INL/MIS-20-59676-Revision-0

Retractable Sensor for Reactor Experiments

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September 2020

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

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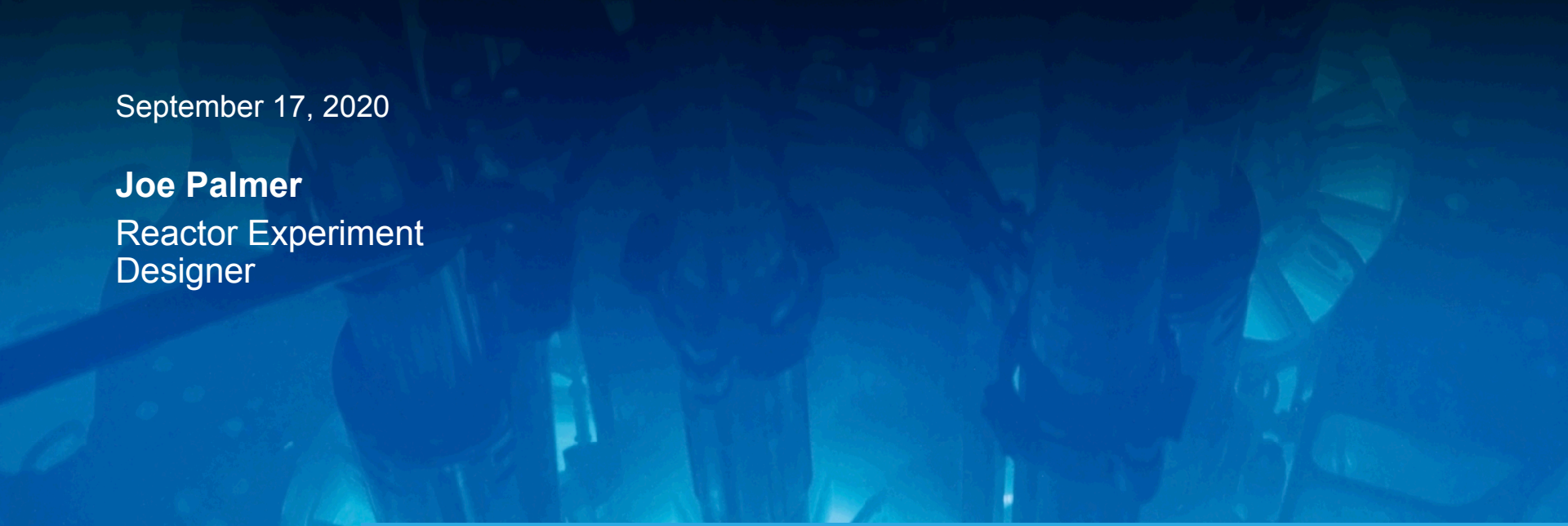
Prepared for the
U.S. Department of Energy

Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517



September 17, 2020

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Reactor Experiment Designer

Retractable Sensor for Reactor Experiments

BYU Idaho ME Capstone Project

Idaho National Laboratory

Irradiation

- Test reactors such as the Advanced Test Reactor (ATR) at the Idaho National Laboratory are used to irradiate nuclear fuels and materials to evaluate performance after high levels of exposure to a reactor in-pile environment.
- The purpose of the experiments is to determine property changes as the materials or fuels are bombarded with fast neutrons (and thermal (slow) neutrons as well).
- Typically, the irradiation must take place at a very specific temperature.
- Sometimes other parameters are monitored as well as properties such as creep, or gas composition, etc. However, the fast neutrons cause changes in not only the materials, but also in the transducers that are placed in the neutron flux, e.g., thermocouples or optical fibers.

Measurements

- This task will be limited to considering temperature measurements. Thermocouples experience decalibration from not only the neutron flux, but also from the very high temperatures that are sometimes measured. Optical fibers darken in a neutron or gamma flux. However, it takes quite a few hours, or days for these changes to manifest.
- High power test reactors typically run at a constant power and so the temperature in an experiment is fairly stable over time.
- Because the changes are typically very slow, even a single temperature measurement per day, would provide 95% of a perfect data set.

