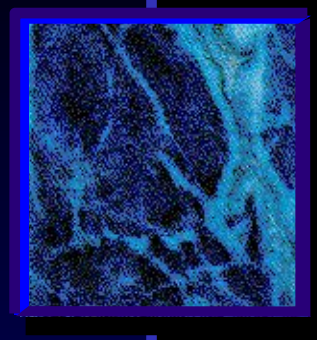


Digital Magnetic Storage on Flexible Media -

Magnetic Tape as the Archival Media

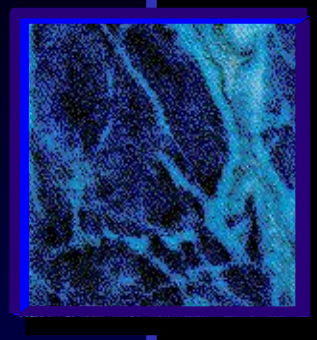
FujiFilm IT Executive Summit

Houston, Texas October, 2013

Dr. Richard Bradshaw

Tape Technology Consulting

Tucson, Arizona USA

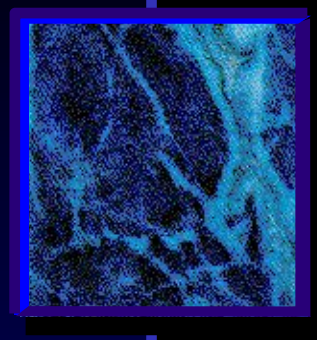


The Digital Universe *

- Total bits generated worldwide in 2007
  ~ $2.25X10^{21}$ bits (281 exabytes)
  growing ten fold every five years from 2004-2007, now growing even faster

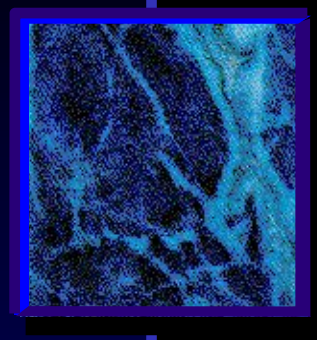
- in 5 years the worldwide collection of bits will exceed $6.02X10^{23}$ bits
  (Avogadro's Number)

* INSIC Tape Storage Roadmap 2012



The Digital Universe *

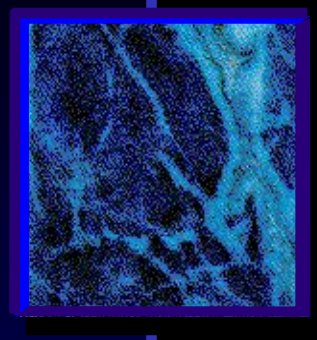
- total data generated exceeds available storage for all formats
- more than half the digital information will not have permanent storage and will be lost!
- by 2020 there will be at least 40 quadrillion storage "containers" needed to store the active information



Archival Storage of Tape

Where does Tape Fit in ?

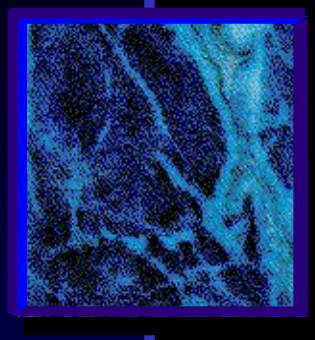
Why is Tape the Best Media for long term storage?



Archival Storage of Tape

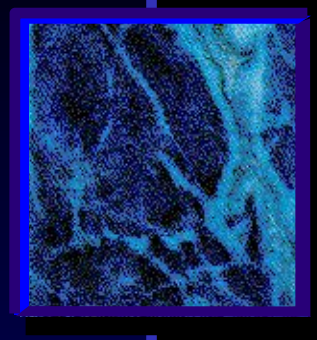
- Tape is the ONLY media with proven ,truly long term data storage and recovery.

- Tape Data Recovery & Failure Analysis a little history to prove the point!



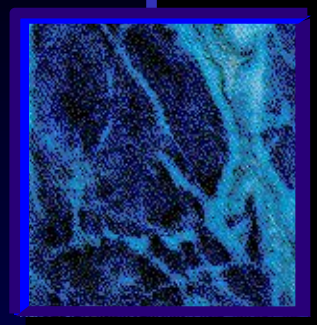
IBM 726 Tape - 1952

single data bit



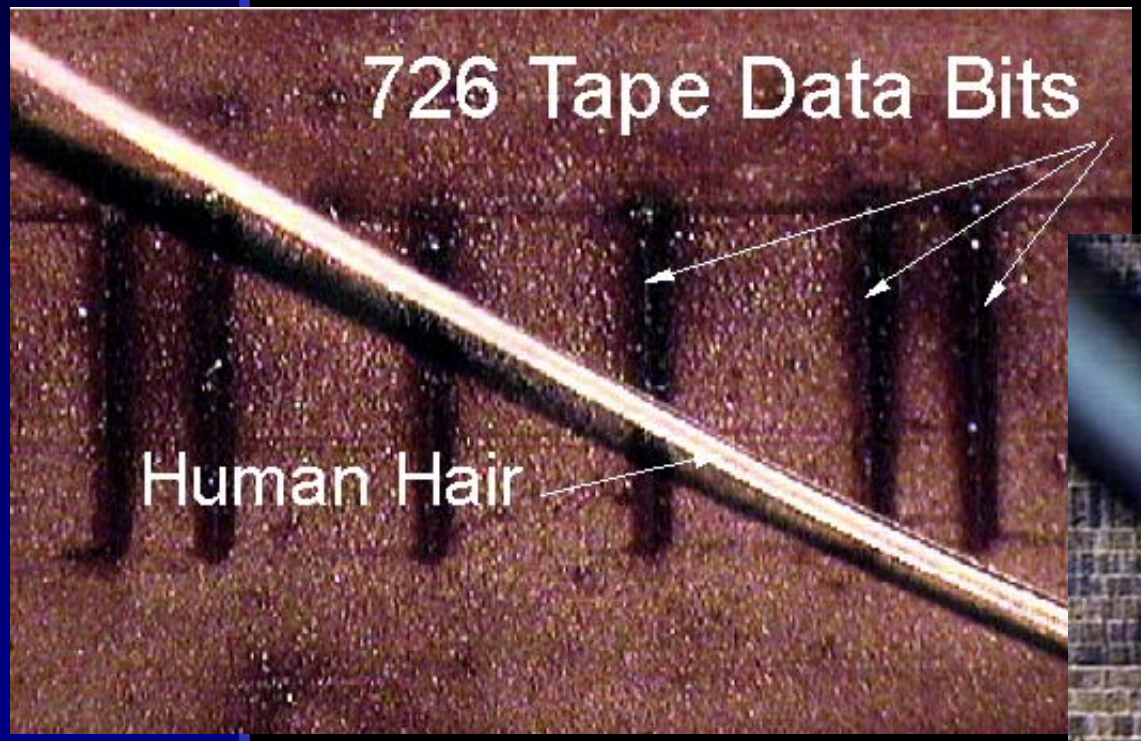
What's the Point?

