社会開発協力部報告書

パキスタン中央電気通信研究所
短期専門家業務完了報告書
(抵抗器製造技術指導)

昭和56年4月

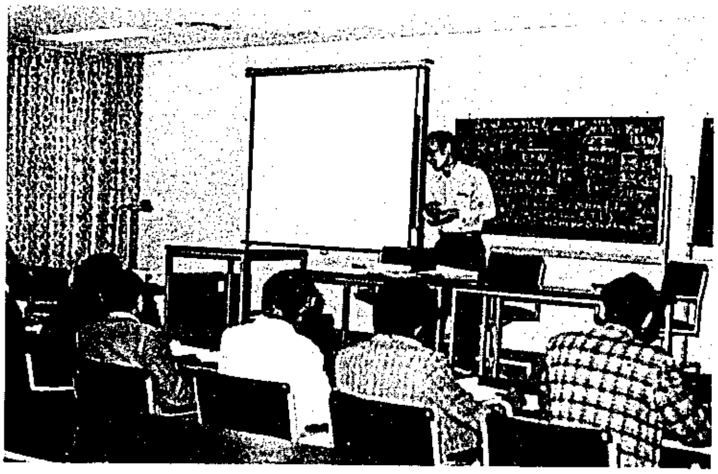
国際協力事業団

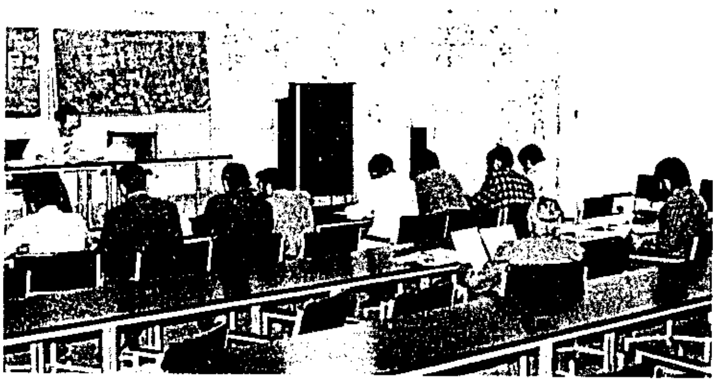
パキスタン中央電気通信研究所
短期専門家業務完了報告書
(抵抗器製造技術指導)

昭和56年4月

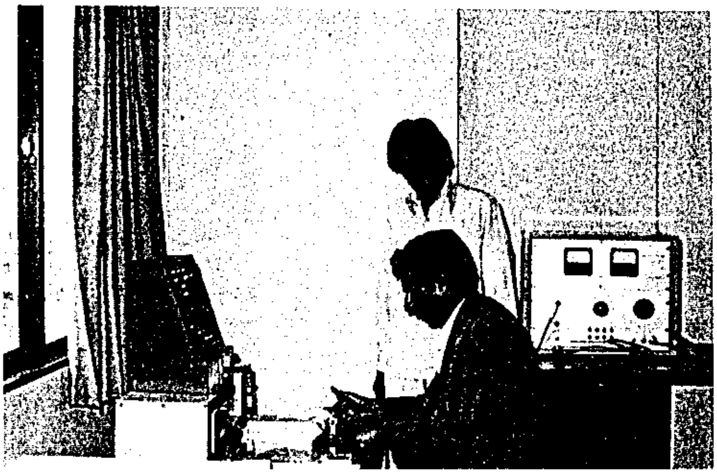
国際協力事業団

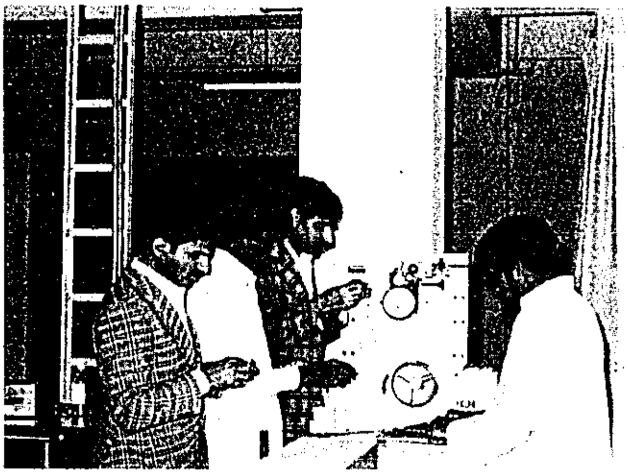
パキスタン中央電気通信研究所



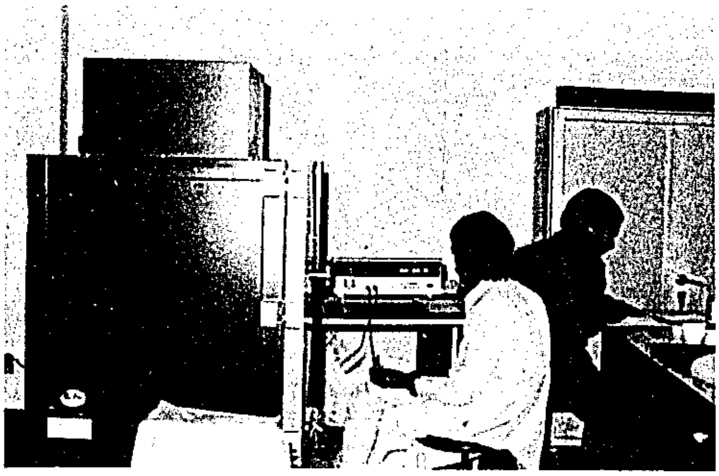


基本技術のレクチュア。後列左側SHEIKH所長



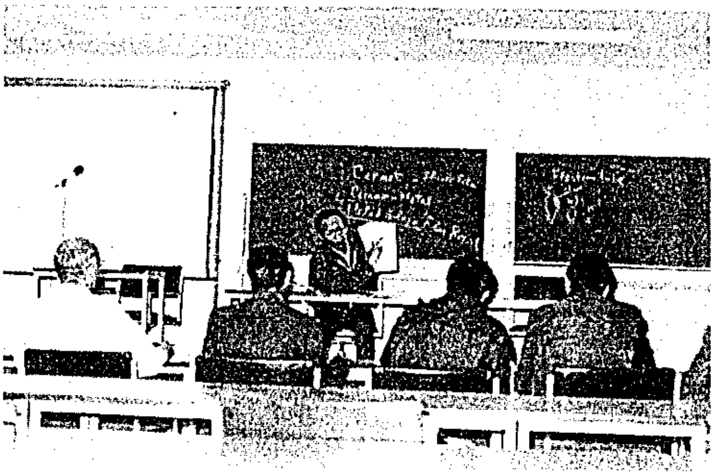


カウンターパートによる試作



カウンターパートによる特性テスト

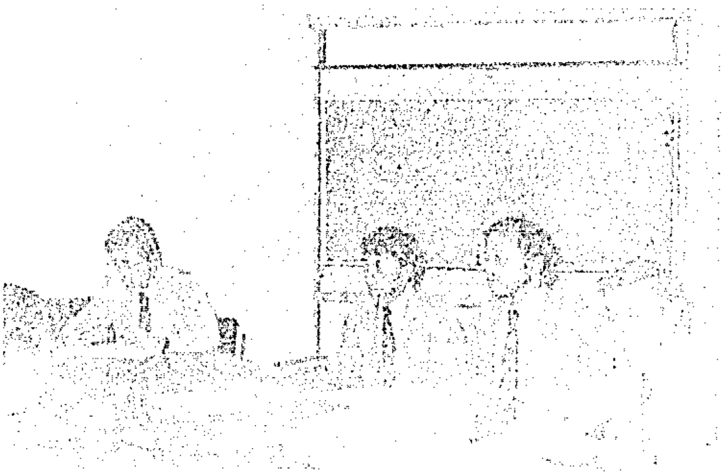
SHEIKH所長（中央）の視察



研究手法および新技術動向のレクチュア

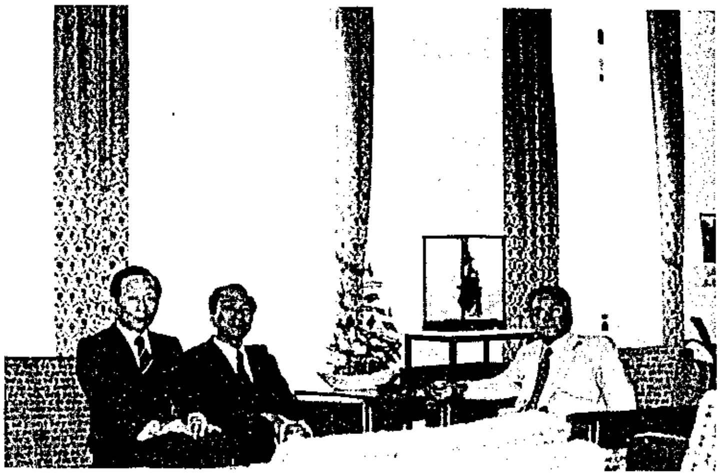
カウンターパートによる歓迎ティーパーティー

左から佐藤首席顧問、関口調整員、中島専門家（搬送）

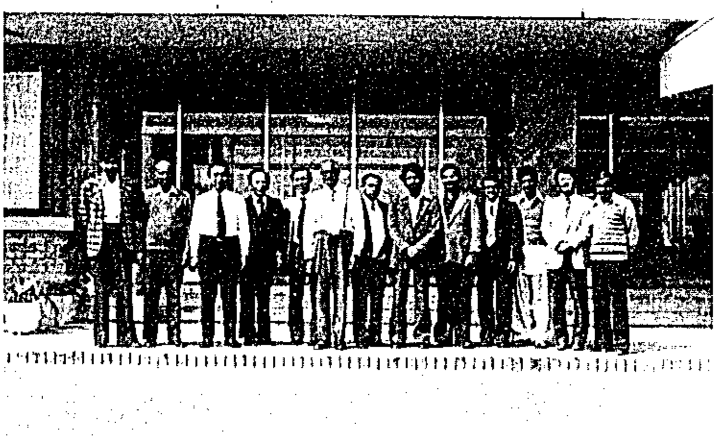


左から星専門家（電子交換機）、大井専門家（マイクロウエーブ）、
倉島専門家（電話機）、加藤斉専門家（P.C.M.）

左から北村(抵抗器)、加藤次雄専門家(データ通信)、佐藤首席顧問
定例専門家会議



パキスタン駐在鈴木特命全権大使を表敬訪問



佐藤首席顧問、SHEIKH所長、カウンターパートとの記念撮影

目　　　次

1. 序　　文

1.1 目　　的

パキスタン電信電話総局中央電気通信研究所（在イスラマバード市）に対しては、去る昭和54年3月に日本政府より技術協力実施討議チームが訪パの上、当該業務に関する討議議事録（R／D）を交換し方式関係については昭和55年1月より長期技術指導が開始されている。また電子部品についても短期技術指導を行う取り決めに基づいてパキスタン政府から日本政府に対して炭素皮膜固定抵抗器製造部門の製造技術に係る指導要請（短期）がなされ、その実施機関である国際協力事業団ならびに郵政省より当社に対し上記業務実施のため短期専門家派遣の依頼があり、これを受けて昭和55年度の技術指導を行うため日本政府派遣短期専門家として訪パした。

業務内容はつぎのとおりである。

(1) 炭素皮膜抵抗器の基本技術を指導すること。
(2) 実験室的製造技術を指導すること。（抵抗器の試作を行い、製造技術移転を図るものとする）
(3) 炭素皮膜固定抵抗器（試作品）の電気的特性の調査・実験の実施を行うこと。
(4) 上記調査・実験のデータの解析を行うこと。
(5) 抵抗器の実用化テスト及びその目途について策定すること。
(6) パキスタン中央電気通信研究所の将来の研究開発技術確立のため研究手法及び抵抗器の新技術の動向について指導すること。

1.2 派遣技術者氏名、派遣国および任国所属機関

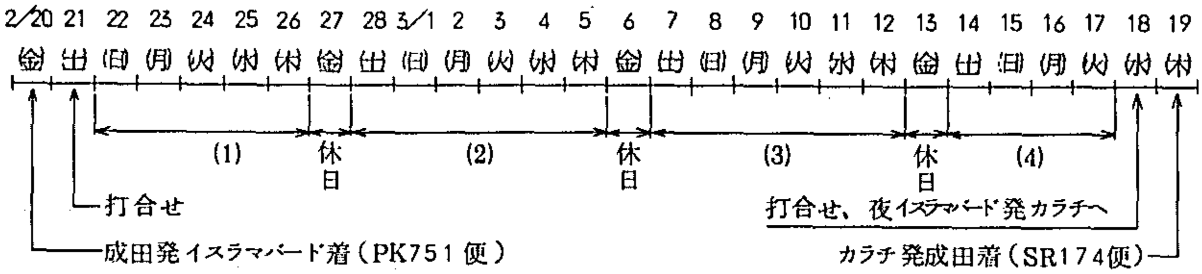
(1) 派遣技術者氏名：北村嘉伸（理研電具製造株式会社、研究開発部主任研究員）
(2) 派遣国：パキスタン回教共和国
(3) 任国所属機関：パキスタン電信電話総局中央電気通信研究所（以下C.T.R.L.と省略する）

1.3 派遣期間

昭和56年2月20日から昭和56年3月19日まで（28日間）

1.4 実施スケジュール

技術指導にあたっては以下のスケジュールに従って指導を実施した。



注1. 日　　程　(1) 基本技術のレクチュア、２月２２日(日)～２月２６日(木)、５日間

(2) 試作指導、２月２８日(土)～３月５日(木)、６日間

(3) 試作品の特性テスト指導、３月７日(土)～３月１２日(木)、６日間

(4) 研究手法、新技術動向のレクチュア、
３月１４日(土)～３月１７日(火)、４日間

注2. 時　　間　(1) レクチュア、０９：３０～１３：００，　１４：００～１５：００．

(2) 試作、テスト、０９：００～１３：００，　１４：００～１５：００．

なお、１３：００～１４：００はカウンターパートが礼拝のためブレーク

注3. 実施場所　(1) レクチュア、C.T.R.L. Ground Floor コンファレンスルーム

(2) 試作およびテスト、C.T.R.L. ３Ｆ回路部品研究室。

1.5 カウンターパートの氏名および人数

カウンターパートの人数、氏名、職責、所属研究室は表１に示すとおりである。

表１　カウンターパートの氏名

No.	Name of Counterpart	Designation	Laboratory
1	MR.Muhammad Amin SADIQ	Divisional Engineer-I	
2	MR.Nusrat ALI	Assist. Divisional Engineer	Circuit Compo.Lab
3	MR.Javed AKHTAR	Assist. Divisional Engineer	
4	MR.Muhammad IQBAL	Assist. Divisional Engineer	
5	MR.Ayaz QURESHI	Assistant Engineer	Circuit Compo.Lab
6	MR.Fazal HUSSAIN	Assistant Engineer	
7	MR.Abdul GHAFOOR	Assistant Engineer	Circuit Compo.Lab
8	MR.Amjad PERVEZ	Assistant Engineer	Circuit Compo.Lab
9	MR.Wasim Anwar KIANI	Engineering Supervisor	Circuit Compo.Lab
10	MR.Mubarak ALI	Laboratory Assistant	Circuit Compo.Lab

(注)　所属が空らんのカウンターパートは方式関係研究室所属のスタッフである。

なお上記カウンターパートへはそれぞれつぎの内容の指導を行った。

(1) 基本技術のレクチュア：MR.Mubarak ALIを除く9名全員。

(2) 試作：回路部品研究室所属の6名全員。

(3) 電気的特性の調査、実験：回路部品研究室所属の6名全員

(4) 研究手法および抵抗器の新技術動向のレクチュア：MR.Mubarak ALIを除く回路部品研究室所属の5名全員と日によって方式関係研究室のスタッフが参加。

また基本技術のレクチュア期間中は時々SHEIKH所長も出席した。

2. 業 務 概 要

(1) C.T.R.L. 関係者との事前打合せの実施

2月21日(土)午前中、佐藤首席顧問ならびに関係長期専門家に対して、今回の業務内容ならびに予め用意した英文打合せ資料に基づき、スケジュールを含む打合せを実施し、首席顧問以下関係者の了解をえた。

引き続き、同日午後首席顧問と共にSHEIKH所長に面会し、英文資料に基づく業務内容、スケジュール等の説明を行い所長の了解をえた。またこの席で所長より、打合せ資料を要約した関係者宛所長名公文書ならびにSADIQ課長名による前半のレクチュアへ出席すべきカウンターパート指名の公文書をそれぞれC.T.R.L.正面玄関内の掲示板へ掲示する旨の説明があった。

(2) 英文テキストの提供

レクチユアに使用するため予め用意した下記英文テキストを2月21日(土)、佐藤首席顧問および加藤斉長期専門家(P.C.M.の専門家、回路部品をこれ迄分担協力)に各1部、またSHEIKH所長へ2部提出した。

1) テキストNo.1: 炭素皮膜固定抵抗器(35頁)

2) テキストNo.2: 熱分解炭素皮膜固定抵抗器設計上の基本概念(14頁)

3) テキストNo.3: 熱分解炭素皮膜、金属皮膜および酸化金属皮膜固定抵抗器の既存技術および将来動向に関する一般情報(33頁)

4) Attached Sheet No.1: 固定皮膜抵抗器の電解現象(1頁)

また3月12日(木)、同じくレクチユアに使用するためC.T.R.L.にて作成した次のテキストを首席顧問、加藤斉専門家に各1部、SHEIKH所長に2部提出した。

5) Attached Sheet No.2: 熱分解炭素皮膜固定抵抗器の研究手法と試作(4頁)

(3) 炭素皮膜固定抵抗器の基本技術の指導

テキストNo.1、No.2およびAttached Sheet No.1の各コピーをカウンターパート9名全員に配布の上、2月22日(日)から2月26日(木)迄の5日間にわたって、C.T.R.L. Ground Floorのコンファレンスルーム(黒板、マイク、スライド設備つき)にてレクチュアを行った。先づテキストNo.1については当該抵抗器の歴史、構成材料、炭素皮膜の性質、抵抗器の定格、抵抗値の標準数列、製造方法、国家規格(JIS)として定められている抵抗器の特性、抵抗器の正しい使用方法、および有用文献の説明を行い、またテキストNo.2については設計上考慮すべき事項を、Attached Sheet No.1については皮膜抵抗器の電解現象とその注意事項をそれぞれ説明し、レクチュアを通してカウンターパートに対し、炭素皮膜固定抵抗器の基本技術に関しその認識をさせた。

(4) 実験室的製造技術の指導

2月28日(土)から3月5日(木)迄の6日間にわたってC.T.R.L.3階の回路部品研究

室にて同研究室6名のカウンターパートに表2に示す抵抗器の試作指導を行った。また試作にあたっては去る昭和54年5月当社より製造設備と共にC.T.R.L.へ納入済の英文製造指導書（86頁）を使用して、正しい製造方法を全員に理解させた。

表2　試作抵抗器

No.	形　名	電力(W)	抵抗値(Ω)	抵抗値許容差(%)	数量(PCS)
1	RD 1/4 P	1/4	1K	± 5	50
2	RD 1/4 P	1/4	10K	± 5	50
3	RD 1/4 P	1/4	100K	± 5	50

なお、各抵抗値毎に完成品50PCS. を得るため、カウンターパートは余裕をみて各抵抗値につき70PCS. 計210PCS. の試作を行った。

(5) 試作品の電気的特性の調査と実験の実施

C.T.R.L.回路部品研究室には現在当該抵抗器のテストに必要な各種試験設備あるいは部品の取りつけ治具等が設置されていないため、原則として抵抗器の製造設備を転用して実施可能なテスト項目、ならびにその他の設備で流用すればテスト可能な項目に限って試作品の特性テストの指導を行う旨予め打合せで確認したのち、3月7日（土）から3月12（木）迄の6日間にわたってC.T.R.L.3階の回路部品研究室およびGround Floor のHumidity Chamber Room にて同研究室6名のカウンターパートに対して表3に示すテストの方法、データの作成、計算、テスト結果の判定、データのグラフ化について指導を実施した。なおテストの指導にあたっては、当該抵抗器の特性基準として定められている日本工業規格"JIS C 6402、炭素皮膜固定抵抗器"（昭和54年8月当社にて英文に翻訳の上、C.T.R.L.へ提供済）をテキストに使用した。

表3　試作品の特性調査

No.	テスト項目	抵抗値と数量			結　果
		1KΩ	10KΩ	100KΩ	
1	寸法検査	10ケ	10ケ	10ケ	全数規格値内
2	抵抗値測定	50	50	50	1KΩ, 100KΩは全数規格値内 10KΩのみ3ケプラス不良(Max+8%)
3	短時間過負荷特性	10	10	10	全数規格値内
4	温度サイクル試験	10	10	10	全数規格値内
5	抵抗温度特性	5	5	5	全数規格値内

(6) 研究手法および新技術の動向に関する指導

Attached Sheet №2およびテキスト№3の各コピーを回路部品研究室のカウンターパート5名に配布し、3月14日（土）から3月17日（火）迄の4日間にわたってC.T.R.L. Ground Floor にあるコンファレンスルームにてレクチュアを行い、当該抵抗器に必要な研究手法および炭素、金属、酸化金属皮膜固定抵抗器を含む既存技術と新技術の動向についてスライドを使用し説明を行いカウンターパートへその認識を深めさせた。

(7) 実験データの解析

えられたデータの解析結果の概要は以下のとおりである。

1) 寸　法

規格値を超えるものがなかったことから、抵抗器の構成に必要な部品は正確に抵抗素体に取りつけられていると判断する。

2) 抵抗値測定

(a) 抵抗値許容差が公称抵抗値に対して±5％であり、ランダムに各抵抗値毎50PCSのサプリングを行ってえられた実測値からそれぞれの公称抵抗値に対する偏差を求めた結果1KΩおよび100KΩはすべて許容差内にある。10KΩについては50PCS中3PCSプラス不良となり許容差不良率は6％である。

(b) 10KΩの許容差不良率6％はやや大きいが、サンプル総数150PCSとしてみると2％となり，これは製造技術の熟練度の向上に伴って更に低減するものと考える。

(c) ±5％級の許容差精度についてはほぼ安定した状態がえられるものと判断する。

3) 短期間過負荷特性

総数30PCSともその抵抗値変化率は規格値内（±0.75％）にあり、このことは抵抗値の調整作業が安定してなされていることを示しており、また瞬時の過電圧印加に対して性能上の問題はないと判断する。

4) 温度サイクル試験

総数30 pcsともにその抵抗値変化率は規格値内〔±（0.75％+0.05Ω）〕にあり、低温側、高温側の温度ストレスに対して抵抗値の変動が少いことを示している。

5) 抵抗温度特性

基準温度と試験温度よりえられた測定値から算出した1℃あたりの抵抗温度係数は規格値（±350 ppm/℃）をみたしており、周囲温度の変動に対して抵抗値が極端にかつ非直線的に変化しないことを示している。

(8) C.T.R.L.関係者に対する中間報告および最終報告

1) 必要に応じて常時佐藤首席顧問、加藤斉長期専門家へ進行状況の報告を行った。また首席顧問の要請により3月5日（木）炭素皮膜抵抗器の今後の技術協力に関する私見文書を提出の上、説明を行った。

2) 毎週1回開かれる専門家会議に出席し、佐藤首席顧問、各長期専門家および関口調整員

を含む全員へ進行状況の報告を行った。

3) 必要に応じて佐藤首席顧問と共にSHEIKH所長に面会し、進行状況の報告を行った。

4) 3月16日(月)、佐藤首席顧問と共に日本大所館へ出向き、松本一等書記官の案内で鈴木特命全権大使ならびに飯島公使を表敬の上、今回の技術指導の目的とその進行状況について報告を行った。

5) 3月17日(火)午後、佐藤首席顧問以下全員へ今回の技術指導の最終概要報告を行った。

6) 3月18日(水)午前、佐藤首席顧問と共にSHEIKH所長に面会し、今回の技術指導を予定通り終了した旨の最終概要報告を行った。

(9) 技術指導の成果

今回の技術指導の成果は以下のとおりである。

1) 受動電子部品の三要素の一つである抵抗器に関し、その基本技術と設計概念について説明した前半のレクチュアでカウンターパートは抵抗器の基本的知識を深めることができた。

2) 製造技術については去る昭和54年当社が納入した設備の受入れ試験の際、簡単な指導を行っていたこともあり、当該抵抗器がすでにP.C.M.、電話器、マイクロウエーヴ、搬送等方式関係の研究室で実験に必要な手作り回路用に少しずつ供給されていたが、その殆どが保護塗装がなされず素子がむき出しのまま取りつけられていた。

このようなことをふまえて、防湿性の重要性を強調して試作指導の結果でき上った試作品は外観的にも良好な形に仕上り、カウンターパートが製造技術についてより理解を深め、製造の技術移転をはかることができた。

3) 試作品のテストはカウンターパートが初めて体験したために、当初はデータフォームの記入もれ、計算ミス等も目立ったが、当該抵抗器の特性基準がどこにおかれ、また機械的、電気的特性として具体的にどのようなことが要求されるかについてカウンターパートは理解を深めた。またデータをグラフ化することで全体の傾向が把握しやすくなることも実際に体験し大きな関心を示した。

4) 後半に実施したレクチュア"研究手法と試作"および"各種固定皮膜抵抗器の既存技術と将来動向"においては、試作品のテスト後に行ったこともあって前半のレクチュアに比較して質問が非常に活発にでて、関心の高揚を示した他、"研究手法と試作"についてはこれが実施ならびに管理にあたって、回路部品研究室のDivisional Engineerが現在空席のためAssistant Divisional Engineer, Mr. Nusrat ALI より自分の責任において立案と管理を行う旨の申し出があり、カウンターパートに積極性がみられるようになった。

5) 前半レクチュアの段階から、カウンターパートより今回の指導終了時に"Techntcal Certificate"を交付してもらえないかとの要望があったため、佐藤首席顧問以下関係者全員ならびにSHEIKH所長の了解のもとにカウンターパート9名中から、回路部品研究室所属Mr. Wasim Anwar KIANI, Engineering Supervisor 1名に対してのみ指導期間中

の熱意を入れて“Technical Certificate”を3月18日付で本人に手渡した。なお当該Certificateのコピーは佐藤首席顧問、加藤斉専門家、SHEIKH所長へも各1部提出済である。

6) カウンターパートが製造した成果品の1部を持ち帰り国際協力事業団へ提出した。

(10) 検討事項

パキスタン政府から日本政府に対しなされた炭素皮膜固定抵抗器の技術協力要請にもとづき、その実施機関である国際協力事業団ならびに郵政省の依頼により昭和55年度の技術指導を昭和56年2月20日から3月19日迄（実質指導期間2月22日から3月17日迄）、C.T.R.L.において行った。以下にその検討事項を述べる。

1) カウンターパートの資質と理解力

当然のことながら、カウンターパート間に資質の差があるため、特にレクチュアについては時間の制約等から十分復習の機会を設けられず残念ながらカウンターパート全員が十分な理解をする迄には至らなかった。しかしカウンターパートは全員特にレクチュアについては熱心に参加をしたほか、全員が電気通信関係の専門教育を受けているので、この点は今後のカリキュラムの組み方と指導期間等を合せて検討することで解決できると考える。

2) 製造および研究試験設備

種々の制約で炭素皮膜抵抗器の製造設備については、抵抗皮膜として機能する炭素皮膜の着膜製造設備が現在C.T.R.L.に設備されていないが、今後当該抵抗器の基礎研究ならびに実用研究をカウンターパートが実施し、かつ炭素皮膜の基本的性質、すなわち、炭化水素の気相熱分解方式により得られる炭素皮膜について(a)その析出のメカニズム(b)炭化水素ガスの通気時間とえられる皮膜の抵抗値、抵抗温度係数との相互関係、(c)ガス通気時間を一定として熱分解温度をパラメータとしてえられる皮膜の抵抗値、抵抗温度係数との相互関係、(d)熱分解温度を一定として基体磁器表面をパラメータ（基体磁器表面の化学処理の有無）として得られる皮膜の抵抗値と抵抗温度係数の相互関係等を理解していくうえでは、将来C.T.R.L.がこの着膜製造設備を導入することが必要であると考える。

他方、抵抗器に限らず他の回路部品をも含めて、これら電子部品の電気的、機械的、諸特性の調査、確認に必要な試験設備あるいは試料の取付け治具等も設置されていないので、特性調査の上からもこれらの設備や治具類の導入が必要であり、抵抗器の試験設備としてその具体例を挙げれば、(a)各種直流安定化電源、(b)オンオフタイマー、(c)電流雑音測定器、(d)振動試験機、(e)端子線強度試験機、(f)負荷寿命試験用恒温槽、(g)耐湿負荷寿命試験用恒温恒湿槽、(h)表面温度計、(i)各種電圧、温湿度自動記録計、その他かなりの設備が必要となるほかに、治具類として耐熱材料を使用した(a)寿命試験用負荷台、(b)抵抗温度係数測定台等の導入が必要である。特に試験設備の欠如は電子部品の性能確認の上で大きな問題点であると考える。

3）職制機構

パキスタン政府関係の職制はパキスタン電信電話総局（以下Ｔ＆Ｔと省略する）に限らず極端に階級制度がはっきりしているため、例えば試作に当っては上位のカウンターパートが実際に製造技術を習得する気がまえに欠けているきらいがある。一つの仕事をチームワークとし分担、協力し合い業務の迅速化を行うといった習慣がない点については今後の指導において是正させ上位のカウンターパートといえども理論のみならず実際面の技術を習得することを認識させる指導が必要であると考える。

4）抵抗値許容差精度の向上

今回は最初の技術指導ということもあって、カウンターパートによる試作品の抵抗値許容差はすべて±５％以内を目標にしたが、さらに精度の高い±２％、±１％あるいは炭素皮膜抵抗器では最高の±0.５％級を歩留りよくねらっていくためには、現状のカウンターパートの技術ではまだまだ困難で、これに伴う細かな指導とかつカウンターパート自身の製造技術上の熟練度向上の努力が必要であると考える。

(11) 今後の技術指導のあり方

1）今回、炭素皮膜抵抗器の基本的技術、製造技術、特性テストの一部、研究手法および新技術の動向等を含む技術指導を終了したこと、またカウンターパートが抵抗値許容差±５％級の抵抗器の製造について一応の自信をもったことからみて、今後５年間さらに炭素皮膜抵抗器の基本的性質、製造技術、をレクチュアと実際面の指導を通してカウンターパートの技術水準向上のため毎年１回短期間でも継続して段階的な技術指導を実施することが望ましいと考える。

2）次回実施のときは、カウンターパート全員に今回の技術指導習得度の全般的な確認ならびに基本技術に含まれる種々の理論計算式の復習をさせたのち、抵抗値許容差精度を今回の５倍の±１％に向上して試作指導とその特性テスト指導を行うことが効果的と考える。

3）またＴ＆Ｔ側にて"負荷電力による炭素皮膜抵抗器の表面温度上昇の測定"あるいは"各形状、各代表的な抵抗値の抵抗温度係数の測定"といった基礎研究に必要な設備、すなわち、表面温度計、各種直流安定化電源、抵抗器の取りつけ治具、温度係数測定治具等を取りそろえることが可能であるならばこれらの設備を用い、基礎研究の進め方についてカウンターパートに対し実験的指導を行うことにより、電子回路部品としての抵抗器の役割をよりいっそそう理解向上させることができると考える。

4）指導期間については、今回の経験からみて、カウンターパートに対して基本技術に含まれる理論式の復習指導をも含めると、上記3)の指導を含めないで1.５ヶ月間、3)の基礎研究指導をも含めると2.５ヶ月間が最低必要であると考える。

5）最終的にはＴ＆Ｔとしての炭素皮膜抵抗器の仕様書（Ｔ＆Ｔ　ＳＴＡＮＤＡＲＤ）をカウンターパートが独自に作成しその標準化を達成できる迄の指導が必要であると考える。

6） カウンターパートの資質については、今回指導を受けたAssistant Divisional Engineerから Engineering Supervisor迄いづれも電気通信関係の専門教育を受けているのでカウンターパート間に資質の差はあるが、これらの研究スタッフが次回以降時間をかけて指導を受ければ内容を十分理解することが期待できると考える。

7） 指導を行うために派遣される専門家の資質については、去る昭和54年3月訪パした日本政府派遣技術協力実施討議チームがT＆T側と交換した討議議事録（R／D）に記載されている派遣専門家の諸条件を満たしていることが要求される他、カウンターパートへ知識と技術を説明するのに必須条件となる語学力（英語）が要求される。

またカウンターパートとの協調性を持つことも大変重要であると考える。

3. 業 務 内 容

3.1 日 程

日程を表4に示す。

表4 日 程

No.	項 目	日程および場所
1	出 国	昭和56年2月20日(金)、成田発10:00(J.S.T.)パキスタン航空PK751便、ペキン経由イスラマバード着18:55(P.S.T.)
2	佐藤首席顧問、SHEIKH所長との打合せ	昭和56年2月21日(土)、午前および午後
3	基本技術のレクチュア	昭和56年2月22日(日)～2月26日(木)、5日間09:30～15:00, C.T.R.L.G.F. コンファレンスルーム
4	試作指導	昭和56年2月28日(土)～3月5日(木)、6日間09:00～15:00, C.T.R.L.3.F回路部品研究室
5	試作品の特性テスト指導	昭和56年3月7日(土)～3月12日(木)、6日間09:00～15:00, C.T.R.L.3F回路部品研究室、GF Humidity Chamber Room
6	研究手法，新技術動向のレクチュア	昭和56年3月14日(土)～3月17日(火)、4日間09:30～15:00, C.T.R.L.G.F. コンファレンスルーム
7	鈴木特命全権大使への表敬訪問と概要報告	昭和56年3月16日(月)、12:00～13:00 日本大使館
8	佐藤首席顧問以下日本側全員への指導終了概要報告	昭和56年3月17日(火)、13:00～14:00 C.T.R.L. 2F コンファレンスルーム
9	関係者への挨拶、技術証明書の交付、夕方カラチへ出発	昭和56年3月18(水)、09:30～13:30 C.T.R.L. イスラマバード発19:00(P.S.T.)パキスタン航空PK309便、カラチ着20:50
10	帰 国	昭和56年3月19日(木)、カラチ発02:10(P.S.T.)スイス航空SR174便、ホンコン経由成田着16:55(J.S.T.)

注(1)　指導期間中、毎日13：00〜14：00はカウンターパートが礼拝を行うため休憩とした。

(2)　レクチュアを実施したコンファレンスルームは黒板、マイク、スライドプロジェクターおよびオーバーヘッドプロジェクターの各設備がある。

3.2　業務項目（別添1参照）

今回の技術指導にあたり、国際協力事業団より要請を受けた別添1記載の6項目よりなる。

3.3　関係者との事前打合せ（別添1，別添2，別添3参照）

(1)　2月21日（土）午前中佐藤首席顧問ならびに加藤斉長期専門家（回路部品研究室を分担協力、P.C.M. 専門家）へ業務内容記載の別添1および実施スケジュール記載の英文打合せ資料別添2を提出のうえ、スケジュールについては2月22日（日）からの1週目に基本技術のレクチュアを、2週目に試作指導を、3週目に試作品の特性テスト指導を、4週目に研究手法と新技術動向のレクチュアを行うことならびに業務内容についてそれぞれ佐藤首席顧問と加藤斉専門家より了解をえた。

(2)　同日午後、佐藤首席顧問と共にSHEIKH所長に面会し、訪パの挨拶をすませたのち、所長へ英文打合せ資料別添2を提出のうえ、業務内容と実施スケジュールの説明を行い所長からもその内容について了解をえた。

この打合せの席で所長より英文打合せ資料を要約した所長名のMR.M.Z.FAROOQUT, Chief Engineer (Staff & Establishment), T&T Directorate — General宛別添3公文書ならびにMR. Muhammad Amin SADIQ, Divisional Engineer−I、の指名による第1週目“基本技術のレクチュア”に出席すべきカウンターパートを記載した公文書をそれぞれC.T.R.L. 正面入口の掲示板へ掲示する旨の説明があった。

3.4　英文テキストの提出（別添4，別添5，別添6，別添7，別添8参照）

レクチュアに使用するため予め用意した次の英文テキストを2月21日（土）、佐藤首席顧問および加藤斉長期専門家へそれぞれ各1部提出したほか、SHEIKH所長へも2部提出した。またこの英文テキストについては後日、所長より首席顧問を通して理研と国際協力事業団の了解がえられるならば本に作りなおしてC.T.R.L. の図書室へ備えつけ全員が利用できるようにしたい旨の要望があった。

(1)　テキストNo.1：　炭素皮膜固定抵抗器（35頁、別添4）

(2)　テキストNo.2：　熱分解炭素皮膜固定抵抗器設計上の基本概念（14頁、別添5）

(3)　テキストNo.3：　熱分解炭素皮膜、金属皮膜および酸化金属皮膜固定抵抗器の既存技術および将来動向に関する一般情報（33頁、別添6）

(4) Attached Sheet №1： 固定皮膜抵抗器の電解現象（1頁、別添7）

また3月12日（木）、同じくレクチュアに使用するためC.T.R.L.にて作成した次の英文テキストを首席顧問、加藤斉専門家に各1部、SHEIKH所長に2部提出した。

(5) Attached Sheet №2： 熱分解炭素皮膜固定抵抗器の研究手法と試作（4頁、別添8）

3.5 カウンターパートの氏名と人数（表1および別添9参照）

SHEIKH所長の指示によりMr. Muhammad Amin SADIQ, Divistonal Engineer−1 C.T.R.L.が前半のレクチュアに出席すべく指名したカウンターパート氏名は別添9に示すとおりである。カウンターパート9名中5名が回路部品研究室所属残り4名が他の研究室より出席した。カウンターパートのポストの内わけは、Divistonal Engineer 1名、Assistant Divistonal Engineer 3名、Assistant Engineer 4名、Engineering Supervisor 1名である。また日によって所長も出席した。

試作および特性テストの指導を受けたカウンターパートは回路部品研究室の上記5名と同研究室所属のLaboratory Assistant 1名を加えた計6名である。

後半のレクチュアに出席したカウンターパートは前半のレクチュアに出席した回路部品研究室5名全員と日によって他の研究室からも出席者があった。

3.6 炭素皮膜固定抵抗器の基本技術の指導（別添4，別添5，別添7参照）

(1) テキスト№1，№2およびAttached Sheet №1の各コピーをカウンターパート9名全員に配布の上、2月22日（日）から2月26日（木）迄の5日間にわたり、C.T.R.L. Ground Floorのコンファレンスルームにてレクチュアを実施して標記の指導を行った。

(2) 第1日目のレクチュアの開始前に、今回の指導の背景と目的を説明し、引き続いて専門家カウンターパート相互に自己紹介を行った。またレクチュアの進め方は前半、後半のレクチュア共にテキストの文章を専門家とカウンターパートの全員が数項目ずつ交代で読みあげ、そのあと各項目のポイントを専門家が説明する旨カウンターパートへ伝えこの方法を後半のレクチュア迄続けた。

(3) レクチュアを実施した項目の詳細は別添テキスト記載のとおりであるが、以下にその主な項目を挙げる。

1）テキスト№1： 炭素皮膜固定抵抗器

① 序　論

② 当該抵抗器の歴史

③ 抵抗材料

④ 炭素皮膜の性質

⑤ 抵抗器の定格

⑥　抵抗値の標準数列、表示および抵抗器の種類

⑦　製造方法の一般説明

⑧　C.T.R.L.における製造方法

⑨　ＪＩＳ規格による当該抵抗器の特性

⑩　抵抗器の正しい使用方法

⑪　有用文献の紹介

⑫　結　　論

2）テキストNo.2：　熱分解炭素皮膜固定抵抗器設計上の基本概念

①　序　　論

②　考慮すべき事項

③　抵抗皮膜

④　基　　体

⑤　端　　子

⑥　保護用ワニスおよび塗料

⑦　結　　論

3）Attached Sheet No.1：　固定皮膜抵抗器の電解現象

(4)　レクチュアに当ってはテキストの各項目のポイントを用語をも含めて口頭または黒板を使って説明し、そのあと個々に質問とその回答を行った他、基本式を用いてカウンターパート全員へ計算練習等も実施した。方式関係の他の研究室からもカウンターパートが出席していたこともあって、用語について初めて聞く者もあり、また計算練習等はAssistant Divisional Engineerクラスが早く解くなどカウンターパート間に資質の差が認められた。なお質問は毎回かなり活発にでた。

