PROFESSIONAL LOSS CONTROL, INC.

ANALYSIS OF ELECTRAY HANGER RODS IN UNIT 1 MECHANICAL PIPE CHASE AT McGUIRE NUCLEAR STATION FOR DUKE POWER COMPANY

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ANALYSIS OF ELECTRAY HANGER RODS

1.0 AREA DESCRIPTION

The area under consideration is the Unit 1 Mechanical Pipe Chase on the 716'-0" elevation of the Auxiliary Building. The bounding walls are constructed of reinforced concrete. The ceiling height in this area is greater than 30 feet. The large open area and the ceiling height will prevent the build up of a significant hot layer. Therefore, only fire plume effects need be evaluated. (See Attachment A for a sketch of the area under consideration.) There are no automatic suppression systems in the area, but smoke detectors are provided. Portable fire extinguishers and hose stations are available for manual fire fighting operations.

2.0 PROBLEM STATEMENT

The problem is to determine if electray hanger rods will lose their support strength due to elongation and possible subsequent failure of the rods due to the temperature of the fire below the rods. In the area are three electrays which contain power and control cables for certain motor operated valves. These valves may be required during certain shutdown operations. A three-hour fire resistive barrier wrap is installed on the electrays to prevent an exposure fire from damaging the cables in the electrays. The exposing cable trays are not wrapped. The postulated fire scenarios of concern are a fire in each of the three cable trays 4-6 feet below one of the electray hangers (see Attachment A) or floor level fires involving transient combustibles.

3.0 COMBUSTIBLE LOADING

The area contains control and power cable trays. The predominant type of combustible in the area is cable insulation. Transient combustibles were considered. However, since the area is a normally (plant operating) unoccupied and locked high radiation area, the presence of

transient combustibles was considered to be unlikely. The total loading in the five (5) cable trays shown on Attachment A is 796 lbs. of cable insulation and the average tray loading is 5.27 lbs/ft^2 of tray surface area. (See Attachment B for cable insulation calculations.) Enclosed combustibles such as cabling in conduit and in wrapped electrays have not been considered in this analysis.

4.0 ANALYSIS

This analysis was conducted in two parts; first, the quantification of the failure temperature of the electray supports, and second, the quantification of the fire exposure plume temperature. Because of the large surface area to mass ratio of the supports (rods), heat transfer to the supports was considered instantaneous and a failure would occur the instant the air temperature exceeded the rod failure temperature.

Manufacturer's data on the hanger rods indicates that for design, the maximum allowable load for a rod is 1,100 lbs. According to the manufacturer, the safe load is much higher. Duke Power Company, however, has limited the maximum allowable load for a rod to 80 lbs. The 1/2" diameter, 13 threads per inch hanger rods have an internal diameter of 0.45 inches. The rods are fabricated from low carbon, mild steel.

Using a loading of 80 lbs. yields a working stress of 503 psi or 0.5 ksi (thousand pounds per square inch).

Attachment C is an AISI graph (1) of yield strength of ASTM A36 steel (common mild carbon steel - yield strength $\cong$ 33 ksi) versus temperature. From the graph we can see that as a fire approaches a temperature of 1600°F, the yield strength of the steel member is in a range of 0-1 ksi. In order to obtain a precise temperature at 0.5 ksi, we must analytically evaluate the problem. From Malhotra (2), we can use the following equation for elastic properties of steel in the 700-900°C (1292-1652°F) range:

$$\frac{f_{yt}}{f_{y20}} = 0.1 - \frac{T° - 700}{2000}$$

where f_{yt} = yield strength at a specified temperature (ksi)

f_{y20} = yield strength at 20°C (ksi)

T° = specified temperature (°C)

We wish to solve for T° since we know f_{yt} is 0.5 ksi and f_{y20} is 33.0 ksi. Solving for T° the equation becomes:

$$T° = 2000\left(0.1 - \frac{f_{yt}}{f_{y20}}\right) + 700$$

$$= 2000\left(0.1 - \frac{0.5 \text{ ksi}}{33.0 \text{ ksi}}\right) + 700$$

$$= 869.7\ °C$$

$$= 1597°F$$

Therefore, in order for the yield strength of the hanger rod to be reduced to 0.5 ksi, the rod would have to be heated to a temperature of 1597°F. An AISI metallurgist feels that at this temperature and with a maximum load of only 80 lbs., the crystalline structure of the steel would essentially remain unchanged. (3)