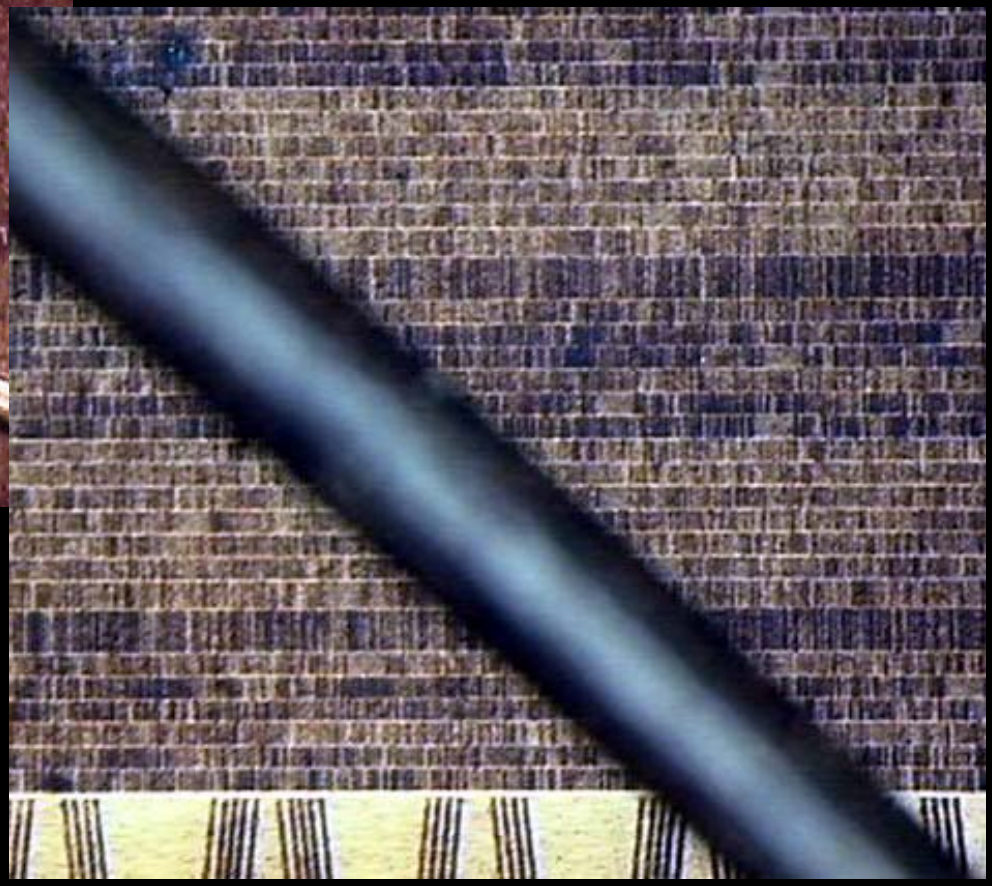
- a fifty year old recording still retains the written data signal
- the tape could be unspooled and read
- ✗ But it couldn't be made human readable because neither the application program or a drive to read the data with were available.

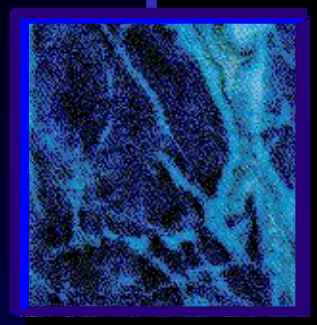


IBM 726 Tape - 1952

& IBM TS1120 - 2006



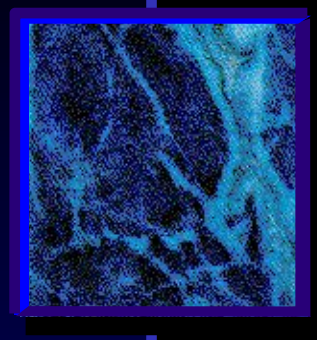




Archival Storage of Tape

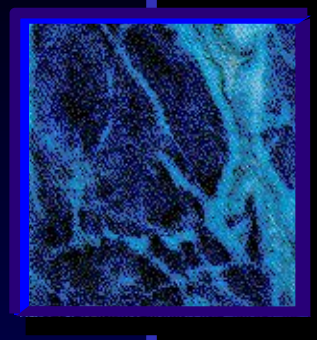
So how do tapes fail & what is the risk for very long term storage?

- tapes fail due to improper design
  - chemical degradation
  - unstable particles
  - poor mechanical properties
- tapes can wear out
- tapes can be damaged or erased



What is the Expected Life of Current Tape?

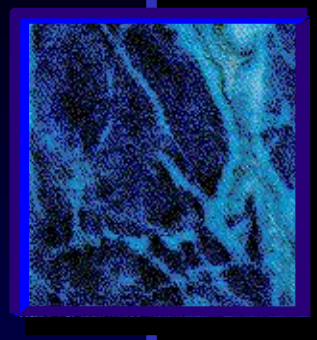
- current particles & binders are chemically stable
- current substrates mechanically stronger & more stable that those used even ten years ago
- current tapes are less sensitive to environmental induced degradation



Archival Storage of Tape

- most tapes brought in for data recovery were over written or damaged and not at risk due to tape degradation

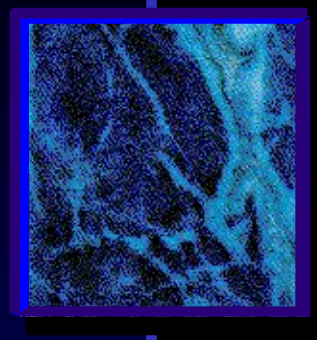
- this is true for even 20+ year old 3480/3490 media which used the very reactive chromium dioxide particles for the magnetic layer



Archival Storage of Tape

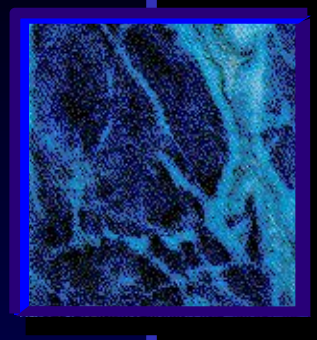
What has experience taught us?

- correct chemical and mechanical formulation can produce tapes that will retain the recorded signal for more than 30 years - demonstrated!
- most data loss is due to transport or handling
- robotic libraries provide the best storage, handling and data integrity checking solutions



Archival Storage - The Real Issues

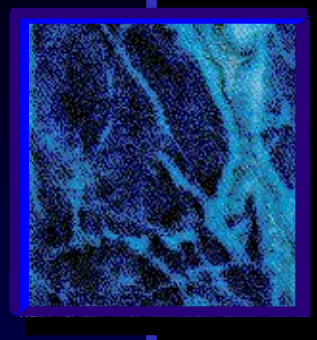
- obsolescence of formats, play back devices and application software occurs faster than signal decay or data loss on tape
- management of the metadata describing the data and its origin and history is likely more important than the data
- the shear size of almost any collection of data makes migration and management seem a very daunting if not impossible task.



The Future of Tape

What's Next?

- >60 TB capacity/cartridge by 2020
- increased virtualization and format migration management, transparent to user
- media reuse and investment protection
- improved (easier) data management
- encryption without a performance hit
- cost effective "at rest" remote storage
- tape creation & migration without physical shipment of tapes



One Final Thought .....

Remember this ...

There is NO Backup for Tape!

Space Shuttle *Challenger* Disaster

January 28, 1986 - the Space Shuttle *Challenger* carrying what would have been the first civilians into Earth Orbit was destroyed shortly after lift off.

Seal Failure during Lift-Off

The Flight Recorders from the Shuttle were recovered after six weeks exposure to salt water at a depth of 90 feet.