(5)　この５日間のレクチュアを通してカウンターパートへ炭素皮膜固定抵抗器の基本技術についてその認識を深めさせた。

3.7　実験室的製造技術の指導

(1)　２月２８日（土）から３月５日（木）迄の６日間にわたってC.T.R.L.３階の回路部品研究室にてAssistant Divisional Enginee以下Laboratory Assistant迄の同研究室所属６名のカウンターパートに対して1.6項、表１記載の抵抗器についてその製造技術指導を実施した。試作にあたっては去る昭和５４年５月当社より製造設備と共にC.T.R.L.へ納入済の英文製造指導書（Tot ８６頁）をテキストとして使用し、正しい製造方法を全員に理解させた。

(2)　C.T.R.L.における製造工程は抵抗膜として機能する炭素皮膜の着膜設備は当初の技術的制約から含まれていないので、着膜済素子を日本から供給し、それ以降完成迄の製造工程となっている。図１にその製造工程を示めす。

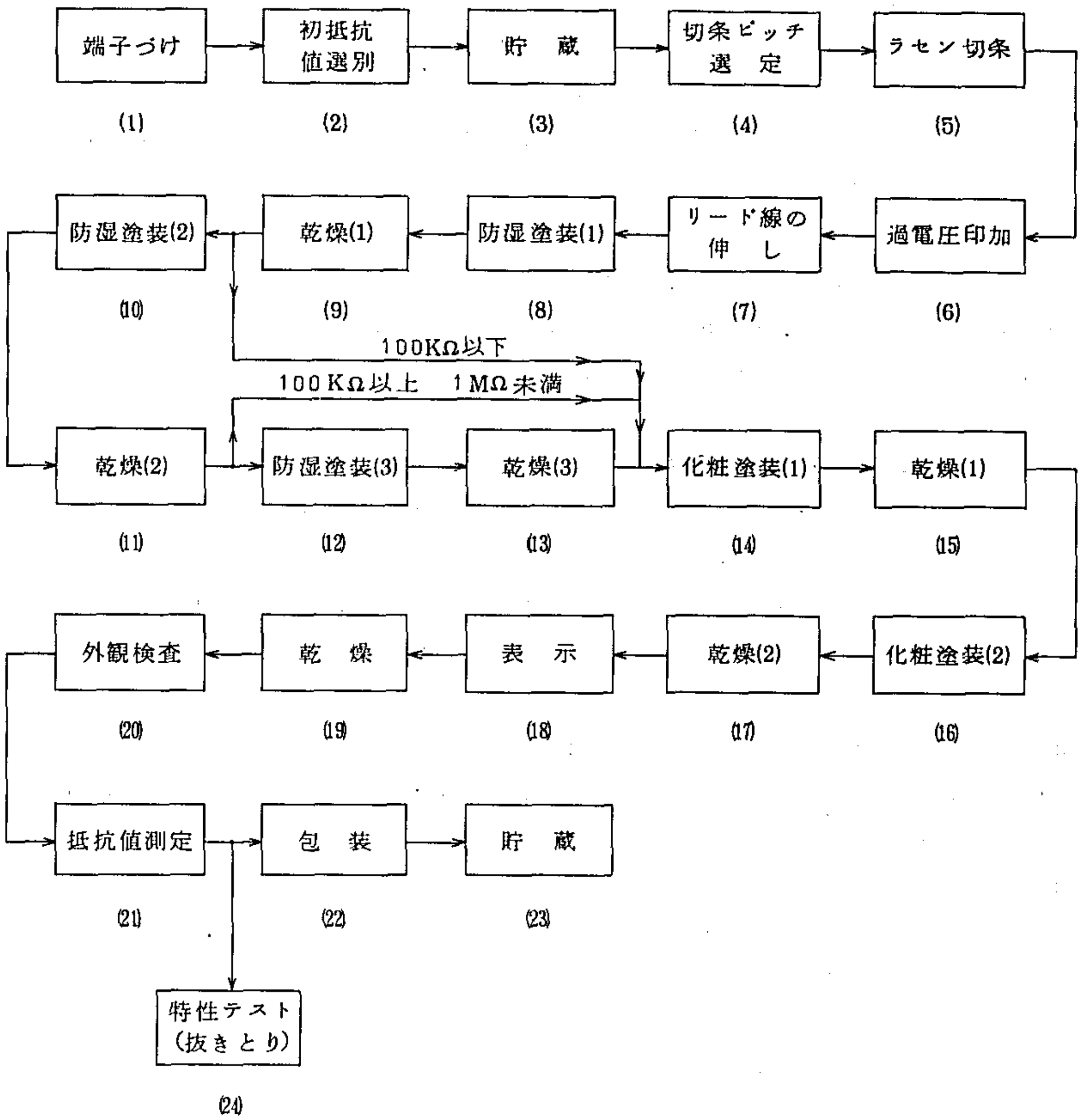


図1　炭素皮膜固定抵抗器の製造工程図

(3) 試作期間中は毎朝カウンターパートに対してその日のうちに終了すべき工程の指示と、当該製造工程の注意事項の説明を行った他常時実験室にて試作の進行状況を見とどけた。

(4) 製造工程中、特に下記の作業について十分な注意と指示をカウンターパートに対して行った。

1）端子づけ作業については抵抗素子の両側へ端子を完全に取りつけること。

2）最終抵抗値へ調整するためのラセン切条作業に当っては、測定器を十分に監視すると共に高速回転中のカッテイングホイールへ抵抗素子を強く押しつけないこと。

切り溝が連続でかつ抵抗トラックの幅が均一になるようにすること。

切条有効長に対して75％以上の切条幅を保持すること。

3）防湿ならびに化粧塗装については、素子へ均一に塗装し、かつピンホールがでないよう室温、高温乾燥時間を規定通り保持すること、塗料の配合比を順守し、調合後の攪拌を数分間十分に行うこと。

4）電圧印加の際メーターのスケールを読み違えせぬよう注意すること。

5）計測器の使用にあたっては測定値ならびに単位を正しく読みとること。

(5) 試作した抵抗器、すなわちRD1／4P 1KΩ±5％，10KΩ±5％および100KΩ±5％ 各50 pcs. は外観的にも予想以上に良好な結果がえられた。

3.8 試作品の電気的特性の調査と実験の実施（別添10参照）

(1) 回路部品研究室には、現在当該抵抗器のテストに必要な各種試験設備、あるいは部品の取りつけ治具等が設置されていないため、別添2の英文打合せ資料記載のとおり、原則として抵抗器の製造設備を転用して実施可能なテスト項目、ならびにその他の設備で流用すればテスト可能な項目に限って試作品の特性テストの指導を行うことで佐藤首席顧問、SHEIKH所長より了解をえた。

(2) 特性の調査と実験の指導は3月7日（土）から3月12日（木）迄の6日間にわたってC.T.R.L. 3階の回路部品研究室およびGround Floor のHumidity Chamber Room にて同研究室6名のカウンターパート全員に対して実施した。

(3) 当該指導の実施にあたっては、去る昭和54年8月当社より英文に翻訳の上、C.T.R.L.へ提供した当該抵抗器の電気的、機械的特性基準が定められている日本工業規格“JIS C 6402、炭素皮膜固定抵抗器”をテキストに使用した。

(4) テストの方法、その目的、データフォームの記入方法、データの計算、テスト結果の判定、データのグラフ化を含む指導をカウンターパート全員に行ったが、これらの実験はカウンターパートにとって初めての経験であるため、試験電圧の値や変化率の計算ミス、データフォームへの記入もれ等もあり、その都度正しく訂正するように指示を行った。

(5) 特性調査期間中は毎朝カウンターパート全員に対してその日のうちに終了すべきテスト項目、テストデータの整理、データフォームの作成、テスト上の注意事項の説明を行った他、ほぼつきっきりで実験室にてテストの進行状況を見とどけた。

(6) 試作品の特性調査とその結果は表5に示すとおりである。

表5　試作品の特性調査と結果

適用規格：JIS C 6402

No.	テスト項目	適用No.	抵抗値と数量			テストの結果
			1KΩ	10KΩ	100KΩ	
1	寸法検査	5.1	10(ケ)	10(ケ)	10(ケ)	全数規格値内
2	抵抗値測定	6.1	50	50	50	1KΩ，10KΩは、全数規格値内(±5%) 10KΩのみ3ケプラス不良(Max+8%)
3	短時間過負荷特性	6.3	10	10	10	全数規格値内
4	温度サイクル試験	6.8	10	10	10	全数規格値内
5	抵抗温度特性	6.2	5	5	5	全数規格値内

注(1)　温度サイクル試験低温側は本来－55℃であるが、Humidity Chamberが－30℃迄しか下がらぬため、－30℃にて低温条件とした。

(2)　抵抗温度特性の測定には試料の取りつけ治具が必要であるが、これがないため、各抵抗器5 pcsをあり合せの接続材料を使ってとりつけ、治具なしで測定を実施した。

(7)　テストデータフォームは別添10に示すとおりであるが、回路部品研究室用としてカウンターパートがカーボン紙でコピーを2部作成した他、佐藤首席顧問、加藤斉長期専門家へコピー1式を提出済である。

3.9　研究手法および抵抗器の新技術の動向の指導（別添6および別添8参照）

(1)　研究手法についてはAttached Sheet No.2（別添8）、新技術の動向についてはテキストNo.3（別添6）の各コピーを回路部品研究室のカウンターパート5名（注：Laborotory Assistant 1名は除く）全員に配布して、3月14日（土）から3月17日（火）迄の4日間にわたってC.T.R.L. Ground Floorにあるコンファレンスルームにてレクチュアを通して指導を行った。

(2)　研究手法については、概要、文献による基本技術の理解、研究の進め方と研究テーマ、仕様書の作成、研究の進め方とその管理等を含む方法に至る迄を詳しく説明した他、方式グループへのサポートグループとして回路部品研究室が機能するよう標準的抵抗値については試作とそのストックを行って常に要求に応じて抵抗器を供給できるよう指導を行った。

(3)　新技術の動向については既存技術をも含くむ炭素皮膜、金属皮膜、酸化金属皮膜抵抗器よりなる固定皮膜抵抗器全般にわたって、それらの標準的製造方法、用途、特性基準、将来動向等についてスライドフイルム、形状見本、当社カタログ等の参考資料を併用して説明を行った。

(4) 金属皮膜抵抗器は薄膜技術の応用であり、また薄膜の製造設備が当研究室に設置されていることもあってカウンターパート全員が非常に関心を示した他、酸化金属皮膜の応用例として、特に透明導電膜についてはガラスを基板に液晶時計のセグメント形成、凍結防止のための航空機用フロントウインドウ、古くはトースター用ヒーター素子等身近かな応用例を説明することにより抵抗膜の応用の広さにも大変興味を示した。

(5) カウンターパート全員はこのレクチュアを受ける前に、基本技術のレクチュア、試作およびテストの指導を終了していたこともあって、この後半のレクチュアに於ては前半のレクチュア以上に活発な質問がでた。

3.10 実験データの解析

えられたデータの解析結果を以下に報告する。

(1) 寸　法

表6に測定した抵抗器の各部寸法の平均値、最大値、最小値およびバラツキを示す。

表6　試作品の各部寸法測定値

適用規格：JIS C 6402，単位：mm

試料と数量	平均、バラツキetc ＼ 測定部分	L	D	d	H
	規格値	13±1.5	2.5±1	0.6±0.1	38±3
RD1/4P 1KΩ ±5%，10pcs	$\bar{x}$	12.402	2.957	0.608	38.142
	Max	12.42	3.00	0.61	38.22
	Min	12.40	2.85	0.60	38.00
	R	0.02	0.15	0.01	0.22
RD1/4P10KΩ ±5%，10pcs	$\bar{x}$	12.406	2.951	0.61	38.184
	Max	12.42	3.06	0.62	38.22
	Min	12.40	2.80	0.60	38.00
	R	0.02	0.26	0.02	0.22
RD1/4P100KΩ ±5%，10pcs	$\bar{x}$	12.404	2.965	0.609	38.182
	Max	12.42	3.06	0.62	38.22
	Min	12.40	2.80	0.60	38.00
	R	0.02	0.26	0.02	0.22

(注)　L：本体の長さ、　D：本体の直径、　d：リード線の直径、
H：リード線の長さ、　$\bar{x}$：平均値、　Max：最大値、　Min：最小値
R：バラツキ。

1） 表6に示すごとく、規格値を超える値がなかったことから、抵抗器の構成に必要な部品は正確に抵抗素体に取りつけられていると判断する。

2） 各部寸法のバラツキ(R)の値が小さく総合的にみて良好な結果がえられている。

(2) 抵抗値測定

表7に実測値より求めた公称抵抗値に対する許容偏差の平均値、最大値、最小値およびバラツキを示めす。又図2から図4に偏差分布別のヒストグラムを示す。

表7　試作品の抵抗値偏差

適用規格JIS C 6402，単位：%

試料と数量 / 平均 バラツキetc	RD1／4P 1KΩ ±5%，50pcs	RD1／4P10KΩ ±5%，50pcs	RD1／4P100KΩ ±5%，50pcs
$\bar{x}$	＋1.118	＋1.622	＋1.2206
Max	＋2.80 －0.20	＋8.0 －0.5	＋3.30 －2.21
Min	±0	＋0.2 －0.1	＋0.18 －0.02
R	3.0	8.5	5.51

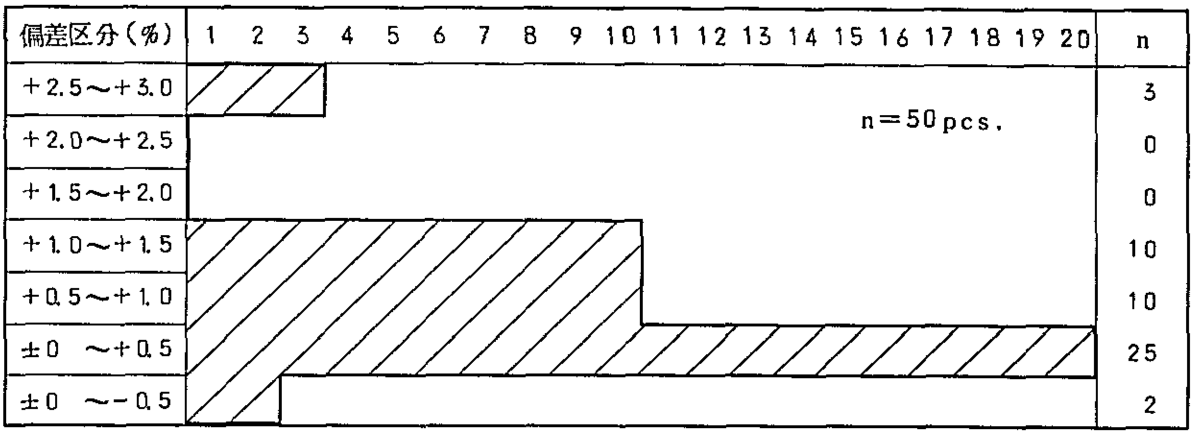


図2　RD1／4PKΩ±5%の偏差分布ヒストグラム

1） 抵抗値許容差が公称抵抗値に対して±5%以内であり、各抵抗値について50pcsのランダムサンプリングを行ってえられた実測値からそれぞれの公称抵抗値に対する偏差を求めた結果、図2および図4に示すとおり、1KΩおよび100KΩはすべて許容差範囲内にあるが、図3に示す10KΩについては50pcs中3pcsプラス不良となり許容差不良率は6%である。

2） 10KΩの許容差不良率6%はやや大きいが、これはカウンターパートの製造技術の熟

練度の向上に伴って更に低減するものと考える。

3） 総合してみれば±５％級の抵抗値許容差精度については、その分布がきれいな正規分布を呈するに至らないが、ほぼ安定した状態がえられるものと判断する。

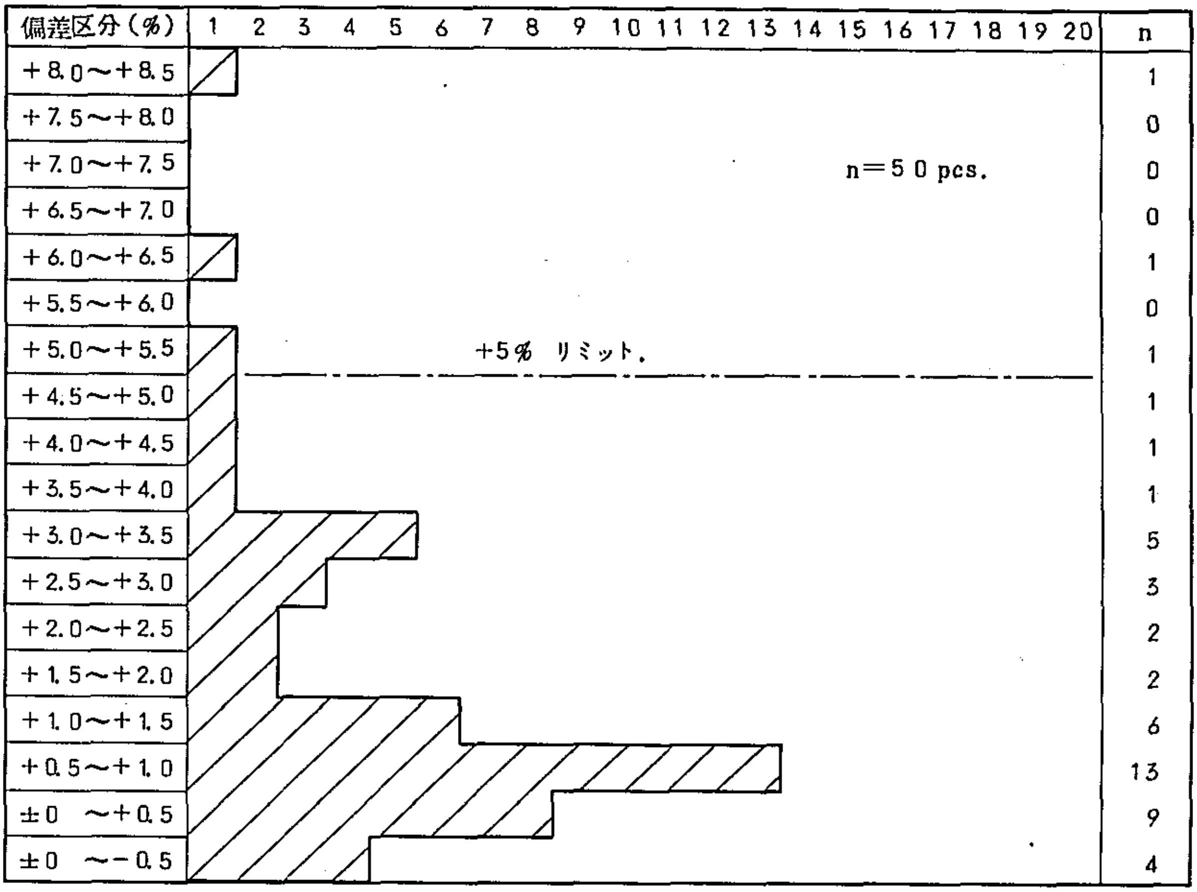


図 3　RD1／4P 10KΩ±5%の偏差分布ヒストグラム

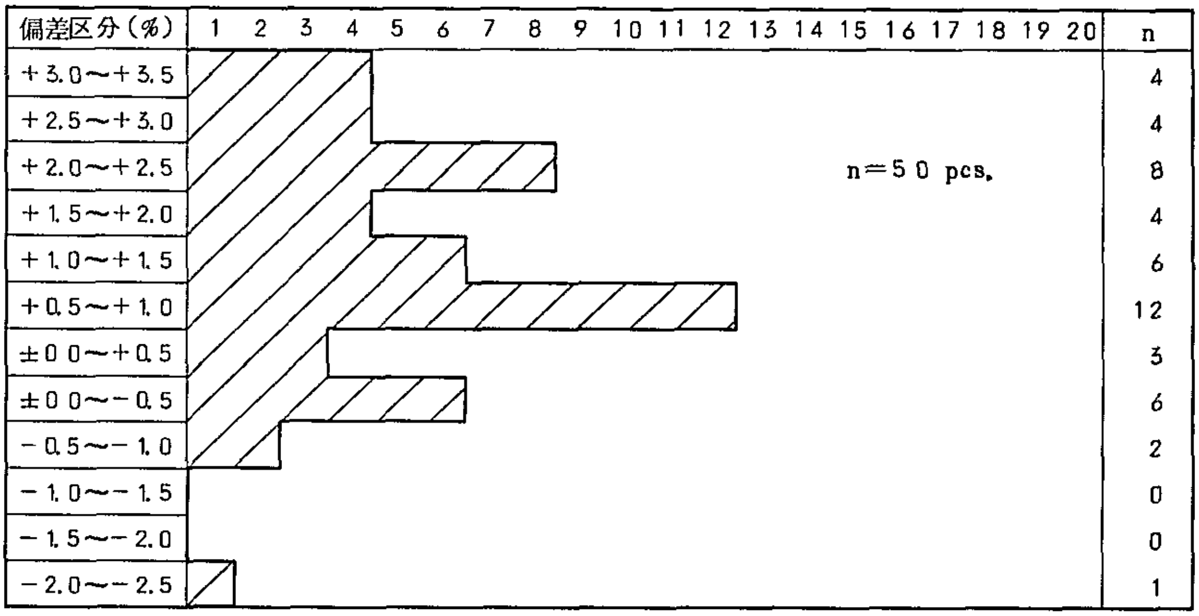


図 4　RD1／4P 100 KΩ±5%の偏差分布ヒストグラム

(3) 短時間過負荷特性

表8に試験後の抵抗値変化率の平均値、最大値、最小値およびバラツキを、また図5にその傾向をそれぞれ示す。

表8 試作品の短時間過負荷特性

適用規格：JIS C 6402，単位：%

試料と数量 ／ 平均、バラツキetc	RD1／4P 1KΩ ±5%，10pcs	RD1／4P10KΩ ±5%，10pcs	RD1／4P100KΩ ±50，10pcs
$\bar{x}$	+0.01	+0.001	+0.001
Max	+0.1	±0.01	±0.01
Min	±0	±0	±0
R	0.1	0.02	0.02

(注) 規格値：±0.75(%)以内

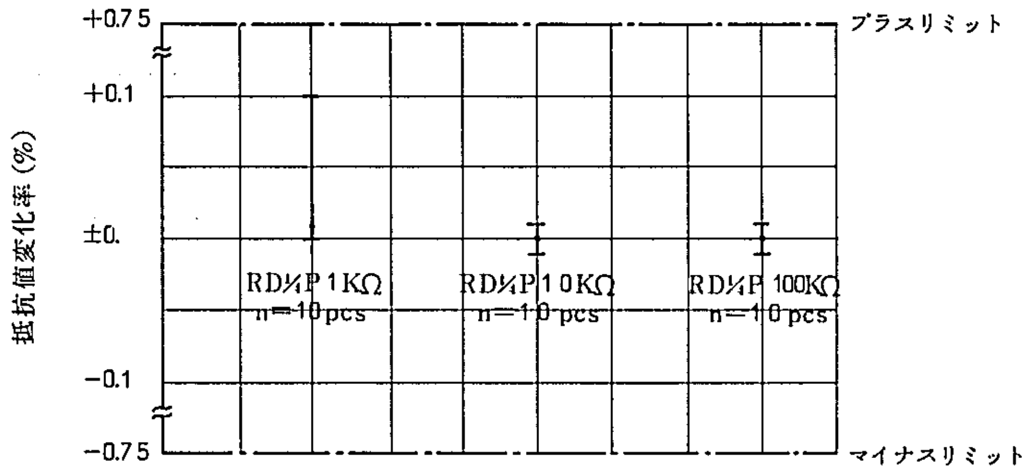


図5 試作品の短時間過負荷特性

テスト結果は表8および図5に示すとおり、各抵抗値ともにその変化率は規格値(±0.75%)内にあり、このことは製造段階において抵抗値の調整作業が安定してなされていることを示しており、また瞬時の過電圧印加に対して性能上の問題はないと判断する。

(4) 温度サイクル試験

表9に試験後の抵抗値変化率の平均値、最大値、最小値およびバラツキを、また図6にその傾向をそれぞれ示す。

表9 試作品の温度サイクル試験結果

適用規格：JIS C 6402，単位:%

試料と数量 / 平均、バラツキetc	RD1／4P 1KΩ ±5%，10 pcs	RD1／4P 10KΩ ±5%，10 pcs	RD1／4P100KΩ ±5%，10 pcs
$\bar{x}$	+0.05	+0.09	+0.121
Max	±0.1	+0.1	+0.16
Min	±0	±0	+0.11
R	0.2	0.1	0.05

(注) 規格値：±（0.75%+0.05Ω）以内

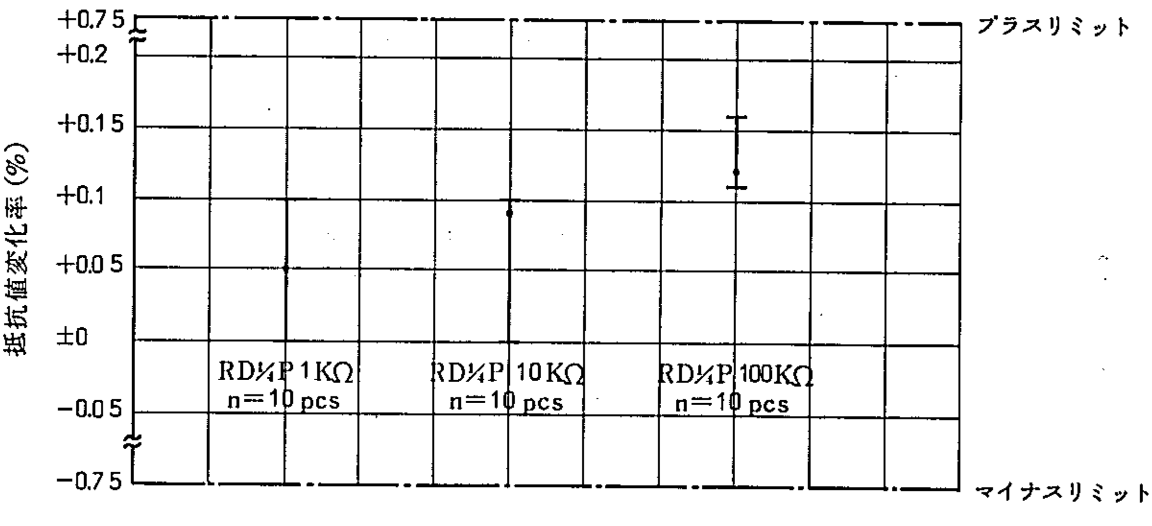


図6 試作品の温度サイクル試験結果

このテストは電子部品の耐候性テストとして重要な項目の一部をなしているが、テスト結果から試料総数30 pcsともにそれらの抵抗値変化率が規格値｛±（0.75%+0.05Ω）｝以内にあって、実装時の電子部品が受ける低温側、高温側双方の温度ストレスに対して抵抗値の変動が少なく安定していることを示している。

(5) 抵抗温度特性

表10に実測抵抗値より算出した抵抗温度係数の平均値、最大値、最小値およびバラツキを、また図7にその傾向をそれぞれ示す。

表10　試作品の抵抗温度特性

適用規格：JIS C 6402,単位：ppm/℃

試料と数量 ＼ 平均、バラツキetc	RD1/4P 1KΩ ±5%, 5 pcs	RD1/4P 10KΩ ±5%, 5 pcs	RD1/4P 100KΩ ±5%, 5 pcs
$\bar{x}$	−218.6	−242.4	−273.8
Max	−286	−248	−285
Min	−191	−232	−267
R	95	16	18

(注)　規格値：±350 ppm/℃以内

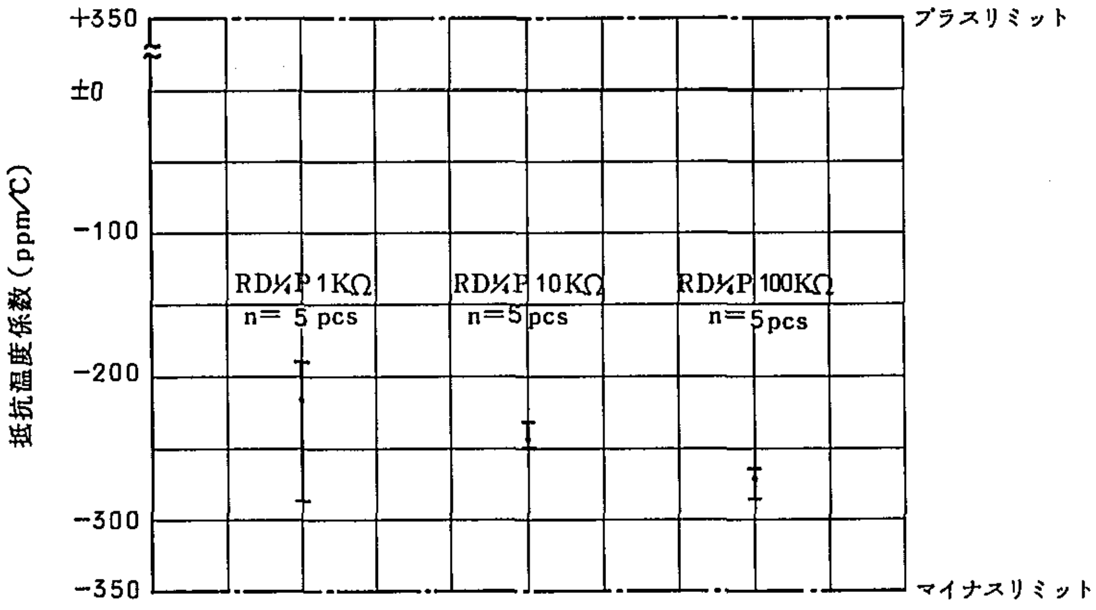


図7　試作品の抵抗温度特性

測定値より算出した1℃あたりの抵抗温度係数は規格値(±350 ppm/℃)以内であり、周囲温度の変動に対して抵抗値が極端かつ非直線的に変化しないことを示している。

3.11 C.T.R.L. 関係者に対する中間報告および最終報告（別添11および別添12参照）

(1) 必要に応じて常時佐藤首席顧問、加藤斉長期専門家へ進行状況の報告を行った。また首席顧問の要請により指導の前半終了の段階で別添11に示す3月4日付技術協力に関する私見文書を提出し今後の協力に関する私見を説明した。

(2) 毎週日曜日の午前中に開かれる専門家会議に出席して、佐藤首席顧問、各長期専門家、および関口調整員の全員へ進行状況の報告を行った。

(3) 必要に応じて佐藤首席顧問と共にSHEIKH所長に面会し、進行状況の報告を行った。

(4) 3月16日（月）、佐藤首席顧問と共に日本大使館へ出向き、松本1等書記官の案内で鈴木特命全権大使ならびに飯島公使を表敬の上、今回の技術指導の目的とその進行状況について報告を行った。

(5) 3月17日（火）午後、佐藤首席顧問以下全員へ別添12示す概要報告書を配布の上、この報告書に従って全員へ今回の技術指導が予定通り終了の旨の最終概要報告をC.T.R.L. 2階コンファレンスルームに行った。

(6) 3月18日（水）午前、佐藤首席顧問と共にSHEIKH所長に面会し、今回の技術指導が、先に所長へ提出した英文打合せおよびスケジュール資料（別添2）にそって予定通り終了した旨の報告とカウンターパートによる試作品（成果品）とテストデータフォームの提示ならびに説明を行い、最後に所長より謝意があった。

4. 技術指導の成果（別添13参照）

(1) 電子回路の構成に必要欠くことのできない受動電子部品の三要素の一つである抵抗器に関し、その基本技術と設計概念について詳細説明を行った前半のレクチュアでカウンターパート全員が抵抗器の基本知識を深めたほか、回路部品研究室以外の方式関係の研究室からもカウンターパートが参加したことで電子部品の重要性をより広い分野の人々へ理解させるのに役立った。

(2) 製造技術については去る昭和54年当社が納入した設備の受入れ試験の際、簡単な指導を行ってあったこともあり、当該抵抗器がすでにP.C.M.、電話機、マイクロウエーブ、搬送等方式関係の研究室で実験に必要な手作り回路用に少しずつ供給されていたが、その殆どが保護塗装がなされず素子が露出したまま取りつけられていたので、これらをふまえて防湿性の重要性を強調して試作指導の結果、でき上った抵抗器は外観的にも良好な形に仕上り、カウンターパートが製造技術についてより理解を深め、さらに抵抗値許容差精度±5％級については製造の技術移転をはかることができた。

(3) 抵抗値許容差精度±5％級が製造できるということは更に許容差精度の高い±2％級、±1％級あるいは炭素皮膜抵抗器の中では最高の精度である±0.5％級の製造にも大きな可能性がある他にC.T.R.L.にある各種計測器に数多く使用されている±5％級の抵抗器が故障した際簡単に自給自足が可能となる。なおカウンターパートへも回路試験器その他二、三の計測器の内部に当該抵抗器と同一形状の抵抗器が数多く取りつけられているのを示し、その互換性があることを認識させた。ラジオ、テレビ、オーディオコンポネントシステム、ビデオテープレコーダー等の各種電子機器には±5％級の炭素皮膜抵抗器がすべて使用されており、またさほど精度を要しない抵抗減衰器、各種計測器あるいは電圧、電流計等の分圧、分流抵抗器としても広く±5％級の炭素皮膜抵抗器が使用されていることから考え今後C.T.R.L.内において当該抵抗器のより広い活用が期待できる。

(4) 試作した抵抗器の特性テストはカウンターパートが今回初めて体験したこともあって、テストの当初はデータフォームの記入もれ、試験電圧あるいは変化率の計算ミス等も目立ったが、徐々に正しいデータを記録できるようになった。また当該抵抗器の特性基準がどこにおかれており、また機械的あるいは電気的特性として具体的にどのような事項が要求されているかについてカウンターパート全員が理解を深めた。

さらにえられたデータをグラフ化する指導を行ったことにより、テスト結果の傾向がよりいっそう把握し易くなることも実際に体験して大きな関心を示した。

(5) この特性テストの指導についてはカウンターパート自ら試作した抵抗器の性能を自分達が直接確かめることができた点でカウンターパートが製造技術のみならずテストの意義と方法等を含めて自信をもつのに役立った。

(6) 後半、回路部品研究室所属のカウンターパート5名に対して行った“当該抵抗器の研究手法

と試作”および“各種固定皮膜抵抗器の既存技術と将来動向”に関するレクチュアにおいては、各種のスライドフィルムおよび各種皮膜抵抗器の形状見本を教材として併用し、またそれ迄にカウンターパートが基本技術製造技術および特性テストの指導を受けていたこともあって、前半のレクチュア以上に質問が活発にでて関心の高揚を示した他、“研究手法と試作”についてこれが実施ならびに管理にあたって回路部品研究室のDivisional Engineer が現在空席のためAssistant Divisional Engineer, Mr. Nusrat ALI より自分の責任において立案と管理を行う旨の申し出があり、カウンターパートに積極性がみられるようになった。

(7) 前半レクチュアの段階から、カウンターパートより今回の技術指導終了時に“Technical Certificate”を交付してもらえないかとの要望があったため、佐藤首席顧問以下関係者全員ならびにSHEIKH所長の了解のもとに、カウンターパート9名中から回路部品研究室所属Mr. Wasim Anwar KIANI, Engineering Supervisor, 1名に対してのみ指導期間中の熱意を入れて、別添13に示す“Technical Certificate”を3月18日（水）付で本人に交付した。なお、当該Certificateのコピーは佐藤首席顧問、加藤斉長期専門家およびSHEIKH所長へも各1部提出済である。

(8) カウンターパートが試作した抵抗器を国際協力事業団へ成果品として提出した。

9. 成果品の提出（別添14参照）

カウンターパートが試作した下記抵抗器（別添14参照）を成果品として提出すると共に図8にその写真を示す。

(1) RD1／4P　1KΩ　±5%，10 pcs

(2) RD1／4P　10KΩ　±5%，10 pcs

(3) RD1／4P100KΩ　±5%，10 pcs

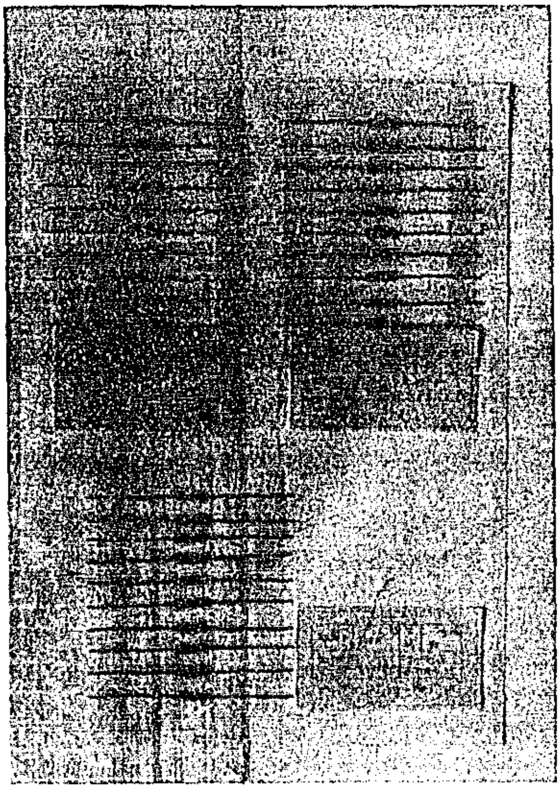


図8　成果品の写真

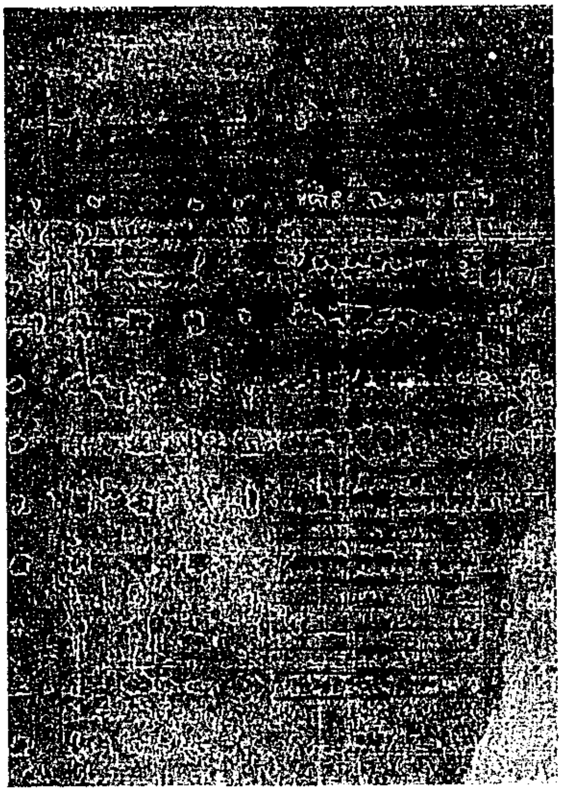


図8　成果品の写真

5. 今後の協力方針

以下に向う5年間の協力方針を述べる。

(1) 昭和55年度において、炭素皮膜抵抗器の基本技術、実験室的製造技術、試作した抵抗器の電気的特性の調査・実験、研究手法及び抵抗器の新技術の動向についてそれぞれ指導を終了したこと、またカウンターパートが抵抗値許容差精度±5%級の製造について一応の自信をもったことから判断して、今後5年間さらに炭素皮膜抵抗器の基本的性質、製造技術をレクチュアと実地面の指導を通してカウンターパートのよりいっそうの技術水準の向上を目的として毎年1回短期間でも継続して段階的な技術指導を実施することが望ましいと考える。

(2) 次回実施にあたっては、カウンターパート全員に基本理論、製造技術、電気的諸特性、参考文献による知識等を含めて今回の技術指導の習得度の確認ならびに基本理論に含まれる種々の理論式による復習をさせる他特性を主にした詳しいレクチュアを実施し、試作指導としては抵抗値許容差精度を一気に5倍に高めてすべての計測機器類に適用可能な±1%級を歩留りよく製造する手法を主要製造工程毎にデータをとりながら実施し、さらにこれら試作品の特性テストを実施するのが非常に効果的であると考える。