The first scenario examined considered a cable fire in cable trays 1, 2, and 5 immediately below the 737' electray hanger. The best available data on free burning cable trays containing Hypalon and EPR jacketed cables appear in the FMRC/EPRI (4) test reports. For these cables, a worst case burning rate of 6.7 kg/min was measured for an array of 12 cable trays, each 8' long and 18" wide. This reduces to a surface controlled burning rate of 0.1 (lb/min)/ft^2 of cable tray or a heat release rate of 1000 (Btu/min)/ft^2 (190 KW/m^2), or 16.67 (Btu/sec)/ft^2 assuming a heat of combustion of 10,000 Btu/lb of cable insulation. Using this burning rate, the cable trays under the electray would burn for approximately 53 minutes.

Cable tray fire test data was examined to establish temperature profiles above burning cable trays. Tests performed by Sandia Laboratories (5) and FMRC/EPRI (4) show that temperatures around 1500°F are reached in the flame region immediately above the surface of a burning cable tray. This temperature drops rapidly with increasing distance above the surface of the cable tray.

The plume temperature profile above the cable fire is dependent on the number of trays in the stack and the width of the trays. The worst case exposure as shown on Attachment A is a fire involving the one 24" wide tray and 2-12" wide trays below. Since plume correlations assume a point fire source, a linear fire source such as cable trays must be evaluated as an equivalent point source. This can be done by assuming a fire length of twice the width of the trays as a point source. This yields a plume equivalent to that of a point source with a heat release rate as follows:

Tray 1	2 ft^2
Tray 2	2 ft^2
Tray 5	8 ft^2
	12 ft^2

$$\dot{Q} = 12\ ft^2 \times 16.67\ (Btu/sec)/ft^2 = 200\ Btu/sec$$

$$H = 4' - Z_o,\quad Z_o \cong -1'$$

$$H = 5'$$

This yields a maximum temperature in the vicinity of the electray support as follows(6):

$$\Delta T = \frac{300\ (K\dot{Q})^{2/3}}{H^{5/3}}$$

where ΔT = maximum temperature increase above ambient (°F)
K = 1 (when there are no nearby walls)
$\dot{Q}$ = total heat release rate (Btu/sec)
H = distance above the top of the fuel package (ft.)

substituting in the above values:

$$\Delta T = 300 \frac{(200 \text{ Btu/sec})^{2/3}}{(5)^{5/3}} = 700°F$$

$$T \cong 800°F$$

The second scenario examined is a floor level fire involving transient combustibles below the electray at the 727' elevation. The electray supports are a minimum of 11 feet above the floor. To reach failure temperature would require a fire approaching 4,500 Btu/sec (5 MW). Using a heat release rate of 290 (Btu/sec)/ft^2(6), this is equivalent to a 4.4 ft. diameter flammable liquid pool fire.

The third scenario examined is a floor level fire involving transient combustibles below the electray at the 737' elevation. The cable tray supports are a minimum of 21 feet above the floor. To reach failure temperature would require an enormous fire of greater than 22,500 Btu/sec (24 MW). This is equivalent to a 10 ft. diameter flammable liquid pool fire. Such a large fire is not considered credible.

5.0 CONCLUSIONS

1) Cable exposure creates a plume temperature around the 737' electray supports (rods) of 800°F. This worst case exposure is approximately 800°F less than the failure temperature of the supports. Therefore, the fire endurance of the electray supports is assured with an adequate margin of safety in the event of a cable fire.

2) The plume temperature around the electray rods in case 1 above is 800°F. Therefore, the radiant heat from the fire to the electray rods at the 727' elevation will be considerably less than 800°F due to the separation between the electrays.

3) The size of a floor level transient fire capable of failing the electray supports at the 727' elevation is 5 MW (4,500 Btu/sec). This is equivalent to a flammable liquid pool fire of 4.4 ft. in diameter. This transient fire exposure, because of the location and inaccessibility of the area, is not a credible event.

4) The size of a floor level transient fire capable of failing the electray supports at the 737' elevation is 24 MW (22,500 Btu/sec). This is equivalent to a flammable liquid pool fire of 10 ft. in diameter. This transient fire exposure, because of the location and inaccessibility of the area, is not a credible event.