Tapes from all three of the shuttle recorders were recovered:

Payload (cargo), Ops-1(engines) and Ops-2 (voice and crew function)

Reel to Reel Recorders

Magnesium alloy reels

gamma iron oxide Ampex media

Reels mechanically damaged and corroded

NASA unwinding unsuccessful

Recovery of the Space Shuttle *Challenger* Flight Recorder Tapes

A Team Effort of IBM Corporation,
Tucson, Arizona

June 1986

Chemical Analysis

- Magnesium hydroxide salt encrusted
- Calcium salts and biological deposits
- Organic crystalline deposits
  (substrate and binder degradation products)

- Significant binder and substrate degradation

Mechanical Analysis

- very low coating adhesion
- poor mechanical integrity

But: dynamic mechanical analysis (DMA) indicated sufficient binder integrity to make separation of the tapes possible

Initial Assessment

- magnetic layer strongly adhered to the backcoat
- magnesium hydroxide primary “glue”

Process Development/Verification

- unrecorded supply reel from payload recorder was used to develop a recovery procedure
- separated tape was written several times and returned to NASA

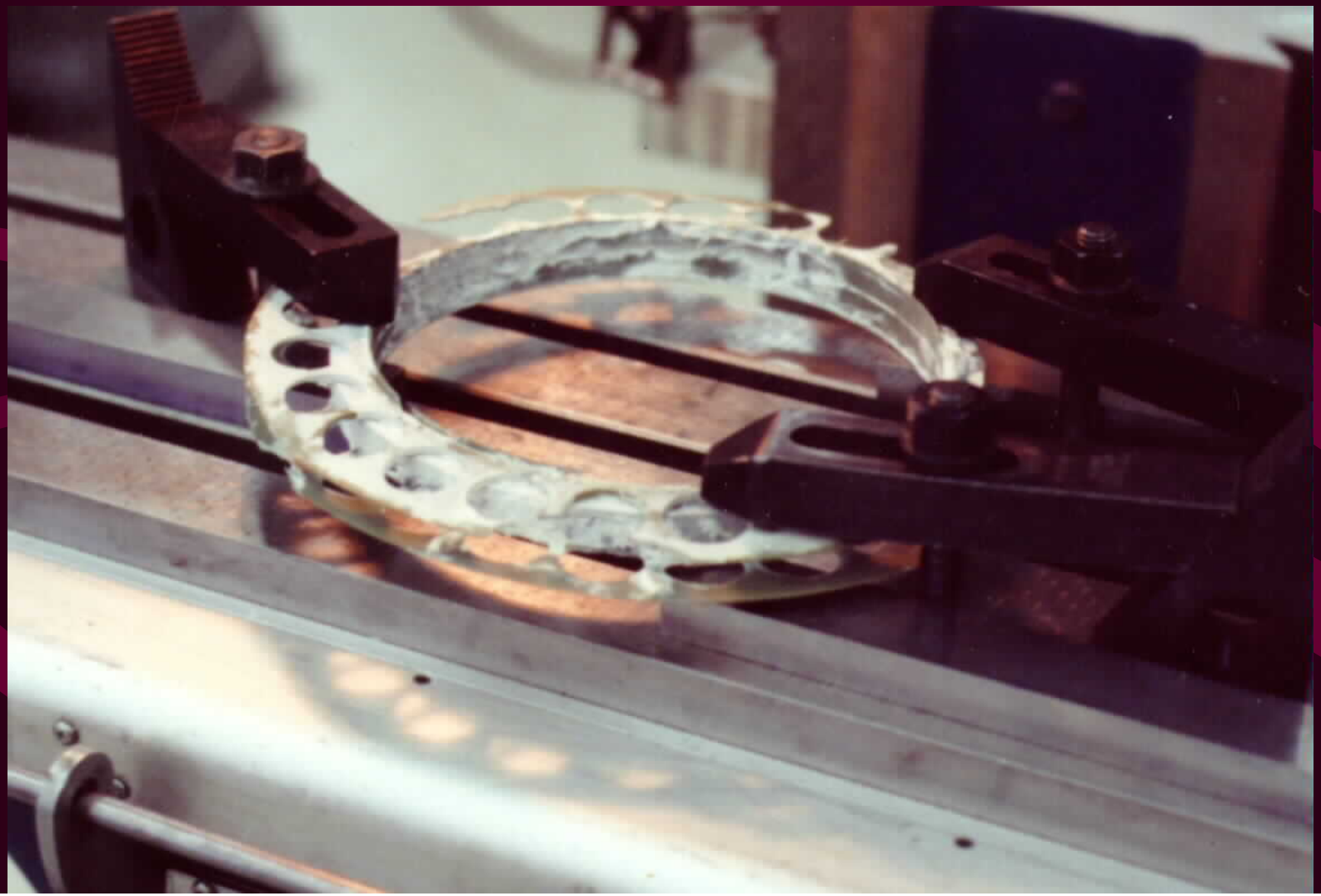
Data Tape Recovery – Ops-1

Data Tape Recovery – Ops-2

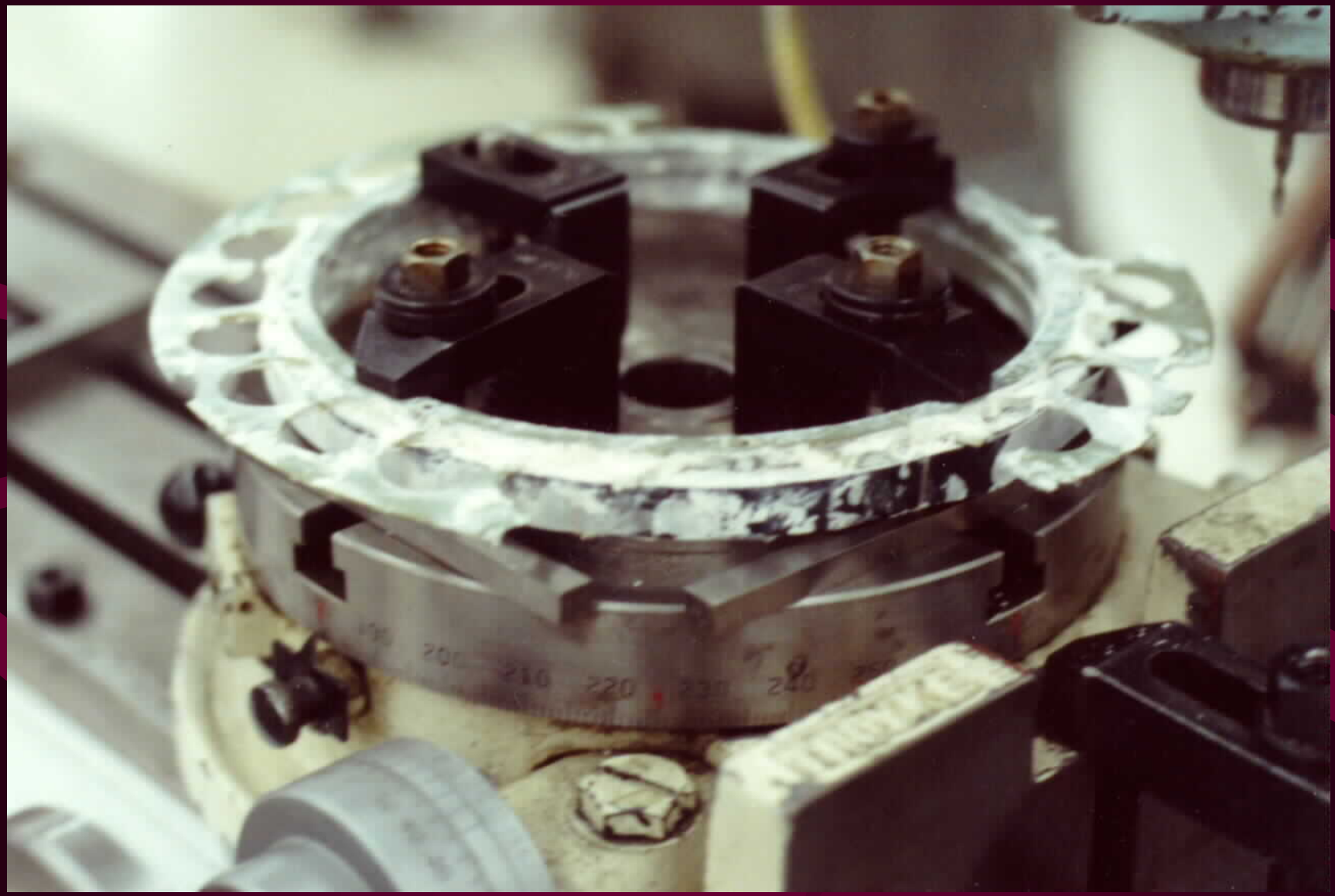
Recovery Process

- rinse tank and collapsible, spring-loaded hub designed and built
- method to remove damaged reel from tape perfected
- chemical rinse and re-lubrication method developed

