USGS
science for a changing world
Department of the Interior
US Geological Survey
Box 25046 MS-974
Denver CO, 80225
April 11, 2005

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington DC 20555

Gentlemen:

The U.S. Geological Survey is herein responding to your request for additional information (TAC No. MC5120) dated March 10, 2005. This concerns the USGS amendment request to its research reactor facility license (No. R-113, Docket 50-274) to allow the use of aluminum-clad TRIGA fuel in the core.

Correspondence concerning this response should be directed to Tim DeBey, Reactor Supervisor.

Sincerely,

Randall L. Lipdale for
Warren Day
Reactor Administrator

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 4/11/05 Randall L. Lipdale

A020

REQUEST FOR ADDITIONAL INFORMATION UNITED STATES GEOLOGICAL SURVEY DOCKET NO. 50-264

1. Your answer to question 3 of our request for additional information (RAI) dated December 7, 2004, discussed fuel temperature in the F and G rings when limiting the measured temperature of a stainless steel clad fuel element to 800°C in the B ring. Technical Specification (TS) D.3 also allows the instrumented fuel element to be placed in the C ring, where fuel temperatures could be lower than in the B ring. Limiting the measured fuel temperature to 800°C in the C ring could result in higher temperatures in the F and G rings than would result from limiting measured temperature to 800°C in the B ring. Please provide maximum fuel temperatures in the F and G rings if the measured temperature of 800°C is taken from an instrumented fuel element in the C ring. (Note that your answer to question 9 below may change the 800°C temperature in this question.)

Response: In reference to question 9 of this document and our response, we are proposing to limit the measured temperature in (stainless steel) fuel elements to 750°C in the B-ring and 667 °C in the C-ring. The table below shows the expected measured fuel temperatures in the B, C, F, and G-rings under these maximum fuel temperature conditions. As shown, the F and G-ring fuel temperatures would be 447°C and 383°C, respectively. These values are below the proposed 500°C fuel temperature limit for aluminum-clad fuel elements.

Description	Cooling medium temp C	B-ring peak temp C	B-ring Δ T (°C)	C-ring peak temp C	C-ring Δ T (°C)	F-ring peak temp (°C)	F-ring ΔT (°C)	G-ring peak temp C	G-ring Δ T (°C)
S.S. - Temp limit conditions	60	750	690	667	607	447	387	383	323

2. The instrumented fuel element contains multiple thermocouples at different locations in the fuel element. Because of this, the temperature reading from the element may not be the true maximum temperature of the fuel in the element. Discuss the accuracy of your measured temperatures as compared to true temperature and the impact this has on the various temperatures given in your RAI request responses.

Response: There are several inaccuracies that can occur in the fuel temperature measurement. One is electronics error from the temperature measuring instrument, an Action Pak AP4350-0003 thermocouple transmitter (see attached data sheet). This instrument has an accuracy of ±0.25% of span with a cold junction compensation error of ± 1°C. The result would be an error of ±4.8°C at 750°C.

The other error occurs from the thermocouple not being at the actual location of peak temperature in the fuel element. For steady state operations, this error is from vertical mispositioning and it is approximately 10°C. During pulsing operations this error is 25% of the measured temperature. The error during pulsing is larger because it is a radial positioning error during the rapid transient: i.e., the peak temperature occurs near the fuel cladding and not at the element centerline. For example, during pulsing operations an indicated temperature of 400°C would equal an actual peak temperature in the fuel element of 500°C. This information is taken from Figure III-21 of the University of Illinois Safety Analysis Report, dated 1969. This figure is attached.

This potential inaccuracy impacts our response as follows: For steady state operations, it should be assumed that the peak fuel temperature is really 15°C higher than indicated. Since none of the allowed *steady state operations show that the F or G-ring temperatures are within 15°C of the 500°C proposed limit (see Table in Question 1 response above), there is no impact to the operational safety.*

During pulsing operations, the expected measured fuel temperature in the F-ring from a $3.00 pulse is 233°C. Applying the expected error of 25% plus 5°C instrument error gives a true peak fuel temperature of 296°C, much less than the 500°C proposed limit. The G-ring temperature would be less, at 252°C true peak temperature (see table below). Therefore the impact of these errors on the temperatures in our previous answers is that the temperatures are still well below the safety system limit of 500°C and there is no impact to the operational safety of the GSTR.