Main Idea

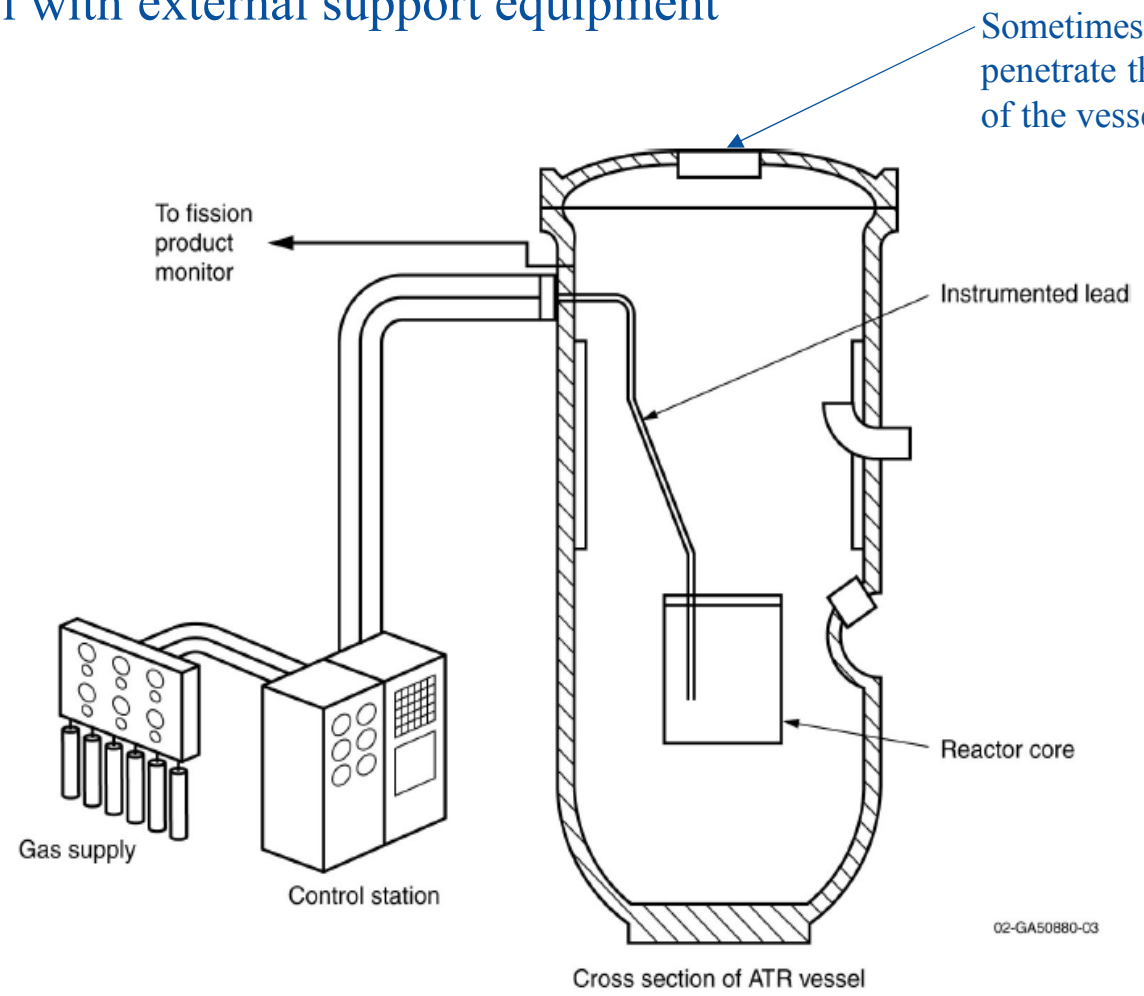
- The basic concept of this effort is to push a very small diameter thermocouple or optical fiber into the location to be measured, leave it for 30 seconds or so for it to come to equilibrium, and transmit the signal, and then pull it up and away from the high neutron flux and high temperature region.
- The distance the thermocouple or fiber would need to move is on the order of 50 – 100 cm. By doing this, the thermocouple junction or optical fiber would spend only a few hours in the high flux/high temperature environment over the life of the irradiation.

Types of Experiments

- Two types of experiments are conducted in ATR: 1) drop-in sealed capsules, and 2) instrumented lead experiments – where a pipe or "lead" serves as a conduit from the reactor core section to a flange at the top or side of the vessel.
- The purpose of the leadout is to provide a path for gas lines or instrumentation from the experiment in the reactor core to the outside world.