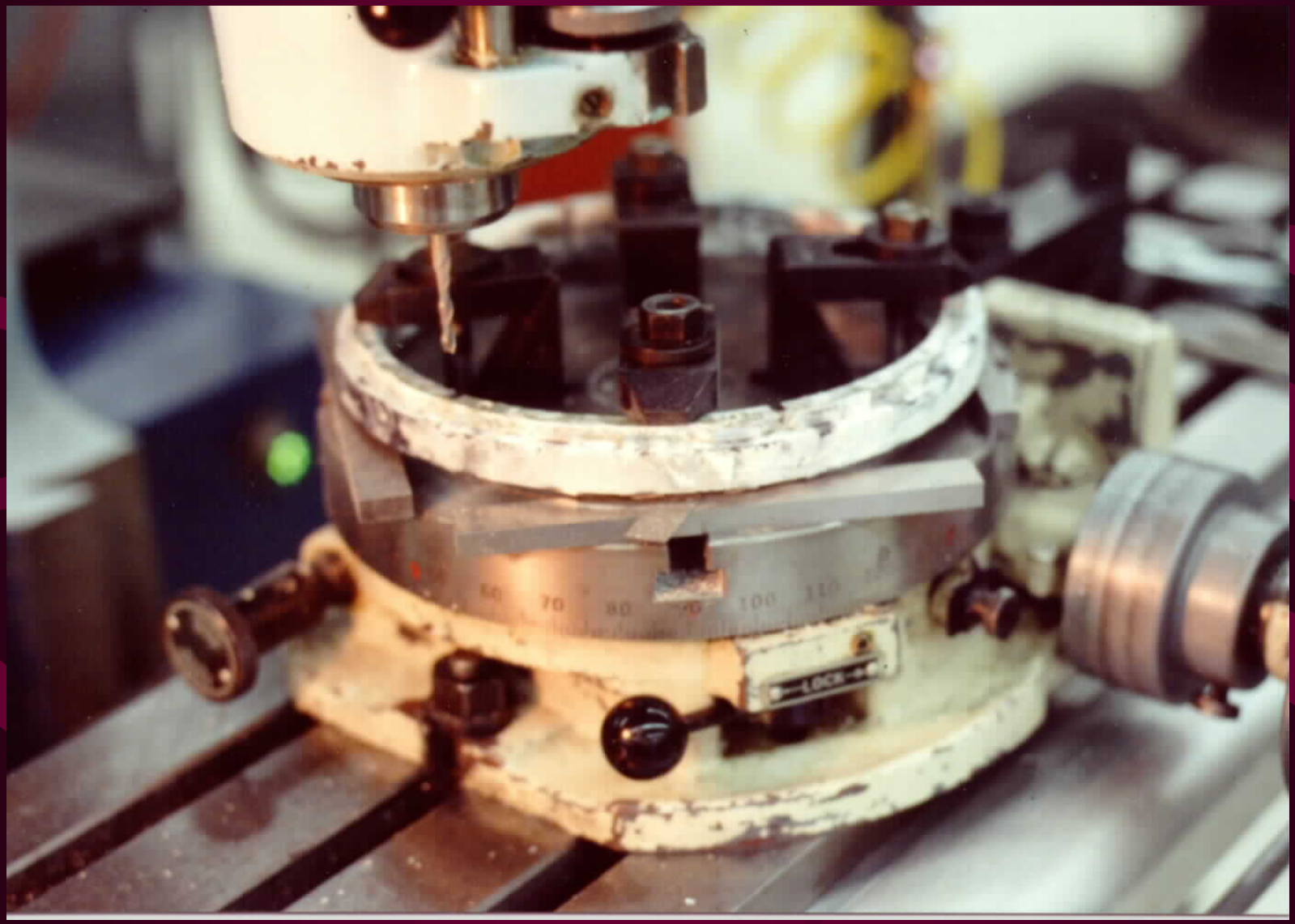
IBM Model Shop Flange Removal



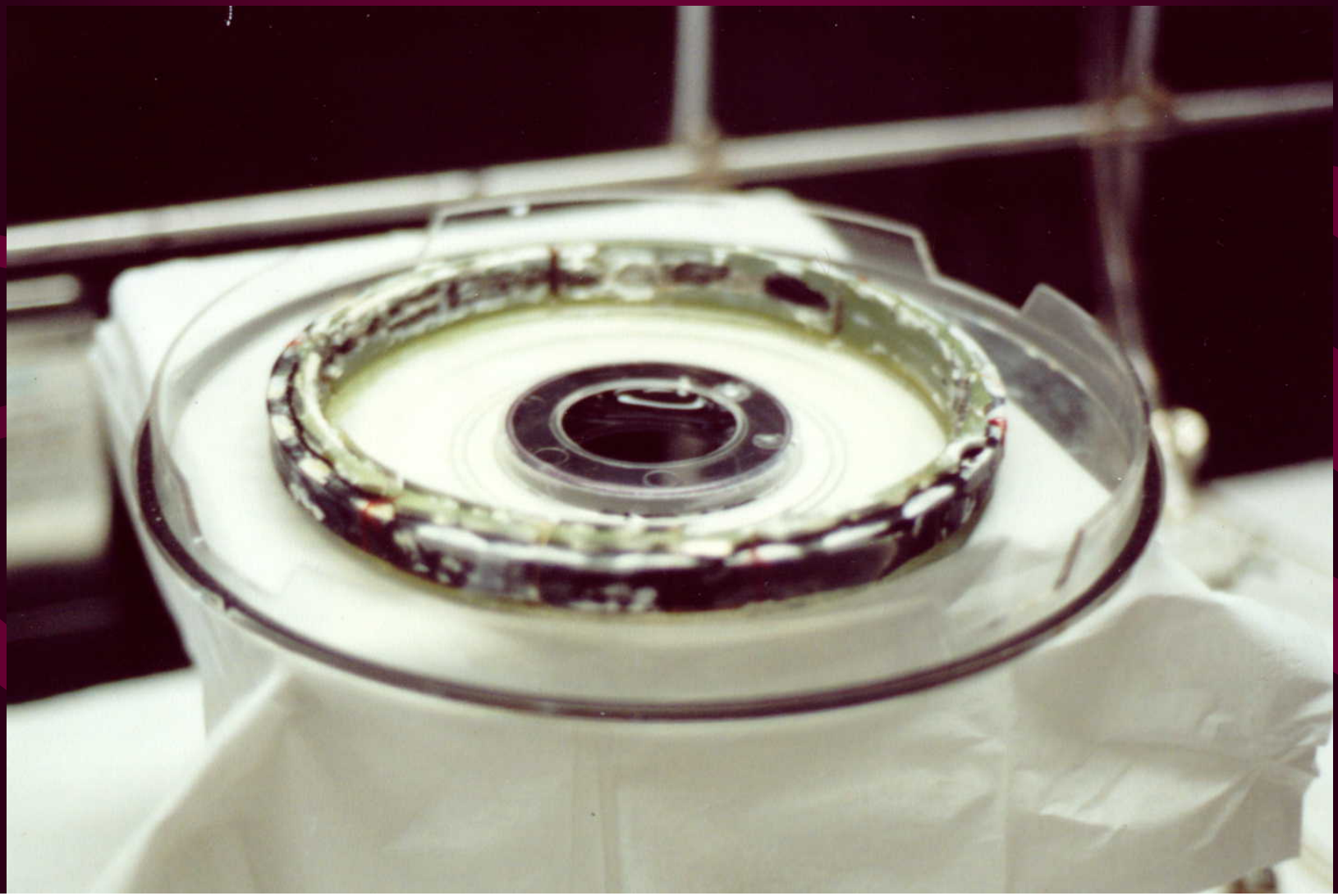
Lower Flange Removal



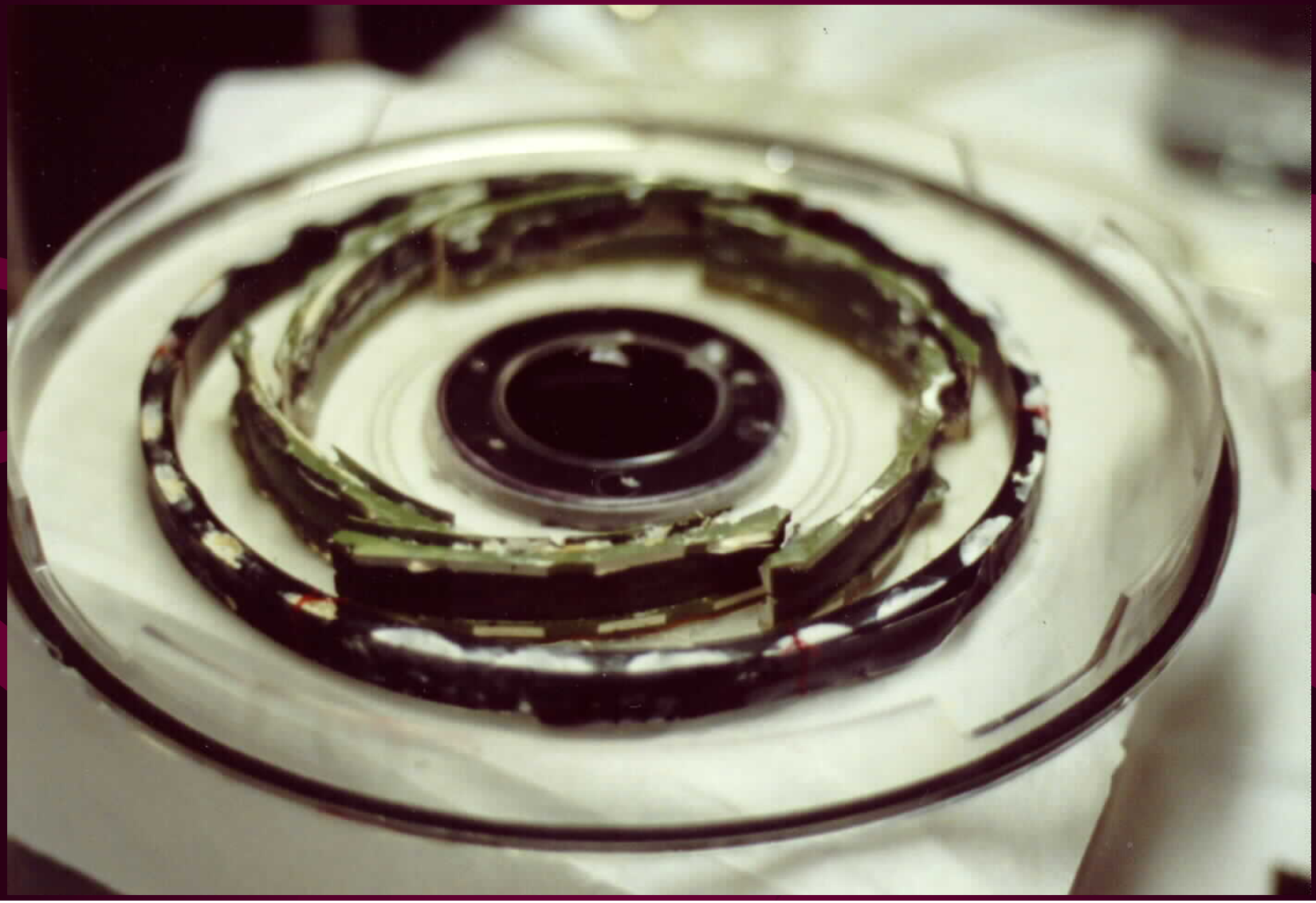
IBM Model Shop Hub Removal



Ops-2 Tape, Flanges Removed

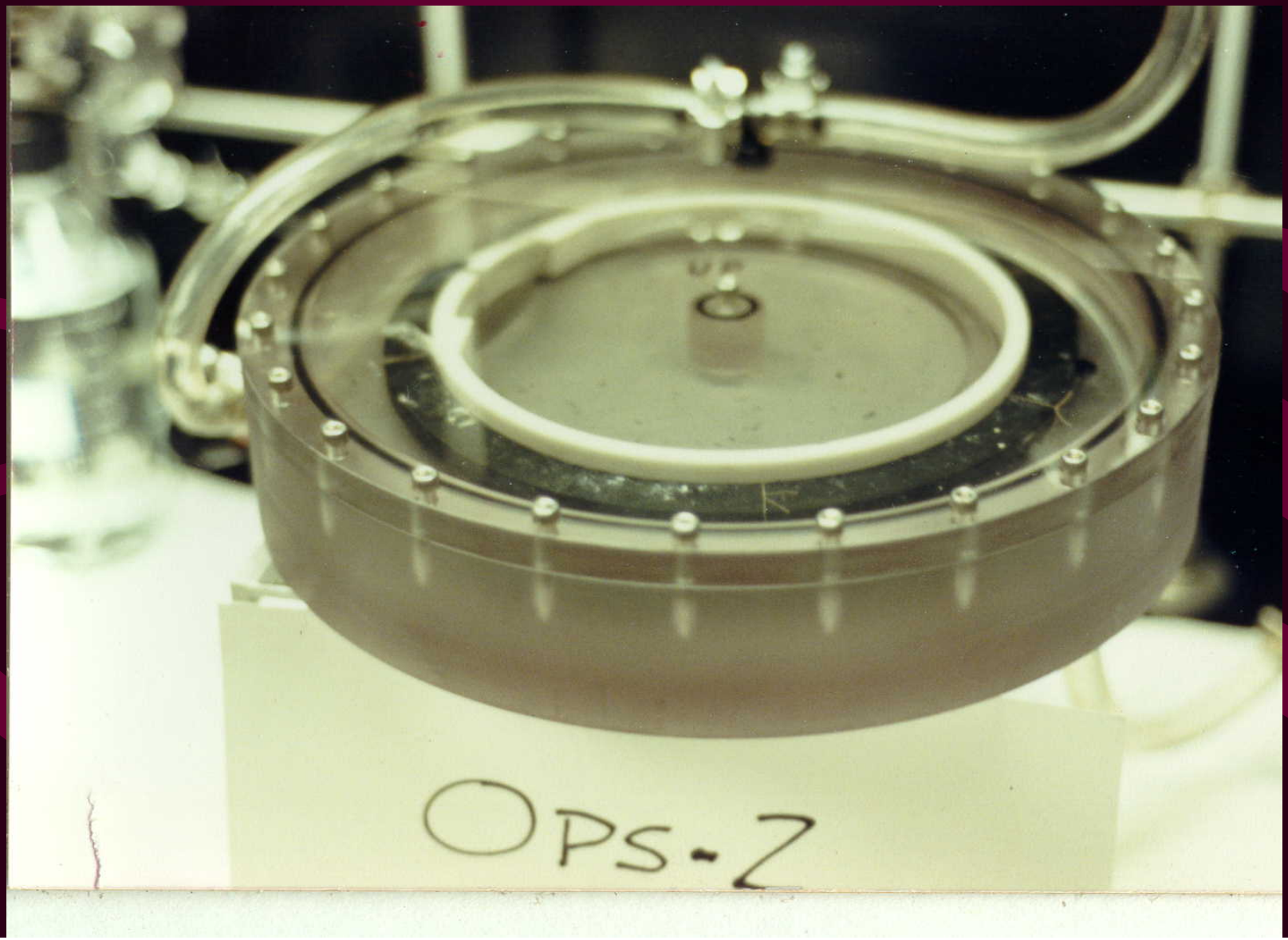


Ops-2 Tape, Flange & Hub Removed

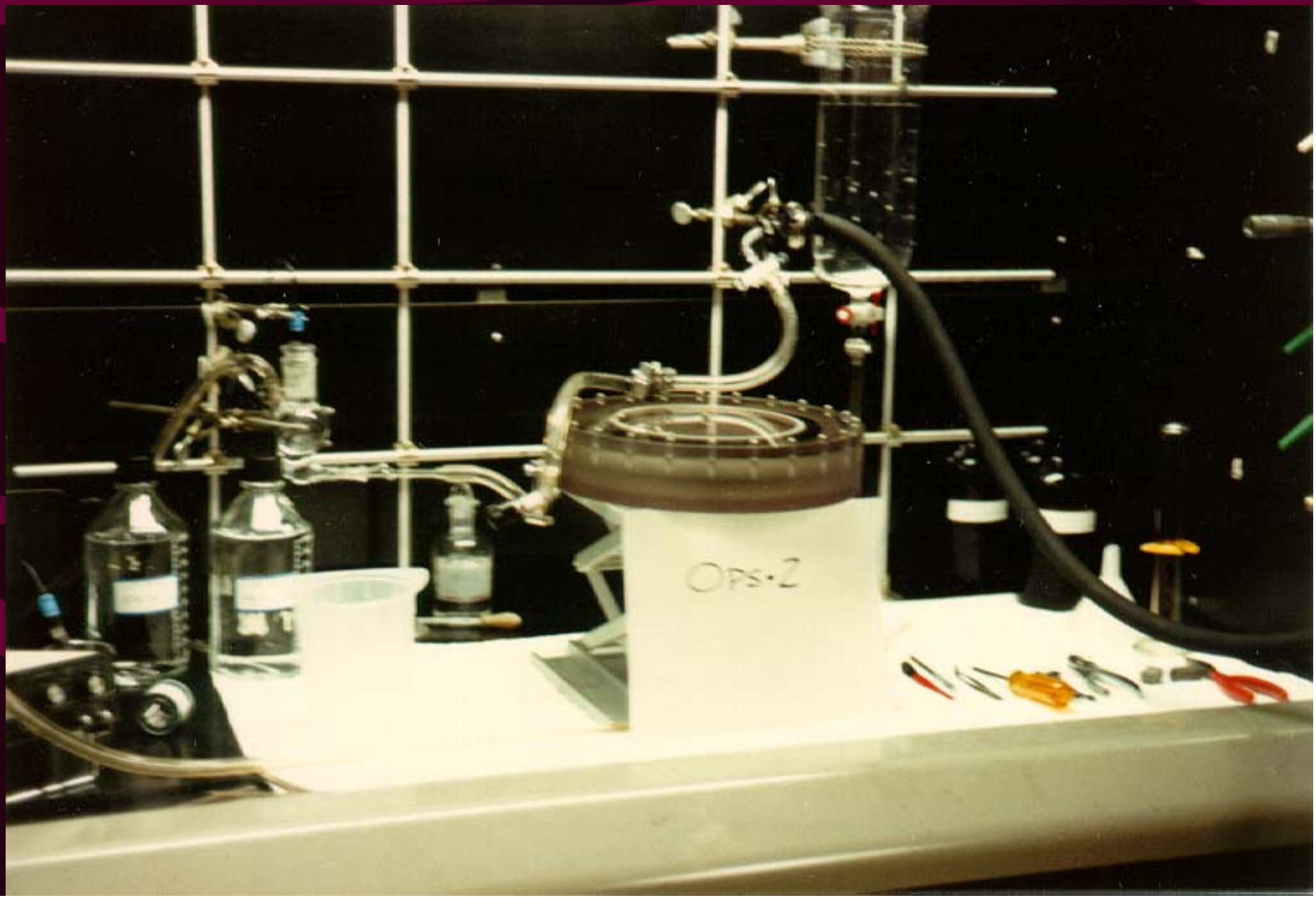


Ops-2 On Delrin Spring-load hub

Transferred to Rinse Tank

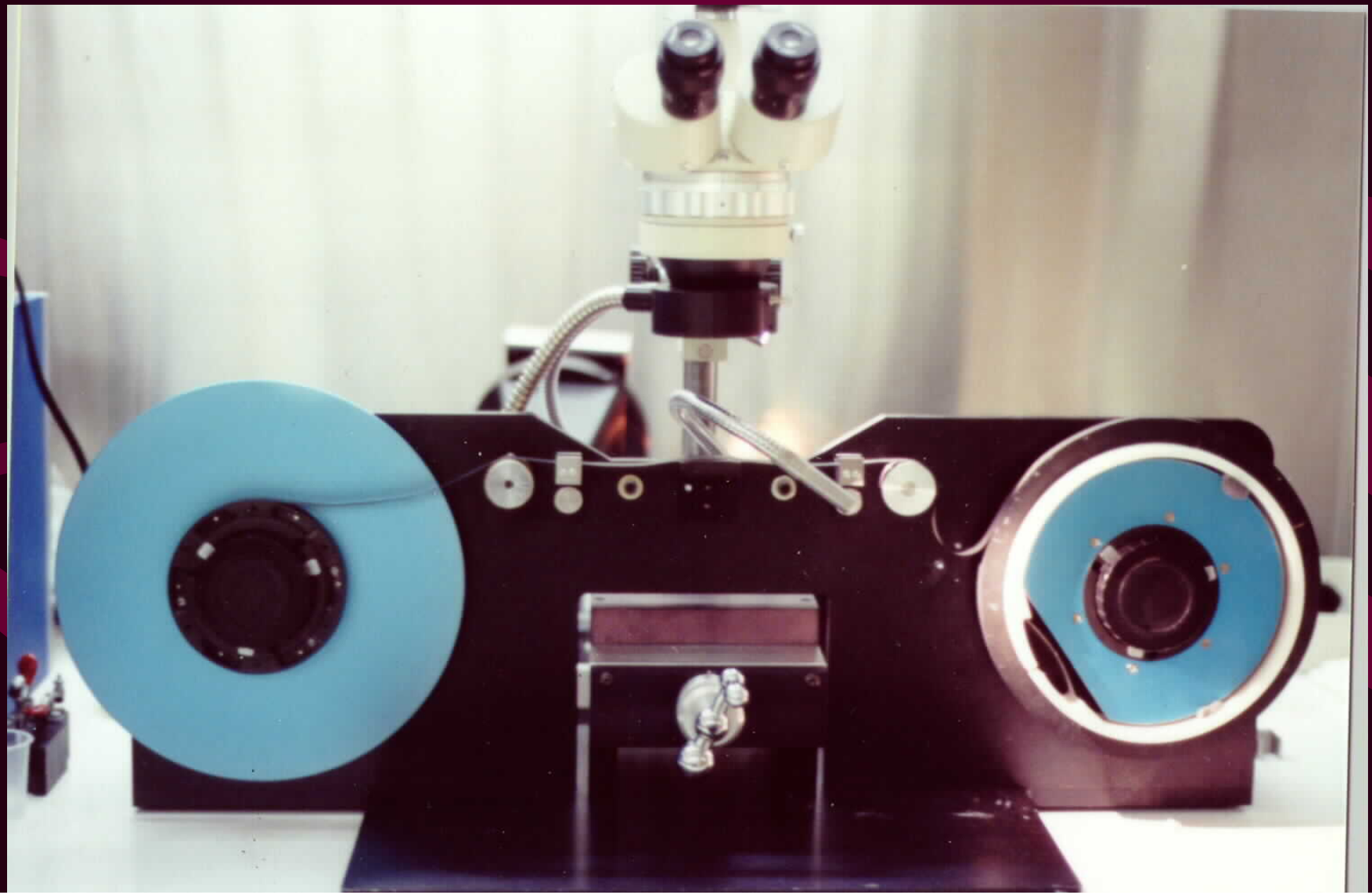


Chemical Rinse Process

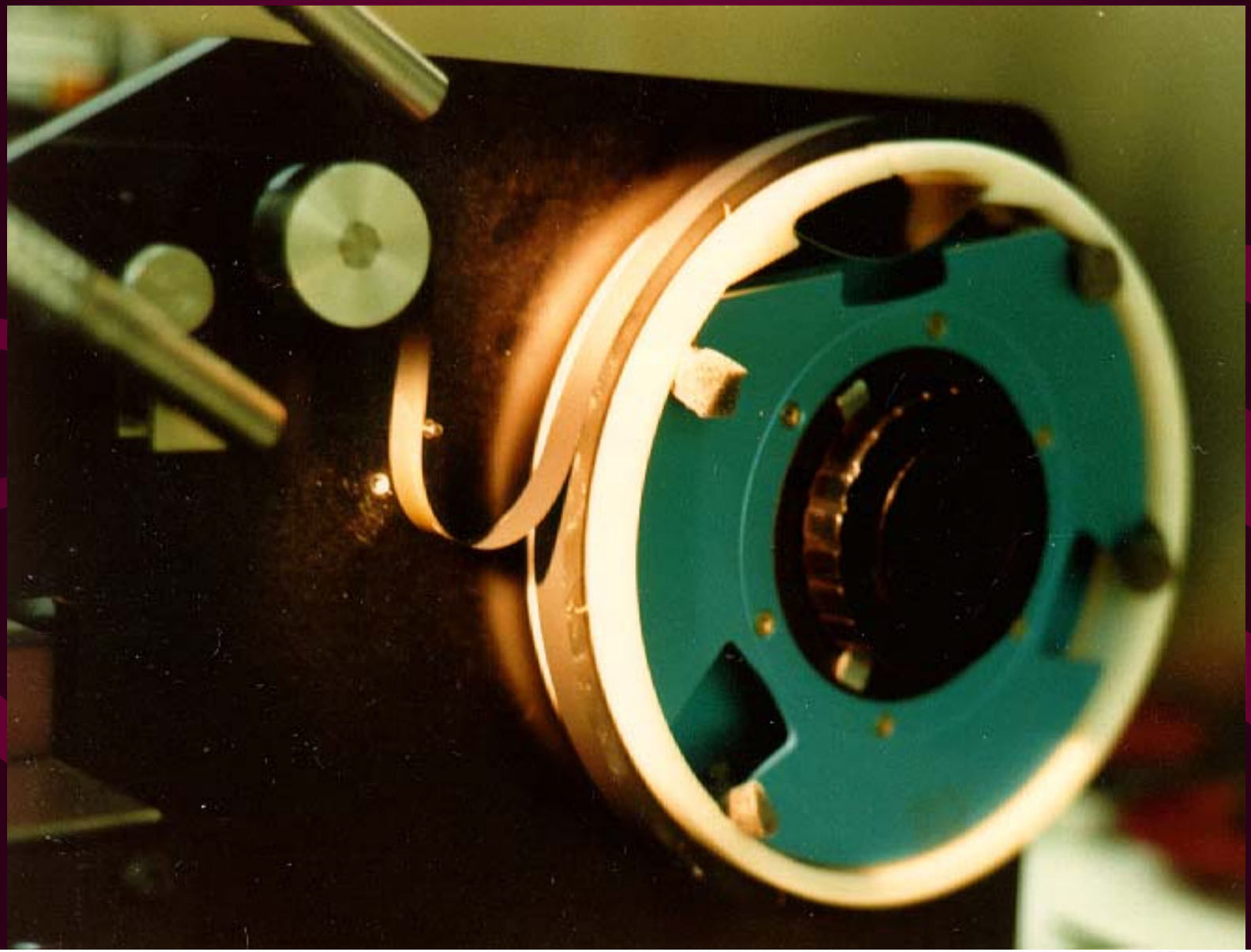


Treated Tape – Ready to Unwind

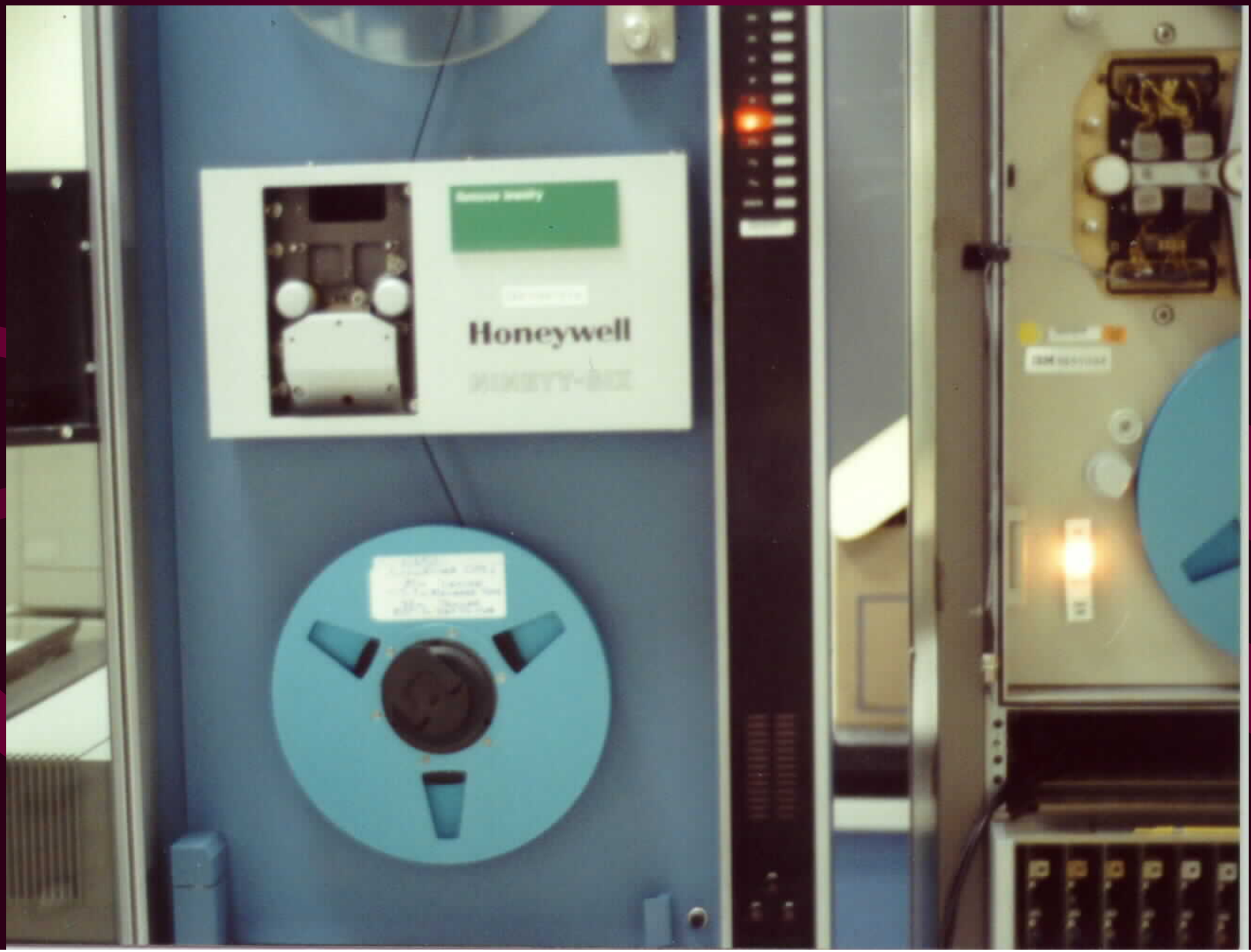
Unwind Fixture



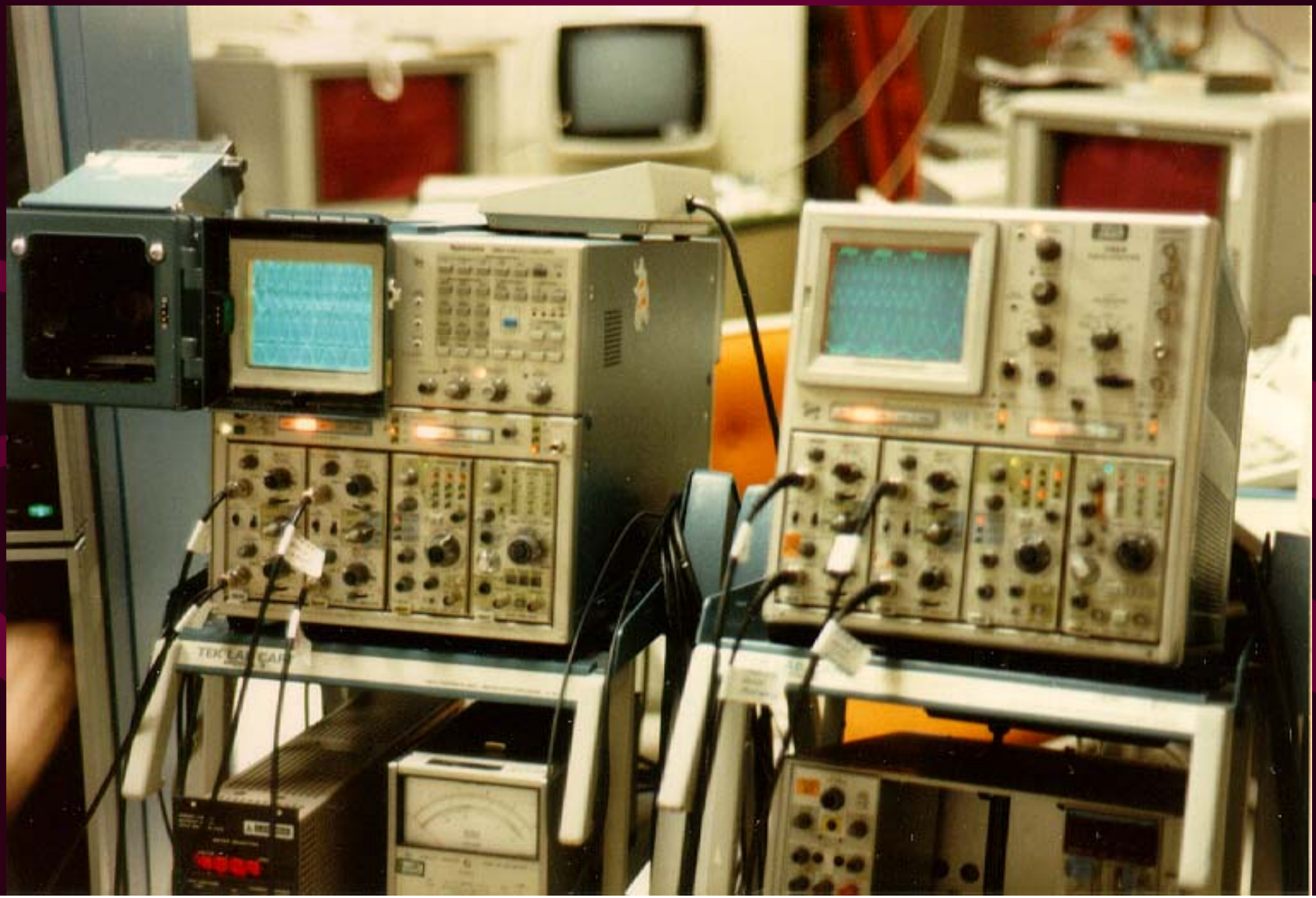
Treated Tape Unwind



Readback Transport



Signal Processing



"... the restoration by IBM engineers was a 'minor miracle.'"

(A NASA official quoted in *The Washington Post* concerning IBM Tucson's restoration of the *Challenger* intercom tapes.)