Description	Cooling medium temp C	B-ring peak temp C	B-ring Δ T (°C)	C-ring peak temp C	C-ring ΔT (°C)	F-ring peak temp C	F-ring ΔT (°C)	G-ring peak temp C	G-ring ΔT (°C)
Nominal $3 pulse – measured temp	20	400	380	354	334	233	213	198	178
Nominal $3 pulse –peak calculated temp	20	500	480	442	422	296	271	252	227

3. What was the wt% of the fuel in the instrumented fuel element used to measure the fuel temperatures given in your responses to our RAI? If the fuel wt% of the instrumented fuel element is different than the fuel wt% of the aluminum clad fuel, explain what effect the difference in fuel wt% has on the conclusions presented in your RAI response.

Response: The instrumented fuel element used to measure the fuel temperatures in the RAI responses was a 8.5 wt%, stainless-steel clad element with a 15" long fuel section. The aluminum-clad fuel elements are 8.0 wt% with 14" long fuel sections. This gives the aluminum-clad fuel elements ~12.2% less uranium loading than the instrumented fuel element that was used to measure the fuel temperatures. The effect would be that the aluminum-clad fuel would generate less power per element and therefore the temperatures would be lower than calculated. This makes our RAI response conservative.

4. Your answer to question 3 of our RAI contains fuel temperature data based on a coolant temperature of 50°C. However, your TSs allow a bulk pool temperature up to 60°C. Please present the data on fuel temperature assuming a coolant temperature of 60°C.

Response: The fuel temperatures were recalculated for the condition of the coolant temperature of 60°C and the results are given below. The net result is that the F and G-ring fuel temperatures increase by 5°C.

Description of GSTR operation.	*Cooling medium temp °C*	*B-ring peak temp °C*	*B-ring ΔT(°C)*	*F-ring peak temp C*	*F-ring ΔT (°C)*	*G-ring peak temp C*	*G-ring ΔT (°C)*
Normal 1 MW ops	*21*	*344*	*323*	*202*	*181*	*172*	*151*
B-ring at 800C	*60*	*800*	*740*	*475*	*415*	*406*	*346*

5. Your original application contained a table with a set of temperature measurements. For the 1 MW steady state measurement take in March of 2002, where was the instrumented fuel element located in the core.

Response: The March, 2002 fuel measurement supplied in the original application was taken in an instrumented element located in the C-ring (location C-5) of the GSTR.

6. Discuss the maximum fuel temperatures in the aluminum clad fuel at the reactor high power setpoint of 1.1 MW.

Response: If the GSTR was operated at 1.1 MW with the pool water temperature at 60°C, the measured fuel temperatures would be as shown in the table below. Also shown, for reference, are measured fuel temperatures at normal 1.0 MW operation.

Description	*Cooling medium temp C*	*B-ring peak temp C*	*B-ring ΔT (°C)*	*C-ring peak temp C*	*C-ring ΔT (°C)*	*F-ring peak temp C*	*F-ring ΔT (°C)*	*G-ring peak temp C*	*G-ring ΔT (°C)*
Normal 1 MW ops	*21*	*344*	*323*	*305*	*284*	*202*	*181*	*172*	*151*
Max. 1.1 MW ops	*60*	*415*	*355*	*373*	*313*	*259*	*199*	*226*	*166*

These data show that fuel temperatures in the F and G-rings are well below the proposed 500°C limit for aluminum-clad fuel. If an instrument/location error of 15°C for steady state operations is applied to the calculated values for 1.1 MW operations, the F and G-ring peak temperatures are 274°C and 241°C, respectively.

7. Your answer to our RAI question 10 was based on a coolant temperature of 50°C. However, your TSs allow a bulk pool temperature up to 60°C. Please present the data on fuel temperature assuming a coolant temperature of 60°C.

Response: This question is identical to question 4. See question 4 for our response.

8. You have proposed changes to TS D.7. It appears that your proposed wording would remove the flexibility to have a core with less than 100 fuel elements operate with a power level greater than 100 kW. Please provide a justification for your proposed change to the TS.