Instrumented lead experiment

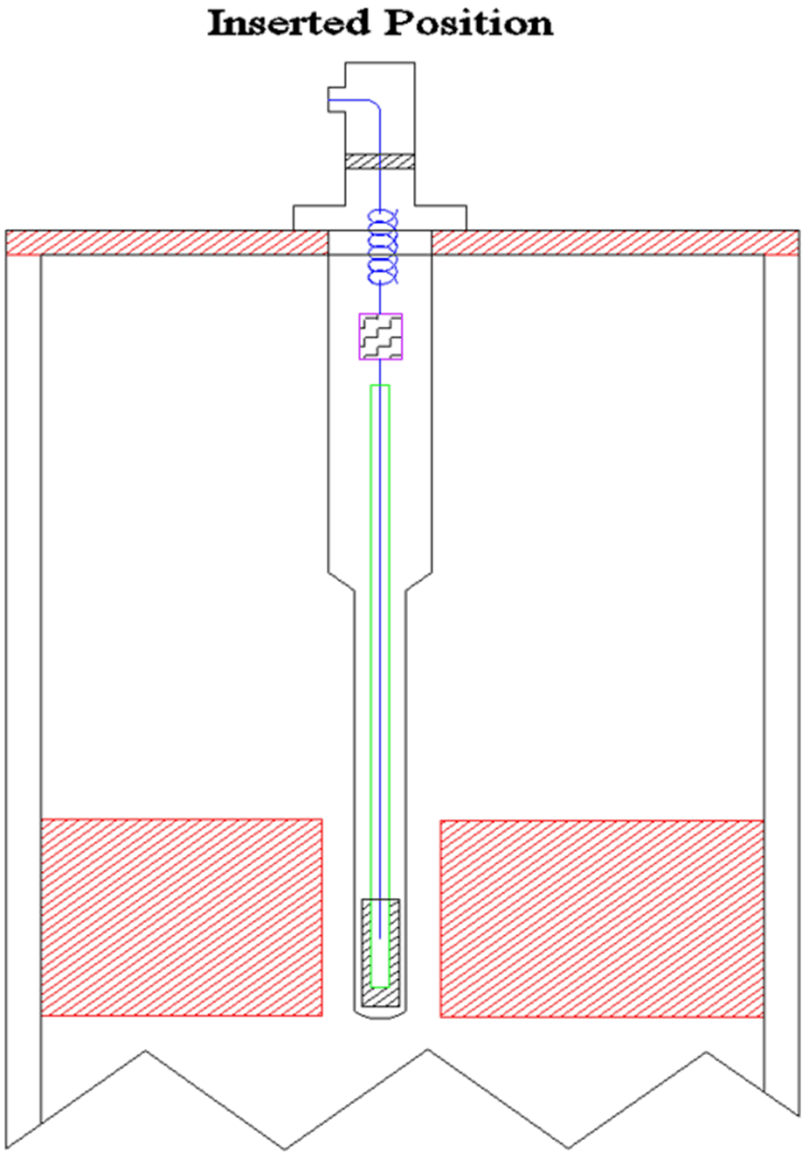
Instrumented lead experiment installed in the Advanced Test Reactor (ATR) vessel with external support equipment