(3) またT&T側にて、(a)負荷電力による炭素皮膜抵抗器の表面温度上昇の測定、あるいは(b)各形状、各代表的な抵抗値の抵抗温度係数の測定といった基礎研究に必要な設備、すなわち表面温度計、各種直流安定化電源、抵抗器の取りつけ治具、温度係数測定治具等を取りそろえることが可能であるならばこれらの諸設備を使用して(a)については各形状の抵抗器について電力比と温度上昇の相互関係あるいは温度分布を、また(b)については単位面積あたりの抵抗値と抵抗温度係数の関係といった炭素皮膜抵抗器の基本的性質をカウンターパートに対して実験を通して指導することにより、電子回路部品としての皮膜抵抗器の役割をよりいっそう理解向上させることができる。

(4) 指導期間については今回の経験から、基本技術の復習、特性テスト時のデータの詳しい判断のやり方あるいはグラフ化の詳しい説明等に殆ど時間を設けることができなかったため、上記(2)の指導期間に1.5ヶ月間、(3)の基礎研究指導をも含めると2.5ヶ月間が最低限必要であると考える。

(5) 基礎研究、総合特性テストを含む実用研究指導の諸段階を経て最終的にはT&Tとしての炭素皮膜抵抗器の仕様書(T&T STANDARD)をカウンターパートが独自に作成し、その標準化を達成できる迄の指導が必要であり、また仕様書の作成にあたっては当該抵抗器の使用側となる方式関係各研究室からの使用条件に関する情報の提供も大変重要であると考える。

(6) カウンターパートは全員レクチュアへの参加は特に熱心であり、その資質については今回指導を受けたAssistant Divisional Engineer(室長代理)からEngineering Supervisor(研究主任)クラス迄いずれも先ず学校で電気通信関係の専門教育を受けさらにT&T通信研

究センターにあるStaff Degree College で一定期間の研修を受けており、カウンターパート間に資質の差はあるが、これらの研究スタッフが次回以降時間をかけて指導を受ければ内容を十分理解することが期待できるのではないかと考える。

(7) 指導を行うために派遣される専門家の資質については、去る昭和54年3月訪バした日本政府派遣技術協力実施討議チームがT＆T側と交換した討議議事録（R／D）に記載されている学歴と職務経験、また皮膜抵抗器全般の知識と当該抵抗器の製造技術を有すること、さらにこれらの知識と技術をカウンターパートへ説明するにたる語学力（英語）を兼ね備えていることが必要である他、カウンターパートとの協調性をもつことも大変重要なことであると考える。

(8) 昭和56年度から昭和60年度迄向う5年間の指導線表案を図9に、また指導内容案を表11にそれぞれ示す。

昭和56年度　昭和57年度　昭和58年度　昭和59年度　昭和60年度

├─ 1〜3月迄の1.5ケ月間（昭和55年度の復習、特性のレクチュア、±1％級の試作とテスト）

├─ 1〜3月迄の1ケ月間（基礎研究のレクチュア、基礎実験）

├─ 1〜3月迄の2ケ月間（実用研究の指導）

├─ 1〜3月迄の1ケ月間（レクチュア主体による品質管理と標準化指導）

├─ 1〜3月迄の1ケ月間（T＆T仕様の作成指導）

(注) 実施時期は昭和55年度の指導終了から1年後を基準にしてあり、特にこの期間に限定の必要はない。

図9　今後5年間の指導線表案

表１１　指導内容案

実施年度	指　　導　　内　　容
昭和５６年度	(1)基本技術復習のレクチュア、理論式の計算演習　(2)電気的、機械的特性のレクチュア　(3)±１％級の試作指導（歩留り向上を目的に主要工程毎にデータをとる）　(4)試作品のテストおよび判定基準の指導
昭和５７年度	(1)基礎研究のレクチュア（電力比と温度上昇、面積抵抗と抵抗温度係数の関係、スパイラルカットのターン数と安定性等）　(2)基礎実験（温度上昇、温度係数、負荷安定性に関する測定　(3)データ解析
昭和５８年度	(1)特性テストを中心に実験主体の指導　1）短時間過負荷特性　2）耐湿負荷寿命特性　3）温度サイクル試験　4）耐振性　5）端子強度　6）抵抗温度特性　7）半田耐熱性　8）パルス特性
昭和５９年度	(1)品質管理と標準化主体のレクチュア　1）品質管理と標準化の意義　2）管理の原則　3）検査の意味　4）品質保証　5）統計的手法：パレート図、特性要因図、ヒストグラム、管理図、等
昭和６０年度	(1)Ｔ＆Ｔ仕様書の作成指導　1）目的　2）使用温度、湿度範囲　3）最大使用電圧　4）抵抗値許容差　5）温度係数　6）その他耐候性基準の決定　7）国際規格（I.E.C.）との整合性

注(1)　昭和５７年度の指導を上記内容で実施するためにはつぎの設備をＴ＆Ｔが準備する必要がある。1）表面温度計　2）各種直流安定化電源　3）抵抗器取りつけ治具　4）温度係数測定治具

(2)　昭和５８年度の指導を上記内容で実施するためには、つぎの設備をＴ＆Ｔが準備する必要がある。1）恒温槽　2）低温槽　3）恒温恒湿槽　4）振動試験機　5）端子強度試験機　6）半田耐熱試験機　7）パルス試験機　8）オンオフタイマー

6. 結　　　論

(1) パキスタン電信電話総局中央電気通信研究所（在イスラマバード市）に対する技術協力に関して去る昭和54年3月日本政府派遣技術協力実施討議チームが訪パの上、当該業務に関して討議議事録（R／D）に基づきパキスタン政府から日本政府へなされた炭素皮膜固定抵抗器の製造技術に係る指導要請（短期）により、その実施機関である国際協力事業団ならびに郵政省から当社への指導依頼を受けて、昭和56年2月20から3月19日迄政府派遣短期専門家として上記研究所にて炭素皮膜抵抗器の技術指導を行った。

(2) 上記研究所滞在中、カウンターパートに対して炭素皮膜抵抗器の基本技術、実験室的製造技術，試作品の電気的特性の調査・実験、研究手法および新技術の動向について指導を行った。

(3) 試作品の電気的特性データの解析、実用化の目途の検討をそれぞれ行った。また試作品の一部を成果品として持ち帰り，国際協力事業団へ提出した。

(4) 今回の指導を通してカウンターパートが炭素皮膜抵抗器についてその理論、製造技術、特性テストの目的と方法また研究手法について多いに理解を深めた他，カウンターパートの要望によるTechnical Certificateを佐藤首席顧問、SHEIKH所長の了解のもとに9名中、1名のカウンターパートに対して交付した。

(5) 問題点としては 1）カウンターパートの資質と理解力、2）製造および研究試験設備，3)カウンターパートの職制機構の三点がある。

1） カウンターパートの資質と理解力

当然のことながら、カウンターパート間に資質の差があり、今回は時間の制約もあって特に必要なレクチュアの復習の機会を設けることができず、残念ながらカウンターパート全員が十分な理解をする迄には至らなかったが、カウンターパート全員がレクチュアを熱心に受けた他、電気通信関係の専門教育を受けているのでこの問題は今後のカリキュラムの組み方と指導期間を合せて検討することにより解決できると判断する。

2） 製造および研究試験設備

製造設備については“2.10の(2)”に述べたごとく、種々の制約から抵抗皮膜として機能する炭素皮膜の着膜製造設備が現在C.T.R.L.に設置されていないが、今後炭素皮膜の基本的性質、すなわち炭化水素の気相熱分解式により得られる炭素皮膜について

(a) その析出のナカニズム

(b) 炭化水素ガスの通気時間とえられる皮膜の抵抗値、抵抗温度係数との相互関係

(c) ガス通気時間を一定として熱分解温度をパラメータとしてえられる炭素皮膜の抵抗値、抵抗温度係数との相互関係

(d) 熱分解温度を一定として基体磁器の表面状態をパラメータ（基体磁器表面の化学処理の有無）としてえられる炭素皮膜の抵抗値と抵抗温度係数の相互関係。

等を理解していくうえでは、将来C.T.R.L.がこの着膜製造設備を導入することが必要であると考える。

研究試験設備については抵抗器を含む他の回路部品用としても現在C.T.R.L.には設置されていないため、試作品の総合的特性を調査研究するうえで大きな支障をきたす。

抵抗器用試験設備についていえば、第一段階として表面温度計、各種直流安定化電源、抵抗器の取りつけ治具抵抗温度係数測定治具を、第二段階として恒温槽（負荷寿命試験用）、低温槽（温度サイクル試験用）、恒温恒湿槽（耐湿負荷寿命試験用）、パルス試験機、電流雑音測定器、振動試験機、端子強度試験機、半田耐熱試験機、オンオフタイマー等をC.T.R.L.にて設置する必要がある。これらの設備の中には回路部品研究室で製造可能なセラミックキャパシターあるいは薄膜混成ＩＣと共用可能な試験設備を含んでいる点からみて共通設備はC.T.R.L.が系統だてて設備導入を行うのがよいと考える。

設備導入を行うとした場合の優先順位としては先ず最初に試験設備を、そのあと着膜設備の順序とするのがよいと判断する。

3）カウンターパートの職制機構

極端に階級制度がはっきりしているため、特に試作のような実習業務については上位のカウンターパートが実際に製造技術を習得する熱意が多少欠けている傾向があり、このような仕事は下位のポストの者が行うといった考え方がある。しかし一つの研究をチームワークとしてとらえ分担、協力し合って研究成果の迅速化が行こなえるように今後の指導において是正してゆく必要があると考える。

§ 現地使用教材および実験データ等の添付一覧表

別添資料No.	添付資料名
1	国際協力事業団の要請による業務内容書面
2	理研作成英文打合せ資料
3	実施日程を含むSHEIK所長名公文書
4	英文テキストNo.1：炭素皮膜固定抵抗器
5	英文テキストNo.2：熱分解炭素皮膜固定抵抗器設計上の基本概念
6	英文テキストNo.3：熱分解炭素皮膜、金属皮膜および酸化金属皮膜固定抵抗器の既存技術および将来動向に関する一般情報
7	英文テキスト Attached Sheet No.1：固定皮膜抵抗器の電解現象
8	英文テキスト Attached Sheet No.2：炭素皮膜抵抗器の研究手法と試作
9	カウンターパート指名公文書
10	試作品のテストデータ
11	抵抗器の技術協力私見文書
12	抵抗器の技術協力に関する概要報告
13	カウンターパートへ交付した技術証明書
14	成果品（カウンターパートによる試作品）
15	日本大使館からパキスタン政府宛の専門家派遣通知
16	佐藤首席顧問より国際協力事業団長沢課長宛の技術指導終了報告

別添資料No.1

業務内容

(1) 炭素皮膜固定抵抗器の基本技術を指導すること。

(2) 実験室的製造技術を指導すること。

（抵抗器の試作を行い、製造方法の技術移転を図るものとする）

(3) 炭素皮膜固定抵抗器（試作品）の電気的特性の調査・実験の実施を行うこと。

(4) 上記調査・実験のデータの解析を行うこと。

(5) 抵抗器の実用化テスト及びその目途について策定すること。

(6) パキスタン中央電気通信研究所の将来の研究開発技術確立のため研究手法及び抵抗器の新技術の動向について指導すること。

別添資料No. 2

TO WHOM IT MAY CONCERN:

REF No: 810033
DATE: Feb. 21, '81
RIKEN DENGU SEIZO Co., Ltd.

Subject: Technical Cooperation on Carbon Film Fixed Resistor

1. Purport

By the request of Chief Advisor Dr. T. SATO, C.T.R.L., Japan International Cooperation Agency and Ministry of Posts & Telecommunications of Japanese Government, RIKEN DENGU SEIZO Co., Ltd. has sent the following engineer to C.T.R.L. Pakistan T & T, for the purpose of technical guidance on Carbon Film Fixed Resistor.

(1) Name of Expert : Yoshinobu KITAMURA

(2) Position in RIKEN: Senior Staff Engineer, Research & Development Department

(3) Term : From Feb. 20 through Mar. 19, 1981

2. Contents of Technical Cooperation

2.1 Lecture

As for "The Fundamental Technique", "The Considerations of Design" and "The General Informations of Present Technique & Future Trend" on carbon film resistor, the expert will deliver lectures with following text books,

(1) Text Book No. 1: Pyrolytic Carbon Film Fixed Resistor (Fundamental Technique) contains 35 pages

(2) Text Book No. 2: Fundamental Considerations on Designing Pyrolytic Carbon Film Fixed Resistor contains 14 pages

(3) Text Book No. 3: General Information of Present Technique and Future Trend on Pyrolytic Carbon Film, Metal Film and Metal Oxide Film Fixed Resistor contains 33 pages

2.2 Trial Manufacturing

Under the advise and check by expert, T & T staff will manufacture the following samples:

(1) RD 1/4 P 1 k ±5 % 50 pcs.
(2) RD 1/4 P 10 k ±5 % 50 pcs.
(3) RD 1/4 P 100 k ±5 % 50 pcs.

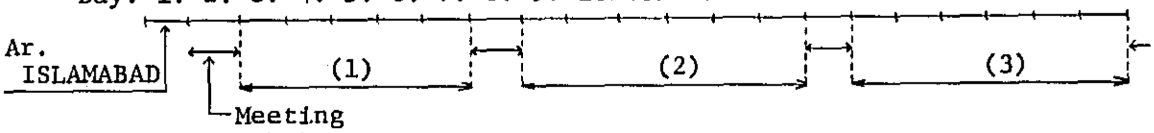
2.3 Test of Sample

For the purpose of inspection of characteristics, T & T staff will do the following test items under the guidance of expert. Tests will be carried out on the basis of JIS C 6402.

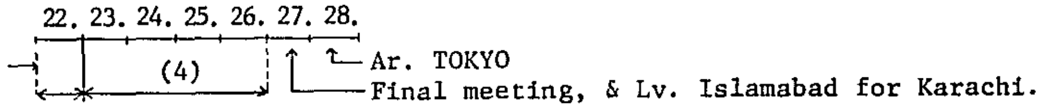
(1) Dimension check .... 10 pcs.
(2) Resistance value measurement .... All sample unit.
(3) Short time over-load test .... 10 pcs.
(4) Others:
The other test items will be limited only the items which can be carried out within a short time.
As for the items, they will be related to the test equipment or test jig, so will be decided after preliminary meeting with Chief Advisor Dr. T. SATO, Advisor Mr. Hitoshi KATO and Divisional Engineer Mr. Mazhar RAZA of Circuit Component Lab.

2.4 Schedule

										Mar.											
Feb.	20	21	22	23	24	25	26	27	28	1	2	3	4	5	6	7	8	9	10	11	12
	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th
Day:	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.



Mar.	13	14	15	16	17	18	19
	Fr	Sa	Su	Mo	Tu	We	Th
	22.	23.	24.	25.	26.	27.	28.



Note: (1)..... Lecture of fundamental technique & Design.
(2)..... Trial manufacturing.
(3)..... Test of sample.
(4)..... Lecture of Present technique & future trend.

Y. KITAMURA
RIKEN DENGU SEIZO Co., Ltd.

別添資料No. 3

Ref. No. CTRL/G-1/81 The 21st February, 1981

My dear Farooqui Sahib,

Mr. Yoshinobu KITAMURA, Expert in Carbon Film Fixed Resistor, who arrived yesterday will start his programme as under:-

1. Lecture on Fundamental Technique & Design .....
   22nd Feb. to 26th Feb. '81
2. Trial Manufacturing .... 28th Feb. to 5th March '81
3. Test of Samples .... 7th March to 12th March '81
4. Lecture of Present technique & Future trend .....
   14th March to 17th March '81

The first programme mentioned above i.e., Lecture on Fundamental Technique & Design will start at 0930 hours and will continue till 1500 hours.

Any body from office of the Director-General, T&T who likes to attend is welcome.

Yours sincerely,

(G. M. SHEIKH)
General Manager

To:

Mr. M. Z. FAROOQUI,
Chief Engineer (Staff & Establishment),
T&T Directorate-General,
ISLAMABAD

Copy to:-

1. Notice Board, CTRL Islamabad.
2. Notice Board, D. G. T&T Islamabad.
3. General Manager, I.T.R. Islamabad (for Notice Board)
4. Director, Microwave (Development) Islamabad (for Notice Board).

別添資料No. 4

PYROLYTIC CARBON FILM FIXED RESISTOR

(Text Book No. 1)

Date: Feb. 12th, 1981
Approval for offering this document to C.T.R.L, PAKISTAN T&T Dept.

Yoshio WADA, Manager
Research & Development Dept.
RIKEN DENGU SEIZO Co. Ltd.

DESCRIPTION
by
Yoshinobu KITAMURA

SENIOR STAFF ENGINEER
RESEARCH & DEVELOPMENT DEPARTMENT
RIKEN DENGU SEIZO Co. Ltd.

4-5 HIGASHI-SAKASHITA 1-CHOME, ITABASHI-KU
TOKYO 174 JAPAN

TEL: 03-966-6176
TELEX: 272-3121

CONTENTS

CONTENTS

1. Introduction

Electronic components which organize electronic circuit networks, are divided into active, passive and mechanical components. Passive components mean resistors (R), capacitors (C), and transformers or coils (L). These passive components (R,C,L) play very important parts to the various kinds of electronic equipments, and are generally called "three essential elements of circuit components". From these points of view, we can understand that resistors are very important electronic component.

Resistors are generally divided into "Fixed Resistors" and "Variable Resistors". Fixed resistors are subdivided into "Fixed Film Resistors" and "Fixed Wire-wound Resistors". Variable resistors are also subdivided like fixed resistors.

In this text book, "Pyrolytic Carbon Film Fixed Resistors" used most for the various kinds of electronic equipments, are selected, and especially, as for "the Style RD-P Carbon Film Fixed Resistors" which have been mainly used for the industrial electronic equipments, their manufacturing method and electrical characteristics are explained in details.

In the field of various kinds of fixed film resistor, pyrolytic carbon film resistors have been used with the most quantity, because they have excellent electrical characteristics and economic price.

They cover very wide applications from electronic equipments for industries such as switching board, telephone, and communications through equipments for consumers such as T.V, Audio and V.T.R.

2. History of Pyrolytic Carbon Film Resistor

Pyrolytic method of hydrocarbons was invented by C.A. Hartman of Germany in 1924, then Siemens GmbH developed the pyrolytic carbon film resistors with the method in 1927.

In Japan, Dr. Akahira of the Institute of Physical and Chemical Research, developed pyrolytic carbon film resistors in 1937, and Riken Dengu Seizo Co., Ltd., founded by the Institute of Physical and Chemical Research, have begun the manufacturing of pyrolytic carbon film resistors at first in Japan. Japanese production quantity of pyrolytic carbon film resistors in 1978, was reached 17,050 million pcs. and their price was also arrived at ¥27,150 million (US$123.5 million).

3. Resistance Materials

Table 1 shows principal resistance materials used for resistors. As shown in Table 1, materials are divided into metal materials and non-metal materials.

3.1 Metal Materials

Metal materials are mainly used for wire-wound resistors and metal film resistors. Generally, the resistivity of these materials is comparatively low, so a week point of them is as follows,

(1) It is difficult to manufacture a resistor having higher resistance value.

(2) Especially, to get high resistance value on wire-wound resistors, resistance wire has to be smaller, and also, the dimension of the resistor becomes very large.

(3) So, in wire-wound resistors with higher resistance value, reactance increases in a high frequency range.

To improve the week points mentioned above, new many alloy materials with high resistivity, and small temperature coefficient of resistance have been developed. On the other hand, metal film resistors with these materials, have been also developed and many improvements to the high frequency range and higher resistance value have been tried up to today.

3.2 Non-metal Materials

Typical non-metal materials are carbon. Carbon materials have higher resistivity than metal materials, and they can cover wider resistance range.

Carbon materials for resistors, can be manufactured as follows,

(1) The method of depositing thin carbon films over the surface of ceramic rod by pyrolysis of hydrocarbons at higher temperature than 1,000 °C.

(2) The method of blending fine powder of carbon such as graphite, carbon-black or acetylene-black in a binder of synthetic resin, then making carbon disperse in a binder. The long term stability and temperature coefficient of resistance of pyrolytic carbon film are a little infe-riorer than metal film, but higher resistance value can be gotten, so pyrolytic carbon film resistors have been used the most quantities in the film resistors up to today.

Table 1 Resistance Materials

No.	Material	Resistivity at 20 °C (μΩ cm)	Measuring temp. range of T.C.R. (°C)	T.C.R. (ppm/°C)	Remark
1	Gold (Au)(1)	2.4	0∿100	4,000	
2	Silver (Ag)(1)	1.62	"	4,100	
3	Platinum (Pt)(1)	10.6	"	3,900	
4	Palladium (Pd)(1)	10.8	"	3,700	
5	Nickel (Ni)(1)	7.24	"	6,700	
6	Titanium (Ti)(2)	42	20	5,460	
7	Molybdenum (Mo)(1)	5.6	"	4,400	
8	Tantalum (Ta)(1)	15	"	3,500	
9	Iridium (Ir)(1)	6.5	"	3,900	
10	Rhodium (Rh)(1)	5.1	"	4,400	
11	Chromium (Cr)(1)	17	"		
12	Zirconium (Zr)(1)	49	"	4,000	
13	Constantan(2)	50	"	50	Cu 55%, Ni 45%
14	Advance (3)	47.56	"	10	Cu 54.5%, Ni 46.63%, Mn 0.54%, Fe 0.11%
15	Manganin(4)	43	"	10	Cu 86%, Mn 12%, Ni 2%
16	Evanohm(5)	133	20∿100	20	Ni 74.5%, Cr 20%, Aℓ 2.75%, Cu 2.75%
17	Nickel-chromium (Ni Cr)(6)	103	"	231	Ni 80%, Cr 20%
18	Gold-platinum (Au Pt)(6)	32.9	0∿160	370	Au 60%, Pt 40%
19	Gold-palladium (Au Pd)(6)	26.4	"	650	Au 50%, Pd 50%
20	Platinum-rhodium (Pt Rh)(6)	21.7	"	1,470	Pt 90%, Rh 10%
21	Silver-palladium (Ag Pd)(6)	42	"	30∿70	Ag 40%, Pd 60%
22	Single crystal graphite, a axis (7)	39		9,000	
23	Single crystal graphite, c axis (7)	10^4		-40,000	
24	Polycrystal graphite(7)	800		-1,000	
25	Pylorytic carbon(7)	$(1∿1.8) \times 10^3$		-180	
26	Carbon black(8)	$(1.7∿36) \times 10^6$			Specific volume 2cc/g
27	Acetylene black(8)	$(2∿4.5) \times 10^5$			

(1) Physical chemistry data file, 1974, Japan
(2) J. Furuhata; Electronics 2, P575 ∿ 578 1957, Japan
(3) Registered trade-mark
(4) Registered trade-mark
(5) Registered trade-mark
(6) International Critical Tables Vol. 6
(7) R.O. Grisdale etc.; B.S.T.J. 30, 271∿314 (1951)
(8) Hand book of carbon black, 1971

4. Nature of Carbon Film

4.1 Resistivity of Conductor

In Fig. 1, assuming that the material of conductor to be considered is homogeneous, but its width, thickness and length are varied, electrical current flowing in the conductor by applying electrical potential to it, increases in proportion to width, and thickness and it is in inverse proportion to length.

Therefore, the ratio of potential and current, V/I is in inverse proportion to width and thickness, and it is in proportion to length.

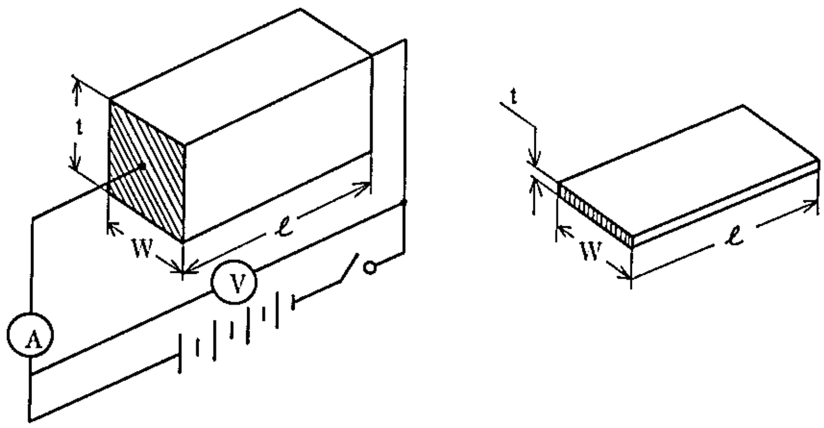


Fig. 1 Shape of conductor

If, this proportional constant is expressed as "ρ", the resistance "R" of conductor, is expressed as follows,

$$R = \rho \times \frac{\ell}{t \times w} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \qquad (1)$$

Where, "w × t" is expressed as the sectional area, so formula (1) can be also expressed as the resistance of material of conductor is in proportion to its length and is also in inverse proportion to its sectional area.

Now, assuming that w, t and ℓ are 1 cm, R is equal to ρ (R=ρ), and R is also equal to the resistance shown as resistance value of the material of conductor which is a cube of 1 cm^3.

This proportional constant is named as "Volume resistivity" or "Resistivity" and it has peculiar value to each material of conductor.

Also, the unit is given as "Ohm per 1 cm^3" or "Ohm-cm".

As shown in Fig. 1 (b), when the thickness "t" is extremely small to the width and length, it is considered that the conductor is like thin film.

In this case, resistivity "ρ" is essentially defined same as mentioned above, but in practical use, it is very difficult to measure the thickness of thin film correctly, so the computation of its resistivity is troublesome very much, and its value is not always correct to the accuracy.

In such a case, instead of the resistivity (Ohm-cm), it is very convenient to use the resistance of film surface of regular square (ℓ=w, unit is not necessary) shown as a area resistivity. As unit of area resistivity is not necessary, it is usually expressed as Ohm/Square or Ohm/□, and area resistivity is also called as sheet resistance "Rs" for the sake of convenience.

The sheet resistance "Rs" is led as follows,

From the formula (1),

$$R \text{ of the conductor} = \rho \times \frac{\ell}{t \times w} \quad \ldots\ldots\ldots\ldots\ (2)$$

Now, assuming that ℓ is equal to "w" (ℓ=w),

$$R = \rho \times \frac{1}{t}\ (\Omega/\square) \quad \ldots\ldots\ldots\ldots\ (3)$$

Namely,

$$Rs = \Omega/\square = \rho/t \quad \ldots\ldots\ldots\ldots\ (4)$$

Where, formula (4) is sheet resistance of film.

Therefore,

$$\rho = Rs \times t \quad \ldots\ldots\ldots\ldots\ (5)$$

By diplacing formula (5) into formula (2),

$$R \text{ of the conductor} = \frac{Rs \times t \times \ell}{t \times w} = Rs \times \frac{\ell}{w} \quad \ldots\ (6)$$

Therefore, Rs is expressed as follows,

$$Rs\ (\Omega/\square) = R \times \frac{w}{\ell} \quad \ldots\ldots\ldots\ldots\ (7)$$

4.2 The Specific Resistance of Pyrolytic Carbon Film.

As for the measurement of the specific resistance of pyrolytic carbon film, R.O. GRISDALE of B.T.L. (U.S.A.) has reported as follows,

For determination of the specific resistance of pyrolytic carbon film, silver electrodes were applied to the ends of films on rods or plates of fused silica, and measurements were made at currents so small that there was no detectable joule heating. Comparative measurements made with and without potential probes showed no detectable contact resistance between these electrodes and the carbon film.

Furthermore, the potential drop, was linear along the specimens, thus indicating their uniform thickness.

Within the limits of experimental accuracy, the specific resistance of pyrolytic carbon film is independent of film thickness: Over the measured range from about 2.5×10^{-6} cm (250 Å) to about 2.5×10^{-4} cm (25,000 Å) thickness there is no change in resistivity.

The specific resistance of pyrolytic carbon film does, however, depend on the conditions under which the carbon film is prepared and it decreases with increase in the degree of preferential crystal orientation for films greater than 3×10^{-5} cm (3,000 Å) in thickness.

Even in the most highly oriented specimens, the specific resistance is greater than "1×10^{-3} Ohm-cm" (1×10^{3} μΩ-cm).

Also, S. SHIMAMUNE of Japan has reported that the specific resistance of pyrolytic carbon film is "$1.34 \pm 0.13 \times 10^{-3}$ Ohm-cm". In this case, the temperature of pyrolysis is "1,000 °C, and the film thickness is 40,000 ± 5,000 Å and the sheet resistance of film is 3.35 Ω/cm^2.

These values are very similar, so we can regard these values as the specific resistance of pyrolytic carbon film.

4.3 The Relationship between Sheet Resistance, Film Thickness, Specific Resistance and Initial Resistance of Pyrolytic Carbon Film

By considering the carbon film resistor as shown in Fig. 2, the resistance between both leads wire is defined as "Initial resistance" (Ro).

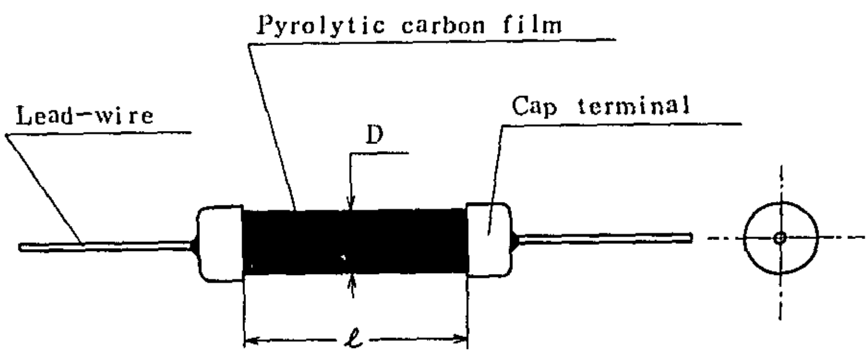


Fig. 2 Pyrolytic carbon film resistor

In this case, "Sheet resistance Rs" is expressed as follows,

$$Rs\ (\Omega/\square) = \frac{\pi D}{\ell} \times Ro \quad \cdots\cdots\cdots \quad (8)$$

Where "D" is a diameter of ceramic body, "ℓ" is a length between inside of both cap-terminals.

When the specific resistance is expressed as "ρ", and the thickness of the film is expressed as "t",

$$Rs\ (\Omega/\square) = \rho \times \frac{1}{t} \quad \cdots\cdots\cdots \quad (9)$$

Where ℓ is Ω-cm and t is also "cm".

So, film thickness "t" is expressed as follows,

$$t = \rho \times \frac{1}{Rs} \quad \cdots\cdots\cdots \quad (10)$$

Also, "Ro" is expressed as follows,

$$Ro = Rs \times \frac{\ell}{\pi D} \quad \cdots\cdots\cdots \quad (11)$$

As well know, when the sheet resistance of carbon film becomes higher and higher, its film thickness becomes thiner and thiner.

Fig. 3 shows an example of the relationship between film thickness and sheet resistance of carbon film.

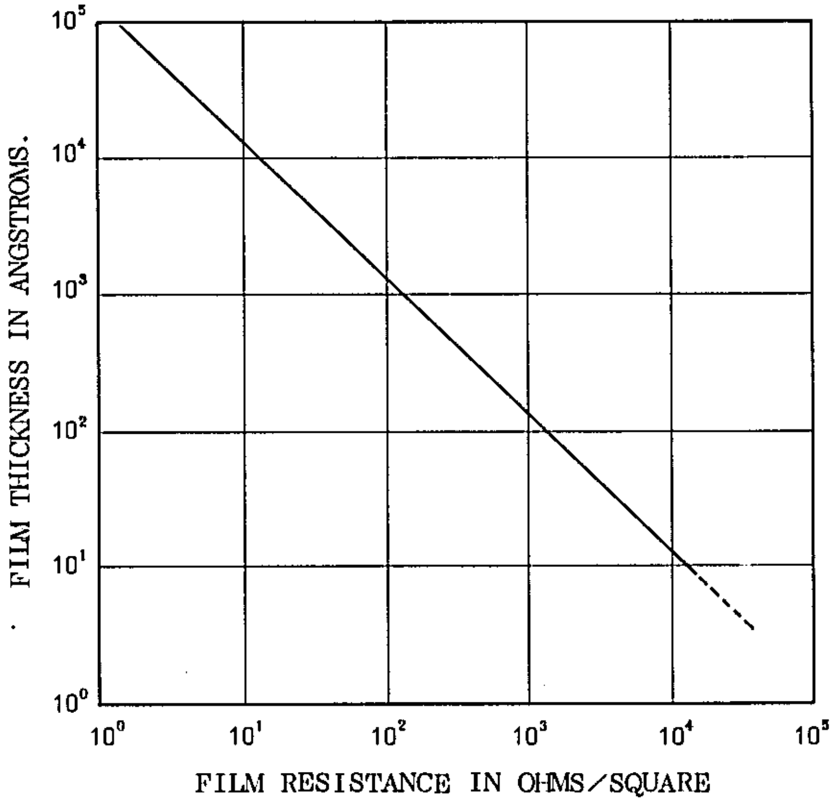


Fig. 3 Relationship between the thickness of a pyrolytic carbon film and its film sheet resistance.

4.4 The Temperature Coefficient of Resistance of Carbon Film.

The temperature coefficient of resistance "T.C.R." of carbon film deposited over the surface of ceramic rod, depends on the film thickness and the thermal expansion coefficient of ceramic rod.

"T.C.R." is expressed as follows, and it is also expressed as "α" instead of "T.C.R.".

$$\text{T.C.R. (ppm/°C)} = \frac{R_1 - R_2}{R_1} \times \frac{1}{t_2 - t_1} \times 10^6 \quad \ldots\ldots \quad (12)$$

Where,

R_1 : Resistance value (Ω) at room temperature at t_1

R_2 : Resistance value (Ω) at test temperature at t_2

t_1 : Room temperature (°C)

t_2 : Test temperature (°C)

It is well known that "T.C.R." of pyrolytic carbon film approaches a limiting value of about "-180 ppm" which is found to be independent of the nature of the base with increasing film thickness. Therefore, this value is characteristic of the carbon film itself. Fig. 4 shows the relationship between "T.C.R.", "Sheet resistance" and "Film thickness".

The value of T.C.R. were obtained over the temperature interval of 30 °C to 60 °C.

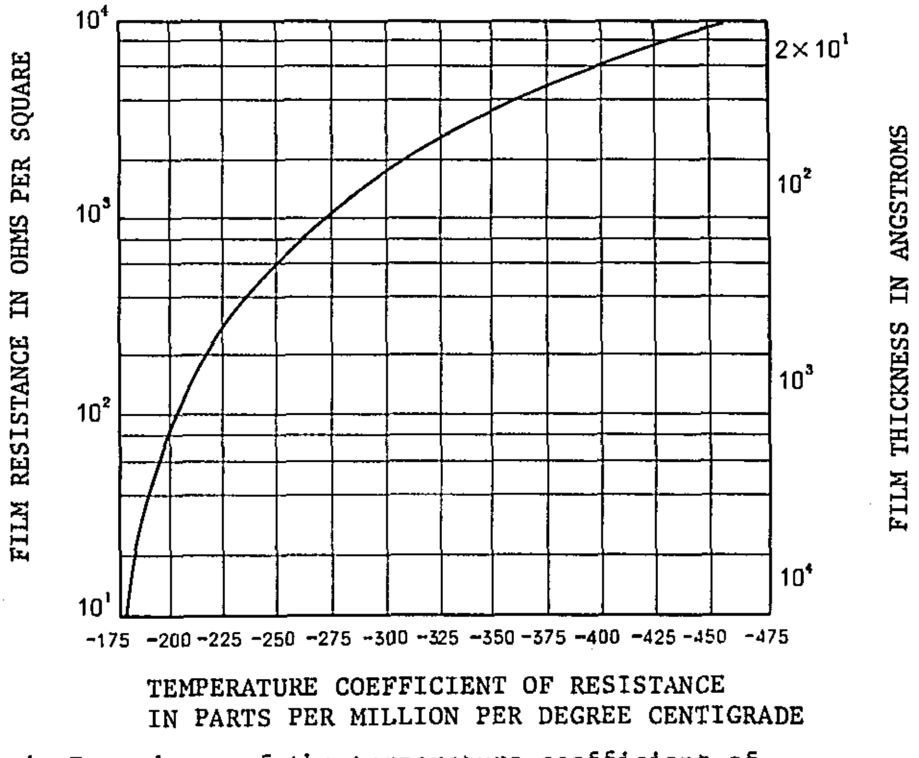


Fig. 4 Dependence of the temperature coefficient of pyrolytic carbon films on film thickness

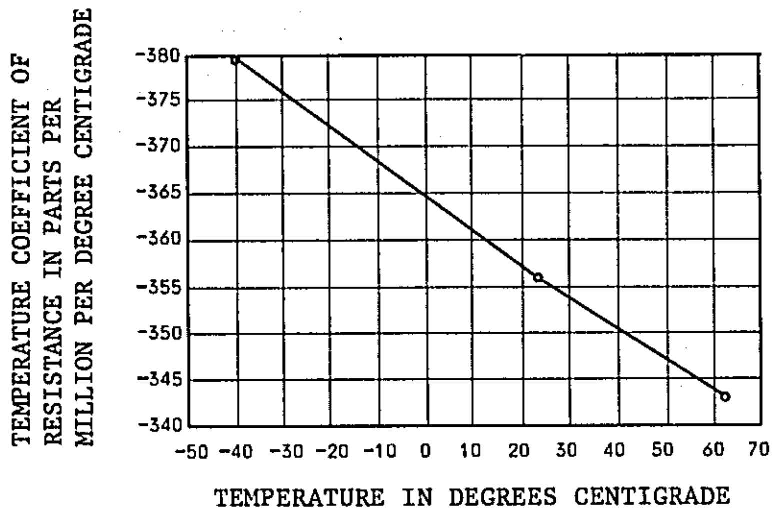


Fig. 5 Dependence of the T.C.R. of a typical pyrolytic carbon film on temperature

Fig. 5 shows the relationship between "T.C.R. and temperature for a typical film", the slope of which is common for all films deposited on the same base.

As the coefficient of thermal expansion of the base increase, the value of T.C.R. for any given film thickness less than 3×10^{-4} cm (30,000 Å) also increases, which serves to emphasize the role of the intercrystal boundaries in determining the properties of pyrolytic carbon, in suggesting that the resistances of these boundaries are dependent on pressure.

The thermal coefficient of expansion for graphite crystals along the C-axis, is 26×10^{-6}/°C and parallel to the base plane is 6.6×10^{-6}/°C, that for films of pyrolytic carbon was estimated to be the order of this later value. Carbon films which had stripped spontaneously from smooth cylindrical silica bases were found to curl away from them, the radii of curvature increasing with film thickness is the manner to be expected if the surfaces of the films originally contiguous to the bases had been deformed largely in conformity with them according to the differential contractions during cooling.

The thermal expansion coefficient of the pyrolytic carbon films was thus determined from measurements of their radii of curvature and of those of the bases from which they had stripped. This coefficient might be expected to depend on the nature of the intercrystal boundaries.

5. Rating of Resistor

5.1 Wattage Ratings

The wattage rating of resistor is expressed as follows,

$$P(W) = E^2 \times \frac{1}{R} \quad \cdots\cdots\cdots\cdots \quad (13)$$

Where,

P : Wattage rating (W)

E : Voltage rating (V)

R : Nominal resistance value (Ω)

The wattage rating of a resistor is determined by the power that it is able to dissipate over a long period without greatly changing its resistance value. There are many practical difficulties in determining this rating accurately, and the usual method is to limit the power dissipated to that which produces a given maximum temperature measured on the surface of the resistor.

The maximum wattage rating depends on the amount of heat which can be transfered to the surrounding air. The temperature of the air will affect this heat transfer. Consequently, in compact equipment operating in hot climates, a derating factor must be applied. In addition, the maximum voltage must also be limited for high-value resistors, as will be described later.

The wattage rating of resistors must, therefore, be regarded as purely nominal-the actual wattage dissipated must be related to ambient temperatures and conditions of use.

The limiting factor in determining the wattage rating of a resistor is the permissible temperature rise, and many tests have been devised to ensure that a resistor has adequate stability at its maximum rating.

It should, therefore, be borne in mind that any design precautions which help to keep the resistor cool will either improve its stability and reliability or its capacity to handle load. With small resistors a high proportion of the power is dissipated along the leads, and thus the best shape for a resistor is short and thick, in order that the longitudinal conduction of the heat is encouraged. With larger resistors, a greater proportion of heat is dissipated by convection and conduction to the surrounding air, so that with these types maximum surface area is the main consideration.