Response: A historical look at the fueling of the GSTR shows that the initial fuel loading for full power operations in 1969 contained 78 fuel elements. By January 1975, the core loading had reached 101 fuel elements and it has not gone below 100 fuel elements for the last 31 years. No future requirement is seen for operation of the GSTR at >100 kW with <100 fuel elements in the core. In fact, having a small core is detrimental to the neutron flux in several of our irradiation facilities. The requirement for 100 elements or more helps to reduce the power produced by each fuel element in the core, thus limiting the peak fuel temperatures and giving a safer operation.

9. TS D.3. contains a fuel temperature limit of 800°C for fuel temperature. However, General Atomics in report E-117-833, "The U-ZrHx Alloy: Its Properties and Use in TRIGA Fuel," discusses a steady-state operational fuel temperature design limit of 750°C based on consideration of irradiation- and fission-product-induced fuel growth and deformation. Please discuss.

Response: The operating history of the GSTR has been such that the existing limit of 800°C has not presented a safety threat; however, the reduction of this limit to 750°C would be prudent and would not affect the GSTR operations. The maximum fuel temperature would occur in a B-ring element, nearest the center of the core. Because of the GSTR Technical Specification allowance for measuring fuel temperature in either the B or C ring, we are herein proposing differing maximum indicated fuel temperature limits for the two locations. The C-ring fuel temperature limit would need to be lower than 750°C in order to assure that the maximum fuel temperature (B-ring) would not exceed 750°C.

The nominal power production in a C-ring element is 88% of the nominal power produced in a B-ring fuel element. Assuming a pool water temperature of 60°C, a maximum fuel temperature of 750°C in a B-ring element would correspond to a maximum fuel temperature of 667°C in a C-ring element. (see table below)

Description	Cooling medium temp C	B-ring peak temp C	B-ring Δ T (°C)	C-ring peak temp C	C-ring Δ T (°C)	F-ring peak temp C	F-ring ΔT (°C)	G-ring peak temp C	G-ring Δ T (°C)
Temp limit conditions	60	750	690	667	607	447	387	383	323

As a result of this information, it is proposed to make the following revision to Technical Specification D.3: to limit the measured fuel temperature to 750 °C for B-ring measurements and 667 °C for C-ring measurements. The proposed change is given below. This proposed change supercedes the proposed change to D.3 in our February submittal. We propose to not specify a limit on the aluminum-clad fuel in the F and G rings for two reasons: (1) the limits being imposed upon the B and C-ring fuel temperatures will inherently protect the F and G ring fuel elements from exceeding 500°C, and (2) no instrumented aluminum-clad fuel elements are available to provide the associated measurements. The necessary calculations to support the safety of the aluminum-clad fuel elements in the F and G rings have been provided in the documents supporting the license amendment request.