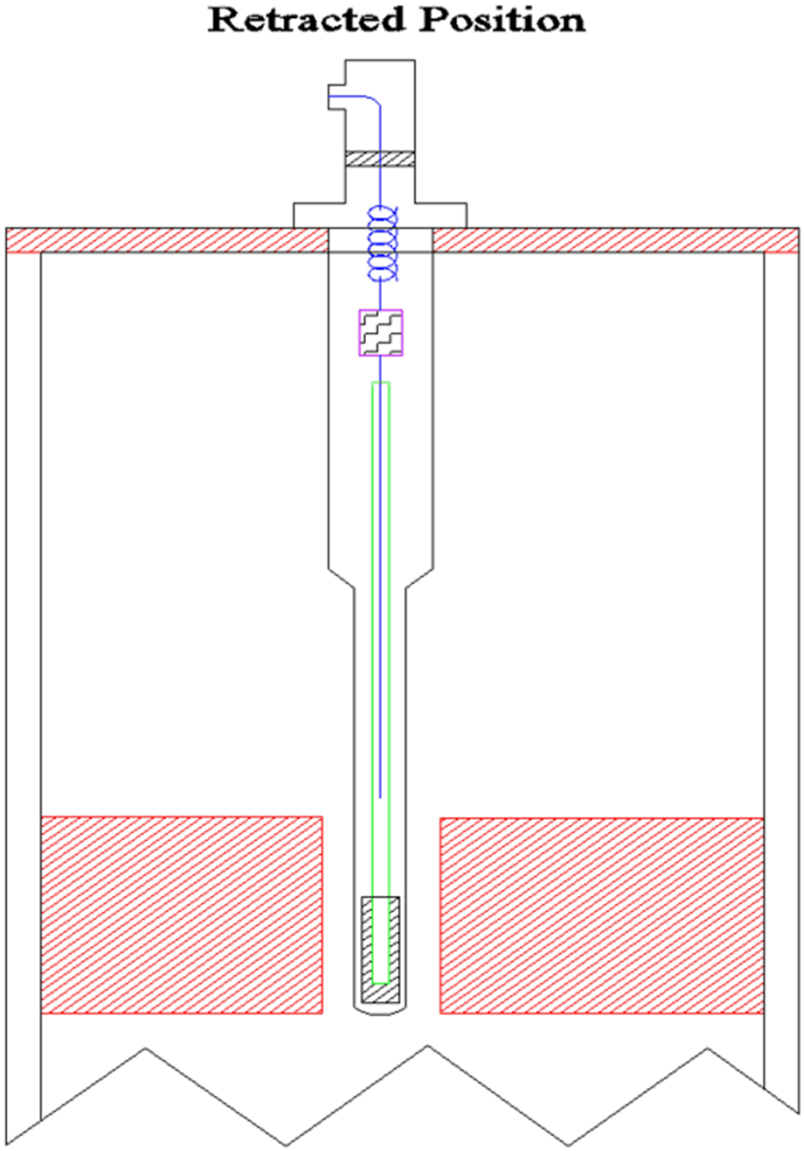


Instrumented lead experiment which penetrates the top of the vessel