The temperature rise of typical carbon film general-purpose resistors was reported by H. SPRATT (Great Britain) against the wattage dissipated at normal temperature. His result is shown in Fig. 6.

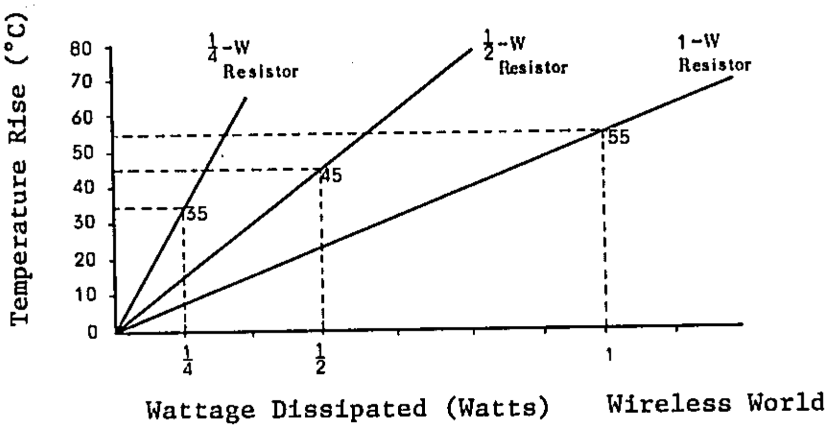


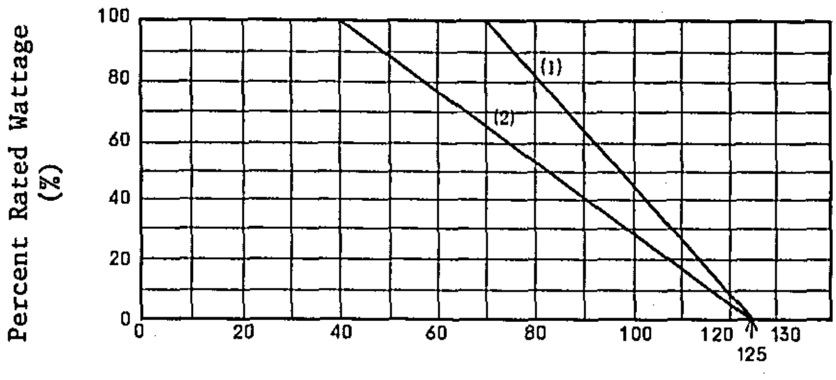
Fig. 6 Temperature rise of general-purpose carbon film resistor against power dissipated.

Full load corresponds to 35, 45 and 55 °C for the quarter-watt, half-watt and one-watt size. If an equipment is operating in an ambient temperature of 70 °C, in case of one-watt size, the temperature rises up to 125 °C. Higher temperature rise makes generally the resistor deteriorated, so it is very important to take care of the loaded power to resistor should be less than 75 % of wattage rating at the design of circuit network.

5.2 Derating of Wattage Ratings

For all types of resistor, "Derating curves" are provided. It shows the relation between the maximum operating temperature and the maximum permissible wattage. So, when the ambient temperature of resistor is higher than the maximum operating temperature, the wattage loaded to the resistor must be derated in accordance with specified derating curve of the resistor.

The derating curve are varied with the type of resistor. The curve of RD-P carbon film resistor specified by Japanese Industrial Standard, JIS C 6402, is shown in Fig. 7.



Ambient Temperature (°C)

Remarks: Line (1) shall be applicable for the characteristic A and B.

Line (2) shall be applicable for the characteristic X, Y and Z.

Fig. 7 The derating curve of style RD-P carbon film resistor specified by JIS C 6402

5.3 Voltage Ratings

The voltage rating of a resistor is computed as follows,

$$E = \sqrt{P \times R} \qquad \text{.................. (14)}$$

Where,

E : Voltage rating (V)

P : Wattage rating (W)

R : Nominal resistance value (Ω).

The maximum permissible voltage across a resistor, is limited by the dielectric strength of the materials of which the resistor is made. Thus, the maximum voltage, and not the maximum wattage, is the limiting factor in resistors of high value.

The voltage limits for service use is shown in Table 2.

From the formula (14), the resistance which is equivalent to maximum continuous working voltage, is called "Critical resistance" and also, it can be seen that the actual loaded power on the resistance value which is over than the maximum continuous working voltage, is derated than its nominal wattage rating.

In case of 1/2 Watt coated carbon film resistor, its maximum continuous working voltage is limited to 350 V. Therefore, the actual power loaded to 1/2 Watt 1 MΩ resistor, is derated as follows,

$$P = \frac{E^2}{R} = \frac{(350)^2}{10^6} = 0.123 \text{ (W)}$$

Table 2 Maximum permissible voltage (For service use)

Standard	Type of resistor	Wattage (W)	Dimension (L × D, mm)	Max. Rated Voltage (V)
JIS C 6402	RD-P (Coated Carbon Film)	1/8	9 × 2.5	250
		1/4	13 × 2.5	300
		1/2	15 × 4.5	350
		1	24 × 7.5	500
		2	52 × 7.5	750
JIS C 6407	RD-M (Insulated Carbon Film)	1/8	6.4 × 2.4	75
		1/4	9.5 × 2.4	250
		1/2	9.5 × 3.5	350
		1	14.3 × 5.7	500
		2	17.5 × 8.1	500
EIAJ RC-2652	RD-H (Coat-insulated Carbon Film)	1/8	3.7 × 1.6	150
		1/4	6.4 × 2.3	300
		1/2	9.5 × 3.5	350

Note: 1) JIS ..... Japanese Industrial Standard.
2) EIAJ ..... Electronic Industry Association of Japan.

Similarly, in case of 1 Watt coated carbon film resistor, its maximum continuous working voltage, is 500 V, therefore, the actual power loaded to 1 Watt 1 MΩ resistor is derated as follows,

$$P = \frac{E^2}{R} = \frac{(500)^2}{10^6} = 0.25 \text{ (W)}$$

6. *Explanation of Resistance Series (E-series), Marking and Classes of Carbon Film Fixed Resistor*

6.1 Explanation of *Resistance Series (E-series)*

It is desirable to reduce the number of resistance values to be made or stocked to a reasonable figure. In addition, the final value of a carbon composition resistor after manufacture is rarely exactly the value aimed at; there is a spread of resistance values in any one batch over and under the target value. In order to use all resistors manufactured, a logarithmic series of values has been chosen so that resistors too far out from one target batch will fall into the next lowest or highest batch. This logarithmic series is based on the ratio between each value and the next, being calculated as follows,

±5 % is composed of rounded values of the theoretical numbers $\sqrt[24]{(10^n)}$, in which the exponent n is a whole number. (E-24 series)

±10 % is composed of rounded values of $\sqrt[12]{(10^n)}$ and is derived from the previous series by omitting alternate terms. (E-12 series)

±20 % is composed of rounded values of $\sqrt[6]{(10^n)}$ and is derived from the 12th root series by omitting alternate terms, (E-6 series)

Table 3 shows the each resistance series.

Table 3 Resistance Series

E- 6	10				15				22				33				47				68			
E-12	10		12		15		18		22		27		33		39		47		56		68		82	
E-24	10	11	12	13	15	16	18	20	22	24	27	30	33	36	39	43	47	51	56	62	68	75	82	91

Note: 1) The figure in the first line shows a ±20 % tolerance.
2) The second line shows a ±10 % tolerance.
3) The third line shows a ±5 % tolerance.

Based on this series of numbers, a number of charts have been composed from which a resistor may be selected.

6.2 Marking

There are two methods in marking of resistor, and their methods are specified by standard or specification for each style of resistor.

6.2.1 Marking by Letters

In the style RD-P carbon film resistor based on JIS C 6402, marking is specified to indicate by letters.

Generally, the contents of marking include the following informations on the surface of resistor body.

(1) Style and wattage

(2) Nominal resistance value

(3) Resistance tolerance

(4) Name of manufacturer

But in the small-sized resistor such as 1/8 W and 1/4 W, there is no space to mark full informations written above, so it is permitted to mark only "Nominal resistance vlaue" and "Resistance tolerance" on its body by JIS C 6402.

6.2.2 Marking by Color Coding

In the marking by color coding, only nominal resistance value and resistance tolerance are indicated on the surface of resistor body. Style, wattage and name of manufacturer are not indicated.

Bands or rings of color are usually placed round the resistors, as shown in Fig. 8 and also the color code used universally is given in Table 4.

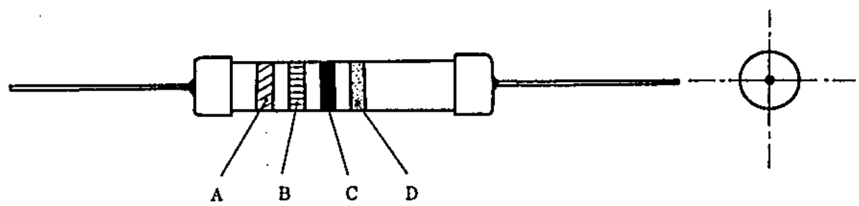


Fig. 8 Color coding schemes for "Fixed Film Resistor"

Table 4 Standard colour code

Colour	A 1st digit	B 2nd digit	C Multiplying factor	D Selection tolerance
Brown	1	1	10	±1 %
Red	2	2	100	±2 %
Orange	3	3	1,000	-
Yellow	4	4	10,000	-
Green	5	5	100,000	-
Blue	6	6	1,000,000	-
Violet	7	7	-	-
Grey	8	8	-	-
White	9	9	-	-
Black	-	0	1	-
Gold	-	-	0.1	±5 %
Silver	-	-	0.01	±10 %
None	-	-	-	±20 %

The colour of the first three rings determine the total value of the resistance-the first ring (A) determines the first digit, the second ring (B) determines the second digit, and the third ring (C) determines the numbers of noughts.

A fourth ring (D), or end colour, is usually to denote the tolerance on value, e.g. a brown ring indicates a 1 % tolerance, a red ring a 2 % tolerance, a gold ring a 5 % tolerance, a silver ring a 10 % tolerance and the absence of a fourth colour indicates a 20 % tolerance.

6.3 Class of Fixed Carbon Film Resistor

Specifications and requirements for resistor vary according to the conditions of use, and Table 5, in the author's opinion, summarizes the main classes of resistors.

Table 5 Class of fixed carbon film resistor

No.	Resistor	Class	Use	Requirement
1	Miniature type carbon film, coat-insulated RD-H	Commercial	Radio, T.V., Audio equipment, etc.	Cost should be cheaper. Good availability & long life essential.
2	Carbon film, coated, RD-P	Profess-ional	Equipment for communications, industrial electronics, etc.	Cost may be higher than commercial, Reliability of greater importance, high accuracy & performance of characteristics essential.
3	Carbon film, insulated, RD-M	Profess ional	Equipments for industrial, ground & airborne radio & radar, guided weapons.	Reliability essential. Operational conditions severe. Must be pan-climatic & cover wide temperature ranges. Airborne resistors must also be light weight. Miniature resistor necessary & sometimes sub-miniature.

7. General Information on Manufacturing of Carbon Film Fixed Resistor.

The process of pyrolytic carbon film on ceramic rods was developed in Germany in 1924, and has since been adopted elsewhere in Europe, Japan and U.S.A. The process consist of pyrolysis of a suitable hydrocarbon vapour at about 900-1,100 °C on to a ceramic rod to produce a coherent carbon film, which forms a stable resistor.

The value of the resistance obtained, is controlled by the pressure of the vapour, the temperature of firing and the time of exposure.

The resistance value is then increased by spiralling the film to form a long continuous path, and this also allows the final value to be accurately adjusted.

The construction of a typical pyrolytic carbon film resistor is as shown in Fig. 9.

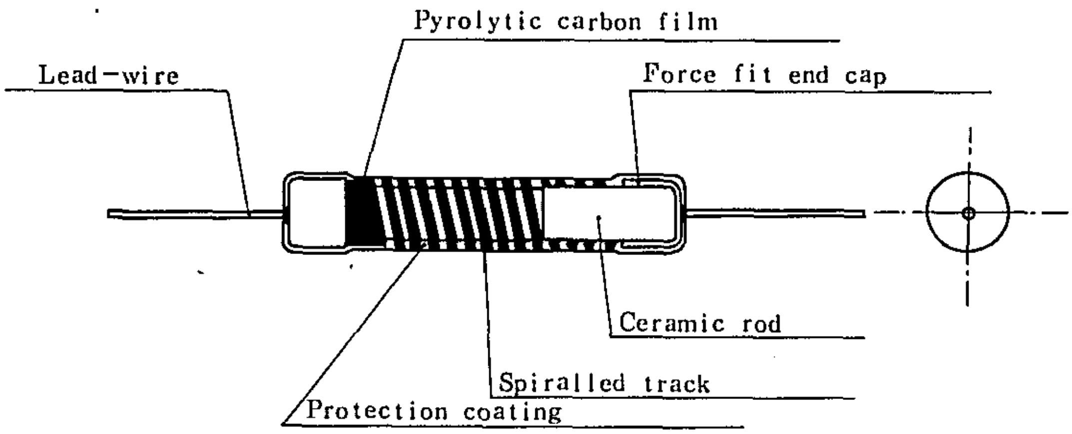


Fig. 9 Construction of style RD-P carbon film fixed resistor

The main stages in the manufacture of a pyrolytic carbon film resistor are as follows,

(1) Preparation of the ceramic body.
(2) Carbon film deposition by pyrolysis.
(3) Fitting end caps.
(4) Spiralling to final resistance value.
(5) Protecting the carbon film by varnish or paint.
(6) Final testing and labelling.

7.1 Preparation of the Ceramic Body

The raw materials used in the manufacture of the ceramic rods or bodies are mainly;

Material	Approx. proportion (%)
China clay	50
Quartz	30
Flux (Oxides of Mg, Zr, Ba, etc.)	20

These proportions will vary according to the desired qualities of the rod. The raw materials are mixed, finely ground, and calcined by heating to above 1,000 °C.

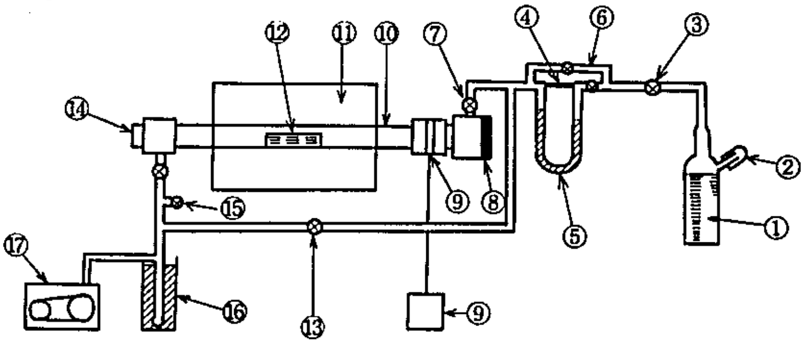
They are then finely ground in water in a ball mill to form a "slurry". This is then filter-pressed into damp cakes, which are put into a pug mill. At this stage, binding agents are added to aid extrusion.

Air is then removed from the cakes, whilst still in the pug mill, by a vacuum connection to the mill. The resultant "slip" is fed to the reservoir of the extrusion plant and extruded in the form of rods suitable size.

The rods are either cut into short pieces or extruded in length with nicks to facilitate subsequent partition. The lengths are dried by infrared radiation or warm air at 70 °C. The rods are then fired by heating in air, the temperature being raised gradually over a period of about 8 hrs to a peak of 1,250 °C (depending on the mix). The temperature is held constant for approximately 1 hr, followed by slow cooling about 12 hrs. The lengths are then partitioned and all rods ground to the correct length and tumbled in a barrel containing water, to remove rough surfaces. They are then examined for surface blemishes, etc., and the approved rods are ready for the pyrolysis process.

7.2 Carbon Film Deposition by Pyrolysis

The batch process is mainly used. Fig. 10 shows a schematic diagram of the batch process.



(1) Hydrocarbons
(2) Leak valve
(3) Needle valve
(4) Capillary tube
(5) Mercury (Hg) manometer
(6) Bypath
(7) Valve to guide hydrocarbon gas
(8) Entrance and exit of specimen
(9) Repeating rotation equipment of reaction tube
(10) Reaction tube
(11) Electric furnace
(12) Specimens
(13) Bypath
(14) Peep window
(15) Leak valve
(16) Trap (Dry ice)
(17) Vacuum pump

Fig. 10 An example of diagram of thermal decomposition equipment for the batch production

In the batch process, many ceramic rods are put at the center of reaction tube made of silica which is kept more than 1,000 °C with electric furnace. Then, ceramic rods are kept at 1030 °C in air at least for 30 minutes. After that, both ends of the reaction tube are sealed with cap and inside air of the tube contains ceramic rods is exhausted by oil-rotary vacuum pump at the pressure of 10^{-1} or 10^{-2} Torr.

Also, inside air of the glass container of hydrocarbon is exhausted through bypass route. When the vacuum level of the inside of reaction tube, is become at specified value, the hydrocarbon gas is flown into the reaction tube through a delivery tube then gas is thermally decomposed in the reaction tube and thin carbon film is deposited over the surface of ceramic rods.

During gas flowing, inside of the reaction tube is continuously exhausted by pump and also, the tube is rotated. After the completion of this process, the reaction tube is taken out from the furnace, keeping the inside of tube vacuum, and then the tube will be cooled. After cooling the tube, the air is flown into the tube and the resistive elements deposited carbon film over the surface of ceramic rods, are taken out from the reaction tube.

The characteristics of the deposited carbon film as a resistor, depend on the film thickness. The surface resistance value of the carbon film expressed in ohm per square, is a function of film thickness. As an initial indication of the quality of the film, it is usual to carry out measurements of the temperature coefficient of resistance. Generally, it can be seen that approximately 3,000 ∿ 5,000 ohm per square, is a practical limit for good electrical characteristics.

Also, the maximum value of temperature coefficient varies with sheet resistance value. Noise of deposited carbon film, depends on the pyrolysis process and deposited carbon film resistors generate noise in a similar fashion to the carbon composition type, but at a very much lower level. The noise appears to be a function of the voltage stress and the thickness of the carbon film. The noise level is inversely proportional to the square of the length of the spiralled track, and it also appears to be a function of the resistivity of the film. For very thick films, i.e. low-resistance films, the noise voltage is very small indeed, and normally can not be measured.

On the higher resistance value, it is possible to measure the noise and the graph of Fig. 11 indicates the approximate magnitude of this effect in a typical 1/2 watt carbon film resistor.

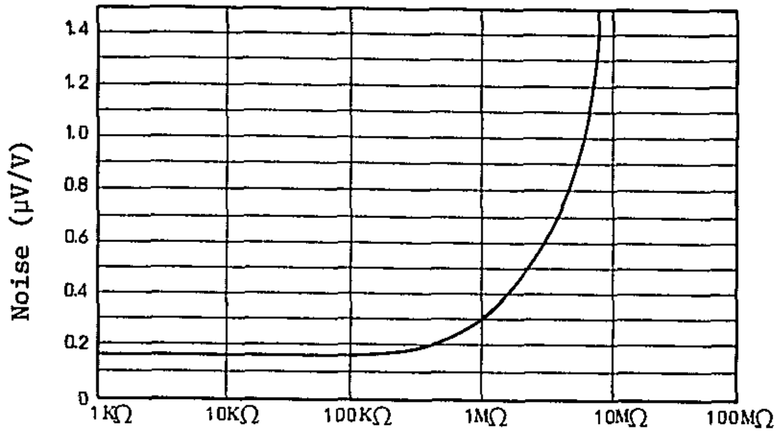


Fig. 11 Observed average noise level for 1/2 watt pyrolytic carbon film resistor

7.2.1 The Mechanism by which Pyrolytic Carbon is Produced.

R.O. GRISDALE of B.T.L. has reported on the mechanism as follows,

It seems reasonably well established that the mechanism by which pyrolytic carbon is produced, is not simply a surface reaction, but is related to that the gas phase dehydrogenation and polymerization of hydrocarbons. Thus, in the case of methane, the simplest hydrocarbon, it is found that, among others, free radicals such as methyl and methylene are present in the gas phase. These combine or polymerize and the resultant products lose hydrogen to yield radicals and molecules of increasing size and complexity. Analysis of the furnace gases from the pyrolysis of methane has shown the presence of acetylene, ethane, benzene, napthalene, anthracene and a long series of more complex materials of decreasing hydrogen content up to pure "carbon" soot itself. It thus appears that pyrolysis of a gaseous hydrocarbon involves the formation of an entire series of molecular species of progressively decreasing hydrogen contents, which are intermediates in the formation of carbon.

While the deposition of pyrolytic carbon films is not a surface reaction in the usual sense, the nature of the substrate surface can profoundly affect the reaction through its catalytic influence. For ceramic surface contaminated with iron or other heavy metals or their oxides this influence is evidenced by the production of soft, sooty, easily removed deposits which can be formed at temperatures considerably below those normally required.

There is evidence that these loosely adherent films may result through the formation of the metal carbides as intermediates.

A great variety of catalytic influences on the deposition of pyrolytic carbon films has been observed: For instance, finger-prints are very clearly "developed" by deposition of thin films, the salts in them appearing to inhibit carbon deposition. If there is back diffusion of gases from the coating zone into the preheating zone and end chambers of a continuous furnace, then several phenomena may be observed: Colloidally dispersed complex hydrocarbons may deposit on the cooler ceramic rod surfaces from the gas phase or they may be mechanically transfered to the rods by contact with already contaminated portions of the furnace mechanism. In either event, their distribution is nonuniform and the contaminated areas provide catalytic nuclei which accelerate carbon deposition in their immediate vicinities, resulting in a pyrolytic film with locally thicker areas. On the other hand, if these complex materials come into contact with certain metallic portions of the mechanism, complex organo-metallic compounds are occasionally formed, and transfer of these to the rod surface generally results in a local inhibition of deposition and hence in films with locally thin areas.

For the production of uniform films of pyrolytic carbon it is generally necessary to employ a substrate which is uniformly clean. Chemical methods of cleaning contaminated surfaces have not proved generally feasible, and to achieve the requisite cleanliness firing of the ceramics at high temperatures in air is usually required. Even this may not be adequate, however, and it is occasionally necessary to reject ceramics with badly contaminated surfaces.

Since the production of pyrolytic carbon involves the synthesis of progressively more complex hydrocarbons, it is natural to expect that the nature of the hydrocarbon employed would be of considerable significance. As pyrolytic carbon is graphitic in nature and thus can be considered originating from aromatic hydrocarbons which possess similar hexagonal carbon structures. Isolation of benzene, napthalene, anthracene and other complex aromatic compounds from the pyrolysis of methane is evidence that the aromatization of methane is probably an intermediate step in the production of carbon. It is therefore to be expected that the use of benzene should increase the rate of carbon deposition and this increase is observed. Similarly, the use of toluene or xylene, leading the more rapid formation of aromatic radicals, should, as is observed, provide even more rapid deposition than does the use of benzene.

Rapid generation of free radicals, whether by catalytic surface reactions or through use of easily "ionized" hydrocarbons, is necessary for rapid deposition of pyrolytic carbon films. However, an excessive rate of generation, as from large concentrations of acetylene, leads to so rapid a gas phase polymerization that coherent surface films can be formed only with difficulty, the principal product being an "aerosol" of soot. Methane is employed in most instances because, being the most thermally stable hydrocarbon, the deposition from it can be so controlled as to yield thin and coherent films.

7.2.2 Structure of Pyrolytic Carbon Film

R.O. GRISDALE of B.T.L. has also reported on the structure of film as follows.

X-ray and electron diffraction analysis of pyrolytic carbon has shown clearly that its fundamental structure is similar to that of graphite, although it differs in two respects: The lattice constant are not quite the same, and the structure possesses a greater randomness, in a sense which will presently be specified.

The hexagonal structure of the most abundant form of graphite is shown in Fig. 12.

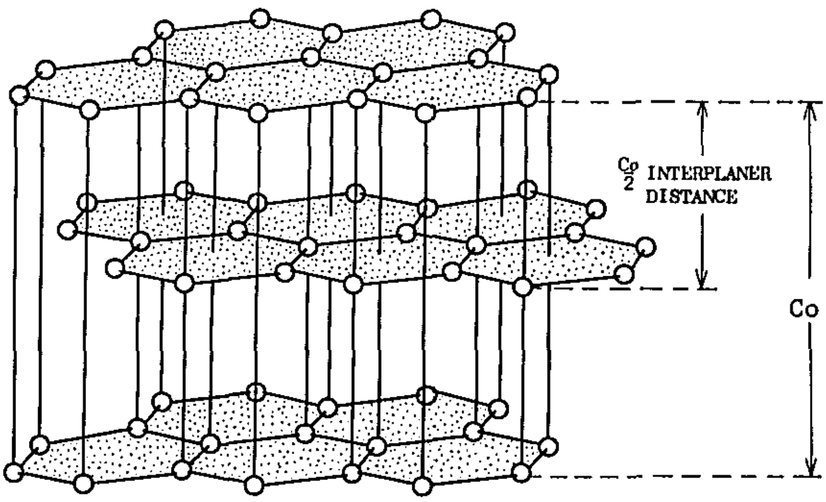


Fig. 12 Structure of the most abundant form of graphite

The carbon atoms are arranged in parallel plane sheets, being located at vertices of hexagons in these sheets. The interatom separation in the sheets is 1.415 Å and the separation between neighboring sheets is 3.345 Å. Alternate sheets of atoms are so displaced that the repeating distance perpendicular to the layers, or along the c-axis of the crystal, is twice the interplanar spacing, or 6.690 Å. Other relatively rare forms of graphite differ from this form only in the way successive planes are displaced or in the repeating distance.

Pyrolytic carbon consists of minute crystal packets composed of parallel plane sheets of carbon atoms in hexagonal arrays as graphite. The areas of these planes are, however, very small, their diameters generally being less than 50 Å. Associated with their small size, there are differences in lattice constants, the interatom distance within the planes being less than in graphite and the interplanar spacing being greater. The extent of these differences is depend on the size of the crystal packet. The interplanar separation as determined in the present work and other investigators is given as a function of the packet size in Fig. 13.

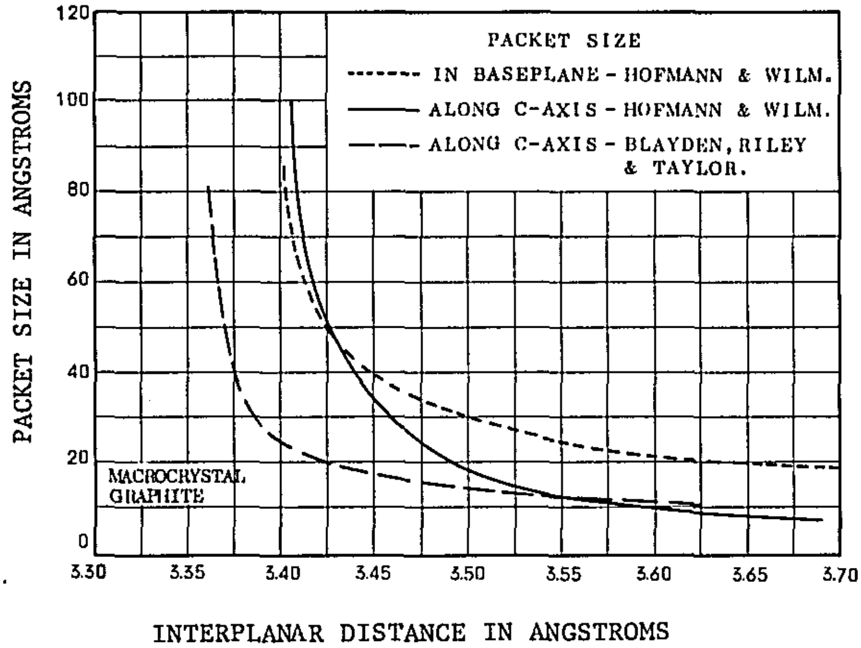


Fig. 13 Dependence of the interplaner separation in crystallites of pyrolytic carbon on crystallite size

The average crystal packet size in pyrolytic carbon appears, for a given parent hydrocarbon, to depend principally on the rate of carbon deposition whether this rate is altered by change in pyrolyzing temperature or in hydrocarbon concentration. When the rate of deposition is changed through use of other hydrocarbons there appears also to be correlation with packet size.

Pyrolytic carbon differs from graphite in important respect; Whereas in graphite the atom layer lie one above the other with the atoms in successive layers in a definite relationship, those in pyrolytic carbon are randomly stacked, the only crystallographic order along the c-axis being the uniform separation of the layers.

The carbon atom has four valence bonds and, in graphite, these valences are completely satisfied within the plane hexagonal network. There is no valence bonding between successive atom layers, these being held together only by relatively weak van der waals forces. The valence between carbon atoms within any one plane is of the resonance-stabilized type, with the result that there is effectively one electron from each atom left over. Some such electrons are free to move over the entire extent of the atom plane, and these provide metallic conductivity. With the larger interatomic spacing along c-axis, many fewer electrons move one plane to the next and along the c-axis, accordingly, the conductivity of graphite is much smaller.

Any single plane of carbon atoms in graphite may be considered to be a single giant molecule. Examination of such a plane of carbon atoms will show, however, as in Fig. 14, that it could better be considered as a free radical since there are free valences at its periphery; and these valences are quite probably satisfied by hydrogen or hydrocarbon fragments, as shown.

Since the number of free valences in a graphite crystal is small relative to the total number of carbon atoms, the actual percentage of hydrogen is very small. Nevertheless, each plane of carbon atoms may be considered to be surrounded by a "hydrocarbon skin".

In pyrolytic carbon, the atom planes may likewise be considered to be surrounded by hydrocarbon skins. However, with an average diameter for these planes of approx. 25 Å, the number of free valences is appreciable relative to the total number of carbon atoms, so that the hydrogen content of pyrolytic carbon may be greater than that of graphite.

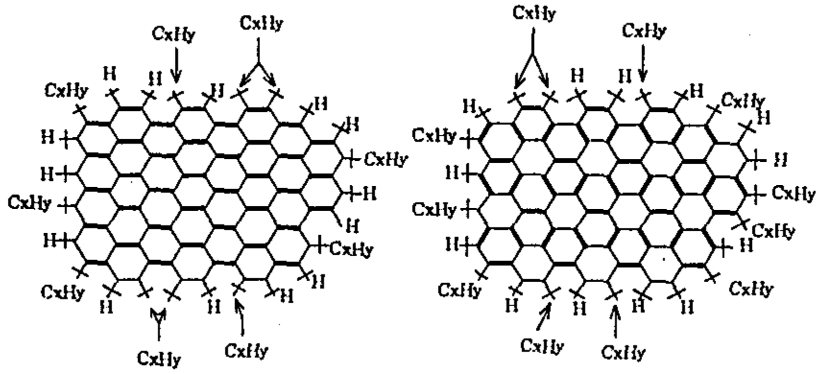


Fig. 14 Two resonance of the valences structure in the carbon atom layer, showing the free valences at the crystal periphery with possible bonding of hydrogen and a hydrocarbon

7.3 Fitting End Caps

Metal cap with lead wire are force-fitted on to the ends of the resistive element to make electrical contact with the carbon film. They are usually before spiralling operation. As the ceramic rods are rarely made to accurate dimensions, it is not easy to adopt any standard process for fitting these end caps and in some cases special selection is necessary before fitting.

7.4 Spiralling to Final Value

For best electrical stability, comparatively thick films are preferred, and a long narrow resistance path is provided by spiralling. The resistor rod is mounted between two chucks rotated at controlled speeds and a rapidly revolving cutting wheel with a narrow "V" edge is pressed against the rod.

A lead-screw controls the pitch of the spiral cut, and a fine groove is cut into the surface of the ceramic rod, isolating a long narrow carbon strip. Spiralling to a desired value can be carried out by handy or automatically control (by monitoring against a resistance bridge) to a tolerance between ±1 and ±5 %.

The maximum increase in resistance, or "Gain factor", is determined by the lead-screw ratio and the width of the cutting wheel (cutting wheel equals to the width of groove).

The gain factor, when multiplied by the circumference of the rod, gives the actual increase in resistance value.

Well, we consider the method of computation to get the gain factor.

As shown in Fig. 15, when "D" is a diameter of resistor body and "ℓo" is effective length of carbon film, the resistance value before spiralling cut is expressed as follows,

$$Ro = Rs \times \frac{\ell o}{\pi D} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (15)$$

Where, "Rs" is sheet resistance of carbon film.

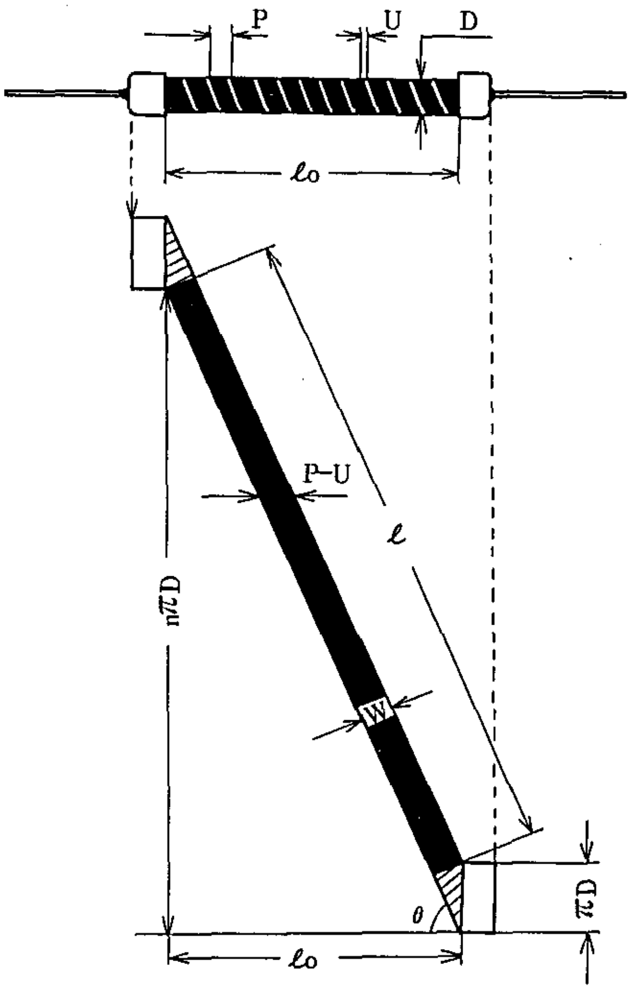


Fig. 15 Developed drawing of spiral cutting

Now, if the effective length "ℓo" is cut spirally by pitch value "P" with groove width "U", the numbers of turns of spiral cutting "n" is expressed as follows,

$$n = \frac{\ell o}{P} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (16)$$

So, a long narrow carbon strip results in the developed drawing as shown in Fig. 15.

In above figure, if the both ending portion written with oblique line is omitted, the resistance value which is shown with rectangular portion is computed as follows,

$$R = Rs \times \frac{\ell}{w} \quad \text{.................... (17)}$$

$$\ell = \sqrt{\ell o^2 + (n\cdot\pi D)^2} - \pi D\sin\theta \quad \text{............ (18)}$$

$$w = (P-U)\cdot\sin\theta \quad \text{.................... (19)}$$

$$\text{Spiral cutting angle } \theta = \sin^{-1} \frac{n\pi D}{\sqrt{\ell o^2 + (n\pi D)^2}} \quad \text{........... (20)}$$

By putting formula (18), (19) and (20) into formula (17), then, by using formula (15), the gain factor "K = (R/Ro)" result in formula (21).

$$\text{Gain factor } K = \frac{R}{Ro} = \frac{(\pi D)^2}{P(P-U)}\cdot\frac{\ell o-P}{\ell o} + \frac{P}{P-U} \quad \text{....... .... (21)}$$

But, when the pitch value is very small (high magnification), ℓo (effective length for spiral cutting) is very large than pitch value, so gain factor K_1 in this case, is expressed as follows,

$P \ll \ell o$,

$$\text{Gain factor } K_1 \doteqdot \frac{(\pi D)^2}{P(P-U)} \quad \text{.............(22)}$$

But, in the case of medium magnification such as the pitch value becomes a little large, gain factor K_2 is expressed as follows,

$$\text{Gain factor } K_2 \doteqdot \frac{(\pi D)^2}{P(P-U)}\cdot\frac{\ell o-P}{\ell o} \quad \text{........(23)}$$

When the pitch value becomes large, gain factor K_3 is expressed as follows,

$P \gg U$,

$$\text{Gain factor } K_3 \doteqdot \frac{(\pi D)^2}{P^2}\cdot\frac{\ell o-P}{\ell o} + 1 \quad \text{.... (24)}$$

Especially, when the length of resistor is very long and following condition is satisfied, gain factor K_4 is expressed as follows,

$\ell o \gg P \gg U$,

$$\text{Gain factor } K_4 \doteqdot \frac{(\pi D)^2}{P^2} + 1 \quad \text{.......... (25)}$$

7.5 Protection

The resistance film is extremely thin and must be protected against damage by handling and moisture. This is one of the most difficult problems which the resistor manufacturer has to overcome and apart from encasing the element in a glass or ceramic tube, numerous varnishes and coatings are in use.

Undoubtedly, one of the best methods of protection is to enclose the element in a glass or ceramic tube and to seal the ends by soldering or by a suitable compound.

But this method is very complicated process and costed very much, so generally, coating, coat-insulation or molding are carried out.

7.6 Final Testing

Resistors are individually tested at various process in their manufacture. In a mass-production system, automatic sorting and testing machines, have been used for final testing by many resistor manufacturers.

8. Manufacturing Method of Carbon Film Fixed Resistor with the Manufacturing System at Central Telecomm. Research Lab.

As for the text book of this paragraph, "MANUFACTURING INSTRUCTION MANUAL FOR NON-INSULATED TYPE FIXED CARBON FILM RESISTOR" presented to C.T.R.L. from RIKEN DENGU SEIZO Co. Ltd., will be used.

The outline is as follows,

8.1 Manufacturing Process

The diagram for manufacturing process is shown in Fig. 16.

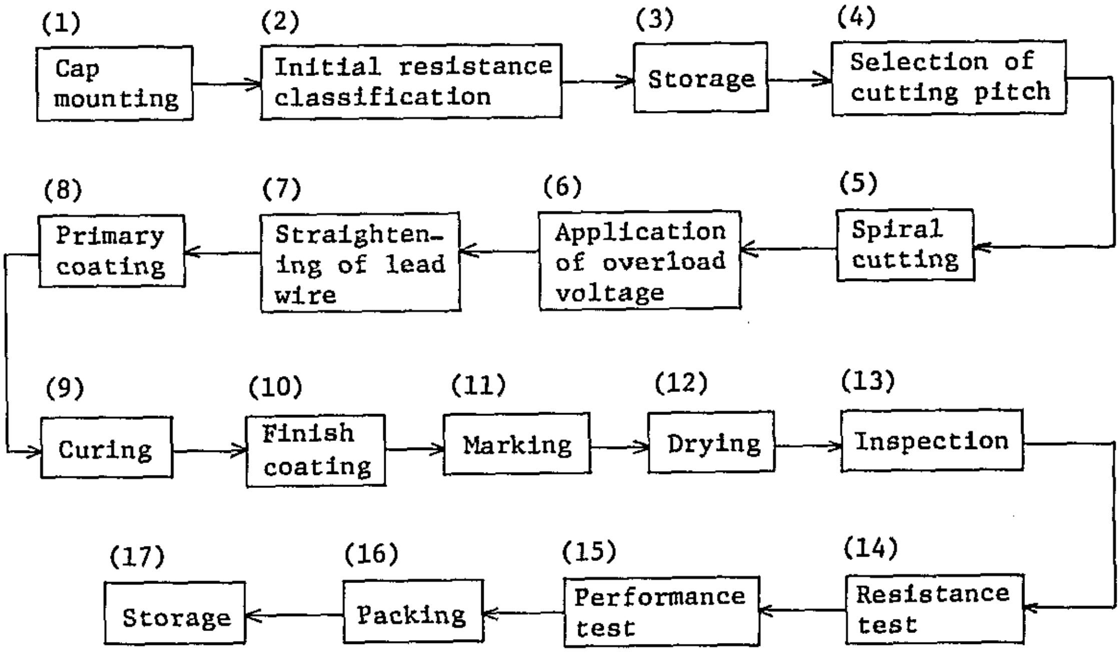


Fig. 16 Diagram for manufacturing process (except carbon film deposition process)

8.2 Explanation for Each Manufacturing Process

(1) Cap mounting.