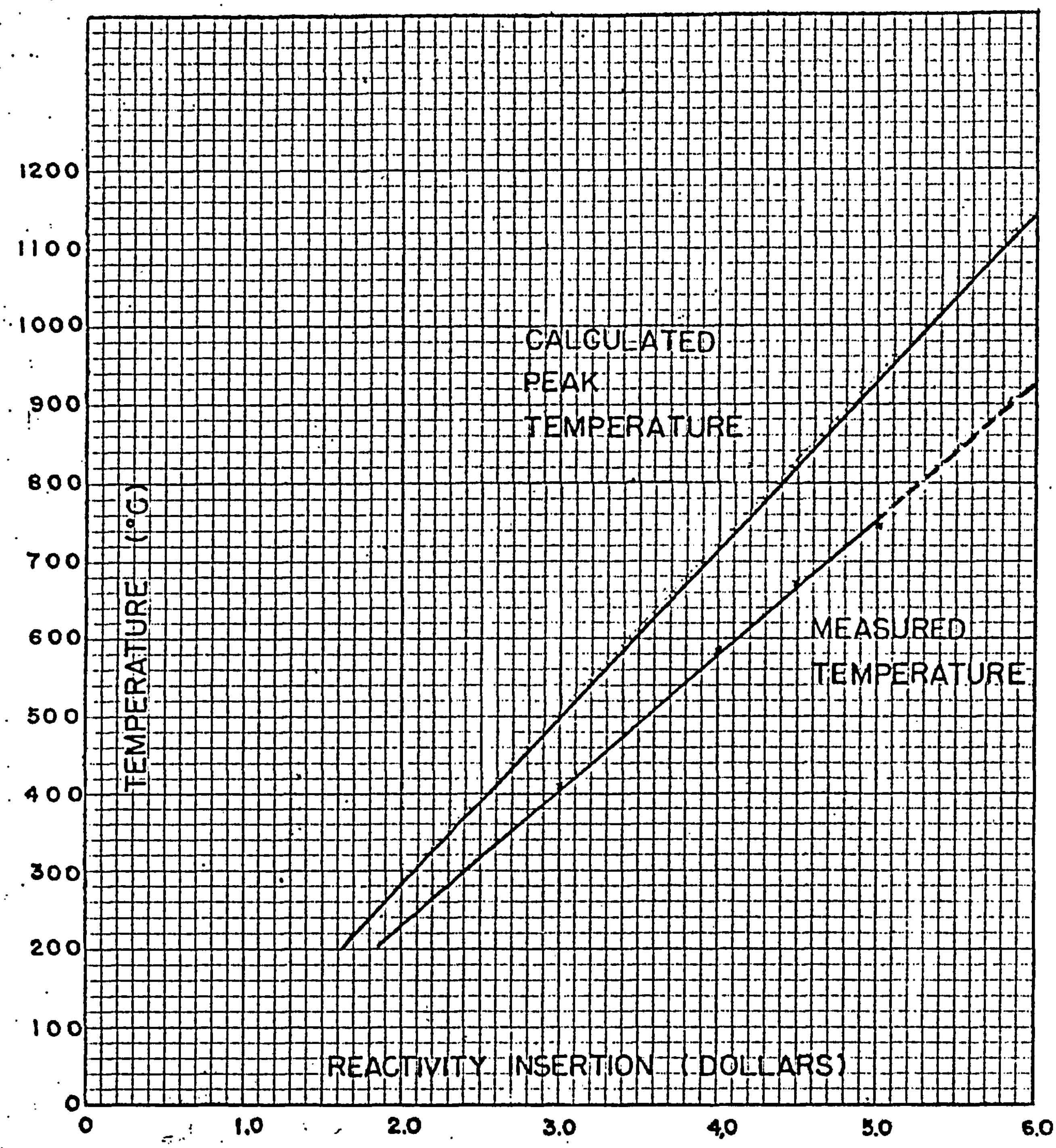
Current wording:

D.3. Fuel temperatures near the core midplane in either the B or C ring of elements shall be continuously recorded during the pulse mode of operation using a standard thermocouple fuel element. The thermocouple element shall be of 12 wt% uranium loading if any 12 wt% loaded elements exist in the core. The reactor shall not be operated in a manner which would cause the measured fuel temperature to exceed 800°C.

Proposed wording:

D.3. Fuel temperatures near the core midplane in either the B or C ring of elements shall be continuously recorded during the pulse mode of operation using a standard thermocouple fuel element. The thermocouple element shall be of 12 wt% uranium loading if any 12 wt% loaded elements exist in the core. The reactor shall not be operated in a manner which would cause the measured fuel temperature to exceed 750°C in a stainless steel clad element in the B ring or 667°C in a stainless steel clad element in the C ring.