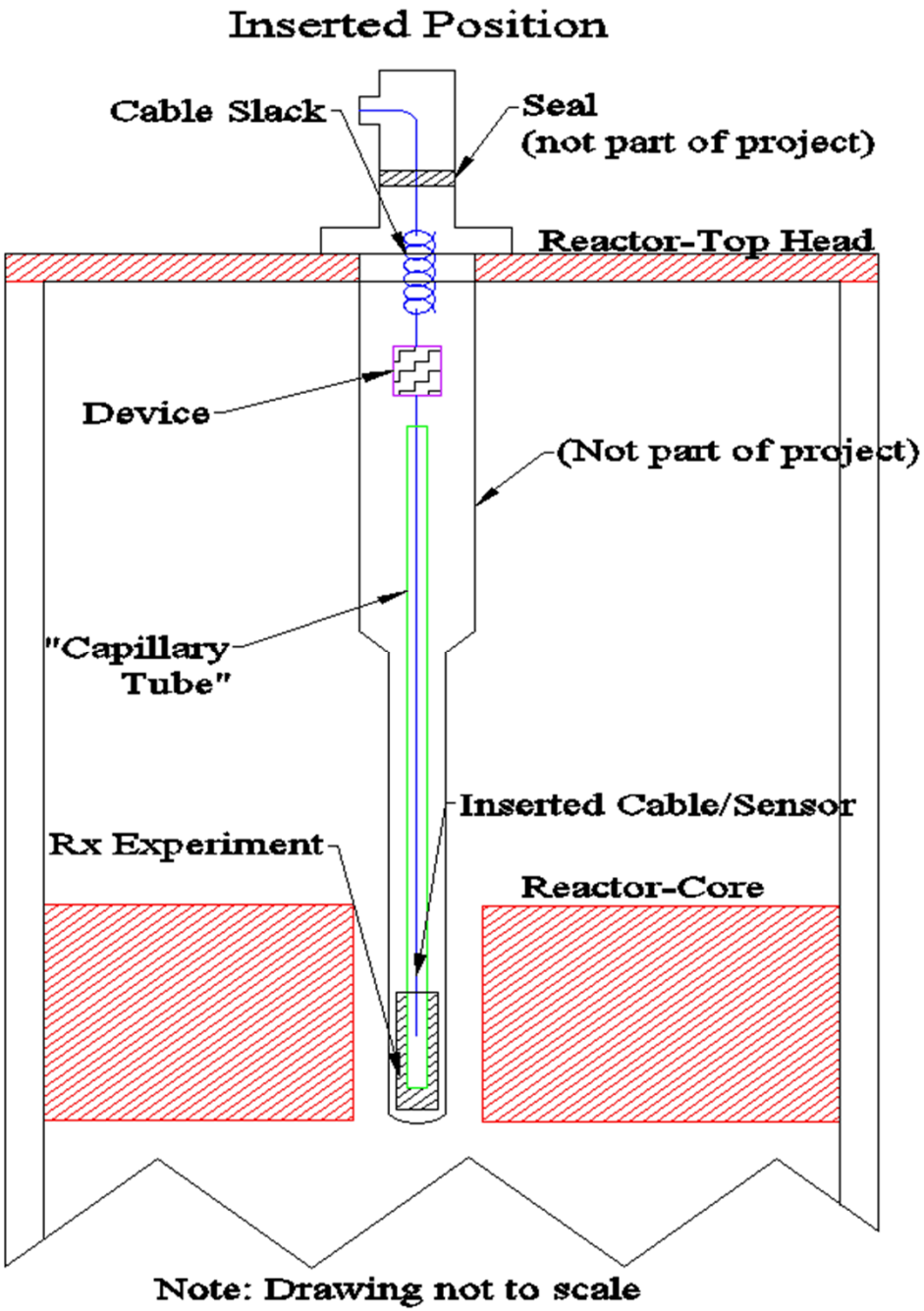
Sensor insertion mechanism would reside in this larger diameter section

