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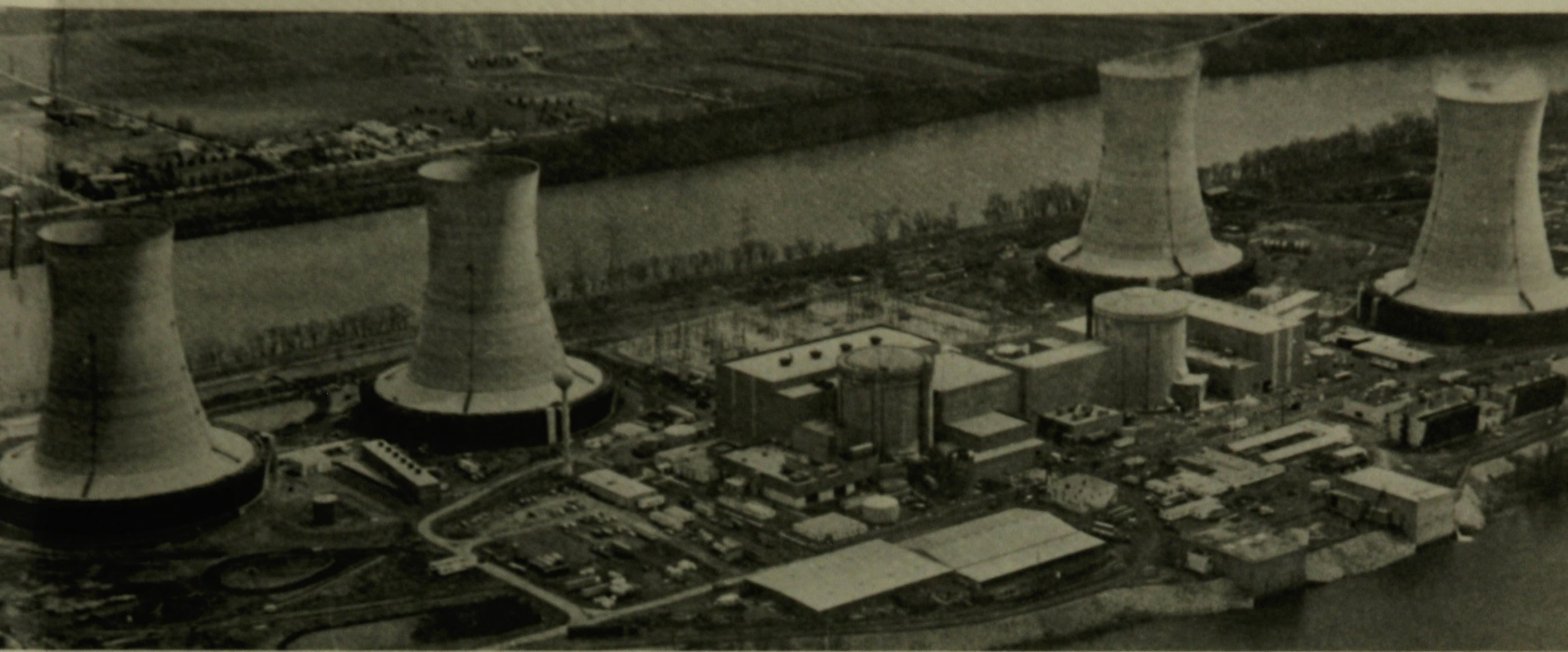

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HP-RT-211 CABLE ANALYSIS

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U.S. Department of Energy
Three Mile Island Operations Office
Under DOE Contract No. DE-AC07-76ID01570

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ABSTRACT

A short length of Raychem Flamtrol (TM) cable, which was connected to a radiation detector from the Three Mile Island (TMI) Unit 2 containment building, has been examined to look for electrical and mechanical degradation. The cable was attached to the connector backshell of detector HP-RT-211 and was removed during the third manned containment entry on October 16, 1980. The ultimate tensile strength, the percent elongation at break, and the insulation resistance have been measured. None of these measurement techniques were sufficiently sensitive to the apparently low environmental exposures this cable piece experienced to allow this section of cable to be used as a dosimeter. All three techniques yielded similar results for the TMI cable and for a comparison "virgin" specimen. This report provides a summary of our methods, results, conclusions, and recommendations.