6.0 REFERENCES

1. Boring, Delbert F., Spence, James C. and Wells, Walter G., "Fire Protection Through Modern Building Codes, Fifth Edition," American Iron and Steel Institute, October, 1981.

2. Malhotra, H.L., "Design of Fire-Resisting Structures," Surrey University Press, 1982.

3. Personal conversation with AISI metallurgist Calvin Cooley.

4. FMRC, "Categorization of Cable Flammability, Intermediate Scale Fire Tests of Cable Tray Installations," Electric Power Research Institute, EPRI NP-1881, August, 1982.

5. Schmidt, W.H. and Krause, F.R., "Burn Mode Analysis of Horizontal Cable Tray Fires," SAND 81-0079, NUREG/CR-2431, Sandia National Laboratories, February, 1982.

6. Alpert, Ronald L. and Ward, Edward J., "Evaluating Unsprinklered Fire Hazards," SFPE Technology Report 83-2, 1983.

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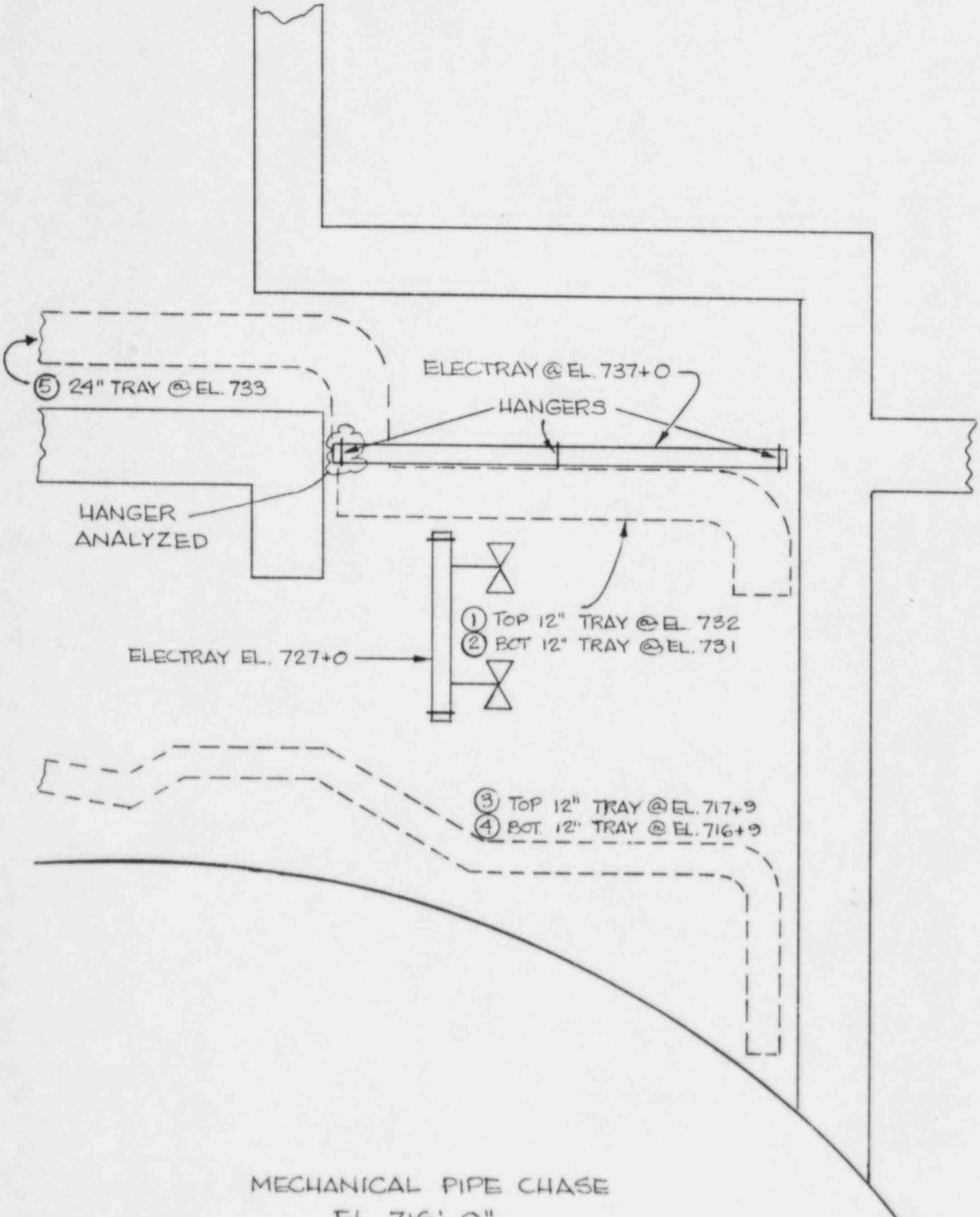