From 1969 University of Illinois SAR

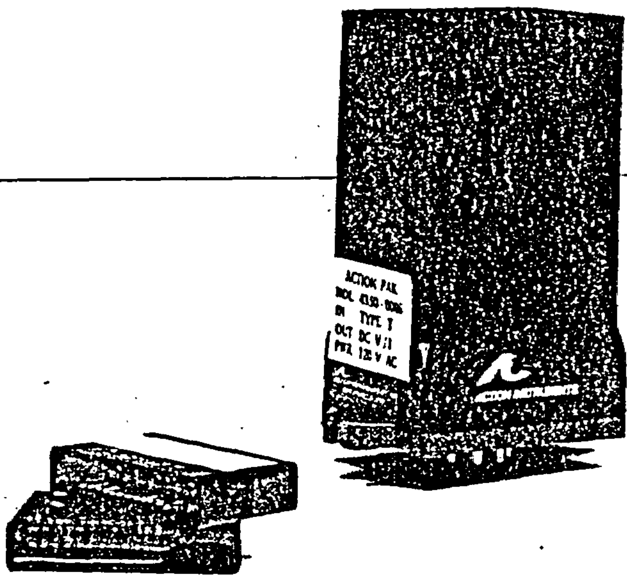


TEMPERATURE Vs. REACTIVITY INSERTION

FIGURE III-21

ACTION INSTRUMENTS

Action Pak AP4350 Isolated Thermocouple Transmitter



- Isolates, Linearizes and Transmits
- Plug-in Input-Ranging Modules for Type J,K,T,E,R,S,B
- 1000 Volt Isolation
- Wide-Ranging Input and Output Adjustments
- Switch-Selectable Voltage/Current Output Ranges
- Three-Year Warranty

The Action Pak AP4350 transmitter combines many useful features in one rugged, reliable package. The AP4350 will accept a thermocouple input directly, and linearize, isolate, and transmit the equivalent temperature reading for data acquisition, indication, or control.

Using plug-in modules, the AP4350 can be easily reconfigured in the field for any popular thermocouple type (J, K, T, E, R, S, B). Additionally, wide-ranging adjustments allow for virtually any input range to be accommodated. Furthermore, the output is field-selectable for a variety of ranges, both for DC voltage and current.

Input signal conditioning includes cold-junction compensation and linearization for the thermocouple input signal. Also, the input is isolated from the output up to 1000VDC or peak AC. The AP4350 combines a high-performance signal conditioner, linearizer, and isolator in a cost-effective, easy-to-use solution for industrial measurement and control.

CALIBRATION

The AP4350 Thermocouple Transmitter can be set for a wide variety of outputs, and the input can be adjusted for any span within the selected thermocouple range down to 10% of the range.

Ranging modules may be changed by removing the case with four screws on the bottom. The four circuit boards can be removed from each other (see photo), and the range module is plugged into the input board.

To set up and calibrate the AP4350, remove the top cover. First set up the output range desired using the settings in the Switch Selection Table. Next select whether calculations will be in degrees F or C, and set S4-1 accordingly (S4-1 on for °C, off for °F).

Also set S4-2 depending on whether the minimum input value is greater than zero degrees, or positive (S4-2 on), or negative (S4-2 off).

Now calculate gain and offset from the following formulas:

$$\text{GAIN} = 100\% \times \frac{TS}{10x\,(TH-TL)}$$

$$\text{OFFSET} = 100\% \times \frac{TL}{TS}$$

Where TS = effective span from Input Range Table
TH = high temperature, corresponding to maximum output
TL = low temperature, corresponding to minimum output.

Next set percentage offset and gain on S2 and S1, respectively, using the table below. (Note that switches are turned OFF to enable that percentage.)

POSITION	1	2	3	4	5	6	7	8
OFF ADDS %	1	2	4	8	10	20	40	80

Switch S1 (offset) or S2 (gain)

All switches off = 165%
All switches on = 0%

Adjust zero and span potentiometers to set output minimum and maximum with desired inputs TL and TH. It may be necessary to adjust the percentage up or down 1% or 2% to get exact calibration.

NOTE: Be sure to use the correct thermocouple wire and a compensated thermocouple simulator or calibrator, or other known thermocouple source to calibrate the AP4350.

EXAMPLE 1: We want our Type J thermocouple input to range from 450°F to 1100°F, with a corresponding output of 0V to + 10V. With the proper Type J module installed (dash 0001), we set S5-1 on and S5-2 off (voltage), and S3-1, 4 & 6 off with S4-2, 3 & 5 on (Switch Selection Table). Since we are calculating in degrees F and our offset is positive (450°F), we set S4-1 off and S4-2 on.