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INTRODUCTION

A section of multiconductor Flamtrol(TM) cable from the TMI Unit 2 reactor was examined to determine what effects, if any, resulted from prolonged exposure to the radiation and thermal environment inside the TMI-2 containment. The cable was manufactured by Raychem Corporation of Menlo Park, California and consists of 10 primary conductors and two coaxial conductors. Each conductor was insulated with a radiation-cross-linked polyolefin described by Raychem as an "extruded, thermally stabilized, highly flame retardant, noncorrosive" material. The entire cable was jacketed in the same material. The trademark name for this material is Flamtrol. Specification 60, issued by Raychem on 20 August 1973, describes the mechanical and electrical properties of the insulation material.[1]

As received from TMI, the cable was approximately eight inches long and covered with Raychem WCSF heat-shrink tubing. An end still had a connector component attached to it. This component showed considerable corrosion damage on its interior. Prior to decontamination at Sandia, a Sandia health physicist took radiation measurements over the entire length of the cable. The maximum and minimum readings are given in Table 1.

TABLE 1. PRE-DECONTAMINATION RADIATION LEVELS

	Beta (mr/hr)	Gamma (mr/hr)
Connector End	12	3
Cut End	9	1

After washing the cable section with water and drying, these readings were substantially unchanged.

Considerable effort was required to remove the heat shrink tubing from the specimen without damaging the cable itself. The connector component had three layers of shrink tubing applied and the two inches of cable immediately behind the component had two layers.

Upon removing the heat-shrink tubing, it was discovered that although the cable section was eight inches long, seven of the primary conductors had been cut to approximately five inches in length prior to installation of the connector. This substantially reduced the availability of test specimens.

Radiation readings were lower underneath the heat-shrink tubing (about 2 mr/hr for a combined beta-gamma count) and a minimum of decontamination was required for the cable itself. Readings on the heat-shrink tubing, however, could not be reduced to the satisfaction of Sandia's Health Physics Division and therefore this material was not examined further.

TENSILE AND ELONGATION MEASUREMENTS

The ultimate tensile strength and percent elongation at failure were measured for three TMI samples and five "virgin" samples. The virgin samples were obtained from a Raychem cable similar to the TMI specimen but which had not been aged or irradiated in any way. Samples of approximately four inches in length were pulled at the rate of two inches per minute using a model 1130 Instron Testing Machine. The strain rate was chosen to agree with that used by Raychem in their Specification 60. The initial jaw seperation was two inches and elongation was measured with an extensometer attached to the specimen. Results from these tests are summarized in Table 2. The stated uncertainties are one standard deviation of the sample population results.

Because of the limited availability of TMI samples, different colors were used for each test. The use of different color pigments in the insulation formulation may cause mechanical property variations. Comparison of three TMI samples with three like-colored virgin samples yields the following results.

TABLE 2. TENSILE STRENGTH AND ELONGATION RESULTS

Sample Group	Ultimate Tensile Strength (psi)	Percent Elongation at Failure
TMI	2592 ± 157	321 ± 88
Virgin	2745 ± 207	351 ± 41

TABLE 3. TENSILE STRENGHT AND ELONGATION RESULTS FOR LIKE-COLORED SAMPLES

Sample Group	Ultimate Tensile Strength (psi)	Percent Elongation at Failure
TMI	2592 ± 157	321 ± 88
Virgin	2873 ± 157	373 ± 39

Both Tables 2 and 3 indicate no significant mechanical differences between the virgin and TMI samples.

RESISTANCE MEASUREMENTS (PRIMARY CONDUCTORS)

The resisitivity and insulation resistance constant, K, were determined for three TMI and five virgin primary conductors. The method involved forming each sample into a loop and submerging a portion of the insulated length in water contained in a stainless steel beaker. During the testing the water temperature remained constant at 72 ± 1°F. A 500 V potential was applied (per ASTM D257) across the sample-water beaker combination and resistance to electric current was measured after one minute of charging time using a Hewlett Packard Model 4923A high resistance meter.[2] Surface currents on the sample were guarded against by silver contacts painted near the ends of the insulation and connected to ground. Connections between the sample and measurement circuitry were also guarded.

The resistivity and K values can be calculated from the measured resistance and dimensions of the sample using Equations 1 and 2.

$$r = \frac{2\pi RL}{\ln(D/d)} \quad (1)$$

$$K = \frac{2\pi RL}{2.303} \quad (2)$$

where

r	=	resisitivity in Mohms - 1000 ft
R	=	measured resistance in Mohms
L	=	submerged length in "kilofeet" (1000 ft)
D	=	insulation outer diameter
d	=	insulation inner diameter
K	=	insulation resistance constant.