MECHANICAL PIPE CHASE
EL. 716'-0"
PLAN

Attachment A

MECHANICAL PIPE CHASE CABLE INFORMATION

1. 12", 26', max fill 50 cables
2. 12", 27', max fill 56 cables
3. 12", 36', max fill 56 cables
4. 12", 36', max fill 53 cables
5. 24", 13', max fill 104 cables

Most typical cables are:

3XJ1261 - 3 conductor 126a.		60 mil PVC
4XJ1261 - 4 conductor		60 mil PVC
12XJ1261 - 12 conductor		80 mil PVC
1SPA16G.3 - 1 shielded pan (ie) 2 conductors		
2SPA16G.3 - 2 shielded pan (ie) 4 conductors		

#12AWG

Each conductor 30 mil EPR, 15 mil Hypalon, Cables have PVC jackets.

30 mil EPR = 10 lb/1000 LF
15 mil Hypalon = 6 lb/1000 LF
15 mil PVC = 6 lb/1000 LF

Each conductor of shield pans 15 mil PVC & 20 mil Hypalon, 30 mil PVC jacket.

Suggest that cables be considered equally distributed among trays.

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CABLE INSULATION CALCULATIONS

A	B		C	(AB) + C
No. of Conductors	Conductor Insulation		Jacket Insulation (PVC)	Total
	EPR	Hypalon		
3	$\frac{10 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{4 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{72 \text{ lbs.}}{1000 \text{ ft.}}$
4	$\frac{10 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{4 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{88 \text{ lbs.}}{1000 \text{ ft.}}$
12	$\frac{10 \text{ lbs.}}{1000 \text{ft.}}$	$\frac{6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{5.3 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{224 \text{ lbs.}}{1000 \text{ ft.}}$
	PVC	Hypalon		
2	$\frac{6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{1.3 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{2 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{40 \text{ lbs.}}{1000 \text{ ft.}}$
4	$\frac{6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{1.3 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{2 \times 6 \text{ lbs.}}{1000 \text{ ft.}}$	$\frac{68 \text{ lbs.}}{1000 \text{ ft.}}$
			TOTAL	$\frac{492 \text{ lbs.}}{1000 \text{ ft.}}$

Cables are considered to be equally distributed among trays:

$$\frac{492 \text{ lbs.}}{1000 \text{ ft.}} \div 5 \text{ cables} = \frac{98.4 \text{ lbs.}}{1000 \text{ ft. - cable}}$$

$$= \frac{0.0984 \text{ lbs.}}{\text{ft. - cable}}$$

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CABLE INSULATION CALCULATIONS (CONT'D)

Tray 1: (26 ft.) (50 cables) $\frac{0.0984 \text{ lbs.}}{\text{ft.-cable}}$ = 127.92 lbs.

Tray 2: (27 ft.) (56 cables) $\frac{0.0984 \text{ lbs.}}{\text{ft.-cable}}$ = 148.78 lbs.

Tray 3: (36 ft.) (56 cables) $\frac{0.0984 \text{ lbs.}}{\text{ft.-cable}}$ = 198.37 lbs.

Tray 4: (36 ft.) (53 cables) $\frac{0.0984 \text{ lbs.}}{\text{ft.-cable}}$ = 187.75 lbs.

Tray 5: (13 ft.) (104 cables) $\frac{0.0984 \text{ lbs.}}{\text{ft.-cable}}$ = 133.04 lbs.