Next we calculate gain and offset:

$$\text{GAIN} = 100\% \times \frac{TS}{10x(TH-TL)} = 100\% \times \frac{1440}{10X\,(1100-450)}$$

$$= 100\% \times \frac{1440}{10x650} = 100\% \times \frac{1440}{6500} = 22\%$$

We set S2-6 off and S2-2 off with the rest of S2 positions on (20% + 2% = 22%)

$$\text{OFFSET} = 100\% \times \frac{TL}{TS} = 100\% \times \frac{450}{1440} = 31\%$$

We set S1-6 off, S1-5 off and S1-1 off with the remainder of S1 positions on (20% + 10% + 1% = 31%). We adjust zero and span so that with our 450°F input the output is 0V, and with 1100°F input the output is 10V.

EXAMPLE 2: Output 4-20mA, input Type T, -50°C to + 125°C (dash 0006) S5-1 off S5-2 on (current) S3-6 off with S3-1 through S3-5 on (4-20mA). S4-1 on (degrees C) and S4-2 off (negative offset).

$$\text{GAIN} = 100\% \times \frac{400}{10x\,(125-50)} = 100\% \times \frac{400}{10\,X\,175} =$$

$$100\% \times \frac{400}{1750} = 23\%$$

S2 = 20% + 2% + 1% = S2-6, S2-2, S2-1 off, all others on

$$\text{OFFSET} = 100\% \times \frac{-50}{400} = -13\%$$

S1 = 8% + 4% + 1% = S2-4, S2-3, S2-1 off, all others on

INPUT RANGE TABLE

Dash Number	TC Type	TS		Input Range
AP4350-0001	J	800°C	1440°F	- 80°C to + 750°C -110°F to +1320°F
-0002	J	400°C	720°F	-150°C to +399.9°C -235°F to +399.9°F
-0003	K	1200°C	2160°F	-140°C to +1370°C -220°F to +2500°F
-0004	K	400°C	720°F	-100°C to +399.9°C -150°F to +399.9°F
-0005	E	800°C	1440°F	0° to +800°C +32°F to +1450°F
-0006	T	400°C	720°F	- 80°C to +399.9°C -110°F to + 399.9°F
-0007	R	1600°C	2880°F	+300°C to +1760°C +550°F to +3200°F
-0008	S	1600°C	2880°F	+300°C to +1760°C +550°F to +3200°F
-0009	B	1600°C	2880°F	+400°C to +1820°C +750°F to +3300°F

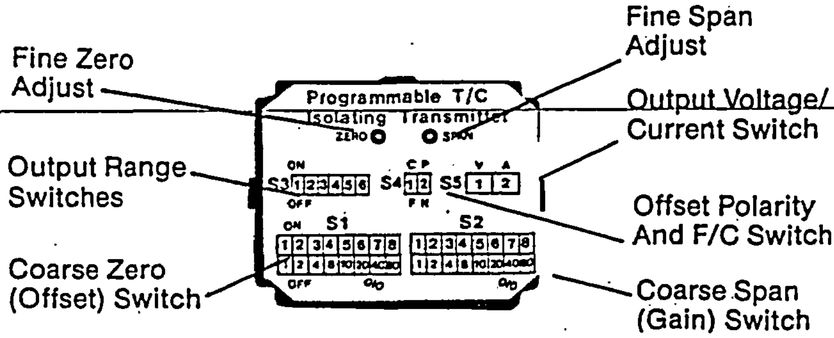
*Switch select for degrees F.