Nozzle for the type is to be mounted on manual, versatile type cap squeezer (RIKEN, model RTC-H) and upon inserting lead cap to inside nozzle, the caps are squeezed in both end of resistive element.

(2) Initial resistance classification.

By using ohmmeter (model SR-3Y, as manufactured by SANWA) initial resistance value are classified by step.

(3) Storage.

The resistor elements of which initial resistance value has been measured and classified by step are stored in plastic container boxes together with labels on which initial resistance values are written.

(4) Selection of spiral cutting pitch.

In order for providing spiral cutting with finished initial resistance value, cutting pitch is selected based on the correlation table on which initial resistance values and thread cutting pitches are listed.

(5) Spiral cutting.

In order for providing spiral cutting with the finished initial resistance values, the automatic switching resistance trimming meter (model CS-N-YTR as manufactured by SANWA) is set at the finished resistance value. Then, grooves are cut as spirally cutting carbon film that is adhering to the surface of element by monitoring meter with manual, versatile type thread cutter (model RCM-H as manufactured by RIKEN). By means of groove cut, the resistance value could be adjusted to objective resistance value by gradually increasing the resistance value of carbon film.

(6) Overload voltage application.

In order to check the resistors to eliminate faulty spiral cutting, overload voltage is applied for short period of time by use of A.C. overloading tester (model RAC-24 manufactured by RIKEN), and those occurring spark or burn are to be rejected as faulty.

(7) Straightening of lead wire.

In order to make painting work easier, the lead wires are straightened on wooden table for the purpose.

(8) Primary coating.

In order for providing protection with carbon film against atmosphere, vapor proof insulation paint for under coating is coated by brush evenly over the surface of elements and are put in line on dryer frame. Numbers of coating are varied depending on the resistance value.

(9) Curing

After curing at room temperature took place for short period of time, the drying frame, on which resistor elements are arranged, is put into dryer oven for high temperature curing for under coating film.

(10) Finish coating

After curing of primary coating completed, vapor proof insulation paint is coated by brush evenly over the under coating for providing face coating with elemental resistor bodies and are arranged in line on frame.

(11) Curing

After drying at room temperature took place for short period of time, the drying frame, on which resistor elements are arranged, is put into dryer oven for high temperature curing for finish coating film.

(12) Marking

After curing finish coating completed, the resistance value is printed over the finish coat on marking equipment, and then the resistor elements are arranged on frame.

(13) Curing

The drying frame, on which resistor elements are arranged, is put into dryer oven for high temperature curing.

(14) Appearance inspection

Visual inspection on bubbles in film coat, uneven painting, unreadable marking, etc. is performed.

(15) Resistance value test

Resistance values of completed resistors are tested to determine if they are within the tolerance (for example: ±1 %, ±2 %, ±5 % of set value) on digital ohmmeter. Those exceeding the tolerance are rejected as faulty.

(16) Performance test

Various performance tests are given at random on the standards provided.

Note: The items of tests can be performed with the testers and loading power source included in this system are as follows (Test jigs are required to be fabricated):

1) Dimension check (Equipments to be used; slide vernier and micrometer)

2) Temperature characteristic of resistance (Only higher temperature side, Equipments to be used; digital ohmmeter and dryer oven)

3) Short time overload (Equipments to be used; digital ohmmeter, A.C. load power source, voltage regulator, etc.)

(17) Packing

The completed resistors for protection against atmosphere, are put in polyethylene bag and sealed, together with label on which type and resistance value are written.

(18) Storage

The resistors in polyethylene bags are put in plastic container box for storage.

9. Electrical and Mechanical Characteristics of Style RD-P Carbon Film Fixed Resistor Specified by JIS C 6402

As for the text book of this paragraph, "JAPANESE INDUSTRIAL STANDARD, FIXED CARBON FILM RESISTOR, JIS C 6402" presented to C.T.R.L. from RIKEN DENGU SEIZO Co., Ltd., will be used.

9.1 Outline of this standard

The electrical and mechanical characteristics of Style RD-P carbon film fixed resistor, is specified clearly in this standard. The dimension of RD-P carbon film resistor, is larger as compared with other style specified by other JIS for the same wattage, but the stability required, is severer than other style of carbon film resistor and especially, the value of resistance change in percent, is the severest in the field of carbon film fixed resistors.

9.2 Test Item

Test items specified in the standard are as follows,

(1) Examination of dimensions

(2) Examination of finishing and marking

(3) Terminal strength test

(4) Resistance value

(5) Temperature characteristic of resistance

(6) Short time overload test

(7) Moisture resistance test

(8) Test of high frequency characteristic

(9) Load life test

(10) Test of resistance to soldering heat

(11) Temperature cycling test

(12) Vibration test

(13) Pulse test

10. Right Use of Resistor

(1) Correlation between temperature, moisture and voltage.
The resistor has correlation between temperature, moisture and voltage, so the circuit designer has to understand that electrical characteristics of resistor in standard or specification, are dependent on these factors.
If the ambient temperature of resistor is higher than specified temperature in its standard, the wattage rating must be derated in accordance with the derating curve of standard or specification.
The resistor which has large heat radiation with load, must be taken care of its radiation.

(2) Voltage rating and wattage rating
The voltage rating of resistor is rated with D.C. or A.C. (at commercial-line frequency), so if the resistor is used in high frequency, impulse, harmonics or resonance circuit, the load of resistor must be derated.
By some of impulse wave form, the deterioration of characteristics of resistor is accelerated, so circuit designer must be take care of impulse circuit especially.
If possible, the circuit designer must avoid to apply high voltage or much current to the resistor under so many resistors are connected in parallel or in series.

(3) Relationship between characteristic test of resistor and moisture
The characteristic test of resistor is decided by the basis of moisture. As for the assembling place of equipment, storage place of

resistor or keeping place of resistor, many attentions must be given to protect the resistor against moisture.
If the moisture is inhaled inside of the housing of resistor, electrolysis will appear on the resistive film under D.C. load especially, then the resistor will deteriorate or cause a failure.

(4) Circuit voltage and operating conditions of resistor
The circuit designer must pay attentions to circuit voltages which are applied to resistor such as D.C., A.C., high frequency, pulse and its wave form, high voltage or low voltage.
Also, he must pay attentions to operating conditions to the resistor such as continuous load, intermittent overload, high ambient temperature or high humidity.

(5) Safety rate of resistor at the circuit design
At the high density and complex circuit such as big system, circuit designer must take a safety rate of resistor.
For instance, the wattage loaded must be limited less than 75 % of wattage rating as the design value of resistor. Also, if the circuit is designed by limiting the maximum resistance up to 30 k ohm for 1/8 watt, 100 k ohm for 1/4 watt, 300 k ohm for 1/2 watt, 500 k ohm for 1 watt and 1 M ohm for 2 watt, the reliability will be become higher.

(6) Handling of resistor
At the connecting resistor to printed circuit board, its handling should be done carefully, and also the resistors must be at least kept apart more than 1/2 of its diameter each other. When the resistors are fit in piles, the resistors must be at least kept apart more than 1/2 of the diameter of resistor each other.

11. Useful Bibliography on Pyrolytic Carbon Film Resistor

The following list shows useful bibliographies on pyrolytic carbon film resistor. Especially, bibliography (1) is estimated highly from many engineers of resistor, and this bibliography is called as a bible of pyrolytic carbon film resistor in Japan.

(1) R.O. GRISDALE et al. "Pyrolytic Film Resistors: Carbon and Borocarbon". The Bell System Technical Journal. 30, P271-314. April 1951.

(2) G.W.A. DUMMER. "FIXED RESISTORS". SIR ISAAC PITMAN & SONS, LTD. 1957.

(3) R.H.W. BURKETT. "The Performance of Pyrolytic Carbon Resistors". Brit. Commun. and Electron., Vol. 6, P264-268, April, 1959.

(4) H.F. CHURCH. "The Long-Term Stability of Fixed Resistors". IRE. Transactions on Components Part P31-40. March, 1961.

(5) P.R. COURSEY. "Fixed Resistors for Use in Communication Equipment". Proc. IEE., Vol. 96, Part 3, P169-186. May, 1949.

(6) C.L. WELLARD. "Resistance & Resistors". McGraw Hill Book Co. 1960.

(7) G.W.A. DUMMER et al. "Recent Development in Fixed and Variable Resistors". Proc. Inst. Elect. Eng., Vol. 109, Part B. Supplement No. 21, P3, 1962.

(8) I.D.L. BALL et al. "High Stability Carbon Film Fixed Resistors, D.C. Failure in Moist Atmospheres". ERA Rept. Ref. Z/T 124; December, 1959.

(9) H. BRANER et al. "Life Characteristics of Carbon Film Resistors after 12,000 hours of Operation". Trans. AIEE, Vol. 78, P201-207. May, 1959.

(10) P. POPKEMA. "Carbon Film Resistors Reliability, Stability and Quality Control Considerations". PHILIPS Product Information 24, 30 Sept. 1970.

(11) Japanese Industrial Standard "JIS C 6402, Fixed Carbon Film Resistor". Dec. 1, 1977.

(12) IEC Recommendation Publication 68 "Basic Environmental Testing Procedures". International Electrotechnical Commission. Dec., 1972.

(13) IEC Recommendation Publication 115-1 "Fixed Resistors, Terms and Methods of Test". International Electrotechnical Commission. June, 1980.

12. Conclusion

(1) In this text book, the following items has been described.

1) History of pyrolytic carbon film resistor
2) Resistance materials
3) Nature of carbon film
4) Wattage and voltage
5) Explaining of resistance series, marking and class of carbon film fixed resistor
6) General information on manufacturing of carbon film resistor
7) Manufacturing method of Style RD-P carbon film resistor with the manufacturing system at C.T.R.L.
8) Explaining of JIS C 6402
9) Right use of resistor

10) Useful bibliography on pyrolytic carbon film resistor

(2) Pyrolytic carbon film resistor has the history more than 50 years since its development, and the resistor has so excellent characteristics that it has been used most quantity in the field of fixed film resistors. In addition to good characteristics, the resistor can be mass-produced, so the price of resistor is become very cheaper in comparison with other film resistors such as metal film or metal oxide film resistor.

(3) Up to today, so many improvements of carbon film resistor have been carried out, and when we look at the future tendency of it, carbon film resistor will be more small-sized due to the development of ceramic substrate having good thermal conductivity.

(4) The field of electronics will be expanded furthermore and the demand of the carbon film resistor will be increased furthermore.

13. Bibliography Used to Prepare This Text Book

(1) S. KONDO. "Investigation of Pyrolytic Carbon Film Resistor Used Forsterite Ceramic as A Substrate". REVIEW OF THE ELECTRICAL COMMUNICATION LAB. N.T.T. Public Corp. Vol. 15, No. 1, 1966.

(2) E. KAWAMATA & Y. KITAMURA. "Derating Curve of Fixed Carbon Film Resistor". Paper of Technical Committee on Electronic Component Parts, I.E.E.E. Japan, No. 57, 1960.

(3) E. KAWAMATA & Y. KITAMURA. "Tin and Carbon Complex Film Resistors". Journal of the Japan Society of Applied Physics". Vol. 44, No. 1, 1975.

(4) R.O. GRISDALE et al. "Pyrolytic Film Resistors: Carbon and Borocarbon". The Bell System Technical Journal. 30, 1951.

(5) G.W.A. DUMMER. "FIXED RESISTORS". SIR ISAAC PITMAN & SONS, Ltd., 1957.

Note: Bibliographies from No. (1) through No. (3) are written with Japanese language.

RIKEN DENGU SEIZO Co., Ltd.
4-5 HIGASHI-SAKASHITA 1-CHOME,
ITABASHI-KU, TOKYO 174, JAPAN

別添資料No. 5

Fundamental Considerations on Designing Pyrolytic Carbon Film Fixed Resistor

(Text Book No. 2)

Date: Feb. 12th, 1981
Approval for offering this document to C.T.R.L, PAKISTAN T & T Dept.

Yoshio WADA, Manager
Research & Development Dept.
RIKEN DENGU SEIZO Co., Ltd.

DESCRIPTION
by
Yoshinobu KITAMURA

SENIOR STAFF ENGINEER
RESEARCH & DEVELOPMENT DEPARTMENT

RIKEN DENGU SEIZO CO., Ltd.
4-5 HIGASHI-SAKASHITA 1-CHOME, ITABASHI-KU
TOKYO 174, JAPAN

TEL: 03-966-6176
TELEX: 272-3121

CONTENTS

1. Introduction

As everybody knows, resistors in practical use, radiate heat to dissipate their wattage due to the applied voltage. Therefore, in previous DIN (Deutche Industrie Normen), the hot spot temperature of resistor was specified less than 60 °C, when the rated wattage was applied to resistor.

In other hand, the following consideration was also existed. Namely, when the rated wattage is applied to the resistor under the rated continuous working temperature, the hot spot temperature including ambient temperature of resistor, should be less than the maximum ambient temperature specified in "Derating curve", and also the resistance change in "Load life test", shall be met the specified value in its standard or specification.

From these point, it is very important to consider the hot spot temperature and resistance change in load life test as design criteria of resistor.

In recent years, characteristics of ceramic substrate used for film resistor, has been improved very much, and small style resistors than 0.5 watt used mainly for electronic equipments of consumer's use, have trended to small-sized.

As a results, power up of resistor has been realized by presupposing that electrical and mechanical characteristics of resistor should be met with specified standard. (Namely resistor rated 1/4 watt, is used as 1/2 watt resistor)

2. Items to be Considered

As described above, it is very important to consider the temperature rise of resistor under load, on designing resistor.

In Fig. 1 the items to be considered, are listed.

3. Resistance Film

3.1 Decision of Sheet Resistance Value

When the completed resistance value (after spiral cutting) is designed for each style of resistor, firstly, the sheet resistance value (Rs) should be decided.

Generally, the sheet resistance is varied with film materials used as resistance film and completed resistance value. When the sheet resistance becomes higher, film thickness of resistance film becomes thiner and thiner, without regard to materials of film.

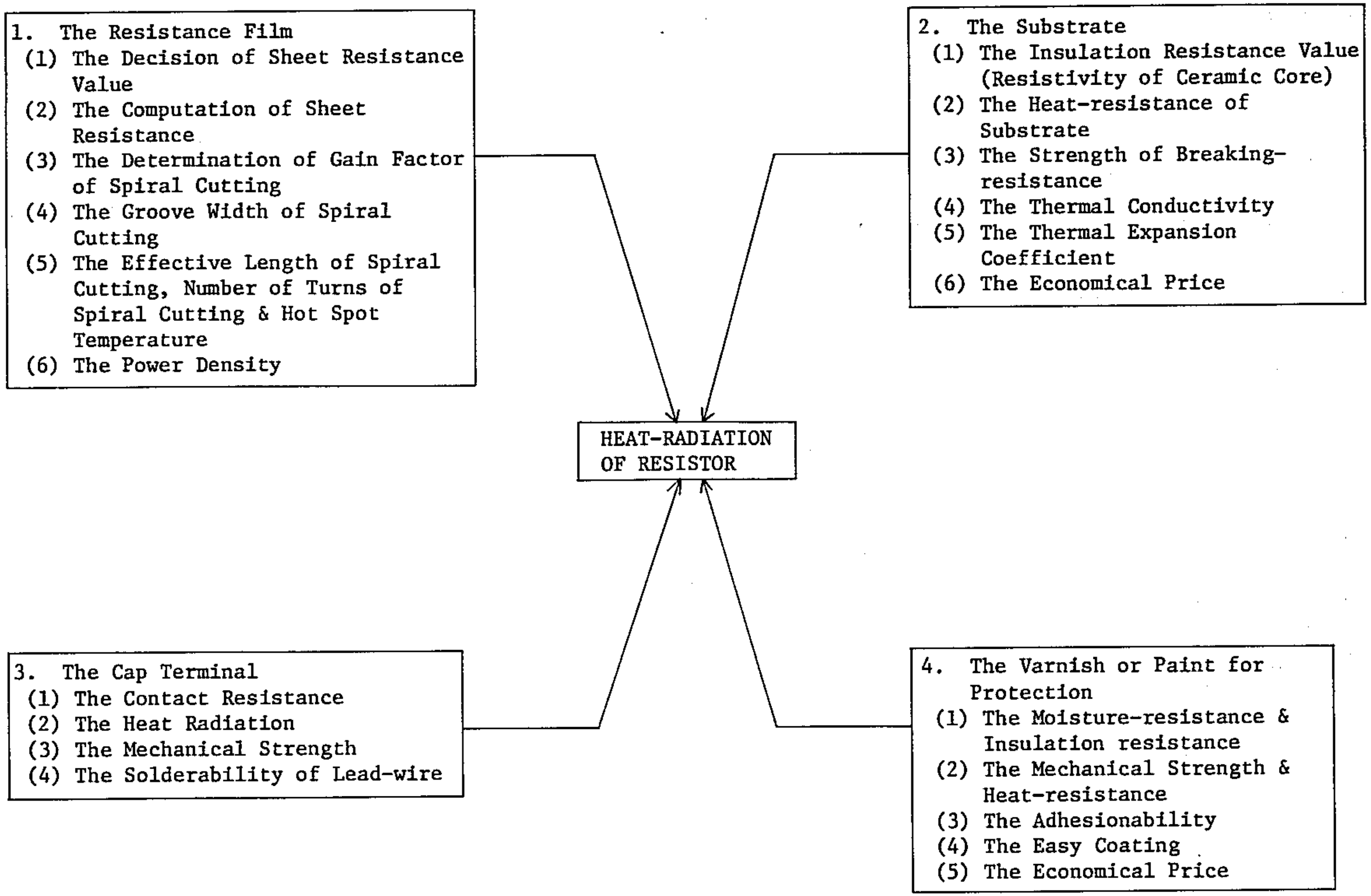


Fig. 1 The factors to be considered on designation of carbon film resistor

So, at the step of design of sheet resistance, it is desirable that appropriate sheet resistance range shall be decided from the applicable sheet resistance. Generally, these sheet resistance is selected from the experimental value accumulated for long time.

Fig. 2 shows the sheet resistance vs. completed resistance value of "Style RD-P carbon film fixed resistor.

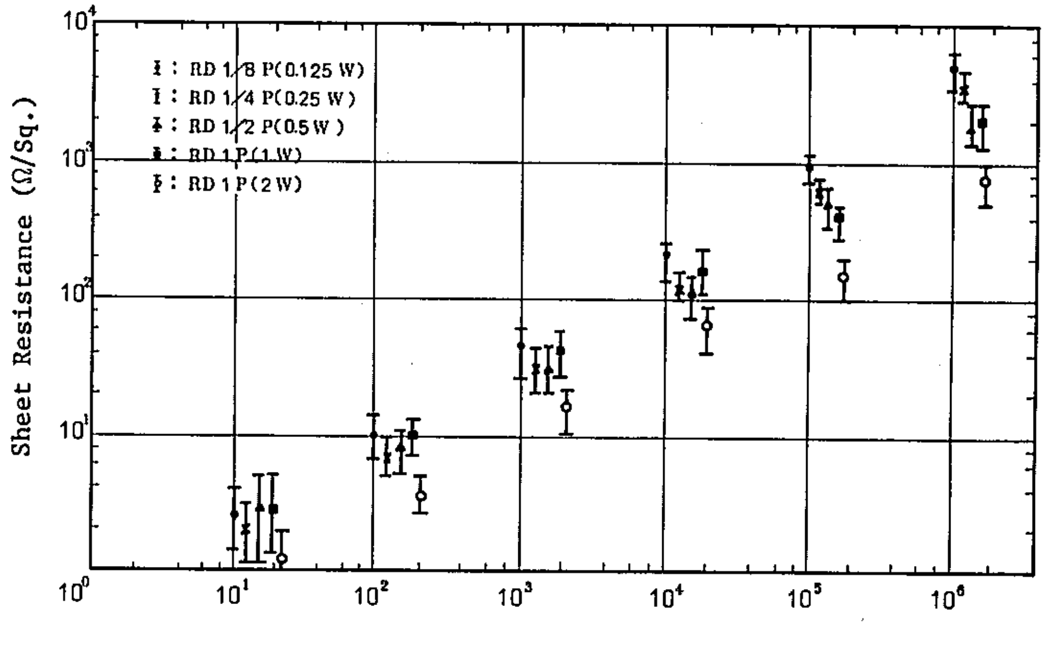


Fig. 2 Relation-ship between the sheet resistance and completed resistance (10 Ω, 100 Ω, 1 kΩ, 100 kΩ and 1 MΩ) of Style RD-P Carbon Film Fixed Resistors

3.2 Computation of Sheet Resistance

By unrolling carbon film resistor as shown in Fig. 3, it can be regarded as resistance film of straight pattern as shown in Fig. 4.

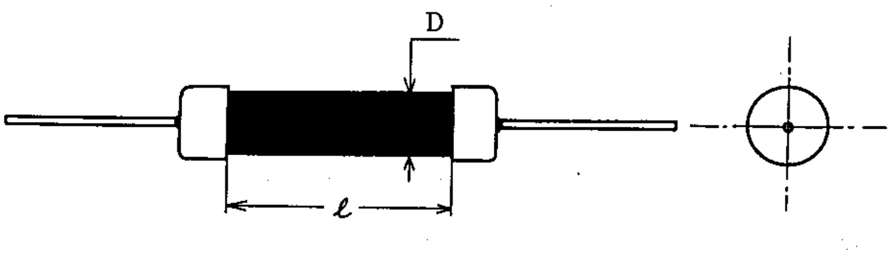


Fig. 3 The style of RD-P carbon film fixed resistor

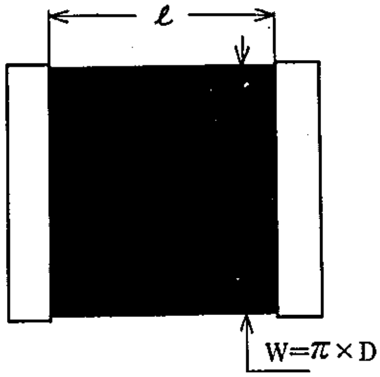


Fig. 4 The unrolled pattern of Style RD-P carbon film fixed resistor

"The sheet resistance (Ω/Sq.)" is computed as follows,

$$Rs(\Omega/Sq.) = Ro \times \frac{w}{\ell} \quad \cdots\cdots (1)$$

Where, "Ro" is resistance value before spiral cutting and "w" is also expressed as "D" so,

$$Rs(\Omega/Sq.) = Ro \times \frac{\pi D}{\ell} \quad \cdots\cdots (2)$$

This sheet resistance value is closely related to "Dissipation power", "Stability" and "Completed resistance after spiral cutting of carbon film resistor".

3.3 Determination of Gain Factor of Spiral Cutting

The gain factor "K" by spiral cutting is generally given as follows,

$$K = \frac{R}{Ro} = \frac{(\pi D)^2}{P(P-U)} \cdot \frac{\ell o-P}{\ell o} + \frac{P}{P-U} \quad \cdots\cdots (3)$$

Where, "Ro" is resistance value before spiral cutting,
"R" is resistance value after spiral cutting,
"D" is diameter of ceramic rod,
"P" is the value of pitch,
"ℓo" is effective length for the spiral cutting.
"U" is the width of groove cut.

At formula (3), $\frac{\ell o-P}{\ell o}$ and $\frac{P}{P-U}$, do not give so much influence to "K", usually, "K" is computed as follows,

$$K = \frac{R}{Ro} = \frac{(\pi D)^2}{P(P-U)} \quad \cdots\cdots (4)$$

Considering only that the temperature distribution of resistor with applying power loading, should be uniform, it is desirable that the pitch width of resistor is narrow close near the cap terminals, and is wider at the center of resistor body from a point of view of heat radiation due to cap terminals with lead wire, but this is impossible in practical use.

Assuming that the diameter of ceramic body "D" is constant, and minimum pitch value "P" is larger than groove width "U" (in practical manufacturing of resistor, "U" is varied in the limit of thickness of cutting wheel with dressing wheel), pitch value should be small to increase gain factor. But effective surface area of resistance film is decreased by spiral cutting, and the decreasing of effective surface area relates to long stability of resistor, therefore, the gain factor should not be increased unlimitedly.

The decreasing ratio of effective surface area should be limited up to 50 %.

3.4 Groove Width of Spiral Cutting

When the power rating of resistor is constant, the voltage rating applied to resistor, becomes higher infinitely as the resistance value increases infinitely by, so in the "Standard or Specification" of each style of resistor, the maximum permissible voltage rating, overload voltage and pulse voltage are specified respectively.

Table 1 shows these maximum voltages specified of "Style RD-P carbon film fixed resistor".

Table 1 Maximum voltages specified for Style RD-P carbon film fixed resistor

Style	RD 1/8 P	RD 1/4 P	RD 1/2 P	RD 1 P	RD 2 P
Power rating (W)	0.125	0.25	0.5	1	2
Max. continuous working voltage (V)	250	300	350	500	750
Max. overload voltage (V)	400	600	700	1000	1500
Max. pulse voltage (V)	500	750	1000	1500	2000

Well, groove width also relates to withstanding voltage closely. If the groove width is wider, the value of withstanding voltage is also become higher. Generally, the maximum groove width is equal to the thickness of cutting wheel (Disk), but the cutting wheel is usually dressed with dresser, so the tip thickness of cutting wheel is become narrower.

In the case of film fixed resistors which is smaller style than 2 watt including pyrolytic carbon film, metal film, and metal oxide film, the minimum groove width should be limited up to 0.2 mm (200 μ) from the point of withstanding voltage.

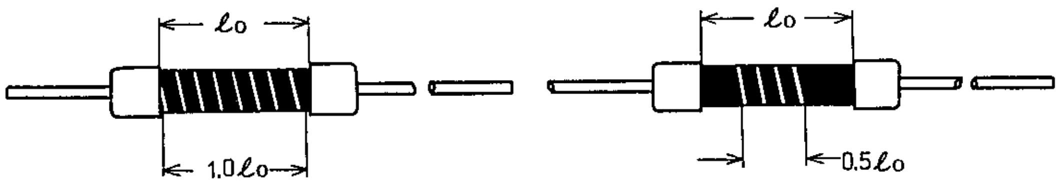
3.5 Effective Length of Spiral Cutting, Number of Turns of Spiral Cutting and Hot Spot Temperature

In Fig. 5, assuming that there are two resistors which have same dimensions and two different initial resistance values, "resistor (a)" has specified initial resistance value and "resistor (b)" has twice initial resistance value to specify.

Now, if "resistor (a)" is attained to completed resistance value by 100 % cut to the effective length of spiral cutting of resistor, "resistor (b)" is to be attained to same completed value by 50 % cut to the effective length.

In this case, number of turns of "resistor (a)" has twice turns of "resistor (b)" and if the same electrical potential is applied to both resistors, voltage per one turn of "resistor (a)" is a half voltage to the voltage per one turn of "resistor (b)".

On the other hand, as for temperature rise of resistor, the hot spot temperature of "resistor (a)" is to become a half value of "resistor (b)".



ℓo: 7.65 mm   U: 0.3 mm

Resistor (a)
RD 1/4 P 10 kΩ

Resistor (b)
RD 1/4 P 10 kΩ

Fig. 5 An example of the difference of number of turns

Fig. 6 shows an example of hot spot temperature of "RD 1/4 P" carbon film fixed resistor against power dissipated, due to the difference of length of spiral cutting.

Therefore, 100 % cut to the effective length should be carried out idealy, but it is difficult technically in practice, so the minimum cutting rate to the effective length should be considered.

This factor closely relates to the hot spot temperature and voltage distribution per one turn of spiral cutting.

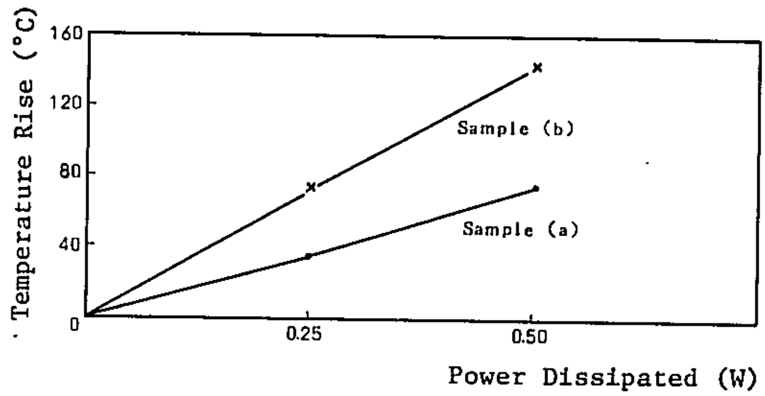


Fig. 6 An example of temperature rise of RD 1/4 P carbon film fixed resistors against power dissipated due to the difference of length of spiral cutting

3.6 Power Density

The power density also closely relates to the hot spot temperature of resistor. To reduce hot spot temperature of resistor, it is also necessary to derate the power density per square of resistance film, but in this case, to get a constant power rating, extending resistance film area is required that the dimensions of resistor becomes larger, and this is not desirable.

Generally, power density of resistance film is not determined easily, and it depends on film thickness and material of ceramic rod as a substrate (heat conductivity of ceramic). So, it is often determined from experimental values.

Fig. 7 shows an example of relationship between power rating and effective surface area of "Style RD-P" carbon film fixed resistor.

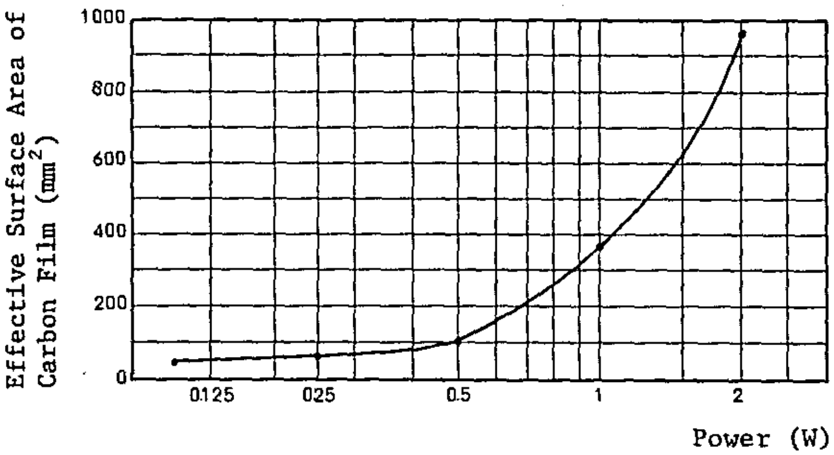


Fig. 7 Relationship between power rating and effective surface area of Style RD-P carbon film resistor

Fig. 8 also shows an example of the relationship of power rating and power density of "Style RD-P" carbon film fixed resistor. In this figure, "curve (a)" shows power density before spiral cutting and "curve (b)" shows power density after spiral cutting. (Assuming that the effective surface area of carbon film is having 50 % after spiral cutting)

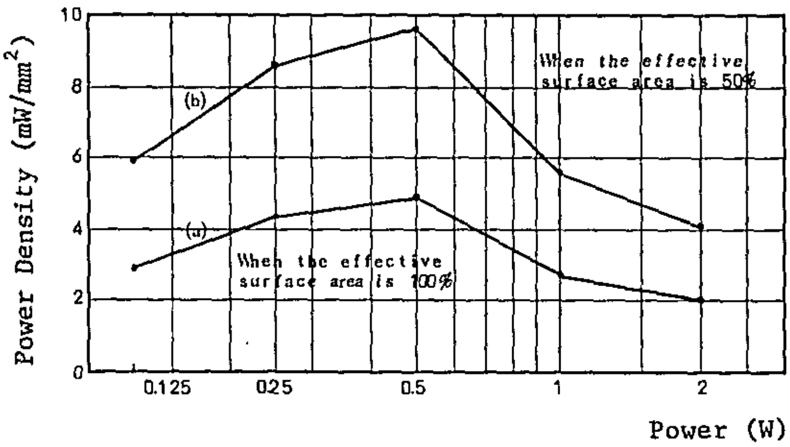


Fig. 8 Relationship of power rating and power density of Style RD-P carbon film fixed resistor

As mentioned above, power density is often determined from the experimental values. If the resistor meets the electrical characteristics required by its standard or specification, power density is not always limited but as for carbon film fixed resistor required severe load life characteristic such as "Style RD-P", it is desirable that the power density is limited less than 10 ∿ 15 milli watt/mm^2 at the maximum value.

4. Substrate

As well known, ceramic rod is generally used as a substrate of pyrolytic carbon film fixed resistor. As for ceramic rod, the following items are very important.

4.1 Insulation Resistance Value (Resistivity of Ceramic Rod)

The insulation resistance value of ceramic rod should be higher. This is related to alkali content (such as Na_2O or K_2O) of the ceramic rod, so it is desirable to use the ceramic rod which the total alkali contents is less than 1.5 %.

Generally, mullite ceramics are used as a substrate of pyrolytic carbon film, and forsterite ceramics are also used but the cost of forsterite ceramics is higher than mullite ceramics.

Fig. 9 shows an example of the relationship between resistivity and ambient temperature of mullite ceramics and also Table 2 shows data of various kinds of ceramic rod for pyrolytic carbon film resistor prepared by ceramic rod manufacturer.

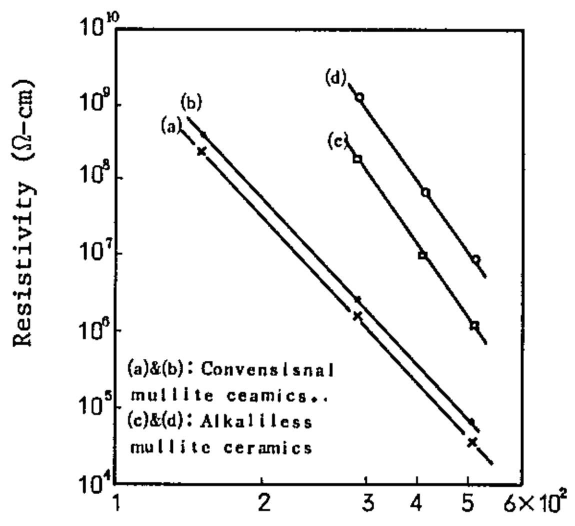


Fig. 9 Relationship between resistivity and ambient temperature of mullite ceramics. (From the data of Mr. S. KONDO, MUSASHINO E.C.L. of N.T.T. Tokyo)

Table 2 Data of Ceramic Rod (From the catalog of manufacturer of ceramic substrate)

Item \ Material	No. 3	SA-63	No. 5	FO-C
Principal Crystalization	Crystbalite & Mullite ($SiO_2+A\ell_2O_3.2SiO_2$)	Alkalilless Mullite ($3A\ell_2O_3.2SiO_2$)	Mullite & Corundum ($3A\ell_2O_3.2SiO_2+A\ell_2O_3$)	Forsterite $2M_gO.SiO_2$
Thermal Expansion Coefficient	4.9×10^{-6}	4.8×10^{-6}	6.0×10^{-6}	10.5×10^{-6}
Specific Gravity	2.44	2.40	2.99	2.87
Water Absorption (%)	0.000	0.000	0.000	0.000
Breaking-resistance (kg/cm^2)	1.303	1.010	1.585	1.470
Electrical Resistance at 300 °C (Ω-cm)	8.4×10^{8}	2.2×10^{9}	4.0×10^{10}	2.5×10^{11}
Softing Point (°C in air)	1,300	1,350	1,400	1,350
Thermal Conductivity ($Cal.cm/cm^2$ sec °C)	0.0027	0.0028	0.007	0.00821
Di-electric Const. (1 MHz 20 °C)	9	9	9	7
$\tan\delta$ (1 MHz 20 °C)	3×10^{-3}	1×10^{-3}	8×10^{-4}	1×10^{-4}
K_2O (%)	0.82	0.50	0.61	0.12
Na_2O (%)	0.55	0.52	0.32	0.38
Principal Application	Widely used for 1/4 W resistors.	Used for 1/2 W or higher resistors.	Used for 1/4 & 1/8 W resistors.	Widely used for 1/20 to 10 W precision resistors.
Features	1. Easily gets in close contact with carbon. 2. Strong mechanical strength	1. Easily gets in contact with carbon. 2. Low alkali content & good electric characteristic	1. Strong mechanical strength. 2. High thermal conductivity.	1. Low alkali content & good electric characteristic. 2. Strong mechanical strength.

4.2 Heat-resistance

Pyrolytic carbon film is generally deposited over the surface of ceramic rod at the pyrolytic temperature between 1,000 °C and 1,100 °C. Therefore, ceramic rod has to withstand such a high temperature, and this is also related to the softening point of ceramic rod.

It is necessary that the softening point of ceramic rod has at least more than 1,250 °C.

4.3 Strength of Breaking-resistance

To withstand mechanical strength required as a resistor, ceramic rod should be required to have its sufficient strength.

If the ceramic rod has a strength of breaking-resistance more than 1.0 kg/cm^2, it is no problem to use as a substrate of pyrolytic carbon film resistor.

4.4 Thermal Conductivity

Temperature rise of resistor and thermal conductivity of ceramic rod have close relationship each other, because a large thermal conductivity means that a thermal conduction to the cap terminal, is very good when the resistor is loaded and it results in making the temperature rise of resistor lower.

The thermal conductivity of mullite ceramics principally used as a substrate of pyrolytic carbon film resistor, is between 0.002 and 0.004 Cal/cm-sec-°C.

4.5 Thermal Expansion Coefficient

It is desirable that the thermal expansion coefficient of ceramic rod is fundamentally harmonized to the each part of construction of resistor, but it is actually impossible to make the thermal expansion coefficient of each constructed materials of resistor a constant value. Therefore, the most important factor is that the difference of expansion coefficient between pyrolytic carbon film and ceramic rod should be smaller as possible to prevent the stripping of carbon film from a surface of ceramic rod.

Table 3 shows an example of the thermal expansion coefficient of mullite ceramic and pyrolytic carbon film.

Table 3 Thermal expansion coefficient of mullite ceramics and pyrolytic carbon film

Material	Temperature (°C)	Thermal expansion coefficient
Mullite ceramics (a)	21 ∿ 400	3.6×10^{-6}/°C
Mullite ceramics (b)	21 ∿ 900	3.4×10^{-6}/°C
Pyrolytic carbon film	20 ∿ 240	$6.5 \sim 7.0 \times 10^{-6}$ /°C

From this table, it can be seen that the thermal expansion coefficient of pyrolytic carbon film has twice value to it of mullite ceramics. Therefore, to prevent the stress against carbon film, generally, "chemical etching processing" is done over the surface of ceramic rod and it results in increasing of carbon film adhesionability against the surface of ceramic rod.

4.6 Economical Price

Although the characteristics of ceramic rod is so superior, the ceramic rod with expansive price is not suitable for practical use. So, from this point, ceramic rod should be economical price and be easy to handling in addition to good electrical and mechanical characteristics.

5. Cap Terminal with Lead Wire

The cap terminal with lead wire relates to contact resistance to the carbon film, heat radiation of resistor, mechanical strength of the resistor and solderability of lead wire.

So, the following items are general requirements for cap terminal with lead wire.

5.1 Contact Resistance

It is desirable that the contact resistance between carbon film and inside of cap terminal is as less as possible, because the contact resistance especially affects to the lower resistance value being less than 5 ohm through 20 ohm. So, cap terminal should be adhered to the carbon film and stable resistance value is necessary.

If the contact conditions are not good, the current noise and voltage coefficient increase in addition to unstable resistance value.

5.2 Heat Radiation

To improve the characteristics under load of resistor, it is important that the heat arised by applying electrical potential, is radiated through cap terminal. But cap terminals with good heat radiation has also good effect of heat absorbability, therefore on the selection of cap material, it is necessary that the cap material harmonized between heat radiation and heat absorbability should be considered.

5.3 Mechanical Strength

The mechanical strength should be adequate to withstand the terminal strength which the resistor is required by its standard or specification.

5.4 Solderability of Lead Wire

The solderability of lead wire has unexpectedly been overlooked, but the solderability plays a part which can not ignore under the operating condition of resistor, and it has been said that most of failures of discrete components such as resistor, capacitor, transistor and diode etc, after assembling as a electronic circuit network, is caused by incomplete soldering.

As a lead wire of film fixed resistor, copper wire plated solder has been widely used, therefore, at a selection of lead wire, it is necessary that the composition of solder and the thickness of solder plating should be considered.

6. Varnish and Paint for Protection

To protect a resistor from mechanical damage and surrounding environment such as moisture or gas etc, and to make a resistor has good electrical insulation, varnish and paint are generally coated over the surface of resistor body. Therefore, following factors should be considered on varnish and paint.