Samples were tested in random order until all had been given three measurements. The results are summarized in Table 4.

TABLE 4. ELECTRICAL RESISTANCE PROPERTIES

Sample Group	Resistivity (Mohms - 1000 ft)	K (Mohms - 1000 ft)
TMI	$3.69 \pm 1.88 \times 10^4$	$1.38 \pm 0.71 \times 10^4$
Virigin	$1.14 \pm 0.91 \times 10^5$	$4.16 \pm 3.14 \times 10^4$

Figure 1 data indicates that insulation color is an important factor influencing resistivity. The TMI samples consistently yielded lower resistivity values than similar colored virgin conductors. Error bars shown in Figure 1 represent one standard deviation for the three measurements made on each cable sample. The error is much less than the differences between virgin and TMI samples. Note in Figure 1 that

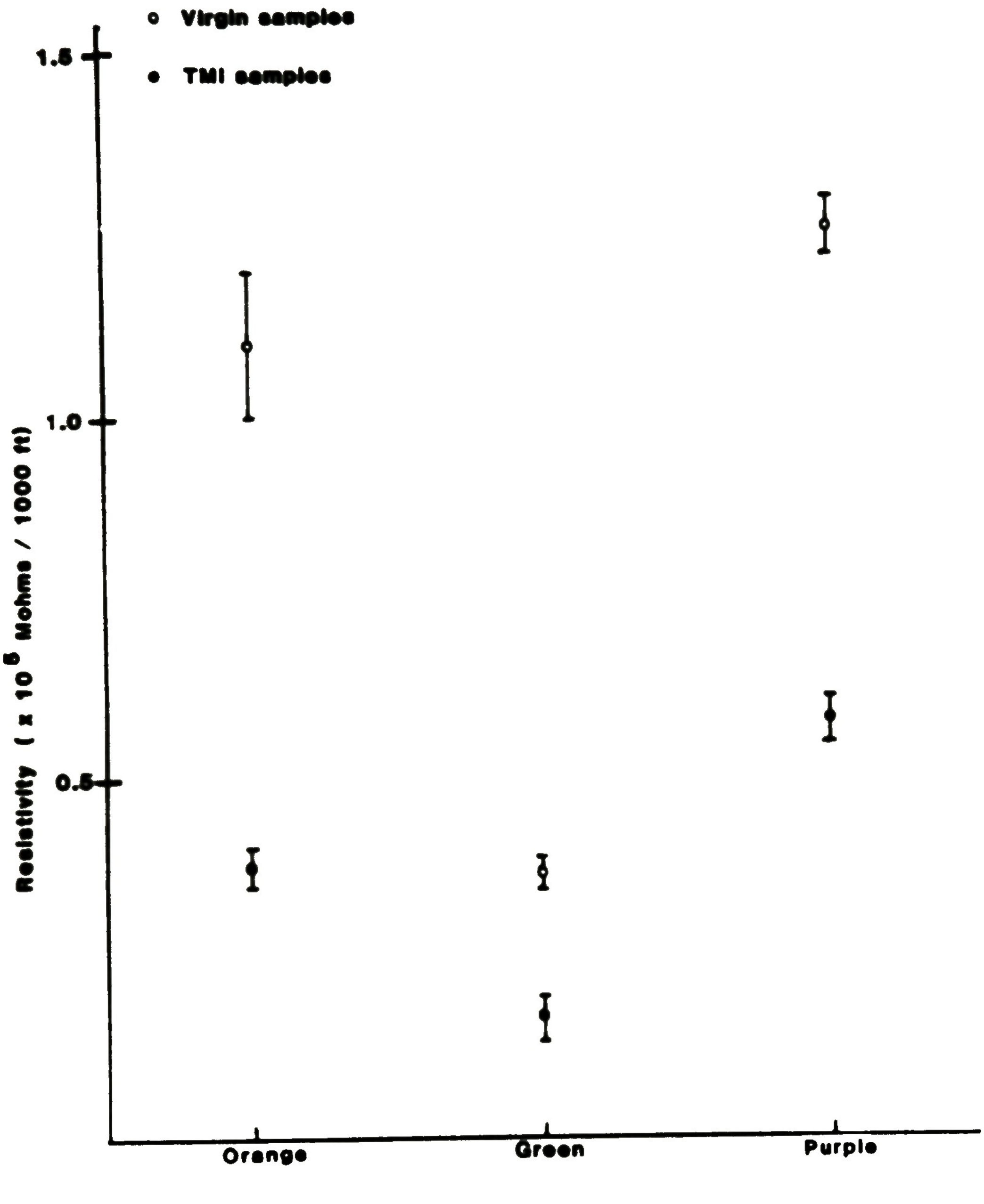

Figure 1 Resistivity vs. color

manufacturing variations, such as color, are as important as the Three Mile Island accident exposure in determining the cables' electrical properties. Hence it is not surprising that Table 4, which reflects the average of different colored cables does not show a substantial difference between the TMI and virgin cables.