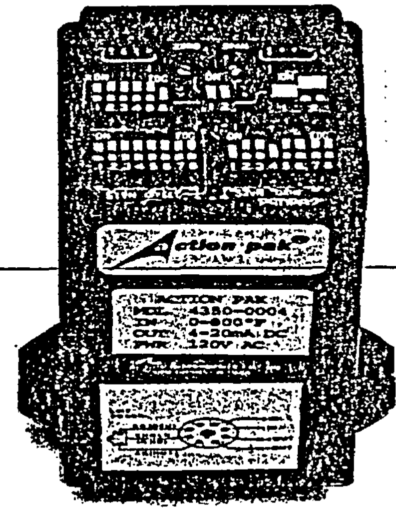
SWITCH SELECTION TABLE

Mode		S3						S5	
		1	2	3	4	5	6	1	2
Voltage	2-10V	ON	ON	ON	ON	ON	OFF	ON	OFF
	1-5V	ON	ON	ON	ON	OFF	ON		
	0-10V	OFF	ON	ON	OFF	ON	OFF		
	0-5V	OFF	ON	OFF	ON	OFF	ON		
	0-2V	OFF	ON	ON	OFF	ON	ON		
	0-1V	OFF	ON	OFF	ON	ON	ON		
Current	4-20mA	ON	ON	ON	ON	ON	OFF	OFF	ON
	2-10mA	ON	ON	ON	ON	OFF	ON		
	1-5 mA	ON	ON	ON	OFF	ON	ON		
	0-20mA	OFF	ON	ON	OFF	ON	OFF		
	0-10mA	OFF	ON	OFF	ON	OFF	ON		
	0-5 mA	OFF	OFF	ON	OFF	ON	ON		
	*0-1 mA	OFF	OFF	ON	ON	ON	ON		