CHEMICAL AND ENGINEERING NEWS
August 25, 1986

Technology

Acid baths help recover *Challenger* tapes

Local IBM experts restored shuttle

By Jim Erickson
The Arizona Daily Star

After three months of work by 16 IBM Tucson engineers, it all came down to a two-syllable exclamation by space shuttle Challenger pilot Michael J. Smith: "Uh-oh!"

Smith's remark, heard on a tape was restored by IBM engineers at the company's General Products Division laboratory on Rita Road. A transcript of the intercom tape was released by NASA earlier this week.

"It's clear that without the IBM (restoration) process, those tapes and that information would have

wreckage in the At
Cape Canaveral, Fla

Initially, officials
Aeronautics and Sp
tion feared that the
be lost because
reacted with the
reels to create a

'A minor miracle'

IBM engineers defy odds — help save Challenger tapes

The Final Word, “Uh-oh”

The Arizona Daily Star

Vol. 145 No. 228 * Final Edition, Tucson, Tuesday, July 29, 1986 35¢ 40 Pages

Challenger crew alive after blast, NASA says

By Paul Recer
The Associated Press

SPACE CENTER, Houston — Space shuttle Challenger pilot Michael J. Smith exclaimed "Uh-oh!" at the moment the spacecraft exploded, and some of the crew apparently lived long enough to turn on emergency air packs, NASA said yesterday.

Smith's remark, heard on a tape of the shuttle's intercom system, was the first indication that any of the seven astronauts killed may have been aware of the Jan. 28 disaster, the worst in the history of space exploration.

The astronauts probably survived the explosion and breakup of the shuttle orbiter and could have had 6 to 15 seconds of "useful consciousness" inside the crew compartment after the blast, said Dr. Joseph Kerwin, an astronaut-physician who investigated the cause of death for the crew.