As a verification of methodology, two orange samples (both virgin) were tested at various submerged lengths. One sample was part of the virgin population reported in Table 4. The other was a section of conductor 12.6 inches in length. Equation 1 predicts that the measured resistance is inversely proportional to the submerged length L. Figure 2 shows the results of these two series of measurements. At $1/L = 0.34 \text{ in}^{-1}$ the results vary by 3.2% reflecting the consistency of the resistance measurements.

RESISTANCE MEASUREMENTS (COAXIAL CONDUCTORS)

The cable contained two coaxial conductors, one each RG58 and RG59. The same apparatus was used as for the primary conductor insulation resistance measurements. In this case, however, the voltage was applied across the coaxial dielectric between the central conductor and the outer shield. All resistence measurements were conducted in accordance with ASTM D257, D-C Resistance of Conductance of Insulating Materials, to the extent possible. This standard requires a one minute specimen charging time at 500 volts. After one minute, the resistance was beyond the measuring capability of the instrument (i.e. in excess of 2.0×10^{16} ohms). This occurred for both virgin and TMI samples.

SUMMARY AND CONSLUSIONS

As reflected in Tables 2 and 3, there were no substantil differenes in tensile strength and elongation between the virgin and TMI samples. Raychem Specification 60 requires a minimum tensile strength of 1800 psi and elongation of 250 percent. Both sample sets clearly surpass these requirements.

