hydraulic fluids

Fluid Number	CFR Method Temperature Rise (°C)* 10 seconds	maximum	MSHA Method
1	0	2	N
2	5	8	N
3	3	12	N
4	6	53	I
5	222	306	I
6	10	99	I
7	34	129	I
8	140	158	I
9	70	204	I
10	107	214	I
11	128	226	I
12	82	242	I
13	218	286	I
14	216	296	I

* Temperature rise = peak temperature °C minus 30°C.

At the present time, no limits have been established for temperature rise or heat flux values in the Center's spray ignition test; however, it would appear that 10-second peak temperature or heat flux values might serve as the base or limit point for rating hydraulic fluids for fire resistance.

7. SUMMARY AND CONCLUSIONS

1. The Mine Safety and Health Administration (MSHA) Spray Ignition Test (included in the Code of Federal Regulations Schedule 30 Part 35 Flammability Regulations for Hydraulic Fluids) was used to determine the fire resistance of 14 different hydraulic fluids. Two water glycol and one synthetic fluid met all the requirements of the MSHA test while the remaining fluids failed to meet the test criteria.

2. Electric sparks as an ignition source (in the MSHA test) were unable to ignite 13 of the 14 test fluids.

3. The exact duplication of results obtained for propane torch and flaming cotton (trough) tests in the MSHA tests questions the need for two flame ignition sources in the MSHA test method.

4. A procedure was developed for calibrating spray nozzles for flow rates. By this method, nozzles which operate within $\pm$ 10 percent of the nozzle manufacturer's stated flow rate might be specified in the test method.

5. Test hydraulic fluids discharged at a faster rate than water in the spray test setup. At the specified test temperature of 65°C (150°F) and pressure of 150 PSIG, the decreasing order of flow rates by fluid type was invert emulsion, synthetic, water glycol, and water. On a percent basis the hydraulic fluid flow rates were 31-131 percent greater than for water.

6. A quantitative spray test concept for determining the fire resistance of hydraulic fluids was developed by the Center for Fire Research at the National Bureau of Standards (NBS). The method uses temperature rise and heat flux measurements to rate or rank fluids for flammability based on their performance in the test.

7. Evaluations of the distances between the spray nozzle and the ignition source, e.g., 45, 60, and 90 cm, in spray ignition tests showed that the "worst case conditions" or highest temperature rise values were obtained for fluids sprayed at a distance of 45 cm (18 in) from the ignition source. The distance specified for the MSHA test is 45 cm.

8. The effect of varying parameters on the fire performance of hydraulic fluids showed that flame intensity increased with nozzle pressure and short nozzle to ignition source distance.

9. A study of the relation of hydraulic fluid temperature to flammability showed in the Center's spray ignition tests that flaming intensity (for all fluid sprays except water glycols) increased with increasing fluid temperatures.

10. A comparison of MSHA test results with stack temperature rise values obtained in the Center's tests showed that a criterion of a maximum acceptable stack temperature of 50°C produced excellent agreement between the two tests (shown in table 9).

11. The combined effect of spray nozzle orifice size and varying fluid pressures on flammability showed that at 100 PSIG pressure the size of the spray nozzle orifice was not critical to temperature rise; however, at 150 PSIG the temperature rise generated by sprays from the large size nozzles (0.025 and 0.028 in) was almost double the temperature values measured for fluid sprayed from the smaller size nozzles (0.014, 0.018, and 0.020 in). At 300 PSIG sprays from the MSHA nozzle (0.025 in) produced the highest temperature rise value, 257°C, and at 500 PSIG the spray from the MSHA nozzle flamed so severely that a 10-second reading could not be attempted. For safety reasons the MSHA specified pressure of 150 PSIG appears adequate for making spray test measurements.

12. The combined effect of spray nozzle orifice size and varying fluid temperatures on flammability showed that sprays from the small size nozzles (0.014, 0.018, and 0.020 in) produced only slight differences in temperature rise for the test fluid sprayed at temperatures of 65, 80, and 95°C.

The larger size nozzles (0.025 and 0.028 in), as expected, allowed more fluid (or fuel) to become involved with the ignition source and thus temperature rise values increased by at least a factor of three over values recorded for smaller size nozzles.

8. RECOMMENDATIONS

Based on the results of this evaluation study, the following recommendations can be made:

1. The MSHA Temperature-Pressure Spray Ignition Test conditions; i.e., 150 PSIG pressure, 65°C (150°F) temperature, spray nozzle orifice size of 0.025 in diameter and distance--spray nozzle to ignition source of 45 cm, all appear to be ideal for conducting spray ignition tests on hydraulic fluids.

2. The flaming cotton test should be used as the sole ignition source for the MSHA spray ignition test because it represents the most severe (or worst case) condition and is safer to conduct than the propane torch test when the torch must be moved in the fluid spray.

3. The main problem or difficulty found with the MSHA spray ignition test method is in the interpretation of test results (i.e., in making decisions as to whether a test fluid flamed for six continuous seconds or not). Since this pass-fail judgement is qualitative and is left to the test operator it sometimes occurs that different viewers of the same test may reach opposite conclusions.

Under such circumstances it is not unexpected that reproducibility of the test among different laboratories may indeed be poor. It is recommended that the present criterion be changed to a maximum temperature rise criterion and that this procedure be developed further and completely evaluated.

9. BIBLIOGRAPHY

[1] Code of Federal Regulations Schedule 30 Part 35 for Measuring the Flammability of Hydraulic Fluids.

[2] NBSIR-81-2247 Flammability Measurements on Fourteen Different Hydraulic Fluids Using a Temperature Pressure Spray Ignition Test.

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NBSIR 81-2373	2. Performing Organ. Report No.	3. Publication Date October 1981

4. TITLE AND SUBTITLE

AN EVALUATION OF THE MSHA TEMPERATURE-PRESSURE SPRAY IGNITION TEST FOR HYDRAULIC FLUIDS

5. AUTHOR(S)

Joseph J. Loftus, Adalberto Maldonado-Rosado, and Paula J. Allen

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

Final Report

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

U.S. Bureau of Mines
Pittsburgh, Pennsylvania 15213 and Mine Safety and Health Administration
Triadelphia, West Virginia 26059

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

The Mine Safety and Health Administration (MSHA) Temperature-Pressure Spray Ignition Test for determining the fire resistance of hydraulic fluids was evaluated in spray ignition tests on 14 different hydraulic fluids including water glycols, synthetics, and invert emulsions. Results of these and of other tests designed to evaluate the test method and its procedures are discussed in this report.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Coal mine; fire tests; hydraulic fluids; invert emulsions; pressure-temperature; spray; synthetics; water glycol.

13. AVAILABILITY

[XX] Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
[XX] Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

44

15. Price

$6.50

USCOMM-DC 6043-P80