6.1 Moisture Resistance and Insulation Resistance (Resistivity)

It is desirable that the moisture resistance of varnish or paint is higher. Namely, it should be considered that the rate of water absorption of varnish or paint is as little as possible.

Also, the insulation resistance should be higher.

6.2 Mechanical Strength and Heat Resistance

The mechanical strength of varnish and paint should be large and also varnish and paint should have sufficient heat resistance not to cause the thermal deterioration under the working conditions of resistor.

6.3 Adhesionability

To the surface of carbon film and cap terminal, good adhesionability and low stress are required.

6.4 Easy Coating

To the surface of resistor body, the coating work should be easy and varnish or paint is required easy handling.

6.5 Example of the Characteristic of Varnish and Paint

Table 4 shows characteristics of varnish and paint used for Style RD-P carbon film fixed resistor which is manufactured at C.T.R.L.

Table 4 Data of varnish & paint for the protection of resistive element

Item \ Characteristic	Varnish for primary coat	Paint for finish coat
Color	Slight brown	Light green
Specific Gravity at 25 °C	1.050∿1.065	1.2
Viscosity at 25 °C (CP)	250∿400	350∿550
Gel Time at 140 °C (Min)	3∿7	
Cure Condition at 160 °C (Min)	60	60
Resistivity at 23 °C (Ω-cm)	$>14^{14}$	$>10^{14}$
Water Absorption, 24 hrs (%)	<0.1	<0.2

6.6 Economical Price

The price of varnish and paint should be cheaper.

7. Conclusion

(1) On designing a carbon film fixed resistor, its fundamental considerations have been described.
Basically, it should be considered that the temperature rise of resistor is closely related to the designation of film fixed resistor.

(2) Various conditions required for pyrolytic carbon film, substrate, terminations and protection material of which construct pyrolytic carbon film fixed resistor, have been described.

(3) When we look at the completed pyrolytic carbon film fixed resistor, it should be paid attention as for an actual resistor that various mechanical and electrical characteristics of the resistor are observed as a synthesized characteristic which the constructive parts, mentioned in (2), has been organized.

RIKEN DENGU SEIZO Co., Ltd.
4-5 HIGASHI-SAKASHITA 1-CHOME,
ITABASHI-KU, TOKYO, 174 JAPAN

別添資料No. 6

General Information of Present Technique and Future Trend on Pyrolytic Carbon Film, Metal Film and Metal Oxide Film Fixed Resistor.

(Text Book No. 3)

Date: Feb. 12th, 1981
Approval for offering this document to C.T.R.L, PAKISTAN T & T Dept.

Yoshio WADA, Manager
Research & Development Dept.
RIKEN DENGU SEIZO Co., Ltd.

DESCRIPTION
by
Yoshinobu KITAMURA

SENIOR STAFF ENGINEER
RESEARCH & DEVELOPMENT DEPARTMENT

RIKEN DENGU SEIZO Co., Ltd.

4-5 HIGASHI-SAKASHITA 1-CHOME, ITABASHI-KU
TOKYO 174 JAPAN

TEL: 03-966-6176
TELEX: 272-3121

CONTENTS

1. Introduction

In the field of passive components, resistor is one of three essential elements of circuit components, and it is indispensable to organize electronic circuit network.

In recent years, with the progress of miniaturization of resistor including fixed resistor and variable resistor, the size of them has been reduced from 1/3 to 1/5 approximately than the size of resistor before miniaturization.

These miniaturized resistors are mainly applied for consumer's electronic equipments such as Radio receiver, T.V., Tape recorder and Audio component system, but the resistor applied for industrial electronic equipment, has been required more stability and reliability than the resistor for consumer's use, therefore the resistor for industrial use, is not so miniaturized up to today.

In this text book, at first, "The History of Resistor", "The Classification of Resistor" and "The General Application of Film Fixed Resistor", have been described, then "The General Information of Present Technique and The Future Trend on Pyrolytic Carbon Film, Metal Film and Metal Oxide Film Fixed Resistor", have been described from the view points of mass-production.

2. History of Resistor

As old-fashioned resistor, resistor coated black ink or graphite colloid over the surface of substrate, had existed, but in 1897, T.E. GRAMBRELL developed carbon film resistor with resistive ink made from mixture of carbon powder and binder.

In 1901, W.H. LEENARD developed vitreous enamel glazed at 700 °C and this method promoted the vitreous enameled wire wound resistor.

In 1919, F.K. KRUGER developed the precise adjusting method of resistance value by cutting over the surface of resistance film spirally, and he contributed very much to the development of film resistor.

Also in 1919, F.K. RICHTMEYER developed metal film resistor by cathode sputtering, and in 1924, C.A. HARTMAN developed pyrolytic carbon film by the pyrolysis method of hydrocarbons.

In 1925, L. BRADLEY developed carbon composition solid resistor and in 1931, J.T. LITTLETON developed metal oxide film resistor by heating-reduction of Tin chrolide.

3. Classification of Resistor

Table 1 shows the classification of resistor. At first, resistors are roughly divided into "fixed resistors" and "variable resistors". Then, they are divided into "carbon group" and "metal group".

Finally, they are subdivided into various kinds of resistor.

4. General Application of Film Fixed Resistor

4.1 Pyrolytic Carbon Film Fixed Resistor

The pyrolytic carbon film fixed resistors have been used for all electronic equipments, and its quantity used, takes No. 1 place in the field of film fixed resistors.

The principal application are as follows,

(1) Radio receiver, T.V. and V.T.R.
(2) Tape recorder and Audio component system
(3) Wire and Wireless communication equipment
(4) Radio waves equipment and electronic computer
(5) Process control equipment and measuring equipment
(6) Telephone receiver and electronic switching systems
(7) Radar systems and missile guidance systems
(8) Car electronics equipment

4.2 Carbon Composition Film Fixed Resistor

As resistance film of this resistor, resistive ink or paste mixtured carbon powder and resin, is coated over the substrate.

(1) Micro wave circuit
(2) Radio receiver and tape recorder (AS printing resistor).

4.3 Metal Film Fixed Resistor

The resistance film of the resistor, are deposited over the surface of ceramic substrate by vacuum evaporation or sputtering, and metal film resistor has very tight resistance tolerance in addition to small temperature coefficient of resistance, so these resistors have been applied for electronic circuit network required very high precision.

The principal applications are as follows,

(1) Wire and wireless communication equipment

Table 1 Classified table of resistor

Name	Classification	Group	Resistance material	Manufacturing method of resistance element	Name of product
Resistor	Fixed	Carbon group	Carbon film	Pyrolytic carbon film	(1) Coated carbon film resistor
					(2) Coat-insulated carbon film resistor
					(3) Insulated carbon film resistor
					(4) Hermetic seal carbon film resistor
					(5) Carbon film strip resistor
				Carbon composition film	(6) Printing resistor
					(7) Strip resistor for micro wave
					(8) Resistor networks
			Carbon composition	Mixture of carbon & resin	(9) Carbon composition resistor (Solid)
				Mixture of carbon, ceramic & resin	(10) Ceramic-carbon composition resistor (Solid)
		Metal group	Metal film	Evaporated NiCr or Ta film	(11) Coat-insulated metal film resistor
					(12) Insulated metal film resistor
				Reduction of Tin chloride	(13) Coated metal oxide film resistor
					(14) Coat-insulated metal oxide film resistor
				Firing of resistor paste contains precious metals	(15) Cermet film resistor (Thick film)
			Resistance wire	Single-winding	(16) Precision wire wound resistor
					(17) Chassis mounted wire wound resistor
					(18) Low power type wire wound resistor
				Multi-winding	(19) Power type coated wire wound resistor
					(20) Fusing resistor
	Variable	Carbon group	Carbon composition	Mixture of carbon & resin	(21) Carbon composition potentiometer
		Metal group	Metal film	Evaporated NiCr or Ta film	(22) Metal film potentiometer
				Firing of resistor paste contains precious metals	(23) Cermet film potentiometer
			Resistance wire	Single-turn type	(24) Pre-set wire wound potentiometer
					(25) Power type wire wound potentiometer
					(26) Low power type wire wound potentiometer
					(27) Precision wire wound potentiometer
					(28) Slide type wire wound potentiometer
				Multi-turn type	(29) Wire wound trimming potentiometer
					(30) Helipot type wire wound potentiometer

(2) Radio waves equipment and electronic computer
(3) Process control equipment and measuring systems
(4) Electronic switching systems
(5) Radar systems, missile guidance systems and other military electronics equipment
(6) Aerospace electronics equipments
(7) Analyzers for medical electronics

4.4 Metal Oxide Film Fixed Resistor

Metal oxide film are deposited by heat-reduction of Tin chrolide. As the heat-resistance of this film is very high, the resistor can with-stand power loading under conditions of smaller style than other film fixed resistor, so this resistor has been applied for the power source circuit of various electronic equipments.

The principal applications are as follows,

(1) Radio receiver and T.V.
(2) Audio component system and V.T.R.
(3) Electronic measuring systems, communication equipment and computer

4.5 Cermet Film Fixed Resistor

The resistor is also called as thick film resistor or metal glaze resistor, and resistor ink is coated over the surface of ceramic core as a resistance film, then element will be fired at high temperature with electric furnace.

The resistor has taken in a merit of carbon composition solid resis-tor, and has made up fore defects of solid resistor.

The principal applications are as follows,

(1) Telephone receiver and communication equipment
(2) Process control equipment and computer
(3) Missile guidance systems

5. General Information of Present Technique, and Future Trend on Pyrolytic Carbon Film, Metal Film and Metal Oxide Film Fixed Resistor

5.1 Pyrolytic Carbon Film Fixed Resistor

5.1.1 Coated Carbon Film Fixed Resistor (Style RD-P)

5.1.1.1 Definition

Resistive element is formed with the carbon film deposition over surface of ceramic rod by pyrolysis of hydrocarbons, and cap terminals with lead wire are mounted both ends of the element, then coating with paint is carried out over the resistor body except for lead wire.

5.1.1.2 Name

Formally, it is called coated carbon film fixed resistor, but generally, is called carbon film resistor or Style P carbon film resistor in Japan.

5.1.1.3 Feature

In comparison with other style of carbon film fixed resistor, the size is larger to same wattage, therefore,

(1) The rate of redundancy is prepared for overload, such as short time duration or pulse.

(2) It is possible to manufacture the resistor having resistance tolerance up to ±0.5 %. The resistor having resistance tolerance ±0.5 %, is only this style.

(3) The resistor is principally applied for industrial electronic equipment including precious measuring equipment, switching system or telephone receiver.

(4) Temperature rise of resistor under load, is less than other style.

5.1.1.4 Construction and Dimension

Fig. 1 shows the construction of "Style RD-P carbon film resistor". Power rating of this resistor is specified from 1/8 watt through 2 watt by JIS C 6402. Resistance tolerance are applied from ±0.5 % through ±10 %. Table 2 shows the power rating and dimensions for every style.

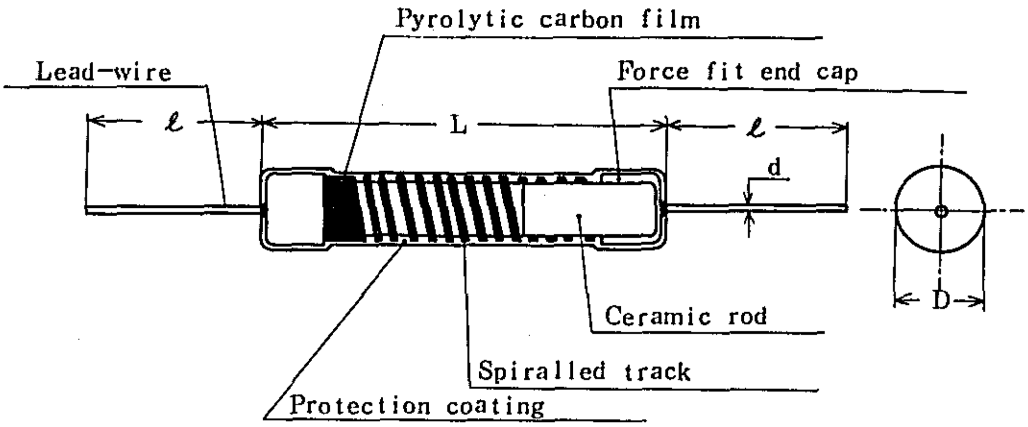


Fig. 1 Construction of Style RD-P carbon film fixed resistor

Table 2 The dimension of resistor

Unit: mm

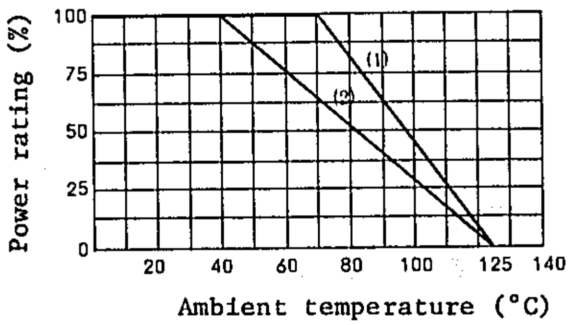
Style	Power (W)	L	D	d*	ℓ
RD 1/8 P	1/8	9 ± 1.5	2.5 ± 1	0.6 ± 0.1	38 ± 3
RD 1/4 P	1/4	13 ± 1.5	2.5 ± 1	0.6 ± 0.1	38 ± 3
RD 1/2 P	1/2	15 ± 1.5	4.5 ± 1	0.8 ± 0.1	38 ± 3
RD 1 P	1	24 ± 1.5	7.5 ± 1	0.9 ± 0.1	38 ± 3
RD 2 P	2	52 ± 1.5	7.5 ± 1	0.9 ± 0.1	38 ± 3

* The lead diameter (d) of the terminal is nominal dimension.

5.1.1.5 Applicable Temperature Range

The applicable temperature range is from 0 °C through 125 °C. For the resistor of characteristic A and B, the rated power can be loaded from 0 °C to 70 °C, but for the resistor of characteristic X, Y and Z, the rated power can be loaded from 0 °C through 40 °C.

When the ambient temperature of resistor is over than 40 °C or 70 °C, the power should be derated for any characteristic of resistor, in accordance with the derating curve shown in Fig. 2.



* Line (1) shall be applicable for the characteristic A and B, also, line (2) shall be applicable for the characteristic X, Y and Z.

Fig. 2 The derating curve of Style RD-P carbon film fixed resistor by JIS C 6402

5.1.1.6 Materials Used

(1) Substrate
Generally, alkaliless mullite ceramic rod is used as the substrate.

(2) Resistance film
The raw material for deposition of carbon film is principally hydrocarbons such as benzene.

(3) Cap
The cap which copper and tin are plated on the steel or brass, are usually used.

(4) Lead wire
The soft copper wire for electrical use specified by JIS, is principally used and also over the surface of wire, solder is plated with the thickness from 5 μ to 20 μ.

(5) Protection
As a primary coating material for the element, varnish such as phenol resin, is usually used and as a finish coating, paint including such as epoxy resin is used.

5.1.1.7 Present Technique of Production

(1) These resistors have been principally used for the telephone receiver and switching system purchased by N.T.T. (Nippon Telegraph & Telephone Public Corp.) or other electronic equipments for the industrial use in Japan.

(2) As mentioned in "Feature Trend", the resistor having especially tight resistance tolerance such as ±0.5 % or ±1 % can be manufactured, therefore the resistor has been used for precise electronic measuring equipment in the field of industrial use.

(3) Therefore, the production quantity of the resistor is not so much in comparison with general purpose carbon film resistor such as coat-insulated type described later.

(4) The production system is medium scale and it is not complete automatic machine. The semi-automatic machine has been comparatively much used in Japan.

(5) The block diagram of general manufacturing process is as shown in Fig. 3.

5.1.1.8 Future Trend

The future trend of this resistor is considered as follows,

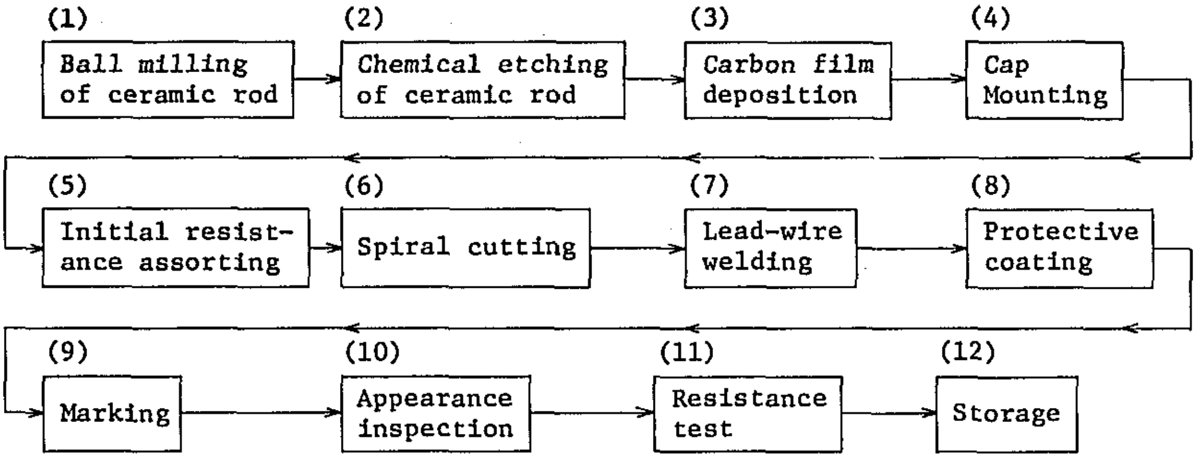
(1) In Japan, considering that the resistor insulated over the surface of this type with paint (Coat-insulated type of Style RD-P), has been applied for "Electronic Switching System of N.T.T." as a standard component, the resistor will be applied for the various precision industrial electronic equipments.

(2) As for the dimension of resistor applied, except for large equipment such as switching system, the resistor which is smaller than 1/2 watt style, will be applied due to the miniaturization of equipment.

(3) The demand of the resistor having ±0.5 % tolerance, will be increased, because in other style of carbon film resistor, this resistance tolerance is not applicable in its standard or specification.

(4) The quantity of demand of this resistor will be increased gradually, but not be increased suddenly, therefore, the manufacturing system will not become full automatically.

(5) As for manufacturing equipments, it is necessary that the automatic spiral cutting machine and the measuring equipment which are applicable to ±0.5 % tolerance, will be developed.



Note:
1) Carbon film deposition is generally carried out by the batch system.
2) Cap mounting is carried out by the automatic capping machine.
3) Initial resistance assorting is carried out by the automatic machine.
4) Usually, spiral cutting is carried out by the automatic cutting machine, but in the case of precise resistance tolerance such as ±1.0 % or ±0.5 %, the cutting is usually with semi-automatic machine or manual cutting machine.
In those case, cap terminal with lead wire is mounted before spiral cutting.
5) From lead welding through marking and resistance test is usually carried out with automatic machine, but when the resistance tolerance is ±0.5 %, resistance test is measured with D.C. bridge or digital ohm meter.

Fig. 3 The block diagram of general manufacturing process of Style RD-P carbon film fixed resistor at manufacturer

5.1.1.9 Direction of Development of Style RD-P Carbon Film Resistor

From the point of view of safety, flame-proof resistor will be required.

5.1.2 Coat-insulated Carbon Film Fixed Resistor (Style RD-H & V)

5.1.2.1 Ddfinition.

Resistance element is formed with the carbon film deposited over the surface of ceramic rod by pyrolysis of hydrocarbons, and cap terminal with lead wire is mounted to the both end of the element, then thick protective coating more than 100μ, is carried out over the resistor body for the purpose of insulation except for lead wire.

5.1.2.2 Name

It is called "Coat-insulated Carbon Film Resistor" or "Conformal-coated Carbon Film Resistor".

5.1.2.3 Feature

In comparison with other styles of carbon film fixed resistor such as coated or insulated(molded) style, the size is the smallest to same wattage. The features are as follows,

(1) As the element is protected with coat-insulation, it is possible to apply the resistor for the crowded electronic circuit, so the equipment will be able to be small-sized.

(2) The resistor is miniaturized.

(3) The method of mass-production has been established, and the price of resistor is the cheapest in carbon film resistor.

(4) In accordance with the requirement of customer, the forming of lead wire and taped lead wire are available.

(5) As the manufacturing system is highly automated, the feature of production of small size carbon film resistor is exhibited, and matching to the automatic insertion of resistor into P.C.board, is the most progressive.

5.1.2.4 Construction and Dimension.

Fig.4 shows the construction of Style RD-H carbon film resistor. Table 3 shows the power rating and dimension for every H style. Fig.5 also shows the construction of Stylr RD-V carbon film resistor. The power rating and other requirements are specified by EIAJ RC-2652 (ELAJ means Electronic Industry Association of Japan. JIS as the national standard, is not yet specified in Japan).

The resistance tolerance is specified for ±2% and ±5% only.

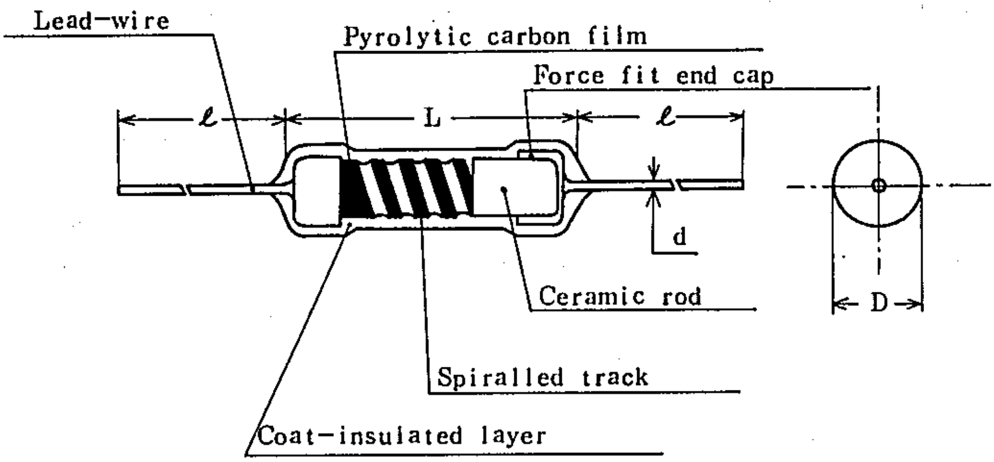


Fig. 4 Construction of Style RD-H carbon film fixed resistor

Table 3 The dimensions of resistor

Unit: mm

Style	Power (W)	L	D	d	ℓ
RD 1/8 H	1/8	3.7 ± 0.4	1.6 ± 0.3	0.4	30 ± 3
RD 1/4 H	1/4	6.4 ± 0.5	2.3 ± 0.4	0.6	30 ± 3
RD 1/2 H	1/2	9.5 ± 1.0	3.5 ± 0.5	0.8	30 ± 3

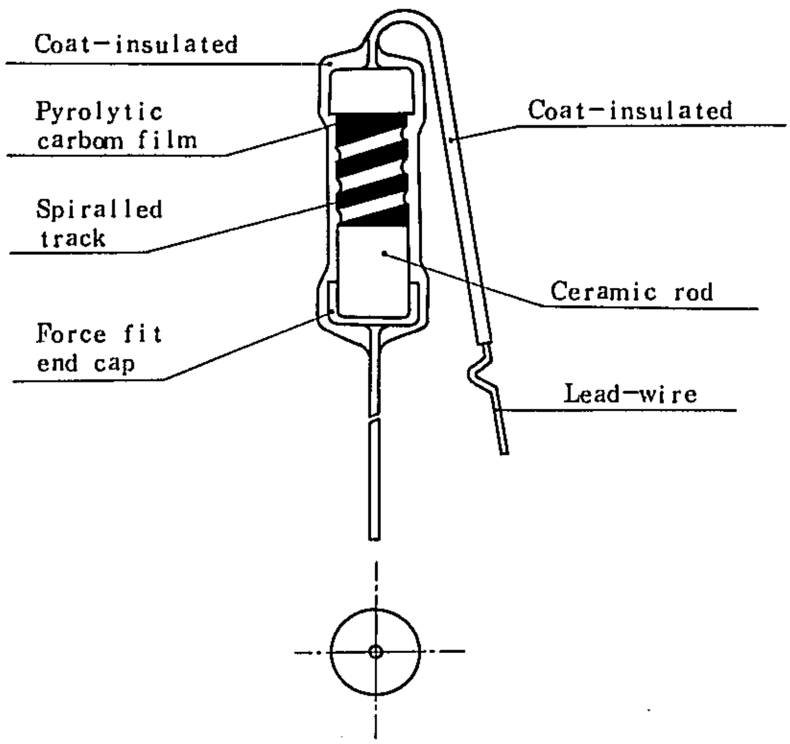


Fig. 5 Construction of Style RD-V carbon film fixed resistor

5.1.2.5 Applicable Temperature

The continuous working ambient temperature at full power, is up to 70 °C, therefore, when the ambient temperature of resistor is higher than 70 °C, the power should be derated in accordance with derating curve shown in Fig. 6.

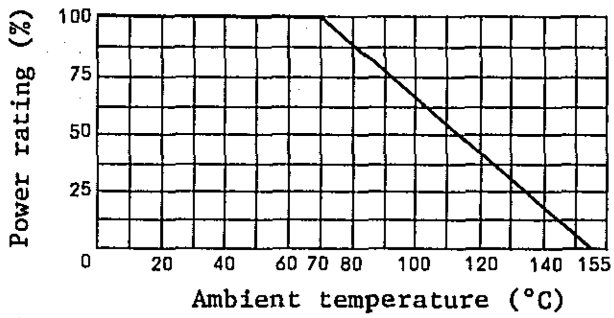


Fig. 6 The derating curve of Style RD-H and RD-V carbon film fixed resistor by EIAJ RC-2652

5.1.2.6 Material Used

(1) Substrate
Mullite, forsterite or alumina ceramic rod is generally used as a substrate.

(2) Resistance film
The raw material for deposition of carbon film is principally hydrocarbons.

(3) Cap
The host material is steel, and multi layer of copper and tin, is plated over the surface of steel.

(4) Lead wire
Soft copper wire plated solder over the surface of wire, is mainly used, but sometimes, the steel wire plated copper over the surface of wire is used to make cost down. (This wire is also called as copper apply wire or copper weld wire, and both names are registered name in U.S.A.)

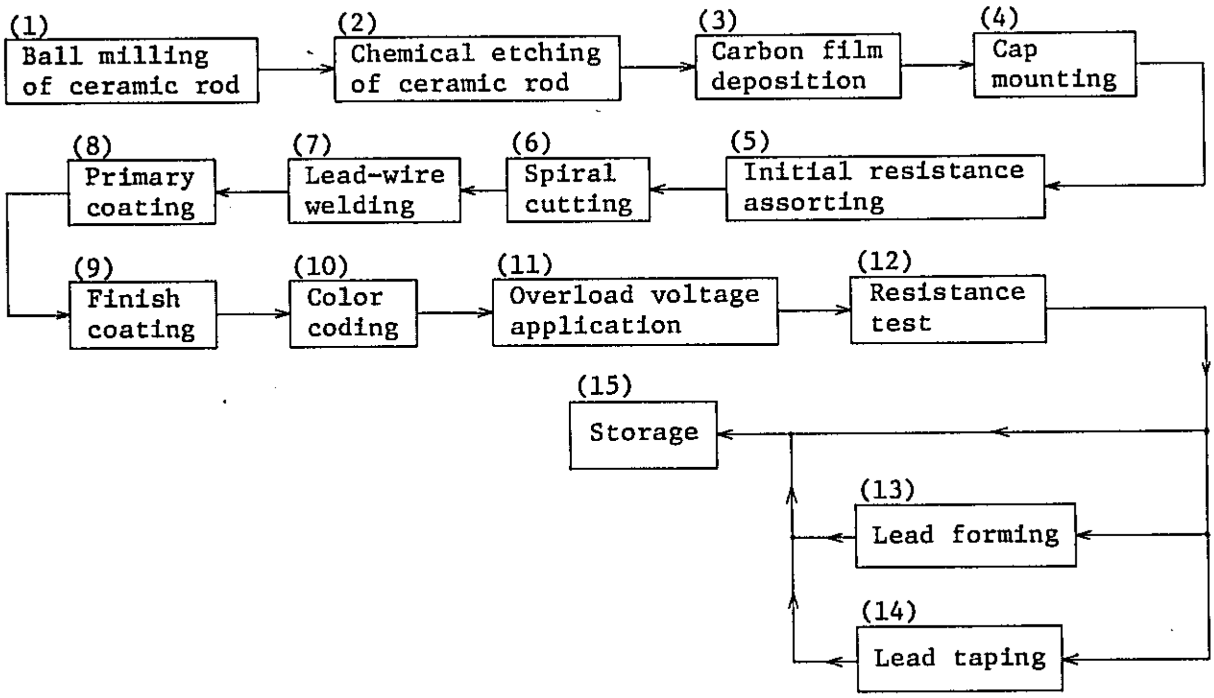
(5) Protection
As a primary coating material for the element, phenol group varnish is used and for the finish coating, paint including epoxy resin is used. In the coating process of this resistor, varnish or paint which has rapid curing nature, is used. As a finish coating, thick coating layer more than 100 μ, is coated to make the resistor body insulated.

5.1.2.7 Present Technique of Production

(1) In Japan, the resistor of this type has been generally used for the consumer's electronic equipment including Radio, T.V., Audio component and V.T.R. in large quantity and major part of manufacturing process of this resistor is constructed of automatic machine.

(2) The numbers of resistor manufactured per month, are different from the manufacturer, but it is expected from 10 million pcs, minimum through 320 million pcs, maximum per manufacturer recently in Japan, therefore, the resistor has been exported in large quantity for U.S.A., West European Countries and South-east Asian Countries from Japan.

(3) The block diagram of general manufacturing process is as shown in Fig. 7.



Note: 1) The process from (1) through (3), are generally carried out by batch system.

2) The process from (4) thorugh (14), is generally carried out by automatic manufacturing machine.
But cap mounting (4), initial resistance assorting and spiral cutting are processed under respective automatic machine due to the difference of machine speed.

3) The process from (7) through (12), is generally carried out under combined automatic machine, (This machine is usually called Coating machine) and if lead forming or lead taping are necessary in the process, it is possible to joint these automatic machine with combined automatic machine called coating machine.

Fig. 7 The block diagram of general manufacturing process of Style RD-H and RD-V coat-insulated carbon film fixed resistor

5.1.2.8 Future Trend

The future trend of this resistor is considered as follows,

(1) The resistor has not rate of redundancy to the overload voltage application or pulse load due to small-sized style, therefore, the improvement of these weak point will be necessary.

(2) As every body knows, electronic circuit network has transferred from vacuum tube to transistor, so from the point of view of electrical characteristics and economy of this resistor, the resistor will pretty occupy the market of carbon composition solid resistor in future. So, application field of this resistor will be developed and production quantity will be increased more and more. It is considered that leading position in its quantity will not be moved for a while.

(3) As for automatic manufacturing equipment, the through system from cap mounting process to resistance check process, will be desired to be developed.

5.1.2.9 Direction of Development of Style RD-H and RD-V Carbon Film Resistor

(1) To assure the safety of equipment from fire, it is important to promote the incombustible resistor.

(2) The adaptability of automatic insertion machine of resistor for P.C. board, should be improved.

(3) The improvement of solvent-resistance of resistor.

(4) The establishment of assurance for dielectric withstanding voltage of resistor.

5.1.3 Insulated Carbon Film Fixed Resistor (Style RD-M)

5.1.3.1 Definition

Resistance element is formed with the carbon film deposition over surface of ceramic rod by the pyrolysis of hydrocarbons, and cap terminal with lead wire are mounted to the both end of element, then compression molding with plastic resin, is carried out over the resistor body for the purpose of insulation.

5.1.3.2 Name

It is called insulated type carbon film fixed resistor formally, and also is called molded carbon film resistor.

5.1.3.3 Feature

(1) As this resistor has been designed for the purpose of improvement of dielectric withstanding voltage and moisture resistance with compression molding, the electrical and mechanical characteristics including items mentioned above, is superior to coat-insulated carbon film resistor.

(2) Its size is smaller than Style RD-P carbon film resistor and is as same as carbon composition solid resistor.
Due to the high dielectric withstanding voltage, good moisture proof and mechanical strength, the resistor has been used for the industrial electronic equipment or military electronic equipment including communication equipment, computer, measuring equipment, process control equipment, missile guidance system, radar system and radio waves equipment etc, since its joint development by RIKEN and TOSHIBA Corp. in 1955.

(3) Due to its small-sized style and high quality, this resistor has been applied for high grade audio component system in addition to industrial or military use in recent years.

5.1.3.4 Construction and Dimension

Fig. 8 shows the construction of Style RD-M carbon film resistor. The power rating and other requirements are specified by JIS C 6407. The resistor also meets with MIL-R-10509 (Military specification of U.S. Forces) and Defense Specification of Japanese Defense Agency.

The resistance tolerances are applied from ±1 % through ±5 %. Table 4 shows the power rating and dimension for Style RD-M carbon film resistor.

5.1.3.5 Applicable Temperature Range

The continuous working ambient temperature at full power, is up to 70 °C, so when the resistor is operated at ambient temperature higher than 70 °C, the power loaded should be derated in accordance with the derating curve shown in Fig. 9.

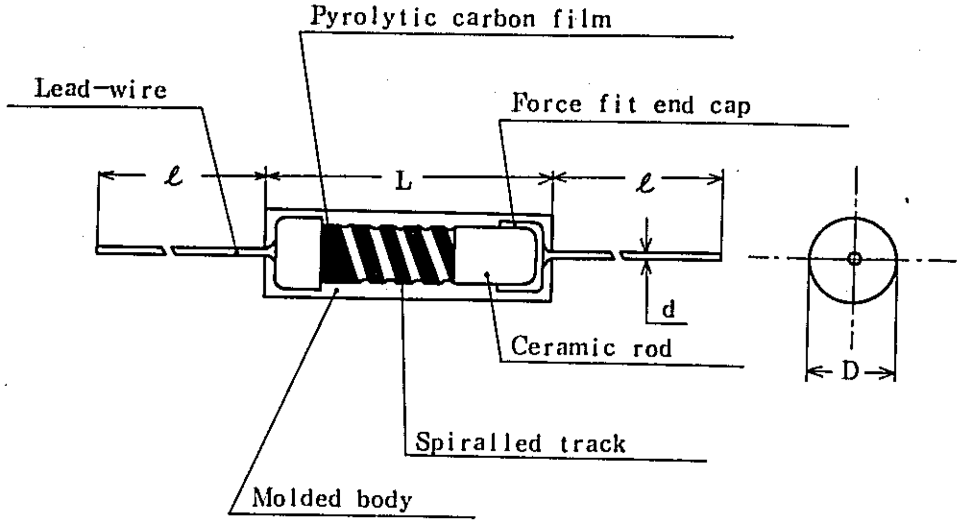


Fig. 8 The construction of Style RD-M carbon film fixed resistor

Table 4 The dimension of resistor

Unit: mm

Style	Power (W)	L	D	d*	ℓ
RD 1/8 M	0.125	6.4 ± 1.0	2.4 ± 0.4	0.5	38 ± 3
RD 1/4 M	0.25	9.5 ± 1.0	2.4 ± 0.4	0.7	38 ± 3
RD 1/2 M	0.5	9.5 ± 1.0	3.5 ± 0.4	0.8	38 ± 3
RD 1 M	1	14.3 ± 1.0	5.7 ± 0.4	1.0	38 ± 3
RD 2 M	2	17.5 ± 1.0	8.1 ± 0.4	1.2	38 ± 3

* The lead diameter (d) of the terminal is nominal diameter.

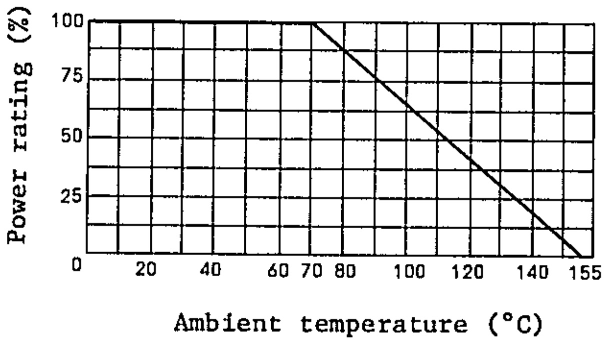


Fig. 9 The derating curve of Style RD-M carbon film fixed resistor specified by JIS C 6407

5.1.3.6 Material Used

(1) Substrate

Alkaliless mullite, forsterite or alumina ceramic rod are generally used as a substrate.

(2) Resistive film

Pyrolytic carbon film is used and raw material for deposition of carbon film is principally hydrocarbons.

(3) Cap

The host material is steel and multi layer of copper and tin is plated over the surface of steel.

(4) Lead wire

Soft copper wire plated solder over the surface of wire, is generally used.

(5) Protection

As a primary coating material for the element, varnish of phenol resin group is used.

As a material for molding element, powder of epoxy resin group is used.

5.1.3.7 Present Technique of Production

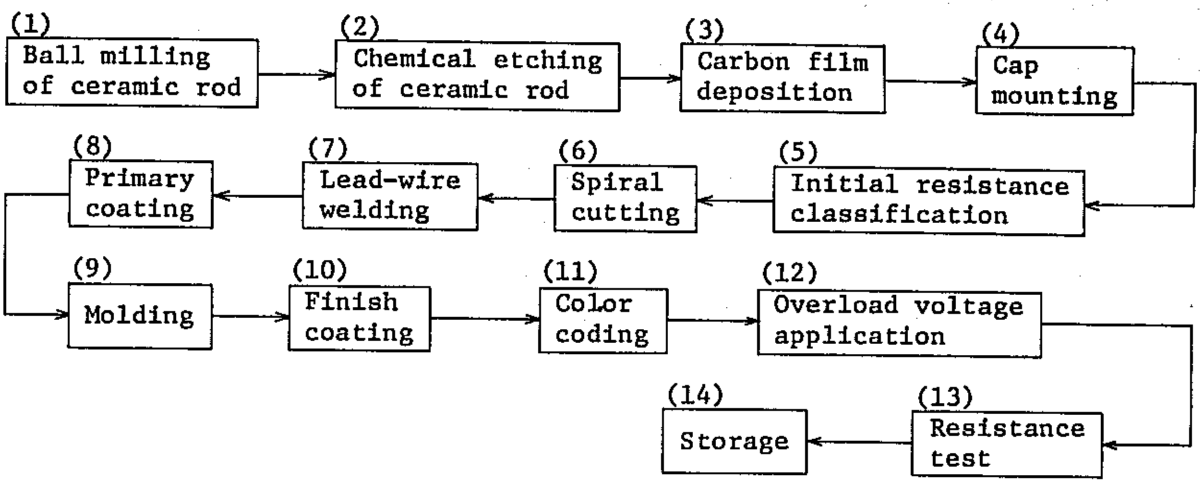
(1) As described in "Future Trend", the resistor has very superior moisture resistance and dielectric withstanding voltage in comparison with other carbon film fixed resistors, due to the molding of resistive element.

(2) The largest problem on mass-production of the resistor, is molding process because compression molding has been carried out under the manual operation due to the mechanism of machine.

Instead of the compression molding, transfer molding has been applied in recent year, and this method has been carried out very much for transistor or diode.

(3) But it is considered that the cost merit of transfer molding is not come up to this type of resistor, so at this stage, it is very difficult to apply combined manufacturing system used for coat-insulated carbon film resistor.

(4) The block diagram of general manufacturing process is as shown in Fig. 10.



Note: 1) The process from (1) through (3), are generally carried out by batch system.

2) The process from (4) through (8) and from (10) through (11) are generally carried out with automatic machine uncombined. Resistance test (13) is also done with automatic measuring equipment.

3) Molding (9) is processed by manual operation with molding machine.

Fig. 10 The block diagram of general manufacturing process of Style RD-M insulated carbon film fixed resistor

5.1.3.8 Future Trend

The future trend of this resistor is considered as follows,

(1) As the reliability requirements of industrial electronic equipment has been increased, it is considered that the demand of the insulated carbon film resistor having high uniformity and stability, will be increased more and more. It is also expected that the demand as audio component for high grade, will be increased.

(2) As for production system, the improvement of molding process is necessary from a point of productivity.

5.1.3.9 Direction of Development of Style RD-M Resistor

(1) From the point of safety, the resistor flame retardant resistance, will be required.