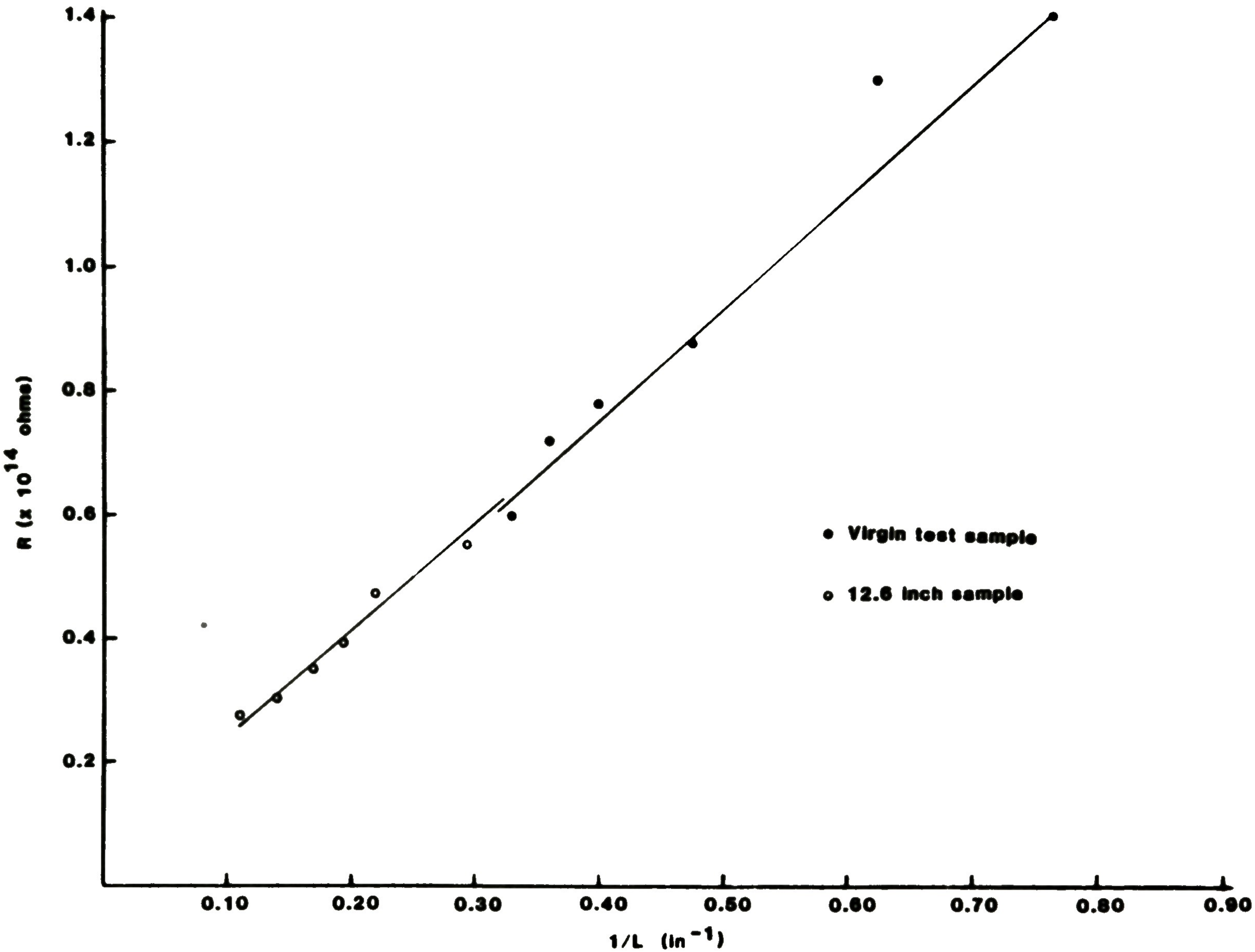

Figure 2 Resistance vs. 1/length (submerged).

Table 2 of Raychem Specification 60 requires the K value at room temperature to be 7.5 megohms - 1000 ft. Results contained in Table 4 indicate that this value is well within the requirements for both virgin and TMI samples.

Since the resistance values for the coaxial dielectric were beyond the capability of the measuring device, it is not possible to form definite conclusions for this cable component.

Two comparisons were made for the TMI cable. First it was compared to results obtained from a similar but not necessarily identical section of virgin cable. It must be recognized that the two samples probably came from different production lots. The TMI specimen was also compared to Raychem Specification 60. However, experimental results for the virgin and TMI cables suggest that minimum specifications, especially for insulation resistance, may be orders of magnitude lower than the actual product characteristics.

Therefore, comparison with specifications does not provide a reasonable assessment of the effect of TMI containment environment on Raychem Flamtrol cable.

Our data also indicate that manufacturing variations were as important as the Three Mile Island environment in establishing electrical properties for our particular cable. This is illustrated by Figure 1.

Hence, this cable is not suitable for use as a dosimeter to establish an independent assessment of the dose experienced by the radiation detector to which it was attached. Other measurements[3] indicate the detector experienced less than 1 Mrad total dose. Our results, therefore, are consistent with Raychem Specification 60 which requires Flamtrol cable to have a substantially higher radiation tolerance than 1 Mrad.

SUGGESTIONS FOR FUTURE WORK

Furture examination of TMI cable should be considered as a useful source of information. First, examination of TMI cable would clarify whether or not the cable satisfied its design goals. Second, the degradation of cable material might be a useful tool in mapping the severity of the containment environment due to the accident.

Raychem claims that Flamtrol(TM) cable will function following an absorbed dose of 200 Mrad. Historically, such claims are based on a qualification program which employs sequential application of environmental stresses. Examination of cable removed from TMI provides an opportunity to examine actual degratation caused by similar stdies have yielded surprising results. Polyvinyl-chloride and low density polyethylene cable material removed from Savannah River reactor were found to be severely degraded beyond engineering predictions.[4] Later scientific study indicated a strong synergistic degradation mechanism existed that had not been considered during the original useful-lifetime predictions.[4] The accident at TMI provides an opportunity to screen for such unanticipated degradation mechanisms.

For this study to be most useful, the cable to be examined should be removed from a severe environmental exposure area of containment. It would be worthwhile to examine other cable materials used at TMI in addition to Raychem Flamtrol to determine if they also satisfied their design goals.

All cable materials will degrade in the presence of radiation, steam and thermal environments. Hence, a cable material that is used extensively throughout containment might be useful to qualitatively map the environmental severity within containment. The cable probably cannot be used as a dosimeter because of the difficulties involved in differentiating among the individual influences of thermal, radiation and steam components of the environment on cable properties.

For either study to be useful, the cable provided should be several feet in length. This allows for a number of samples sufficient to perform meaningful statistical analysis. In addition, the cable should not have been altered during or after installation. For example, the application of heat-shrink tubing complicates engineering analysis by adding a significant non-accident heat exposure to the cables' history. Finally, an effort should be made to provide unexposed or low exposure identical cable for comparison purposes. This cable might be located outside of containment or in extra stock maintained at Three Mile Island.

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