The force of the crew compartment's hitting the ocean was so destructive, however, that the precise cause of death for the crew could not be determined, he said.

The intercom tapes, which include enthusiastic chatter among the crew about the moments after liftoff, were recovered from the wreckage of the Challenger and analyzed by National Aeronautics and Space Administration and IBM engineers. (Some of the IBM work was done at the company's Tucson plant.)

The tape, a transcript of which was released by NASA yesterday, offered no evidence that any crew members other than Smith knew anything was abnormal prior to his single exclamation 73 seconds after launch — the very second that ground controllers lost communication with the craft.

Previously, the last known words from the Challenger were those heard from Commander Francis R. "Dick" Scobee to ground controllers, when he responded "Roger, go at throttle up," confirming that the shuttle's main engines had been raised to full power.

School teacher Christa McAuliffe and mission specialists Ronald McNair and Gregory B. Jarvis are not heard on the recording.

NASA said the three "could monitor all voice activity but did not make any . . . comments."

Admiral Richard H. Truly, associate administrator for space flight, said it was not unusual for there to be no comment from crew mem-

See CHALLENGER, Page 2A

1983 AP photo

Michael J. Smith
At explosion: "Uh-oh!"

Challenger Tape Recovery Team

Ed Bartkus, SEM, tape handling
Ric Bradshaw, chemical process
Blair Finkelstein, signal capture and copying
Clem Kalthoff, vessel & support hub design

Resources & technical support of entire
IBM Tucson Laboratory & Model Shop