(2) Higher resistance value to the Style 1/8 watt or 1/4 watt will be also desired.

5.2 Metal Film Fixed Resistor

5.2.1 Coat-insulated Metal Film Fixed Resistor (Style RN14K)

5.2.1.1 Definition

Resistive element is formed with the metal film deposition over the surface of ceramic rod by the vacuum evaporation or sputtering and cap terminal with lead wire is mounted to both end of element, then thick protective coating is carried out over the resistor body for the purpose of insulation.

5.2.1.2 Name

It is called coat-insulated metal film fixed resistor or conformal coated metal film resistor.

5.2.1.3 Feature

In comparison with carbon film fixed resistor, the resistor has more excellent electrical characteristics and the size of resistor is smaller than insulated metal film fixed resistor. The features are as follows,

(1) The temperature coefficient of resistance (T.C.R.) is usually within ±100 ppm/°C.

(2) As the element is protected with coat-insulation, it is possible to apply the resistor for the crowded electronic circuit network, so the equipment can be small-sized.

(3) As the electrical characteristics synthesized is inferior to insulated metal film fixed resistor, but the price of resistor is very cheaper due to the mass-production system like coat-insulated carbon film fixed resistor.

(4) Therefore, the resistor has been applied in large quantity for the industrial electronic equipments or medical electronics equipments including communication equipment, radio waves equipment, computer, process control equipment, measuring system and analyzer.

5.2.1.4 Construction and Dimension

Fig. 11 shows the construction of Style RN14K metal film fixed resistor. Also, Table 5 shows the power rating and dimensions.

The power rating and other requirements are specified by EIAJ RC-2651 (JIS as national standard, is not yet specified. This resistor also meets U.S. Military specification MIL-R-22684).

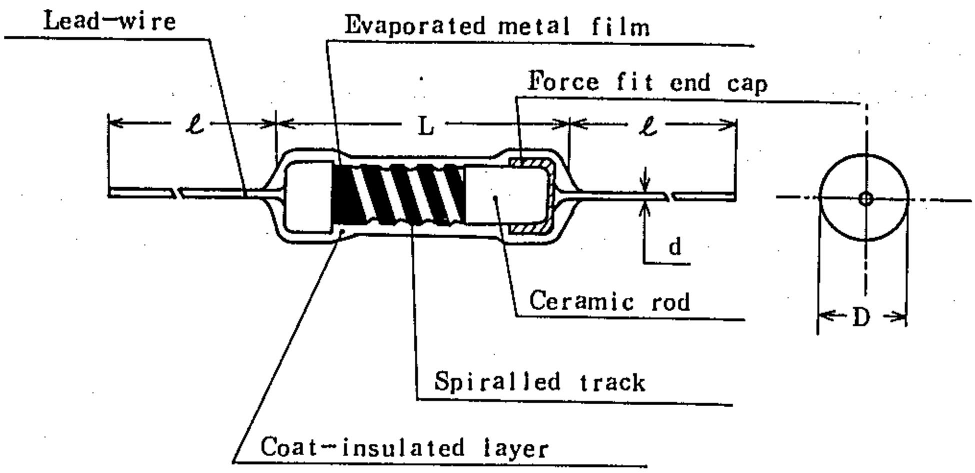


Fig. 11 The construction of Style RN-14K metal film fixed resistor

Table 5 The dimension of resistor

Unit: mm

Style	Power (W)	D	L	d*	ℓ
RN14K 2E	0.25	2.3 ± 0.5	6.4 ± 1.0	0.6	38 ± 3
RN14K 2H	0.5	3.6 ± 0.5	9.5 ± 1.0	0.8	38 ± 3
RN14K 3A	1	4.8 ± 0.5	14.3 ± 1.0	1.0	38 ± 3

* The lead diameter (d) of the terminal is nominal diameter.

5.2.1.5 Applicable Temperature Range

When the ambient temperature of resistor operated, is up to 70 °C, the resistor can be loaded with full power but if the resistor is operated at ambient temperature higher than 70 °C, the power loaded should be derated in accordance with the derating curve as shown in Fig. 12

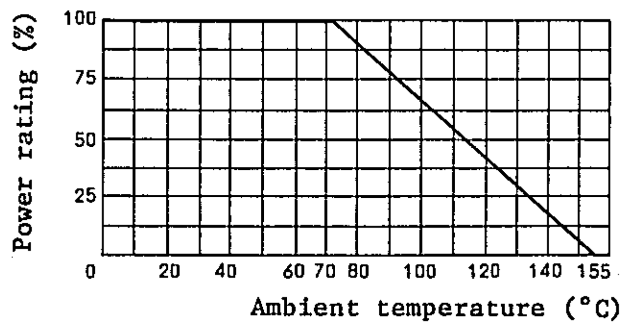


Fig. 12 The derating curve of Style RN14K metal film fixed resistor specified by EIAJ RC-2651

5.2.1.6 Materials Used

(1) Substrate

Forsterite or alumina ceramic rod are principally used as a substrate.

(2) Resistive film

Evaporated NiCr film by vacuum evaporation method including resistance-heating or electron beam, and sputtered Ta film by D.C. or H.F. sputtering method have been generally used.

(3) Cap

Generally steel cap plated copper and tin over the surface of steel has been used, but brass cap plated copper and tin has been also used.

(4) Lead wire

Soft copper wire plated solder over the surface of wire, has been used.

(5) Protection

As a primary coating material for the element, varnish of phenol resin group has been used.

As a finish coating material, epoxy paint has been used.

5.2.1.7 Present Technique of Production

(1) In Japan, the price of coat-insulated metal film fixed resistor lies between the coat-insulated carbon film fixed resistor and insulated (molded) carbon film fixed resistor, due to the establishment of mass production.

(2) From this cost merit, the resistor of this style has been applied for industrial and medical electronics equipments such as computer, process control equipment, electronic switching systems, communication equipments, measuring equipments and medical analyzer etc.

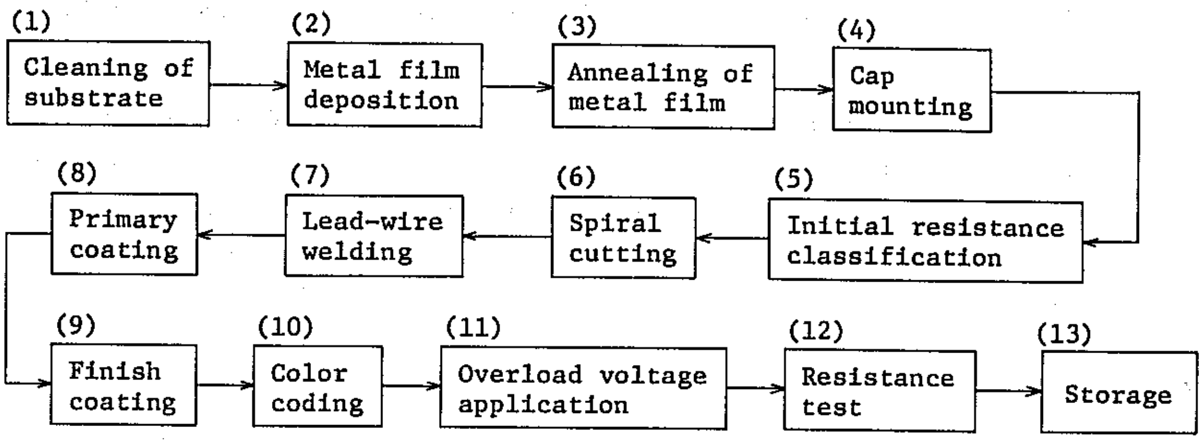
(3) Block diagram of general manufacturing process is as shown in Fig. 13.

5.2.1.8 Future Trend

The future trend of this resistor is considered as follows,

(1) The resistor has been developed for the purpose of supplying with cheaper price and large quantity, therefore, the demands of this resistor will be increased further more for the application of industrial and medical electronics equipment.

(2) As one of features of this resistor, the noise level is lower than carbon film resistor, so it will be applied for high grade audio component system.



Note: 1) The process from (1) through (3), are generally carried out by batch system.

2) The process from (4) through (12), are generally carried out by individual automatic manufacturing machine or testing machine.

Fig. 13 The block diagram of general manufacturing process of Style RN14K coat-insulated metal film fixed resistor

(3) As for automatic manufacturing equipment, the through system from cap mounting process to resistance check process, will be desired to be developed.

5.2.1.9 Direction of Development of Style RN14K Resistor

(1) Standard T.C.R. value is now ±100 ppm/°C, but its value will be transferred to ±50 ppm/°C in future with the progress of manufacturing know-how.

(2) In the field of higher resistance value, the resistor is inferior to carbon film resistor, so the development of high stable resistance film will be required.

(3) To prevent the electronic equipment from fire, it is very important to promote the incombustible resistor.

5.2.2 Insulated Metal Film Fixed Resistor (Style RN)

5.2.2.1 Definition

The resistor usually means high stability metal film fixed resistor insulated completely such as plastic molding, and it meets U.S. Military specification MIL-R-10509.

As the electrical characteristics are the highest of film fixed resistors, the resistor is generally considered as the representation of film resistors.

Resistance element is formed with the metal film deposited over the surface of ceramic tube with the vacuum evaporation or cathode sputtering, and cap terminals with lead wire are mounted to the both sides of element, then molding with plastic resin is carried out over the resistor body, for the purpose of insulation.

5.2.2.2 Name

The formal name is high stability precision metal film fixed resistor, but usually, it is called "Insulated Metal Film Fixed Resistor".

5.2.2.3 Features

Instead of being larger size than coat-insulated metal film fixed resistor, the electrical characteristics are the most excellent, and the standard resistance tolerances are ±0.1 %,(B), ±0.25 % (C), ±0.5 % (D) and ±1.0 % (F).

The features are as follows,

(1) T.C.R. value is very small, namely, the standard values specified are ±25 ppm/°C and ±50 ppm/°C.

(2) The continuous working ambient temperature of the resistor is very high and it is possible to make the resistor loaded with rated power up to 125 °C.

(3) The resistance drift at long term, is very small. Also, the resistance change at other test items, is very small in comparison with coat-insulated metal film fixed resistor.

5.2.2.4 Construction and Dimension

Fig. 14 shows the construction of Style RN metal film fixed resistor. Also, Table 6 shows the power rating and dimensions. Power rating and other electrical requirements are specified by MIL-R-10509 and JIS C 5720 ∿ 5722.

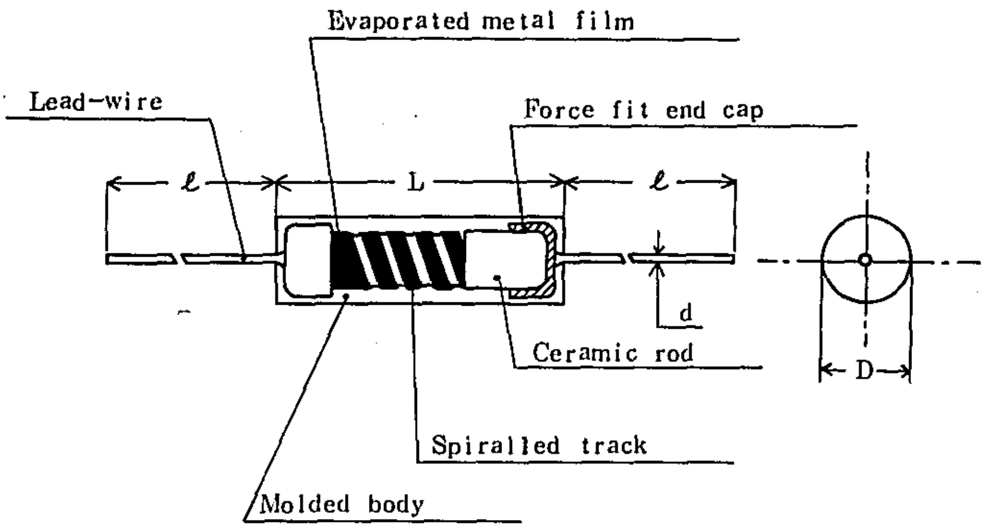


Fig. 14 The construction of Style RN metal film fixed resistor

Table 6 The dimension of resistor

Unit: mm

Style	Power (W)	L	D	d	ℓ
RN 55	0.1	5.56∿ 7.14	1.98∿ 3.57	0.58 ∿0.69	38 ± 3
RN 60	0.125	7.94∿11.11	2.39∿ 4.19	0.58 ∿0.69	38 ± 3
RN 65	0.25	13.49∿16.66	3.97∿ 6.35	0.58 ∿0.69	38 ± 3
RN 70	0.5	17.5 ∿22.2	5.6 ∿ 8.3	0.762∿0.863	38 ± 3
RN 75	1	25.4 ∿28.5	8.73∿11.11	0.762∿0.863	38 ± 3

5.2.2.5 Applicable Temperature Range

When an ambient temperature of resistor operated, is more than 125 °C, the power loaded should be derated in accordance with the derating curve as shown in Fig. 15.

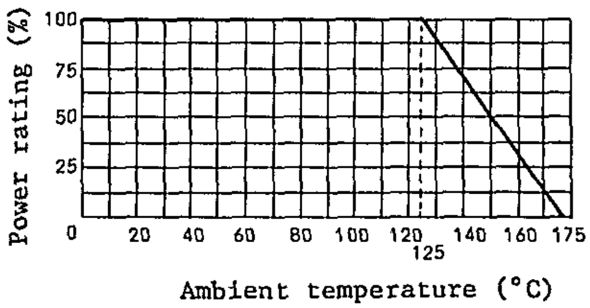


Fig. 15 The derating curve of Style RN metal film fixed resistor specified by MIL-R-10509

5.2.2.6 Materials Used

(1) Substrate

Forsterite or alumina ceramic tube is usually used as a substrate.

(2) Resistive film

Evaporated NiCr film or sputtered Ta film is usually used.

(3) Cap terminal

Generally, both steel and brass cap plated copper and tin, are used.

(4) Lead wire

Soft copper wire plated solder is principally used.

(5) Protection

As a primary coating material for the element, varnish of phenol resin group or silicon resin group is used, and as a molding material, powder of epoxy resin group is used. As a finish coating over the molded body, epoxy paint is usually used.

5.2.2.7 Present Technique of Production

(1) The resistor has been principally used for military electronics equipments such as communication equipment, computer loaded in the aircraft, missile guidance system and radar system.

Therefore, its production quantity is not so large in comparison with coat-insulated metal film fixed resistor in Japan, and the scale of production is medium.

But, in U.S.A., the demand of military electronics equipment is so large that mass-production system is carried out.

(2) To assure the quality of resistor, its manufacturing process is the most complicated in comparison with other film fixed resistors.

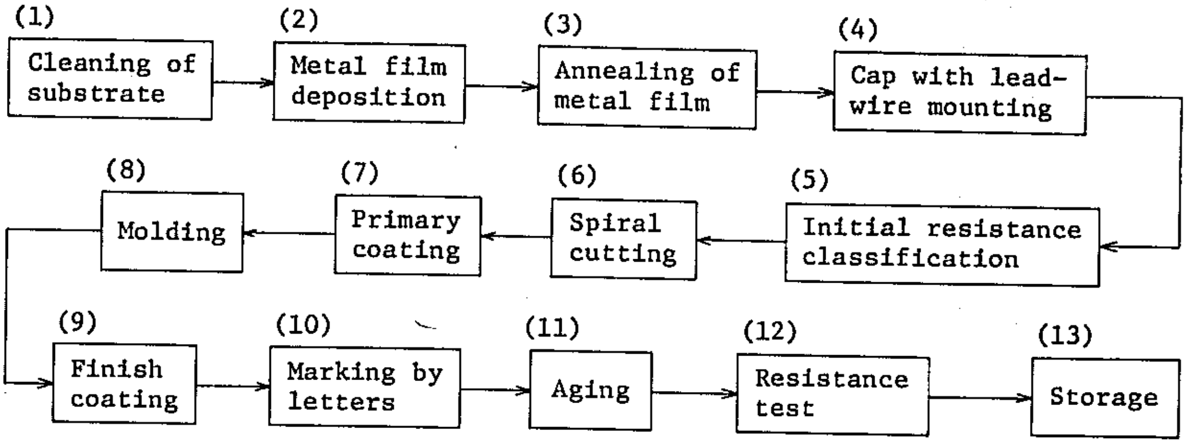
(3) The largest problem of production of this resistor, is as follows,

1) For the resistor with resistance tolerance of ±0.1 % or ±0.25 %, at this stage, there is not automatic spiral cutting machine, so this process is generally carried out under manual operation machine.

2) To prepare good moisture resistance, plastic molding is carried out after primary coating, but it is very difficult to automate the process as same as insulated carbon film fixed resistor now.

3) Therefore, the cost of resistor is very expensive than coat-insulated metal film fixed resistor.

(4) The block diagram of general manufacturing process is as shown in Fig. 16.



Note: The following items are very important.

1) As for the process (2) "Metal film deposition",
   (a) Pressure of inside of vacuum chamber.
   (b) The surface temperature of substrate.
   (c) Composition and film thickness of metal evaporated.
   (d) Evaporation method.
   (e) Temperature of evaporation source.
   (f) Rate of evaporation.
   (g) Evaporation duration.
   (h) Distance between substrate and evaporation source.

2) As for the process (6) "Spiral cutting",
   (a) At first, rough spiral cutting is carried out.
   (b) Then, spiral cutting for fine adjusting is carried out.

3) It is ideal that the process from (1) "Cleaning of substrate" through (7) "Primary coating", will be carried out in the "Clean room".

Fig. 16 The block diagram of general manufacturing process of Style RN insulated metal film fixed resistor

5.2.2.8 Future Trend

(1) The demands for military and aerospace electronic equipment will be increased further more.

(2) If the production cost will be down, applications of the resistor will be extended to the industrial electronics equipments.

(3) LASER cutting machine has been now put to practical use for thin film hybrid circuit. If the cost of machine will be down, and the machine will be taken into spiral cutting process, it is expected that the resistance adjusting accuracy will be increased.

5.2.2.9 Direction of Development of Style RN Resistor

(1) At this stage, ultra precision resistor having resistance tolerance of ±0.01 % has been developed, but the cost of resistor is very high, therefore, it is expected that the cost down of the resistor will be performed due to the development of new materials or manufacturing know-how.

(2) The resistor established reliability by MIL-R-55182, will be developed in Japan too.

(3) The resistance range will be extended towards higher value due to the development of new resistance materials.

5.3 Metal Oxide Film Fixed Resistor

5.3.1 Coated Metal Oxide Film Fixed Resistor (Style RS)

5.3.1.1 Definition

The resistive element is formed with the deposition of metal oxide film over the surface of ceramic tube, rod or glass tube, then, cap terminal with lead wire is mounted both sides of element.

Finally, coating with paint is carried out over the resistor body except for lead wire.

5.3.1.2 Name

Formally, it is called coated metal oxide film fixed resistor, but generally, is called metal oxide film resistor.

5.3.1.3 Features

(1) T.C.R. value is usually within ±350 ppm/°C, and is smaller than carbon film fixed resistor.

(2) Heat-resistance of resistive film is very strong.

(3) The resistor can withstand high power loade in comparison with the element size, so the resistor has been applied for power source circuit network of electronic equipment.

(4) As a particular application, the resistance film deposited over the glass substrate, has been used as a transparent heater, and it has been used for the front window of aircraft or automobile to prevent the window from freezing.

5.3.1.4 Construction and Dimension

Fig. 17 shows the construction of Style RS metal oxide film fixed resistor.

Also, Table 7 shows the power rating, and dimensions of resistor. The power rating and other electrical and mechanical requirements are specified by EIAJ RC-2645. (JIS as a national standard is not yet specified in Japan)

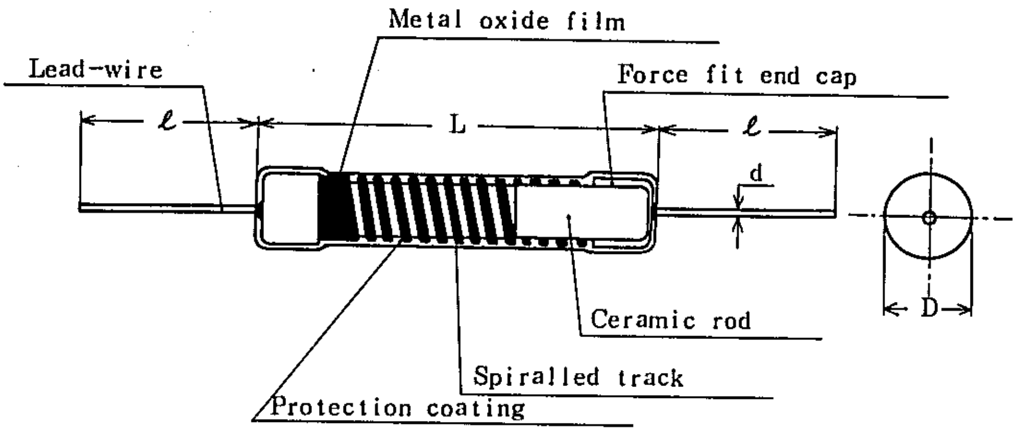


Fig. 17 The construction of Style RS metal oxide film fixed resistor

Table 7 The dimension of resistor

Unit: mm

Style	P (W)	L	D	d	ℓ
RS 1/2 B	0.5	9±1.0	3±1.0	$0.7^{+0.07}_{-0.05}$	30±3
RS 1 B	1	$12^{+0.5}_{-1.5}$	3.6±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 2 B	2	$16^{+0.5}_{-2.0}$	5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 3 B	3	$25^{+0.5}_{-2.0}$	7.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 4 B	4	$32^{+0.5}_{-2.0}$	7.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 5 B	5	$40^{+0.5}_{-2.0}$	7.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 7 B	7	$53^{+0.5}_{-2.0}$	7.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3

5.3.1.5 Applicable Temperature Range

When an ambient temperature of resistor operated, is up to 70 °C, the resistor can be loaded with rated power, but if the resistor is operated at higher ambient temperature than 70 °C, the power loaded, should be derated in accordance with the derating curve as shown in Fig. 18.

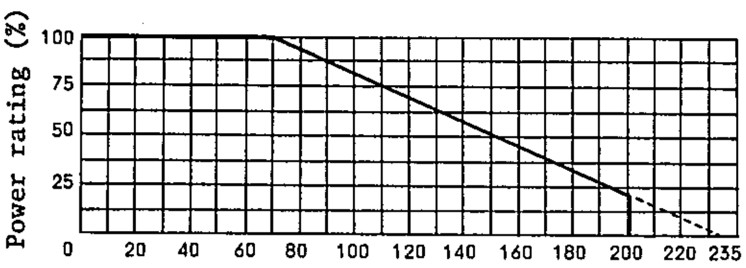


Fig. 18 The derating curve of Style RS metal oxide film fixed resistor specified by EIAJ RC-2645

5.3.1.6 Materials Used

(1) Substrate
Alkaliless mullite ceramic or forsterite ceramic tube are generally used. Sometimes heat-resistance glass tube is, also used.

(2) Resistive film
Tin oxide film, indium oxide film or cadmium oxide film are used, but generally, tin oxide film added antimony or indium slightly, is used.

(3) Cap terminal.
Generally, steel cap plated copper and tin over the surface of steel, is used.

(4) Lead wire
Soft copper wire plated with heat-resistance solder is usually used.

(5) Protection
As a primary coating material for the element, varnish of silicon resin group is applied.
As a finish coating material, colored silicon resin paint is also used.

5.3.1.7 Present Technique of Production

(1) As for the deposition method of resistance film, there are four methods. Namely, they are spray, coating, dipping and vacuum evaporation method.

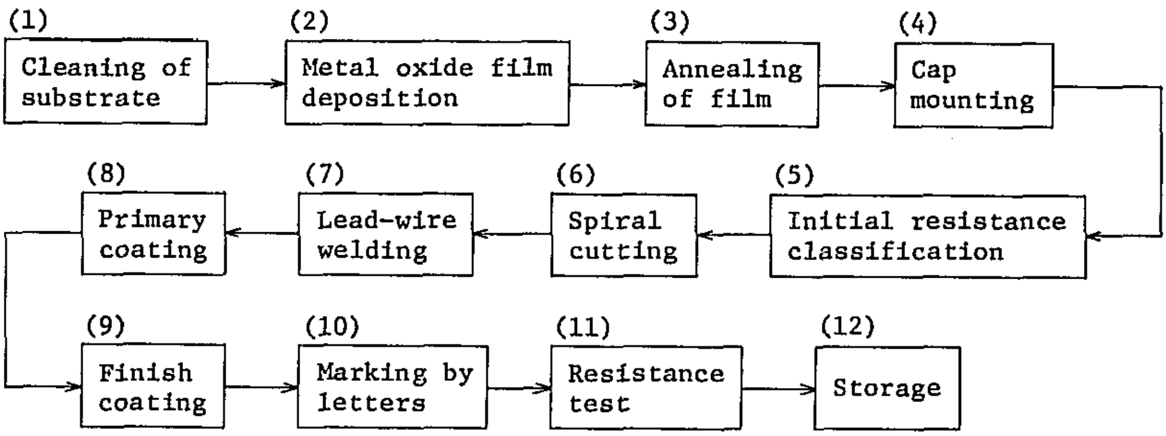
(2) Generally, the spray method is very popular. The method is as follows,

1) Firstly, tin dichloride, antimony trichroloride, hydrochloric acid and alcohol, are dissolved in the distilled water. Secondly, substrate will be heated between 400 °C∿700 °C. Finally, the solution including chrolides, will be sprayed over the surface of substrate heated, then thin metal oxide film will be formed by heat-reduction over the surface of substrate.

2) As the conduction mechanism is very complicated, it has not been solved clearly up to today, but it is considered that impurity in the film, contributes to the electrical conduction.

(3) In the manufacturing process of metal oxide film resistor, the most important factor is conditions of film deposition. In addition to the condition of film deposition, the selection of coating materials, also, gives an influence to the electrical characteristics of completed resistor.

(4) The block diagram of general manufacturing process is as shown in Fig. 19.



Note: After film deposition, annealing of film is usually carried out, but if the annealing temperature and duration are not suitable, antimony (Sb) in the film, will be sublimated, and the electrical characteristics of the film fall in a wrong way.

Fig. 19 The block diagram of general manufacturing process of Style RS metal oxide film fixed resistor

5.3.1.8 Future Trend

The future trend of this resistor is considered as follows,

In comparison with other type of film resistor, the resistor can withstand higher power load, so it is expected that the demands of power source circuits will be increased, but from the view point of flame proof, the demands will move toward coat-insulated (Flame-proof type described next paragraph) style.

5.3.1.9 Direction of Development of Style RS Resistor

(1) The extension for higher resistance will be necessary.

(2) As for the protection of element, heat-resistance varnish or paint with shorter curing time, will be necessary.

(3) As for the application of transparent film, manufacturing process with cheaper cost will be required.

5.3.2 Coat-insulated Metal Oxide Film Fixed Resistor (Style RS-F, Flame-proof Type)

5.3.2.1 Definition

The resistance element is formed with the deposition of metal oxide film over the surface of ceramic tube or rod, then cap terminals with lead wire are mounted both sides of element.

Finally, thick coating with flame-proof paint is done over the resistor body except for lead wire.

5.3.2.2 Name

Formally, it is called coat-insulated metal oxide film fixed resistor, flame-proof type, but generally, is called flame-proof metal oxide film resistor.

5.3.2.3 Feature

(1) The resistor is completed flame-proof type, so it is very safety for the fire.

(2) The insulation resistance of the coating layer, is very high.

(3) As for T.C.R. of the film, heat-resistance of the film and power loaded, they are as same as coated metal oxide film fixed resistor.

5.3.2.4 Construction and Dimension

Fig. 20 shows the construction of Style RS-F metal oxide film fixed resistor.

Table 8 also shows the power rating, and dimensions of resistor. The power rating, other electrical and mechanical requirements are specified by EIAJ RC-2655. (JIS as a national standard, is not yet specified in Japan)

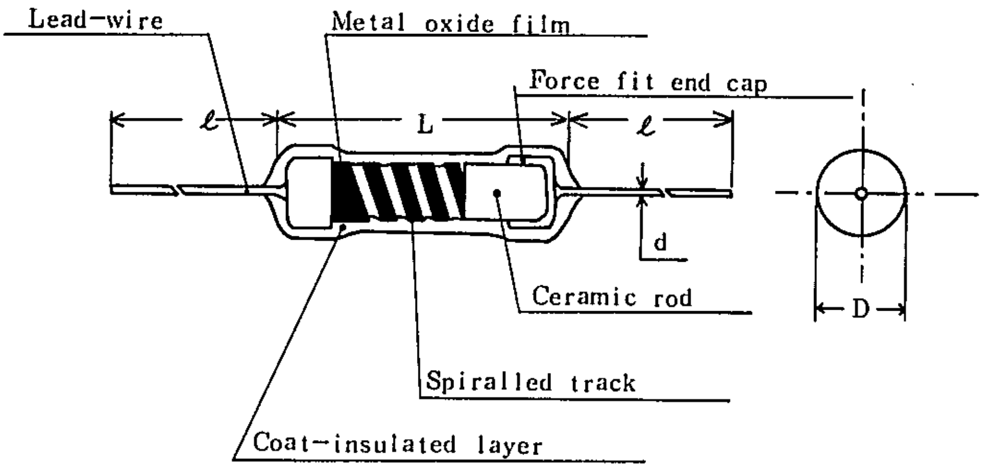


Fig. 20 The construction of Style RS-F metal oxide film resistor

Table 8 The dimension of resistor

Unit: mm

Style	P (W)	L	D	d	ℓ
RS 1/2 FB	0.5	10±1.0	3.5±1.0	$0.7^{+0.07}_{-0.05}$	30±3
RS 1 FB	1	13±1.0	4.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 2 FB	2	$17^{+0.5}_{-2.0}$	6.0±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 3 FB	3	$26^{+0.5}_{-2.0}$	8.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 4 FB	4	$33^{+0.5}_{-2.0}$	8.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 5 FB	5	$41^{+0.5}_{-2.0}$	8.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3
RS 7 FB	7	$54^{+0.5}_{-2.0}$	8.5±1.0	$0.8^{+0.08}_{-0.05}$	38±3

5.3.2.5 Applicable Temperature Range

When an ambient temperature of resistor operated, is up to 70 °C, the resistor can be loaded with rated power, but if the resistor is operated at higher ambient temperature than 70 °C, the power should be derated in accordance with the derating curve as shown in Fig. 21.

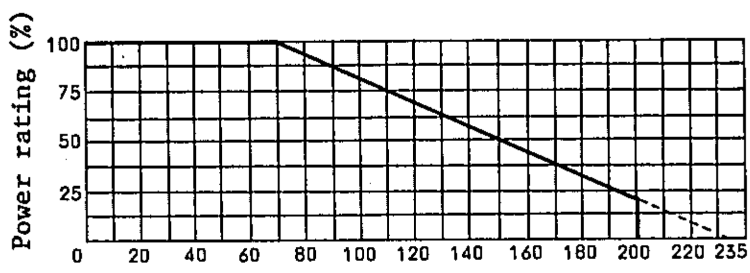


Fig. 21 The derating curve of Style RS-F metal oxide film fixed resistor specified by EIAJ RC-2655

5.3.2.6 Materials Used

(1) Substrate.

Alkaliless mullite ceramic or forsterite ceramic is generally used.

(2) Resistive film

Tin oxide film added antimony or indium slightly, is used.

(3) Cap terminal

Generally, steel cap plated copper and tin over the surface of steel, is used.

(4) Lead wire

Soft copper wire plated with heat-resistance solder, is usually used.

(5) Protection

As a primary coating material for the element, varnish of silicon resin group is used.

As a finish coating material, colored silicon resin paint is coated with thicker layer to the resistor body for the purpose of insulation of the element.

5.3.2.7 Present Technique of Production

(1) As for the deposition method of resistance film, it is as same as coated metal oxide film fixed resistor.

But, usually, spray method is carried out.

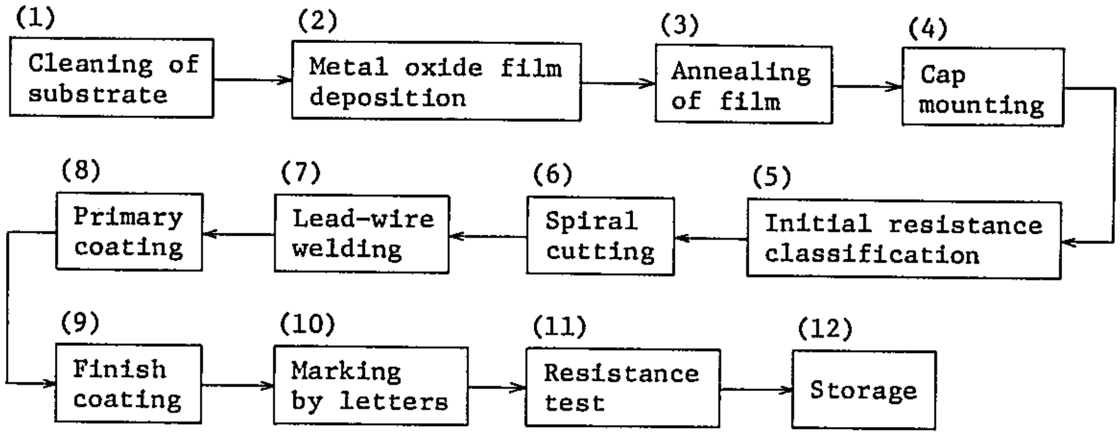
(2) The procedures of spray method is as same as the coated metal oxide film fixed resistor.

(3) In the manufacturing process of coat-insulated metal oxide film fixed

resistor, the most important factor is the conditions of film deposition.

In addition to film deposition, the selection of coating materials also gives influences to the electrical characteristics of completed resistor.

(4) The block diagram of general manufacturing process is as shown in Fig. 22.



Note: 1) After film deposition, annealing of film is generally carried out, but if the annealing temperature and duration are not suitable, antimony (Sb) in the film, will be sublimated, and the electrical characteristics of the film fall in a wrong way.

2) The thickness of finish coating should be enough for the purpose of insulating element.

Fig. 22 The block diagram of general manufacturing process of Style RS-F metal oxide film fixed resistor.

5.3.2.8 Future Trend

From a view point of coat-insulated style with flame-proof, it is considered that the demands will be increased further more than coated style, in relation to the prevention from fire of equipment.

5.3.2.9 Direction of Development of Style RS-F Resistor

(1) The resistance extension for higher value will be necessary.

(2) Heat-resistance varnish for primary coating and paint for finish coating which have shorter curing time, will be necessary as for the protection of resistive element.

(3) More small-sized style will be requested from customer, so the development of new substrate will be necessary.

6. Conclusion

(1) By the appearance of transistor, the demands of vacuum tube decreased suddenly, therefore, when the semi-conductor integrated circuits appeared, it was considered that the demands of discrete components such as resistor, capacitor or coil would be decreased like vacuum tube. But on the contrary, the demands of resistor have increased for past 10 years, because in semi-conductor integrated circuits, the precise resistive element such as metal film or carbon film resistor can not be manufactured.
Also, resistive element with high power can not be manufactured in the semi-conductor integrated circuit, and it is considered that these problems will not be solved in the near future.
Therefore, the demands of resistor will be increased further more in the near future. But in the electronic circuit network such as "Ladder circuit" which the same resistance values having small power are required, the demands of "Resistor Networks" will be increased instead of discrete film fixed resistor from the point of assembly cost of the circuit.

(2) To make the weight of equipment lighter, the style of each resistor will be tended toward more small-sized.

(3) With the progress of automatic manufacturing machine, the cost of resistor will trend cheaper price than the present price.

RIKEN DENGU SEIZO Co., Ltd.
4-5 HIGASHI-SAKASHITA 1-CHOME,
ITABASHI-KU, TOKYO, 174 JAPAN

Electrolytic Phenomena of Fixed Film Resistor

1. Introduction

In the voltage dependence, there are electrolytic phenomena, and problems of moisture-resistance load life which is attendant upon this phenomena.

These phenomena are divided into two reasons, namely, one arises by intermediation of moisture invaded into resistor, and also others arise by the influence of ion in the substrate such as ceramic or grass which will be able to move at higher temperature.

Common affairs for both sides, are that these phenomena arise under D.C. load conditions, and especially, arise in the case of ununiform electric field distribution or large electric field locally.

The resistors which these phenomena come into problem, are carbon, metal and metal oxide film fixed resistors with spiral cutting over the thin resistance film.

2. Electrolytic Phenomena by Moisture

When the moisture invends into resistor, the moisture adhered at the cut groove, is electrolyzed by electric field which is applied between cut groove, and resistance film of anode side or cathode side, will be damaged.

For example, if the resistance film is carbon film or metal film, the film of anode side is subjected to anodic oxidation and the film of its side will become extinct, and the resistance value will increase or will open.

This phenomenon is called as "<u>anodic oxidation</u>".

On the other hand, when the resistance film is metal oxide film, such as Tin Oxide, the film will be reduced by activated oxygen, by contraries of the cases of carbon or metal film, and the resistance value will be once decrease by electroly, but the resistance film reduced of cathodic side, will lose the adhesionability to the substrate.

So, the film trends to be come off from the substrate, and sometimes, resistance value will be open.

This phenomenon is called as "<u>cathodic reduction</u>".

3. Electrolytic Phenomenon at High Temperature

As a electrolytic phenomenon at high temperature, the influence of alkali ion in the ceramic or grass substrate, is taken up.

When the temperature of resistor will become higher due to the electrical potential application, and the contents of alkali ion (mainly Na^{+}) in the substrate, such as ceramic or grass, are much, the mobility of alkali ion will increase and its ion will be drawn to the cathodic side by the electric field between cut groove, and the resistance value of film will be increased.

This has been very important problems as for film resistor under the condition of D.C. load life test at high temperature, but since the development of alkaliless substrate, this problem is practically solved.

Date: 9 Mar. '81

"Technique of Research and Trial Manufacturing
on Pyrolytic Carbon Film Fixed Resistor"

Description by
Yoshinobu KITAMURA
Expert on Carbon Film Resistor

1. Technique of Research

1.1 Outline

The test items of mechanical or electrical characteristics which are required for fixed film resistor, are generally common, and are not especially related to the material of resistance film. So, with the pyrolytic carbon film fixed resistor which can do trial manufacturing at C.T.R.L., it is the best way that research staffs of circuit component laboratory, carry out the research on fundamental nature or various characteristics, required for fixed film resistor, with each research theme and also they understand about them.

1.2 Method

1.2.1 Understanding of Fundamental Technique from Bibliographies

(1) Research staffs should carry out the reviews sufficiently for the contents of "Text Book No. 1".

(2) Especially, to understand the theoretical content of spiral cutting, each staff should compute "Gain Factor" with all style of resistor which they can manufacture at C.T.R.L. from the formula described in "Text Book No. 1", then they should make the graph which shows the relationship between pitch value and magnification from the result of computation.

(3) Staffs should understand that spiral cutting process and coating process with varnish or paint, control the characteristics of pyrolytic carbon film fixed resistor, in the manufacturing process at C.T.R.L.

(4) It is also very important for staffs to understand the contents of JIS C 6402 which is applied for this resistor as a it's quality standard.

(5) By getting the bibliographies listed in "Text Book No. 1", it is very important that staffs should understand about them.

1.2.2 Progressing Method for Research & Theme of Research

(1) Originally, to carry out the fundamental research of pyrolytic carbon film resistors, it is necessary that the research should be started from the process of carbon film deposition which influences their characteristics, but at this stage, the experimental manufacturing system for carbon film deposition, is not installed at C.T.R.L.
So, as a first step, it is desirable to carry out the various experiments on the factors, excepting the research of carbon film deposition process. But, in order to understand "the pyrolytic carbon film" essentially, it is necessary that the research of carbon film deposition will be carried out in the future.

(2) As for the themes of research, fundamental and practical themes (Practical themes mean principally characteristic tests) are considered and, at this stage, it should be put stress on fundamental themes.

But some problems, if the fundamental research is carried out, are existed, i.e. fixing jigs, D.C. power sources or other measurement equipments for resistors, must be prepared.

The fundamental research themes and jig or equipment to be prepared, are described under:

1) Measurement of surface temperature rise of carbon film resistor with power application.
(Equipments required: Surface thermometer, D.C. Power source, fixing jig).