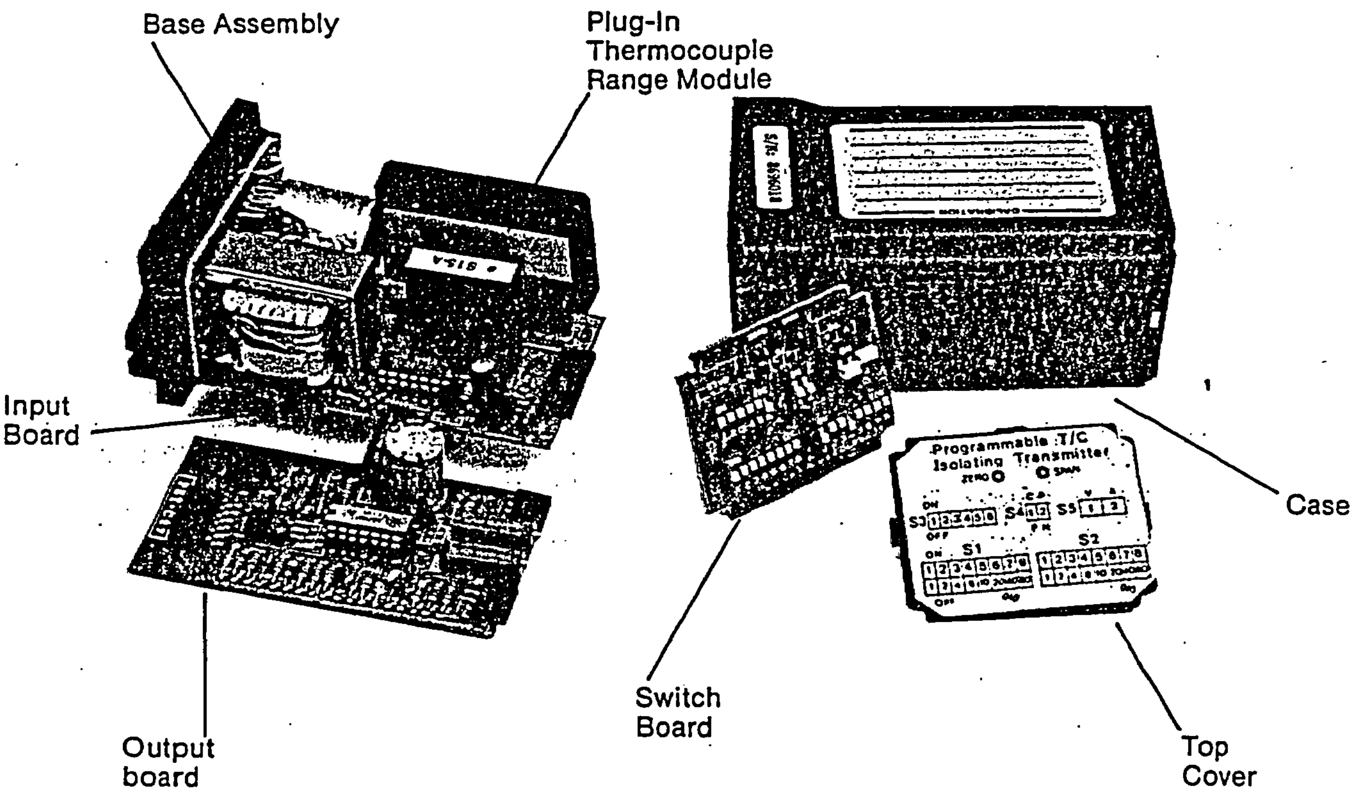
*0-1mA may program but not recommended

CONFIGURATION SWITCH LOCATIONS

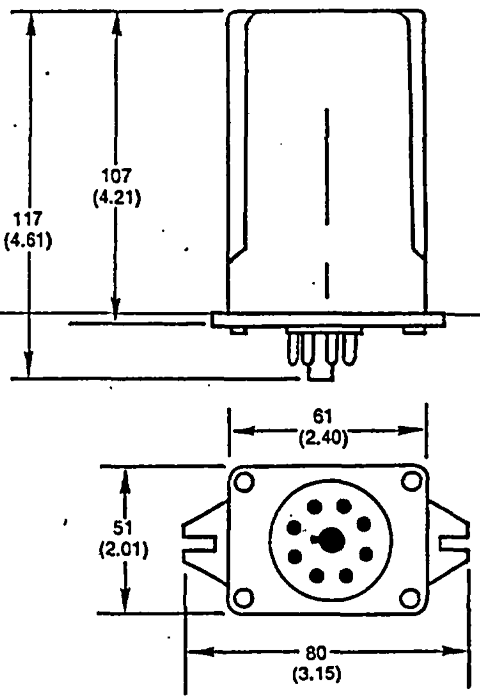




MAJOR COMPONENT SUBASSEMBLIES

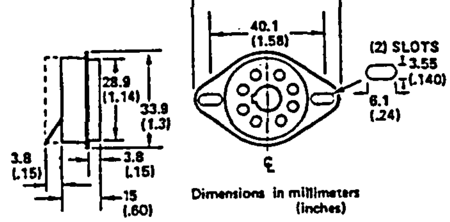


DIMENSIONS

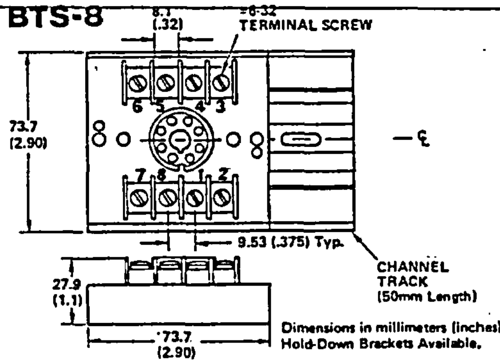


MOUNTING HARDWARE

APS-8



BTS-8



SPECIFICATIONS

Inputs

Wide-ranging inputs and outputs, field-selectable via top accessed DIP switches and potentiometers. Ten to one adjustability/turn down range. Plug in modules for thermocouple input types J,K,T,E,R,S,B.

Outputs

Field-rangeable: 0-10V, 2-10V, 0-5V, 1-5V, 0-1V, 4-20mA, 0-10mA.
Voltage Outputs: 10mA drive capability.
Current Outputs: 10V compliance capability.

Accuracy

± 0.25% of span.

Noise and Ripple

0.1% of span, rms.

Response Time

200mSec typical.

Stability

Zero: ± (0.02%/°C plus 2μV/°C).
Span: ± 0.01%/°C.

CJC Error

± 1°C, typical.

Conversion Time

500mSec.

Common Mode Rejection

120dB, DC-60Hz.

Power

110V ± 15% AC; 50Hz - 400Hz. 4W Max.

Environmental

0°C to +60°C.

Isolation

Input to output, or either input or output to power line: 1000V DC or peak AC.

Burnout

Open thermocouple detect: goes to minus overrange.

ORDERING INFORMATION

Model No.	Description
AP4350-000X	Transmitter with ranging module (see table).
V042-000X	Extra ranging module (see table) to change transmitter range.

How To Order:

Specify AP4350-000X according to the 4-digit dash number from the Input Range Table. To order modules separately, specify V042 and the desired 4-digit dash number: V042-000X.

Ranging modules may be ordered separately (ranging module required for operation).

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Data Sheet 721-0330B
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