Visual Info

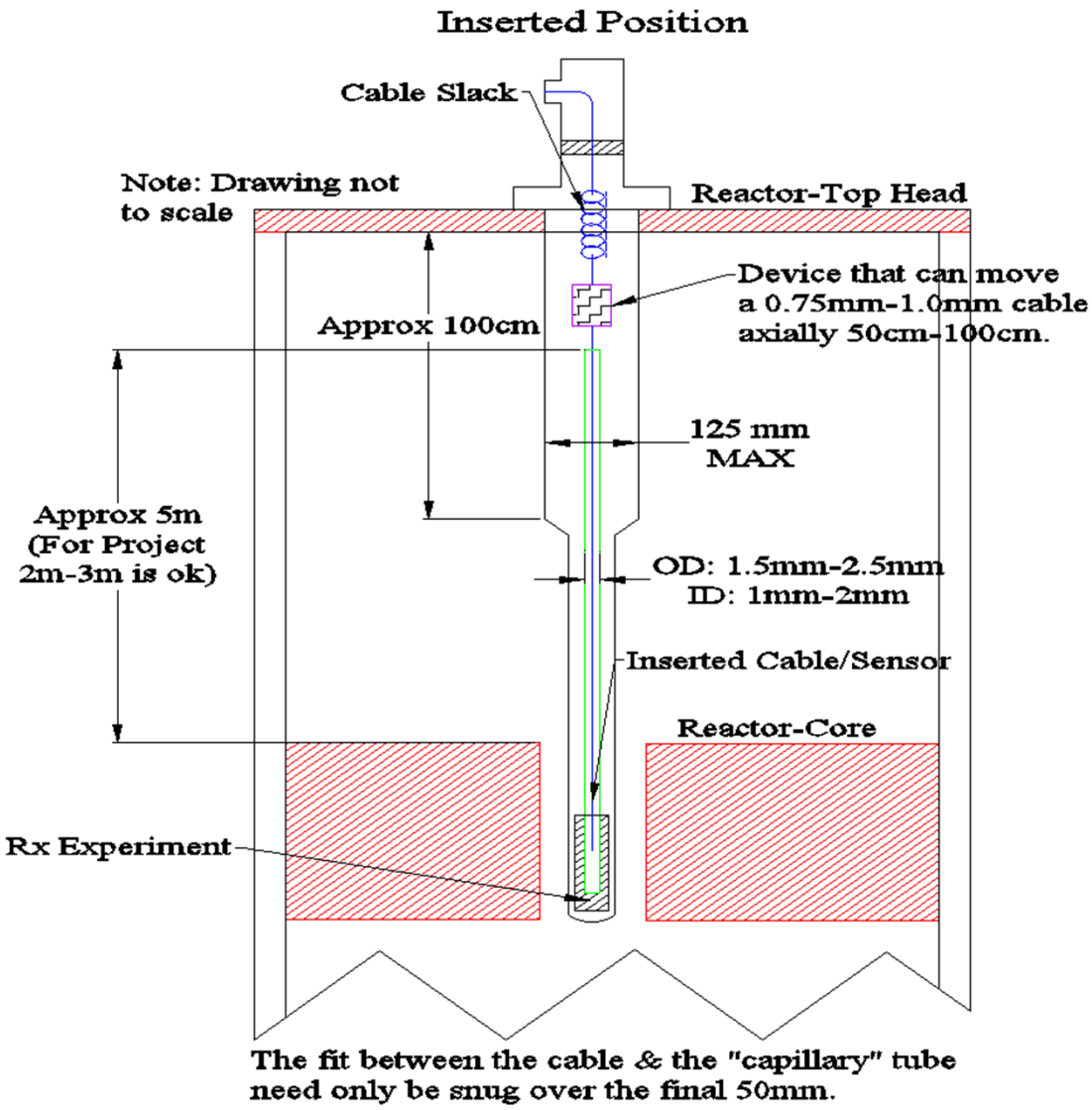




- The entire experiment train is basically a long, sealed pipe.
- Sensor is inserted into and retracted from a protective guide, AKA “capillary tube”.
- If some type of mechanism could be installed at the top of the pipe to drive the sensor in and out of the critical location, the integrity and accuracy of the sensor could be preserved.
- One of the primary challenges facing this concept is, where does the extra cable length go when the sensor is retracted?



- At its largest, the upper part of the leadout pipe is only about 125 mm in diameter, and so there is not much volume for the actuating device, or for the extra cable.
- The bottom of the pipe is the experiment section and resides in the reactor core. The top of the pipe passes out of the reactor top head, or through the upper part of the side of the reactor vessel.
- The harsh environment is only at the bottom of the pipe.



Present to Future

Present

- When measuring temperatures of 1100°C or higher, even the best commercial thermocouples experience more than 50°C drift after 30 days of irradiation in a high-power reactor.
- Optical fibers are also used for high-temperature measurements in reactor experiments, and they suffer darkening of the fibers after only a few days of operation in a high flux environment, due to interactions between the fibers and fast neutrons or gamma rays.

Future

- If successful, this effort will provide a device, which when fully developed, will provide a means of obtaining accurate temperature measurements through hundreds of days of irradiation.
- Furthermore, the basics of such a device could likely be applied to other in-pile measurements; possibly even allowing visual observations (through fiber optics) of changes taking place in the specimens during irradiation.