TOTAL 795.86 lbs. cable insulation

AREA OF TRAYS

Tray 1: (1 ft.) (26 ft.) = 26 ft^2

Tray 2: (1 ft.) (27 ft.) = 27 ft^2

Tray 3: (1 ft.) (36 ft.) = 36 ft^2

Tray 4: (1 ft.) (36 ft.) = 36 ft^2

Tray 5: (2 ft.) (13 ft.) = 26 ft^2

TOTAL 151 ft^2 cable tray surface area

$$\text{Average Tray Loading} = \frac{795.86 \text{ lbs.}}{151 \text{ ft}^2}$$

$$= \frac{5.27 \text{ lbs.}}{\text{ft}^2}$$

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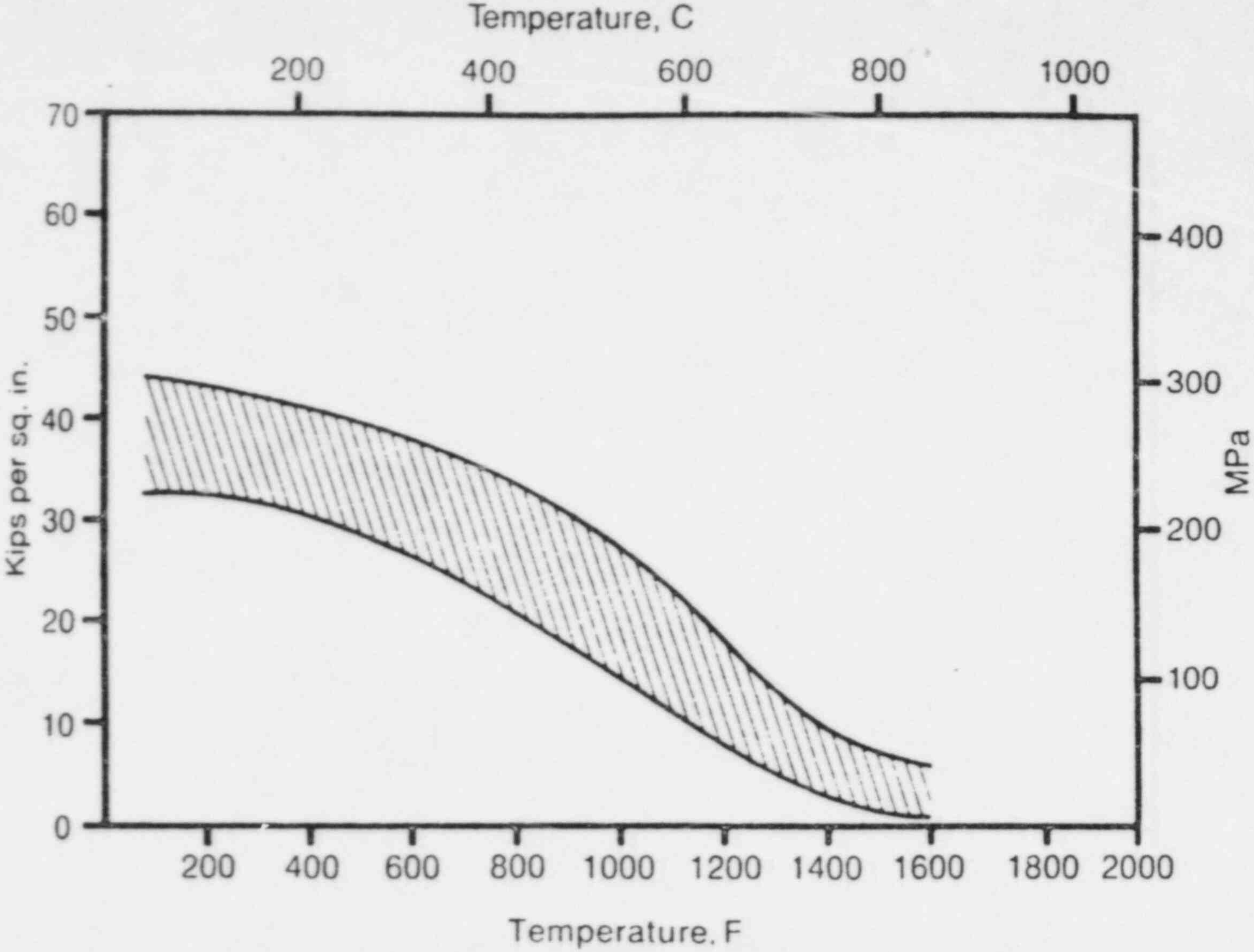

Yield strength of ASTM A36 structural steel at elevated temperatures.

Attachment C