2) Measurement of T.C.R. for each style of resistor with representative resistance value. - As a result of measurement, the relationship between initial resistance and T.C.R. can be conducted.
(Equipments required: Measurement jig for T.C.R., in this case, heat-resistance lead wire covered with teflon, must be connected to the jig).

3) Relationship between numbers of turn at spiral cutting and load stability.
(Equipments required: D.C. Power source, on-off timer, load stand).

4) Research for derating curves (In order to carry out this theme at the same time with varying the conditions of ambient temperature, it is necessary to prepare two or three high temperature chambers.

In the themes listed, it is better that staffs carry out theme "1)" and "2)" especially at first.

(3) After the completion of fundamental research themes, for the second step, it is better for staffs to select the practical research themes from the test item specified in JIS C 6402 and to understand various characteristics which is required to carbon film resistor.
But, in this case, in addition to some jigs or equipments listed in "(2)", it is necessary to prepare various environmental test equipments so, as for the practical research themes, it should be limited within applicable themes with use of environmental test equipments already installed in C.T.R.L.

1.3 Drafting of Specification.

At the stage which staffs will be able to have fixed outlook for fundamental and practical research, they should carry out the drafting of specification or standard of carbon film resistor which is necessary for T & T.

Also, it is very important to receive the demands from other laboratories, such as telephone, carrier, P.C.M. etc., at the preparation of this document.

1.4 How to progress the research and it's management?

Now, in the circuit component laboratory, the post of divisional Engineer is left vacant so, Assistant Divisional Engineer should carry out the planning of how to progress the research and it's management. But, if it is impossible, A.D.E. must prepare his original plan for long-term Japanese expert then he should carry out it under the advice of expert.

2. How to progress the trial manufacturing?

2.1 Purpose

As for the circuit component laboratory, it is very important to make the laboratory function as a support group to other laboratories such as telephone, carrier, P.C.M. etc.

In order to perform these activities, staffs must understand to supply resistors as soon as possible when research staffs of other laboratories want to have some resistors for their experimental electronic equipment.

2.2 Stock of Completed Carbon Film Resistor

With accepting the demands from other laboratories and also with specially-fixed style of resistor such as 1/8 watt or 1/4 watt, it is better to stock resistors with E-6 series values, at least 50 pcs for every resistance value. (For example, it has six kinds of resistance value to the order of 10 Ω, 100 Ω, 1 kΩ, 10 kΩ, and 100 kΩ. So the total of kinds of value is thirty and it's total quantity becomes 1,500 pcs for the style).

PAKISTAN TELEGRAPH AND TELEPHONE DEPARTMENT

OFFICE OF THE GENERAL MANAGER C.T.R.L. ISLAMABAD

No. CTRL/G-28/80-81/

Islamabad, February 21, 1981

SUBJECT: FUNDAMENTAL TECHNIQUE AND DESIGN OF CARBON FILM FIXED RESISTOR

It is for information to all concerned that a lecture on the above mentioned subject will be delivered by Mr. KITAMURA Japanese Expert from 22-2-1981 to 26-2-1981 in Conference room (Ground floor). The timing will be as under:-

0930 hrs to 1300 hrs
1400 hrs to 1500 hrs

The following will be the participants:-

1. Mr. Muhammad Amin Sadiq DE
2. Mr. Nusrat Ali ADE
3. Mr. Javed Akhtar ADE
4. Mr. Muhammad Iqbal ADE
5. Mr. Ayaz Qureshi AE
6. Mr. Fazal Hussain AE
7. Mr. Abdul Ghafoor AE
8. Mr. Amjad Pervez AE
9. Mr. Wasim Anwar Kiani E.S.

All the participants are requested to attend the lecture regularly.

DIVISIONAL ENGINEER-I
CENTRAL TELECOM. RESEARCH
LABORATORIES ISLAMABAD

Copy for information to:-

1. P.A. to G.M. CTRL, Islamabad
2. All concerned

別添資料No. 10

No. 1/18

TEST DATA SHEET

TEST ITEM: Dimension Check

STYLE & RESISTANCE VALUE:
RD 1/4 P 1 kΩ J (±5 %)

Q'TY: 10 pcs

STANDARD No: JIS C 6402

PLACE OF TEST:
Circuit Comp. Lab. C.T.R.L

DATE OF TEST: 8th March 1981

TEMPERATURE & HUMIDITY:
24 °C 59 %

TEST VOLT: A.C.
D.C. V

Requirement:

No.	L	D	d	H			Judgement
	13±1.5	2.5±1	0.6±0.1	38±3			
1	12.42 mm	2.98 mm	0.61 mm	38.00 mm			Good
2	12.40 mm	2.97 mm	0.60 mm	38.00 mm			"
3	12.40 mm	2.90 mm	0.60 mm	38.20 mm			"
4	12.40 mm	2.85 mm	0.61 mm	38.20 mm			"
5	12.40 mm	2.99 mm	0.61 mm	38.20 mm			"
6	12.40 mm	2.90 mm	0.61 mm	38.20 mm			"
7	12.40 mm	3.00 mm	0.61 mm	38.20 mm			"
8	12.40 mm	3.00 mm	0.61 mm	38.22 mm			"
9	12.40 mm	3.00 mm	0.61 mm	38.20 mm			"
10	12.40 mm	2.98 mm	0.61 mm	38.00 mm			"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:

No. 2/18

TEST DATA SHEET

TEST ITEM: Dimension

STYLE & RESISTANCE VALUE:
RD 1/4 P 10 kΩ J (±5 %)

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

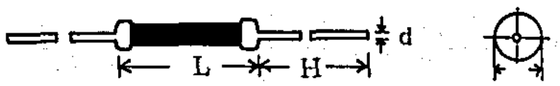
PLACE OF TEST:
Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 8th March 1981

TEMPERATURE & HUMIDITY:
24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement:



	13±1.5	2.5±1	0.6±0.1	38±3				
No.	L	D	d	H	Unit:	mm	Judgement	
1	12.40	2.98	0.62	38.22			Good	
2	12.40	2.97	0.61	38.00			"	
3	12.42	2.90	0.61	38.22			"	
4	12.40	3.80	0.61	38.18			"	
5	12.42	2.98	0.60	38.20			"	
6	12.40	2.99	0.62	38.22			"	
7	12.40	3.06	0.60	38.20			"	
8	12.42	2.85	0.61	38.20			"	
9	12.40	2.99	0.61	38.20			"	
10	12.40	2.99	0.61	38.20			"	
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Remarks:

No. 3/18

TEST DATA SHEET

TEST ITEM: Dimension Check

STYLE & RESISTANCE VALUE:
RD 1/4 P 100 kΩ J (±5 %)

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

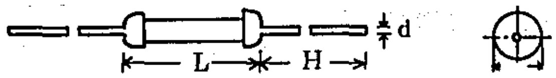
PLACE OF TEST:
Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 8th March 1981

TEMPERATURE & HUMIDITY:
24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement:



No.	L	D	d	H	Unit: mm		Judgement
	13±1.5	2.5±1	0.6±0.1	38±3			
1	12.40	2.98	0.62	38.20			Good
2	12.40	2.97	0.61	38.00			"
3	12.42	2.90	0.61	38.22			"
4	12.40	2.80	0.61	38.20			"
5	12.42	2.98	0.60	38.20			"
6	12.40	2.98	0.61	38.20			"
7	12.40	3.00	0.61	38.20			"
8	12.40	2.99	0.61	38.20			"
9	12.40	2.99	0.61	38.20			"
10	12.40	3.06	0.60	38.20			"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:

No. 4/18

TEST DATA SHEET

TEST ITEM: Resistant Measurement

STYLE & RESISTANCE VALUE:
RD 1/4 P, 1 kΩJ (±5 %)

Q'TY: 50 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST:
Circuit Compo. Lab. C.T.R.L.

DATE OF TEST: 7th March 1981

TEMPERATURE & HUMIDITY:
24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Resistance Tolerance must be within ±5 %.

No.	Resis. Value	Deviation	Judgement	No.	Resis. Value	Deviation	Judgement
1	1.004 kΩ	+0.4 %	Good	21	1.000 kΩ	+0.00 %	Good
2	1.001 "	+0.1	"	22	1.005 "	+0.5	"
3	1.003 "	+0.3	"	23	1.000 "	+0.0	"
4	1.000 "	+0.00	"	24	1.004 "	+0.4	"
5	1.004 "	+0.4	"	25	1.010 "	+1.0	"
6	1.003 "	+0.3	"	26	1.008 "	+0.8	"
7	1.000 "	+0.00	"	27	1.000 "	+0.00	"
8	1.026 "	+2.6	"	28	1.010 "	+1.0	"
9	1.002 "	+0.2	"	29	1.005 "	+0.5	"
10	1.003 "	+0.3	"	30	1.000 "	+0.00	"
11	1.000 "	+0.00	"	31	1.002 "	+0.2	"
12	1.004 "	+0.4	"	32	1.026 "	+2.6	"
13	1.013 "	+1.3	"	33	1.002 "	+0.2	"
14	1.013 "	+1.3	"	34	1.010 "	+1.0	"
15	1.000 "	+0.00	"	35	1.001 "	+0.1	"
16	1.009 "	+0.9	"	36	1.028 "	+2.8	"
17	1.013 "	+1.3	"	37	1.003 "	+0.2	"
18	1.013 "	+1.3	"	38	1.002 "	+0.2	"
19	1.010 "	+1.0	"	39	1.000 "	+0.00	"
20	1.008 "	+0.8	"	40	1.014 "	+1.4	"

Remarks:

No. 5/18

TEST DATA SHEET

TEST ITEM: Resistance Measurement

STYLE & RESISTANCE VALUE:
RD 1/4 P, 1 kΩ J (±5 %)

Q'TY: 50 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST:
Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 7th March 1981

TEMPERATURE & HUMIDITY:
24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Resistance Tolerance must be within ±5 %.

No.	Resis. Value	Deviation	Judgement	No.	Resis. Value	Deviation	Judgement
1	0.998 kΩ	-0.2 %	Good	21			
2	0.999 "	-0.1	"	22			
3	1.005 "	+0.5	"	23			
4	1.010 "	+1.0	"	24			
5	1.003 "	+0.3	"	25			
6	1.006 "	+0.6	"	26			
7	1.006 "	+0.6	"	27			
8	1.006 "	+0.6	"	28			
9	1.003 "	+0.3	"	29			
10	1.005 "	+0.5	"	30			
11				31			
12				32			
13				33			
14				34			
15				35			
16				36			
17				37			
18				38			
19				39			
20				40			

Remarks:

No. 6/18

TEST DATA SHEET

TEST ITEM: Resistance Measurement

STYLE & RESISTANCE VALUE:
RD 1/4 P, 10 kΩ J ±5 %

Q'TY: 50 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST:
Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 7th March 1981

TEMPERATURE & HUMIDITY:
24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Resistance Tolerance must be within ±5 %.

No.	Resis. Value	Deviation	Judgement	No.	Resis. Value	Deviation	Judgement
1	10.30 kΩ	+3.0 %	Good	21	10.02 kΩ	+0.2 %	Good
2	10.04 "	+0.4 "	"	22	10.09 "	+0.9 "	"
3	10.06 "	+0.6 "	"	23	9.99 "	-0.1 "	"
4	10.09 "	+0.9 "	"	24	10.40 "	+4.0 "	"
5	10.02 "	+0.2 "	"	25	10.12 "	+1.2 "	"
6	10.09 "	+0.9 "	"	26	10.04 "	+0.4 "	"
7	10.08 "	+0.8 "	"	27	10.24 "	+2.4 "	"
8	10.30 "	+3.0 "	"	28	10.48 "	+4.8 "	"
9	10.07 "	+0.7 "	"	29	9.99 "	-0.1 "	"
10	10.03 "	+0.3 "	"	30	10.09 "	+0.9 "	"
11	10.10 "	+1.0 "	"	31	10.09 "	+0.9 "	"
12	10.12 "	+1.2 "	"	32	10.26 "	+2.6 "	"
13	10.03 "	+0.3 "	"	33	10.06 "	+0.6 "	"
14	10.18 "	+1.8 "	"	34	9.95 "	-0.5 "	"
15	10.31 "	+3.1 "	"	35	10.10 "	+1.0 "	"
16	10.30 "	+3.0 "	"	36	10.06 "	+0.6 "	"
17	10.08 "	+0.8 "	"	37	10.04 "	+0.4 "	"
18	10.03 "	+0.3 "	"	38	10.35 "	+3.5 "	"
19	10.53 "	+5.3 "	No good	39	10.26 "	+2.6 "	"
20	10.26 "	+2.6 "	Good	40	10.21	+2.1 "	"

Remarks:

No. 7/18

TEST DATA SHEET

TEST ITEM: Resistance Measurement

STYLE & RESISTANCE VALUE: RD 1/4 P, 10 kΩ J (±5 %)

Q'TY: 50 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 7th March 1981

TEMPERATURE & HUMIDITY: 24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Resistance Tolerance must be within ±5 %.

No.	Resis. Value	Deviation	Judgement	No.	Resis. Value	Deviation	Judgement
1	10.13 kΩ	+1.3 %	Good				
2	10.80 "	+8.0 "	No good				
3	10.07 "	+0.7 "	Good				
4	10.35 "	+3.5 "	"				
5	9.96 "	-0.4 "	"				
6	10.12 "	+1.2 "	"				
7	10.16 "	+1.6 "	"				
8	10.02 "	+0.2 "	"				
9	10.64 "	+6.4 "	No good				
10	10.05 "	+0.5 "	Good				
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:

No. 8/18

TEST DATA SHEET

TEST ITEM: Resistance Measurement

STYLE & RESISTANCE VALUE: RD 1/4 P, 100 kΩ J (±5 %)

Q'TY: 50 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 7th March 1981

TEMPERATURE & HUMIDITY: 24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Resistance Tolerance must be within ±5 %.

No.	Resis. Value	Deviation	Judgement	No.	Resis. Value	Deviation	Judgement
1	99.98 kΩ	-0.02 %	Good	21	102.90 kΩ	+2.90 %	Good
2	102.19 "	+2.19 "	"	22	103.10 "	+3.10 "	"
3	99.10 "	-0.9 "	"	23	100.92 "	+0.92 "	"
4	100.50 "	+0.5 "	"	24	101.03 "	+1.03 "	"
5	100.36 "	+0.3 "	"	25	99.69 "	-0.31 "	"
6	102.80 "	+2.8 "	"	26	99.91 "	+0.09 "	"
7	102.10 "	+2.10 "	"	27	101.27 "	+1.27 "	"
8	101.43 "	+1.43 "	"	28	102.90 "	+2.90 "	"
9	101.10 "	+1.10 "	"	29	100.58 "	+0.58 "	"
10	99.55 "	-0.45 "	"	30	101.93 "	+1.93 "	"
11	100.85 "	+0.85 "	"	31	101.93 "	+1.93 "	"
12	101.00 "	+1.00 "	"	32	100.76 "	+0.76 "	"
13	100.93 "	+0.93 "	"	33	100.60 "	+0.60 "	"
14	100.18 "	+0.18 "	"	34	103.10 "	+3.10 "	"
15	97.79 "	-2.21 "	"	35	102.30 "	+2.30 "	"
16	100.83 "	+0.83 "	"	36	100.43 "	+0.43 "	"
17	100.73 "	+0.73 "	"	37	103.10 "	+3.10 "	"
18	100.65 "	+0.65 "	"	38	102.40 "	+2.40 "	"
19	102.10 "	+2.10 "	"	39	100.91 "	+0.91 "	"
20	101.46 "	+1.46 "	"	40	99.44 "	-0.56 "	"

Remarks:

No. 9/18

TEST DATA SHEET

TEST ITEM: Resistance Measurement

STYLE & RESISTANCE VALUE: RD 1/4 P, 100 kΩ J (±5 %)

Q'TY: 50 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 7th March 1981

TEMPERATURE & HUMIDITY: 24 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Resistance Tolerance must be within ±5 %.

No.	Resis. Value	Deviation	Judgement	No.	Resis. Value	Deviation	Judgement
1	101.87 kΩ	+1.87 %	Good				
2	99.95 "	-0.05 "	"				
3	103.30 "	+3.30 "	"				
4	102.40 "	+2.40 "	"				
5	102.40 "	+2.40 "	"				
6	101.57 "	+1.57 "	"				
7	102.07 "	+2.07 "	"				
8	102.50 "	+2.5 "	"				
9	100.65 "	+0.65 "	"				
10	99.65 "	-0.35 "	"				
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:

No. 10/18

TEST DATA SHEET

TEST ITEM: Short-time Overload Test

STYLE & RESISTANCE VALUE:
RD 1/4 P, 1 kΩJ

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST:
Circuit Component Lab. C.T.R.L.

DATE OF TEST: 9 March 1981

TEMPERATURE & HUMIDITY:
23 °C 50 %

TEST VOLT: A.C. 39.5 V
D.C. -

Requirement: Resistance change in percent = ±0.75 (%)

No.	R_1	R_2	$R_1 \sim R_2$				Judgement
1	1.000 kΩ	1.000 kΩ	0.00 %				Good
2	1.007 "	1.008 "	+0.1 "				"
3	1.004 "	1.004 "	0.00 "				"
4	1.004 "	1.004 "	0.00 "				"
5	1.007 "	1.007 "	0.00 "				"
6	1.006 "	1.006 "	0.00 "				"
7	1.007 "	1.007 "	0.00 "				"
8	1.007 "	1.007 "	0.00 "				"
9	1.010 "	1.010 "	0.00 "				"
10	1.003 "	1.003 "	0.00 "				"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks: 1. Test voltage is applied for 5 seconds.
2. R_1 is resistance value before test.
3. R_2 is resistance value after test.

No. 11/18

TEST DATA SHEET

TEST ITEM: Short-time Overload Test

STYLE & RESISTANCE VALUE:
RD 1/4 P, 10 kΩJ

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST:
Circuit Component Lab. C.T.R.L.

DATE OF TEST: 9 March 1981

TEMPERATURE & HUMIDITY:
23 °C 50 %

TEST VOLT: A.C. 125 V
D.C. -

Requirement: Resistance change in percent = ±0.75 (%)

No.	R_1	R_2	$R_1 \sim R_2$				Judgement	
1	10.103 kΩ	10.103 kΩ	0.00 %				Good	
2	10.008 "	10.007 "	-0.01 "				"	
3	10.28 "	10.28 "	0.00 "				"	
4	10.249 "	10.25 "	+0.01 "				"	
5	10.050 "	10.050 "	0.00 "				"	
6	10.119 "	10.199 "	0.00 "				"	
7	10.034 "	10.035 "	+0.01 "				"	
8	10.111 "	10.111 "	0.00 "				"	
9	10.001 "	10.001 "	0.00 "				"	
10	10.104 "	10.104 "	0.00 "				"	
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Remarks:
1. Test voltage is applied for 5 seconds.
2. R_1 is resistance value before test.
3. R_2 is resistance value after test.

No. 12/18

TEST DATA SHEET

TEST ITEM: Short-time Overload Test

STYLE & RESISTANCE VALUE:
RD 1/4 P, 100 kΩJ

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST:
Circuit Component Lab. C.T.R.L.

DATE OF TEST: 9 March 1981

TEMPERATURE & HUMIDITY:
23 °C 50 %

TEST VOLT: A.C. 395 V
D.C. -

Requirement: Resistance change in percent = ±0.75 (%)

No.	R_1	R_2	$R_1 \sim R_2$				Judgement
1	101.00 kΩ	100.99 kΩ	-0.01 %				Good
2	103.17 "	103.18 "	+0.01 "				"
3	103.34 "	103.34 "	0.00 "				"
4	101.17 "	101.17 "	0.00 "				"
5	102.01 "	102.01 "	0.00 "				"
6	99.87 "	99.87 "	0.00 "				"
7	100.10 "	100.11 "	+0.01 "				"
8	101.47 "	101.47 "	0.00 "				"
9	103.14 "	103.14 "	0.00 "				"
10	100.82 "	100.82 "	0.00 "				"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks: 1. Test voltage is applied for 5 seconds.
2. R_1 is resistance value before test.
3. R_2 is resistance value after test.

No. 13/18

TEST DATA SHEET

TEST ITEM: Temperature Cycling Test

STYLE & RESISTANCE VALUE: RD 1/4 P, 1 kΩJ

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 10 March 1981

TEMPERATURE & HUMIDITY: 23 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement:
-55^{+0}_{-3} °C (For 30 min.) → 25^{+5}_{-0} °C (For 10 min.) → 85±3 °C (For 30 min.)
Numbers of cycle is 3. Resistance change = ±0.75 % + 0.05 Ω

No.	R_1	R_2	$R_1 \sim R_2$				Judgement
1	1.0037 kΩ	1.004 kΩ	+0.1 %				Good
2	0.999 "	1.000 "	-0.1 "				"
3	1.007 "	1.007 "	0.0 "				"
4	1.003 "	1.004 "	+0.1 "				"
5	1.005 "	1.006 "	+0.1 "				"
6	1.007 ""	1.007 "	0.0 "				"
7	1.006 "	1.007 "	+0.1 "				"
8	1.009 "	1.010 "	+0.1 "				"
9	1.002 "	1.003 "	+0.1 "				"
10	1.007 "	1.007 "	0.0 "				"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:
1. Due to the low temperature chamber (Humidity chamber) Temperature for lower side is -30 °C.
2. R_1 is resistance value before test.
3. R_2 is resistance value after test.

No. 14/18

TEST DATA SHEET

TEST ITEM: Temperature Cycling Test

STYLE & RESISTANCE VALUE: RD 1/4 P, 10 kΩJ

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 10 March 1981

TEMPERATURE & HUMIDITY: 23 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement:
-55^{+0}_{-3} °C (30 min.) → 25^{+10}_{-5} °C (10 min.) → 85^{+3}_{-0} °C (30 min.)
Number of cycle is 3 → 25^{+10}_{-5} °C (10 min.), Resistance change: ±0.75 % +0.05 Ω

No.	R_1	R_2	$R_1 \sim R_2$				Judgement
1	10.09 kΩ	10.10 kΩ	+0.1 %				Good
2	9.99 "	10.00 "	+0.1 "				"
3	10.10 "	10.11 "	+0.1 "				"
4	10.02 "	10.03 "	+0.1 "				"
5	10.11 "	10.12 "	+0.1 "				"
6	10.04 "	10.05 "	+0.1 "				"
7	10.24 "	10.25 "	+0.1 "				"
8	10.27 "	10.28 "	+0.1 "				"
9	10.00 "	10.00 "	0.0 "				"
10	10.09 "	10.10 "	+0.1 "				"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:
1. Due to the low temperature chamber (Humidity chamber) Temperature for lower side is -30 °C.
2. R_1 is resistance value before test.
3. R_2 is resistance value after test.

No. 15/18

TEST DATA SHEET

TEST ITEM: Temperature Cycling Test

STYLE & RESISTANCE VALUE: RD 1/4 P, 100 kΩJ

Q'TY: 10 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 10 March 1981

TEMPERATURE & HUMIDITY: °C %

TEST VOLT: A.C. D.C. V

Requirement:

-55^{+0}_{-3} °C (30 min.) → 25^{+10}_{-5} °C (10 min.) → 25^{+3}_{-0} °C (30 min.)

Number of cycle is → 25^{+10}_{-5} °C (10 min.), Resistance change: ±0.75 % + 0.05 Ω

No.	R_1	R_2	$R_1 \sim R_2$				Judgement
1	100.91 kΩ	101.02 kΩ	+0.11 %				Good
2	103.1 "	103.20 "	+0.10 "				"
3	103.20 "	103.36 "	+0.16 "				"
4	101.07 "	101.19 "	+0.12 "				"
5	101.92 "	102.03 "	+0.11 "				"
6	99.78 "	99.89 "	+0.11 "				"
7	100.02 "	100.13 "	+0.11 "				"
8	101.36 "	101.48 "	+0.12 "				"
9	103.00 "	103.16 "	+0.16 "				"
10	100.72 "	100.83 "	+0.11 "				"
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks:
1. Due to the low temperature chamber (Humidity chamber) Temperature for lower side is -30 °C.
2. R_1 is resistance value before test.
3. R_2 is resistance value after test.

No. 16/18

TEST DATA SHEET

TEST ITEM: Temperature Characteristic of Resistance

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

STYLE & RESISTANCE VALUE: RD 1/4 P, 1 kΩJ

DATE OF TEST: 10 March 1981

Q'TY: 5 pcs

TEMPERATURE & HUMIDITY: 23 °C 50 %

STANDARD No.: JIS C 6402

TEST VOLT: A.C.
D.C. V

Requirement: Temperature resistance coefficient is ±350 ppm/°C

No.	R_1 (at 23 °C)	R_2 (at 73 °C)	TCR (ppm/°C)				Judgement
1	1.0029 kΩ	0.9923 kΩ	-207				Good
2	1.027 "	1.012 "	-286				"
3	1.0097 "	0.9997 "	-194				"
4	1.0174 "	1.0075 "	-191				"
5	1.001 "	0.990 "	-215				"
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks: 1. R_1 is at room temperature.
2. R_2 is at +73 °C (room temp. +50 °C).

No. 17/18

TEST DATA SHEET

TEST ITEM: Temperature Characteristic of Resistance

STYLE & RESISTANCE VALUE: RD 1/4 P, 10 kΩJ

Q'TY: 5 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Comp. Lab. C.T.R.L.

DATE OF TEST: 10 March 1981

TEMPERATURE & HUMIDITY: 23 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Temperature resistance coefficient is ±350 ppm/°C

No.	R_1 (at 23 °C)	R_2 (at 73 °C)	TCR (ppm/°C)				Judgement	
1	10.42 kΩ	10.29 kΩ	-245				Good	
2	10.490 "	10.361 "	-241				"	
3	10.073 "	9.954 "	-232				"	
4	9.96 "	9.835 "	-246				"	
5	10.118 "	9.990 "	-248				"	
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Remarks:
1. R_1 is at room temperature.
2. R_2 is at room temperature +50 °C.

No. 18/18

TEST DATA SHEET

TEST ITEM: Temperature Characteristic of Resistance

STYLE & RESISTANCE VALUE: RD 1/4 P, 100 kΩJ

Q'TY: 5 pcs

STANDARD No.: JIS C 6402

PLACE OF TEST: Circuit Compo. Lab. C.T.R.L.

DATE OF TEST: 10 March 1981

TEMPERATURE & HUMIDITY: 23 °C 50 %

TEST VOLT: A.C.
D.C. V

Requirement: Temperature coefficient of resistance is ±350 ppm/°C

No.	R_1 (at 23 °C)	R_2 (at 73 °C)	TCR (ppm/°C)				Judgement
1	99.85 kΩ	98.40 kΩ	-285				Good
2	102.10 "	100.70 "	-267				"
3	100.82 "	99.41 "	-274				"
4	103.30 "	101.87 "	-271				"
5	102.30 "	100.88 "	-272				"
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Remarks: 1. R_1 is at 23 °C at room temperature.
2. R_2 is test temperature (room temperature +50 °C).

別添資料No.11

パキスタン電々中央電気通信研究所
佐　藤　　首席顧問　　殿
加　藤　斉　長期専門家　殿

§ 炭素皮膜抵抗器の技術協力に関する私見

56年3月4日(水)
短期専門家
北　村　嘉　伸

T&Tスタッフによる試作が予定どおり明日終了の見込です。指導内容の前半を経過した段階で標記について以下にその私見を申しあげます。

1. カウターパートの理解力その他

今回実施された第一回目の技術協力が終了すれば、カウンターパートは炭素皮膜抵抗器の性質、製法、二、三の特性および研究手法を習得する運びになります。しかし前半のLecture終了後、御報告申しあげましたようにテキストの文章自身は理解しても、簡単な計算等が一部の者を除くと出来ないケースが多く、しかも残念なことにそれが肝心のCircuit Compo. Lab.のスタッフに多いことです。従って後半の日程でもし時間が許すならばCircuit Compo. Lab.のスタッフだけにでも複習をさせたいと考えております。

2. 今後の技術協力

(1) 実施の機会

今後の技術協力については、どの組織から専門家が派遣されるかは別問題として、諸条件が許すならば毎年1回短期間ででも継続して実施することが望ましいと考えます。

(2) 今後の指導内容

基本的事項は今回の技術協力で時間的な制約はありますが、一応完了しますし、またカウンターパートが試作技術についてそれなりの自信をもっていをことからみて、指導内容の主体を研究手法のテーマに移行させることがよいと考えます，従ってもしこの内容をスムースに実施する為にはまづ基礎研究に必要な器材をT&T側が取り揃えておく必要があり、現状のままでは次回の効果が期待しがたいと考えます。

(3) 研究活動の立案、実施およびその管理

理想的には、カウンターパートが自発的に研究を今後どのように進めてゆくか、少くともA.D.E.クラスがその方法を立案し、スタッフに実施させかつ管理を行うことが望ましいわ

けですが、現状ではそれが望み薄のように見受けられます。従って専門家がいないと実質的な活動が為されないということは、T＆Tにとっても損失になるため折にふれ長期専門家よりこの点についてカウンターパートへアドバイスをして頂きたいと考えます。

以　　上

別添資料No. 12

パキスタン電信電話庁、中央電気通信研究所
佐藤　首席顧問、長期専門家、関口調整員　各位殿

§ 炭素皮膜固定抵抗器の技術協力に関する概要報告

56年3月17日(火)
短期専門家
北　村　嘉　伸

技術協力終了にあたり、標記について下記のとおり御報告申しあげます。

1. 目的；(1)炭素皮膜固定抵抗器の基本技術の指導、(2)実験室的製造技術の指導、(3)試作品の特性の調査（テスト方法の指導）、(4)テストデータの解析、(5)研究手法及び新技術動向の指導

2. 派遣期間；昭和56年2月20日～昭和56年3月19日（実質指導期間；昭和56年2月22日～昭和56年3月17日）

3. 標記協力に関する関係者間の打合せ
(1) 2月21日（土）午前中、佐藤首席顧問、中島、倉島各長期専門家へ今回実施する事（JICAとの取ぬ決めによる業務内容）および英文にて作成した標記要旨と日程について説明の上、細部について打合せを行った。
(2) 2月21日（土）午後、佐藤首席顧問と共にSheikh所長に面会し、上記英文書類を提出の上、実施内容と日程の諒解をとりつけた。又所長から当該書面を要約した文書を掲示する旨の話があった。
(3) 3月5日（木）午後、標記抵抗器の今後の協力のあり方について、佐藤首席顧問、加藤斉長期専門家と打合せを実施した。又この席で研究手法に関する日本文原案の説明をし、原案を英訳の上テキストとして使用することで諒解をえた。

4. テキストの提出
2月21日英文テキストブック（82頁）2セットを佐藤首席顧問および加藤斉専門家用に又2セットをT＆T用としてShejk所長にそれぞれ提出した。

5. 指導内容
Counterpartに対して次の内容の指導を実施した。

5. 1　基本技術の指導（テキストNo.1，No.2 & 別添1にそってLecture を実施した）

(1)　実施期間：2月22日〜26日　於Ground Fr. Conference room.

(2)　テーマ：基本技術および設計

(3)　出席者：9名（Circuit Compo. Lab. 以外のメンバーを含む）

5. 2　実験室的製造技術の指導（製造指導書にそって試作指導を実施）

(1)　期間：2月28日〜3月5日　於3rd Fr. 実験室

(2)　試作内容：RD1／4P　1KΩJ，同10KΩJ，同100KΩJ 各 50 pcs.

(3)　出席者：回路部品研究室の6名（うち1名はLaboratory Assistant）

5. 3　試作品の特性調査の指導（当該抵抗器の適用規格JIS C 6402によりテスト指導を実施した）。

(1)　期間：3月7日〜3月12　於3rd Fr. 実験室とG.Fr. Humidity Chamber Room.

(2)　テスト項目

1）寸法検査：1KΩJ，10KΩJ，100KΩJの各抵抗器について本体の直径と長さ、リード線の直径と長さを各々10pcs，Tot 30pcs 測定させた。

2）抵抗値検査：各抵抗値50pcsづつランダムサンプリングの上測定させた。10KΩJのみ3pcs．許容差不良が認められた。（測定総数150pcs）

3）短時間過負荷試験：各抵抗値10pcs，Tot 30pcsを実施させた。

4）温度サイクル試験：各抵抗値10pcs，Tot 30pcs実施させた。なおHumidity ChamberがJISで規定の−55℃迄低くならぬため低温側のみ−30℃で実施させた。

5）抵抗温度特性：測定に必要な取りつけ治具がないため、簡略な方法で各抵抗値5pcs，Tot 15pcsを測定させた。

上記テストの実施に当ってはCounterpartに対してData Formの指導も合せて実施し、全てのデータの作成を行てなはせた。又データにはCounterpartがサインし内容チエック後Expertもサイン済。

5. 4　新技術の動向と研究手法の指導（テキストNo.3および別添2にそってLecture を実施した）

(1)　期間：3月14日〜3月17日　於Ground Fr. Confence room.

(2)　テーマ：1）炭素皮膜、金属皮膜および酸化金属皮膜固定抵抗器の既存技術と将来動向（1部スライド使用）

2）炭素皮膜固定抵抗器の研究手法および試作

(3)　出席者：5〜10名（Circuit Compo. Lab. 以外のメンバーを含む）

6. 関係文書の提出（佐藤首席顧問および加藤斉専門家へ下記文書を提出した。）

(1) “研究手法と試作”に関する原案（和文）、3月5日提出

(2) “抵抗器の技術協力に関する私見文書”、3月5日提出

(3) “研究手法と試作”（英文，別添2）3月12日提出

(4) “テストデータフォーム1式”3月14日提出

7. 考　察

(1) 前半のLectureは基本の内容を含くむため、その理解力についてはCounterpartの資質に差があり、特に計算等はA.D.E. クラスの限られたメンバーにしか残念ながら理解されなかった。

(2) 試作については製造指導書をまだ十分勉強していない。また許容差±1％あるいは±0.5％級を歩留りよく作るためには更に練習と経験を積む必要があると考える。

(3) 特性テストについても、JISで要求される内容を殆んど理解していない。又データをとる経験がないためか、ごく簡単な計算が全く出来なかったり、間違っているケースが多い。またデータフォームへの記入モレが目立った。

8. 結　論

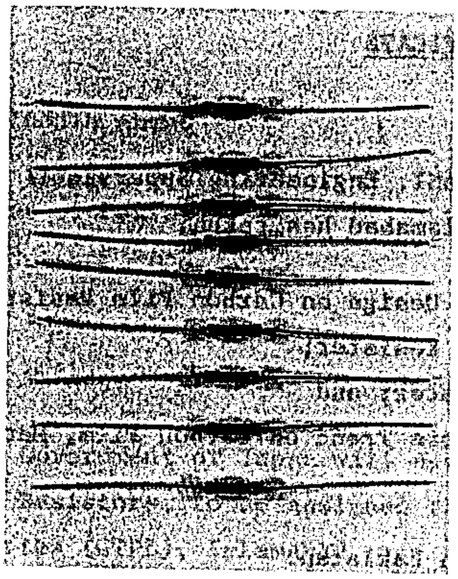
(1) 2月20日来バし、2月22日より3月17日迄炭素皮膜抵抗器に係る各種技術指導をT＆T側Counterpartへそれぞれ実施した。

(2) 今後の当該抵抗器に関する技術協力のあり方については、去る3月5日佐藤首席顧問へ意見書を提出済であるが、どの組織から専門家が派遣されるかは別問題として引き続き継続の必要があろう。現状で打ち切るとCounterpartの技術のレベルアップは非常に難い。

終りに、今回の技術協力実施にあたり多大な御支援を頂いた佐藤首席顧問、加藤斉長期専門家始め各専門家の皆様、関口調整員ならびにお世話になった日本大使館、松本一等書記官、国際協力事業団、長沢海外センター課長、同課、川上氏、郵政省大臣官房国際協力課、土岐主査に厚く御礼申しあげます。なお、帰国後JICAへ提出する報告書のコピーを後日・佐藤首席顧問へ郵送申しあげます。

別添資料No. 14

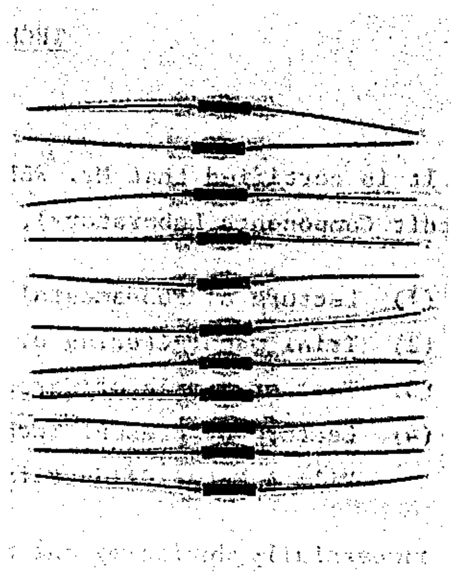
成果品（カウンターパートによる試作品）の写真



Label C

RD1／4P	(Ω) 1K	% ±5	(pcs) 10
Date 7-3-1981		Worker C.T.R.L.	

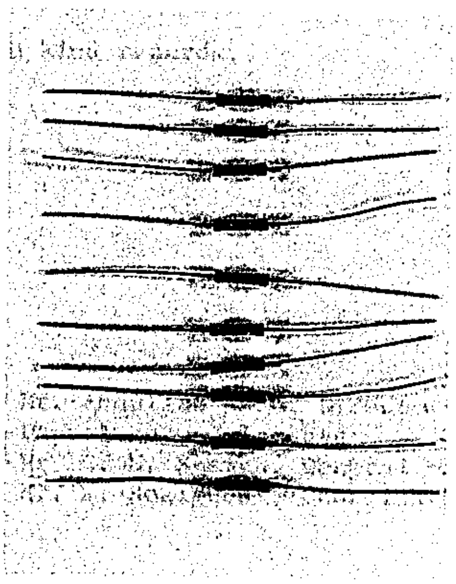
Lot No,



Label C

RD1／4P	(Ω) 10K	% ±5	(pcs) 10
Date 7-3-1981		Worker C.T.R.L.	

Lot No,



Label C

RD1／4P	(Ω) 100K	% ±5	(pcs) 10
Date 7-3-1981		Worker C.T.R.L.	

Lot No,

Dated: 18th Mar. 1981

TECHNICAL CERTIFICATE

It is certified that Mr. WASIM ANWAR KIANI, Engineering Supervisor (Circuit Components Laboratory), C.T.R.L. Islamabad has taken:

(1) Lecture of Fundamental Technique & Design on Carbon Film Resistor;
(2) Trial manufacturing of Carbon Film Resistor;
(3) Test of Sample of Carbon Film Resistor; and
(4) Lecture of Present Technique & Future Trend on Carbon Film, Metal Film & Metal Oxide Film Resistor,

very successfully during my one month stay in Pakistan.

Yoshinobu Kitamura

Yoshinobu KITAMURA
Short Time Expert on
Carbon Film Resistor

別添資料No. 15

JDG/5133/12/R

Islamabad: February 8, 1981

Mr. Afzaluddin Ahmad
Deputy Chief
Economic Affairs Division
Government of Pakistan
ISLAMABAD

Dear Mr. Ahmad,

The Government of Japan will despatch a short-term expert in the field of Electric Resistors, to be assigned to the Central Telecommunication Research Laboratories (CTRL), Islamabad.

The Japanese expert, Mr. Yoshinobu KITAMURA, presently Serior Engineer, Research and Development Department, Riken Dengu Seizo Company Limited, Tokyo, will be assigned to the CTRL from the 20th February to the 19th March, 1981 (one month).

Kindly communicate the above to the concerned authorities at your earliest convenience.

With kind regards,

Yours sincerely,

RITARO MATSUMOTO
First Secretary

cc: 1. Mr. Abdullah Khan, Director-General Pakistan T&T Department, Islamabad
2. Mr. C. N. Sheikh, General Manager, CTRL, Islamabad
3. Mr. K. Sekiguchi, Coordinator, CTRL, Islamabad

別添資料No.16

社会開発協力部

海外センター課長　長沢幸敏殿

昭和56年3月19日

パキスタン中央電気通信研究所

首席顧問　佐藤寿彦

炭素皮膜固定抵抗器の技術指導終了報告

パキスタン中央電気通信研究所に対する炭素皮膜固定抵抗器の短期技術指導が終了したので報告します。

記

1. 短期専門家氏名　：　北村嘉伸
（所属先：理研電具製造株式会社）

2. 派遣期間　：　昭和56年2月20日～昭和56年3月19日

3. 指導内容　：　国際協力事業団指定の通り

JICA