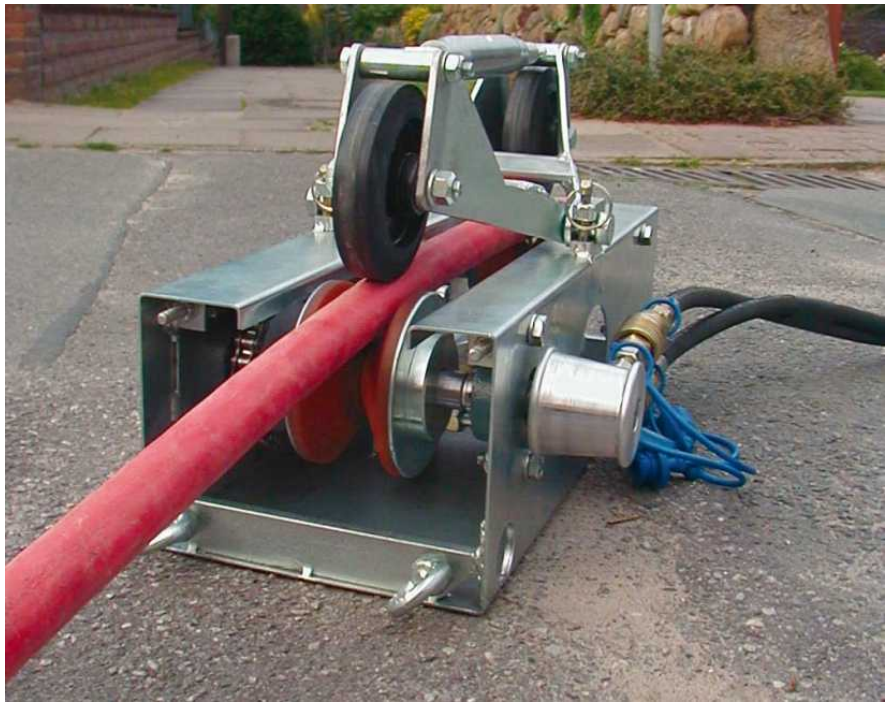
Some get started ideas

Maybe there is something already out there . . .

I Googled “cable pusher” and got the following

Some get started ideas

This was my original idea (but of course on a miniature scale), i.e., rollers driven by an electric motor.



These two examples are obviously gigantic compared to what we need. But I still think that perhaps there is something out there that could be adapted, so you don't have to start from scratch.

Some get started ideas

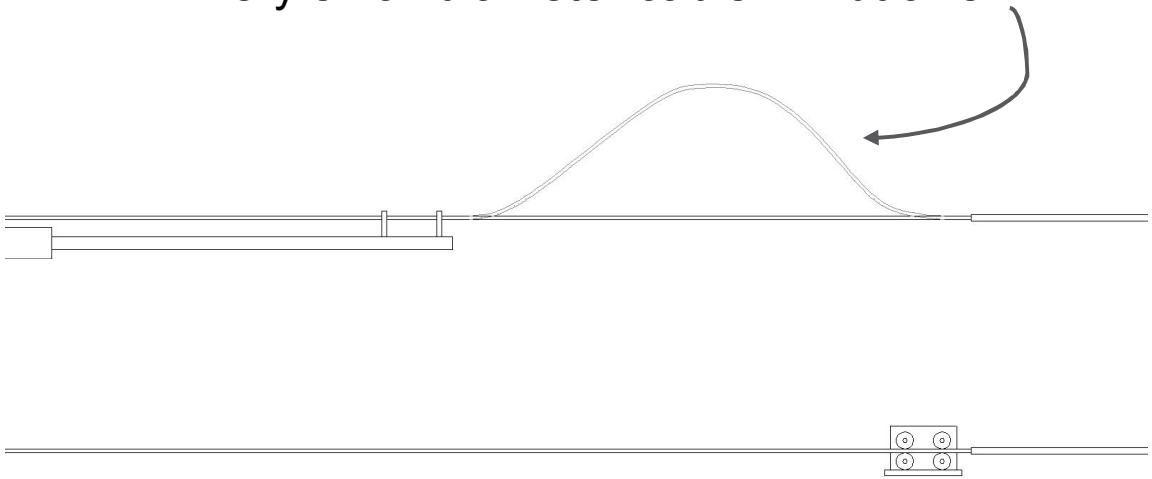
Perhaps a linear motor

Or, a pneumatic actuator

But these require a lot of space for a “throw” of 50 to 100 cm

Problem with linear (pneumatic or electric) actuators

Problem with these single throw actuators is that the very small diameter cable will buckle



The rollers based “feed it in” concept can avoid buckling. One challenge of the rollers concept is to get enough friction to grip the small diameter cable.

Some get started ideas

- One of the main issues is how tight the fit must be between the capillary guide tube and the sensor cable.
- The looser the fit the less resistance the drive will have to overcome.
- A thermocouple must fit fairly tightly near the junction area. This is because all materials placed in the reactor core are subject to nuclear heating and the thermocouple will run at its own temperature if not thermally “sunk” to the surroundings.
- Only the tip plus, say, 25 mm, need be a tight fit.
- For this study a loose fit all the way to the bottom is OK. We can later procure a capillary tube that has been swaged down at the bottom.

Some get started ideas

- I recommend that you immediately procure the capillary tube and the representative “cable” so you can start getting a feel for the issues you will be facing.
- You can buy mineral insulated thermocouple cable in 0.8 mm and 1.0 mm sizes, or just buy wire in these sizes – we are just trying to demonstrate the operation of the retract mechanism, so it is not necessary to have real thermocouple cable. [An optical fiber is very small and will reside inside a 0.8mm to 1.0 mm tube – so for our purposes it would look the same as the TC cable or the wire.]